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ENS 501

Environment and Ecology

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Department of Forestry and Environmental Science
School of Earth and Environmental Science

Uttarakhand Open University
Haldwani, Nainital (U.K.)

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Title	:	Environment and Ecology (ENS 501)
ISBN	:	XXXX-XXXX
Copyright	:	Uttarakhand Open University
Edition	:	2023(Restricted Circulation) This is the first copy of the contents subjected to final editing later.
Published By	:	Uttarakhand Open University, Haldwani, Nainital – 263139
Printed at	:	

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Unit 1: Introduction to Environment

Unit Structure

1.0 Learning Objectives

On completion of this unit you should be able to understand

- The need of environmental sciences.
- What is environment, and the need for interdisciplinary approach to study?
- Types of environment.
- Importance of environmental studies

1.1 Introduction

Environmental science is an interdisciplinary subject created by the needs of rapid development of the industrial era. In the last century, especially last decades several serious environmental issues have become a focal point of the scientific community. These are mainly pollution leading to global warming, ozone layer depletion, acid rain; and deforestation leading to water crisis, desertification, global warming: also rapid population growth leading to depletion resources.

Above circumstances require a holistic knowledge about working of our environment supporting life on this planet and thorough understanding the changes causing problems. Since no single existing subject covered the above lacunae in knowledge completely, hence environmental science as a separate subject was required to understand the complex subject and find the solutions.

1.2 Definition

The word environment is derived from the French verb environner, which means to "encircle" or "surround." Thus, our environment can be defined as the physical, chemical and biological world that surrounds us, as well as the complex of social and cultural conditions affecting an individual or community.

Environmental science is defined as an interdisciplinary academic field that integrates various academic fields (particularly sciences) to study the structure and function of our life-supporting environment and to understand causes, effects, and solutions of different types of environmental problems. In other words, environmental science is the scientific study of all the components or factors that make or influence our life-supporting biophysical environment. Environmental sciences involves multiple disciplines, like Biology, Geology, Chemistry, Physics, Engineering, Sociology, Health, Anthropology, Economics, Statistics, Philosophy, Ecology.

In simple terms environmental sciences deals with every issue that affects an organism. Environmental science is methodological study of the environment and includes the study of all biophysical as well as anthropogenic conditions or circumstances under which an organism lives.

Environment, Ecology and Ecosystem: Environment, Ecology and Ecosystem are three different terms. But they are interrelated. And we must understand all of them to understand environment.

Ecology - At the same time we should understand Ecology which is understanding interaction of an organism and its environment.

The term ecology was coined in 1866 by the German scientist Ernst Haeckel.

Ecology is the branch of biological science concerned with the relationships and interactions between living organisms and their physical surroundings or environment.

Ecology comes from the Greek words oikos (house or place where one lives) and logos (study of). Ecology means the study of the "house" in which we live i.e. our immediate surroundings which envelop us and with whom we interact with us on everyday basis.

Ecology can be defined more specifically as the "Study of the interactions between organisms and the non-living components of their environment or "Study of interrelationship between the organism and Environment"

The basic unit of ecology is ecosystem. Living organisms and the environment in which they live and with which they exchange materials and energy combine to make up an ecosystem. An ecosystem comprises of the biotic components – the living plants and animals including all the microbes and the abiotic components – air, water, minerals, soil, temperature, humidity etc. that constitute the environment. Third and essential component of most natural ecosystems is energy, usually starts in the form of sunlight, rarely it may be chemical energy. Common examples of land-based or terrestrial ecosystems include forests, deserts, jungles, meadows and alpine and semi-alpine ecosystems. Water-based or aquatic ecosystems include streams, rivers, lakes, marshes, estuaries and oceanic ecosystems. There are no specific limitations on the size of an ecosystem, and the boundaries are also not well defined in many cases. A small water body can be studied as a separate ecosystem. A desert comprising hundreds of miles or large oceans and even the whole surface of earth can be viewed as an ecosystem.

Structural units of ecology: The basic structural units of ecological organization are species and populations. A biological species are defined as all the organisms potentially able to interbreed under natural conditions and to produce fertile offspring. A population defined as of all the members of a single species occupying a defined geographical area at a particular time. An ecological community is composed of a number of populations that lie and interact within a defined region.

Scientists like to use term natural environment as a better term to use given the common use of the word environment. It is a known fact that the Earth includes a large Environment. Definitely, any organism has a relationship with its environment. Humans have a unique working relationship with domesticated animals like cows, chickens, dogs etc. This study of how the existence and activities of an organism influence its environment and the vice versa is called ecology.

Ecosystem is a large geographical area where both biotic and abiotic components interact with each other. E.g. Desert, Ocean, Sea etc.

Check your progress

1) What is environment?
2) What we study in environmental sciences?
3) What is ecology?

1.3 Types of environment.

Before discussing types of environment we must know what constitutes the environment. Environment is constituted of following elements

1) **Physical elements** like land, sunlight, temperature, air, elevation, latitude, water bodies, climate soils, rocks and minerals. They interact amongst themselves and with biological elements to constitute unique environment at a place.It can be divided into three spheres

   i) The lithosphere (solid earth)

   ii) The hydrosphere (water component)

   iii) The atmosphere (gaseous component)

2) **Biological elements** such as plants, animals, microorganisms and humans constitute the biosphere. They interact amongst themselves and with physical elements. Biological components can be categorized into

   i) Plants (flora)

   ii) Animals (fauna)

3) **Cultural elements** such as economic, social and political elements are essentially man-made features. They are the latest entrants to the environment and affect the system.

As such the types of environment can be decided on the constituents' separately or the unique small spatial units.

Classification on basis of physical elements.

i) Lithospheric Environment

ii) Hydrospheric Environment

iii) Atmospheric Environment

Classification into small spatial systems like

i) Mountain Environment

ii) Glacier Environment

iii) Plateau Environment

iv) Coastal Environment

v) Oceanic environment

From the conceptual point of earth being a unique planet to support life environment can be classified into two broad types:

I) **Essential life-supporting biophysical environment:** It includes all the biophysical entities as well as the processes that contribute to providing all humans and other living beings the basic material needs of life, that is, oxygen, water, food, and habitat. In fact, the concepts of environmental sciences are based on this meaning. The "essential life-supporting biophysical environment" is also termed as "environment", "natural environment", "biophysical environment", "biosphere", or "ecological system".

II) **Non-essential life-assisting environment:** It includes all the entities or processes that assist human life in various ways, but cannot be considered essential for the physical survival of life on this planet. It includes social systems, language, technology, economic system, education, and various aspects of human civilization. Although we can survive physically, without these entities the life will be largely in wild or natural form. "Non-essential life-assisting environment" is also known as "anthropogenic environment", "social environment", "man-made environment", or "built environment".

Classification on basis of life

1) The natural surroundings of an organism, both living and physical are its environment. Physical objects like land and manmade object, light and other forms of energy, water, air etc. which surround us, are our physical environment. It is classified as "abiotic" environment.

2) Humans, other animals, plants and microbes surrounding us comprise our living environment. It is classified as "biotic" environment.

Check your progress

i) What are constituents of environment?

ii) Define types of physical environment?

iii) What is biotic and abiotic environment?

1.4 Importance of environment

The importance of environment studies can be judged with the fact that earth is the only planet known to support life. It is a rare place in known universe with delicate balance of optimum temperature, radiation, atmosphere and water to support life. Also on earth the resources are limited. This applies to all components of environment, coming in stress to the point of crisis due to recent exponential development. Examples are water crisis, energy crisis, agricultural crisis, housing scarcity, and practically scarcity of almost all natural resources.

Also the issue of pollution is important, be it air pollution, water pollution, toxic landfills, noise pollution, etc.

The health issues arising out of pollution and climate change are affecting the majority population of the world. Smog is regularly affecting north India every winter and affecting health of millions of people. We are in constant danger of environmental disasters like Bhopal gas tragedy, Endosulfan tragedy in Kerala, Chernobyl reactor leak, Fukushima reactor leak etc. We yet not able to understand fully the health implications of these disasters many of which occurred several decades back.

The new infectious diseases starting from AIDS epidemic followed by Ebola, MERS, SARS and now ongoing COVID 19 pandemic, are challenging the very existence of mankind. They are also raising serious questions on our unsustainable lifestyles and bringing into focus the perils of rapid globalization. The advances in transportation industry have not only contributed to pollution but also blown local environmental phenomenon into global one. In future environmental sciences may become an integral part of epidemiology for managing heath disasters like the current COVID crisis.

With the advancement in fields of satellite imaging and computations now it has become possible to predict the fickle weather systems within reasonable limits. This has greatly helped aviation, shipping sectors and fishing a lot. It has also helped a lot in managing disasters. At the same time human activities have interfered a lot in weather phenomenon bringing into play new variables into an already uncertain system. Hence environmental sciences are going to play a major role in metrology in future.

The rapid and indiscriminate development in past century has made the study of environment very important for all disciplines. Environmental sciences involves multiple disciplines, like Biology, Geology, Chemistry, Physics, Engineering, Sociology, Health, Anthropology, Economics, Statistics, Philosophy, Ecology. The importance of environmental sciences is for all of them.

The objectives of environmental sciences are

1. Comprehensive knowledge of environmental issues and how they affect us and what is our role in them.
2. Understanding pollution and its implications. To create a pollution-free environment (that is, clean air, water, land, and food) by adopting different methods of preventing and controlling pollution.
3. Optimal utilization and conservation of our natural resources such as water, forest, minerals, and fossil fuels. Reducing wastage and recycling.
4. Adopting eco-friendly lifestyles by knowing environmental implications of one's activities, preventing and controlling pollution, and utilizing the resources efficiently and minimizing wastages.
5. Encouraging eco-friendly industries by adopting clean and efficient technologies and installing pollution control systems.
6. Solving critical global environmental issues like global warming, climate change, ozone-layer depletion, desertification, and energy crisis by using interdisciplinary knowledge and approach.
7. Sustainable developments by ensuring equal distribution of natural resources in all classes and conserve the natural resources for future generations, as well as by conserving delicate nature in every way possible.

The importance of the subject can be summed in three burning issues:

1. **International importance of environmental issues especially pollution:** environment issues like global warming and ozone depletion, acid rain, marine pollution and biodiversity must be tackled with international efforts and cooperation. These cannot be solved by the efforts of single society region or nation.
2. **Problems due to unsustainable development:** Recent uncontrolled development, led to Rapid unplanned Urbanization, Unregulated Industrial Growth, Clogged Transportation Systems, Unsustainable Agriculture and Housing problems for masses etc. Developed world has phased out these issues locally. However to cleanse their own environment they managed to move the 'dirty' factories to developing nations. Rapid skewed unequal growth is an enormous issue for the developing nations and is also affecting developed world to some extent.
3. **Explosively increase in population:** In the developing world especially India population explosion is biggest issue. India with 16 per cent of the world's population and only 2.4 per cent of land area exerts a very heavy pressure on the natural resources including land and scarce water. Agricultural experts have recognized soil health problems like deficiency of micronutrients and organic matter, soil salinity and damage of soil structure. Water crisis is a major issue not only in India but many developed nations as well.

Future avenues

- Disaster management.
- Assessment of impact on epidemiology of both infectious and non-infectious diseases.
- Occupational health.
- Assessment of environmental changes in weather.

We should understand that development of environmental science is still in nascent phase and applications both academic and practical shall be far greater than what we currently use it for.

More than any discipline environmental studies has a major role of public awareness. That's why it has become subject right from pre-school up to university. People have to be made aware of changes around them. How the environmental changes affect their lives? How their actions are contributing to the disastrous changes in environment? What is the cost of inaction? How they can contribute in improving environment? Ultimately only collective action of whole mankind can only stop the downward spiral of changes occurring to our environment. And nobody can escape the ill effects of this biggest man-made disaster.

Governments across the world are now focusing on this issue more seriously than ever. Indian government has a separate ministry for Environment and separate green tribunal for the same. Both are contributing in not only direct efforts to conserve environment but government is taking numerous steps to educate public about the environmental pollution and resource crisis. State governments are also acting vigorously in this field.

Intergovernmental panels like United Nations Environment Programme (UNEP) and IPCC are co-coordinating between all nations on this sensitive issue.

Check your progress

1) What are objectives of studying environmental sciences?

2) Mention the important issues in environmental sciences.

1.5. Scope of Environmental Sciences

Environmental sciences knowledge is of tremendous use in most of the areas of development. These areas are studied as scope of the subject. Environmental science has a vast scope since it covers a wide range of subject matters or issues related to our complex life-supporting systems. The areas of applicability define the career opportunities related to the subject.

Major areas of applicability of the subject are

1) management of natural resources, water crisis, energy crisis,
2) conservation of ecosystem and biodiversity, desertification
3) prevention and control of pollution, including climate change, ozone layer depletion
4) managing development in terms of population, urbanization, health

In last few decades, environmental science is considered important for many economic activities. This has given rise to job opportunities in this field.

