दूरस्थ शिक्षा

स्व-अध्ययन सामग्री

M.Sc. Final (BOTANY)

MB-07

PLANT ECOLOGY

मध्यप्रदेश भोज (मुक्त) विश्वविद्यालय, भोपाल (म.प्र.)

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Printed by : **P Square Solutions** H-25, Site-B, Industrial Area, Mathura.
Quantity : 250

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CHAPTER 1

CLIMATE, SOIL AND VEGETATION PATTERNS OF THE WORLD

LEARNING OBJECTIVES

- Introduction
- Major Life Zones or Biomes of the World
- Major Vegetation
- Soil Types of World
- Vegetation Organization
- Ecological Niche
- Vegetation Development
- Analytical Character
- Synthetic Characters

Introduction

Biome is the largest unit of similar type of vegetation, which is affected by regional climate. Actually, local factors interact with each other and develop the vegetation in same direction. So the regional area interacting with regional climate and biota is known as "Biome". Whole earth surface can be divided into so many biomes which form the large land community. It means the aquatic ecosystem cannot be categorized into biomes. Biome is the total community unit, but not the vegetation zone alone. In the biomes, both plants as well as animals are considerable. Some European ecologists use the term 'major life zone'

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in place of Biome. But in case of North America, the meaning of life zone is differing. It indicates the series of temperate zone like: — Alpine Temperate, Tropical Zones. Hart Meristem proposes this term. The life zones are based on the distribution of organisms. So, one life zone may have more than one community. But in majority of cases, the meaning of life zone and biome is similar.

Major Life Zones or Biomes of the World

At world level, important biomes are as follows:

Tundra

It covers the arctic zone. It can be seen in the pale artic and Nearctic zone. In both the regions, many species are common like: —Grasses, sedges, mosses, lichen and sometimes Betula and Salix can be seen. Its major part is covered with snow.

Northern Coniferous Forest Biome

It is present in between North America and Eurasia and it is having thick belt of evergreen vegetation. Its main life forms are trees like: —Spruce, Firs, and Pines.

Moist Temperate Coniferous Forest Biome

It can be seen in west coast of North America, which is present from central California to Alaska. Generally rainfall is very high in this zone and temperature is low. Here, conifers are dominant, and these are known as temperate rain forest. Main species are *Tsuga heterophylla, Thuja plicata Abies grandis, pseudotsuga etc.* In the South zone, *Sequoia* and in North zone, *Picea* are found. Epiphytic mosses are also present.

Temperate Deciduous Forest Biome

It is present in Eastern North America, Europe, a part of Japan, Australia and upper zone of south America. Dominant trees are Beech, Maple, Chestnut and Oak. Herbs and shrub layers are well developed. In sub-climax stage, pines are also present.

Broad Leaved Evergreen Subtropical Biome

It can be seen in central and Southern Japan and in Florida, Gulf and South Atlantic coast. Climate is moist and temperature is less. In the summers, temperature is high, so broad-leaved evergreen plants occur. Main plants are *Quercus virginiana*, magnoliales and Tropical

species like: —*Ficus, Lysiloma, and Bursera*. Beyond it, few species of epiphytes are also present.

Temperate Grassland Biome

It covers major area of earth surface. Rainfall is 10–30 inches and temperature is high. Grasslands occur in the central zone of continents. In North America, it is divided into East-West zone. Here, main species are *Andropogan gerardi, Panicum virgatum, Spattina pectinata, Andropogan scoparius, Stipa sparetea, Sporobolus, Agropyron, Boutelova, Poa and Bromus*.

Tropical Savanna Biome

When grassland is having some small shrubs or small trees, then it is known as savanna grassland. It occurs 40 to 60 inches rainfall here. It is present in Africa, South America and Australia. Main species are Panicum, Panisatum, Andropogan, Imperata, Adansonia, Euphorbia and Palms.

Desert Biome

It occurs where rainfall is less than 10cm like: —Sahara Desert, Australia, West-North America, Tibbet, Bolivia, Gobi etc. in the Central Sahara desert, there is no rainfall. Main life forms are annuals, succulents, desert shrubs, lichen, mosses etc.

Chaparral Biome

It is present in mild temperate regions. Climax vegetation is made up of shrubs and trees. These communities are common in California, Mexico, along the Mediterranean sea and South coast of Australia. This community shows Fire climax. Main species are Adenostoma, Arctostaphylos. Species of Mediterranean region are Machie and species of Australian region are known as Mallae. Eucalyptus is dominant in Australian region.

Pine Juniper Biome

It can be seen in region of colarado river, Arizona, New Mexico, Navada and West Central California. Rainfall is 10 to 20 inches. Main species are Pinus adulis, Pinus monophylla, and Juniperus.

Tropical Rain Forest Biome

it can be seen near the equator. Rainfall is 80 to 90 inches. It is present in 3 zones:

I. Amazon and Orinoco region in South America and Central America.

II. Congo, Nizer and Zamebezi region of West Africa and Medagaskar.

III. Indo-Malaya-Borneo New Guinnea region.

Here large trees, small trees, shrubs, herbs and lines are present. So, it is said as biodiversit rich area. Here, Ferns, Palms, Climbers and Epiphytes can be seen.

Tropical and Deciduous Forest Biome

It shows the intermediate condition between desert and savanna as well as it also indicates Tropical Rain Forest. These are based on good total rainfall and these are common in Africa, Australia and Brazil. Vegetation is thorn- forest type.

Major Vegetation

The vegetation zone of the earth surface is divided into four regions on the basis of climatic and geographical conditions.

Arctic Zone

It is the polar region divided into two zones.

Arctic Proper

This is around the North Pole and covered with ice whole year. Main vegetation is algae, few flowering plants, mosses, lichen etc. It shows tundra biome type of vegetation.

Sub-artic

It is zone from Southern Artic to Northern limit of temperate zone. It is cold area, main vegetation is bogs, small trees, shrubs, herbs, conifers, betula, salix, pteridophytes, orchids, insectivorous plants, mosses and lichens. In Alaska, tali evergreen forests are present.

North Temperate Zone

It is present at Eastern and Western hemisphere of earth, which is divided into two zones:

North Temperate Zone of Eastern Hemisphere

It is divided into two zones:

Mediterranean Flora

It is situated in South mountain range of Europe and Mediterranean sea of Asia. Main vegetation is fruit trees, olives, nut trees, oranges, palms, cacti, *Accacias, Atriplex, Polygonum, Phoenix* etc.

Western and Central Europe

It is situated in sub arctics in North and Alps and British island in South. Here, gymnosperms, tall trees, oaks, maple, butter cups, chestnuts, orchids, roses, viola, salvia, Dianthus are common.

Northern Africa

It consists of Northern part of Morocco, Algeria, Libya and Egypt. Rainfall is less. Main species are broad leaved oaks, conifers, herbs and shrubs. Xerophytes and Accacia are common in deserts. Some parts of Sahara deserts are also included in this zone.

Himalayas, Eastern Asia and Japan

In China, natural vegetation is replaced by cultivated vegetation. In China and Japan, Ginkgo biloba and Cycas are common. Beyond it, Rhododendron, cinnememmon camphora, Bignonia is also available.

North Temperate Zone of Western Hemisphere

It consists of USA and Canada. It is temperate zone, but tropical plant Schizea pusilla is present. Conifers and Deciduous trees are dominant. Main species are cherries, palms, roses, orchids, *Ulmus americana, Sequoia sempervirens, Salicornia, Rumex, Monotrapa, Primula* and Xerophytes.

Tropical Zone

It includes Tropical Africa, Tropical Asia, Mexico, South America, which is divided into two zones.

Palearctic

It has two botanical areas.

Tropical Africa

It includes Sahara desert. Rainfall is less or absent. Main trees (species) are mangroves, shrubs, small trees, *Ficus, Bombyx, Legumes, grasses, Welwitschia, Boressus, Tamarindus, Asparagus, Clematis, Phaseolus, Cassia fistula, Erythrina, Accaia, Albezzia, Zizypus, Bauhinia* etc.

Tropical Asia

It includes Arabia, Burma, Pakistan, Ceylon, Thailand, Island of Indian Ocean. In Arabian zone, Acacias, prosopis, Coffea arabica and in Sri Lanka zone, rice, sugercane, banana, mango, papaya, ferns and in Burma and Thailand, rice, jackfruit, orange, mango, banana, beetle nut etc. In Malaya, Java and Sumatra, Palms are common. Other species are insectivorous plants; *Lianas, Albezzia, pterocarpus, Tamarindus, Bombyx, Cassia, Dandrocalamus.*

Neotropic

It includes Mexico and South America. In Mexico, rainfall is low, so xerophytes are common. At higher altitude, Pinus, Spruce, Quercus, Populus are common. In wet areas, mosses, Bamboos, Palms, Orchids, Maximiliana, Mangroove vegetation, epiphytes and leguminous trees are common.

South Temperate Zone

It includes South Africa, Australia, New Zealand. In African area, main vegetation is fern and gymnosperms. In lower wet regions, Salix and Phermites. In dry region, grasses and Acacias are common. In Australia, Palms, Nuts, Eucalyptus, Acacia, Casurina are common. In New Zealand, main vegetation is Conifers and Ferns. New Zealand is richest in Bryophytes.

Soil Types of World

In the world, Dokucharyev gave first classification of soil. He divided the soil into 3 groups which are :

Zonal Soil

ZONE	SOIL TYPE
1. Boreal	Tundra (dark brown soil)
2. Taiga	Light grey podsol soil
3. Forest steppe	Grey and dark grey soil
4. Desert steppe	Chestnut brown or white soil
5. Steppe	Chernozem soil
6. Desert	Aerial yellow soil
7. Sub tropical and tropical forest	Laterite and red soil

Transitional Soil

1. Dry land moor soil
2. Carbonate containing soil
3. Secondary alkaline soil

Abnormal Soil

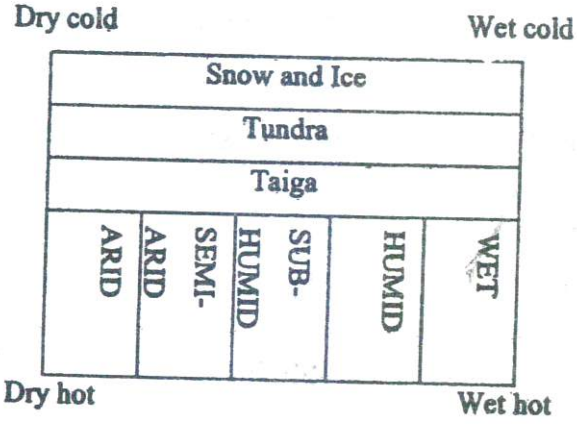
1. Moor soil → Cold region soil
2. Alluvial soil → Transported through water
3. Aeolian soil → Tranported through wind

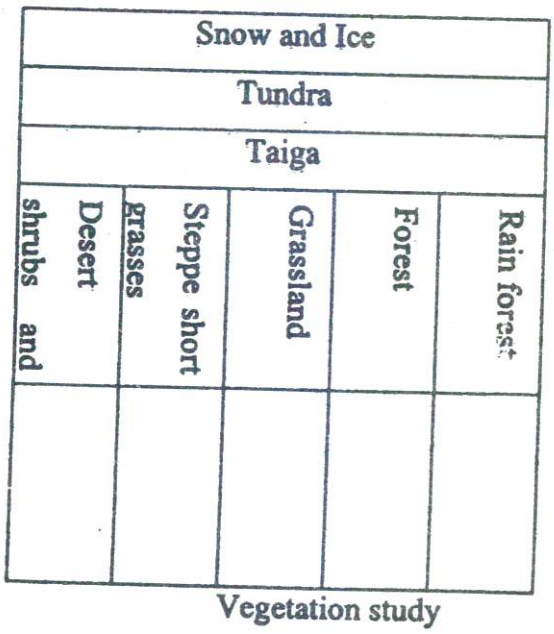
The most recent classification of soil type is proposed by soil survey staff of USDA(1960), which is following:

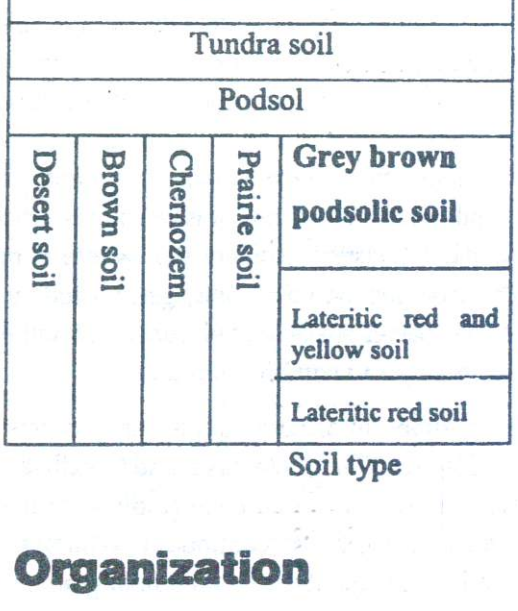
1. Entisols → Azonal soil
2. Vertisol → Grumu soil
3. Inceptisol → Brown forest soil
4. Aridisol → Desert redish desert soil
5. Mollisol → Chernozem, chestnut, brunizem,
6. Spodosol → Podsol, brown podsolic soil

7. Uttisol → Red yellow podsolic, laterite soil
8. Oxysol → Laterite soil, latosols
9. Histosol → Bog soil
10. Alfisol → Grey brown podsol soil

Climate, vegetation and soil are intimately related and soil formation is affected by vegetation and climate. This relationship is indicated in the following schematic representation:







Vegetation Organization

Concept of Community and Continuum, Ordination, Coefficients

Ecology is the science related with interaction between biotic and abiotic factors. It is further divided into so many branches, the group of similar type of plant growing in similar climate and edaphic zone. It is called as community and the study of community is known as synecology. Basically, the name of the community is provided and classified on the basis of following feature:

i. Major structural features like: dominate species, life forms or indicates.

ii. Physical habitat of the community.

iii. Functional behavior of the community.

Actually, community maintains the continuity, because the edge effect and ecotone zone is the common area inbetween two communities. This concept of continuity is called as continuum concept, which is determined by the gradient analysis based on so many coefficient, which are known as community coefficient. When the communities and species are arranged according to their gradients, then this is known as ordination and the ordered arrangement of species and community is known as continuum.

Continuum and Ordination of Community

Community is the complex structure of vegetation, the main basis of its classification and name of classification and community is structure of community, because it's, composed of

organisms. So according to some ecologist, the name of the community should be given on the basis of dominant, then known as pine community. But it is suitable when only one or two species are changing, then these criteria cannot be used. It is also proposed that the name of community should be given on the basis of eco system. It should be meaningful and indicate the structure of community. So, generally the stable characters of community are used. Like-for aquatic communities, stream rapids community, mud flat community, and pelagic community or sand beach community. It is well known that communities show successive changes. So it is the interesting problem that where is the boundary of one community and from which place, second community gets started, and in the majority of cases, the communities and the species are delimited from one another and the continuity is maintained from one community to another community.

According to Clements and Daubenmire, communities are discrete units with definite boundaries. But according to Gleason, Curtis, Whittaker and Goodball, population indicates the response, which is independent of environmental gradient. In this case, communities overlap with each other, and it is named as continuum. Whittaker analysed the great smoky mountain national park and obtained the altitudinal gradient view from floor to top. He studied five zones which are following:

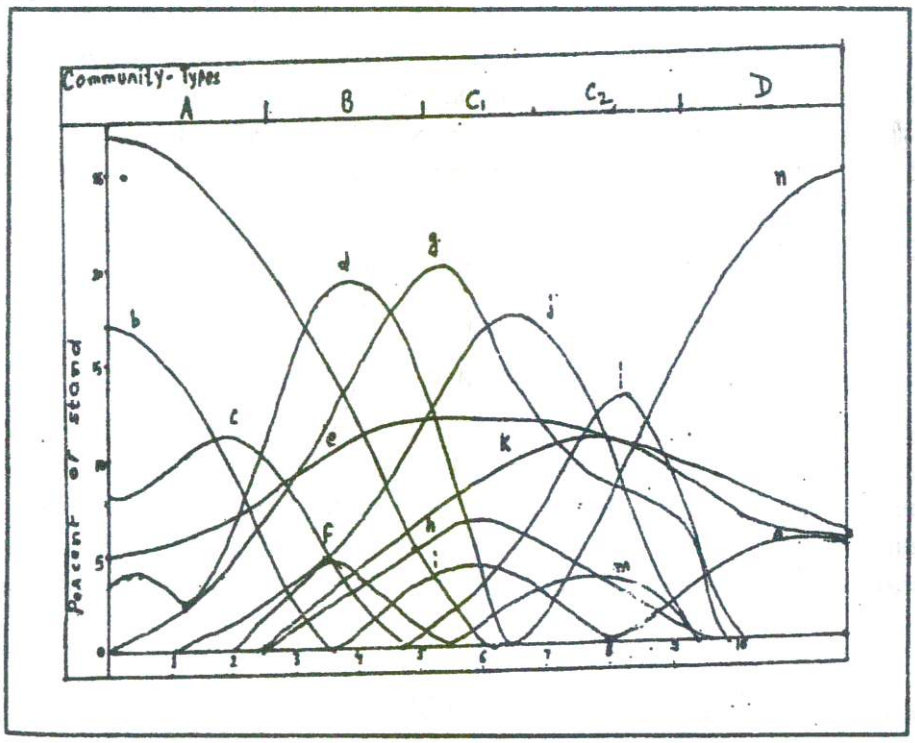


Figure 1.1

i. Multihued cove forest

ii. Dark green Hemlock forest

iii. Dark red oak forest

iv. Reddish brown oak heath vegetation

v. Light green pine forest

We can consider the 5 zones as discrete communities, or 5 zones can be considered as single continuum. In these communities, the response of individual species is changing according to environmental conditions. Whittaker studied about 15 species, which are dominant trees and observed the overlapping along gradient. These 5 communities are named as A, B, C_1, C_2, and D. The graphical representation indicates that one or two species are dominant in each community. All the forests are interlinked by exchange of nutrients, energy, animals and watershed zone.

To find out the continuum in the continuity, population species and community is arranged in ordered form, for which different techniques are used.

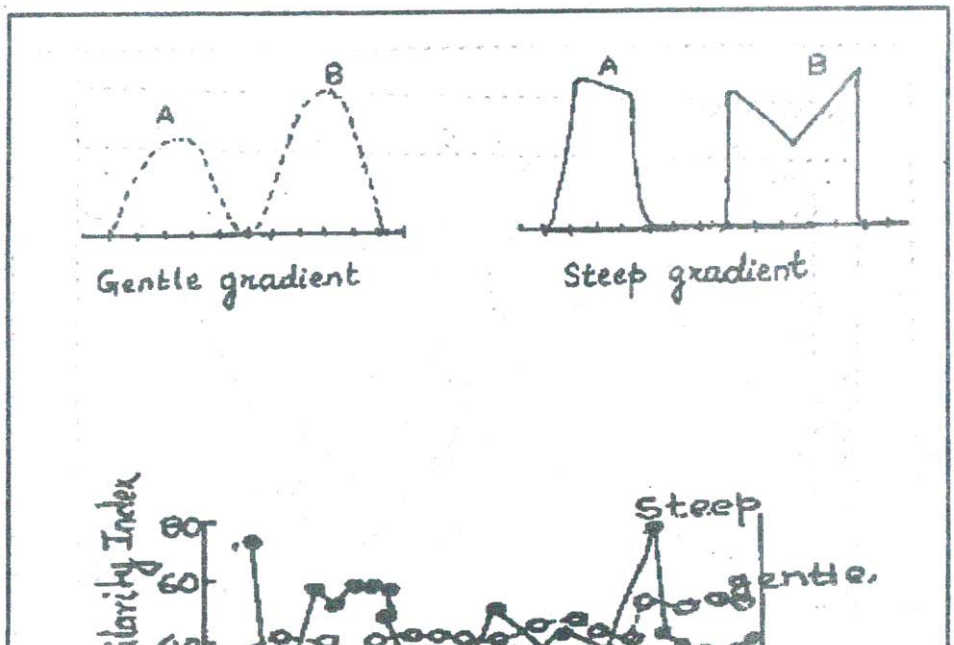


Figure 1.2: Altitude in Meters

These techniques are called as ordination techniques and ordering the species, population and community is called as ordination. So, the ecologists who are using the geographical approach observe the continuity in the communities, while ecologist working in the topographic or steep gradient uses the term zonal concept. Continuum concept is based on the continuity of community. Beals compared the vegetation change in a steep and gentle attitudinal gradient and clearly indicated that in the gentle gradient, the discontinuity is very less, while in the steep gradient, the discontinuity is much more.It is studied with the help of dissimilarity indices.

Comparison in Dissimilarity Index in Steep and Gentle Gradient

If the gradient analysis is carried out in steep and gentle slope then steep community indicates the high degree of dissimilarity and the dissimilarity in gentle community is very less. It means in the steep gradient, the species shows sudden appearance and sudden disappearance. So, Beals concluded that in steep gradient, vegetation could impose disjunctions. Although the environment gradient is continuous while in a gentle gradient indicates reverse condition. So the three important processes are responsible for creating differentiation in community.

a. Competitive exclusion

b. Symbiosis between groups of species

c. Co-evolution of the groups of species.

Many factors like fire and antibiotic production shows boundary. Buell studied the maple basswood forest and Spruce (Fir) forest in the Minesotta, which indicates sharp boundaries and it, does not change with topography. So the gradient analysis is used to detect the continuity and discontinuity of communities. It shows the relationship between the population components as well as it shows how communities are delimited.

Community Coefficients

Community is a group of different population component. It is vast group of species, and as the number of species increased; the complexity of community is also increased. So, for the determination of the complexity in community, some indices are used. These indices are based upon some coefficients, which are known as community coefficients.

For determining the continuum and discontinuity, similarity or dissimilarity in the community is studied as well as the degree of association is also important. On the basis of degree of similarity, species are placed in same community or different communities. For finding the similarities in the community, coefficient of similarity is calculated. It is the main criteria for community classification. It shows that greater the number of species is common in the

communities, then greater affinity in the community is seen. Some important coefficients are following which indicate the species structure in the community.

Index of Dominance (C)°

$$C = \Sigma(n_i/N)^2$$

Where n_i is the importance value for each species (number of individual, biomass, production, and so forth).

N is the total of importance values

Index of Similarity (S) Between Two Samples

$S = 2C/ (A+B)$

Where A is the number of species in sample A

B is the number of species in sample B

C is the number of species common to both the samples.

Note: Index of dissimilarity = 1–S

Indices of Species Diversity

1. 3 species richness or variety indices d

   $d_1 = S–1/\log N$

   $d_2 = S/\sqrt{n}$

   d_3 = S per 1000 individuals

   Where S is the number of species,

   N is the number of individuals, etc.

2. Evenness index e.: –

   $e = H /\log S$

where,

H is the Shannon index

S is the number of species

3. Shannon index of general diversity H.

$$H = -\Sigma (n_i/N) \log (n_i / N)$$

$$= \Sigma Pi \log Pi$$

Where (–) n_i is the importance values for each species

N is the total of importance values

P_i is the importance probability for each species (n_i /N).

Interspecific Association

The association of two or more than two species is known as interspecific association or species association. In the association species must grow together, like in many areas Stipa cornata and Bouteloua gracilis grow together in Great Plains. In British Colombia Agropyron and Poa grow together. In the Malwa zone Dicanthium and Indigofera grow together. This association is actually occurring due to same ecological amplitude of two or more species. It may be similar in geographic range, climatic factors and life forms. Many times the different life forms exclude the competition and increase the dependence of species on one another. This increasing dependance is indicated by association index. This association may be due to shed, food and protection etc. When the environmental conditions change, then the association may be changed. When any species is growing as dominant species in one stand then it may be sub-dominant in another stand. Like in North Dacota Agropyron is associated with Muhlenbergia, Carex, Eurotia, but in British Colombia Agropyron is dominant but other genera are absent. This presence and absence indicates the favorable or unfavorable environment.

The interspecific association can be calculated by different formulae. The simplest method is to find out the presence of 'A' species with 'B' species and following formula can be used for association index

$$\text{Association index} = \frac{\text{Number of samples where 'A 'occurred with' B'}}{\text{Number of samples for species 'A'}}$$

If species 'A' is present in 40 sample area and in 30 sampling area 'A' and 'B' are present together, then association index of species 'A' will be:

$$\text{Association index} = 30/40 = 0.75$$

So the maximum association index may be 1 or 100% generally this index is less than one. This result shows that 3/4th area is indicating association of 'A' and 'B'. The association index

can be calculated by following formula

$$\psi^2 = \frac{(a+d)^2 - (b+c)^2}{(a+b)(b+c)(c+d)(a+d)}$$

Where,

A = number of samples where species a and b both are present

B = the number of samples in which species a is present and b is absent

C = the number of samples in which species a is absent and b is present

D = the number of samples in which both the species are absent.

Ecological Niche

Griennel proposes ecological niche term. He proposed the term for reducing the competition in the ecosystem. Actually, each organism has limited range of space and diet selection and this range is determined by so many factors. So, the limited favorable area where species can enjoy the different factors is known as Ecological Niche. Basically, niche is related with Micro-habitat. According to Griennel, species is the distributional unit in which it is held by structural and instinctive limitations and no any two species can occupy the same space. The meaning of niche is a place, employment or best-fit activity of organism. So, the niche is differentiated from habitat. It is based on the physical and functional role of the organism. So, on the basis of habitat and trophic level, niche can be differentiated.

Type of Niche

Habitat Niche

It is also known as Spatial Niche. When any organism is showing the fixed territory or living space, then it is known as Habitat or Spatial Niche. It shows the differentiation in microhabitat. It means the habitat of many species may be similar, but the micro-habitat of organisms differs, which reduces the competition in the organisms. It is supported by so many examples. O'Neill reports one interesting case.

He studied the seven species growing at the same habitat and all species having the same trophic level. But it is observed that all seven species show different microhabitats, and it produces many gradients in the decomposition stage. These species and microhabitats are following:

1. Euryurus erythropygus: Dominants in heartwood of logs

2. Pseudopalydesmus serratus: Superficial wood of log
3. Narcueus amerelcanus: Outer surface of logs but below the bark.
4. Seutotus aranulatus : Under log but on log surface
5. Fontaria Virginians: Under log but on ground surface
6. Cleidognia species: Within litter leaves
7. Abacion: Below litter on ground surface

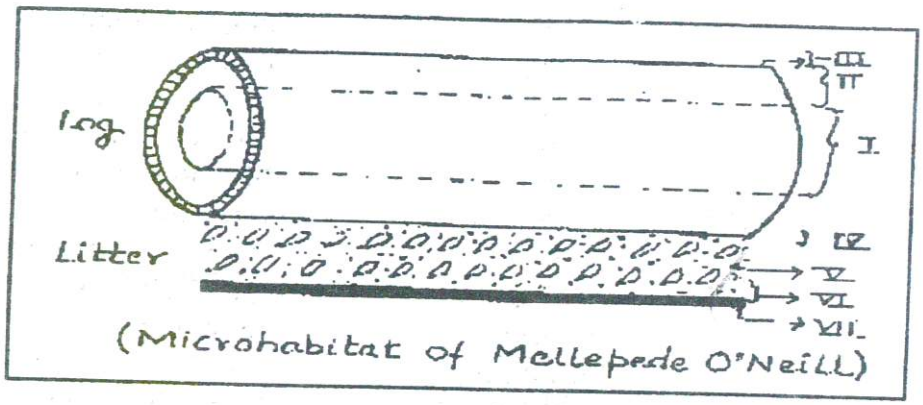


Figure 1.3: Microhabitat of Mellepede O'Neill

Similar examples were studied by Sharma and Dwivedi. They studied that the microhabitat of fungal species indicate the same habitat, but the microhabitat differs like Myrothecium roridum present at upper inflorescence axis, while Myrothecium stratisporum the middle internodes, and Stagnospora graminella present at lower internodes.

Trophic Niche

The niche, which is based on the functional behavior of the organisms in the ecosystem, is known as Trophic position of the organism in the ecosystem. Many examples are given in the favor of Trophic niche. The Galapagos is land of the South America, the nature of three bird species is studied. These birds indicate similar habitat and microhabitat. But the food trophic position is different.

a. Geospiza: It searches the food from ground surface.
b. Camarhynchus: It searches the food from upper surface of tree.
c. Certhidia: It is insect eaten. Similarly, in another example it is indicated that two birds are living in the same nest, it means the microhabitat is similar, but these indicate major differences in the trophic level, like ploceous melanoephalur is the insect eater bird, it means it is carnivorus while ploceus collasis is seedeater

bird. It means it is herbivores in nature. One interesting point is studied in aquatic ecosystem, where two aquatic bugs is living together in the same habitat. These are Notonacta and Corixa. But, Notonacta is predator, while Corixa is detritivore.

Multifactor Niche

If the organisms is affected by two or more than two factors at a time, then it is known as Multifactor Niche. Hutchinnson gives this idea. According to him, at a time, many pressures are applied on organism, which determine the various range of organism's movement. Generally, the space of organism movement is limited in the ecosystem, which is known as Niche space. If any organism is controlled by two factors at a time, then it is known as area Niche. If Area Niche of two organisms is independent, then it shows the organisms is independent, and then it shows the Non- competitive environment. Similarly, if organism is controlled by three factors, then this niche is known as 3-D Niche or Hyper-volume niche. Hutchison proposes this term. It the niche of two organisms is completely separated, then it will be Non-competitive niche. But, if any part of Niche overlap with each other, then it is known as Overlapping Niche. It shows increasing competition in the environment. If we take the 4th factors, then it is known as fundamental niche. With the help or study of fundamental Niche, we can find out the degree of competition in the ecosystem. As the overlapping increases, the competition parallel increases. The complete overlapping of organism is going on, then the species fight with each other, and in this competition, one species is destroyed and only one species survive. It favors the "Survival of the fittest" concept proposed by Darwin. The graphical representation of 2-D and 3-D niche is.

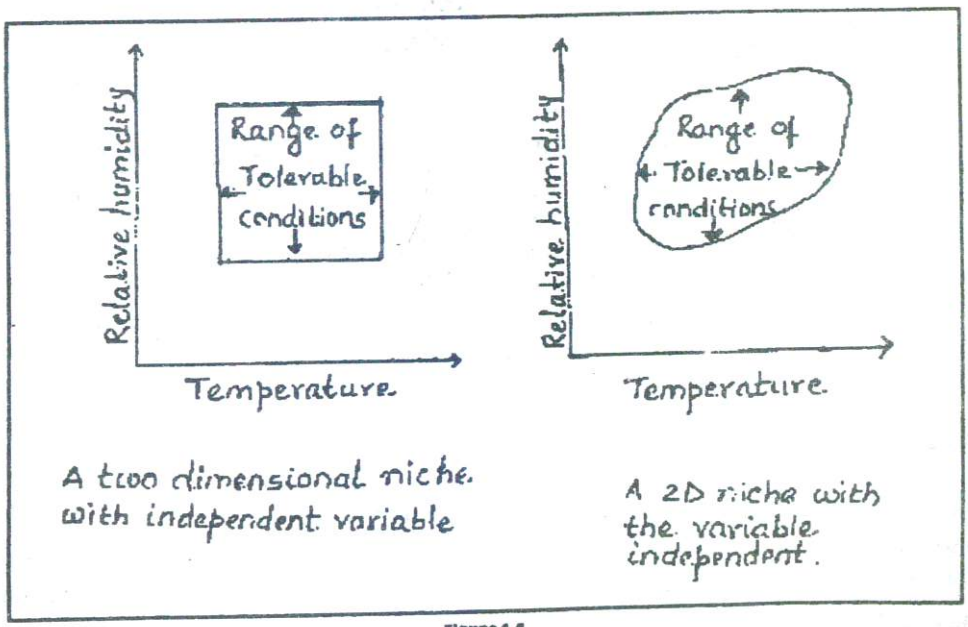


Figure 1.4

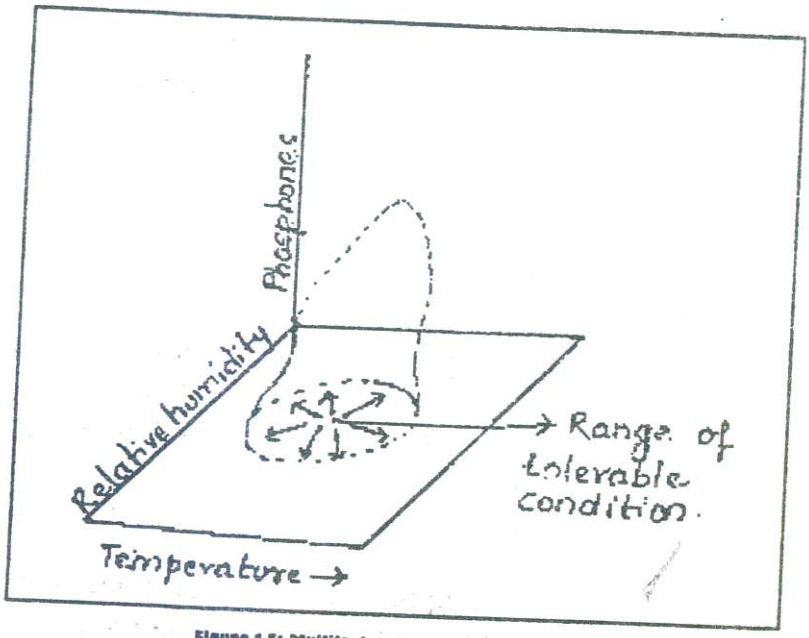


Figure 1.5: Multifactor or Hyper-volume Niche

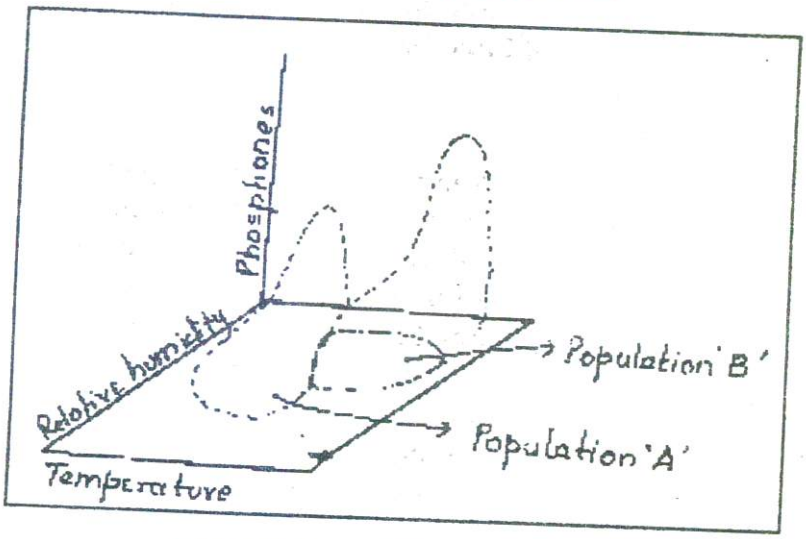


Figure 1.6: Multifactor Niche with Overlapping Area

Vegetation Development

In any ecosystem, dynamic changes take place, these changes may be fast or slow. Due to these changes, vegetation pattern in the ecosystem goes on changing, or we can say that another community is replacing one community. But a stage comes, which shows stability, which is called as climax stage. Hence, those natural serial stages, through which serial changes occur in the community and vegetation pattern is also changed, is called as succession.