Major career options related to the subject are as follows:

I. **Industries:** Industries need to comply with numerous environmental norms. Hence, environment experts are required to guide the industries for controlling pollution, adopting clean technologies, proper waste disposal, and carrying out environmental audit. CPCB and norms of green tribunal and other legal bodies and authorities are being implemented vigorously in industries and they need experts for the same.

II. **Consultancy:** Environment consultancies are hired by various government bodies, industries, advocacy and rights groups and NGOs for carrying out different types of field-based studies, laboratory based analyses or, population studies; which are often required in environment impact assessment (EIA) and other compliance processes. Environment is becoming important issue for litigation and all parties need help for the same.

III. **Research and development (R&D):** R&D opportunities in this area include studying pollution in detail and its implication on environment and humans. Various governments industries and NGOs bodies are supporting the research in this field as it is the biggest issue of this millennium. Enormous funding is also being done for the development of clean and efficient technologies for future.

IV. **Academics:** Environmental science is taught at every level of education, from school to university level. A large number of teachers or academicians are required for this purpose. Environmental studies are now being focused right from primary education.

V. **Green marketing:** Environmental quality certifications like ISO-14000 are also being incorporated in marketing strategy—this creates many career opportunities. Many eco-friendly products are being promoted in market, experts are reuired to create awareness in public about them.

VI. **Media:** Mainstream print and electronic media requires experts to report and analyze environmental issues to generate awareness about the environment, hence there is an immense need for skilled manpower in this field. Deicated green media have come up in form of magazines and newspapers, who regularly publish articles on environmental theme, for example, Down to Earth, a magazine published by Centre for Science and Environment.

VII. **Green advocacy:** Environmental lawyers are emerging as major players in ensuring proper implementation of environmental norms, laws, and programmes. Public Interest Litigation (PIL) empowers a common man to fight against any anti-environment activity.

VIII. **NGOs:** These days, most of the environmental programmes are being implemented through NGOs, with the help of funds from national and international agencies. Green-peace, IPCC, WWF, CSE, CEE, TERI, Tarun Bharat Sangh, and Vatavaran are some examples of environmental NGOs. Uttarakhand has many environmental groups like Uttarkhandsewanidhi (USKN), CHIYA etc. Uttarakhand is home to historic Chipkoandolan in pre- independence era.

IX. **Government jobs:** A number of conventional jobs are available in government bodies such as environmental ministry, pollution control boards, national parks, and biosphere reserves.

X. **International agencies:** Various international agencies such as UNEP, IUCN, TSBF, and World Bank require qualified human resources to implement environment-related projects.

XI. **Environmentalism:** Though not a direct employment scope but environmentalism is much bigger movement across world to conserve our planet, its wildlife, natural resources. It is addressing the major issues affecting people like pesticide use, air pollution, water pollution, solid waste disposal, water crisis, energy crisis, radiation and other environmental crisis. There is a constant pressure by environmentalists on all major governments and international forums to act now on this issue. They have achieved major success in form of Davos summit resolutions, etc to bring a consensus on environmental action. But a lot is still required to bring the change required for life to continue on this planet.

We must understand that we not only studying environmental sciences for just a career or academics; but for larger issues pertaining to our health and for the very sake of survival of future generations.

XII. **Environmental ethics:** In the era of rapid development and to provide a better lifestyle for masses, several ethical questions arise when there is always an environmental cost to pay. We all are aware that environment has to be protected, but at the same time there are harsh social, economic and political realities. We have to provide food, water, housing and basic infrastructure to masses. A minimum quality of life has to be provided to the citizens by a responsible social government. Hence ethical issues arise and have to be addressed each time. We have to develop constantly, with due concern to climate change, preserving biodiversity, reducing pollution. There are multiple unanswered questions, which we have to address in almost every public infrastructure project as regards to environment. Fortunately in India we are establishing bodies/authorities to answer the same.

Check your progress

1) What are the areas of application of environmental sciences?
2) What are career avenues in field of environmental sciences?
3) What is environmentalism?

1.6. Summary

In this unit you have learnt that we need require a holistic knowledge about working of our environment supporting life on this planet and thorough understanding the changes causing problems. We need the knowledge to answer several serious environmental issues have become a focal point of the scientific community. These are mainly pollution leading to global warming, ozone layer depletion, acid rain; and deforestation leading to water crisis, desertification, global warming: also rapid population growth leading to depletion resources.

Environment is the physical, chemical and biological world that surrounds us, as well as the complex of social and cultural conditions affecting an individual or community. We have also learnt that we can study this interdisciplinary academic

field by integrating various academic fields (particularly sciences) to study the structure and function of our life-supporting environment and to understand causes, effects, and solutions of different environmental problems.

We have learnt about Environment, Ecology and Ecosystem and their co-relation. Ecology is the branch of biological science concerned with the relationships and interactions between living organisms and their physical surroundings or environment.

We have classified environment physical elements, and more importantly as biotic and abiotic environment. We learnt that environment can be classified as local systems. For the purpose practicality the most important classification is "essential life-supporting biophysical environment" and "non-essential life-assisting environment".

Understanding environment is important for supporting life on earth. We have to understand and find solutions for the problems of pollution, resource crisis and population growth. The drastic climate change needs to be addressed to sustain life on this planet. Only public awareness and action with state and international support can solve the serious environmental issues we are facing.

The scope is unlimited not only in career options like Academics, industries, research and development, media, NGOs, marketing, government and international jobs; but more importantly in making public aware about the rapid environmental changes. Only by proactive environmentalism we can save our environment to protect our health and life of our future generations. Environmental ethical questions need to be answered in development projects related to needs of masses.

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GLOSSARY

Abiotic factors - Physical Objects like land and manmade object, light and other forms of energy, water, air etc. which surround us, and the elements/compounds found in them.

Atmosphere – Gaseous envelope around the earth, the air. It has many gases out which N2, O2, CO2 and water vapour are most important.

Biosphere – All parts of earth where the living organisms live.

Biotic factors – Living organisms in environment or ecosystem, like animals including humans, plants and microbes.

Demography – Study of populations.

Desertification – The process of desert formation, it is manifested by permanent loss of plant cover in a region, and the loss of capacity of the land to support plant growth.

Ecology – It is the branch of biological science concerned with the relationships and interactions between living organisms and their physical surroundings or environment.

Ecosystem – Entity arising out of functional interaction of biotic components with abiotic components of environment.

Environment - The physical, chemical and biological world that surrounds us, as well as the complex of social and cultural conditions affecting an individual or community.

Epidemic – Large sudden outbreak of a infectious disease in a community.

Epidemiology – The branch of medicine which deals with the incidence, distribution, and possible control of diseases and other factors relating to health.

Fauna – The collective term for all animals in a given ecosystem or environment.

Flora - The collective term for all plants in a given ecosystem or environment.

Hydrosphere – The portion of earth having water in liquid or solid form.

Lithosphere – Solid rocky crust of earth.

Metrology - Study of measurement, or study of weather.

Pollution – Man made unfavorable changes in the natural environment which are harmful to the life on earth.

Organism – The primary unit of life, any form unicellular or multicellular which can survive and reproduce.

Unit 2: The Earth's Environment

Unit Structure

2.0 Learning Objectives

After going through this unit, you will be able to

- Define Earth's environment
- Know about different components of environment
- Come across the various human activities affecting environment
- Get aware about human impacts on the environment

2.1 Introduction

In previous unit you have studied about the general concept of environment and its types. Now you know that everything that surrounds us is referred as environment and it is a kind of life supporting system.Environment embraces all living and non-living things that interact with each other. Any sort of manipulation in both living and non-living components creates a huge imbalance in earth system that leads to survival risk of living organisms.

In this unit we will discuss about Earth’s Environment and its various components i.e biotic and abiotic components in detail. Through this you will understand the nature, structure and composition of living and non-living factors of the environment. We will also study about the ongoing various human activities in this Mother Nature that means over exploitation of ecosystem services and theirconsequences.

2.2 The Earth’s Environment

The Earth environment is highly complex and dynamic in nature that comprises several systemsinteracting with each other. The Earth’s environment has constantly changed since its formation approx. around 4.5 billion years ago. It includesabiotic (non-living) and biotic (living) components. Abiotic components include atmosphere, hydrosphere and lithosphere whereas plants, animals and microorganisms come under biotic environment. The atmosphere of the Earth acts as an envelope and keeps its environment warm and its ozone layer protects the organisms from harmful UV- radiations. The hydrosphere is the rich source of water essential for survival of living organisms. And the lithosphere is rich in minerals and nutrients essential for the growth of plants which releases oxygen essential for the survival of living forms. So, all this interaction makes the earth’s environment a perfect place in the whole universe. The optimum distance of the earth from the sun creates a unique favourable environment where temperature is neither very hot as in planet Venus or Mercury nor very cold as in Jupiter and other planets of the solar system that are far away from sun. But the balance between these components of the environment is now disturbed by human or anthropogenic activities.

The environment of the Earth can be better understood by knowing its components and their ways of interaction that makes environmental conditions favourable for the survival of living organisms. Firstly, we go through the components of environment.

2.3 Components

Environment means the surrounding of an object or an organism. It is the sum total of all the factors and conditions that play important role in the survival of an organism. The environment consists of two main components (Fig. 2.1): abiotic (non-living) and biotic (living).

2.3.1 Abiotic Components

The abiotic components of Earth's environment comprise of:

(a) Atmosphere

(b) Lithosphere

(c) Hydrosphere

Living organisms of earth require inorganic metabolites from above mentioned three

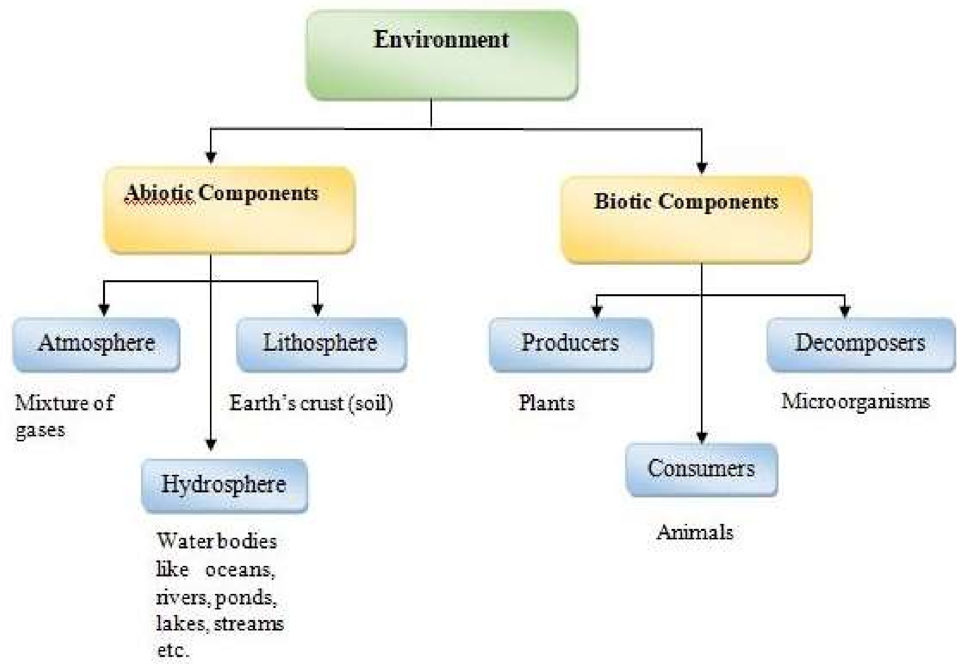

Figure 2.1. Flow chart showing detail representation of components of environment

abiotic components. The atmosphere ensures the availability of oxygen, carbon dioxide and nitrogen, the chief component needed for the survival of organisms. The hydrosphere makes available the liquid water, the major inorganic nutrient required by all living organisms. Finally, the lithosphere provides all other minerals.

a) Atmosphere (Air): Gaseous envelope that covers our planet earth is called atmosphere. It is the most dynamic components, as lots of changes takes place in it from one altitude and season to another over short period of time. It is stretched to thousands of kilometres above earth's surface. The atmosphere is the reservoir of life- giving gases like oxygen and carbon dioxide and several elements essential to life on earth. It is intact to earth by force of gravity. It serves many important functions like trapping of heat by allowing short wavelength radiation to enter and reach the earth's surface and is nearly opaque to long wavelength terrestrial radiation thus maintaining average temperature of 35°C. It protects the earth surface from harmful radiations of sun, serve as the store house of water vapours which results in precipitation (rainfall), several biogeochemical cycles like oxygen, carbon dioxide, nitrogen, phosphorous, water cycle etc., required for the circulation of essential elements are present in it. Thus, the presence of air and water together makes the planet earth perfect place in the entire solar system for the survival of living entity.

Composition of Atmosphere: Earth's atmosphere is the mixture of various gases (Table 2.1). It consists of nitrogen, oxygen, argon, carbondioxide, hydrogen, helium, ozone etc.

Table-2.1. The composition of Atmosphere

Gases	Relative Percentage
Nitrogen(N2)	78.08
Oxygen(O2)	20.95
Argon (Ar)	0.93
Carbon dioxide (CO2)	0.03
Neon (Ne)	0.0018
Helium (He)	0.00052
Methane (CH4)	0.00015
Krypton (Kr)	0.0001
Hydrogen(H2)	0.00005
Nitrous oxide(N2O)	0.00005
Xenon (Xe)	0.000009
Ozone(O3)	0.000007

Besides above mention gases the earth's atmosphere also consists of water vapours, dust particles, smoke, salts, pollen grains, microorganisms and other impurities particularly in lowermost layer. The composition of atmosphere is not constant and it varies from place to place, season to season with respect to time. The atmospheric pressure gradually decreases as we move upward.

Structure of Earth's Atmosphere: The atmosphere of earth comprises of five concentric layers or zones with varying temperature and density. There is fluctuation in temperature at each zone with increasing height or altitude. On the other hand, density decreases rapidly on moving upward. The different layers of the atmosphere with increasing altitude can be identified as troposphere, stratosphere, mesosphere, thermosphere and exosphere(Fig.2.2).

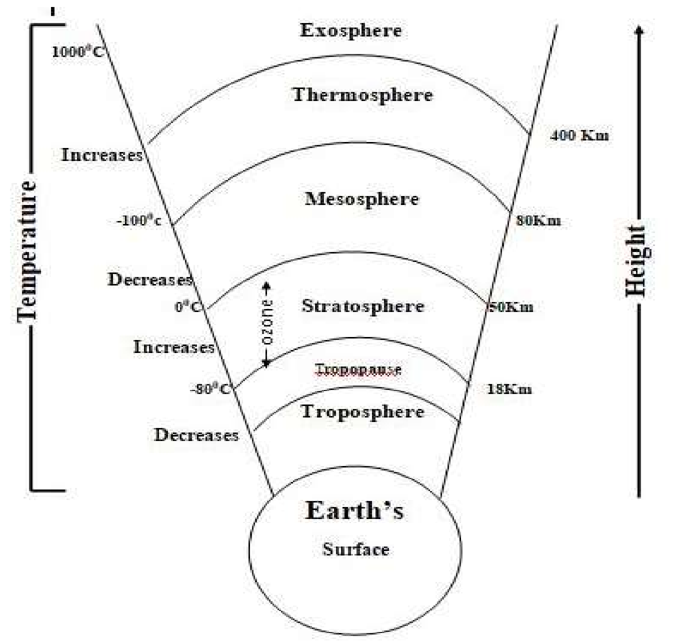

Fig. 2.2. Structure of Earth's Atmosphere

Troposphere: It is the lowermost first layer or zone of earth's atmosphere lying in very close contact with the earth. It extends up to a height of 18 kms above the equator and 8 kms near the poles or we can say approximately up to the height of Mount Everest. The temperature in this zone decreases with the increase in the altitude. All the activities related to weather and climate change occurs in this zone. Clouds are present in this layer.

Stratosphere: This is the secondlayerpresent above the troposphere and extends vertically up to a height of 50 kms. The temperature in this zone increases as we move upwards. There is zone called tropopause that separate troposphere from stratosphere. This layered is marked by the presence of ozone layer. Commercial aeroplanes fly in lower stratosphere just above tropopause.

Mesosphere: This is the third layer of the atmosphere present next to stratosphere extending upto a height of 80 kms. The temperature again decreases in this layer as we move vertically upward.Satellites orbit above this layer and most meteors vaporizes in this layer before reaching the stratosphere.

Thermosphere: It is the fourth layer extending up to a height of 400kms. Here the temperature increases with the height. Here in this region UV-radiations and cosmic rays cause ionisation of oxygen molecules and nitric oxide. It is electrically charged layer and responsible for the reflection of radio waves. Therefore, this region is also called ionosphere.

Exosphere: The uppermost layer of the atmosphere above the thermosphere is called exosphere or outer space. It extends beyond the thermosphereup to 32,190 kms and is marked by very high temperature more than 1000^{o}C due to solar radiations.

b) The Hydrosphere (Water): Layer of water on earth's surface is referred to as Hydrosphere. In other words, hydrosphere includes all liquid components, viz., oceans, lakes, rivers, etc. Water is essential for the survival of all life forms on earth. Life originated in water. It covers about three quarters approx. 71% of the total earth surface in the form of oceans, lakes, rivers, ponds, streams and other water bodies. It is therefore, also designated by names like "Blue Planet", "Water planet". It exists in three forms solid (snow), liquid (water), and gaseous (water vapours). Water vapours are the invisible form of water whereas rain, fog, clouds, snow, hail,dew are the visible form of it.

Structure of a water molecule: A water molecule consists of two hydrogen atoms and one oxygen atom. The hydrogen atom has one electron andoxygen has eight electrons. Two hydrogen atoms bond with oxygen by sharing a pair of electrons forming a covalent bond.

Physical properties: Water is a tasteless, odourless liquid at ambient temperature and pressure.It is a viscous transparent liquid with high viscosity and protects flora and fauna from mechanical disturbances. The solid form of water (ice) is lighter than liquid water because of having maximum density at 4^{o}C.Water has a high specific heat capacity and due to this property of water large water bodies (ocean and lakes) maintain a relatively constant temperature.Being a universal solvent, water dissolvesnatural elements and many organic chemicals. Due to greatest surface tensionextraordinary amount of water can be retained within soilthrough capillary action and is available to terrestrial plants.All types of natural water contain various salts or ions (Na, K, Ca, Mg, Cl, NO_3, CO_3, HCO_3, SO_4 etc.) responsible for its salinity. The salinity of fresh water varies greatly while that of marine water is almost constant. Thus, salinity of water acts as an important limiting factor in the distribution of organisms.

Distribution of water on earth's surface: Water is the most abundant component of living matter. Majority of it is present on land (below its surface), in atmosphere and in biomass. Around 97% of water is in oceans and 2% of is stored in the form of ice sheets. Only 1% is available as fresh water.Oceans are the largest water bodies that cover most of the earth's surfaceand its water is saline due to the presence of various salts. The temperature of water in oceans varies from the surface to the depth (decreases with increase in depth) playing important role in the distribution of marine organisms. On land water is present in the forms of rivers, lakes, ponds, steams and ice sheets.Water is present in atmosphere in the form of water vapour formed by the heating of surface water of different water bodies by sun. Water vapours present in the atmosphere gives a measure of atmosphere moisture or humidity. The atmospheric moisture comprises of visible (fog, mist and clouds) and invisible water vapours. Water vapours decrease the intensity of irradiations by absorbing solar radiations. Thus, high and low moisture is detrimental to organisms.

The continuous circulation or constant interchange of water between the different components of earth's environment is carried through a natural process known as **Hydrological Cycle or Water Cycle.** It involves process like evaporation (including transpiration), condensation, precipitation. Solar energy evaporates water from hydrosphere into the atmosphere. Water vapours thus produced are cooled and condensed at higher altitudes to form clouds and precipitation as rain or snow then return the water to the hydrosphere.

c) Lithosphere (Soil): The rigid solid component of earth is called lithosphere. It consists of rocks and mixture of weathered rock materials leading to the formation of minerals. It is the main source of minerals and their metabolites required by all organisms of earth. The lithosphere is multi-layered and composed of three main layers: crust, mantle and core (Fig. 2.3).The **crust** is the outermost layer of lithosphere which is lighter in density than other two layers. It is a very complex rigid zone and its surface is covered with soil that supports the biotic components of the earth.It is further divided into outer crustal layer (solid in nature) 8 to 40 km thick and inner layer (partly molten) 45-100km thick. It consists of rocks rich in silica and aluminium. Therefore, it is called the **SIAL layer**. The crust is made up of different types of rocks: igneous, metamorphic and sedimentary rocks. The crust is of two different types: continental (under the land) and oceanic crust (under the ocean). The continental crust is less dense and extends up to 30-50km. It is composed of mainly of graphite. The oceanic crust is dense and extends up to 5 - 10 km. It is made up of different types of basalts. Various elements constitute the earth crust (Fig.2.3). The second layer **mantle** is present below the crust and above the outer core.It extends up to 2900km. It is further divided into outer asthenosphere and inner mesosphere. Asthenosphere is 100-400km thick and mainly composed of silica and magnesium.Geologists often refer to this layer as **SIMA**. Mesosphere is 2400-2750km thick. It is a transitional zone often referred by geologist as wholly SIMA.**Core** is the ball-shapedcentre most layer which is about 3500km thick. It is

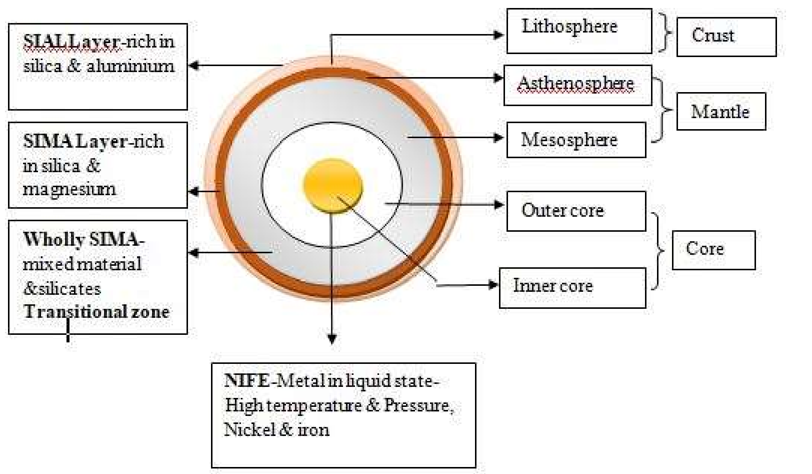

Fig. 2.3. Structure and elemental composition of lithosphere

made of two layers, outer and inner layer. The core of the earth is very hot and dense. Because of high temperature and pressure all metals present here are in liquid state. Unlike crust and mantle the core is composed of metals specifically, nickel and iron that accounts for earths magnetism. It is therefore referred as **NIFE**. Thus, lithosphere is the source of minerals, various types of rocks and fossil fuels.

In lithosphere we deal not only with the study of mineral and rocks but also with different types of landforms and soil.

Landforms: The surface of lithosphere is uneven and it varies from place to place. Depending upon its shapes, structure, appearance and composition it is categorised into different major types of landforms viz., **mountains, hills, plains, plateau, valleys and deserts**. These are formed as a result of sudden changes caused by earthquake, floods, movement of tectonic plates, volcanic eruption etc. Further they are subjected to gradual and continuous changes. These landforms have great influence on various life forms of earth as they determine the land use pattern and climate of an area. Apart from this it also acts as the natural barrier leading to geographical isolation and resulting in speciation in due course of evolution.

Igneous rocks	Sedimentary rocks	Metamorphic rocks
Formed by gradual cooling and solidification of molten rocks (magma)	Formed by deposition and hardening of weathered mineral particles (sediments)	Formed by metamorphosis of pre-existing rocks (igneous and sedimentary rocks)
Also known as primary rocks	Also known as stratified rocks	Also known as hard coal
Basalt, granite and diorite are some common types	Limestone, sandstone and shales are some examples	Marble, quartzite, slate, schist and some important types of

Rocks: The earth crust consists of rocks made up of minerals. The soil forming rocks on the basis of mode of their formation can be classified as igneous, sedimentary and metamorphic rocks (Table.2.2).

Soil: Soil is the loose top layer of earth's crust formed by physical, chemical and biological

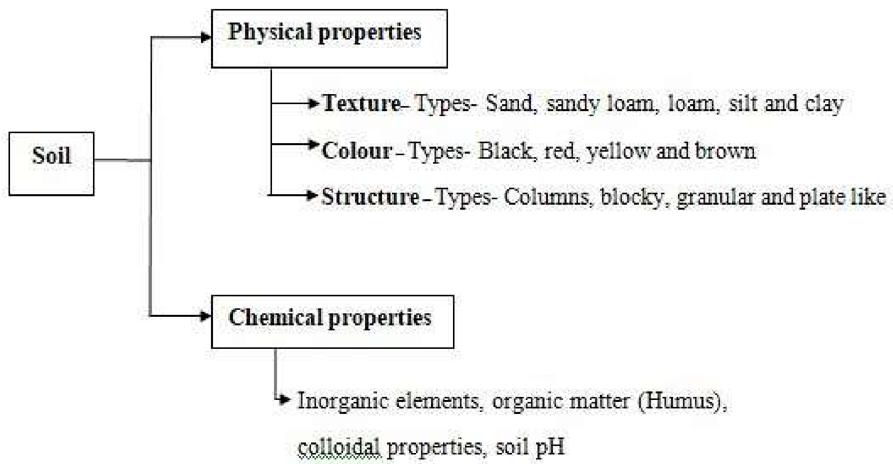

Fig. 2.4. Properties and composition of soil

weathering of rocks. It is the basic natural resource on which life flourishes and is made up of solid, liquid and gaseous substances. According to Treshow (1970), soil can be defined as "a complex physical and biological system providing support, water, nutrient and oxygen for the plant". The study of soil is known as pedology.