Succession goes on by different pathways and is affected by different factors. Succession depend mainly on the following factors.

1. It is a sequence of environmental and vegetation changes.
2. It is based on the Disturbances of area.
3. In succession, different steps occur in a serial.

Temporal Changes

During the succession, continuous vegetation changes occur and one type of plant community is replaced by another type of plant community. That is why, succession is the most dynamic stage. Following are the type of changes that occurs in the vegetation.

Replacement Changes

When in any community one type of vegetation stand destroyed due to any cause like forest fire, change in climate and change in edaphic factor, then new vegetation appears at this place which is known as replacement change. This replacement change may be two types, which is Non-cyclic Type and Cyclic Type.

Non-cyclic Replacement

It is considered as normal change. When an individual of any species die away, then another member of the community occupies this area. But it may be same species or it may be other species like after the death of chestnut tree; area is covered by Chestnut Oak, Red oak and Red maple. Such changes are taking place at species level. It is not based on one species replaced by other species. So, it takes a long time for the development. When a large dominant tree died away, then at its place, seedlings of different species appear. But out of these so many seedlings, signal the significant change in the community. But if slowly this process is continued then the floristic composition of the community will be completely changed. So, such changes are created inside the community.

Cyclic Changes

When a series of vegetation and habitat changes with time, then these are known as cyclic changes with time, and then these are known as cyclic changes. When Watt studied the seven different types of communities, then in each community, different type of patches was observed and all the patches were selected with each other. These changes were in the definite order, which may be upgrade series or downgrade series, like in the cairngorns community, colliona vulgaris is found at the peak level, which becomes dominant after the

death of cladiona silvakita. When cladiona disintegrates and base soil is exposed, then calliona stems starts the growth. Another species Arctostaphyllos also initiate the growth in the bare soil and slowly it becomes dominant. With these changes, the environmental gradient is associated in grassland in Daccota of Nort-West, where wheats, small shrubs and grasses occur. In normal conditions, Botelua, Stipa, Corax and Agropyron occur. In the downward series, development of saline takes place. Then due to leaching of soluble salts, alkaline soil develops. It is having less ion exchange capacity, so the vegetation is destroyed. In this case Botelua becomes dominate but in the saline soil it is replaced by Agropyron, Digitalis and Puccinalla, while in the upgrade series, calcification and sodium ion concentration reduces it to low shrub stage the first grass stage the second stage and final stage can be seen and these changes takes place in a cyclic manner. Polygonum, Lepidium, Atriplex, Plantago indicates shrub stage. The first grass stage is indicated by Agropyron. Puccinalla and Disticlis and second grass stage is indicated by Buchloe grass is dominant and in the first stage Boutelua, Stipa, Corax, and Agropyron are dominant. So, the cyclic changes are intracommunity changes, while directional changes are intercommunity changes. The upgrade series of cyclic changes may be confused with succession (so, the replacement changes may be simple to complex changes). Non-cyclic changes are simple, while cyclic changes are complex changes. These changes are within the climax and within the direction and the cyclic series is the internal dynamics of community.

Changes in Ecosystem Properties during Succession

In the ecosystem, changes occur during the successional stages. These changes may be progressive or retrogressive but successional changes are always progressive during the succession. Here are the following type of changes that occur.

Fluctuation Changes

When the random changes are taking place in the ecosystem then they are known as fluctuation changes. These changes occur due to the response of climate and is also known as adaptability. These changes may be regular and cyclic type as well as the changes may be irregular. Fluctuation occurs at large level, local level or at a smaller area. Generally, ecosystem is the complex system so if one factor is changed then it causes the sequential changes and the changes in the environment cannot be easily predicted, while the fluctuation changes within the community can be expected. So, if one species is affected then it shows a long series of changes. These changes may be in kinds of species, dominance penology and in growth rate.

Directional Changes

These are the real successional changes. Although these are known as non-cyclic changes, but the changes are taking place in an ordered sequence and due to directional changes, the community becomes more complex, which is known as progression and changes from more to less complex community is known as retrogression. If the succession occurs due to changing the factors plant then they are known as antigenic changes but if the changes are created by any outside (or external) factor, then they are known as allogenic changes. Generally succession is a progressive development, which takes place from simple to complex community. During succession many factors change like diversity, stability, productivity, self-maintanace and soil maturity. These are positive directional changes like in hydrosere succession the sequential step are

i. Phytoplankton stage

ii. Free floating stage

iii. Submerged stage

iv. Reed swamp stage

v. Marsh meadow stage

vi. Herb stage

vii. Shrub stage

viii. Climax stage.

In this stage, climax stage is the most stable stage and these changes are continuous changes. If any stage is interpreted, then nature of all community changes. Some directional changes may be deflected like formation of savanna from tropical rain forest through forest and shrub stage. Some ecologist considered the retrogressive changes as successional changes, which is induced by changes in climate, grazing, browsing, trampling, soil erosion, repeated flooding etc.

Rate of Change

In the different communities, rate of changes is differing. It is dependent on the factors causing the succession like the xerosere lichen stage can be seen hundreds of year. In the areas like arctic and alpine zone, the rate of change is very less, because climate is complex there. So their community shows stability in the primary stage. But if the rate of disturbances

is higher, then rate of change in community will also be higher. During the development stages the trends of changes are as follows:

Table 1.1: Community Energetic

Ecosystem attributes	Developmental stages	Mature stages
i. Gross production/community Respiration (P/R ratio)	Greater or less than 1	Approaches 1
ii. Gross production/standing crop biomass(P/B ratio)	High	Low
iii. Biomass supported/Unit energy flow(B/E ratio)	Low	High
iv. Net community production	High	Low
v. Food chain grazing detritous	Linear, predominantly predominantly	Web like

Table 1.2: Community Structure

vi. Total organic matter	small	Large
vii. Inorganic nutrients	extra biotic	Intra biotic
viii. Species diversity- Variety component	Low	High
ix) Species diversity equability component	Low	High
x) Biochemical diversity	Low	High
xi. Stratification and spatial heterogeneity	Poorly organized	well developed& organized

Table 1.3: Life history

xii. Niche specialization	Broad	Narrow
xiii. Size of organism	Small	Large
xiv. Life cycles	Short, simple	Large, complex

Table 1.4: Nutrient Cycling

xv. Mineral cycles	Open	Closed
xvi. Nutrient exchange rate, Between organism and Environment	Rapid	Slow
xvii. Role of detritus in nutrient regeneration	Unimportant	Important

Table 1.5: Selection Pressure

xviii. Growth form	For rapid growth (r-selection)	For feed back control(k-selection
xix. Production	Quantity	Quality

Table 1.6: Overall Homeostasis

xx. Internal symbiosis	Undeveloped	Developed
xxi. Nutrient conservation	Poor	Good
xxii. Stability	Poor	Good
xxiii. Entropy	High	Low
xxiv. Information	Low	High

Mechanism of Ecological Succession

Nudation

Beginning of vegetation growth in the bare area is called as Nudation , which depends on following factors;

1. Topographic: Topography of any region is important for vegetation and according to this topography growth begins. Eg: growth and attachment of lichens on rocks, growth of phytoplanktons in lakes or bryophytes in cold desert.

2. Climatic factor: The rate of plant growth depends on climatic factor of the region as light, temperature and rainfall. If factor is favorable, then rate of succession will be more.
3. Biotic factors: When vegetation starts growing then struggle starts among different species. This struggle may be positive or negative.

Invasion

When species invade any new area, then it shows following processes:

Migration

Temporary transference of species from any other area to newly developed area is called as migration. Due to migration, species increases its dispersal area.

Ecesis

Process of establishment of a species in the new area is called as ecesis. During species development it shows positive or negative relationship with other species. If positive relationship is there then species can be better established.

Aggregation

When slowly many species aggregate in the area then struggle takes place among them and the species, which get well established during this struggle, is shown in the form of effective species. This species are found in a group.

Competition and Co-action

When many species aggregate at the same place, then among them either a struggle takes place for shade and nutrients, it is called as competition or species positively associate with each other to benefit each other, it is called as reaction.

Reaction

When plants grow in the bare area then it affects soil and climate, it is called as reaction.

Stabilization

When continuous changes are taking place in the community, then a stage comes, when the community becomes stable, it is called as climax and the process is called stabilization.

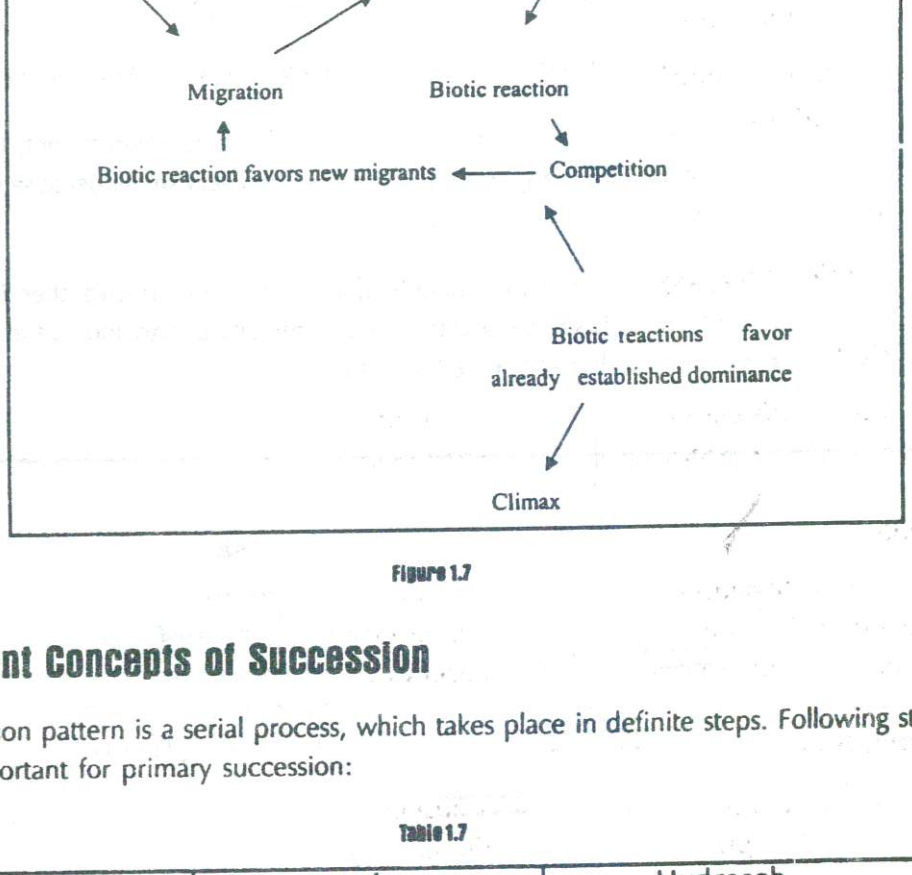


Figure 1.7

Current Concepts of Succession

Succession pattern is a serial process, which takes place in definite steps. Following steps are important for primary succession:

Table 1.7

Xerarch	Mesarch	Hydrarch
Crustose lichen	Grassland	Phytoplankton
Foliose lichen	—	Submerged
Moss stage	—	Free floating
—	—	Reed swamps
—	—	Marsh meadow
Herb stage	Herb stage	Herb stage
Shrub stage	Shrub stage	Shrub stage
Climax stage	Climax stage	Climax stage

Two models have been given for primary succession of plants.

1. Relay floristic model: In it, when next community develops then this area is formed. The first community disappears, while in the second model all community adds new community and develops together (Figure 1.8).

2. Initial floristic model: A model has also showed Autogenic mechanism for succession, which are mainly based on three processes;

   a. Facilitation: This process indicates adopted species in the distributed area.

   b. Tolerance: This process indicates that by changing environment, there is no effect of it on the species or, if there is, then very small, because species can tolerate this environment.

   c. Inhibition: When environment is modified by early species, then it is not suitable for early species and this species inhabits growth and due to which, growth of another species get increased.

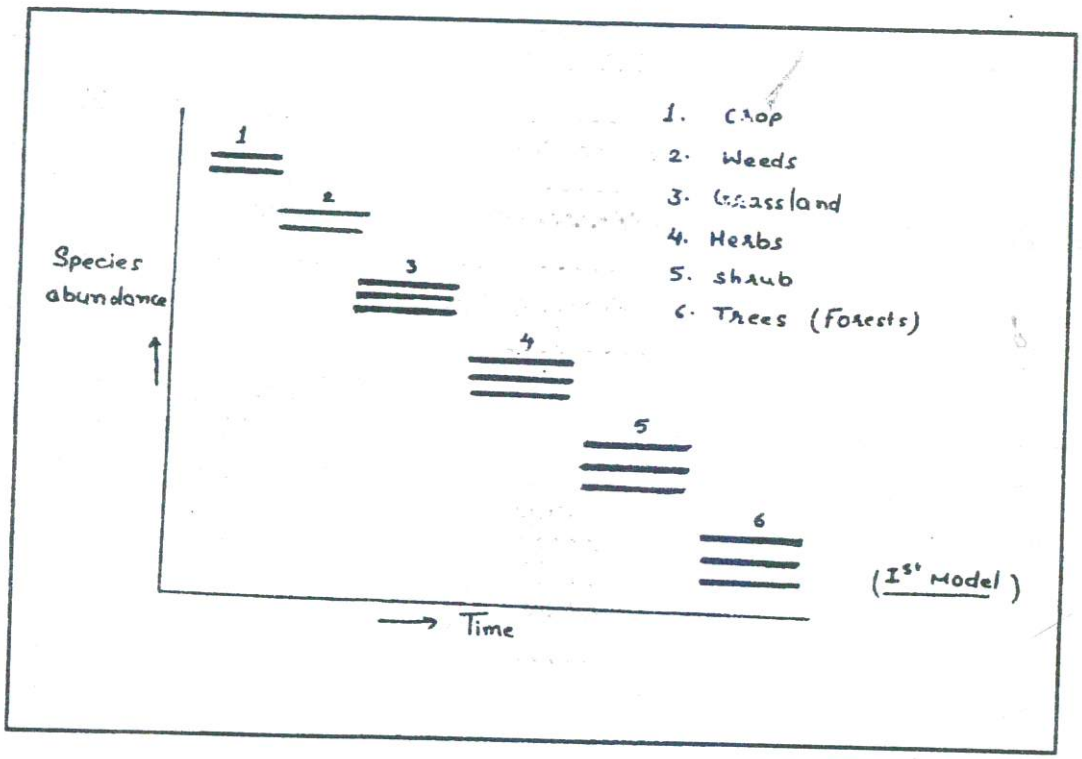


Figure 1.8: Succession Model I. Relay Floristic Pattern (Without Old Vegetation)

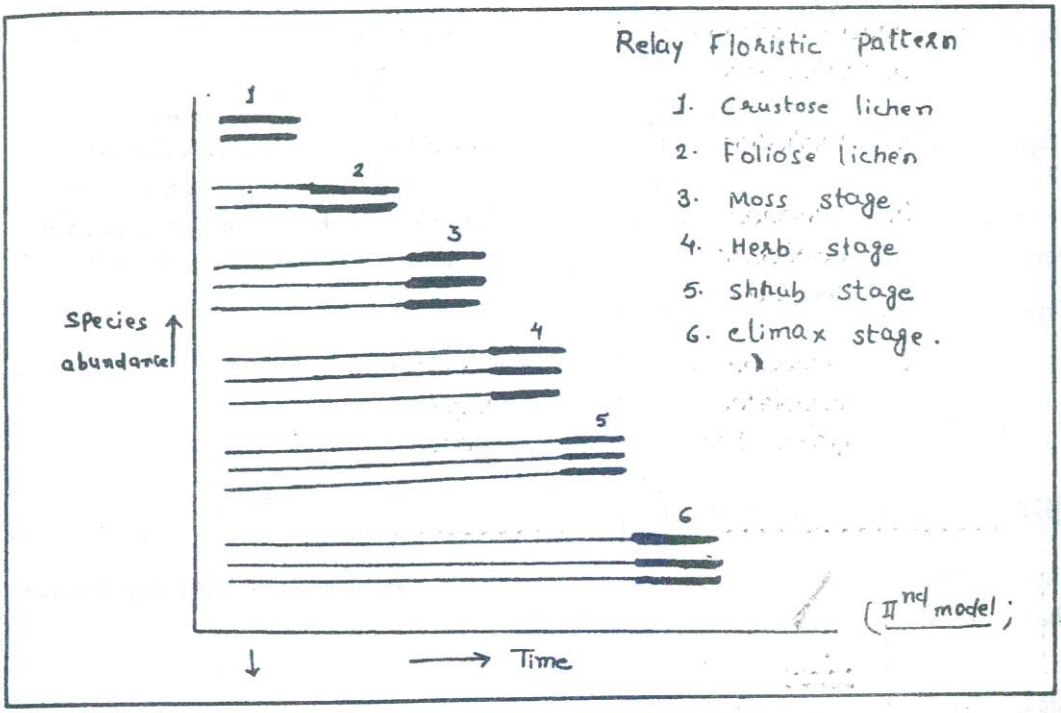


Figure 1.9: Succession Model II. Relay Floristic Pattern (With Old Vegetation)

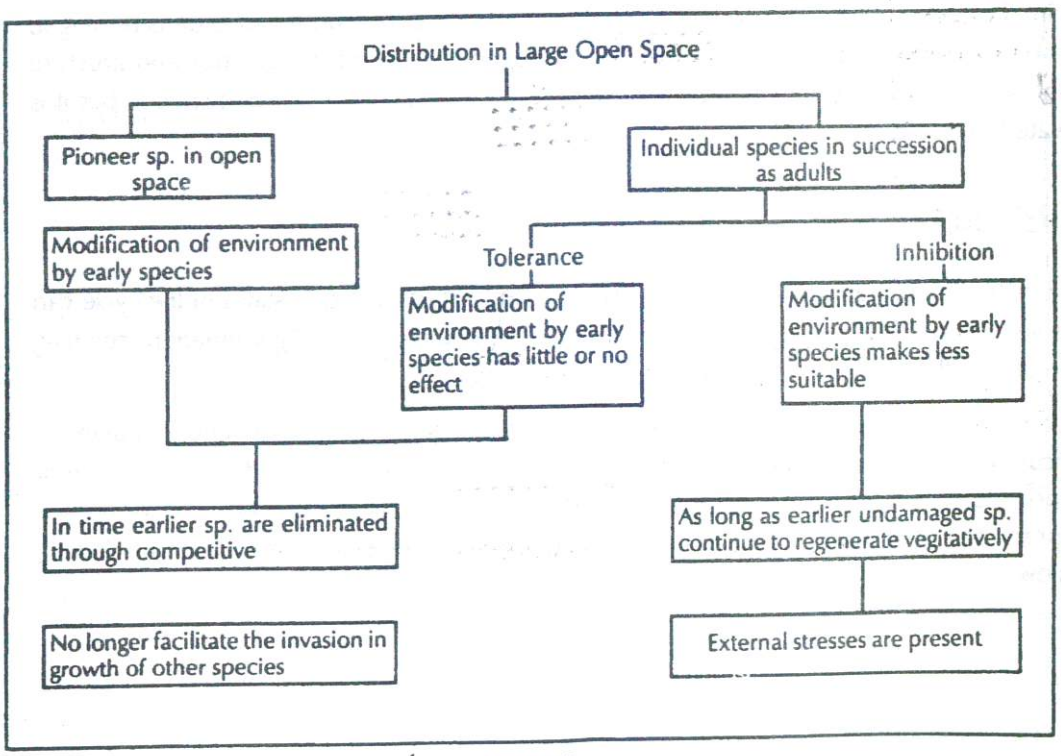


Figure 1.10

Analytical Character

In nature different types of vegetations are found in different regions. The group of plant in a specific region is called as community and the study of community is called synecology. The study of community is done by many ways but mainly it is done with the help of synthetic and analytical characters. Analytical characters are those that can analyze the vegetation of community.

Types of analytical characters: These are two types;

1. Qualitative characters
2. Quantatitative characters

Qualitative Characters

These are the characters, which depend on the quality of plant. These are called as qualitative characters. These are as follows:

Physiognomy

It indicates the outer structure of community that depends on dominance density, height, and colour. According to Cane and Castro, physiognomy is a kind of vegetation and structure that is result of life forms of dominant plant. It does not indicate any one species but it is related with the whole group.

B. Phenology

It is related with periodicity. It is clear that as time changes different states of life cycle can be seen hence regular seasonal process is called as periodicity.eg germination, seedling formation, flowering, fruiting etc.

But different species grow in a definite time period. Eg Rohu germinates in January, flowering occurs in March and fruiting occurs in April. The study of death and time of different processes is called as phenology or it is a calendar of different processes and when it is represented by diagram then it is called as phenogran. Eg, in some species these are having following type of phenogram.

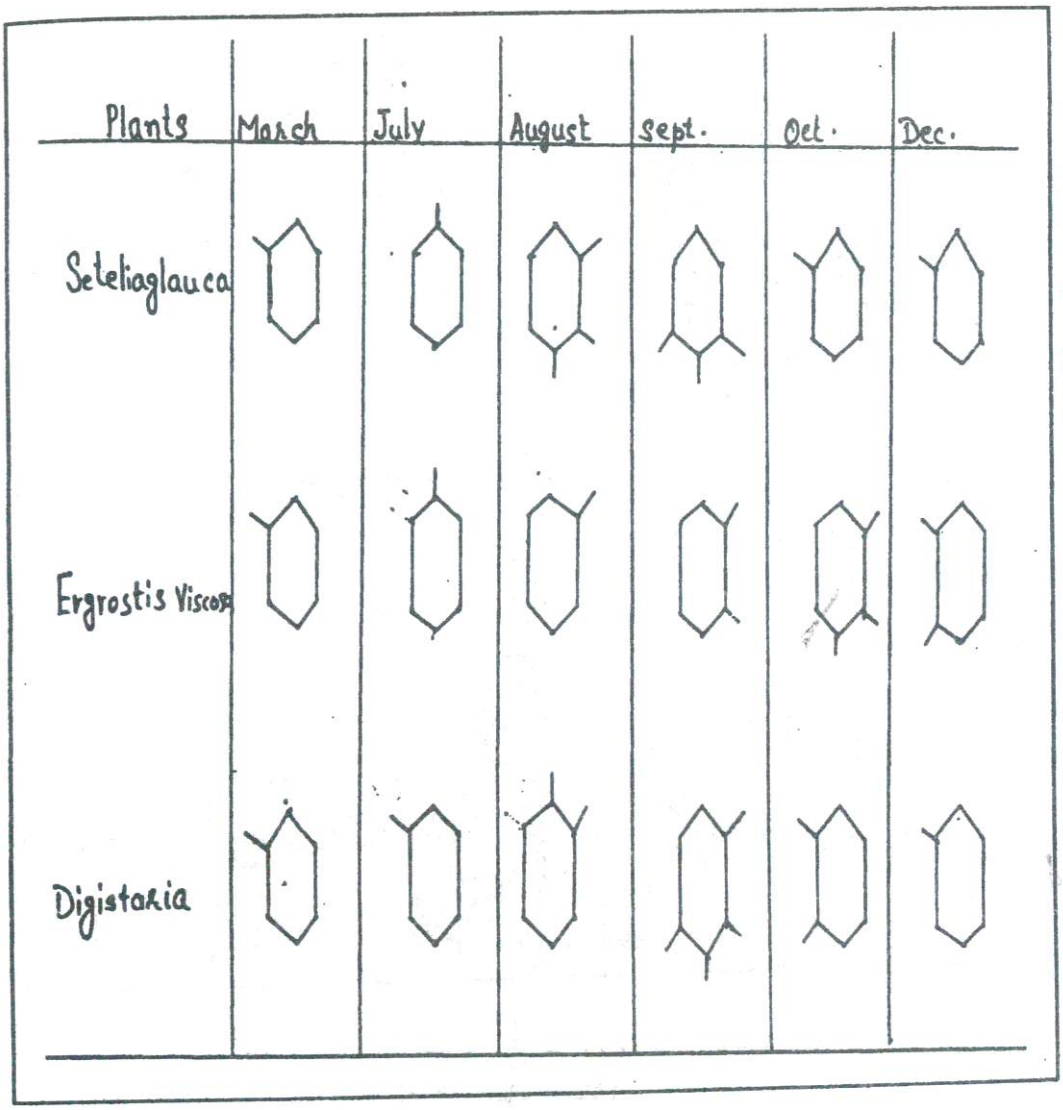


Figure 1.11

Stratification

In the community, length of different plant are different. Eg, lichens are the smallest, herbs are small, shrubs are bigger then herbs and trees may be small or large.

The plants, which shows the same length they form a stratum or herbs, shrubs, small and large tree represent the different strata. This process of strata formation is called as stratification. Different strata are found in all the natural regions while only one stratum is found in agriculture region.

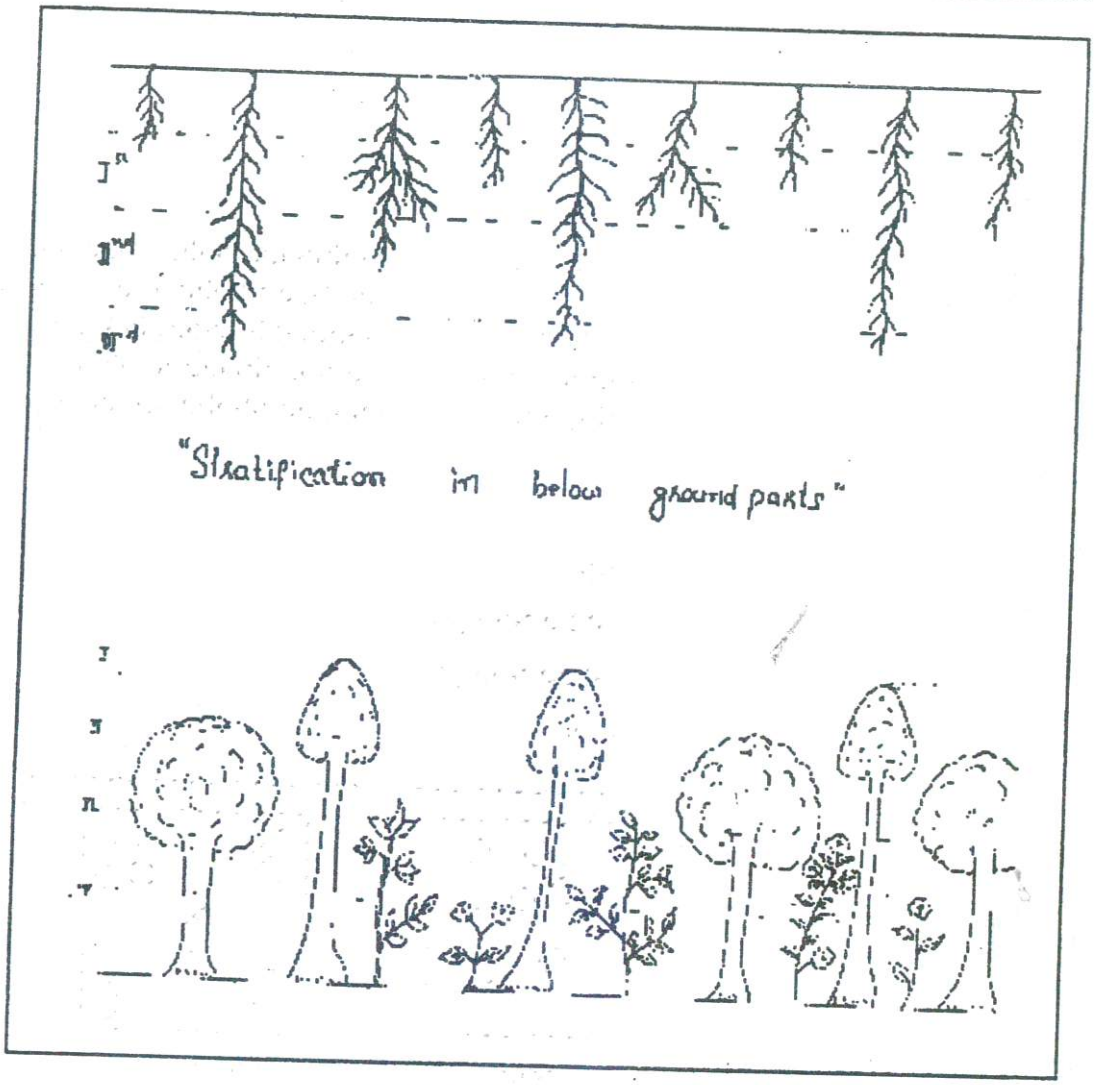


Figure 1.12: Stratification in above ground part

Abundance

Plants are not spread uniformly in the area. These are present in groups or patches hence, relative distribution of species in any community is known as abundance. These are classified into five classes:

1. Rare
2. Occasional
3. Frequent

4. Abundant
5. Very abundant.

Dispersal and Sociability

Distribution of any species in the horizontal area is called as dispersal. If the species get distributed freely and frequently then it is called as random dispersal. But if species is spread or distributed in order then it is called as regular. But if species is present in a group then it is called as contagious. While when different species indicate relationship with each other then this relation is called as sociability. According to Brown and Blanket, sociability is characterized into five classes:

S1 class: The plant grows alone.

S2 class: The plant grows in a small group.

S3 class: Many small groups are found at the same place.

S4 class: Many large groups are found at the same place

S5 class: Plant show continuous population.

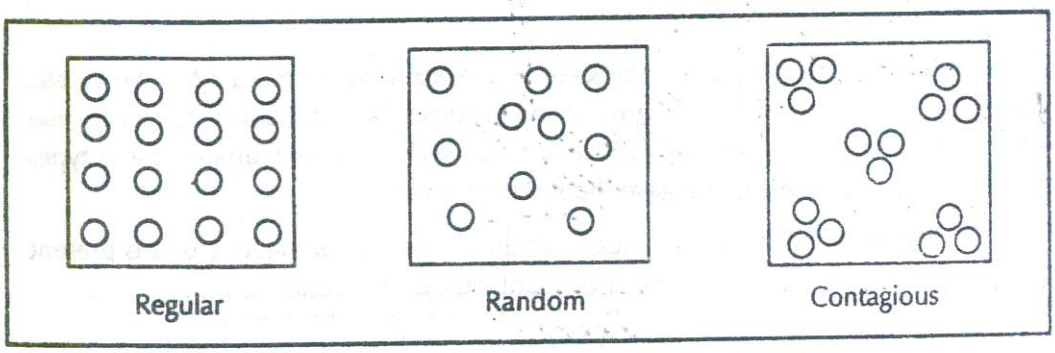


Figure 1.13

Vitality

Normal growth and reproductive capacity is called as vitality. It indicates the alive capacity of the plant. It depends on weight, length of stem, root length, leaf area, leaf numbers, flower number, fruits, seeds etc. According to T. Mishra and Puri vitality is classified into three groups:

1. Fully developed plants: which completes life cycle.
2. Plants which do vegetative propogation.
3. Plants those remain alive for very small time.

Later on Brown and Blanket gave 4 classes but Daubenmire gave 5 classes.

1. V1: plants germinate but die away without reproduction.
2. V2: plant remains alive for many long years but do not reproduce.
3. V3: plants take part only in vegetative reproduction.
4. V4: plants reproduce sexually very rare.
5. V5: plants reproduce fully by sexual reproduction.

Dissiminitue Type

It is kept in qualitative character. Later on organ which spread seeds are called as Disseminate that can be of following types:

1. Anemochore: When organ help in wind distribution. Eg, Tridex.
2. Zoochore: When organ help in distribution in animals. Eg, Xanthium.
3. Hydrechore: When organ is helpful in distribution in water. Eg, Hydrilla.
4. Autochore: When organ is helpful in self. Eg, Vinca rosea.

Life form

Morphologist divides the plants on the basis of growth form as tree, herbs, shrubs etc. Similarly Raunkier represented life forms. He had related plant adaptations to climate and the nature to be alive. He identified 25 life forms, which have been arranged in 5 types later on. Brown and Blanket, also gave the same 5 forms.

1. **Phanerophytes**: Plant is a woody shrub or tree and perrinating bud is present at a height more then 30 cm. Eg, Succulent plants cactus.

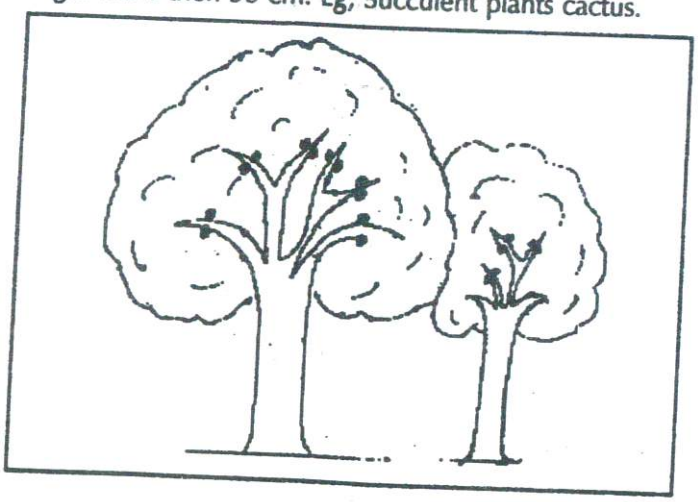


Figure 1.14

2. **Chamaephytes:** These are small shrubs in which buds are present below 25 cm. eg Tripfolium.

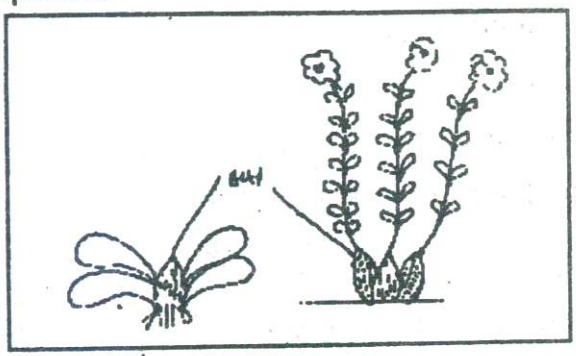


Figure 1.15

3. **Haemocryptophytes:** Plants are herbaceous and found in the cold regions and bud is present below the level and in unfavorable conditions covered with litter. Eg Primula.

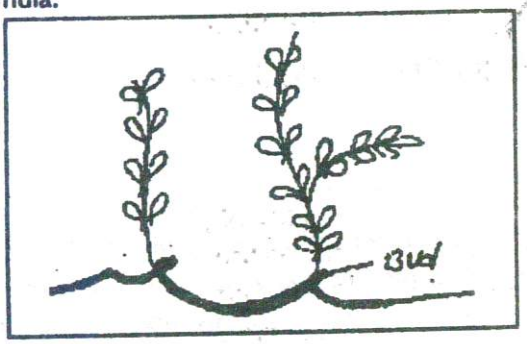


Figure 1.16

4. **Cryptophytes:** In it bud is present deeply in the soil, which is covered with soil. It is called as Geophytes.

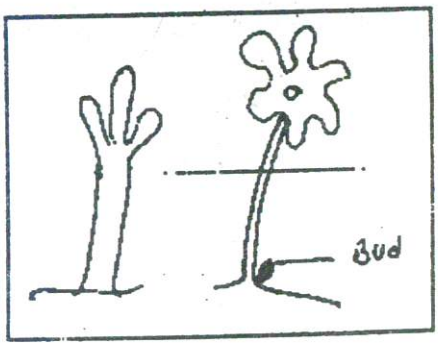


Figure 1.17

5. Therophytes: These are seasonal plants and in favorable season they complete their life cycle and in unfavorable conditions these are found in the form of dominant seed. Eg Annual herbs.

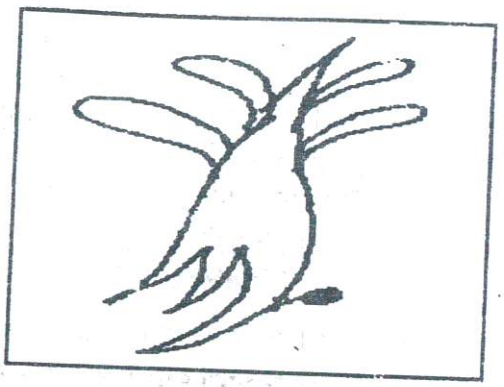


Figure 1.18

Quantitative Characters

Population Density

The parameter which shows mathematical number of any species is known as density or the number of plant of species present in unit area is called as density. Density represents the quantity of competition. It is affected by many factors, which may depend on density or may be free from density. It is calculated by following formula

$$\text{Density} = \frac{\text{Total number of individual of the species in all the sampling units}}{\text{Total number of sampling units}}$$

This value is represented in number/unit area.

Frequency

It shows the distribution of plants of any species in any community. It is indicated in percentage. Hence, its determination depends on the size of sampling unit. It can be determined with the help of quadrate transect point. Small quadrate represents less frequency while bigger quadrant represents more frequency. Hence, to determine frequency right quadrant should be chosen. Raunkies has divided frequency into 5 classes.

A. Class A : 0–20%

B. Class B : 21–40%

C. Class C : 41–60%

D. Class D : 61–80%

E. Class E : 81–100%

Raunkier compared different communities on the basis of frequency and presented the law of frequency. If in a class order of frequency a>b>c>d and d<e then it shows homogenous distribution. In this situation frequency histogram will be J shaped. Natural distribution is homogenous type but if the number of species is more in classes then it is called as heterogeneous distribution. Percentage frequency can be determined by following formula:

$$\text{Percentage Frequency} = \frac{\text{No. of sampling unit occur for one species} \times 100}{\text{Total number of sampling units}}$$

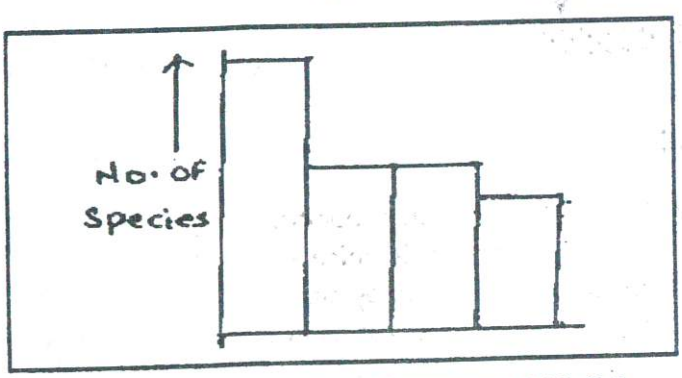


Figure 1.18: Normal Frequency Histogram (Homogeneous distribution)

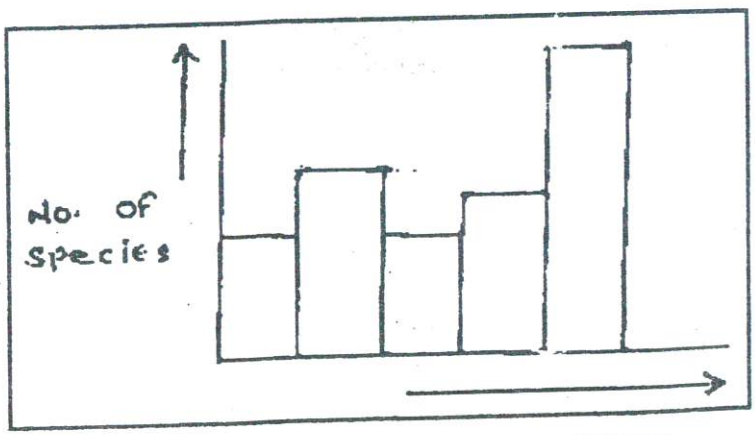


Figure 1.20: Per cent Frequency Histogram (Heterogeneous distribution)

Dominance

It represents the relative importance of species in the community. According to Hansen and Churchill it is a synthetic character but according to Dobenmyre it is an analytical character because many times number of organisms does not give the correct idea. In grasslands large trees are dominant but its frequency is negligible. Density is also negligible. In this situation dominance represents the real situation.

Cover

Area occupied by plants is called as cover. This cover is of two types.

1. Area occupied by green canopy is called as herbage cover while area covered by basal part is called as basal area or basal cover. If we see the relationship between herbage cover and basal area then it can be clearly concluded that ratio of herbage cover and basal area continuously increases from herbs to trees. Hence, it is an important criterion to determine dominance. In vegetation, herbage cover is important which can be determined by making manually a chart or by pantograph.

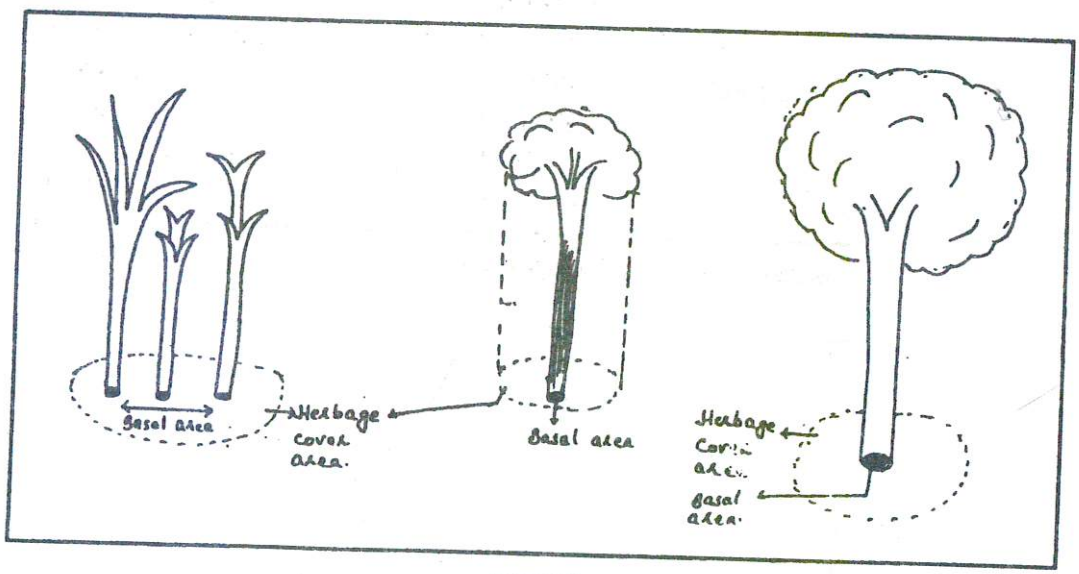


Figure 1.21

Height of Plant

It represents the strength of the plant because due to positive growth, length of the plant increases. By this we get the information about favorable environment. Length is proportional to weight of plant and with the increase in length weight also increases.

Weight of Plants

It is an important quantitative character, which is the best character to determine growth. It is directly length bounded. Weight of plant is determined by two methods:

1. Green parts in which there is amount of water present, also calculate weight.
2. Weight is taken after drying the plant. It is called as dry weight, which is proportional to favorable conditions.

Volume of Plant

Basal area and herbage is calculated separately. Similarly length of plant is also calculated but they do not give any useful information separately. In this situation volume of plant becomes important. Length is dependent on dimension and area depends on two diameters while volume is a 3-D parameter. Hence, determination of parameter is used to find out productivity in the research field.

Synthetic Characters

Synthetic characters are important characters to get the information about community. A group of different species occurring in any area is called as community, and the study of community is called as synecology. To study any community, two types of characters are important; synthetic character and analytical characters. Analytical characters are those characters, which are based on the data obtained from field. But knowledge of synthetic characters depends on analytical characters. Thus, synthetic characters indicate integration and coordination of analytical characters, because when many data tables are summarized into a single table, then it is called as synthesis or association table.

Important synthetic characters for any community are as follow:

Presence and Constancy

With the help of analytical characters frequency, uniform distribution of species in the community can be determined, while how one species gets distributed in different stands of the same community, can be determined by presence and constancy. As any species is found in 18 stands among 20 stands, then its presence or constancy will be 90%. If sample area of same measurement is taken for all the stands then, uniform distribution is called as constancy. But if in different stands, different sampling area is taken, then uniform distribution is called as presence, although it is always tried that same area should be taken in the different stands of one community. But, if in different stands, different types of vegetation

are present, and then same sampling area is taken. If only one sampling area is taken, in which maximum species are included, then it is called as minimal area. It is determined with the help of graphical representation of Species area curve. On the basis of % in stands, species may be divided into 5 classes, which are as follows:

Class A: Species are present in less than 20% stands
Class B: Species are present in 21 to 40% stands
Class C: Species are present in 41 to 60% stands
Class D: Species are present in 61to 80% stands
Class E: Species are present in 81 to 100% stands

If maximum species occur in IV and V classes, then there will be homogenous floristic pattern in community. If constancy of any species is more, then these show wide amplitude. It means these easily grow different microhabitats. If species grows in more than 80% stands, then it is called as constant species. If these show high cover, then species will be dominant. As the number of constant species increases in the communities, the similarity or relationship among the communities also get increased.

Fidelity

The character which limits any of the species to one community, is called as Fidelity. It is related with the range of the species. If the fidelity of any species is more, then it shows the distribution in the limited area or community. But, if fidelity of the species is less, then it will shows distribution in many communities. Its main reason is different adaptation range or amplitude of different species. The fidelity decreases for those species, which show association with others. While those species, which are prevented from association, their distribution gets limited and fidelity becomes high. Species having low fidelity show more dispersal, adaptation and migration. On one side fidelity indicates distribution of species in the different communities, on the other side the constancy indicates distribution of species in different stands in a single community.

Brown and Blanket divided the species into five classes on the basis of fidelity:

1. Characteristics species (faithful species): –
   a. Exclusive: species which are, completed limited to one community.
   b. Selective (Feste): It shows homogenous distribution in one community, but sometimes also present in other community.
   c. Preferential (Holde): These species are found in different communities, but for being alive, the most favorable or adoptable condition are found only in one community.

2. Companion species:

   Indifferent (vage): These species grow in many communities and species do not give preference to any community.

3. Accidental species:

   a. Strange (Fremade): These are found in the earlier stages of succession and in later stage, these are found in very few communities.

It is clear from this that exclusive, selective and preferential species have much more fidelity, due to which rate of homogeneity also increases. These species, which show higher fidelity, are called as indicator species.

Dominance

Dominance is an important characteristic of vegetation, which shows the effect of one or more species in the stand. Other species get suppressed more or less due to dominant species, or their vitality reduces. Those species are dominant, which adopt suitably according to the environment of community and which shows positive interaction with all other species. Number of dominant species is less in mature grassland; while in tropical rain forest, many species are dominant. Dominance is based on the following analytical character.

I. Herbage cover

II. Population density

III. Frequency

IV. Height

V. Life form

VI. Vitality.

In savanna, some trees and shrubs are found along with grasses. In this community, trees are dominant with grasses, but ecological dominance is shown by grasses, because these show more effect on plants and habitat. Hence, dominance is not based upon any one analytical character but it depends upon many characters.

e.g.-The dominance of grasses is due to production of more seeds, high sociability,higer herbage cover, deep root system, more dry weight, presence of uniform distribution. In India, Parthenium is dominant due to low fidelity. In USA, Bromus tectorum is dominant due to the following main reasons:

- Large seed production
- Rapid root and shoot growth

- Early maturity
- Rapid adaptation in the drought or any other unfavorable or extreme conditions.

Physiognomy and Pattern

Appearance of any stand or community is known as physiognomy. It is based on different qualitative and quantitative characters. eg, type of species, species dominance, life form, population density, herbage cover, height of species, sociability, stratification, species association etc. eg: Dicanthium is found in the basket form due to which it gets protected from trampling effects. Physiognomy is mainly used in the identification of community and in comparison of different communities. It is a useful character for the primary survey of community. It is also used in the general description of vegetation of any strand. Whole sociological analysis can be done with the help of physiognomy.

Similarly, pattern represents that species is found singly or in a group or in a clump. Physiognomy shows diversity in the groups as in grassland presence of shrub and trees along with grasses. But for pattern the quantitative study of it is the must. If we have to see pattern in the small area, then small quadrate is used to perform sampling. But if pattern is to be seen in large area, when the species are in a group and there are larger gap in the middle, then large quadrate is required. Four pattern vegetation analysis quality; density, herbage cover and frequency are studied. Pattern can be divided into three groups:

1. Morphological: In which growth of rhizome or propogation organ is considered important.
2. Sociological: Association or competition of species becomes important in it.
3. Physiognomic: In it topographic variation in soil moisture, nutrient concentration, soil texture, soil structure are important factors.

During primary colonization of species, species distribution may be random. But some spots are favorable for growth. At such places plants aggregates which show morphological and physiognomy pattern. While on development many species represent competition, replacement of plants, species association, and sociological pattern. But as the climax stage is achieved pattern becomes ineffective. But then also three kinds of patterns can be seen.

Conclusion

Synthetic characters are those characters, which summarize all the qualitative and quantitative character and we can do comparative study of many communities together or of different stands of one community.

Review Questions

1. What are the Major Life Zones of the World?
2. Describe Index of Dominance.
3. What is Ecological Niche? Discribe types of Niche.
4. What is Analytical Character? Discuss it.
5. Describe about 'Fidelity'.

CHAPTER 2

ECOSYSTEM ORGANIZATION

LEARNING OBJECTIVES

- Structure and Functions
- Primary Production
- Energy Dynamics
- Litter Fall and Decomposition
- Global Biogeochemical Cycles

Structure and Functions

Ecosystem is the branch of ecology. First of all, the scientist A. G. Tansley used the term ecosystem at the place of Ecological system. Ecosystem is the dynamic stage of ecology, in which the contents flow of energy and nutrients goes on. Hence, Ecosystem can be defined as "the functional relationship among living and non living components present in any community, is called as Ecosystem."

In any Ecosystem, mainly two components are always present, which are in the form of biotic environment and non-living abiotic environment. These components represent complex relationship in the ecosystem.

Components of Ecosystem

Mainly two types of components are found in the Ecosystem, it can be divided into other components also, which are as follows:

A. Abiotic components: It is the non-living component of ecosystem. These components are mainly air, water and soil. Plants, animals or microbes take oxygen, carbondioxide and nitrogen from air and control the metabolism. Oxygen and carbon dioxide, both are useful for plants, while only oxygen is important for animals. In the same way, plant gets nutrients from the soil. These are micro and macronutrients. Main macronutrients are C, H, O, P, S, N, K, Ca, Fe, Mg, while important micro-nutrients are Zn, B, Mn, Mo, and Cu.

B. Biotic components: It is the living component of the ecosystem. This component shows the transfer of substances in organic form. Biotic components are of the following type:

1. Producers: They are the first component of ecosystem and food chain starts from them. Since these components prepare its own food, so they are called as producers. These are also known as autotrops. All chlorophyllous green plants are included in this category. Much biodiversity is seen in plants, as algae, fungi, bryophytes, Pteridophytes, gymnosperms and angiosperms etc. These all plant group are found either in soil or in water and convert inorganic compounds into organic compounds.

2. Herbivores: This group depends on plants directly for food. These are microorganisms like pests, leachetc or bigger organisms like rhinoceros, barasinga, elephant. Elephant is the biggest herbivore present on earth. These organisms are either grazers or browsers (who eat leaves).

3. Carnivores: A group of organisms, which is indirectly dependent on plants and directly dependent on animals for their food. They take other animals as their food. Hence, they directly take organic compounds (substances). Other carnivores also eat carnivores. Hence, a group of such organisms, which cannot be eaten by other organism, is known as top carnivores. Eg. Peacock, eagle, lion, tiger etc. These are the last tropic level of the grazing food chain.

4. Decomposers: It is a group of microorganisms. Hence called as micro consumers, which takes only dead organic matter as their food, and these are called as saprophytes. These decompose complex organic substances into simpler organic substances, and are called as decomposers. They change organic substances by doing their Minralization into inorganic substances.

According to Odum also, ecosystem can be divided into five components, which are as follows:

i. Abiotic components

ii. Producers

iii. Herbivores

iv. Carnivores

v. Decomposer.

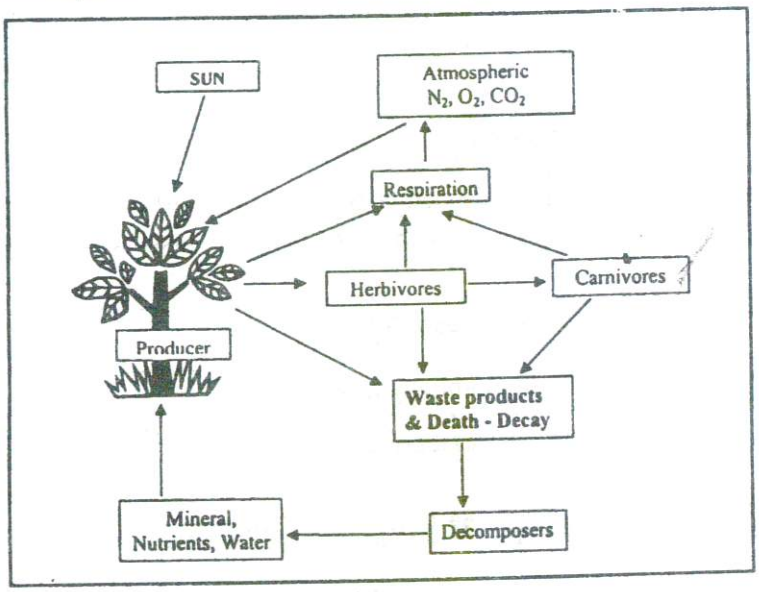


Figure 2.1

Primary Production

In the ecosystem mainly two components are proposed -Biotic factors and Abiotic factors. Biotic factors have the efficiency to accumulate the food. So, the amount of food that is either produced or taken from other factors is known as productivity. The important component that can synthesize food itself, are known as producers. All the green plants are producers. Basically, the food synthesized through the green plants is known as primary production and this primary productivity are of following types:

Gross Primary Productivity

The total amount of food synthesized by plants per unit time per unit area is known as gross primary productivity. It is also known as total photosynthesis or total assimilation.

Net Primary Productivity

After synthesis of food, its some part is used in the metabolic processes, so the amount of food retained after metabolism, is known as net primary productivity. It can be calculated by following formula:

$$NPP = GPP - R$$

Where, NPP – Net primary productivity

GPP – Gross primary productivity

R – Respiration rate

Net Community Productivity

In the plants, larger amount of food is accumulated. But, it is used by herbivores. So, after taking of the food by herbivores from plants, the remaining food is known as Net community productivity.

$$NCP = NPP - GSP$$

Where, NCP–Net community productivity

GSP–Gross secondary productivity

Methods for Determination of Primary Productivity

The best method to determine the primary productivity is to determine the rate of energy flow, but it is too difficult. So, in the different conditions, different methods can be used to determine primary productivity. Some important methods are as follows:

1. **Harvest method:** In this process, smaller plot is selected, the standing crop is cut down and particular time is given for the regeneration of crop which may be 7 to 15 days. After this time period, standing crop is again cut down. It is dried away at 60°C in oven. Then, its dry weight is determined or with the help of calorimeter, its value is determined in calorie. With the help of following formula, NPP is determined:

$$NPP = \frac{\text{Dry weight of plants}}{\text{Time in days}} \times \text{Area}$$

The unit of productivity will be gms/ day/ unit area

But, with the help of this method, we can find out only NPP, not GPP.

2. **Oxygen measurement (D.O. method or Light and dark bottle method):** This method is suitable for determination of NPP and GPP in the aquatic ecosystem. It is based on the oxygen measurement. Its basic principle is to evolve oxygen during photosynthesis. It is clear that it's rate of photosynthesis is higher, and then the rate of oxygen evolution will be high. In this method, three bottles are taken and the pond water is filled in these bottles. Then, the D.O. of first bottle is determined. Then, one bottle is covered with black paper or black cloth, which is known as dark bottle. In this bottle, photosynthesis cannot occur but respiration will take place. The third bottle is known as light bottle where photosynthesis as well as respiration will occur. These bottles are hanged in the pond. After 6-8 hours, bottles are taken out and D.O. is determined in both the bottles, and following observations are taken:

   a. D.O. of bottle A (initial D.O.) = A ppm

   b. D.O. of dark bottle = B ppm

   c. D.O. of light bottle = C ppm

   Now, the NPP and GPP are calculated by the following formula:

   a. Respiration rate = (B–A) ppm

   b. NPP = (C–A) ppm

   c. GPP = NPP + R

   It is useful only for aquatic ecosystem but not for terrestrial ecosystem.

3. **Carbon assimilation method:** This method is based on use of carbon dioxide during photosynthesis. In this process, 3 plants having similar shape and size are selected. These plants are covered with bell jars. Each bell jar is having inlet for air and outlet is connected with calcium hydroxide. Now, the first set is control set, second set is covered with black paper or black cloth, which will indicate only respiration and the third, will indicate photosynthesis as well as respiration. This set up is kept in the sunlight and after 6-8 hours, the quantity of calcium hydroxide is determined in the limewater. Actually, CO_2 reacts with limewater to form calcium carbonate. This calcium carbonate is taken out, dried away and its weight is determined, and with the help of molecular weights, the weight of carbon dioxide is calculated. Its basic principle is:

   100 gm $CaCO_3$ Eq. = 44gm of CO_2

   The main observations are following:

   a. Amount of CO_2 in Ist set = A gms

   b. Amount of CO_2 in IInd set = B gms

c. Amount of CO_2 in IIIrd set = C gms

With the help of these observations, productivity can be calculated as follows:

a. Respiration rate = (B–A) gms

b. NPP = (A–C) gms

c. GPP = NPP + R

4. **pH method:** This method is suitable for aquatic ecosystem. In aquatic ecosystem, CO_2 is present as soluble gas and presence of CO_2 will indicate lowering of pH. So, as the CO_2 is used up in the photosynthesis, pH parallels increase. This increase in pH will be directly proportional to rate of photosynthesis.

5. **Disappearance of raw material:** Any synthetic process needs the nutrients so, the calculated amount of nutrient is transferred into the soil and the initial analysis of soil sample is carried out. After 24 hours, again the analysis of soil sample is carried out and the loss of nutrients during 24 hours is calculated. The rate of photosynthesis is directly proportional to loss of nutrients. In the ecosystem, CO_2 is present as soluble gas and presence of CO_2 will indicate lowering of pH. So, as the CO_2 is used up in the photosynthesis, pH parallels increase. This increase in pH will be directly proportional to rate of photosynthesis.

6. **Radio isotopic method:** It is the standard and exact method to determine the productivity. In this process, $^{14}CO_2$ is provided to the plant and after 2 hours, radioactivity is measured in the plants. It is directly proportional to the rate of photosynthesis.

7. **Chlorophyll method:** It is indirect method. It is clear that photosynthesis is based on the amount of chlorophyll. So, if the plants have higher amount of chlorophyll, then the rate of photosynthesis will be higher. In this method chlorophyll is extracted from the leaves and its concentration is determined through spectrophotometer. Generally, this method is used for comparison of productivity of different communities.

8. **Herbage cover method:** It is indirect method because in it the plants or in community, amount of green canopy is higher, then the rate of photosynthesis will be higher. So, it is used for the comparison of productivity of different communities.

9. **Global pattern of primary productivity:** " Annual average rate of net plant production. The number after the bar is K cal/m^2/year; the number within the parentheses is area in 106 km^2.

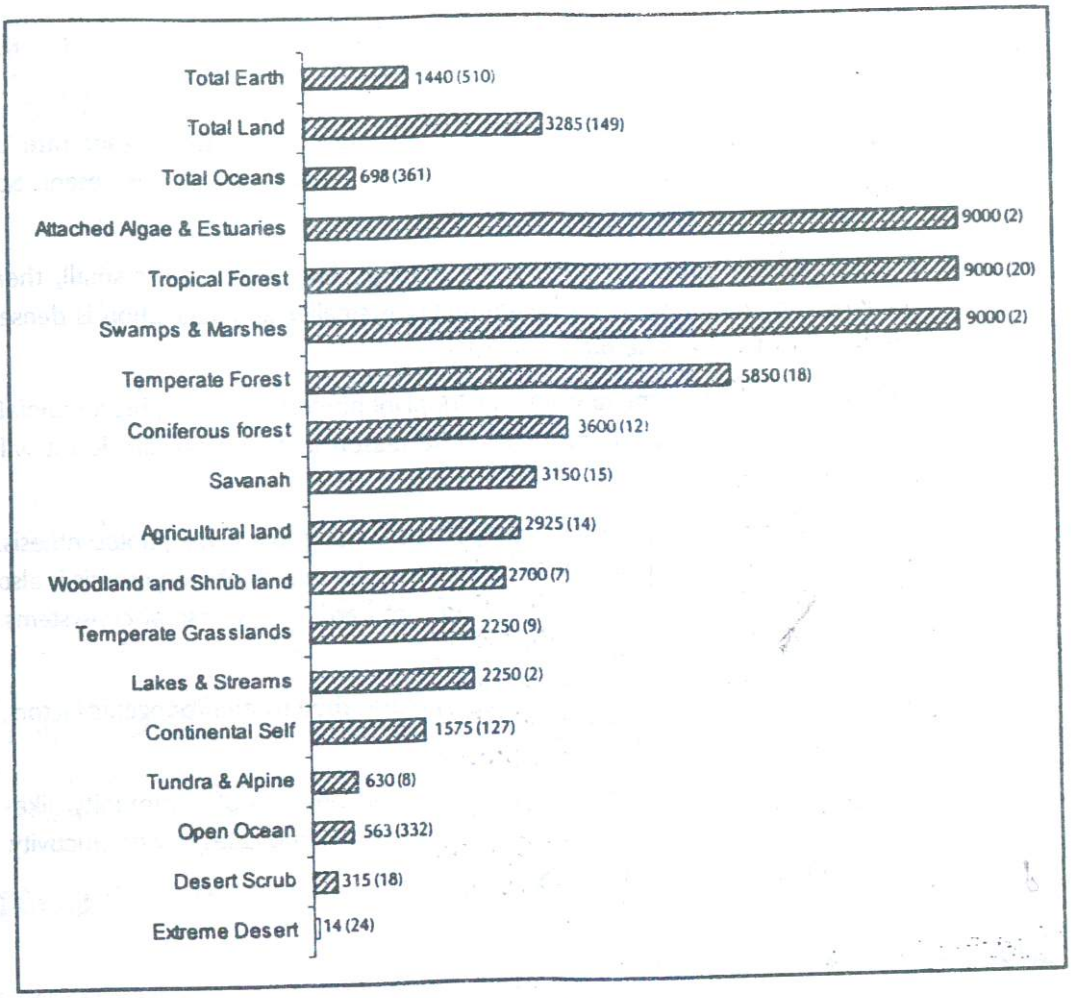


Figure 2.2

Factors Controlling Primary Productivity

Primary productivity is controlled through all these factors that control the rate of photosynthesis some important factors are the following: .

1. Size of community: If the community is large, then the productivity of the community will be high.
2. Herbage cover: The green canopy of the plant is known as herbage cover, and this is the plant part where photosynthesis occurs. So, larger the canopy more the productivity.
3. Availability of nutrients in soil: It is proved that the rate of absorption of nutrients is directly proportional to productivity. If the soil is nutrient rich, then the productivity will be high.

4. Concentration of CO_2: CO_2 is the raw material for photosynthesis and as the CO_2 concentration increases; the rate of photosynthesis will increase up.
5. Types of plants: It is clear that tropical plants have the higher rate of photosynthesis, because in the tropical plants, photorespiration is absent. So, efficiency of synthesis will rise up.
6. Density of vegetation: If community is large, but vegetation is small, then productivity will be less. But if community is smaller and vegetation is dense, then productivity will be high.
7. Rainfall: The water is the raw material for plant photosynthesis so; higher rainfall will indicate higher productivity. It is the reason that tropical rain forest will indicate highest productivity.
8. Solar radiations: Light is another important limiting factor for photosynthesis. So, as the amount of solar radiations increase, the rate of photosynthesis is also increased. Generally, solar radiations are not barrier in terrestrial ecosystems. But it is barrier for aquatic ecosystem.
9. Disturbances in community: If community is disturbed by anthropogenic factors, and then its productivity will be low.
10. Type of community: The productivity is based on type of community, like-desert community, tundra biome, alpine community, indicates low productivity. Whereas rain forests indicate higher productivity.

Energy Dynamics

Trophic Organization

In any ecosystem, mainly two types of components are present, which are called as abiotic and biotic components. Biotic components interact with each other and form food chain and food web. Thus, biotic components represent dynamic state of ecosystem, in which continuous flow of energy takes place in the form of food. This energy flow goes on generally through the conduction process. Hence, energy transfers from one level to another level in a serial wise manner. Like producers convert photo energy into food, this energy in the form of food transfers into herbivores and then, from herbivores to carnivores. "Thus that energy level in the dynamic ecosystem through which transfer of food or energy takes place, is called as trophic level."