2.3.2 Biotic Components

In previous topic we have discussed the abiotic components of the earth's environment. Now in this topic we will go through the biotic factors of the environment. Biotic component includes mainly producers, consumers and decomposers (Fig.2.5).

a) Producers (Autotrophs)

These are autotrophic green plants. They also include chemosynthetic and photosynthetic bacteria, algae, blue green algae (cyanobacteria) and diatoms. Producers (plants) convert light energy of the sun into potential chemical energy in the form of organic compounds. For this purpose, they utilize CO_2 liberated during the process of respiration and combustion and in turn they release O_2 which is used by other organisms. Producers play key role in temperature regulation and maintain the balance between carbon dioxide and oxygen in the earth's atmosphere and are the very essential biotic component on which the entire living organisms are dependent directly or indirectly.

Self-Assessment-1

Q.1.What are the two main components of Earth's environment?

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Q.2. Which layer of Earth's atmosphere reflects radio waves?

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b) Consumers (Heterotrophs)

Consumers includes heterotrophic organisms mainly animals that are unable to synthesise their own food and are dependent on autotrophs for their survival. Consumers are mainly categorised into following types:

Primary consumers (Herbivores): These are the organisms that derive their nutrients from plants or feed on them. They are first order consumers, also known as plant eaters. e.g. deer, rabbit, mice, squirrels, goat, cattle's, many insects like grasshoppers, insect's larvae, many small fishes, zooplanktons, small crustaceans, copepod etc.

Secondary consumers (Carnivores): Secondary consumer includes carnivores that feed on herbivores e.g. frogs, snakes, lizards, small insectivorous birdsetc.

Tertiary consumers (Top carnivores): This category includes those carnivores that feed on secondary consumers e.g. large fishes, water birds, eagles, wolves, lion, tigers etc.

Omnivores: These are the consumers that can feed on both plants and animals. They have diversified feeding habit. Because of this they have great advantage to survive in stressful situations like food shortage. In other words, they are generalists. Examples human, bear, pigs, cat fish etc.

c) Decomposers

Decomposers are the micro-organisms that feed on dead and decaying organic matter. They secrete enzymes that convert complex organic matter into simple and soluble inorganic substances which is then utilised by plants and other organisms. They are therefore, also called saprotrophs or micro consumers or osmotrophs. Thus, they act as the recycler of the nutrients.

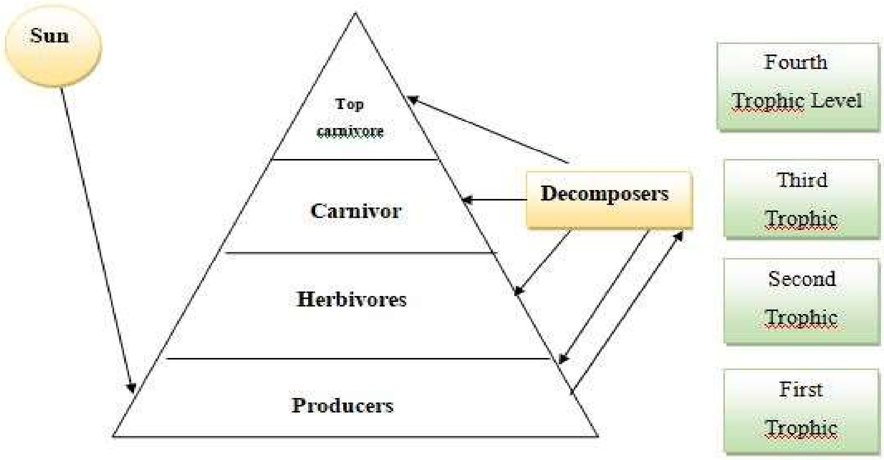

Fig. 2.5. Biotic components of the environment at different trophic level

Self-Assessment-2

Q.3. Give some examples of omnivores?
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…………………………………………………
Q4. Organisms that recycle the nutrient are known as?
…………………………………………………
…………………………………………………

2.4 Human Activities on Earth

We all know that earth's environment is a suitable place for the survival of all living organisms including humans. Today,earth's environment has been undergoing drastic and significant changes due extensive human activities and natural processes. Environmental forces like earthquake, floods, drought, landslides, fires and epidemics have impact on human beings whereas at the same time various human activities like deforestation, environmental pollution and degradation etc., also have severe negative impact on the environment. Alterations in abiotic and biotic components by human activities are the root cause of various environmental problems that affect sustainable development. Increase in the level of CO_2 and other greenhouse gases and depletion of ozone layer arethe major environmental problems that are concerning mankind.

Since the period men have evolved on earth, he had tried to explore available natural resources of earth for making its life more comfortable and easier.Rapid industrialisation, urbanisation and agricultural development have great contribution to this. Not onlythis, in order to meet the need of growing population he utilised all the renewable and non-renewable natural resources. For this purpose, he not only overexploited the natural resources of earth but also led to the extinction of many diversified flora and fauna of earth. Thus, imposing major threats to the biodiversity,wildlife and earth systems. Some of the human activities that have caused direct or indirect degradation of environment are -

2.4.1 Overpopulation

Reproduction or population growth is necessary for the survival of any species. But if it reaches to a condition that is undesirablewhere the number of existing human population exceeds the carrying capacity of the earth. Then, it results into a condition known as **overpopulation**which is emerging as a great challenge for the world. It is the outcome of number of factors like better medical facilities, reduced mortality rate, lack of family planning, advance technology facilitating fertility treatment etc. In order to meet the increasing demand of growing population it creates great stress on natural resource, especially on land. High cost of living, unemployment, conflicts, wars are the result of overpopulationthathave pronounced effect on environment like exhaustion of natural resources and degradation of environment.

2.4.2 Deforestation

The thinningof forests by humans is known asdeforestation or forest clearance or forest destruction. It is the result of over-gazing, indiscriminate cutting down of trees for fuel and timber, over-exploitation of land as pasture for livestock's and their production, agriculture, industrial setup and expansion of settlements. The growing demand of our highly populated cities are resulting in fast disappearing forests and also leads to theextinction of endangered flora and fauna. The devastating effects of deforestation can be sum-up as: soil erosion, climate change, biodiversity loss, air pollution, water pollution, soil pollution, disturbances in global water cycle.

2.4.3 Urbanization

As we all know the urbanization is the moving of rural population to metropolitan cities in search for better facilities regarding medical, education, employment, better transportation and easy availability of things. As a result of continuous movement from villages to cities, the cities are becoming overcrowded and villages are getting vacant. This situation had created immense pressures on cities and to cope up with this increasing pressure, destruction of natural habitats of animals is taking place. In cities use of automobiles and other means of transport emits 80% of CO_2 that is mainly responsible for poor air quality and ultimately leads to global climate change. Because of overpopulation, in cities there is more CO_2 emission and high temperature than its surrounding rural areas. This difference in temperature is more pronounced during night hours which create urban heat island impact. This severely affects air and water quality, ecosystem and human health. Some of the consequences ofurbanisationare summarized below:

- It had resulted in shift in feeding habits and habitat of animals. For example, some insectivorous birds have become granivorous. Mosquitoes are more in cities than rural area due to warm and moist temperature of cities.
- Generation of large amount of sewage and other wastes that are dumped in rivers, lakes and oceans are the consequences of urbanisation.

2.4.4 Industrialization

Industrialization had helped in development of various areas like agriculture, automobiles, and manufacturing. Economic development, prosperity and rise in the standard of living of people are the outcome of industrialization. Urbanization and population explosion are the result of it. Apart from this it had generated immense employment for the people to sustain livelihood. It is responsible for large scale production of goods within short period. Apart from these benefits, it has become root cause of deterioration of environment that can be summarized into following main points:

- Air, water and land pollution due to industrial discharge
- Climate change and global warming due to the release of industrial smoke

- Generation of hazardous waste (heat and radioactive substances from thermal and nuclear power plants), mercury, lead etc. Minamata epidemic due to consumption of heavily mercury contaminated fish.
- Depletion of natural resources
- Degradation of land quality due to disposal of industrial discharge etc.

2.4.5 Over-utilization of natural resources

To fulfil the need of growing population of humans for fuel, food, fodder, shelter and lifestyle has given rise to other major causes of environment degradation that is indiscriminate utilization of natural resources(energy, water and raw materials) at a faster rate than it is regenerated or replenished. If natural resources are not used judicially it may ultimately lead to water scarcity, depletion of oil, coal and natural gas, loss of forest cover and extinction of species and pollution.

2.4.6 Expansion of telecommunication

Invention of new technologies made life of man easier. It enabled human beings to make maximum use of environment and its resources. Thus, allowing them to over exploit the environment.Telephones, computers, mobiles, televisions etc., resulted in e-waste that is not only harmful for humans but also affect environment. Some of the detrimental consequences of advance technologies are: increase exposure to harmful radiations, surge in e-waste and energy usage, increase mining of rare minerals, disposal of electronic wastes.

2.4.7 Transport system

Construction of roads and invention of different means of transportation like trains, buses,cars, aeroplanes, cruise shipsetc., not only helped to link various countries, cities and villages but also has reduced travelling time considerably. Transportation system has proved the back bone of development achieved through industrialization and urbanization. All this was the one side of the coin. But we have to discuss the other side of the coin i.e., environmental problems arising due to it. All that can be summarized into following points

- It has led to the destruction of land and ecosystem.

- Depriving wildlife from their homes and space. Creating the situation of conflicts between man and wild animals
- Loss of biodiversity
- Transportation system burns most of the world's petroleum acting as the major source of air pollution by the emission of CO2 and nitrous oxides.
- Water pollution due to spillage of oil during transportation
- Significant contributor of global warming

2.4.8. Intensive Farming or Intensive Agriculture

It means use of all possible industrial tools and techniques for agricultural practices in order to get maximum output (yield). To achieve these fertilizers, pesticides and plant growth regulators are extensively used. Eutrophication and biomagnifications are two major consequences of intensive farming which will be discuss later in this unit.

Self-Assessment-4

Q.5. Write any two human activities that are responsible for degradation of environment?

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……………………………………………………………………………………………

Q.6. Generation of large amount of sewage is the result of?

………………………………………………………………………………………………

2.5. Impact of human activities on environment

In this section we will learn how human activities influence their environment and how the environment in turn has negative and positive impact on humans and other organisms of the earth. The complex and diversified connection between the environment and human activities can be studied by categorizing it into two main groups:

- Utilisation of natural resources
- Production of wastes

2.5.1 Utilization of natural resources

Natural resources include food, land, water, soil, minerals, plants, animals etc. Natural resources can be divided into two main categories: Inexhaustible and Exhaustible. Inexhaustible resources are available to environment of earth in immeasurable quantity. Such resources may or may not show some changes in their quantity due to human activities. We all are aware that solar energy, geothermal and wind power, rainfall are some examples of inexhaustible resources. Whereas exhaustible resources are limited and can be exhausted if they are used by humans indiscriminately. They are further classified as renewable and non-renewable resources. As we all know that renewable resources such as agricultural land, water and forest can be regenerated or regained or reconstructed once they are used up. Contrary to this fossil fuels (coal, natural gases and oils) are non- renewable resources.

We all are depended on these natural resources for our survival and to fulfil our day to day needs mostly for food and water. Our dependence on these resources has increased considerably due to increasing human population and to meet their requirements. Our efforts to make life more comfortable and luxurious have added to our dependency on environmental resources. This situation has resulted in the depletion of available natural resources very fast even before it is expected.

2.5.2 Production of wastes

Utilization of natural resources generate immense amount of waste that pollutes air, water and soil. The waste produced can be biodegradable or non-biodegradable. Industrial effluents, mining activities, agricultural practices (burning of crop reside, use of pesticides and fertilizer), thermal plants are the major sources of wastes that have drastic acute or chronic effect on the health of organisms. Wastes generated due to household human activities contribute to the pollution of different abiotic components of the earth especially soil.

The above-mentionedenvironment degrading activities of human beings have finallyresulted in ecological imbalance.Following are the outcomes of environment deteriorating activities of humans.

1) Greenhouse effect and Global warming: Solar radiation of short wavelength enters the earth's troposphere while the long wavelength infrared solar radiations are reflected back and during this process some of the solar radiations are absorbed by the naturally occurring greenhouse gases of earth's atmosphere acting as a natural blanket keeping the earth's atmosphere warm and maintain earth's temperature roughly at 15^{o}C. Thus, the phenomenon of entrapment of long wavelength terrestrial infrared radiations in earth's atmosphere is known as **greenhouse** effect and gases which help in this are called **greenhouse gases**(carbon dioxide, methane, nitrous oxide, chlorofluorocarbons (CFCs) and ozone etc.). It is a naturally occurring process that has been accelerated over a period of time due to anthropogenic activities. When the concentration of greenhouse gases increases in the atmosphere due to natural and mostly by anthropogenic activities the temperature of the earth's atmosphere increases. This steady rise in average temperature of earth is known as **Global warming.**

2) Climate change: As soon as we hear the word climate change our mind get filled with the thoughts of greenhouse effect and global warming. Climate change refers to a continuous long-term shift in temperature result of natural processes and mostly due to human actions. Several national and international meetings, conferences, seminars and symposium are organised time to time to discuss and to find solution of this global problem. There are two main causes of this world wide problem.

i) **Natural causes:** These are the activities of nature which occur time to time and influence the nature's climate. The natural processes of climate change are occurring from the time earth has evolved. We can say this is occurring since time back of earth history. Volcanic activity, solar radiations, and inclination of earth have crucial role in climate change.

ii) **Anthropogenic causes:** Human population and activities like burning of fossil fuels and deforestation have played crucial role in disturbances of earth's climate. Human activities have resulted in the increase in the level of greenhouse gases that has led to considerable heating of earth's atmosphere resulting in global warming. Similarly, conversion of forest into agricultural land and cutting down of trees to meet the needs of growing human population have resulted in change in climatic conditions.

The Intergovernmental Panel on Climate Change (IPCC) established by World Meteorological Organisation (WMO)in 1988 and the Unite Nations Environment Programme (UNEP)reached to the conclusion that climate change is real and human activities are root cause of it. The United Nations Framework Convention on Climate Change (UNFCCC), the main international treaty on climate work to stabilise greenhouse gas concentrations in the atmosphere at a level that will not pose serious threat to environment.

Consequences of Climate Change

- An increase in precipitations (approx. 0.5 -1%) during winter and autumn in northern hemisphere
- Rapid melting of Glaciers and polar ice caps.
- Increase in sea level resulting in submerging of land area near sea
- Change in type, coverage and distribution of vegetations
- Migration of species
- Mass extinction when organisms are not able to adjust itself to changing climate.
- Increase in the frequency and magnitude of extreme weather conditions and disasters.
- Heat stress and transmission of infectious diseases

3) Ozone Depletion: As we all know that ozone layer is present in the stratosphere of the atmosphere and protects us from harmful ultra violet radiations of the sun. Over the past few years, the ozone has gained the attention of environmentalists. The main reason of concern is its gradual thinning or depletion due release of chemical containing chlorine or bromine from industry andhuman activities especially air pollution.Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFs), carbon tetrachloride (CCl_4), methyl chloroform arethe examples of some ozone depleting substances (ODS) that destroys the protective ozone layer of earth. Out of these CFCs have significant role in ozone layer depletion. They are widely used in various industries as:

- coolants in refrigerators, air conditioners and large chillers

- cleaning agents
- blowing agents in foam industries
- fire extinguishing agent
- propellant in spray and aerosols
- solvents in dry cleaning process

Ozone depletion contributes to direct and indirect effects. Skin burn, eye cataracts, skin cancer are direct effects whereas reduced plant growth, low chlorophyll content, harmful mutations are indirect effects of it.

4) Bioaccumulation and Bio-magnification: Bioaccumulation is the selective gradual accumulation and storage of substances inside the living cells of organisms. These substances can be pesticides or other chemicals. In bioaccumulation chemical substances get absorbed into the organism at a faster rate than it is catabolised or excreted out of the body. In simple language it is the build-up of toxic chemical substances or residue in the body of living organisms. Bioaccumulation ultimately leads to Bio-magnifications. Bio-magnifications is the increase in the concentration of toxic chemical residues (like DDT - Dichlorodiphenyltrichloroethane and BHC - Benzene hexachloride) in the tissues of an organisms at each trophic level of food chain. The concentration of toxic substances increases as we move upward in the food chain. During the year1960s with the publication of Rachel Carson's Book **"*Silent Spring*"** (1962)public attention was drawn towards the hazards of indiscriminate use of persistent pesticides like DDT on environment. Being non-biodegradable,its residue persists in environment for a long period of time. It was linked with reproductive failure and death of predatory birds. A decline in their number was noticed due to thinning of egg shells as a result of which the birds were unable to hatch their eggs. And later in year 1972 the use of DDT for agricultural purpose was banned. Still, till date DDT residue persist in environment.

5) Eutrophication: Eutrophication is phenomenon in which the water bodies like ponds and lakes becomes enriched with nutrients due to different human activities. Fertilizers especially urea are used in large scale in order to obtain high yield. These fertilizers are very good source of plant nutrients like nitrogen, phosphorous and potassium. During rain excessfertilizerrun-off into nearby water bodies from agricultural fields resulting in an increase in nutrient level of that particular water body. Run-off from urban lawns, golf courses and sewage (domestic waste) rich in phosphates and nitrate ions also add up to nutrient content of the water bodies. Thus, in due course of time it becomeshighly productive or eutrophic (means well nourished). This stimulates rapid growth of phytoplankton, resulting in **algal blooms.** Theydisrupt normal functioning of the ecosystem and compete with other aquatic plants for light for photosynthesis. The excess growth of algal bloom causes turbidity of water thus blocking the penetration of light. In the absence of sunlight, the other aquatic plantsare not able to synthesise their food. This cause the death of aquatic plants that provided food and shelter to other animals of that water body. The excessive growth of algal blooms results in oxygen depletion that ultimately results in the death of many aquatic organisms such as fishes. Methane and ammonia gases are released by decomposition of excessive algal bloom. Some algae also produce toxins that are lethal to animals and humans.

6) Pollution: One of the major significant causes of degradation of earth's environment is Pollution. Rapid industrialisation in race for development has resulted in unlimited exploitation of natural resources and release of harmful chemicals or gases in nature causing environmental pollution. Irony is that industrialisationis necessary to meet the demands of rapidly growing population of humans. So, it becomes necessary to discuss pollution. So, question arises what is pollution?

Pollution can be defined as an undesirable change in the physical, chemical or biological properties of air, water and land due to human activities to a degree that is harmful for the biotic component of the earth. The substances or agents that are responsible for the undesirable change are known as pollutant. Sources of pollution are often classified into two categories:

- Point sources that have single identifiable location or source, such as a channel through which wastes are dispose of, such as pipes and sewers. For example, power plant and industrial wastes are discharged into rivers and sea.
- Non-point sources don't have single identifiable source instead the source or location of pollution is diffuse i.e., spread over a wide area and difficult to mark.

Run-off from agricultural fields and urban areas are examples of non- point source of population.

The three major types of pollution based on nature and type of environment affected are: Air pollution, water pollution and soil pollution

Air pollution: It is the introduction of substances (gaseous and particulate air pollutants) that causes adverse changes in the atmospheric conditions and degrade the quality of air. The natural and mostly anthropogenic sources are responsible for the introduction of the air pollutants in the earth's atmosphere. The main source of air pollution is the burning of fossil fuels such as coal and oil (petrol and diesel). Another main reason is the destruction of forests. Gaseous emission of industry, automobiles, thermal power plants and domestic combustion. Carbon compounds (CO_2, CO), sulphur compounds (SO_2, H_2SO_4 etc.), nitrogen oxides (NO, NO_2, HNO_3), ozone, hydrocarbons, fluorides, particulate matter etc., are the principal air pollutants.

Water Pollution: It is defined as the presence of undesirable substances in water resulting in change in its physical, chemical and biological properties make it unfit for drinking. It is an age-old problem. Human activities like sewage disposal, testing of nuclear weapons, trade waste disposal has contaminated most of the available water resources. The major sources of water pollution are: domestic sewage, industrial wastes, agricultural wastes, thermal pollution, radioactive wastes, off-shore oil drilling, asbestos and heavy metals etc.

Water pollution not only makes water unfit for domestic use, but also have severe impact on the environment. Polluted water is the source of water borne infectious diseases, main cause of algal bloom resulting in depletion of oxygen in water bodies and ultimately resulting in the death of organisms living in it. Water polluted with heavy metal like lead, mercury, arsenic, zinc, copper etc have harmful effects on human body such as cancer, kidney, liver, brain and nervous system damage.

Soil Pollution: It is defined as any physical, chemical or biological change in the structure and properties of soil due to the presence of toxic chemicals substances and other alterations. In other words, it is the contamination of soil. Sources of soil pollution are: industrial discharges, urban wastes (sewage), agricultural practices, heavy metals, radioactive pollutants etc. Human activities are primary source of soil pollution. Large scale contamination of soil may lead to reduced soil fertility, alteration in soil structure, reduced nitrogen fixation, disturbances in soil flora and fauna.

7) Desertification: It is the result of human activities like urbanisation, deforestation, overgrazing, depletion of ground water and inappropriate agricultural practices. It is the gradual process by which fertile land is converted to desert or barren land. Thus, we can say it is a form of land degradation which results in reduction in yield, livelihood, increased temperature and chances of flood in heavy rainfall areas.

8) Acid Rain: Acid rain is the outcome of air pollution caused by human activities in the blind race of development. Sulphur dioxide and nitrogen oxide are the main contributor to air pollution. They are released in the atmosphere by burning of fossil fuels, power stations, vehicles and industries. When present in atmosphere in high concentration these oxides (SO_2 and NO) are oxidised into acids(sulphuric acid and nitric acid respectively). The resultant acids get dissolved in water in the atmosphere and fall as acid rain. It can occur in the form of snow, fog, hail, sleet etc.Sulphuric acid, nitric acid, carbonic acids are the main components of acid rain.Acid rain is responsible for corrosion of exposed surfaces, deterioration of limestone and marble building and historical monuments like Taj Mahal. Not only thisit also interferes with natural nitrogen and sulphur cycle.

9) Biodiversity Loss: Many plant and animal species of this planet are under the threat of extinction or have extinct due to human activities like pollution, climate change, intensive farming, destruction and degradation habitat due to deforestation and urbanisation, over exploitation etc. Recreational activities like fishing and hunting, introduction of non-native species for agriculture and ornamental purpose, poaching for food, pleasure, medicines (Yarshagamba -KeedaJadi, caterpillar fungus), fur, ivory are affecting the biodiversity and resulting in its loss.

10)Soil Erosion: Soil erosion occurs both naturally and by human activities. It is the displacement or wearing away of upper top soil layer which is highly fertile and rich in nutrients. Soil erosion results in decline or loss in soil fertility and moisture, change in soil structure that results in low productivity. Human activities which are responsible for this are overgrazing, unsustainable land use, intensive farming, mining, constructions etc. It is clear that if this problem persists agriculture and pasture land will face the drastic consequences affecting functioning of natural ecosystems.

Self-Assessment-5

Q.7. Full form of IPCC?

…………………………………………..................

Q.8. Which book drew public attention towards environmental problems?

…………………………………………..................

2.6. Summary

Every entity living in this earth is surrounded by material and forces that constitutes its environment. This environment is made up of non-living (abiotic) and living (Biotic) components. Both the components of earth's environment are dynamic and vary with space and time. There is continuous interaction between all the components of environment. This interaction is either positive or negative. The abiotic components such as atmosphere, lithosphere and hydrosphere together provide life supporting system for the biotic component such as producers, consumers and decomposers. The presence of atmosphere and hydrosphere makes earth's environment perfect place for survival of life in the whole universe.Changes in lithosphere can cause changes in landforms. Similarly, pattern of circulation in hydrosphere and atmospherebrings about change in climate and seasons.

Human beingsoccupy central place in the environment asenvironmental problems are studied in context with thethem and humans solely are responsible for various environment related problems that theyare facing now. Human activities like deforestation, industrialization, urbanization, overpopulation, over utilization of natural resources had tremendously degraded the environment. These human activities have finally resulted in major environmental issues and challenges such as pollution, climate change, global warming, acid rain, desertification etc., The degenerated and chemically altered environment will make our survival more and

more difficult. The greenhouse gases added in the atmosphere will persist in the environment for centuries to come. And the long-lastingCFCs too will continue depleting ozone layer. Forests cleared will take years to rejuvenate and regenerate. The exhausted natural resources will take years to replenish. The flora and fauna that have extinct will never be seen again.Now it depends upon us to act now or do nothing. Therefore, issues concerning environment should be addressed with solid planning and active cooperation and participation of every individual keeping in mind importance of every component of earth's environment.

Terminal Questions

Q.1. Define environment. Give an account of different components of environment.

Q.2. Describe the structure of atmosphere in detail with the help of suitable diagram.

Q.3. Write note on:

i. Types of soil forming rocks
ii. Abiotic component
iii. Hydrological cycle
iv. Landforms
v. Consumers

Q.4. Give an account of structure and elemental composition of lithosphere.

Q.5. What are the various human activities that has led to the degradation of the environment? Discuss.

Q.6. Discuss in detail about Biotic components of the Earth.

Q.7. What do you mean by Global warming? Discuss in detail.

Q.8. Explain:

(i) Biomagnification

(ii) Overpopulation

(iii) Acid Rain

(iv) Deforestation

Q.9. Explain the impact of excessive human activities on the Earth's environment.

Glossary

Abiotic: Non-living part or components of the environment such as air, water. Soil etc.,

Acid rain: rainfall that has become acidic due to the presence of pollutants like sulphur and nitrogen oxides and their reaction with the water of the atmosphere.

Algal Bloom: It is a rapid increase in the population of algae.

Altitude: Height above sea level.

Anthropogenic: man-made, not natural or associated with human activities.

Asthenosphere: A layer in the upper mantle of the earth which is highly viscous and weak, present just below the lithosphere.

Atmosphere: The gaseous envelop that surrounds the earth.