Green plants $\longrightarrow$ Herbivores $\longrightarrow$ Carnivores $\longrightarrow$ Top carnivores

T_1 T_2 T_3 T_4

In this chain, each level has been shown in the form of trophic level, which is represented by T_1, T_2 T_3 and T_4. For any ecosystem, first trophic level is always occupied by producers (Green plants) and top carnivores form last trophic level. Normally, in any ecosystem, 3–5 trophic levels are there. In this, T_1 shows producers, T_2 shows herbivores, and T_3 to T_5 shows carnivores. In a pyramid also, each level is represented by trophic level.

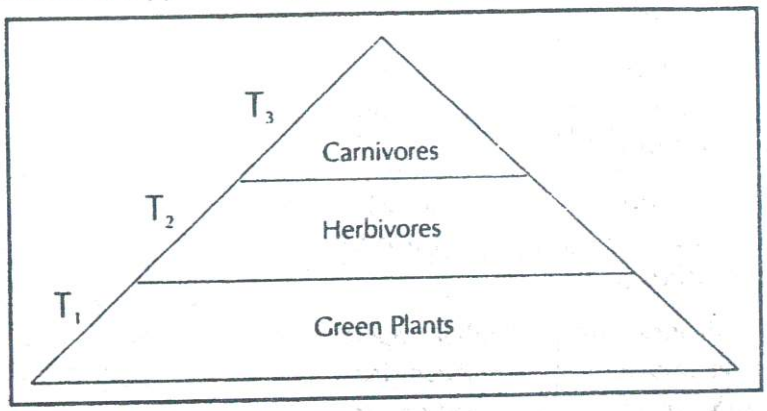


Figure 2.3

In this pyramid, first trophic level is shown by grass, second trophic level shown by insects and third trophic level shown by frog, fourth trophic level shown by snake and fifth trophic level shown by eagle. First trophic level T1 shows producers, while last trophic level T5 shows top carnivores.

Energy Flow Pathways and Ecological Efficiencies

Energy Flow Pathway

At the earth surface, the main source of energy is sun, which transfers the energy as radiations. These radiations are visible and invisible. The range of invisible radiations is 1Å to 3800Å, and 6800Å to 106 meters. These radiations are following:

Table 2.1

S. No.	Radiation	Range
1.	Gamma rays	1 Å to100 Å
2.	X- rays	100 Å to1000 Å
3.	UV- rays	1000 Å to3800 Å
4.	Visible radiation	3800 Å to6800 Å
5.	Infrared	6800 Å to10, 000 Å
6.	Fared	10,000 Å to 1, 50,000 Å
7.	Radio waves	More than 1, 50,000 Å

Out of these radiations, limited radiations transfer at the earth's surface and after the biosphere. This photo energy is basically changed into chemical energy by photosynthesis and then in the form of chemical energy, transferred from one trophic level to another trophic level. Its flow is unidirectional, which is from producers to decomposers.

Ecological Efficiencies

Basically, green plants conserve the photo energy. And in different ecosystems, the floristic composition is different. The efficiency of ecosystem through which it can conserve maximum amount of energy, is known as ecological efficiency. In different ecosystems efficiency differs, like in different ecosystem, highest amount of energy is conserved in tropical rain forest. From the sun, only 1/50 million part of solar energy is transferred at the earth surface, because solar radiations travel through the space in the form of water. Its λ is 0.03 Å to many kms. But, major amount of radiations is lost away in space. Upto 300 nm wavelengths, is filtered by ozone layer. So, at the earth surface, 300nm to 10,000 nm and more than 1 cm length waves enters. These waves can penetrate the atmosphere up to 28 kms. altitude. But upto the earth surface, mainly visible and infrared components transfer. Its range is 300 nm to 380 nm UV, 380–680 nm visible and 680 nm to 1000 nm infrared waves. If the day is clear, then radiations are made upto 10% UV, 45% visible and 45% infrared. Plants absorbed strongly the blue and red light, which is ranging from 400 to 450 nm and 600 to 700 nm.

So, in the ecological efficiencies, we study following 3 types:

1. Amount of solar energy transferred in the ecosystem.
2. The amount of energy used by green plants for photosynthesis
3. The quantity and pathway of energy flow from producers to consumers.

About 34% of the radiation are reflected back, 10% radiations hold by O_3 layer, water-vapor and atmospheric gases, while 50% reaches at the earth surface. It means the green plants can use little quantity of solar radiation, which is 1–5% only. The remaining energy is absorbed by vegetation or water. It means only 0.02% of sunlight transferred in atmosphere is used in photosynthesis, like at the earth surface, total incoming radiations are 1,18,761 gm calorie/cm^2/yr, out of which 1,18,761 gm/calorie/cm^2/yr, remain unutilized. So, the gross production is 111–gm/calorie/cm^2/yr. So, the efficiency of ecosystem is only 0.1%, out of which 23 gm/calorie/cm^2/yr utilized in metabolic reactions of producers.

15 gm/calorie/cm²/yr is consumed by herbivores and 3 gm/calorie/ cm²/yr used by decomposers and 70 gm/calorie/cm²/yr is remained as net community productivity. This summarized pathway is as follows:

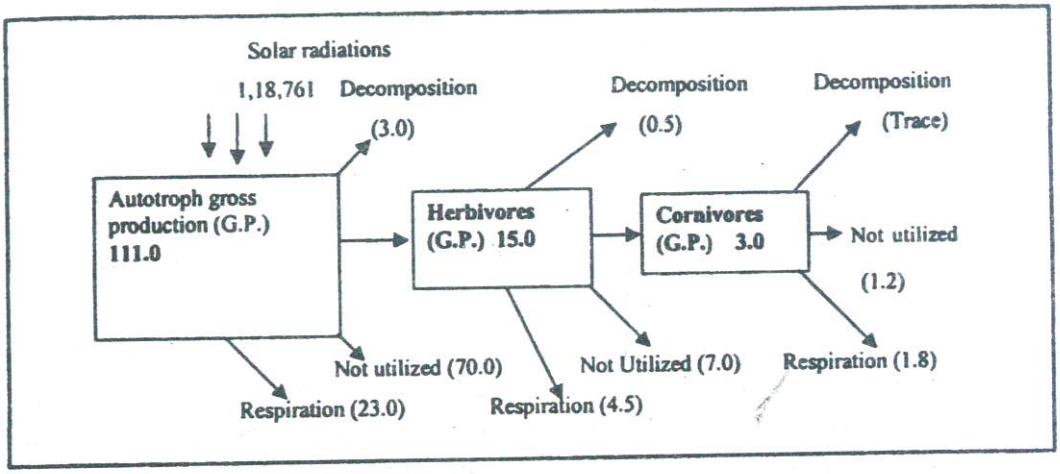


Figure 2.4: Energy Flow Diagram for a Lake (Data are represented in gram calorie/cm²/year)

The highest efficiency can be seen in tropical rain forest and least efficiency in desert ecosystem and alpine ecosystem.

Energy flow in food chain: It is clear that plants are major receptor of energy, because it can convert the photo energy into chemical energy. This energy is transferred through following 3 models:

a. Conduction: When energy is transferred from particle to particle, then it is called as conduction. Like - from producer to decomposer, energy transfers through herbivores to carnivores.

b. Convection: When energy source is transferred near the energy receptor or energy receptor is transferred to the energy source, then it is known as convection. Like -herbivores come near to the plants and eat them away. Here, plants are the energy source and herbivores are energy receptor. But if insects are transferred near to the lizard and lizard eats it away, then insect is the energy source and lizard is the energy receptor.

c. Radiation: When energy is thrown away in the form of packets and small of part it is taken by receptor, and then it is known as radiation, like energy transferred from sun to producers. Through this process the energy flow in the ecosystem is a systematic process. It means it is based on some laws, which are as follows:

1. Law of energy conservation: It is the first law of Thermodynamics. According to this rule, it means in any trophic level energy is distributed in such a way that total amount remains constant.

   Total energy in Autotrophs = Energy transferred in herbivores + energy as waste product + energy used in metabolism + not utilized energy

   $111 = 15 + 3 + 23 + 70$

   Similarly, this law can also explain the transformation of photo energy into chemical energy.

2. Distribution of energy flow: Second law of thermodynamics indicates it. According to this law, energy flow is unidirectional process and in the ecosystem, energy transfer is from producer to decomposer through herbivores and carnivores.

3. 10% rule: According to this rule, only 10% energy is transferred from one trophic level to next trophic level. Odum proposed the models for energy flow, which are also called as Box Pipe model. Trophic level is represented by Box and energy flow is indicated by pipe. Odum proposed 2 types of energy flow models:

Single channel Model: This type of energy flow model is based on grazing food- chain only. So it is known as single-channel model. But, it cannot show the energy budget. The representation of this model is as follows:

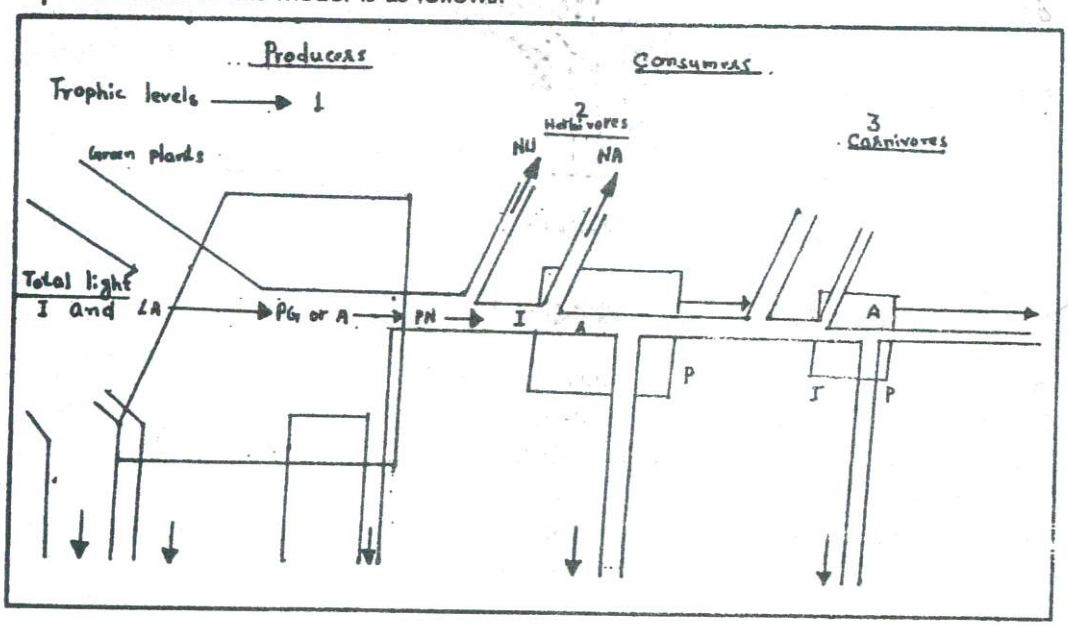


Figure 2.5

Double-channel Model or Y-shaped model: Those models which are based on grazing food chain and detritus food chain, are known as Double-channel model or Y-shaped model. These are complex, but perfect model, and show the energy budgets. Grazing food chain is based on dead organic matter. So, one is above ground chain and one is below ground chain. A general Y-shaped energy flow model is following:

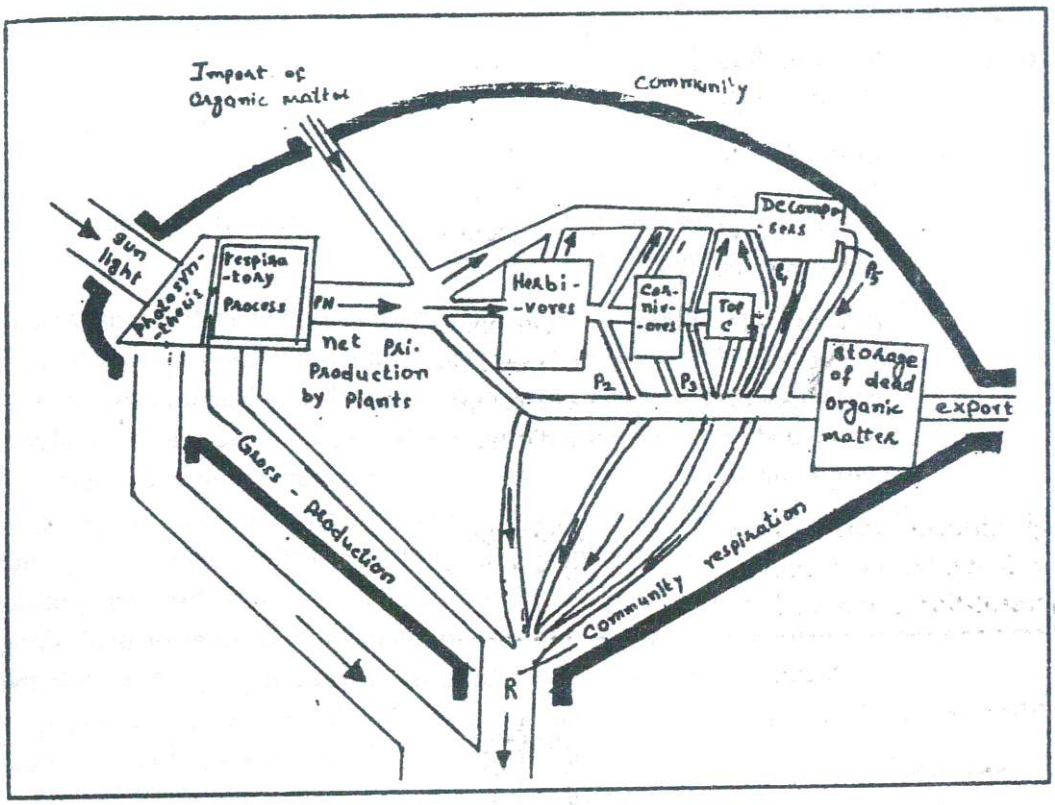


Figure 2.8

Litter Fall and Decomposition

In the ecosystem, energy flow occurs through two types of food chain, which are grazing food chain and detritus food chain. Grazing food chain is based on energy transferred from dead organic matter. Such organisms, which are based on dead organic matter, are known as detritivore, and the fresh dead organic matter of the plants is known as litter. This litter starts decomposition in the soil and changed into humus duff and minerals, which is known as litter decomposition, and the pathway is known as detritus cycle.

Mechanism of Litter Decomposition

Litter decomposition is totally based on microbes, which are known as saprophytes, and which gets the energy through the decomposition of dead organic matter. Mainly these saprophytes are bacteria; slime moulds, fungi and protozoan worms. It is the essential step of the minerals cycling. Basically, these microbes are fungi, which secretes the enzymes and change the complex material into the simple compounds. So, the litter decomposition occurs in the following three steps:

1. The dead organic matter that is complex in nature dissociated into simple organic compound.
2. Minralization of simple organic compound carried out through microbes, through which inorganic compounds are produced.
3. Transformation of inorganic compounds from one form to another form. Mainly, dead organic matters are proteins, polysaccharides and lipids. Proteolytic bacteria in which protein gets changed into peptones and then polypeptides decompose protein. Other microbes break the peptide bonds. So, amino acids are realized. Ammonifying bacteria now remove the NH_3 from amino acids and form the free ketoacids. Plants either absorbs this NH_3, as released into atmosphere, or nitrifying bacteria, Nitrosomonas and Nitrobactor activate upon the NH_3 and through nitrification, nitrate is produced. This nitrate is either absorbed by plants or through leaching, transferred into the underground water or denitrifying bacteria convert it into free N_2, which is transferred into atmosphere. If in the soil, N_2 fixing bacteria are available, then N_2 is again fixed in the form of NH_3. In such a way, Minralization and immobilization processes take place in the soil and it is a sequential process. If any step is interfered, then ecological imbalance is created.

   In the plant litter, second measure component is polysaccharide and in the plants, higher amount of cellulose, hemi cellulose, pectin and lignin can be seen. Many microbes secretes cellulase, pectinase, diastase and lignase enzyme which can dissociate the complex polysaccharides into the disaccharides, while lactase, maltase and invertase are also secreted by microbes, which can convert dissacharides into monosaccharides, and monosaccharides are absorbed by microbes as a carbon source. The major complex compound is lipid. Many bacteria secrete lipase enzyme which can dissociate the lipids, and finally, it is changed in to CO_2 and H_2O.

Factors Affecting Litter Decomposition

1. Humidity: The litter decomposition is a biochemical process, so it is controlled by all those factors, which can show bacterial growth. As the percent humidity increase in the soil, the number of microbes also gets increased, which enhance the rate of decomposition.
2. Aerobic nature of soil: In the soil, if the amount of oxygen is higher, then aerobic decomposition of soil takes place. But if water log condition is created, then anaerobic decomposition takes place and further, suitable rate of decomposition, and aerobic condition is necessary with higher humidity.
3. Temperature: At very low or very high temperature, bacterial activity and enzyme activity gets affected. So, the moderate temperature from 28°C to 35°C is most suitable for decomposition and it shows maximum rate of decomposition.
4. Nature of litter: If litter is having higher amounts of complex compound like lignin and cellulose, then the rate of decomposition will be slow, but if amount of simple organic compound is higher, then it shows higher growth rate of microbes, which enhance the decomposition rate of organic matter.
5. Availability of litter: Litter is the raw material for the microbial growth. So, if litter is available continuously for the microbial growth then the rate of decomposition will be high.

Global Biogeochemical Cycles

In any ecosystem, there is relationship between two major components. These are abiotic and biotic components. Biotic components represent all the living organisms, which are plants, animals and microbes, while abiotic components represent non-living and living components. These components consist of lithosphere, hydrosphere and atmosphere. Hence recycling of matters takes place in all these environments. Actually living organisms require 40 necessary minerals, which get deposited in the organic form in the body and later on, after death, microorganisms decompose them. These type of cycles, which depend on living organism and non living matter, are called as "Biogeochemical cycle". Actually this word consists of Bio + Geo, where Bio word is represent living organisms, and Geo word is consist of geological forces, which may be physical or chemical. Hence, the movement of substances in between along the ecosystem is called as biogeochemical cycle. Biogeochemical cycle is of two types:

a. Those cycles in which nutrient is found in gaseous form and atmosphere plays an important role in this cycle, then these are called as "atmospheric cycle". Example- Carbon cycle.

b. Those cycles, which complete in the hydrosphere itself only, then this type of cycle is called as edaphic cycle or sedimentary cycle.

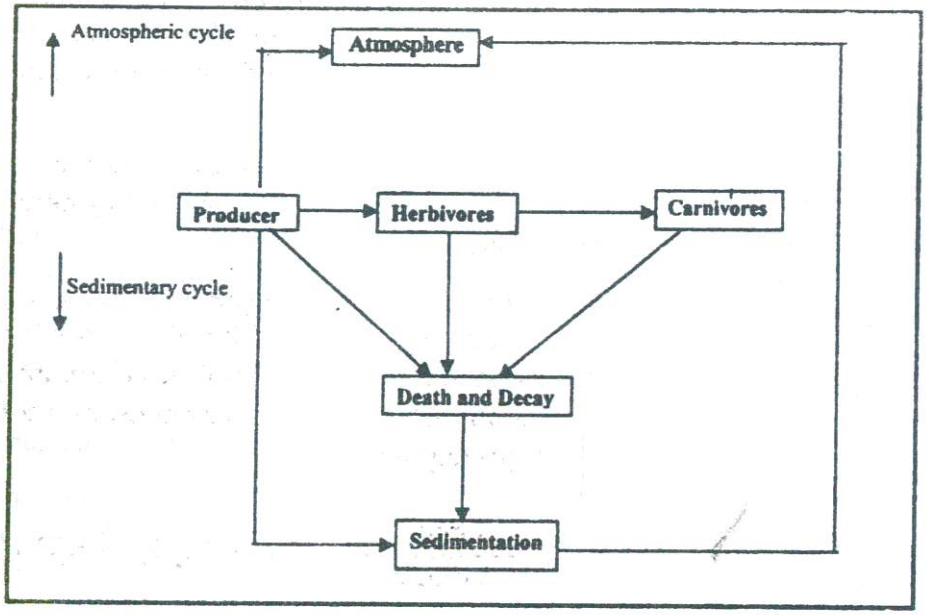


Figure 2.7: Representation of Atmospheric and Sedimentary Cycle

Carbon Cycle

Carbon is found in every living organism in the organic form, while in the environment or atmosphere; it is present in the inorganic form. The main source of carbon is atmosphere, where it is present in the form of CO2 in the concentration 0.345% or 345ppm. In the carbon cycle, producers and decomposers are two major components, which regulate carbon cycle.

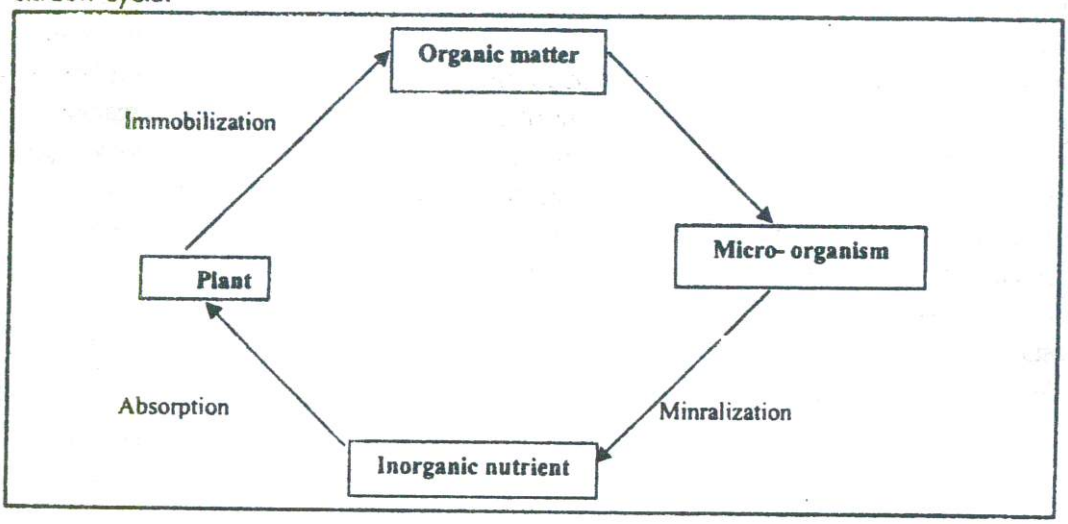


Figure 2.8

In the carbon cycle, two processes are very important:

1. Immobilization: The process in which inorganic carbon is converted into organic carbon; then it is called as immobilization. Green plants regulate this process only, because they convert CO_2 into glucose in the presence of sunlight and chlorophyll.

2. Minralization: The process in which organic carbon is converted into inorganic carbon, is called as Minralization. This process is regulated by decomposers, which are bacteria, fungi, nematodes etc.

   Carbon cycle is a gaseous cycle, because this cycle goes continuously in between atmosphere and terrestrial area (lithosphere) and it mainly depends on CO_2. Concentration of CO_2 in the atmosphere is 345 ppm. Green plants absorbs CO_2 from atmosphere and converts this CO_2 into glucose in the presence of chlorophyll and sunlight. It is called as photosynthesis.

$$6CO_2 + 12H_2O \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

In this process, inorganic carbon gets converted into organic carbon i.e. glucose. This glucose gets transformed into various forms as starch, cellulose, glycogen etc. In plants it is stored in the form of starch. From plants these substances enter the food chain and when herbivore eat plants, then organic contents gets into herbivores and these enter from herbivores to carnivores. Thus, these remain in organic form in the whole food chain. Although they get transferred from starch to glucose and from glucose to glycogen, yet in each tropic level these organic compounds gets oxidize during respiration due to which organic compounds converts into CO_2.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow C_6H_{12}O_6 + 6CO_2$$

This CO_2 enters into the atmosphere, but a large part of organic compounds enters soil in the form of excretory substances. Similarly after death also, this compounds enter into the soil, where different types of decomposers converts it in the form of complex organic compounds to simple organic compound like starch and cellulose get converted into glucose. This gets decomposed in the presence of cellulosic fungus, later on, during anaerobic decomposition, and then this gets converted into alcohol and acids.

$$(C_6H_{10}O_5)\,n \xrightarrow{+H_2O} n\,C_6H_{12}O_6$$

$$\text{Cellulose} \xrightarrow{\text{Cellulase}} n\,C_6H_{12}O_6$$

$$C_6H_{12}O_6 \xrightarrow{\text{Fermentative bacteria}} 2C_2H_5OH + 2CO_2$$

At last, these gets converted into CO_2 by aerobic fungus and bacteria

$$2C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

$$CH_3COOH + O_2 \longrightarrow 2CO_2 + H_2O$$

This CO_2 reacts with water and forms H_2CO_3, which forms carbonates from rocks. Along with it, carbon deposits in the form of coke, coal and petroleum, which later on are used in the form of fuel and are released in the form of CO_2 into the atmosphere which is called as combustion.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$H_2CO_3 + Ca^{++} \longrightarrow CaCO_3 + 2H^+$$

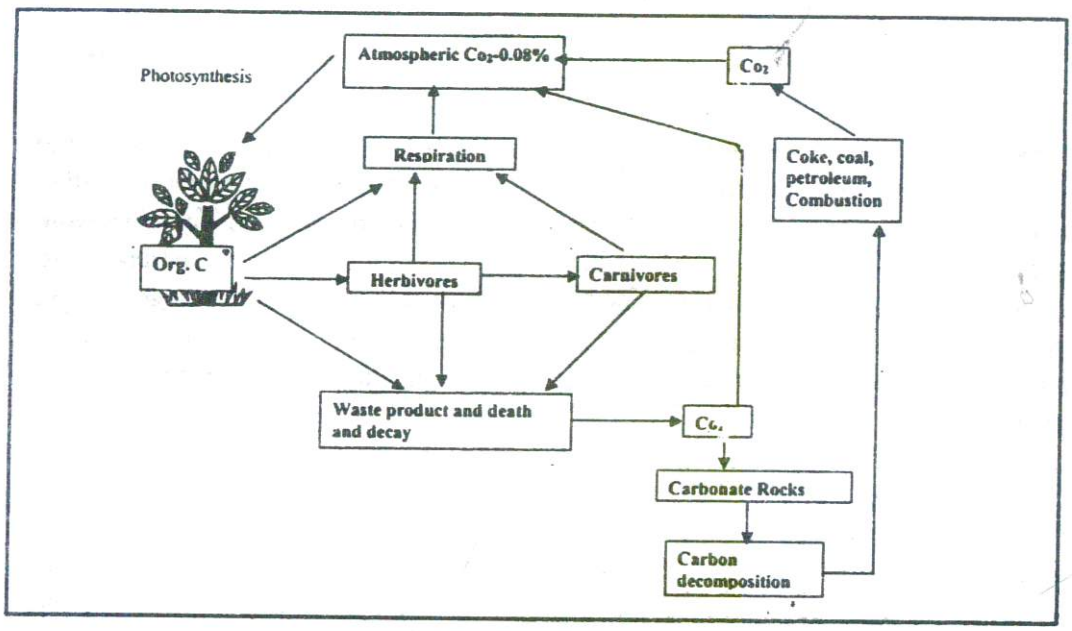


Figure 2.8: Carbon Cycle

Carbon cycle goes on in between terrestrial zone, atmosphere and hydrosphere, in which global cycle shows 10^{15}gm carbon deposition.

Nitrogen Cycle

Nitrogen is an important nutrient for plants and animals. 78% nitrogen is found in atmosphere normally, but plants cannot absorb nitrogen directly from atmosphere. They absorb it as ion from the soil. Hence nitrogen can be divided into two forms, available and unavailable

form. Gaseous form is unavailable form like N_2, N_2O, NO_2, NO etc, but ionic forms as NO_2, NO_3^- and NH_4^+ of nitrogen are available form. Hence, it is necessary for nitrogen to be converted from gaseous to ionic form. Then only, plants can absorb nitrogen. Nitrogen cycle is also a gaseous cycle. Following steps are important in nitrogen cycle:

1. Nitrogen fixation: The process in which unavailable form of nitrogen (gaseous) gets converted in to available form (ionic form), is called as nitrogen fixation. This process takes place by two ways. When nitrogen gets fixed due to physical factors, then it is called as physical nitrogen fixation. In this process nitrogen converts into nitrate while if nitrogen gas is converted into fixed form ammonium r.itrogen with the help of living organisms, then it is called as biological nitrogen fixation. This process is regulated by microbes e.g.; Rhizobium, pseudomonas, cyanobacteria etc.

2. Minralization: The process in which organic nitrogen is converted into inorganic nitrogen, is called as Minralization. Since in this process, the first product is ammonia, so it is called as ammonification. This process is anaerobic and is regulated by ammonifying bacteria.

3. Nitrification: The process in which ammonia is converted in to nitrate, it is called as nitrification. This is an aerobic process, hence takes place in the presence of oxygen. NH_3, first of all, converts into nitrite, Nitrosomonas. Later on it regulates this process, and these nitrites get converted into nitrates. Nitrobactor regulates this process.

4. Denitrification: The process in which nitrate, nitrogen gets converted into nitrogen gas, is called as denitrification. Denitrifying bacteria like pseudomonas denitrificans controls this process. It is an anaerobic process. The nitrogen present in the atmosphere converts into ammonia or nitrate by physical or biological nitrogen fixation and enters into the soil.

$$N2 \xrightarrow{\text{Cyanobacteria}} 2NH_4^+$$

$$N2 \xrightarrow{\text{Physical nitrogen fixation}} NO_3^-N$$

In this form, NH_4^+ or NO_3^-N is absorbed by plants and plants convert it into organic nitrogen by Immobilization. This organic nitrogen is in the form of amino acid and proteins in the plants, which enter into animals through food chains. In the form of different animals and plants, it enters into the soil, or after death, it enters into the soil. Here, Ammonifying bacteria degrade it and change it into NH_3. This NH_3 gets oxidized and forms NO_3^-N.

$$\text{Organic -N} \longrightarrow NH_3$$

$NH_3 \longrightarrow NO_2^-N$

$NO_2^-N \longrightarrow NO_3^-N$

This NO_3^-N changes into N_2 by denitrifying bacteria, which enters into the atmosphere in the form of gas. Or NO_3^-N enters into the underground water by the process of leaching.

$$NO_3^-N \xrightarrow{\textit{Pseudomonas denitrificans}} N_2$$

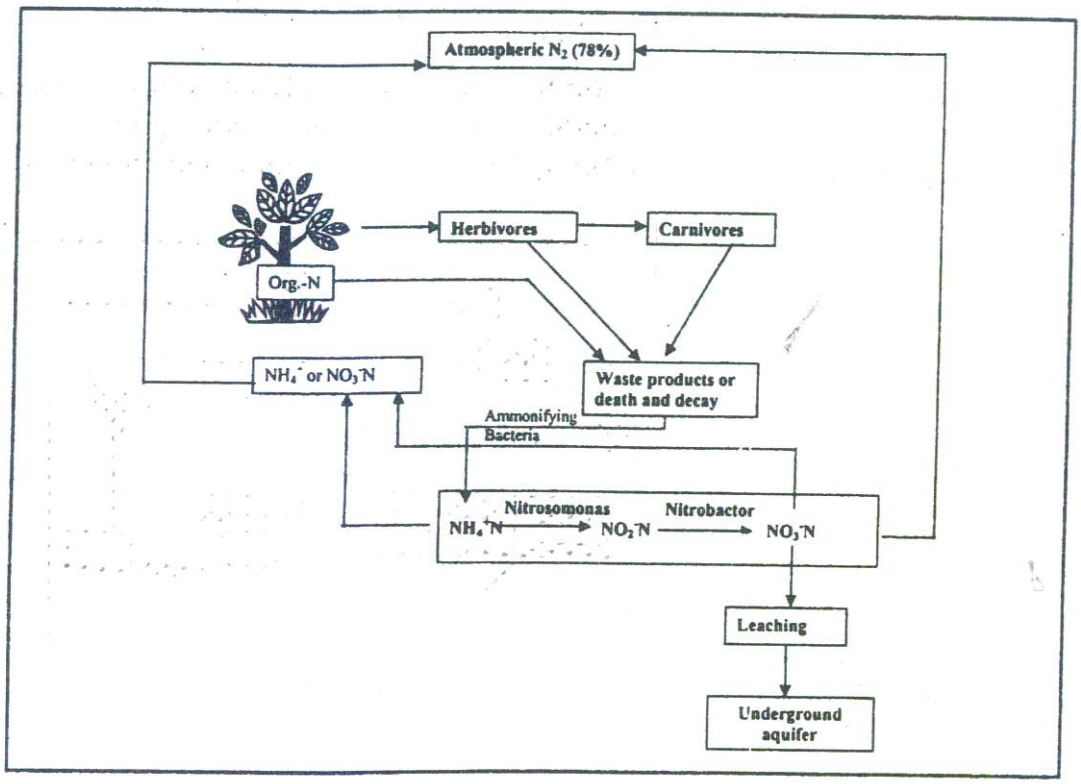


Figure 2.10

Sulphur Cycle

Sulphur is an important compound for plants and animals. It is found in some amino acids like cytosine, methionine etc. It is also an important constituent of proteins, hormones and vitamins. Sulphur cycle is partially a sedimentary cycle, whose most of the parts runs in the form of sediments, while SO_2 and SO_3 are found in the atmosphere in the form of H_2S gas. Hence, in the soil and sediments, its large reservoir pool is found and in small reservoir, it is in the form of sediments. Following steps are involved in this:

1. Immobilization: In this process, inorganic Sulphur gets converted into organic Sulphur, which is called as immobilization. Green plants regulate this process.