Bioaccumulation: Gradual increase in the concentration of chemical substances in specific organs or tissues of organisms at a faster rate than it is lost by catabolism and excretion.

Bio concentration: It is the specific bioaccumulation process by which concentration of certain chemicals exceeds in the organisms than its surrounding.

Biomagnifications: It is increase in the concentration of persistent toxic chemicals at each trophic level in a food chain.

Biodiversity: Variety and variability among life forms.

Biotechnology: Use of biological processes on industrial scale to produce useful products.

Biotic: living components of environment; pertaining life.

Climate: variation of weather in a region over long periods of time.

Deforestation: Conversion of forest areas into non-forest area for agriculture, urban use or developmental process.

Desertification: Conversion of fertile, productive land into desert due to drought, inappropriate agricultural practices, deforestation and excessive utilisation.

Ecology: The study of the inter-relationships between organisms and environment.

Ecosystem: The structural and functional entity of biotic communities and their environment.

Effluents: liquid waste or sewage emitted from a source into the water bodies thus polluting it.

Environment: The external conditions in which an organism lives and interacts.

Erosion: The wear and tear of land or soil due to displacement of solid/sediments by agents like wind, rain, water or ice.

Eutrophication: A rapid dense growth of the algae or aquatic plants due to excessive nutrients added frequently to the water bodies by run-off from land.

Exosphere: Outermost layer of the atmosphere lying after thermosphere.

Fauna: All the animal species inhabiting in this Earth.

Flora: All the plant species inhabiting in this Earth

Forest: land with canopy cover

Global warming: Rise in average global temperature of the Earth mainly due to human activities.

Greenhouse effect: Trapping of heat by allowing short wavelength solar radiations and inhabiting long wavelength radiations resulting in increase in temperature.

Groundwater: Water located beneath the ground surface.

Herbivore: Animals which feed on plants.

Hydrosphere: That part of the earth which is covered by water.

Insecticides: Toxic chemical used to kill insects.

Lithosphere: The crust and the mantle of the earth rich in minerals and nutrients.

Intergovernmental Panel on Climate change (IPCC): Established in 1988 by World Meteorological Organization and UN Environment programme and is dedicated to providing the world with objective, scientific information related to climate change.

Natural resources: valuable naturally occurring substances.

Non-renewable resources: Resources like fossil fuels which have finite supply and take millions of years to replenish.

Overpopulation: When the number of existing human population exceeds the carrying capacity of earth.

Ozone Layer: Protective layer present in the stratosphere of atmosphere protecting organisms from harmful UV-radiations.

Ozone hole: Thinning of the protective stratospheric ozone layer.

Pollution: Undesirable change in the physical, chemical or biological characteristic of the environment due to chemical substances that are harmful for the organisms.

Phytoplankton: floating or freely suspended aquatic plants.

Renewable resources: Resources which can be used again and again and that can be replenished and regenerated.

Silent Spring: Environmental science book by Rachel Carson published in 1962.

Stratosphere: that layer of the Earth's atmosphere which is present above the troposphere.

Sustainable: Able to be maintained at a certain rate or level.

Thermosphere: Part of the atmosphere present above the mesosphere in which temperature increases with the increase in height.

Weathering: breaking down of rocks into small particles.

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Unit 3: Environmental Factors

3.0 Learning Objectives

This unit will be very helpful to the students to understand

- About various physical environmental factors
- Their influence on the living organisms
- How living organisms get adapted to their environment?
- How the distribution of living organisms is limited by various limiting physical factors to which they are adapted?

3.1 Introduction

In previous units we have discussed about the earth's environment its components and human activities. Now we know that the earth's environment is made up of abiotic and biotic components, thus constituting living and non-living environment respectively.In this unit we will learn about various factors of environment such as temperature, light, water, humidity, weather conditions, fire, currents, pressures etc. and their effects on the living organisms. Apart from this we will also discuss about limiting factor that have detrimental effect on the organisms at their maximum and minimum levels. With the knowledge of these factors viz., physical and limiting it is easy to understand the working of various interlinked systems of environment.

3.2 Environmental Factors

Any constituent or state of the environment which have direct or indirect influence on the distribution, growth, development, reproduction, behaviour and survival of an organism in any specific way is called **environmental factors** or **ecological factor** or **eco factor**. Each abiotic components of environment are a complex of various factors. For example, atmosphere includes factors light, temperature, moisture, gases. Hydrosphere includes water and lithosphere includes soil and minerals. These factors can also be categorized as: direct, indirect and remote.

The **direct** environmental factors are those which influence an organism directly such as light, temperature, atmosphere, humidity, soil, water and soil nutrients. On the other hand, **indirect** factors express their impact through direct factors such as wind, precipitation, soil structure. The **remote** environmental factors express their effect remotely through indirect factors which in turn influence the direct factors. The best examples of this are topographic factors like altitude. These environment factors are highly diversified, intricately mixed, inter linked and interrelated with one another and show variation from place to place. Therefore, different types of organisms whether plants, animals or microorganisms they are able to survive and flourish under different environmental conditions. Due to morphological, physiological and genetic modifications the organisms are able to adjust and adapt according to the surrounding environmental conditions. This is called **epharmony**

Those factors of the environment which determine the distribution of an organisms on the planet earth are called determining factors. They are divided into the following five groups:

1. **Climatic or aerial factors-** Physical forces and material factors related to aerial environment. These include- light, temperature, rainfall(precipitation), humidity etc.

2. **Topographic or physiologic factors-** These are related to surface behaviour or physical geography of the earth e.g., steepness of slopes, direction of mountain chains, altitude**.**
3. **Edaphic factors-** Related to both physical and biotic factors of the soil such as the formation and composition of soil.
4. **Biotic factors-** It includes all the types of interaction and relations among the living organisms- plants, animals and micro-organisms.
5. **Fire-**It is the physical factor generally the outcome of anthropogenic activities.

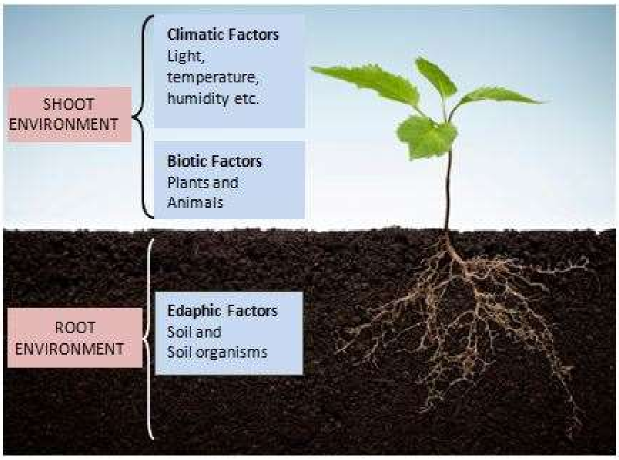

Figure 1. Model of Plant representing Climatic, Biotic and Edaphic Factors of an Environment

All the above-mentioned factors except biotic factors constitute **abiotic** or **physical factors**. These factors can be well understood and explained with the model of a Plant, where edaphic factors correspond to root while climatic and biotic factors correspond to shoot **(Fig.1).**

3.3 Interaction of Environmental Factors

All the factors of the environment (physical and biological) interact either positively or negatively with each other. A change in one factor causes a change in another factor(s). Similarly change in any physical factor brings about a change in biotic factors or component and vice- versa. An organism under natural environmental conditions is influenced by many factors at the same time. Thus, all environmental factors function in conjunction not in isolation.

Broadly, we can say that all the life forms on this earth are influenced by numerous diversified environmental factors and conditions, where the effect of one factor is modified by one or many factors. Therefore, it becomes customary to study the effect of each environmental factor separately (analytical approach). But to have a broad holistic approach it becomes mandatory to study the factors taking into account all the possible parameters to draw conclusion related to the impact of these factors on the living organisms as changes in the earth's environment are responsible for the evolution of life forms on this planet Earth.

3.4. Physical Factors of the Environment

The physical factors are mostly concerned with their effect on the living organisms. The important physical factors of the environment are as follows **(Fig.2)**:

- Light
- Temperature
- Water
- Wind
- Humidity
- Weather
- Soil
- Current and Pressure
- Fire

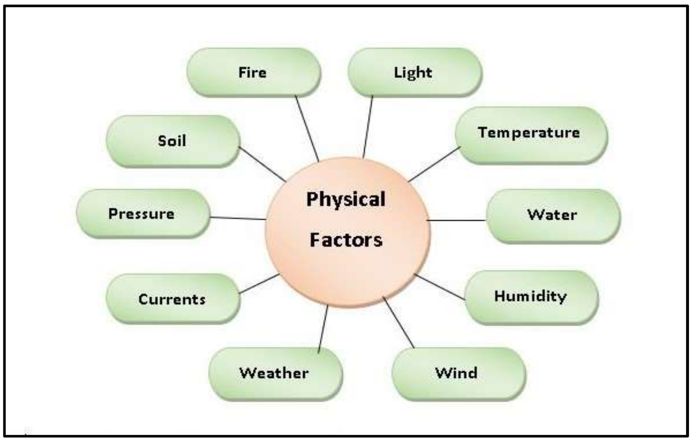

Figure 2 Various Physical factors of the Environment.

3.4.1. Light

It is one of the most essential ecological and physiologicalfactors, without which existence of life on the earth cannot be imagined. Sun is the main unidirectional source of light and energy and has great ecological significance. Light varies in wavelength, intensity and duration (length of the Day). Apart from this it also acts as limiting factor at its maximum and minimum levels. The various effects of light on various living entity and their functioning can be summarised in following headings:

a) Effects of light on Vegetation: Light is required by plants to perform the process of photosynthesis, in which solar energy is converted to chemical energy. Plants directly rely on light to prepare their food therefore; they are correctly said producers. Plants are categorized into **Short Day Plants (SDP)** and **Long Day Plants (LDP)** on the basis of duration of light required for their growth, development, reproduction (Flowering). A general thumb rule is that 1% increase in the duration of available light period will result in 1% plant growth and ultimately 1% increase in Plant yield. On the basis of their tolerance to light intensities, they are categorized into following groups:

Sciophytes- plants that prefer shady places and have sparsely distributed thin and larger leaves.**Heliophytes**- plants that prefer to grow well in direct sunlight and have crowded small and thicker leaves.Thus, the effect of light on plant can be summarized as Follow **(Table - 1)**

Table 1. Light and its effect on Plants.

Features	Effects
Chlorophyll	Needed for the formation of chlorophyll. Determines the number and position of chloroplasts.
Transpiration rate	Light regulates the opening and closing of stomata thus affecting the rate of transpiration.
Distribution	It also affects the distribution of plants on earth surface. Due to less light intensity in polar regions plants distribution is highly restricted in comparison to tropical and equatorial regions.
Pigment	High intensity of light results in formation anthocyanin pigment responsible for floral colours. Carotenoids and flavin mediate photo response. Phytochrome pigment that have important role in seed germination require red light for its formation.

Orientation	Plants show phototropism. Stem show positive phototropism (towards light) and root of the plants show negative phototropism (away from the light).
Photosynthesis	Blue and red light are useful for photosynthesis
Germination	Light also affects seed germination either by promoting or inhibiting it especially, red and blue light promote seed germination.
Development	Light intensity has tremendous effect on the development of vegetative (leaf, root and stem) and reproductive (flowers, fruits and seeds) structures. Diffused or low intensity light favours development of vegetative structures and intense or high intensity light favours the development of reproductive structures. Very low or less than optimum light retards the plant growth.
Other specialised reactions	Opening and closing of flowers, folding and unfolding of leaves of some plants is also governed by change in light intensity. Example, Portulacca commonly known as office glory or morning flower opens up when sun rises and closes with the sunset.

Do You Know?

The ecological understanding of response of plants to light is of great significance. In case of Betel leaves (pan ka patah) cultivation in our country, knowledge of photoperiodism in selection of season and species plays crucial role. Because of this they are grown in artificial conditions (in shady environment) that promotes growth of leaves with less hard tissues and chorophyll (H. R. Singh,1989) that have high market demand and price.

(B) Effect of light on animals: As an important ecological factor, light has pronounced affect in animals too. It affects the distribution, growth, development, reproduction, locomotion etc. Light also regulates the production and release of certain hormones in animals. The effect of light on animals can be explained in following points given in **Table - 2.**

Table 2. Light and its effect on the Animals.

Features	Effects
Distribution, Colour and Structure	Light influences the distribution, colour, morphological structures, and formation of pigments responsible for colouration in animals. In cave animals' colour and eyes are lacking or greatly reduced. In case of other terrestrial animals' colouration is prominent and for this purpose have photoreceptors. Aquatic animals living at the depth of water bodies where penetration of light is not possible are either blind or have reduced or telescopic eyes.
Development	Some organisms are able to show normal development only in the presence of proper sunlight else their development is retarded and even result in mortality. E.g., Salmon fish. But on the contrary solmon and trout eggs are killed when exposed to direct sunlight. Mytilus larvae prefer darkness during early stage of development.
Locomotion and Orientation	There are three types of locomotion based on light: phototaxis (towards or away from light), photokinesis (movement on the basis of light wavelength and phototropism (movement of a particular part of the body). An increase and decrease in light intensity affect the orientation behaviour in animals. For example, Planaria, a platyheminthes, earthworm an annelida prefers dark area and shows movement away from light as light intensity increases there is increase in the rate of change of direction (negative phototaxis). Euglena a protozoan show positive phototaxis. Example of photokinesis - Locusts stops their flight when sun is hidden by clouds. Dendrocoelum lacteum (flatworm) that prefer dark, wet damp places when exposed to dim light turns occasionally but the rate of turning increases as the light intensity increased. Similarly, ammocoet larvae of Lamprey Lampetra planeri is usually found buried with their head pointed in downward direction in the bottom of water bodies when exposed to high intensity light show active swimming that helps to burrow them again moving away from light source.

	Similarly, sunlight play significant role in honeybees. They are able to orient toward food source and home only when they use sun as a compass to find out the direction of food source. Some insects like moths and other nocturnal animals like bats, owls etc., are active only when there is dark or when very low intensity of light is present.
Metabolism	Metabolic activities are also affected by fluctuation in light intensity. Increase in light intensity increases food intake and enzyme activities in most of the organisms.
Biological clocks	Daily light cycles (Day and Night) have profound role in the development, metabolic activities and behaviour of an organisms. They help in determining daily sleep hours and activity period of an organism. For example, humans and most of the animals are active during the day and their activity ceases during night (also known as Biological Clock). Copepods and zooplanktons come to surface of water as the night advance and with the onset of day again return to bottom.
Reproduction	Light have significant effect on the reproductive activities of many organisms. Duration (day length) and intensity (low or high) of light is decisive in initiation and inhibition of breeding. Gonads in birds become active only during summer when light intensity is high. In case of catfishes increased day length is responsible for attainment of maturity. Quail are long day breeder. Sheeps are short day breeder.
Migration	Migration in most migratory birds, eels and salmon fishes are affected by photoperiodism. Some birds migrate towards north in summer when days are long and migrate towards south in response to short days of winter.
Pigment formation	The light intensity also changes colour of skin. Pigment formation is induced by light e.g., skin colour of lizards and frog becomes light in bright light. In humans due to exposure to direct sunlight for long period results in tanning and even darkening of skin due to the production of melanin.

3.4.2. Temperature

The temperature is the most familiar and important physical factors of the environment and exerts its influence upon living organisms in several ways. The body temperature of many animals fluctuates with the change in the environment temperature. Such animals are called cold-blooded or poikilothermic (ectothermic) animals. e.g., all animals like reptiles, fishes, amphibians except birds and mammals. On the other hand, birds and mammals are able to regulate their body temperature at a constant level irrespective of the surrounding temperature and are known as warm-blooded or homeothermic (homoiothermic) or endothermic animals. In comparison to above mentioned two categories some animals have limited power of temperature regulation and they are called heterotherms, e.g., the monotremes and some marsupials. In all cases the temperature of an animal depends on the balance of those factors which tend to add heat and those which tend to decrease it. Temperature regulates all biological, physiological and chemical processes. It is also responsible for the zonation and thermal stratification that occur in both water and land environment. It plays significant role in the distribution, growth, development, respiration, reproduction, survival etc. Temperature varies greatly from place to place in different environment such as aerial, terrestrial, aquatic (fresh or marine). Temperature variation is much more pronounced in terrestrial environment in comparison to aquatic. Not only this, there is fluctuation in day and night temperature. Even there is great variation in temperature of different regions of earth. Temperature of polar region is very cold and of tropical and equatorial region is hot. The effects of temperature arenumerous and pronounced which can be discussed under the following headings.

a) **Effect of temperature on distribution:** The temperature act as an essential limiting factor in the distribution of plants and animals. Temperature can limit the distribution of any species at any stage of the life. The temperature particularly affects the distribution of poikilotherms or the so-called cold-blooded animals whose body temperature is mostly dependent on that of the environment. The temperature is not a limiting factor for most birds and mammals and this is the reason why only the birds and mammals occur in the coldest as well as in the warmest parts of the world. For instance, coral reefs require a minimum temperature of 21^{o}C for their existence;

therefore, they don't exist in colder regions with temperature below 21^{o}C. Aquatic animals have a narrow range of tolerance to temperature than terrestrial animals. Temperature also plays significant role in the distribution of plants. Latitude and altitude of a place also brings variation in temperature. These three together are responsible for the type of vegetations of a particular geographical area. For instance, vegetations of tropical and subtropical regions are different from that which is found in temperate and alpine regions. Earth's vegetation can be chiefly divided into following four categories on the basis of temperature prevailing in a particular geographical area:

- **Microtherms**- Plants that can survive inlow temperature e.g., plants of temperate and high-altitude regions dominated by mixed coniferous type forest.
- **Mesotherms**- Plants that can tolerate high temperature of summer and low temperature of winters e.g., deciduous forests of tropical and subtropical regions.
- **Megatherms-** Plants those are capable ofsurviving in high temperature prevailing throughout the year e.g., plants of tropical rain forest.
- **Hekistotherms**- Plants that can tolerate extremely low temperature e.g., plants growing in alpine regions.

b) **Effect of temperature on metabolism:**It regulates the metabolic, enzymatic, hormonal activities both in plants and animals. The rate of metabolism and enzyme activities increases with increasing temperature. Not only this, temperature also influences the rate of transpiration, evaporation, photosynthesis and respiration.

c) **Effect of temperature on growth, development and reproduction:** An optimum temperature is necessary for the process of growth and development to proceed at a normal rate and it varies from species to species. In oysters change in optimum temperature results in reduced growth.An extreme of temperature act as limiting and even proves fatal. Temperature also determines the breeding seasons of organisms. Some animals breed throughout the year and some in winters or summer or spring depending on the temperature. Temperature affects the fecundity (egg laying capacity or ability to produce young ones)and sex-ratio in animals. For example, Daphnia (a small planktonic crustacean)commonly known as water flea reproduces parthenogenetically resulting in emergenceof females from the eggs. But when the temperature of the environment is increased, they reproduce sexually giving riseeither male or female individuals. In case of alligators and crocodile’s temperature determines the sex. Only male offspring’s hatches from the eggs when temperature is around 34^0C or above and when temperature is around 30^0C all female offspring emerges from the eggs. In insect’s optimum temperature favours rapid growth and multiplication whereas extremes temperature slows down this process or have adverse effects. Structures like spores, cysts, pupa, cocoon, seeds are produced to cope up with unfavourable environment conditions (like extremes of temperature). Plants undergo dormant or inactive state known as Dormancy during which plant stops growing actively, also known as resting period. Plants also show seed dormancy (seed germination is ceased) to avoid unfavourable conditions. Some animals undergo hibernation (winter sleep), a state of inactivity during winter to conserve energy and some aestivation (summer sleep), a state of inactivity during summer. Insects undergo diapause, aperiod of suspended development.

d) **Temperature and moisture**: The interaction of temperature and moisture depends on the relative as well as the absolute values of each factor. The temperature exerts a more severe limiting effect on organisms when the moisture is either very high or very low. The moisture plays more critical role in the extremes of temperature. For example, the cotton boll weevil cannot develop if the relative humidity is less than 40% or more than 88%, no matter how favourable the temperature may be. The animal remains dormant, regardless of the humidity, if the temperature is lower than 10^oC or higher than 39^oC.

e) **Effect of Temperature on animal behaviour and structural modification**: Certain animals show variations in responses to certain stimulus with variation in temperature. It may show positive response to one stimulus at one temperature and negative response to the same stimulus at a different temperature. Temperature changes are also known to affect structural changes. Drosophila may undergo structural modifications at high temperatures. Facets of eyes, eye size and change in number of eggs than usual i.e., 6 is also affected by change in temperature. This can be well explained by the phenomenon of cyclomorphosis, which explains the relation between seasonal changes in temperature and change in body structure accordingly. Thus,cyclomorphosis can be defined as*different structural modifications undergone by certain animals to cope up with the seasonal changes in temperature*. It is observed in head size during different seasons in Cladocera (Daphnia). Colour patterns in many insects can be induced or changed by regulating the temperature under which they develop.

3.4.3. Water

Water serves as a fundamental media for existence of life forms on earth due to its certain unique properties. It is also referred as universal solvents. It effects growth and geographical distribution of both plants and animals. A plant varies in the amount of water they are able to absorb from the soil and transpire. Plants that have more water requirement and have high transpiration rate are limited to habitat where there is sufficient water. Water act as the limiting factor in land environments than aquatic as the amount is subjected to great fluctuations. Aquatic animals also maintain a proper balance of water by the process of osmoregulation. Water also plays significant role in metabolism. The heat holding capacity of water helps in the maintaining constant temperature.On the basis of amount of water required for excretion animals are divided into three main categories: ammonotelic (more water is required for elimination of waste), ureotelic (less water is required for elimination of waste) and uricotelic (least amount of water is required for elimination of waste). If the total gain in water is equal to loss, the animal is said to be in water balance. On the other hand, if water loss is not covered by an equal gain, the animal is called in negative water balance.

3.4.4. Humidity

The moisture in air in the form of water vapour is called **humidity**. In other words, humidity represents the amount of water vapour in theatmosphere.Humidity along with light and temperature plays an important role in regulating the activities and the distribution of organisms.Animals in rain forests live only where the air is almost saturated with moisture`. Desert animals live where the air is extremely dry. According to Gloger’s rule, the birds and mammals of warm humid regions tend to be darker in colour than inhabiting the cold or dry regions of their geographical range. Insect *Lepisma saccharina* (silver fish) reproduces only when relative humidity is 85 to 90 percent. Young ones die when relative humidity is less than 70 percent.*Tse -tse* fly vector of *Trypanosoma gambiense* do not survive when relative humidity is more than 88 percent. Larva of Silkworm,*Bombyx mori* do not undergo pupation when air is moist. Humid conditions also favour the growth of several microorganisms and fungi.

3.4.5. Wind

Wind has direct(mechanical) and indirect (Physical) effect on living organisms. This effect is more pronounced in case of plants. Mechanical effects of high speed of wind includebending, flattening, and breakage of tree branches and uprooting of trees. Physical effects include desiccation, salt spray near sea coast, dwarfing and deformation. Not only this, wind also had positive aspect that is it helps in dispersal of pollens, seeds, small organisms, and wind pollination (anemophily). It is alsoessential for movement of clouds resulting in rain in various parts of the world.

3.4.6. Weather

Many of the physical factors like the temperature and light are correlated with seasonal changes in weather. Some animals in the temperature zones can tolerate a wide range of temperature fluctuations. Many, however, are killed at extremely low temperature. But their races are preserved by their spores, eggs and larval forms, which can withstand such extreme conditions. The hazards of winter are met by animals in various ways like migration, hibernation, and changes of food habits. This is the reason why food chains in winter differ greatly from those in summer.

3.4.7. Soil

Soilis an edaphic factor of great ecological significancewhich is formed by the breaking down and decomposition of rocks due to weathering (action of rain, water, wind, temperature etc.), the action of soil organisms, earthworms, and interactions of various chemical substances.It determines the distribution of plants and its type directly or exerts indirect effect with the help of other essential factors like temperature and water. It provides minerals, nutrients and medium for support and anchorageto plants. It also provides homes for large number of organisms like bacteria, fungi, protozoa, nematodes, rotifers, earthworms, molluscs and burrowing animals.The importance of soil may be realised from the statement of Sundar Lal Bahuguna (1987): “the eternal truth that soil and water are the two basic capitals of humankind and natural forests are the mothers of rivers and the factories for manufacturing soil”.

3.4.8. Currents and Pressures

Currents are generally movement of large quantity of water from one place to another. Water currents have profound impact on the distribution of various organisms particularly planktons. They also redistribute heat, nutrients, gases, minerals, food particles and other substances supporting many aquatic organisms and ultimately, ecosystems of the world. Oceanic currents regulate the global climate.

In the ocean hydrostatic pressure plays significant role. It increases proportionately with increasing depth of the water body. The impact of pressure in depth of the sea is more on animals which have air spaces, cavities, bladders or sacs in their body. Therefore, to overcome this stress organisms living in deep sea water either don’t have air spaces, cavities or bladder to avoid crushing by pressure and in any case, they are present, then they are filled with fluid or oil. Thus, oceanic pressure has depressing effect slowing down the pace of life.But this is quiet opposite in case of land. Here the atmospheric pressure decreases proportionately with the increase in altitude above sea level.

3.4.9. Fire

Fire is both limiting and regulatory ecological factor. It is caused by physicalas well as biological phenomena.Under physical causes comes lightening, sun heating during summer, rubbing of trees and volcaniceruptions. Biological causes are further two types: natural and anthropogenic. Fire scars provide us with valuable informationregarding the history of a forest. The fire used for clearing the forest has several known impacts:

- Destruction of flora and fauna
- Destruction of organic matter (Humus)

- Climate change
- Disturbances of Biogeochemical cycles
- Removal of Fire sensitive species thus disturbing ecological balance.