2. Minralization: In this process organic Sulphur gets converted into inorganic Sulphur. This process takes place in the presence of microbes.

3. Reduction-Oxidation: In this process, SO_2 or SO_3 gets reduced in the form of H_2S or H_2S gets oxidized in the form of SO_2 or SO_3.

In Sulphur cycle, sediments play the major role. Due to microbial activity, organic Sulphur gets converted into H_2S and SO_2 or SO_3, which being water- soluble represents upward movement, which can be absorbed by plants. This process is called as microbial recovery. This recovery is taking place mainly in the form of SO_2 or SO_3.

Similarly, SO_2 and SO_3 are produced due to combustion of fossil fuels. Volcano activation is the other source of SO_2. This SO_2 form SO_3 in the atmosphere by oxidation, which mixes with rainy water to form H_2SO_4. This H_2SO_4 gives SO_4^- ions, which later on enters the soil

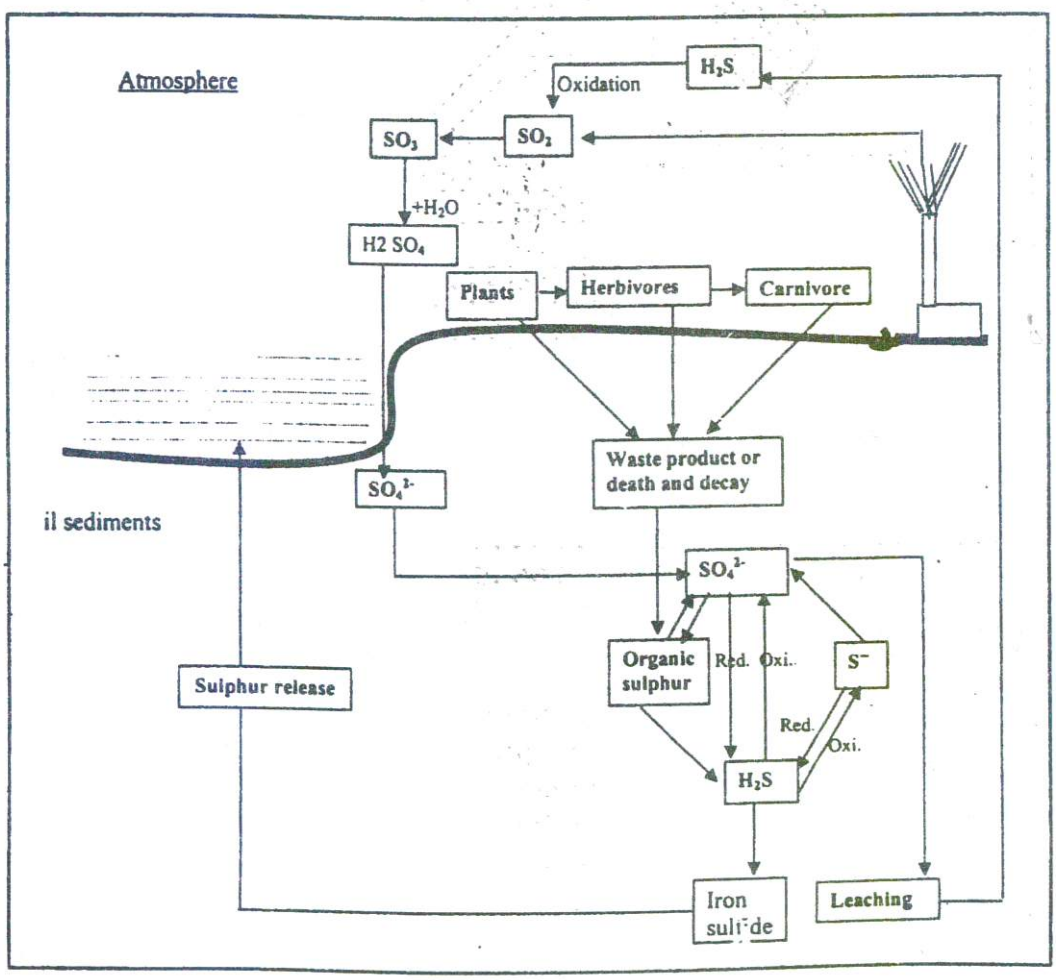


Figure 2.11: Sulphur Cycle

and form the salts in the soil. Thus, Sulphur again reaches back into the soil in the form of SO_4^- from the atmosphere.

Organic S ⟶ H_2S

$2H_2S + 3O_2$ ⟶ $2H_2O + 2SO_2$

$O_2 + 2SO_2$ ⟶ $2SO_3$

$H_2O + SO_3$ ⟶ H_2SO_4

H_2SO_4 ⟶ $2H+ + SO_4^-$

$Ca^+ 2 + SO_4^-$ ⟶ $CaSO_4$

Plants in the ionic form as- S^- or SO_4^-, which is known as fixed Sulphur form, while SO_2 and SO_3 are gaseous form, which cannot be absorbed by plants, also absorb Sulphur. Mainly, Sulphur cycle depends on erosion, sedimentation, leaching, rain adsorption like physical process and production and decomposition like biological process.

Phosphorous Cycle

It is the simplest biogeochemical cycle. Mainly, it is related with lithosphere and hydrosphere, and atmosphere plays a negligible role in this cycle. Actually, phosphorous is present in the form of PO_4^{-3}. It is called inorganic form. A large amount of phosphorous is found in the form of sedimentary deposit, which is 1000 times more than the soil and ocean. Mainly, the flow of phosphorous takes place in between the soil and ocean.

Mainly living organisms take the inorganic form present inside the soil and after it is converted into organic phosphorous by the process of biosynthesis. But after the death of organism or after the excretion, dead organic matter enters into the soil, where it is converted into inorganic phosphorous by microbial activity. During rain, this organic or inorganic phosphorous reaches in the water and it enters into the ocean by the flow of river. In ocean, dead organic phosphorous decomposes due to microbial activity, and when this inorganic phosphorous is present in upper part of ocean, then it gets absorbed by living organisms, but when it enters into the deep ocean, then its sedimentation takes place, and then it forms the phosphate rocks.

Hence, it is clear that very small amount of phosphorous takes part in this cycle. Thus, its larger amount is present in ocean or in soil. Its quality is very less in fresh water. Similarly,

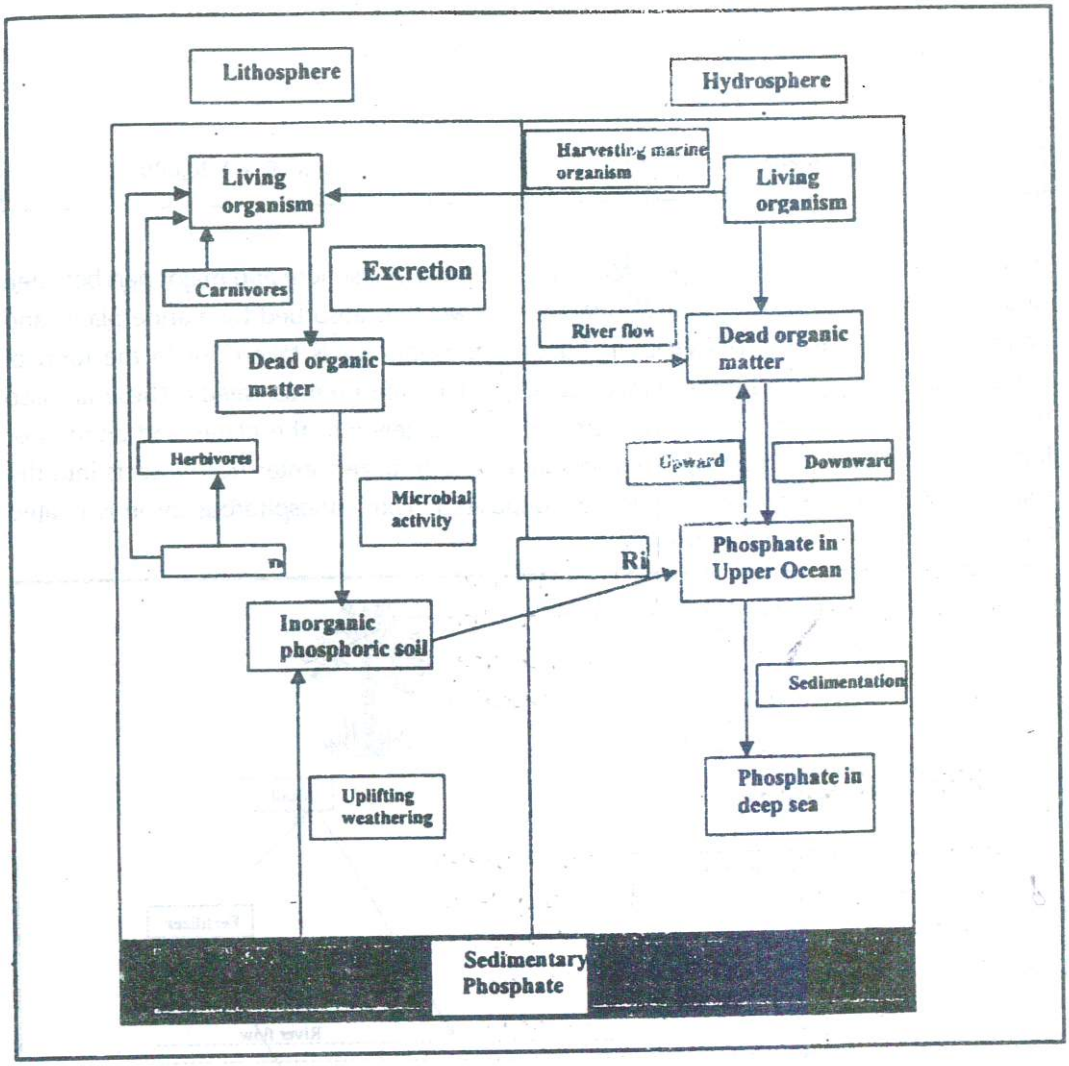


Figure 2.12: Phosphorous Cycle

amount of phosphorous in the different biomass is very less. Although more amount of phosphorous is present in aquatic biomass as compared to terrestrial biomass.

Table 2.2: Stock of Phosphorous in the Main Section of Ecosphere

S. No	System	Quantity of phosphorous (106 tons)
1	Biomass	
	a. Terrestrial	1805 – 2020
	b. Marine	128
	c. Fresh water	<1

contd...

2	Hydrosphere	
	a. Fresh water	90
	b. Marine water	1,20,000 – 1,28,000

It means that maximum part of phosphorous is found in lithosphere and major part between or among the available P is soluble in the ocean, which is absorbed by marine plants and animals, excreted in the ocean itself. But this phosphorous is taken out in the form of ocean plant and animal by the human activity, which are used as weeds. These are also used as fertilizers and on the land, if phosphorous enters into the plants and animals or fertilizers are made from phosphate rocks and these fertilizers enter from insects into the soil, among which its maximum part gets deposited. Thus, phosphorous cycle is related only with lithosphere and hydrosphere.

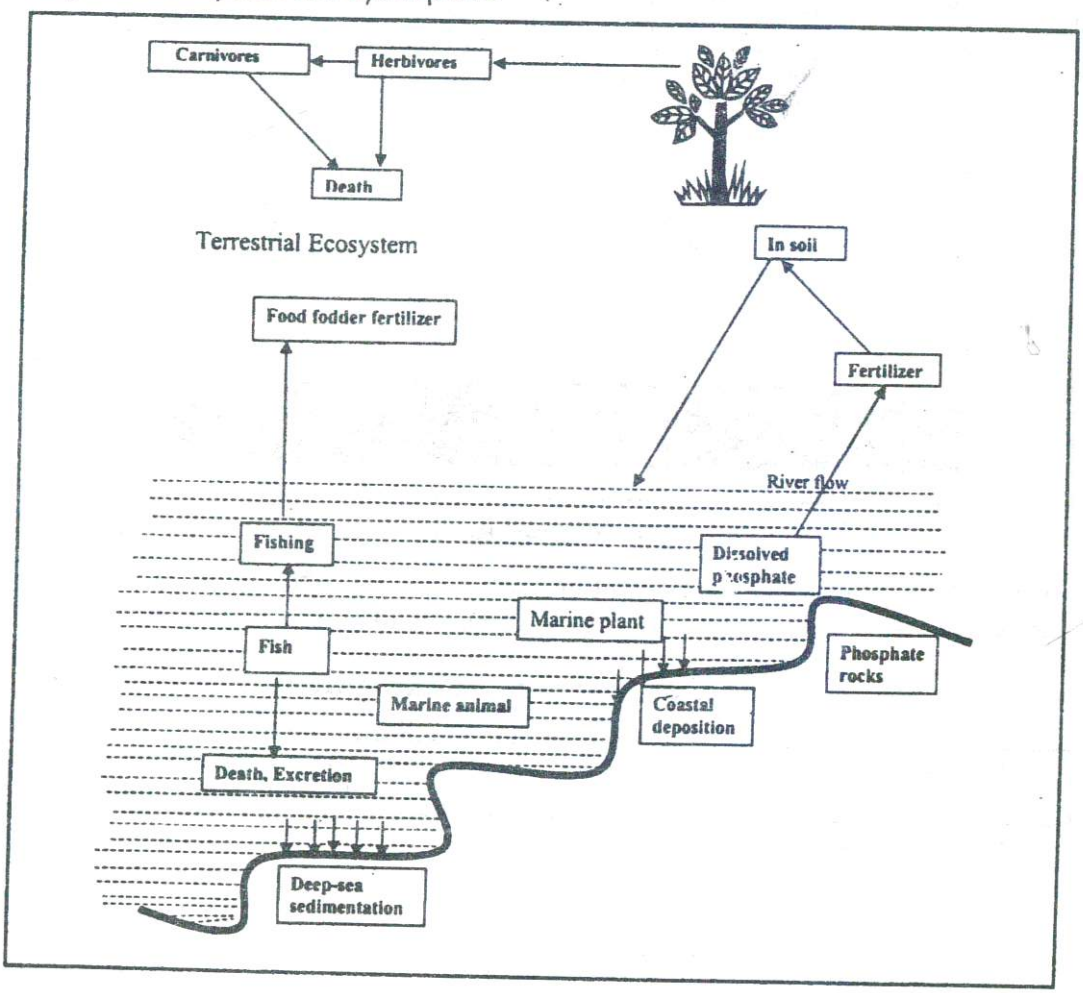


Figure 2.13: Outline of Phosphorous Cycle

Review Questions

1. What is Ecosystem? Describe its components.
2. Describe Primary Production. What are the factors effecting it?
3. What is Energy Dynamics?
4. Write a short note on:
   i. Nitrogen Cycle
   ii. Carbon Cycle
   iii. Sulphur Cycle
   iv. Phosphorus Cycle.

CHAPTER 3

BIOLOGICAL DIVERSITY

LEARNING OBJECTIVES

- Concepts and Levels of Biodiversity
- Role of Biodiversity in Ecosystem Function and Stability
- Speciation
- Extinction
- IUCN Categories of Threat
- Distribution and Global Pattern of Biodiversity
- Terrestrial Biodiversity Hot Spots
- Inventory

Concepts and Levels of Biodiversity

Concept

Biodiversity is related with different species found in the nature. Rogen first of all gave this word in 1986. Although biodiversity is controlled by different methods, but biotechnology has an important contribution in biodiversity conservation. It is hoped that in the 21st

century, its conservation will totally be dependent on biotechnology. The whole world can be divided into four zones on the basis of biodiversity and biotechnology.

1. Countries poor in both biotechnology and biodiversity, such as, Arabian countries.
2. Countries poor in biodiversity, but rich in biotechnology, such as, UK, USA, France.
3. Countries rich in biodiversity, but poor in biotechnology, such as, India, Nepal, Bhutan, Pakistan.
4. Countries rich in biodiversity and rich in biotechnology. It includes no country.

Hence, relations have been established among such countries, which come in second and third zones. Some countries can transfer biotechnology to them and others can transfer biodiversity to them. If biodiversity is determined in a specific area, then it is called as point or alpha biodiversity, but if biodiversity is observed in the whole space, then it is called as beta biodiversity.

Causes for Biodiversity Conservation

1. Interdependence: In ecosystem, all the species are dependent on one another. Hence, if one species gets destroyed, then 40–45 species get affected.
2. Ecology: The specific characters of any region are controlled by the species found there. Hence, if species gets destroyed, then ecosystem gets unbalanced.
3. Economy: In several countries, economy is based on the forest products. Hence on the destruction of species, economy also gets affected.
4. Biology: Different types of genes are found in different species. These genes are the main source of variations. Hence, on the destruction of species, genes also get affected.

Current Level of Biodiversity

It has been observed that in the whole space, approx. 108 species are found, among which 10 species are extincting every year. At the global level, every year 1.8% forests are going to extinct. In the forests, 2 million species have been observed, among which every year about 4000 species are getting destroyed due to deforestation. The current status of biodiversity is as follows:

i. Diversity in terrestrial system is more than that in the marine system.

ii. Arthropoda is having much of the biodiversity.

iii. Among the mammals, rodents are having much of the biodiversity.

iv. Among monocots, orchids are having much of the biodiversity.

In tropical areas, there is much of the biodiversity.

Role of Biodiversity in Ecosystem Function and Stability

Community is the diversified group of plants, and in any community, directional changes continuously occur. But when any community attains the climax stage, then it shows minimum changes, because in the climax stage, ecosystem becomes self-regulated and self-maintained. So it maintains dynamism and stability. Actually, in this state, it does not need the external sources. In climax stage, ecosystem shows the buffer capacity and it resists the external changes. Any developed ecosystem maintains constant climate, edaphic factors and vegetation component. This property of maintenance of stability in the ecosystem through resistance against external changes is known as ecosystem resistance. As we know that ecosystem has the buffer efficiencies so, if slight changes occur beyond the resistance or any part of ecosystem gets damaged, then it returns to good condition quickly. So, the efficiency of the ecosystem through which it returns to original state after damage, is known as resilence. It means the ecosystem stability is based on these two major mechanisms, which are 'resistance' and 'resilence'. So when any community becomes stable with climate, then it is known as ecosystem stability. It shows equilibrium with climate and it cannot be replaced through competition. According to Clemant, in the equilibrium condition, particular climate can develop dominant characteristic species. As these species are dominant, these can resist any change in the ecosystem; and if any change occurs in the community, then it quickly returns to the original state.

Stable stand shows steady state in case of productivity, structure and population. In this condition, community shows maximum diversity and homogeneous distribution of species. Each community is self-maintaining and stable. This stand persists for a long time with little or no change. Any change that may occur within the population, it may be the replacement of micro community. But it may be phasic cycle and such changes cannot change the community. This stability is also indicated by maximum biodiversity and many growth forms. If any stand is in this condition, the ecosystem shows minimum competition and maximum production. Species show integral association in place of competition. That's why, species composition cannot be easily changed.

The stability of ecosystem is affected because plants are continuously destroying. The main causes of destruction of community is following:

a. Requirement of land for colonization.
b. Requirement of land for industrialization.
c. Requirement of land for agriculture.
d. Requirement of land for dams, roads and railway lines.
e. Use of trees as fuel plants.
f. Use of trees in building construction.
g. Use of wood as furniture.
h. To fulfill the demand of overpopulation.
i. Rapid rate of pollution that can destroy the sensitive species.
j. Removal of nutrients from ecosystem.
k. Addition of pollutants in the ecosystem

So, for maintaining the stability in the ecosystem, it is necessary to conserve the biodiversity. Due to similarity in the vegetation, when any disease is caused then suddenly the whole vegetation is destroyed. But if biodiversity is higher in the area then limited vegetation is affected. Higher biodiversity shows higher gene pool, which can show buffer capacity in the ecosystem. For maintaining biodiversity different processes can be used. Some important processes are the following:

1. In situ conservation
    a. National Park
    b. Sanctuaries
    c. Biosphere reserve
    d. Individual projects
2. Ex situ conservation
    a. Gene banks
    b. Seed banks
    c. Field gene banks
    d. Botanical gardens

3. Ecological restoration
4. Conservation as hot spots
5. Reducing pollution
6. Increasing green belt development

The details of the processes are described in different units.

Speciation

Plants show variation in the nature, which is known as evolution. Evolution is controlled by many forces. When daughter generation indicates different characters from parental generation then it is known as differentiation. Different models of speciation are described. Models are based on the forces which cause speciation.

Characters of Speciation Models

a. In real life, more than one model may be needed to explain the origin and evolution of species.

b. Theoretical models derived from empirical studies show an observation of differences among species.

c. Very few studies initially identify "sister species pair".

d. If few populations are taking part in the interbreeding initially, then it is not necessary that daughter generation will also take part in reproduction. It will restrict the gene flow.

Models of Speciation

Geographic Speciation — Initiated by Geographic Distance

General Principles

i. Requires separation of two populations by a geographic distance to prevent interbreeding between them.

ii Most common mode of speciation in both plants and animals.

iii. Lots of circumstantial evidence in support of geographic races.

iv. There is a theoretical relation between degree of genetic differentiation between two populations and speciation.

Polymorphism → local races → geographical races → semispecies → biological species

Three Major Models

i. Classic "dumbbell" or allopatric model:

a. Range of ancestors extends across new territory.

b. Geographic barrier bisects ancestral range into two separate areas.

c. Separated populations diverge genetically with low gene flow between them due to distance.

d. Subsequently, populations cannot interbreed when they come together.

e. Results in divergent taxa with roughly equivalent geographic extents.

f. Very widespread series of populations diverge very slowly so it may not be common.

g. But, may have been more frequent earlier in earth's history when organismal genomes were simpler and climatic condition were less seasonal, more homogenous over broader areas.

ii. Founder effect model-

a. Small populations become separated from mass range of ancestors.

b. Small "founder" population diverges genetically from widespread one, to the point that they can't interbreed if they come into contact later.

c. Genetic bottleneck and stochastic processes play important roles in species diversity.

d. Covers many cases of speciation, like in oceanic islands.

iii. Peripheral isolates model-

a. Mode of allopatric speciation filling the gap between classic allopatric and founder effect model.

b. According to Myre, "allopatric" model- small,marginal population become genetically divergent from interior populations and from different species due to the selection pressure.

Polyploid Speciation

It is initiated by chromosome doubling.

General Principles

a. Chromosome doubling prevents interbreeding of polyploid with individuals of lower ploidy because of meiotic imbalances.

b. New polyploid is free to diverge through silencing of different duplicated gene loci.

c. Divergence may occur between different populations with the same general origin but generated with in different locations.

d. Abrupt type of speciation arises spontaneously in plants.

e. Molecular evidences suggest that land plants as a whole are ancient polyploids in which much gene silencing has taken place.

f. Does not require geographic separation - truly sympatric type speciation.

Models

i. Allopolyploid speciation

   a. Chromosome doubling takes place in a hybrid (often sterile) between two races or species.

   b. Tetrasomic inheritance increases range of heritable variation in allopolyploid`s progeny.

   c. Several confirmed cases reveal multiple origin of similar forms through multiple hybridization and doubling events in different localities e. g. Draba, Polypodium, Tragopogon.

   d. Very common and widespread in ferns, angiosperms; sometimes create confusing allopolyploids complexes.

ii. Autopolyploid Speciation

   a. Isolated autopolyploid populations can diverge to form new species by differential silencing of duplicate gene loci; like in some fern groups.

   b. Autopolyploidy is rare as compared to allopolyploidy.

Chromosomal Speciation

General Principles

a. It may not require appreciable geographic isolation.

b. It may happen quickly.

c. It is aided by very small size of population.

Models

i. Homoploid hybrid speciation

   a. Initial inter-racial or inter-specific hybrid produced

   b. Genome reorganization takes place in subsequent hybrid generation.

   c. New form cannot interbreed with parents because of inability to form balanced gametes in meiosis.

   d. It is confirmed in some cases like in Helianthus.

ii. Quantum speciation

   a. Abrupt genetic changes in relatively small number of generations.

   b. Begins with few individuals from depauperate gene pool.

   c. It is initiated by catastrophe or founding of new isolated population.

   d. Divergence and isolation is effected via chromosomal rearrangements or allelic shifts from stochastic processes like Clarkia.

iii. Stasipatric speciation

   a. Involves multiple neighboring populations.

   b. Each generates different chromosomal aberrations.

   c. Different types can interbreed because heterozygous condition does not produce viable gametes.

   d. Proliferation of adjacent sister species.

   e. Documented in some animal groups only, but not clearly understood in plants.

f. Different chromosomal types meets biological species criterion - but many regard these as chromosomal races and not distinct species.

Ecological Speciation

It is initiated by ecological shift. It includes sympatric and parapatric speciation.

i. Two population gradually adopt to different niches or ecological conditions.

ii. With extensions, it can show allochronic and other types of sympatric and parapatric speciation.

iii. Number of closely related plant species pairs shows ecological divergence.

iv. Other forces of divergence and isolation may help it.

v. Three genes are involved for habitat fidelity, assertive mating and habitat based fitness.

Asexual Speciation

i. It occurs in clonal and parthenogenetic organisms, in which progeny is produced without sexual reproduction or recombination.

ii. Divergence simply accumulated mutations or by intermittent hybridization with other types followed by periods of asexual reproduction.

iii. Famous examples of hybrid apomictic complexes are compositae family and rose family.

iv. Few fern species like Pallaea atropurpurea (3x) reproduces by apogamous process.

Problematic Deviation

i. Symbiont species: Two or more unrelated organisms living interdependently is known as symbiotic species like lichens.

ii. Ring species: Series of subspecies in which neighboring sets of population share limited gene flow. Such subspecies are generally morphologically or ecologically similar. But subspecies present at end of continuum cannot interbreed with each other.

iii. Polytypic species: Species show more than one morphology and present in more than one locality.

Extinction

The process through which species are disappearing from nature is known as Extinction. It is expected that one species per day is going to extinct.

Mechanism of extinction

In any ecosystem, stability is indicated by higher biodiversity, because species show positive interactions. But these species are also having one important character, which is interlinking character. It means species are strongly correlated with each other. It is this condition, due to which any change in the climate or attack of disease, any sensitive species disappears from nature. When this happens its extinction will affect other species also, and other species, which are dependent on these species, will become weak. In that case, a chain reaction gets started in the ecosystem, which will indicate the retrogression of the ecosystem. With disappearance of one species, the nature of soil and climate are also affected and it will increase up the rate of extinction for maintaining the record of threatened and extinct species, "RED DATA BOOK" is published by IUCN.

Factors Affecting Rate of Extinction

The main causes for the extinction of species are as follows:

Overpopulation

It is the fact that if population is high, then we need more resources and it will affect the ecosystem.

Overexploitation

Nature is providing us sufficient amount of resources, but lack of maintenance and the exploitation of nature is resulting in the form of change in climate.

Pollution

It is again the result of luxurious life style, because irregular expansion of cities and industries are rapidly increasing the amount of pollutants in the environment, which are destroying the species.

Unavailability of Alternative Source

Actually, the tribal and villagers are using natural resources, because they are not having alternative source, likes they are cutting forest because it is their employment. They are using the wood as a fuel.

Lack of Awareness

It is the May or threat. Actually, we don't know that what are we getting and what are we losing. That's why unknowingly; we are destroying the nature.

Selfishness

It is the fact that human being is a selfish race, and he is framing the rule in the favour of them. In that case, we avoid the nature, and it is creating the problem.

Natural Phenomenon

Many natural processes like- earthquakes, volcanoes etc. are responsible for the destruction of nature, but the natural processes are related with evolution and in that case, the rate of extinction will be very low.

Evolution and Speciation

It is the natural process of extinction of species, because as the new species evolve, older species gets extincted so, the succession pattern of ecosystem shows extinction.

Shifting Cultivation

Actually, if one agricultural area become sterile, then the forest land is used as an agricultural field, it is known as shifting cultivation. So, it can destroy the species.

Habitat Destruction

Many habitats are destroyed because we need the land for colonies, agriculture, dams, roads and railway lines. So, during the cutting (clearing) of forests, so many species gets extincted.

Competition and Invasion

When new weed species enter the ecosystem, then it competes with the local species for resources and during this competition, new species invade the area while local species extinct away. Like, in India, the common roadside plant was Cassia tora, but as the parthenium entered in these areas it invaded the whole zone. It replaced the cassia tora and at present time, cassia tora has disappeared from all such areas.

IUCN Categories of Threat

Several plant and animal species have become extinct and lives of many hundreds are threatened. IUCN's threatened plants committee found that about 10% (20,000 to 30,000) of the world's flowering plants are dangerously rare or under threat (Eckholm, 1980). Among forest, tropical rain forests are the most threatened. The food and agricultural organization of the united nation estimates that about 40% of the tropical forest of the world have already been destroyed and that virtually all the remaining forests would be finished by the end of the century. About 20,000 seed plant species of our planet are threatened. According to IUCN the plants are of two types. Some plants are rare, which are less in number and some are common, which are higher in number. But on the basis of following points IUCN proposed different categories of plants:

1. The present and past distribution.
2. Decline in number of population in due course of time.
3. Abundance and quality of natural habitats.
4. Biology and potential values of species.

So following categories are proposed by IUCN:

Endangered (E)

Those plants, which are present in higher numbers in the nature but later due to overexploitation or any other reasons these plants are rapidly decreasing in numbers, are known as endangered plants. If this rate of disappearance is continued then soon plants will be extinct from nature. Such group of plants is known as endangered plants. It is indicated by the reduction in number of critical level, as well as shows reduced size of habitat. If proper protection is not given to such species then it has the immediate danger of extinction. Like Areca concinna, Euphorbia abdelkuri.

Vulnarable Plants (V)

Those plants, which are of higher number in nature at the present time but if overexploitation is continued. There is a chance that very soon these plants will be included in the endangered category. Such group of plants is known as vulnerable group. This taxa indicate the decreasing trend in all the populations. It is due to overexploitation, extensive distribution of habitats, environmental disturbances and against these factors no protection is given to this taxa, then it is in serious threat. Like Ranunculus ophioglossifolius

Rare Plants (R)

Those plants which are already very less in number in the nature, are known as rare plants. If exploitation of such plants is carried out then it may disappear rapidly from nature. These are not endangered or vulnerable, but these are having the less numbers. So in the nature it shows a great risk. These genera present in a restricted geographical area and the distribution is very less. Like Cyclamen mirabile, Salvia saxicola.

Extinct (Ex)

Those plants, which have completely disappeared from nature are known as extinct plants. This category shows loss of gene pool from nature. It is estimated that one species per day is disappearing from nature.

Threatened Species

Generally this term is used for those species, which needs the conservation. It includes three categories, which are endangered, vulnerable and rare.

Out of Danger Species

The species which are categorized as endangered, vulnerable, rare or threatened, but due to proper protection and conservation, the species are having higher numbers now, are known as out of danger species. So these are relatively secured species.

Intermediate Species

The species, which are suspected to belong to the endangered, vulnerable or rare category, but we are having very less information about this species, are known as intermediate species. We cannot categorize it in rare, vulnerable or endangered category.

These categories of plants are recorded in the red data book, published by International Union of Conservation of Nature and Natural Resources.

Distribution and Global Pattern of Biodiversity

In the world till now about 2,80,000 species are described. Recently in 2002 list of 4,22,000 species has been proposed. Overall biodiversity (plants and animals) is following:

	Higher plants	2,84,000
2.	Fungi	69,000
3.	Algae	26,900
4.	Bacteria	4,800
5.	Virus	1,000
6.	Protozoa	30,800
7.	Insects	7,51,000
8.	Other animals	2,81,000

19 large families in the order of sequence are following:

	Family	Genera	Species
1.	Compositae	1,000	20,000
2.	Orchidaceae	750	20,000
3.	Papillionaceae	440	10,750
4.	Graminae	620	10,000
5.	Rubiaceae	500	9,000
6.	Euphobiaceae	300	5,750
7.	Labiatae	185	4,550
8.	Scrophullariaceae	235	4,150
9.	Cyperaceae	90	4,100
10.	Melastomataceae	240	3,700
11.	Myrtaceae	95	3,600
12.	Asclepediaceae	255	3,300
13.	Cruciferae	375	3,200
14.	Acanthaceae	250	3,100

15.	Verbanaceae	75	3,000
16.	Umbelliferae	320	2,850
17.	Palmae	250	2,500
18.	Lauraceae	32	2,500
19.	Solanaceae	88	2,300

Terrestrial Biodiversity Hot Spots

Hot spot means "Rich Diversity Region". It is clear that different geographical region have different plant distribution. High degree of variation are seen at global level but in few areas genetic variation is at higher level, which shows the original gene at hot spot and hottest hot spot. India's climate show much variation from Himalaya to Thar Desert of Rajasthan. Here plants from Alpine to Tropical types are presnt. In India 20,000 species of trees are present.

Hot Spot And Hottest Hot Spot Of India

i. Vegetation of eastern Himalayas
   a. Sikkim: Upper Assam and Tibet - West Bengal.
   b. Phenerogams: 4000 species.
   c. Mixed Sal forest (Shorea species) Bamoboo, Abies, picea, Juniperus.

ii. Vegetation of Deccan
   a. A.P., Tamil Nadu, Karnataka, Maharashtra, M.P. and Orissa.
   b. Dry Deciduous forest type
   c. Tectona grandis, Shorea robusta (700-1000 m)
   d. Evergreen forest (200-400 m) Santalum album.
   e. Presence of Halophytes in Godawari Delta like Avicinea alba, Avicinia marina.

iii. Mangroove Vegetation
   a. Plants present on Swampy substrate.
   b. Bengal Bay, Maharashtra sea coast, Bank of Godawari, Kerela Andaman and Nicobar.
   c. Present in alkaline soil.

d. Avicenia species: Acanthus, Rhizophora are main species of Sunderban in W. Bengal.

e. Rhizophoraceae family is maximum in Andaman and Nicobar.

iv. Vegetation of Western Himalaya

a. West part of Kumaon, Kashmir and Tibet.

b. Forest of Pinus longifolia, Quercus incena, Q. dialata Deciduous plants - Acer, Alnus, Betulla.

c. Chandrawaga Village: Pinus girardiana, and Cedrus species.

d. Shiwaliks: Forest of S. Robusta

e. Dehradun, Mussori: Epiphytic orchids and ferns.

v. Vegetation of Assam

a. North Himalaya: East Mismihill, S. Khasi hill, Garo hills, W.-Sankesh river.

b. Tropical cinnamomum: Michelia Forest, Bhramputra valley, Dipterocarpus, Mesua-Michelia association.

c. Stereospermum: Cedrella - In this zone valley of Mikir hills and Naga hills are present. Here Tetrameles, Sterospermum,Chelonides species are important.

d. Deciduous plants: Shorea - Dilenia - Lagerstromia.

e. Mikir: Jaintia Hills - S. robusta, Langerstromia

vi. Vegetation of Gangetic Plain

This includes: U.P, Bihar, Orissa, W. Bengal. It is divided into - upper, middle and lower Gangetic plains. Its main species are - Acacia nilotica, Acacia modesta,Fficus hispida.

Aquatic Vegetation: Nyphoides, Nymphea. Marshy species - Polygonum, Typha etc.

vii. Vegetation of Indus Plain

Arid zone: Punjab, H.P., Rajasthan, Gujrat, Main species are - Prosopis, Specigera, Capparis species, Ephedra, Dalbergia, Calotropis procera, Euphorbia.

viii. Vegetation of Malabar

It is the zone of - Maharashtra, Mysore and Kerala Zone.

Tropical forest: Dipterocoupus indicus, Vateria indica.

Teak Forest: T. Grandis, Santalum album, Palmae, myrtaceae, orchidaceae in Assam and ceylon.

Temprate forests: Michelia nilgirica, Gardonia obtusa, in Nilgiri hills.

Hot Spot and Hottest Hot Spot at Global Level

1. Northern Realm:
   a. Arctic and sub arctic zone: Rhododendron, Sedum saxifraga: Papaver species.
   b. Boreal region: Picea, Abies.
   c. Central European region: Quercus, Petrala, Fagus Silvatica, Tilia, Acer, Ulmus.
   d. Mediterranean Region: Pinus, Quercus.
   e. Central Asia: Coniferous and Deciduous Forest, grassland and scrub.
   f. Near East zone: Anagesis, Atriplex, Haloxylon, Salsola.
   g. Eastern Asia: Grassland, Quercus, Betula, Populus, Salix, Abies, Picea
   h. North America: Conifers
2. Palaeotropic Realm :
   a. Indian Region : T. grandis, S. robusta, Pinus insulacis
   b. Malaysia : Rafflesia, Rhiganthus, Agathis.
   c. Tropical Africa : Tropical rain forest to dessert. Bamboo, Savanah, Steppe grassland.
   d. Medagasscar : Graminae, Malastomaceae, Cypeaceae.
   e. Pacific Region : Endemic family - Degeneriaceae.
3. Neotropical Realm :

   Tropical and subtropical forest, throne forest, true savannah, pampean grassland.

   Dessert zone, mountain zone-palmae, leguminosae, myrtaceae, bignoniaceae cactaceae.
4. South Realm :
   a. South Africa : Protea, Rochea, Pelargonium.

b. Newzealand - Acacia, Casurina, Euclyptus, Drimys, Uncinia, 30 Leguminosae species are present in Newzealand.

c. Australia - Eucalyptus, Acacia, Cephalotus, Cycus, Bowenia, Macrozamia, Compositae, Graminae, Cyperaceae, Orchidaceae.

d. Temperate South America - rubiaceae, Lilliaceae, Bignoniaceae, Compsitae.

e. Antarctic region - Deschampsia antartica a grass, CALOBANTHUS CRASSIFOLIS.

Inventory

To manage any ecosystem, it is essential to have an accurate picture of resources, location, description and condition. To find out all these facts about ecosystem is known as inventory. Inventory is the management tool. The plants present at the earth surface show integral unit. It is necessary to identify natural resources; we must know the details of the natural resources. Different parameters are determined with the help of inventories. It is carried out at regular intervals during growing season and the detailed information of growth period is obtained. During the inventory, following parameters are calculated with the help of inventories formulae:

1. Leaf area index
2. Stem volume
3. Crop distribution and yield
4. Species and structural diversity
5. Weight and chlorophyll content of vegetation
6. Attack of disease and insect
7. Density and biomass of animal population
8. Thermal and chemical pollution of aquatic ecosystem
9. Heat, water vapour and carbon dioxide flux of earth surface
10. Evapotranspiration and water content of soils and vegetation
11. Forest fire
12. Depth and density of snow

Actually many problems can be solved, if we are well known with physical and biological status of ecosystem. The forest ecosystem is an integrated unit and it may be thousands of kilometers long. So the suitable mapping of these resources is necessary. With the help of

inventory, we can provide the information about quantity and quality of ecosystem. The forest inventories may be of following types:

Individual Inventory

When the information about individual species is obtained, then it is known as individual inventory. We can determine the height of plant, bark thickness, age of plant, disease on the plant etc.

Planning and Level Inventory

It is important at management level. It is based on aerial photography. It is carried out through remote sensing technique. It gives idea about ecosystem classification and sampling. Different information can be obtained through these inventories, like species composition, age of tree, herebage cover, stand density, history of ecosystem, environmental sensitivity, problems in ecosystem etc.

Operational Inventory

It is related with the economics of the ecosystem. How much profit we can get from ecosystem without affecting it, is indicated in operational inventory. Laws control it and laws are based on forest and ecosystem. Study for this purpose, we must know the numbers of trees in ecosystem, volume of trees, density of trees, age of trees, growth rate of trees, history of ecosystem etc.

So for the determination of the position of the ecosystem from time to time, inventory is maintained, because it gives idea about increasing or decreasing forest areas and biodiversity and the decisions are taken on the basis of inventories. In the fixed interval of time, the inventory cycle is repeated.

Review Questions

1. What is Biodiversity? Describe its types.
2. What is the role of Biodiversity in Ecosystem Function and stability?
3. What is IUCN? Describe it.
4. Describe role of inventory in managing Biodiversity.

CHAPTER 4

AIR, WATER AND SOIL POLLUTION

LEARNING OBJECTIVES

- Air Pollution
- Water Pollution
- Soil Pollution
- Ozonolysis and Ozone Holes
- Green House Effect and Global Warming

Air Pollution

Presence of one or more contaminants in the outer atmosphere, like dust, fumes, gas, mist, odour, smoke etc, which causes adverse impacts on man, plants, animals and non-living matter is called as air pollution.

According to Indian standard Beaurau (IS - 4167) 1996 " presence of such contaminants in ambient atmosphere, which affect negatively the activities of man, plant, health and other substances is called as air pollution."

According to American Medical Association " the increased amount of external substances in the air, which can damage living organisms and non living things is known as air pollution."

Composition of Air

Atmosphere acts as insulating sheath on the earth surface. It decreases or lowers light and heat of sun. Ozone layer acts as a protective umbrella. Satellites have no atmosphere, due to which there is no life. Only atmosphere supports the life. If there has not been atmosphere, then day temperature at equator may be 82°C and night temperature may be –142°C. At these temperatures life has not been possible. Atmosphere is reservoir of oxygen and carbon dioxide, which are essential for plant and photosynthesis and respiration in animals, respectively. 75% of atmosphere of earth surface is below 16 kilometers and 99% is at below 30 kilometers. Normal pressure of atmosphere is one bar. Atmosphere can be divided into the following zones:

Troposphere

It is the lowermost gas layer of atmosphere and it is present up to 10 kilometers of height. 66% atmosphere is present within this range. In this region clouds and weather are controlled. Temperature decreases with increasing altitude in this zone.

Tropopause

It is combined part of upper troposphere and lower stratosphere, which is present at an altitude of 10–18 kilometers. It's height on poles is six kilometers. Altitude of tropopause from India is about 16 kilometers.

Stratosphere

It is present from 18 kilometers to 32 kilometers altitude. This layer is free from weather change. Hence, jet planes take flight in this very belt. Temperature increases with increasing altitude in stratosphere. Main reasons beyond it, is ozone 'ayer. Ozone layer is present from 18 kilometers to 32 kilometers altitude. It absorbs ultra violet rays and converts it into heat and chemical energy, due to which temperature increases. Ozone thickness is highest at equator and lowest at poles. In troposphere ozone is harmful for plants and animal life.

Mesosphere

It is a peaceful place, where some exothermic reactions occur. Here lapse rate is positive or it means, here temperatures decreases with altitude. Due to more volume here, long radio waves are emitted.

Ionosphere

It is also called as thermosphere, because here temperature reaches up to 1430°C, due to which all atoms are present in the ionic form. Here free electrons are present due to which, this area acts as a good conductor. It is found from 115 kilometers to 700 kilometers altitude.

The area beyond the 700 kilometers is called as exosphere. From the view of air pollution troposphere, tropopause and stratosphere are important. In troposphere composition of air is following:

1.	Nitrogen	78.09%
2.	Oxygen	20.95%
3.	Argon	0.93%
4.	Water vapor	Variable
5.	Carbon dioxide	0.032%
6.	Neon	0.0018%
7.	Krypton	0.0001%
8.	Methane	0.00015%
9.	Helium	0.00052%
10.	Ozone	2×10^{-6}%
11.	Xenon	8×10^{-6}%
12.	Nitrogen oxide	2×10^{-5}%
13.	Carbon monoxide	1×10^{-5}%
14.	Hydrogen	5×10^{-5}%
15.	Ammonia	6×10^{-7}%
16.	Nitrogen peroxide	1×10^{-7}%
17.	Nitric oxide	6×10^{-8}%
18.	Sulfur dioxide	2×10^{-8}%
19.	Hydrogen peroxide	2×10^{-8}%

Brief History of Air Pollution

Air pollution is related to the evolution of species. Like release of methane and hydrocarbons from marsh areas, anaerobic decomposition of substances and use of fossil fuels for cooking. But mainly these impacts have been seen from 1860, when very fast and irregular industrialization began. Also with the increase in the population, air pollution increases rapidly. Before industrialization could complete its two decades first air pollution disaster was recorded in London in December 9 - 13, 1873, where 250 people died away due to air pollution. In London, where rapid industrialization took place, about ten air pollution disasters were recorded, in which thousands of people died away and some became permanently handicapped.

Air Pollutants

Main air pollutants are following:

1. **Aerosols:** Solid or liquid micro particles, which are present in air.
2. **Droplets:** Small liquid particles, which remains in air or accumulated in air.
3. **Dust:** These are produced from crushing, grinding, blasting, processing, cement production and thermal plants.
4. **Fly ash:** These produce from coal burning.
5. **Fumes:** These are small solid and liquid particles ranging below 0.001 micron, which produce from distillation, calcinations or metal processing.
6. **Fog:** These are produced due to mist.
7. **Gases:** These are produced from different mechanisms like from vehicles or industrialization.
8. **Mists:** Liquid particles formed from vapor condensation are called as mists.
9. **Particles:** These are solid or liquid. It is also known as suspended particulate matter.
10. **Smog:** Particles or molecules or formed from smoke and fog.
11. **Smoke:** Particles of size below 0.001 micron, which are air borne aerosols. It is called as smoke.
12. **Soot:** Particles, which are formed from incomplete combustion of carbonaceous substances, are known as soot.

13. **Vapor:** Gaseous state of matter, which is generally solid or liquid, is known as vapor.

Sources and Causes of Air Pollution

Important air pollution sources are following:

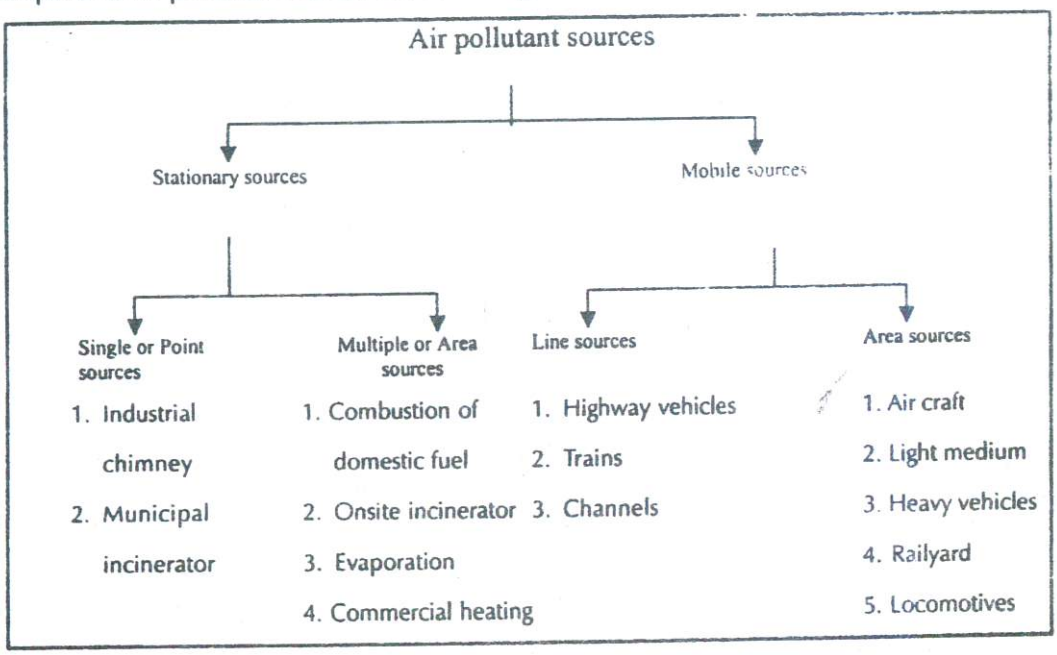


Figure 4.1

Similarly, pollution sources can be divided into artificial and natural sources. Total pollutants are 2900 × 10^6 TPA. Among these are, 2600 × 10^6 TPA is released from natural sources, only 300 × 10^6 TPA is released from artificial sources. 400 tones per year nitric oxide is released from bacterial activity of soil, while only 50 × 10^6 TPA nitric oxide is released from artificial sources. Major pollutants are as following:

Natural Sources

Table 4.1

S. No.	Pollutant	Natural sources
1.	Carbon dioxide	Plant and animal release, fossil fuel biodegradation.
2.	Carbon monoxide	Forest fire, methane and aldehyde oxidation, chlorophyll decay and synthesis

contd...

		of terpenes and oxidation of oceanic contents.
3.	Sulfur oxides	Volcanoes, oceanic sulfides, sulphide bacterial decay.
4.	Hydrogen sulfides	Volcanic eruptions, swamp and marshes, biological activities.
5.	Nitrogen oxide	Lightening and electrical storms, soil bacteria actions, fossil fuels, biomass burning.
6.	Ammonia	Soil, biological decay
7.	Hydrocarbons	Biological processes
8.	CFCs	Scented smell
9.	Methane	Animals, vegetation decaying and wetlands.
10.	Suspended particulate matter (SPM)	Sea salt spray, soil dust, dust storms, forest fire, volcano eruptions, microbes, allergens like pollens.
11.	Gas to particles	Terpenes, aerosols, hydrocarbons.

Artificial Sources

Table 4.2

S. No.	Pollutant	Natural sources
1.	Carbon dioxide	Combustion
2.	Carbon monoxide	Auto exhausts, Industrial processes, Metallurgical operations, petroleum refining, organic chemical industries.
3.	Sulfur oxides	Oil and coal combustion, thermal power plants, boilers, ore processing, non metallic mineral roasting and heating, fertilizer productions, sulfuric acid plants, plastics, paints, varnish productions, oxidation towers.
4.	Hydrogen sulfides	Sewage treatment and chemical processing.

contd...

5.	Nitrogen oxide	Combustion, heating of non-metallic minerals, cement, glass and refractory processing.
6.	Ammonia	Fertilizer productions and sewage treatments.
7.	Hydrocarbons	Combustion exhaust.
8.	CFCs	Propellant in aerosols, refrigerant, cleaning solvents.
9.	Methane	Rice production, animal husbandry, land fills, coal scams, biomass burning, melting permafrost.
10.	Suspended Particulate Matter (SPM)	Agriculture, coal fly ash, steel, iron and cement processing, non fossil fuel combustion and incineration.
11.	Gas to particles	Hydrogen sulfide and sulfur dioxide converted in to sulfates, conversion of ammonia in to ammonium, nitrogen oxides.

Anthropogenic Sources

Table 4.3

S. No.	Pollutant	Natural sources
1.	Aldehyde	Auto exhaust, waste incineration, fuel combustion, photochemical reaction, thermal decomposition of oil.
2.	Ammonia	Chemical industries, coke ovens, refineries, stock yard and fuel incineration.
3.	Arsenic	Metal smelter, Arsenical pesticides and herbicides, arsenic soldering.
4.	Asbestos	Asbestos factory, mines, construction sites.
5.	Barium	Industrial mining, refining and production of barium, diesel fuel additives.
6.	Baryllium	Fluorescent lamp production, rocket motor fuels.
7.	Boron	Boron industries, petroleum fuel, coal additives.

contd...

8.	Cadmium	Air pollution, art supplies, bone metal, cigarette smoke, fresh water fish, food, fungicides, highway dusts, incinerators, mining, nickel-cadmium batteries, oxide dust, paint, phosphate fertilizer, power plants, sea food, sewage sludge, smelting plants, tobacco and tobacco smoking, welding fumes.
9.	Chlorine	Industrial processing, accidental leakage during transportation.
10.	Chromium	Metallurgical and chemical industries, chromate compounds, cement and asbestos industries.
11.	CFCs	Refrigerators, propellants, deodorants, cleaning solvents, fire extinguishers, blowing and foaming agents.
12.	Ethylene	Motor vehicle emissions, chemical industries, agricultural wastes, plants emissions.
13.	Hydrogen chloride	Bye products of chlorinated organic compounds, burning of coals, plastics, papers, gasoline.
14.	Hydrogen sulfide	Biodegradation of proteins, paper mills, industrial disposals, sewage treatment plants, refineries.
15	Iron	Iron steel plants, combustion of coals and fossil fuels, flyash, incinerations, welding rods.
16.	Lead	Ammunitions, batteries, canned foods, ceramics, dolomites, dusts, food crops growing around industries, gasoline, hair dyes and rinses, leaded glasses, news prints and colored advertisements, paints, pesticides, pottery, rubber toys, soft coal, soil solder, tobacco smoke, vinyl `mini-blinds`.
17.	Manganese	Blast furnaces, organic fuel additives, use of welding rods, incinerations manganese containing products.

contd...

18.	Mercury	Mining and refining of mercury, laboratorical mercury.
19.	Nickel	Coins, cosmetics, coins, dental material, hair spray, industrial waste, jewelry, medical plants, metal refineries, metal tools, nickel-cadmium batteries, [illegible] appliances, shampoo, solid waste, incinerator, stainless steel, kitchen utensils, tobacco and tobacco smoke.
20.	Phosphorus	Phosphate fertilizer, phosphoric acid, emissions from vehicles.
21.	Peroxy acetyl nitrate	[illegible] and sun rays.
22.	Radioactive substances	Fossil fuel combustion, laboratories, radioactive minerals, atmospheric dust, nuclear power stations.
23.	Selenium	Combustion of fuel, refineries, waste gases, manufacture of paper products.
24.	Vanadium	Vanadium refining industries, alloy industries, vanadium rich soil.
25.	Zinc	Zinc refineries, brass production, galvanization.
26.	Hydrogen cynide	Blast furnace, metal plating, fumigation.
27.	Phosgene	Chemical and dye making industries.
28.	Suspended particulate matter	All manufacturing processes.

Due to increasing industrialization, pollution is increasing. Different processes are responsible for emissions of different pollutants. Some important processes and their pollutants are following:

Table 4.4

S. No.	Artificial sources	Pollutants
1.	Combustion of fuel	Smoke, carbon dioxide, sulfur oxides, metallic oxides.
2.	Power generation - Thermal power plant	Smoke, carbon dioxide, sulfur oxides, dust

contd...

	- Nuclear power plant	Radioactive compounds like Iodine-131, Argon-41, Stransium-90, Cesium-137.
	- Hydro power plant	Methane from water logged areas.
3.	Incinerators	
	- Open burning	Smoke
	- Commercial, municipal and industrial incinerators.	Smoke, Carbon monoxide, nitrogen oxides & flyash.
4.	Petroleum refineries	
	- Boilers, heaters & regenerators.	Noise, sulfur oxides, hydrocarbons.
	- Reactors, storage tanks, compressors, generators.	Nitrogen oxides, SPM, carbon monoxide, odour.
5.	Inorganic fertilizer and chemical production	SPM, odour, noise, hydrogen fluoride, ammonia, phosphoric acid and acid mist.
6.	Plastic, paints, varnish, rubber, pesticides, insecticides, detergents, phenols, methanol productions.	SPM, odour, noise, carbon monoxides, sulfur oxides, gases, vapors.
7.	Pulp and paper: blowers, washers, furnaces, evaporators, oxidation towers.	Mercaptans, sulfur oxides, SPM, noise, odour, hydrogen sulfides.
8.	Agriculture: ploughing, crop spraying, dusting and field burning.	Dust, odour, insecticides, pesticide, hydrocarbons, lead, arsenic, phosphate, soot, smoke, flyash.
9.	Food processing: drying, preserving and packaging.	Dust, vapor, odour.
10.	Transportation vehicles	Hydrocarbons, sulfur oxides, nitrogen oxides, dust, noise, aromatics.
11.	Roasting and heating processes of non-metallic minerals.	Mineral, organics, SPM, sulfur oxides, nitrogen oxides, dust.
12.	Ferrous metallurgical processes	Smoke, fumes, carbon monoxide, odour, vapour, fluorides, hydrogen sulfide.
13.	Non-ferrous metallurgical processes	Dust, fumes of copper, zinc etc.
14.	Roasting, smelting and refining.	Sulfur oxides.

Effects of Air Pollution

Effects of Pollutants on Man, Material and Vegetation

1. **Dust:** Due to dust pneumoconiosis disease has been seen in the workers of these industries. Pulmonary infections, tuberculosis have also been observed in the workers to a extent. Animals become more sensitive to E. coli due to such infections.

2. **Aldehyde:** It causes eye irritation, skin and respiratory irritation in man. These pollutants form smog through photochemical reaction. Smog causes neurotic banding and glazing in the Petunia sp. on lower surface of leaf.

3. **Ammonia:** It affects mucous membrane, eyes and respiratory tract in man. It shows acute collapse and chlorosis in plants. It is a water soluble gas, so it increases the pH of water by neutralizing acidic components of water, so aquatic system is affected. Ammonia decolorizes varnish, paint surface and fabrics. Its higher amounts destroys the non-ferrous metals like copper, zinc and their alloys. It reacts with cellulose and softens the wood. It also has adverse effect on plastics, fibre glass, nylon, PVC etc.

4. **Asbestos:** Asbestos can cause diseases like lung cancer, pulmonary fibrosis and pleural calcification and have been seen in the workers. It also indicates bronchial carcinomas, mesothelioma disease in pleura and peritoneum.

5. **Barium:** It indicates muscular stimulation, hence it affects heart muscles, central nervous system and respiratory tract.

6. **Beryllium:** Chronic berylliosis disease is caused by it, which indicates multifocal granulomatous inflammation. It is an autoimmune disease. If in soil, it is more than 1 ppm, then soil becomes toxic.

7. **Boron:** It affects central nervous system, due to which death occurs. Trace amount of it is must for plants, but in higher amount it is toxic for plants. Hence it is also used as herbicide.

8. **Chlorine:** It is harmful for humans, plants and minerals. It shows eyes, nose and throat infection (irritation). Higher amount of chlorine damages lungs and causes diseases like edema, pneumonitis, bronchitis. Chlorine also shows marginal and apical chlorosis, foliage bleaching. It degrades metals, paints and decolorizes textiles.

9. **Chromium:** Tri and hexavalent chromate compounds are toxic for human beings. It dissolves in water and forms chromic acids, which shows water toxicity.

It makes a hole in nasal septum, which is called as chrome holes. Along with it chromate ions also shows lesions in the lungs and respiratory tract. It shows renal damage, dermatitis, erythema, and oedema like disorders. Chromium is toxic for plants as well. It decolorizes the metals, paints building materials, paper and textiles.

10. **Ethylene:** It forms photochemical smog with nitrogen oxides and ozone. It shows eye irritation in man. In the plants morphogenetic effects can be seen because it is plant hormone also. It enhances rate of fruit ripening. It also behaves as senescence factor initiating ageing in early age.

11. **Hydrogen chloride:** It shows coughing by inhalation, nasal choking, inflammation of respiratory tract and ulcer like abnormalities. It destroys metals and alloys. It reduces soil fertility. pH of aquatic ecosystem lowers, which causes destruction of aquatic flora and fauna.

12. **Hydrogen sulfide:** It shows headache, conjunctivitis, sleeplessness, irritation and pain in the eyes. Its higher concentration inhibits oxygen transfer and cell enzyme activity. It also destroys nervous tissues. In plants it destroys young roots, young plant tissues. It decolorizes paints, copper, zinc and argentums.

13. **Iron:** It causes a disease in the lungs known as pigmantism. Iron oxide is considered as carcinogen carrier. It shows staining in the form of iron oxide on paints and textiles.

14. **Pesticides:** It inactivates immunological system and shows toxicity. It may be directly or indirectly toxic.

15. **Phosphorus:** It shows skin irritation and systemic poisoning. Its higher concentration affects nervous system. Many of the substances get destroyed due to phosphoric acid.

16. **Radioactive substances:** It shows leukemias and other cancers. Cataract, less life span, genetic disorders, mutations have been seen.

17. **Selenium:** Selenium poisoning shows eye, throat, nose problems, irritation of gastrointestinal tract and respiratory tract. Long term effect have been seen in the form of kidney, liver and lungs damage. Herbivores died away by eating food, containing selenium. Most of the plants like wheat, barley, corn and rye get damaged due to selenium accumulation.

18. **Silica:** It causes a lung disease known as silicosis, which frequently occurs in mine workers. Due to this, vital capacity of lungs get reduced. Respiratory rate becomes low and coughing like abnormality is seen.

19. **Carbon monoxide:** It forms carboxyhaemoglobin, when it reaches in RBC, which restricts oxygen transfer. So it shows heart and respiratory disorders. 2% carboxyhaemoglobin indicates change in behavior, 5% carboxyhaemoglobin shows change in cardiac and pulmonary functions. 10% carboxyhaemoglobin shows headache, obesity, laziness, dullness, low respiration and death.

20. **Sulfur oxides:** Plants are more sensitive towards sulfur oxides. It causes chlorosis and necrosis in the plants. Its higher concentration destroys zinc, copper, steel, nickel, cotton, linen, rayon, marbles, nylon and leather. It indicates mucous membrane, respiratory tract and lung disorders in human beings.

21. **Arsenic:** Abdominal pain, burning of the mouth and throat, cancer (especially skin and lung) diarrhoea, nausea, neuritis, peripheral vascular problems, skin lesions, vascular collapse can be seen due to deposition of arsenic.

22. **Cadmium:** Anaemia, dry and scally skin, emphysema, fatigue, hair loss, heart disease, depressed immune system response, hypertension, joint pain, kidney stones or damage, liver damage, loss of appetite, loss of sense of smell, lung cancer, pain in the back and legs, yellow teeth are common symptoms of cadmium poisoning.

23. **Lead:** Abdominal pain, anemia, anoxia, anxiety, autoexhaust, bone pain, brain damage, confusion, constipation, convulsions, dizziness, drowsiness, fatigue, headache, hypertensions, inability to concentrate, indigestion, irritability, loss of appetite, loss of muscle co-ordination, memory problem, miscarriages, muscle pain, tremors, vomiting, weakness are result of lead poisoning.

24. **Mercury:** Abnormal nervous and physical development (foetal and childhood) anemia, anoxia, anxiety, blood changes, blindness, depression, dermatitis, difficulty in chewing and swallowing, dizziness, drowsiness, emotional instability, fatigue, fever, hallucinations, headache, deafness, blue lines on gums, inflammation of gums, kidney damage or failure, loss of appetite and sense of smell, loss of muscle co-ordination, memory loss and metallic taste in mouth, nerve damage, salivation, tremors, vision impairment, vomiting, weakness and weight loss are important symptoms of mercury poisoning.

25. **Nitrogen oxides:** Nitrogen oxides show three lacs times more affinity with haemoglobin, so it binds the haemoglobin and reduces oxygen carrying capacity of blood. It shows pulmonary irritation and oedema disease. It initiates lung cancer. It also damages the plants.

26. Hydrocarbons:

a.	Benzene	Bladder cancer
b.	Bichloromethyl ether	Urinary bladder cancer
c.	Bichloroethyl ether	Lung cancer
d.	Ethylene dichloride	Stomach, spleen and lung cancer
e.	Vinyl chloride	Liver cancer
f.	Ethylene amines	Liver cancer
g.	Propio-acetone	Carcinogen
h.	Nephthylamine	Bladder cancer
i.	Nitrophenol	Bladder cancer
j.	Dichlorobenzidine	Cancer

Effect on Atmosphere

Global level effects of air pollution are following:

1. Photochemical smog
2. Acid rain
3. Global warming
4. Ozonolysis

Its local effects on atmosphere are as follows:

1. Visibility reduction
2. Fog formation and precipitation
3. Solar radiation reduction
4. Changes in temperature and wind distribution.

The main reason of reduction of visibility is the increasing of light scattering. It decreases contrast between object and sky, so light intensity decreases by particle reflection, diffraction and reflection.

Effects on Vegetation

Major effects of air pollution is present very much on the leaf structure of vegetation. Main effects due to phytotoxicants are as follows:

1. Bifacial necrosis: Tissues of both the surfaces of leaf get destroyed.
2. Pigmented lesions: Brown, black, purple, or red spots on the leaf are seen.
3. Epinasty: Upper surface leaf shows rapid growth.
4. Acute injury: Leaf damages due to plasmolysis and tissue collapse.
5. Chronic injury: Chlorosis is present due to destruction of chlorophyll.
6. Chlorosis: Different types of chlorosis are shown due to pollutants, which can be marginal, laminar, interveinal and apical chlorosis.
7. Abscission: It increases leaf fall and decreases plant life.
8. Necrosis: Leaf tissues are destroyed and show necrotic spots. Tissue shows specific color like sulfur oxide shows bleaching, yellowing due to ammonia, browning due to fluoride, silvering and bronzing due to peroxy acetyl nitrate (PAN).

Effect on Water Bodies

Acid rain is caused due to nitrogen oxides and sulfur oxide, due to which pH lower down in the aquatic ecosystem. It destroys aquatic vegetation and fishes. Water becomes toxic, BOD and COD of water increases due to dying of plants and fishes. Dissolved oxygen of water decreases and the number of acidophiles increases in the water.

Water Pollution

Today water pollution is a very big problem for the whole humanity. Water pollution can be defined as follows:

"Presence of any external substances like organic, inorganic, radiological or biological in the water, by which quality of water lowers down and problems are created in its use. It is called as water pollution."

> *" any change in the quality of water, by which we cannot use the water is known as water pollution."*

Source of Water Pollution

There are many sources of water pollution. Each pollutant affect the quality and characteristics of water differently. Some important sources of water pollutions are following:

Physical

Physical characteristic due to which quality of water gets lowered, are many types. Which are following:

1. **Temperature:** Due to increase in the temperature of water, oxygen concentration is decreased. This discharge of hot water from coolant factories causes thermal pollution. Increasing temperature of water decreases dissolved oxygen and flora and fauna are badly affected. Similarly, if discharge is more, then also due to temperature shade, fishes die away.
2. **Turbidity and Colour:** Change in turbidity and colour causes aesthetic pollution in water, because form of water has been changed, so it is not used. Turbidity is caused due to organic and inorganic substances, which are present in domestic and industrial effluent. It decreases transparency of water. So sunlight does not reach up to lower level for algae and plant and its productivity is affected. Dyes and pigments are main source for increasing turbidity.
3. **Suspended and Floating Matters:** In these pollutants slit, sand, metal pieces, rubber, wood chips, paper, foam, scams are included, which are thrown away by human beings in water. This pollution occurs due to uncontrolled disposal of sewage. Due to this, algal communities get badly affected and due to deficiency of oxygen, number of anaerobic organisms increase fermentation rate, so fishes die away and give bad odour.

Chemical Pollutants

Domestic and industrial effluents change the chemical characters of water and chemical pollution occurs. It has many sources, which are following:

1. **Nitrates and Phosphates:** Agriculture near the rivers and disposal of domestic sewage in the water increase the concentration of nitrates and phosphates in the water. Dead organic matters also form nitrates through bacterial decomposition. Phosphate pollution occurs due to phosphate rocks, sewage and synthetic detergents.
2. **Chlorides:** Decomposition of organic matter is the main source of chloride pollution.
3. **Fluorides:** In surface water generally less concentration of fluorides is present, but it is a main problem of underground water like it can be seen in Jhabua district.

Toxic Elements

Many of the toxic elements are present in aquatic ecosystem, which are produced due to industrial processes, metal processing, calico printing and power generation. Some important metals are following:

1. Cadmium: Range of cadmium level in natural water is less than 1 microgram per litre, but industrial discharges, metal or plastic pipes etc are the main sources of cadmium.
2. Lead: In water lead mainly comes from lead processing industries and lead pipes.
3. Mercury: Heavy metal mercury is a dangerous metal pollutant. It is discharged from mercury and other metal mines in the inorganic form. Its main sources are mining, refining, paper and pulp industry, acetylene, acetaldehyde synthesis, vinyl chloride synthesis, caustic soda industries.

Synthetic Detergents

Sodium alkyl sulfate is a synthetic detergent, which is commonly found in dish detergents, shampoo and commercial toothpaste. Its concentration is increased, when use of sodium tripolyphosphate is done in domestic and industrial processes. Its concentration is increasing day by day in water.

Pesticides

Group of many organo-chlorine compounds is the main source of water pollution in which pesticides like DDT, aldrin, endosulphone, chlorinated phenoxy acids are included. Important herbicides are hexachlorobenzene, penta chlorophenol, and polychlorinated biphenyl (PCB). In water, the sources of organochlorine pesticides are mainly two types:

1. Run off from agricultural land.
2. Discharge of industrial water.

Tar Poisoning

Due to leakage of crude oil from tankers, in the marine life tar poisoning is caused.

Plastics

Like oil spills, plastics are also dangerous source for marine mammals. Near about 6,39,000 plastic containers and bags are thrown in the sea daily. Besides these, plastic fishing gears used by fisherman are also cause of it, about 1,50,000 tonnes of these get discarded in the sea every year. Picnic utensils sandwich bags, paper cups etc are thrown in the water after being used by boaters and beach travelers.

Biological Pollutants

Biological organisms are also a cause of water pollution, which include pathogenic organism and nuisance organisms. Pathogenic bacteria, viruses and parasites contaminate water. Nuisance organisms include five kinds of organisms, which are biological slimes, mollusca, algae and nematodes.

Industrial Pollution

As compared to other segments of society, industry pollutes the water very much. Water gets polluted due to uncontrolled rejection of wastes. In industries, many waste products are formed due to refining, mixing, blending and extraction, by industrial manufacturing operators.

Effects of Water Pollution

Health Hazards of Water Pollution

Toxic water pollutants may enter in human system through the following parts:

1. Oral route of ingestion
2. Through penetration by insect vectors on skin or mucous membrane

Polluted water may cause following diseases:

Table 4.5

S. No.	Pollutant source	Diseases
1.	Water borne, in which water gets polluted due to infecting agents by vehicle	Infection, Hepatitis, Cholera, Typhoid.
2.	By use of insufficient available water, infection develops.	Scabies, leprosy, Trachoma
3.	By infecting agents from aquatic animals, persons drinking or walking in water	Schistosomiasis, Guinea worms
4.	By the infections of water related vectors, which breed in the stagnant water	Malaria, Sleeping sickness, Yellow fever.

Hazards Associated with Ingestion of Polluted Water

Pathogen becomes the main source of disease either directly or indirectly by transmitting from water into food. It includes animate pathogen like bacteria, viruses, protozoans, helminthes etc. and inanimate pathogens as organic and inorganic chemicals as well as radioactivity.

Bacterial infection has commonly been seen in rural or urban populations. Following diseases can be caused due to infection of water borne bacteria:

Table 4.6

S.No.	Diseases	Causative organisms
1	Cholera	Vibrio cholerae
2	Bacillary dysentery	Shigella sp.
3	Typhoid	Salmonella typhii
4	Paratyphoid	Salmonella paratyphii
5	Gastroenteritis	Shigella proteus
6	Infantile diarrhoea	Enteropathogenic E. coli
7	Leptospirosis	Leptospira sp.
8	Tularaemia	Pasteurella tularensis
9	Infective hepatitis	Virus has not been identified
10	Intestinal amoebiasis	Entamoeba histolytica
11	Dracontiasis	Guinea worm
12	Distomatosis	Fasciola sp., Dicrocolium sp.
13	Ascariasis	Ascaris lumbricoides

Due to higher concentration of nitrate in surface water, methamoglobinemia is caused. Nitrate poisoning has been frequently noticed in the Rajasthan, which is the cause of death, in children. In Rajasthan, due to high concentration of fluorides in water body fluorosis problem is there. Inanimate pathogens are associated with following diseases:

Table 4.7

S. No.	Diseases	Chemical	Concentration
1	Methaemoglobinemia	Nitrates	20 – 300 mg/l
2	Dental carries	Fluorides	Less than 0.5 mg/l
3	Fluorosis	Fluorides	6 – 12 mg/l
4	Black foot	Arsenic	6.24 – 0.96 mg/l

contd...

5	Minimata disease	Methyl mercury	1 – 10 microgram/l
6	Shortened life	Lead	0.5 mg/l
7	Itai - Itai	Cadmium	1 – 10 microgram/l

In Japan, minimata disease is found. Here the people consume polluted fishes and shelfish, which become methyl mercury poisoned. It has been identified as a disease first of all by Hosokawa (1956), which includes following facts:

1. Minimata disease has been identified in the end of 1953.
2. In 1956, it took epidmic form.
3. Observed symptoms were new, which were not available in literature.
4. Prior to human symptoms, it was recognized firstly by the symptoms of cats.
5. Patients were mainly fisherman or their family members.
6. Patients were also the consumers of minimata bay fishes.
7. Disease was not infectious.

Liver gets affected due to high concentration of DDT, PCB and other chlorinated hydrocarbons. Along with it, cholesterol level and nervous system functions also get affected. DDT and other insecticides are carcinogens. Besides this DDT inhibits the calcium absorbtion in bones.

The main factor of pesticides hazard is its dosage. Xintaras, et al (1979) listed sixteen symptoms of neurotoxicity of leptophos in men. These symptoms are following:

1. Drooping of eyelids, blurring of double vision.
2. Deficiency in memory or thinking ability.
3. Difficulty in speaking.
4. Paralysis in any part of body.
5. Loss of balance or staggering.
6. Tingling in hands and legs.
7. Difficulty in walking.
8. Problem with co-ordination.
9. Spells of dizziness.

10. Muscle weakness.
11. Nervous or uncontrolled tension.
12. Frequently feel fatigued.
13. Difficulty in sleeping.
14. Change in hand writing.
15. Drowsy or sleepy during the day.
16. Unexpected sweating

Radioactive elements directly or indirectly enter in the huma.. bodies and accumulate there. It becomes the cause of leukemias, bone cancer and hereditary disease.

Hazards Associated with Polluted Water Contact

Contact with water pollution cause many diseases. Animate and inanimate pathogens are present in polluted water. These become the cause of health hazards by penetration through skin or mucous membrane. Important diseases are following:

Table 4.8

S.No.	Disease	Causatives
1.	Internal schistosomiasis	Schistosoma mansoniiS. japonicum
2.	Genitourinary schistosomiasis	S. haematobium
3.	Swimmer`s itch	S. haematobium
4.	Leptospirosis	Leptospiros sp.

Insect vectors living in the water can also cause diseases. Following diseases are transmitted by water associated insects vectors:

Table 4.9

S.No.	Disease	Causatives	Insect vector
1.	Malaria	Plasmodium sp.	Anopheles mosquito
2.	River blindness	Volvulus sp.	Similium sp. (Black flies)
3.	Yellow fever	Arbovirus group B	Aedes mosquitoes
4.	Sleeping sickness	Trypanosoma gambience	Tse-Tse fly
5.	Filarasis	Wuchereria bancroftii	Culex sp.

Ecological Effects

In water pollution, the major effect is on aquatic ecosystem. Fishes start dyeing and aquatic plants destroyed. Main problem is not of biodegradable substances, but is of non biodegradable substances, which show two major problems:

A. Bioaccumulation: It is the process in which pollutants are accumulated in vital tissues. Like mercury is accumulated in fishes methyl mercury.

B. Biomagnification: It is the process in which pollutant enters in to food chain and then trophic level to trophic level, its concentration is increased. Like DDT is sprayed in the water as 1 ppm but through food chain it becomes upto 125 to 300 ppm in human beings.

Economic Effect

Mainly aquaculture activities are affected due to water pollution. Fishes start dying in the ponds, dams, rivers and lakes. Fishes become toxic due to bioaccumulation of toxins. When these fishes are consumed as food by people, then these people die out or become handicapped. Due to acid rain, buildings are destroyed. Metallic articles get damaged. Pipes transferring water get rusted and slowly degraded. Diseases increased among people, due to which a very big part of salary gets expended over it.

Due to more and highly polluted water, it has to be treated more and more by public health department, so water treatment cost is increased. Similarly, other economic effects have been seen, to be caused by water pollution.

Thus, expenditure of buildings, health, agriculture, metallic articles increased and it badly affects the economy.

Soil Pollution

Soil is the uppermost fertile layer of earth surface, where plants, animals and microbes are found. Soil pollution is mainly the result of agricultural practices, solid waste disposal and liquid disposal. At this time different types of poisonous chemicals are being used, which remains in the environment and they enter from soil to food chain and food webs. Hence, soil pollution is related with following other pollutants:

1. Use of chemicals like fungicides.
2. Mining and smelting operations and disposal of different substances in the soil
3. Disposal of domestic solid waste in the soil.
4. Disposal of industrial effluent in the soil.

Causes of Soil Pollution and Sources

1. Soil pollution by agricultural practices: Chemical fertilizers are used in the agricultural fields to maintain the continuous fertility. Along with it, pesticides are used to control diseases and vectors, which is the main source of pollution.
2. Pesticides: Pesticides are generally used to kill fungi insects or other animal pests. Man uses all these to improve his own environment (surroundings), but it causes harmful effect to the environment.
3. Insecticides: These are biologically inactive components, which are helpful in insects and pest control. These insecticides are organochlorines and organophosphates. Organochlorine shows pollution and damage. These are permanent and non-biodegradable, as DDT remains in the environment nearly for 120 years.
4. Fungicides: These are two types, which are sprayed in the form of dust, as sulfur compounds or systemic fungicides like thiram, ziram, maneb, karathane etc. Although due to less toxicity, these are not much harmful for plants, animals and organisms.
5. Herbicides: These are organo-chemicals, which stop plants growth. These are sprayed in the soil or in the leaves. These destroy unwanted plants. These are used in agricultural forms, road clearing and forest management.
6. Solid waste disposal: Due to modernization solid waste disposal have been much increased. Its main reasons are following:
   a. Rapid growth of human population.
   b. Accumulation of people in the urban areas.
   c. Increase of disposal items.
   d. Social activities, attitudes and advancement.
   e. Use of new substances and recycling of old substances.
   f. Having no knowledge of long-term effects of disposable substances.

Main sources of solid waste are as follows

a. Refuse: Solid waste matter.
b. Garbage: Animal and vegetable wastes.
c. Rubbish: Household wastes
d. Litter: Street refuse
e. Industrial: Manufacture wastes

7. Mineral wastes: Its main sources are mining, milling and industrial processing.
8. Industrial wastes: Different heavy metals are produced by industries like copper, zinc, mercury, lead, selenium etc. causing soil pollution.

Effects of Soil Pollution

Insecticides are having following negative impacts:

1. Permanent and non-biodegradable compounds show bio-accumulation and bio-magnification like DDT.
2. The compounds cause toxic effects on plants and animals, which can block fertility, hormone imbalance and enzyme action.
3. These are fat soluble, so accumulated in adipose tissue.
4. These show pollution upto a large distance from the place of origin due to spreading by air and water.
5. Mercury fungicides show lethal effects on organisms.
6. In Vietnam near about 1.7 million hectare of fertile soil has been destroyed by the use of 2, 4, 5-T and picloram, in which 86% forest and 14% agricultural area.
7. Constable and Meselson showed that when 2, 4, 5-T and 2, 4-D were sprayed on mangroves, then they got destroyed completely. It increased soil erosion in the coastal areas.
8. Some herbicides like monuron, simazin block the photosynthesis, which causes the plant death.

Similarly due to extreme use of fertilizers, following effects may be seen.

1. Change in the mobility of soil nutrients.
2. Rapid growth of weeds in the crop areas.
3. Destruction of ionic balance and high acidity.
4. Deficiency of trace elements.

Similarly, effects of solid waste disposal are also complex. It increases complexity by changing from one form to other form. Due to mining the wasteland area is increasing. Around copper fields, the whole area has been changed into desert.

Heavy metals are harmful for the organisms, living in the soil and water. Fishes absorb copper with the help of gills, which destroys tissues. Most of the heavy metals show the

same effects on the human beings like nausea, vomiting, dizziness, nervous disorders, mental disorders, memory loss, and paralysis also. The effects of important heavy metals on health of human being is following:

Selenium

Selenium poisoning shows eye, throat, nose problems, irritation of gastrointestinal tract and respiratory tract. Long term effect have been seen in the form of kidney, liver and lungs damage. Herbivores died away by eating food, containing selenium. Most of the plants like wheat, barley, corn and rye get damaged due to selenium accumulation.

Arsenic

Abdominal pain, burning of the mouth and throat, cancer (especially skin and lung) diarrhoea, nausea, neuritis, peripheral vascular problems, skin lesions, vascular collapse can be seen due to deposition of arsenic.

Cadmium

Anaemia, dry and scally skin, emphysema, fatigue, hair loss, heart disease, depressed immune system response, hypertension, joint pain, kidney stones or damage, liver damage, loss of appetite, loss of sense of smell, lung cancer, pain in the back and legs, yellow teeth are common symptoms of cadmium poisoning.

Lead

Abdominal pain, anemia, anoxia, anxiety, autoexhaust, bone pain, brain damage, confusion, constipation, convulsions, dizziness, drowsiness, fatigue, headache, hypertensions, inability to concentrate, indigestion, irritability, loss of appetite, loss of muscle co-ordination, memory problem, miscarriages, muscle pain, tremors, vomiting, weakness are result of lead poisoning.

Mercury

Abnormal nervous and physical development (foetal and childhood) anemia, anoxia, anxiety, blood changes, blindness, depression, dermatitis, difficulty in chewing and swallowing, dizziness, drowsiness, emotional instability, fatigue, fever, hallucinations, headache, deafness, blue lines on gums, inflammation of gums, kidney damage or failure, loss of appetite and sense of smell, loss of muscle co-ordination, memory loss and metallic taste in mouth,

nerve damage, salivation, tremors, vision impairment, vomiting, weakness and weight loss are important symptoms of mercury poisoning.

Ozonolysis and Ozone Holes

Long back 4000 years ago there was no ozone layer at the earth surface. So ultra violet radiations reached the earth surface and life was not possible here. At that time the life was present only in the depth of oceans, where UV radiations might not have reached. Slowly ozone layer got formed due to photochemical reactions of different gases. Especially ozone layer is formed after origin of cynobacteria, which are first photosynthetic organism and produces oxygen. This oxygen is changed into ozone in the presence of UV rays. Ozone is present at each altitude, but stratospheric ozone filters UV rays. If there will be no ozone layer, then biosphere will burn like a furnace.

Formation of Ozone Layer

Surrounding the earth, 12 to 32 kilometers ozone layer is present, which is also called as ozone umbrella. Stratosphere ozone restricts UV rays by coming to the earth and thus protects the earth from harmful radiations. Stratospheric ozone has the maximum concentration of 10 ppm. Ozone is formed mainly by the following photochemical reactions:

Where,

$$O_2 + h\upsilon \xrightarrow{240\ nm} O + O$$

$$O + O_2 + M \longrightarrow O_3 + M$$

M = Oxygen, nitrogen or any other inert molecule, which lowers the excess energy and stops the ozone decomposition.

Ozone can be prepared in the lab. Ozone word consist of Latin word ozo = smell. A German scientist prepared ozone by electric discharge.

$$O_2 \xrightarrow{\text{Electrical Discharge}} O + O$$

$$O + O_2 \longrightarrow O_3 \text{ (Ozone)}$$

It is a poisonous gas, so if it is present at earth surface then it is harmful, but presence at height of 12 kilometers above the earth surface is life supporting.

Depletion of Ozone Layer

In the recent years, it has been seen that ozone layer is becoming thin and it is getting degraded. Holes are being also getting formed in the ozone layer. It is a serious matter because if ozone layer is continuously depleting, then the protective covering of the earth will get destroyed and there will be no protection from UV rays. By satellite of USSR (1967) it has been confirmed that ozone amount is decreasing. This decrement was very fast in 1960 and due its depletion it became a serious problem. The main reason for this is release of nitrogen oxides from nuclear test held in USSR, USA and France. Later nuclear tests were banned, so for some time ozone layer was stable. In 1971 Curtzen a scientist of USA observed that nitrogen oxide gases released from supersonic aircrafts depletes ozone up to 40%. Joseph Foreman a scientist f British Antarctica survey team, observed a large ozone hole in the ozone layer of south pole during his study of atmosphere of south pole. Approximately 40% reduction in the ozone has been taken place there. It was a red signal and alarming situation, so there is necessity to prevent ozone depletion.

Causes of Ozone Depletion

Natural Process

Ozone absorbs short wavelength (210 – 293 nm) UV very rapidly and releases atomic oxygen. It is a natural process in which loss of ozone takes place. but there is no effect of it on ozone equilibrium because as soon as the amount of ozone, which dissociates it is formed by atmosphere in same amount.

During natural process of ozone depletion, atmospheric nitrogen converts into nitrogen oxides by solar activity. Hence, the amount of nitrogen oxides increases. Then these gases reach upto ozone layer and deplete ozone layer by photochemical reaction. On the global basis maximum nitrogen oxides are formed by bacterial decay like nitrous oxide. This nitrous oxide remains inert in the troposphere, but in stratosphere, it reacts with oxygen atom to form nitric oxides and it enters into the ozone destruction cycle. When NO2 forms HNO3 by reacting with water then this cycle ended up. In the next step nitric oxide on reacting with water forms HNO2. This acid dissolves in water and reaches the troposphere through rain.

$$2N_2O + O_2 \longrightarrow 2NO$$

$$NO + O_3 \longrightarrow NO_2 + O_2$$

Anthropogenic Process (Manmade Sources)

Chlorine Hypothesis

Chlorofluoro-carbon and chlorofluoro-methane (CFC and CFM) are also responsible for destruction of ozone umbreila. CFC, CFM and halons are released by many equipments. When CFC were being discovered, then they were called as miracle chemicals, because these are non-toxic, non-flammable and stable. These are used as coolant in refrigerator, air conditioners, blowing plastic fumes, spray canes and computer cleaning. But in the recent years, it has been found out that these are responsible for ozone depletion. It is supposed that one molecule of CFC destroys the one lakh molecules of ozone. Halons used in fire extinguishers, also deplete ozone. These are having ten times more capacity. It has been seen that concentration of halons is getting doubled in each five years.

$$CFCl_3 + h\hat{u} \longrightarrow CFCl_2 + Cl^*$$
$$Cl^* + O_3 \longrightarrow ClO + O_2$$
$$ClO + O \longrightarrow Cl + O_2$$

Nitrogen oxide hypothesis

Scientists are worried that nitrogen oxides load is increasing in the atmosphere by human activities, which affect ozone concentration. Supersonic air crafts take flight in ozone layer, because there is less air resistance present in the ozone layer. By exhaust of these aeroplanes, water vapor and nitrogen oxides comes in the stratosphere. Reaction between nitrogen oxides and ozone are as follows:

$$NO + O_3 \longrightarrow NO_2 + O_2$$
$$NO_2 + O_2 \longrightarrow NO_2 + O_2$$
$$NO_2 + O_2 \longrightarrow N_2O_5$$
$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$
$$H_2O + h\hat{u} \longrightarrow OH + H$$
$$H + O_3 \longrightarrow OH + O_2$$

Sulfate Hypothesis

It has been seen that sulfate aerosols released from chimneys from factories get accumulated in the atmosphere in between 15 – 22 kilometers. There quantities are ever more due to

population and over industrialization. These surface aerosols convert ozone into oxygen. Hence, these are also the causes of ozone depletion.

Effects of Ozone Depletion

Effects on Human Beings

a. Narrow band of UV radiations affect immune system. It may cause patches on the skin.

b. Three types of cancer may be caused by UV rays, which are basal cell carcinomas, squamous cell carcinomas, and melanomas.

c. Due to UV the blood flows fast in the blood vessels near the skin, so skin swells and becomes red. Skin burns are also caused.

d. Cornea and lense of eyes also absorb UV rays and it causes photokeratitis and cataracts.

e. At ground level ozone directly enters in the body, which affects lungs and causes toxic impact on it.

f. Lung cancer and DNA breakage occur due to ozone exposure.

g. Due to photochemical smog, air pollution increases, which affect human health.

h. Due to less amount of ozone, number of inflammation increase in the lungs.

Effects on Biotic Community

a. Many micro-phytoplanktons may be die away due to UV exposure.

b. Due to decrease in the phytoplanktonic productivity, zooplanktons may also get affected, marine organisms, fishes etc. will get affected due to decrease in the amount of food.

c. Due to decrease in the population of fishes, the coastal people will get affected.

Effects on plants

a. There may be lesions on the plants.

b. Due to damage, photosynthesis in the plants will get affected.

c. Due to UV radiations, evaporation rate of surface water will get increased and soil moisture will be decreased.

d. There will be decrease in the yield of plants.

e. Flower production will be less.

f. Pollen germination also decreases.

Effect on Climate

Due to decrement in ozone temperature, wind pattern and precipitation will be affected. So the spectrum of solar electromagnetic radiations coming to the earth, will get changed. Due to increase in UV green house gases will be there and it will increase global warming. It affects global energy and radiation balance.

Steps for Reducing Ozone Depletion

1. Use of CFC must be lowered.
2. In place of CFC, alternative resources or substances must be used.
3. Montreal protocol (1987) must be followed.
4. In USA Bioact FC – 7 is being used as successful alternative in place of Freon - 12.
5. One such bacteria has been discovered, which may degrade ozone depleting chemicals.
6. Satellite research institute of Germany has developed a method to use hydrogen as a propellant in sprays, which is environmental friendly. It is safe also and is an alternative of CFC.

Green House Effect and Global Warming

The term was first coin by J. Fourier in 1827. Green House Effect (GHE) is an effect by virtue of which there occurs a rise in the temperature of the earth. It is mainly due to increase in concentration of carbon dioxide in the atmosphere. Heating up of earth's atmosphere due to the trapping of infra-red radiations (reflected from the earth surface) by the carbon dioxide layer in the atmosphere.

This blanket of carbon dioxide gas in air allows the sunlight to come in freely but does not allow the infra-red radiations reflected by earth surface to go out. As a result gradually the atmosphere gets heated up during the days as well as night.

The name green house effect comes from the fact that this effect is used in horticulture for the upbringing of green plants in small houses made up of glass walls and glass roofs.

That's why it is also known as glass house effect. It allows the sunlight to come freely but does not allow the long wavelength infra-red radiations reflected by soil, plants and other contents of green house to go out. These trapped infra-red rays show their heating effect due to which the temperature is raised. Thus, without external supply of heat, the temperature inside a green-house is found to be higher than its outside.

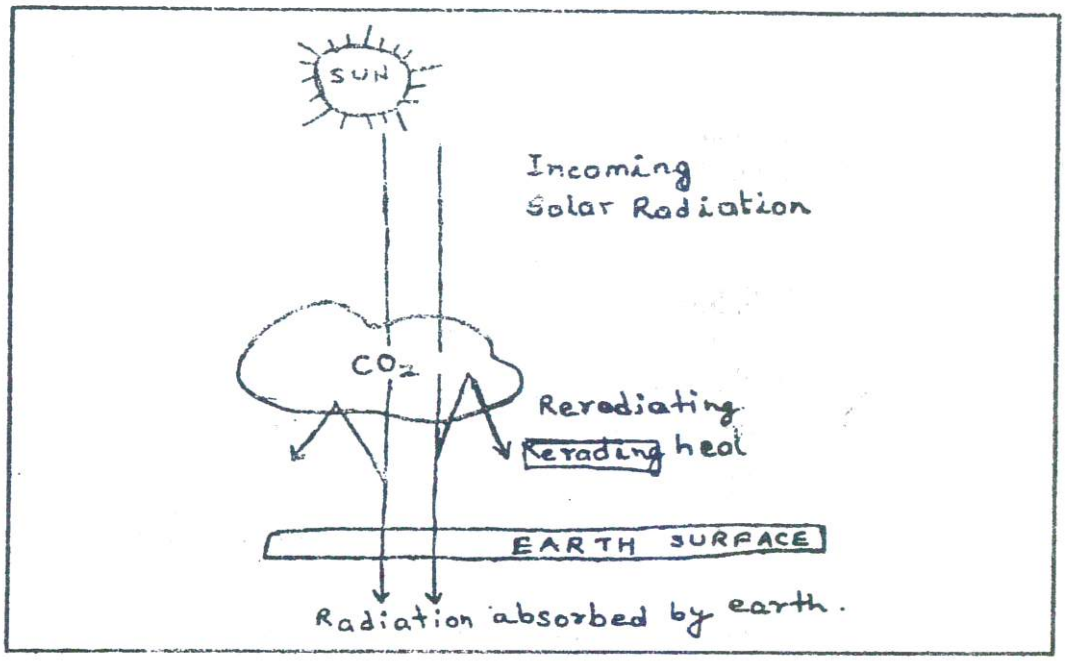


Figure 4.2: Distribution of Solar Radiations at the Earth Surface

Relationship in Increasing Carbon Dioxide Concentration and Temperature

Years	Carbon dioxide concentration
20,000 years ago	200 ppm
10,000 years ago	280 ppm
1860 year	290 ppm
1960 year	320 ppm
1990 year	345 ppm
2030 year	expected doubled

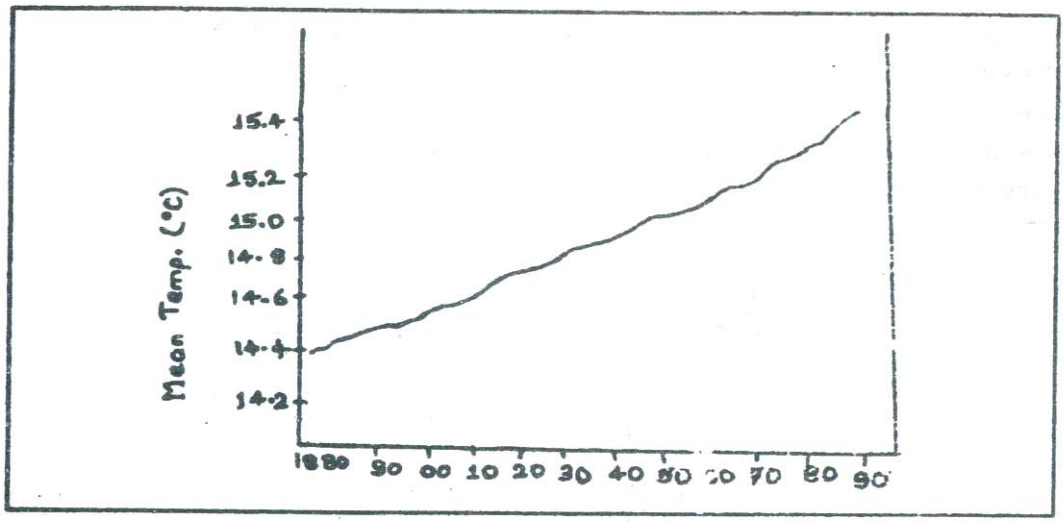


Figure 4.3: Increasing Trend in Temperature

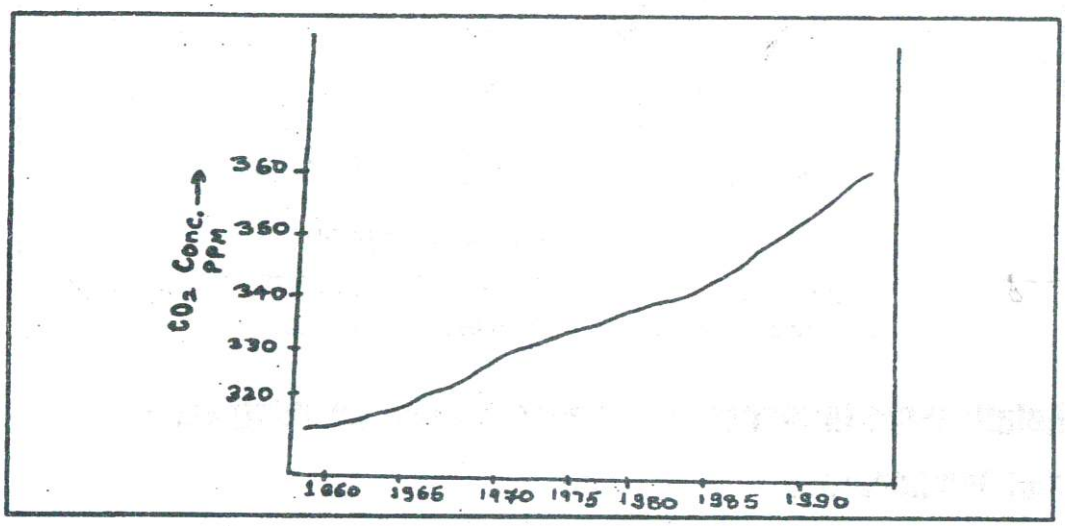


Figure 4.4: Increasing Trend in Carbon Dioxide

So it is clear from both the graphical representation that carbon dioxide concentration is directly proportional to increase in temperature. Although gases also behave like green house, but major role is played by carbon dioxide.

Causes of Green House Effect or Green House Gases

Those gas which can trap infra-red radiation, present in sunlight to produce green house effect leading to heating up of the environment are known as Green House Gases (GHE). These are carbon dioxide, methane, nitrous oxide, ozone, carbon monoxide, choloroflurocarbon and water vapors etc.

It has been estimated that carbon dioxide accounts for about 50% of the GHE, CFC is 20%, methane 16%, ozone 8%, and nitric oxide 6%.

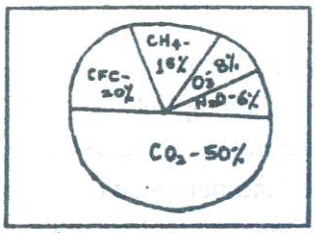


Figure 4.4: Percentage Concentration of Different Green House Gases

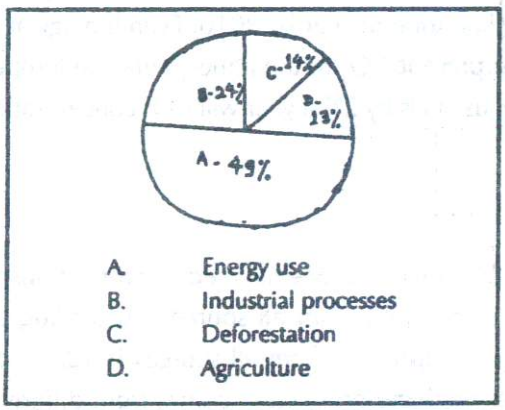


Figure 4.5: Human Activities Contributing Green House Gases

The major sources of green house gases are developed countries like USA, Russia, European countries, China and Japan.

Important Green House Gases

Table 4.10

Properties	Green House Gases				
	H	CH_4	H_2O	O_3	CFC-11/12
Atmospheric concentration by volume	360 ppm	1650 ppb	304 ppb	Variable	0.230 ppb/ 0.400 ppb
% Increase /yr	0.4	1.0	0.25		5.0
% Concentration of GHE	50	18	06	08	14
Estimated temperature increase °C	0.71	0.2	0.1	0.6	0.24/0.12
Effective then CO_2	01	30 times	200 times		1000 times
Sources	Combu-stion of fossil fuels, industries agricul-ture, defo-restation	Rice production, animal husbandry, marshy lands, coal seams, biomass burning, natural gas leaks.	Nitrogen fertilizers, land clearance, biomass burning, fossil fuel combustion	Photo-chemical oxida-tion	Propellant & deo-dorants in aero-sols, refrigerants cleaning solvents, fire extinguisher, blowing agent for foamed or extruded poly-mers, sterlizers for medical suppliers.

Carbondioxide

Concentration of carbon dioxide in the air is normally 0.003%, but the concentration of CO_2 in the air is going on increasing from past few years, as it is the principal air pollutant, O_2 the major amount is released by burning fuel (coal, coke, oil etc.) for domestic cooking, heating etc. and the fuel consumed in the furnaces of power plant and industries, human and animal respiration, forest fires and deforestations. Man kind is adding about the 5.1 billion tones of CO_2 to the atmosphere by burning fossil fuels, not only in the rich capitalist countries but increasing in the communist countries also. The present rate of increase will have risen to over 10 billion tones a year by 2010. Even if magically CO_2 production stops increasing now, with the present CO_2 in the atmosphere the temperature will continue to rise up. Only if fossil fuel use falls by 2% a year will CO_2 concentration in the air, stop rising.

Methane

The other important GHG is methane. Methane emission in atmosphere is estimated to be 225, 423 and 550 tones per year from all sources. According to the World Resource Institute estimate, Indian contribution from all sources is 12.1% of the total production. According to Bolls global methane production comes from different sources as follows:

A.	Non-biological sources	32%
B.	Rice field	18%
C.	Ruminants	18%
D.	Marshes	13%
E.	Other sources	6%

It accounts for about 1/8 of the heat trapping ability of the GHG and that proposition is rising fast because the methane concentration is growing at about 1% a year, which is 2.5 times faster than carbon dioxide. Reaction of methane in atmosphere plays different roles under different spheres of ozone.

Ozone

In stratospheric methane can react with chlorine radiants, forming HCl which slows the rate at which Cl and ClO destroys stratospheric ozone.

$O_2 + h\bar{v} \rightarrow O^*$

$O^* + O_2 \rightarrow O_3$

$CFC \rightarrow Cl$

$Cl + O_3 \rightarrow ClO + O_2$

Methane is oxidized by free radical OH. It is a source of water vapor in the stratosphere.

$O_2 + h\bar{v} \rightarrow O^*$

$O^* H_2O \rightarrow OH + OH$

$OH + CH_4 \rightarrow CH_3O + H_2$

$NO_2 + h\bar{v} \rightarrow NO + O$

$O + O_2 \rightarrow O_3$

$NO + O_3 \rightarrow NO_2 + O$

CFCs

CFCs and halons are manmade chlorinated and brominated compounds, which pose dangers to the stratospheric ozone layer. They trap heat 10,000 times more effectively than carbon dioxide and are estimated to be responsible for 15 – 20% of the total projected global warming. They are mostly used in replaceable luxuries such as air conditioners, refrigerators and fire extinguishers. Stopping CFC production by the end of the century would probably cut green house warming upto 15%.

Nitrous and Nitric Oxide

Sources are wood, oil and coal stores and furnaces, cigarettes, fire-places, combustion engines.

Water Vapor

Human, plants and animal activities, showers, washing etc.

Predictions of Climatic Change due to GHE

1. If the concentration of atmospheric CO_2 is doubled then it will increase up the global mean temperature 2.8 to 5.2°C and precipitation by 7.1 to 15.8%.

2. CO_2 is also expected to influence intensely the process of depletion of ozone layer, which would further make the climate hot.
3. With the increased CO_2 level, the oceans would be required to absorb and decompose more CO_2, which can raise their level of acidity.
4. Clouds formation, snow and ice coverage and water vapor and biophysical feed back become uncertain, which will affect the forecast.
5. Global mean precipitation increase heating of the surface, which will lead to increase evaporation and as a result global precipitation gets increased. However, in some regions rainfall decreased.
6. Thermal expansion of oceanic water is associated with surface and oceanic warming is predicted. Rate and extent of melting of glacial continental ice are far less certain. Prediction of changes in mean sea level remains uncertain and difficult.
7. Northern high altitude precipitation increased: High latitudes are expected to experience increased poleward. Penetration of warm, moist air, leading to increased annual precipitation and river run off.
8. Summer continental soil moisture decrease and dryness is increased: In some mid latitudes interior continental regions soil moisture is decreased in summer and in spring also.
9. Regional vegetation changes.
10. Tropical storms increases: Increased frequencies and intensities of tropical storms like hurricanes.
11. Warm tropical area increased.
12. According to World Health Organization mosquitoes may have longer lives and breed in large numbers due to global warming and hence may spread malaria.
13. Increase in mean global temperature, in association with depletion in ozone layer may increase the incidence of non-malanoma skin cancer.

In such a way GHE changes in mean sea level, energy supply, energy demand, water resource availability and political and social effects.

Control of Green House Effect

1. To conserve the standing primary and old growth forests.
2. Introduce natural forest management systems, which can replace the destructive biomass.

3. To increase up the harvest efficiency by harvesting more species.
4. Expansion of fuel wood plantation to provide energy and reduce the pressure on natural forests.
5. Establishment of plantation on surplus crop land in industry area.
6. Restoration of degraded ecosystems through natural regeneration and reforestation.
7. Modification in fuel system, which is used in energy production. So use alternate energy sources like tidal power stations, wind power plants, solar power system etc.
8. Water logging area releases the methane and other green house gases like rice field. Water logging condition is occured due to construction of dams for hydro power plants. So if water logging condition is avoided. percentage of hydrocarbons can be reduced.
9. CFC is 1000 times powerful than carbon dioxide, so the use of CFCs should be banned all over the world.

Conclusion

North-south debate of enforcing for reduction of gases in atmosphere by developed nations is still but instead of minimizing their economic sources they enforced small nations to go for it. So the problem of green house effect is not still solved and would become a havoc for entire globe in future years. However, there is need of legislation to deal with fumes of petrochemical units, ash, carbon particles etc.

Review Questions

1. Describe about the Composition of Air.
2. What are the Effects of Pollution on Man, Material and Vegetation?
3. Describe Soil Pollution and its causes.
4. What is Green House Effect?

CHAPTER 5

ECOSYSTEM STABILITY

LEARNING OBJECTIVES

- Concept (Resistance and Resilence)
- Ecological Perturbations
- Ecology of Plant Invasion
- Environmental Impact Assessment (EIA)
- Ecosystem Restoration
- Ecological Management
- Sustainable Development
- Sustainability Indicators

Concept (Resistance and Resilence)

Community is the diversified group of plants, and in any community, directional changes continuously occur. But when any community attains the climax stage, then it shows minimum changes, because in the climax stage, ecosystem becomes self-regulated and self-maintained. So it maintains dynamism and stability. Actually, in this state, it does not need the external sources. In climax stage, ecosystem shows the buffer capacity and it resists the external changes. Any developed ecosystem maintains constant climate, edaphic

factors and vegetation component. This property of maintenance of stability in the ecosystem through resistance against external changes is known as ecosystem resistance. As we know that ecosystem has the buffer efficiencies. So, if slight changes occur beyond the resistance or any part of ecosystem gets damaged, then it returns to good condition quickly. So, the efficiency of the ecosystem through which it returns to original state after damage, is known as resilence. It means the ecosystem stability is based on these two major mechanisms, which are 'resistance' and 'resilence'. So when any community becomes stable with climate, then it is known as ecosystem stability. It shows equilibrium with climate and it cannot be replaced through competition. According to Clemant, in the equilibrium condition, particular climate can develop dominant characteristic species. As these species are dominant, these can resist any change in the ecosystem; and if any change occurs in the community, then it quickly returns to the original state.

Stable stand shows steady state in case of productivity, structure and population. In this condition, community shows maximum diversity and homogeneous distribution of species. Each community is self-maintaining and stable. This stand persists for a long time with a little or without any change. Any change may occur within the population. It may be the replacement of micro community. But it may be phasic cycle and such changes cannot change the community. This stability is also indicated by maximum biodiversity and many growth forms. If any stand is in this condition, the ecosystem shows minimum competition and maximum production. Species show integral association in place of competition. That's why, species composition cannot be easily changed.

Ecological Perturbations

If the ecosystem is maintaining constant stage, and any such change is taking place in the ecosystem that cannot be resisted by the ecosystem, and it initiates the instability of the ecosystem, then the mechanism is known as perturbation. Perturbation is controlled mainly by two factors:

Natural Factors

It is well known that in the nature continuous changes occur. That's why, no ecosystem or community can resist the changes for a long time, and ultimately the species start disappearing, which creates change in the floristic composition. Only a single change in the ecosystem can initiate the series of chain reaction. It means if the floristic composition is changed, then edaphic factors change. The replacement of species can change the climate and ultimately, new community gets established, like, origin of terrestrial plants from aquatic plants; and bryophytes had been replaced by Pteridophytes. Later on, Pteridophytes have been replaced by gymnosperms. Again, due to change in the temperature, gymnosperms

have been grown in the limited area and the expansion of the angiosperms occurred. All these changes are the natural changes. Sudden changes are also caused in the ecosystem due to earthquakes and volcanoes, like, during the carboniferous period, so many forests became underground due to earthquakes and volcanoes, which was the great period for carbon deposition.

Anthropogenic Factors

As we have seen that the changes are initiated by nature, but the rate of natural changes are very slow, while the changes initiated by humans and animals indicate higher rate and the ecosystem gets disturbed rapidly, like- at present time, man is continuously destroying forest vegetation due to the following reasons:

i. Requirement of land for colonization.
ii. Requirement of land for industrialization.
iii. Requirement of land for agriculture.
iv. Requirement of land for dams, roads and railway lines.
v. Use of trees as fuel plants.
vi. Use of trees in building construction.
vii. Use of wood as furniture.
viii. To fulfill the demand of overpopulation.
ix. Rapid rate of pollution that can destroy the sensitive species.
x. Removal of nutrients from ecosystem.
xi. Addition of pollutants in the ecosystem.

Beyond these, overgrazing and irregular grazing are also the major problems, which are leading to the destruction of ecosystem. These all factors are known as anthropogenic factors, and the ecosystem cannot resist these fast changes. That's why; one by one species disappear from the nature. It is clear that species shows interdependence nature. So, if one species gets disappeared, then it shows the weak association. Parallel to it, the resistance mechanism of ecosystem gets weakened. With decreasing resistance, the rate of change automatically gets increased. If the changes are going fast, then the ecosystem cannot be recovered. So, resilence mechanism becomes useless. It leads to the sterility of the ecosystem and slowly it causes desertification. Now days, this process is fast, which is affecting the floristic composition, climate and edaphic factors.

Ecology of Plant Invasion

Invasion in the ecosystem is a common phenomenon. Many species invade the area because they are better adopted to the changing climate, it is known as invasion. Generally, it is harmful to species. These are non-native plants. It shows an increasing threat to the composition and structure of natural communities across the globe. Biological invasions are considered to be one of the major threats to the earth's biodiversity. Non-native woody species, introduced by humans, can spread into native forests, pastures, or cultivated areas. Such species are termed, "invasive". Many animals and plants are highly invasive and some species dramatically affect the structure and function of ecosystems.

Introduction is Initiation of Invasion

Nearly all the introductions of woody plants which have become invasive, have been introduced intentionally by horticulturists, botanists, foresters or gardeners. Some examples of introduction changed into invasion are as follows:

1. A number of species introduced to tropical botanical gardens have become invasive.
2. During the 1980s it was realized that a number of introduced trees were spreading in the logged and natural forests of the East Usambaras in Tanzania.
3. Due to its prolific natural regeneration, Leucaena leucocephala, is generally considered to be a weed, yet it was planted mainly as a fodder crop, in the Karnataka region of India in early 1980. Within ten years, the species had become a problematic weed in cultivated land.

Invasive Tendencies and Species Biology

Although most introduced species do not become invasive, it has been estimated that about 1% of introduced species do become invasive (e.g. Groves 1986). It has now been realized that biological invasions may become a serious and ever-increasing problem in some continental regions. Below a number of reasons are given for invasive species to become increasingly problematical:

1. Large gaps created by logging operations appear to be more readily invaded by exotics than natural tree fall gaps.
2. If climate changes, many areas of natural vegetation are isolated and species will fail to move to other islands.
3. The conservation of biodiversity becomes increasingly significant in disturbed areas as areas of natural or semi-natural vegetation steadily decrease.

4. Susceptibility of natural areas to invasions is higher if a large seed source is available around it. The smaller the area of natural vegetation, the more likely it is to be invaded.

Detection of Invasion

The following points are essential in detecting the early stages in an invasion:

1. Awareness that the species is a problem in another region where climatic and environmental factors are similar.
2. First-hand knowledge in identifying and recognizing the species in the wild is essential.
3. Active governmental or voluntary organization in the field of plant invasions is necessary to provide background response.

Conclusion

Thus, we can conclude from the above discussion that invasion is harmful to ecosystem. So it must be controlled by all the possible ways.

Environmental Impact Assessment (EIA)

The former study done by experts before beginning the major projects, which indicates or predicts the effect of project on environment, is known as "EIA" (Environmental Impact Assessment). The projects may be construction of dams, railway lines, roads and factories. Mainly, EIA concentrates on problems, resources required for projects and the by-products of the project. It shows harmful impacts of project on flora, fauna, climate and living standard. When once the problem is identified, then such techniques are discovered, which can minimize the harmful effects of projects on environment. It is also helpful for decision-making, because the authorities permit the project when it does not show harmful effects.

Aims of EIA

EIA is having the following aims:

1. It indicates the suitability of the project with the environment.
2. It shows the budget and time required for launching the project.
3. It shows the techniques through which the local environment can be conserved.
4. It shows benefits without causing problems.

EIA as Management Tool

EIA is a tool for the officers, managers and decision makers. They can study the impact of project on the environment as well as the benefits, budgets and the time needed for the project launching. Actually, now days, industrialization is very fast and it is causing serious problem for the environment. Many times, environmental cost is not included in the project. So after launching the project, if environmental cost is imposed, then products become costly, which affects profitability. That's why, EIA is a tool that indicates initial cost. It provides the answers for following questions:

1. Can it be operated safely without any serious risk?
2. Can the local environment adjust itself with additional wastage and pollution?
3. Will its location affect the agricultural land or colonial land?
4. How will it affect the local small-scale industries?
5. Is there available a suitable infrastructure for the project?
6. How much water, energy and other resources will be conserved by the project?
7. What human resources will it require or replace, and what social effects may this have on the community?
8. What damage it may cause to national assets?

Who is Involved in EIA Process?

In the EIA committee, all responsible authorities should be included, which are as follows:

1. Project developer, which is a private company because he must know about the site of the project and how can he minimize the adverse impact on the environment.
2. Investor, because he provides money for the project, so he must know the viability of the project.
3. Representative from the government organization: These are the members of decision-making committee. So, the EIA will help them to take the suitable decision.
4. Public representatives: These are local citizens and they must know that how their life is going to be affected due to this project.
5. Regulators: They must know that the environmental aspects are acceptable or not.

6. Regional planner: He must know that how the impacts will affect the further developments.
7. Politicians: They must know that who and how will he be affected.

Integration of EIA with Project

Now days, Governments are aware with the harmful effects of the project, because without knowing the impacts of project that it is launched, it may create serious problems, like- "Narmda Valley Project". Although, it is regulated by many environmental laws, but EIA is also legal requirement for the major project. So, when anybody is going to launch any project, then first of all, EIA report should be prepared. Many private agencies are involved for the preparation of such reports. EIA is a practical management tool, which is useful in day-to-day decisions.

EIA Management Principles

There are following principles for the EIA management:

Focus on Main Issues

EIA should be concentrated only for impacts on the environment, otherwise report becomes complex and it can confuse the decision-makers.

Involvement of Appropriate Persons

If we involve non-essential persons in the EIA committee, then it will be the wastage of time and money. So, basically, three types of participants should be involved-

a. Person who is managing the EIA process and expert of assessment.
b. Those persons, who are related with ideas, finance, designs and policies.
c. Authorities that permit and control the project.

Link Information

The informations are needed for decision-making and these are following informations-

a. Impacts of the project launching on environment and techniques for minimizing the harmful impacts.
b. The process through which the projects are synthesized.

c. Developer and investor must know the viability of the project and they must know the problems during processing.

d. When engineers create the designs, EIA will provide the standards for designs.

e. The EIA report can be published for the information of local residents.

Options for Mitigation of Impacts

It is based on the following points:

a. Pollution control technology

b. Reduction, treatment and disposal of wastage

c. Compensation to affected group

d. Several alternate sites

e. Change in the project design and processing

f. Programs for the positive use of local resources.

Presentation of Information

Information should be presented in a form, which is helpful for decision makers. Format should be meaningful, like, hard facts and predictions should be presented because it gives reliability to the report and report should be given in a suitable terminology, which is used by the decision makers. All the information should have the documentary proof.

The EIA Process

If the project is small and we are not producing such products that are harmful for the environment, then it doesn't need the EIA. The EIA is preliminary and screening type. Screening is the first type of EIA. For screening, the projects are compared with the standard list, like, if we are going to manage a coalmine, then we must prepare the EIA. But if we cannot screen the project for EIA, then preliminary assessment is carried out. During this assessment, if no any harm is indicated, then EIA is not necessary. If on the basis of preliminary assessment, authorities explain that complete EIA is needed, then EIA should be prepared. An organization is made for EIA, which includes planner, developer, experts, financer, researchers and decision makers. It is based on the following points:

EIA Study

It is carried out for getting the answers of five questions;

a. What will happen as a result of project?

b. What will be the degree of changes?

c. Do the changes affect environment?

d. What can be done about them?

e. How will we show the decision makers that the impacts can be minimized?

Identification

For the answer of the 1st question, preliminary assessment is carried out. For this, different parameters are considered, as- air quality, noise level, wildlife habitats, species diversity, social and cultural systems, employment level, then all the impacts are summarized, like- air and water pollution, jobs provided to local persons, improvement in the living standards. It means that positive and negative aspects are considered.

Prediction

When preliminary assessment is carried out, then we find out the answer of the 2nd question and prediction is carried out for knowing the extent of changes. Mainly, toxic gases, emissions and toxic liquid effluents should be considered because it can affect the biosocio-economics of the local residents.

Evaluation

It shows the answer for the 3rd question, which shows that the changes will affect the local life or not.

Mitigation

If the answer of 3rd question is yes, then EIA proceeds to the answer of the 4th question that is- "What can be done about them?" For this purpose, such technologies should be used, which can mitigate the harmful impacts. For this purpose, we can change the project site, process and raw materials, and introduction of pollution control technology.

Documentation

It provides the answer for 5th question. The proper documents should be prepared for decision makers, in which it should be indicated that what type of problems will be created and how can it be solved?

Using the Results

Decision makers can use all the results that are indicated by EIA report. Planners and designers can use it. It is used for reducing the conflictions and pollution and it can be used in the day-to-day processing.

Resources Needed for EIA

Following resources are needed for EIA:

a. Qualified multidisciplinary staff
b. Technical guidelines
c. Information about environment
d. Laboratory facilities
e. Administrative resources
f. Institutional arrangements
g. Monitoring and enforcement powers.

Ecosystem Restoration

In 1935, the workers of Civilian Conservation Corporation started replacing the tall grass on the farmland, which was present in 24 hectares. Now, it has become such a center through which drought and economic problem has been solved. It has been called as beginning of Restoration Ecology. Ecological restoration can be defined as follows:

" Ecological Restoration is a way of balancing and renewing the ecosystem."

The time taken in the restoration of any ecosystem depends on the type of vegetation. It is maintained for many years by tree plantation. But for proper reforestation, it is necessary to know the nature of the ecosystem.

Goals of Ecosystem Restoration

1. Its main aim is to maintain the ecosystem and to balance the degraded ecosystem, in which co-ordination among biodiversity, functional integrity, physical environment; habitats, periodic stress and landscape must be maintained.
2. To maintain the balance between the natural and developed forest by ecological restoration, by which sources can be obtained in lesser cost, like- water conservation, controlling of flood water, separation of particulates from air, to increase the amount of fertile soil, to control soil erosion, germplasm conservation. Along with these, some others are nutrient transformation, pollutants control, and conservation of endangered species.
3. In ecological restoration, natural regeneration is increased. It also increases regeneration in degraded ecosystem. Hence, ecological restoration is a kind of adaptive management.
4. Restoration provides the facilities for the plant regeneration.
5. Different stresses, like- pollutants, drought, salt etc. can be managed by Ecological Restoration.
6. The aim of restoration is to show the positive relationship among nature and culture also, because if man himself will be involved in restoration process, then only he will stop the destruction.
7. Ecosystem restoration is concerned with environmental ethics.
8. Ecosystem restoration forms the diverse and functional ecosystem.
9. It protects the ecosystem from natural disasters, like- fire, storms and flood.

Mechanism of Forest Restoration

Many hypotheses are related with forest structure, dynamics and functions, which are as follows:

Some Typical Stages are not Essential

Classical succession theory shows that forest changes take place in a definite range. These changes take place in plants, animals and microbes, and abiotic factors, because of which one community gets replaced by another community. In a definite time, change in the competition and physical structure takes place, which shows succession. Under natural conditions, succession takes place slowly. Hence, in ecological restoration, such plants are

prepared that increase the rate of succession. Active restoration brings out the change very fast, due to which climax stage is reached earlier, like- in forest ecosystem, many plants have been prepared and on the basis of trial and error, suitable part is selected. Some species act as pioneer species in the community and these show site characters. Plants are prepared in such a way that competition among the plants must be low and positive relationship must get increased. Although the direction of change is not determined by experiments, but some species can show the direction of change, like, Sasafras and Diospyros show early succession. Hence, it has been shown that Sassafras and Diospyros are necessary species of community development. But its economic value is less. Hence, if pines are grown in its place, then hardwood successional species will be obtained. Hence, the best way to have the hardwood is to establish the pines as the early successional species. From artificial plantation, successional species will also be affected, as from Sasafras and Diospyros, oak community develops, while pine Sasafras and oak replace community. Carman obtained the following results after doing plantation in four regions:

1. Black locust plantation field was cleared by clear cutting
2. Clear cutting of Andropogan and solidago plantation was done.
3. Plots having pine plantation were clear-cut.
4. Plantation having Sasafras and Diospyros was cleared.

When in these clear-cut plots, plantation of Juglans nigra and Tulip trees was done. Then, on the 1st plot, highest growth was seen and on 2nd plot, lowest growth had been seen. On 3rd and 4th plot, medium growth had been seen. In Pine clear-cut plot, Red Oak growth had been seen more, while in other regions, less growth had been seen. This growth depends on soil nitrogen, soil pore volume, bulk density, organic matter content, mycorrhiza, phosphorous fertilizer, allopathic compounds released by Andropogan and Sasafras. If late successional species are directly entered onto the open and disturbed type, then these do not grow, because of unfavourable conditions for species. But on bare land coalmines, hardwood plants have been successfully planted. Some late successional species, like-White Oak has been successfully planted on the bare land. It has also been observed that if mixed plantation is done, then species get easily established. Two factors are very much important for the plant growth and they are- plantation of seedling and porous fertile soil.

Forest Require Minimum Components and Area

Four criteria have been adopted for knowing the forest types, which are- Physiognomy, floristic composition, ecological structure and habitat relations. Nitrogen-fixing bacteria, Actinomycetes and mycorrhiza play an important role in the community. Even if any one or two components get disappeared from the forest, then normal forest functions get affected. Hence, for proper development of forest, suitable number of microbes is necessary.

Stress on ecosystem gets increased on missing of the component and forest damage has been seen.

Many experiments have also been done for this, as- When and how new species reaches in the forest. It has also been seen that species occurring naturally get distributed very fast, while artificial species have a limited distribution, because here the main problem is of dispersal agents, as in Visconsin University, distribution of Singuinaria could not become possible because specific species of ants were absent. Hence, it is clear that only one factor can also inhibit restoration. Hence, for any ecosystem restoration, important components must be known. If these components are made available, then the rate of restoration can be increased. The number of strata can also affect ecological restoration. In a bare land, no strata is there. In different areas, ecological restoration depends on seed dispersal, pollination and other factors.

Factors in Development of Forests

It has been observed that oak plantation gets established on the coalmine surface, but it is not successful at other places, because on coalmines, it has no competition with herbs, while on other places, due to competition with herbs, these are not successful. Dense herbaceous cover inhibits the growth of oak. Hence, for forest development, along with seed dispersal, competition and predation are also important factors.

Stress and Environmental Changes

Old forests developed in different environment. Upland habitats have now been changed into xeric, while down land surfaces show sedimentation. Flood chances also get increased there. Soil type gets changed due to erosion and hydrological cycle shows differentiation. These environmental changes affect forest type. Even small change in the environment affects the community to a extent; as- tree species are sensitive to nutrient cycle, acidity, salinity, rainfall etc. Hence, for ecological restoration, proper research should be done on stresses and environmental changes.

Depletion of Genetic Resources

When continuity of plant growth remains maintained, then gene pools also remain in a much larger amount. But gene pools get disturbed due to forest cutting and destruction. For the testing of genetic potential, plants from different habitats and geographical localities are taken. Many species show high genetic variability. Genetic crisis has been observed due to hybridization.

Exotic Species

In old forest, older plants get destroyed and new exotic species are seen. Aggressive shrubs play an important role in the forest development. Hence, it is necessary to include new exotic species in restoration, because it shows the steps for the future.

Ecological Management

Concepts

Ecosystem is the group of biotic and abiotic factors, where factors are functionally related. These factors indicate the changes during succession, but after climax, ecosystem attains the stability. So in the early period, ecosystem development was considered. As the population is increased, pressure is exerted on the natural resources and the new techniques are given for population management. Later it has been seen that increasing population is affecting ecosystem in a negative way and the retrogressive changes are taking place in the ecosystem. So many factors are responsible for that, like- drainage system, nutrient supply in the aquatic ecosystem, increasing air and water pollution, acid rains, entry of UV rays that are responsible for the retrogression of the ecosystem. Malthus proposed that the rate of population growth is very high as compared to food supply. So, population' term has been proposed that means population + pollution and it is related with the ecosystem degeneration. That's why now this approach has been shifted from population management to the ecosystem management. So the management practices through which ecosystem can be managed at present status is known as "Ecosystem Management". It means for the management of ecosystem, following aspects are important:

1. Ecosystem is the complex community. So, we must have the knowledge of different components of ecosystem.
2. It must be found out that which factors are responsible for degradation of ecosystem.
3. Such techniques must be developed that can neutralize the impact of degradation factors on ecosystem.
4. Such arrangements should be done that can maintain the original status of ecosystem in the future.

Actually, living space is the functional unit and ecosystem is the supply depot. So, the mutual relationship must be established between ecosystem and living space, and man should be ready to apply the ecological principle. The ecological principle is "quality in control of quantity is the basis of biological evolution". But any type of protection indicates

quantitative expansion in place of quality and it is true in the case of human population. Now in man, quantitative expansion of knowledge, power and productivity is increasing without any control system and it is leading to the anomalous situation.

According to Hutchinson, "the biosphere should be repaired by man as the repairing of car and radio is done". While according to White, "the concept of unlimited exploitation must be changed".

According to Ehrlich, "population bomb is more explosive than hydrogen or atom bomb".

Garett and Hardin proposed a principle "Tragedy of Commons". According to him, " if the ecosystem is being used by everybody without any barrier, then the individual gain is a temporary gain but damage of ecosystem is a permanent loss". According to Boulder and Wager, technology alone cannot solve the population and pollution dilemma. The moral, economic and legal barrier with complete public awareness is an important aspect for conservation" That's why, future applied ecology is based on the ecosystem management. Another important factor is educational program which is of two types:

1. Field training programs
2. University degree program.

In these programs, 2nd program is harmful for long run bases. So, for the better management of ecosystem, special programs for applied ecology should be run, and the training of students should be carried out in open system. Students should be guided for adopting the specific branch of ecology, which can behave like good ecological managers. Now days, different aspects are interconnected, like- conservation ecology, natural resource management, ecological restoration science, pollution control, remote- sensing and the most advanced aspect- sustainable development.

Sustainable Development

Basic Concepts

Brundlendt proposed concept of sustainable development in 1987. He proposed better solutions for ecological management. According to him, direction of development should be in such a way that without disturbing the nature or ecology, development must be continued and human beings must get better life. The better direction of development is that in which we can transfer the natural assets to the next generation in the similar stage as we got it from our past generation. Such a development is known as Sustainable Development. Thus, Sustainable Development is "meeting the needs of today without reducing the quality of life for future generations."

It includes scientists, environmentalists, politicians and society, because nature cannot be maintained by the effort of a single person. Moreover, without sacrificing with our needs, we can conserve the nature. It is based on the following points:

1. Development: It is two types: quantitative or qualitative. Quantitative development indicates expansion irregularly, while qualitative development is based on natural principles, which favor the nature. Regeneration capacity of the earth is so high but we are using less and destroying more, like we are having huge amount of water, but all of it is not available to man which is due to lack of sustainability.
2. Needs: It is necessary to identify the basic needs, because a few rich persons are destroying the nature for managing their living standard and poor people are the sufferers. It means that our interpretation for the needs is wrong. That's why proper redistribution of resources among the people is necessary, because inequality in the society leads to irregular development. So it is a major barrier for sustainable development.
3. Future generations: It is our moral duty to provide better environment to the future generations. It doesn't mean that we cannot use the resources. Actually if the use of resources is our right, then the regeneration of resources is our duty. So if we are using our right, we must fulfill our duty.

Goals of Sustainable Development

Five major goals have been proposed for sustainable development-

i. Resource conservation: Conservation of natural resources shows that if we are using the resources, then we must maintain the purity of the resources.

ii. Built development: Direction of the development must be constructive. It means development should be parallel to the nature, which will not disturb the nature.

iii. Environmental quality: Such developments must be avoided which degrade or pollute the environment. Only such developments should be adopted that initiate regeneration of ecosystem.

iv. Social equality: Such developments should be avoided which will promote the difference among rich and poor people, because sustainable development means to induce equality in the society.

v. Political participation: It is well known that the decision authorities are politicians. So, if environmentalists or society provides any recommendation, then we must involve the politicians, otherwise the decisions will be useless.

Assumptions and Trends

The sustainable development is based on strategies, policies and methods. So we must assume the needs of future and policies should be decided according to the needs. To fulfill these needs, particular methods must be adopted. The imagination and forecasting are also important. If the present trends are constructive, then we must follow it, otherwise it should be changed.

Present Conflicts and Future Priorities

Environment degradation is important for rich persons as well as for poor persons. But if the poor are not getting the food, space and energy source, then they will destroy the nature for getting these things because their priority is to get the food. So the present confliction is that rich community is trying to maintain the nature because they are having the other sources for fulfilling the needs, but poor people are destroying the nature, as they are having no alternative. It is the fact that survival is the priority. So without fulfilling the needs of poor, we cannot achieve the target of sustainable development. That's why our future priority must be to enhance the living standard of poor.

General Principles for Sustainable Development

Ten general principles have been proposed for maintaining sustainable development-

1. Fundamental change in attitude: Sustainable development is mainly based on essential needs, but many times non- essential facilities are assumed as essential needs. So we must change the attitude. For this purpose, following means can be adopted:
   a. Environmental census and projections
   b. Monitoring targets
   c. An integrated education and publicity policy
   d. Publishing and rewarding major achievements
2. Facilitating innovation and replicating best practices: At present time, many trends are quite good which protect the nature. But these practices are not common. So the expansion of such practices will be beneficial for the environment. For this purpose, supportive programs must be launched, like- to provide the financial aid for energy-saving technologies, penalties for damaging the environment, funding for innovative research.

3. Sustainability indices: The minimum criteria should be fixed for sustainable development and target should be set for improving the environment. Such agencies should be involved which can provide positive decisions in favor of the environment.

4. Initiation level: Scope of sustainable development is maximized when initiation takes place at all levels. These levels and techniques are as follows:

   a. Community involvement

   b. Decentralization

   c. Positive incentives

   d. Removal of barriers

   e. Creation of policy and administrative framework.

5. Redefining growth in terms of quality of life: It is clear that irregular expansion is known as quantitative growth, but we need qualitative growth which favors the nature as well as living standard.

6. Redefining costs and profitability: Generally in the costs of products, the cost of environment is not included. So the cost of pollution control should be included, then the profitability is calculated.

7. Long-term planning: the nature is degraded much due to short-term planning. So, the long-term planning should be carried out which gives time to natural regeneration.

8. Continuity of policy and framework for decision making: If once the policy is administered, then it must be continued which will indicate the positive growth. Actually many decisions are changed due to political pressures. So if once the decisions are taken on the basis of framework, then it should not be changed.

9. Environmental standard, capacity limits and impact assessment: For the standard limits, national bodies should take the decisions and time to time, decisions should be revised.

10. Finance for long-term planning: Finance is the backbone for any technology. So, if once the decisions are implemented, finance should not be the barrier. Hence, before the implementation, finance should be available.

Sustainability Indicators

When the excessive use of natural resources is carried out, then it starts degradation. It can change the flora and fauna of the ecosystem. So any type of change in the ecosystem will

indicate the change in sustainability. Thus, those factors that can indicate the progression or retrogression in sustainable development are known as Sustainability Indicators and the main stress is given to the selected characters, which is helpful to maintain the sustainable development. For example, in aquatic ecosystem, the status is oligotrophic. It shows no vegetation in the water, or only phytoplankton can be seen. But if suddenly the excessive growths of higher plants occur, then it shows that water is receiving the minerals from the outer environment. Due to excessive concentration of minerals, the growth rates of plants suddenly increase. Mainly it indicates the sewage disposal or agriculture around the aquatic ecosystem. This condition is known as eutrophication. If we want to maintain the sustainability of such ecosystem, then we must survey the watershed area of the ecosystem, because in the catchment area, if sewage is disposed, then ultimately it will be transferred into the aquatic ecosystem. Even irregular drainage system, leaching up of fertilizers from agricultural fields may cause the problem.

Similarly, in the forest ecosystem, changing vegetational component will show a change in the ecosystem. If the ecosystem is moving towards the complexity, then it shows sustainable development. But if vegetation becomes sparse or smaller plants grow at the place of large trees, then it will indicate retrogression development and in this condition, we must repair the ecosystem.

The other sustainability indicator is soil factor. If soil is rich in organic component or humus, then it will show development of forests. But if the soil is lacking minerals or humus, then it will show retrogression. Similarly, increasing salinity in the soil will lead to the degradation of ecosystem. So in the soil, change in pH, conductivity cation exchange capacity (CEC), salinity, % organic carbon, microbial biomass is the major sustainability indicator.

The climate is also the indicator of sustainability. Constant climatic factors, proper rainfall and no change in temperature will indicate constant nature of ecosystem. But increase in temperature, decrease in rainfall and increase in pollution will indicate the negative development. In such a way, vegetation composition, changes in the soil factors, change in the climatic factors can be used as sustainability indicators.

Review Questions

1. What is Ecological Perturbation?
2. Describe ETA and its aims.
3. What are the Principles of EIA Management?
4. Describe about Ecological Management and factors effecting it.

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