Apart from above mention impacts of fire it has certain ecological importance.

- Regeneration of vegetation by stimulation of dormant seeds lying down in soil.
- Increases porosity of soil by increasing noncapillary pores in the soil.
- Many pests and parasites are killed by fire.
- Used for removal of weeds
- Maintenance of soil pH.
- Maintenance of grasslands
- Destruction of litter by burning.

Self-Assessment-1

Q.1.What are various physical factors of environment? Name them.

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Q.2.What do mean by micotherms?

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Q.3. What are poikilothermic animals? Give examples.

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3.5 Limiting Factors

Existence and survival of an organisms or a group of organisms depends uponprevailing complex environmental conditions. Any condition that approaches or exceeds the limits of tolerance is said to be a limiting condition or a limiting factor (Odum, 1983). Under steady state conditions anorganism needs essential materials or substances that are necessary for survival, growth and reproduction. Therefore, any factorthat tends to slow down this process is known as limiting factor.This can be well understood with the help of following laws that will give usan insight into how organisms are greatly influenced by their environment?

3.5.1. Liebig's law of minimum

An organism proves to be weak when essential elements needed for its growth and development is not available in optimum quantity. Justus Liebig in 1840 explainedclearly in hisstudies on the effect of various environment factors on the growth of plant and he reached to the conclusion that the crop yield was frequently limited not by the essential elements like carbon dioxide and water needed in large quantitiesthat was available in abundance, but by the other elements like zinc that was needed in minute quantities and was scarcely available in the soil.This was later knownas the "Liebig's law of the minimum."According to this law *"growth of a plant is dependent on the amount of food stuff available to it in minimum quantity*". In a simplified form growth is dictated not by total available resource but by the resource that is scarce or absent.

Liebig-Blackman law of limiting factors: The Liebig law generally took into account chemical material required by plants in their natural environment. The first constraint associated with Liebig law was that it was strictly applicable only under steady state condition. That is, when there is balance between energy and material inflow and outflow. Therefore, the statement given by Liebigwas combined with the law of limiting factors first proposed by British physiologists F. F. Blackman (1905) who studied the factors affecting the rate of photosynthesis and observed that the rate of photosynthesis in the plant was mostly governed by the level of the factors that was operating at a limiting intensity. According to him amount of carbon dioxide, water, sunlight, chlorophyll and temperature of the chloroplast are the five factors that have decisive role in controlling the rate of photosynthesis. The two-concept combined together form the so-called**Liebig-Blackman law** of limiting factors.

The factor interaction: The second important consideration is factor interaction. In this case high concentration or availability of some substances or the action of some factors other than that factor which is present in minimum quantity can also modify or manipulate (increase or decrease) the rate of utilisation of the factor that is present in minimum. In some cases, the organisms are even capable of replacing the deficient factor or the substances of the environment with a chemically closely related substance. This can be explained with the help of calciumlevel in molluscs. Strontium has physical and chemical properties similar to calcium and barium and occurs naturally in the form of celestine and strontianite. Molluscs to some extent substitute calcium with strontium in their shells as the latter is available in abundance in their environment. Similarly, plants growing in shady area require zinc in low quantity as compared to those growing in direct sunlight. Therefore, low concentration of zinc will act as limiting factors in case of plants exposed to direct sunlight.

The law of minimum was further restated or modifiedbroadly by Taylor in year 1934.According to him"*The functioning of an organism is controlled or limited by that essential environmental factor or combination of factors present in the least favourable amount. The factors may not be continuously effective but only at some critical period during the year or perhaps only during some critical year in a climatic cycle*."But according to Odum, the concept of minimum should be restricted to chemical materials viz., oxygen, phosphorus etc., which are essential for proper physiological growth and reproduction of an organism. While other factors and the limiting effect of maximum are included in the law of tolerance. Thus, Liebig law of minimum deals with one aspect of the concept of limiting factors.

3.5.2. Shelford law of tolerance

Not only too little of something act as the limiting factor as proposed by Liebigbut also too much of a substance as in the case of heat, light and water also have limiting effect. Thus, an organism has an ecological minimum and maximum in between these two zones there is

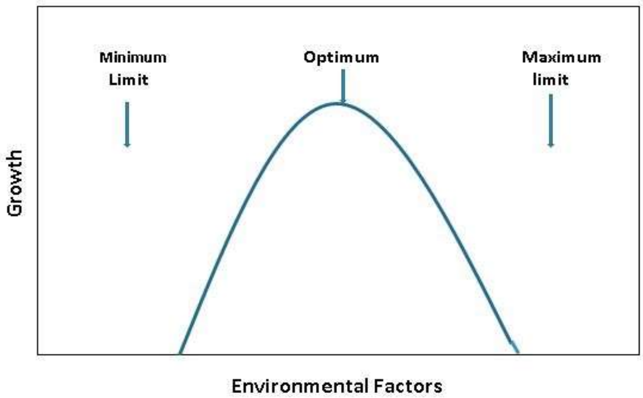

Figure 3: Graphical representation of maximum, optimum and **nit with respect to environmental factors (Like Temperature).**

range known as limits of tolerance **(fig.3)**.

The concept of maximum and minimum in the survival of an organism was incorporated in the law of tolerance by **V. E Shelford** in 1913.According to this law the abundance or distribution of an organism can be controlled by certain environmental factors where levels of these exceed the maximum or minimum limits of tolerance of the organisms. Any value lying between these critical limits will naturally fall in the limits of tolerance(**fig.4**) for an organism. But before this range is crossed on either side and limits of tolerance are reached, there is a zone of physiological stress here the organisms try to adapt itself. Beyond this zone, if the organism is exposed for a considerable time it will lead to the disappearance of the species from that area as long as such conditions prevail.

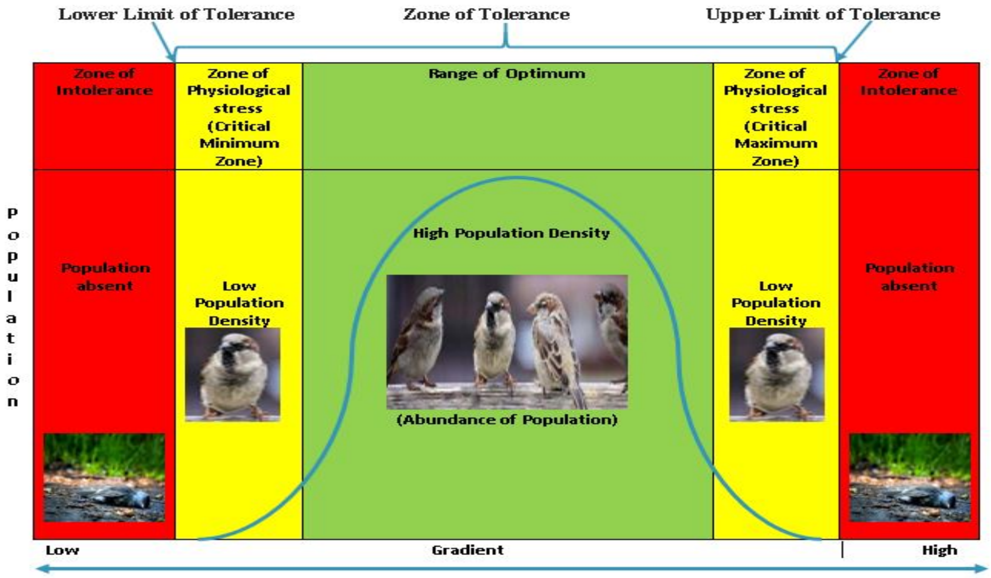

Fig.4. Graphic illustration of Law of tolerance (Smith, 1977; Verma and Agarwal, 2012).

Further according to this law there are following two zones for every environment factor.

1) Zone of tolerance

2) Zone of intolerance

1) Zone of tolerance- It lies between the lower and upper limit of tolerance. It is the most favourable zone for the growth, development and survival of an organism. Therefore, it is also known as zone of compatibilityor the biokinetic zone or the zone of capacity adaptation. Further this can be subdivided into:

Optimum zone- with most favourable and advantageous environmental conditions for the growth and development of an organisms and result in population rise or build-up.

Critical minimum zone- lowest bearable limit below which activities of an organisms inhibited so that the organism could survive in adverse environmental conditions

Critical maximum zone- highest maximum bearable limit beyond which the activities of an organism is ceased to survive adverse environmental conditions.

2) Zone of intolerance -The zone at the either end of the zone of tolerance is known as zone of intolerance or lethal or resistance zone. Here in this zone the environmental conditions are least favourable. The organisms in the zone are not able to withstand harsh climatic condition as a result unable to survive.Therefore, in this zone organisms are absent.

Some subsidiary principles to the law of tolerance are mentioned below:

- Organisms have a wide range of tolerance for one environmental factor and a limited range for another.
- Only those organisms are widely distributed which have wide range of tolerance for all the environmental factors.
- When one environment factor is not conducive for an organism than the limit of tolerance for other factors is also greatly reduced. For example, when the availability of nitrogen in the soil is less than the optimum the resistance of the grass to the drought is reduced. In other words when the amount of nitrogen is low in the soil than more water is required to prevent plants from wilting (Penman, 1956).
- In nature organisms are not always provided with optimum range of a particular physical environmental factor. Instead other environmental factor exerts significant influence on the organism. For example, certain tropical orchids grow better in full sunlight than in shade when they are kept cool (Went, 1957). But in nature they grow only in shade as they cannot tolerate the heat of direct sunlight. Even

Examples of tolerance ranges

Take temperature for example. Polar bears are able to survive and withstand very low temperature. But are unable to withstand hot temperature of tropics. Giraffe can survive in high temperature condition of Savana but are unable to withstand the cold climate of arctic and eventually die.

interspecific interactions like competition, predation, and parasitism also prevent organisms to take benefit of optimum physical environmental conditions.

- Physical environmental factors prove more limiting to various reproductive stages (seeds, eggs, larvae) of plants and animals due to very restricted range of tolerance. For example, Adult blue crab (marine animal) can survive in sea as well as in fresh water with high chloride content. But on the contrary their larval forms are unable to survive and reproduce in fresh water. Here in this case the river water acts as limiting factor.Similarly, Cypress tree can grow submerged in water and even in dry upland, but needs moist unflooded area, a combination of both the conditions for the growth and establishment of seedling.Species having narrow range of tolerance are represented by prefixes “steno” meaning narrow and those having wide range of tolerance are represented by “eury” meaning wide(**Fig.5**).Therefore, following terms are used to show relative degree of

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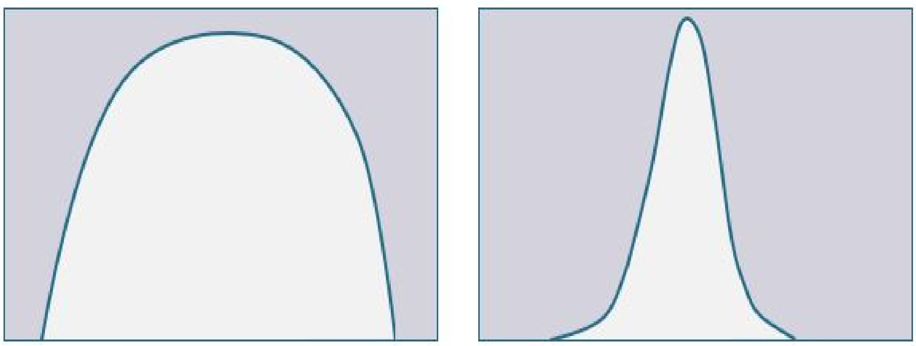

A. Eurytopic **B. Stenotopic**

Fig.5. Tolerance curves showing two main types of responses of an organism to different environmental factors

- ❖ Eurythermal- organisms which are able to tolerate a wide range of temperature.
- ❖ Stenothermal- organisms which are able to tolerate small range of temperature.

- Stenohaline- able to tolerate only a narrow range of salinity.
- Euryhaline- able to tolerate wide range of salinity.
- Stenophagic- has a narrow range of food.
- Euryphagic- has a wide range of food.
- Stenohydric- tolerant of a narrow range of moisture or humidity.
- Euryhydric-tolerant of a wide range of moisture or humidity.
- Stenobathic- can tolerate only limited changes in depth.
- Eurybathic- tolerant to both deep and shallow water.
- Stenoecious- have restricted range of habitat or niche.
- Euryoecious-have broad range of habitat or niche.

Self-Assessment-2

Q.4. What are the two main laws that explains the influence of environment on the organisms?

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Q.5. Law of Minimum was given by_____ in year ____?

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Q.6. What do you mean by eurythermal and stenothermal animals?

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3.5.3. Importance of limiting Factors

1. It is valuable because it gives the environmentalist an insight of complex environmental conditions.
2. To discover factors those are operationally significant (Odum, 1983).
3. To determine how environmental factors, affect an individual, population and community.

Case Study:

Great South Bay on Long Island, New York is the best example of concept of limiting factors. How too much of one factor act as limiting for one organism and proves favourable for other, thus changing the ecosystem of that area. Here in this case, the duck manure from the large duck farm situated in this Island acted as the main cause for the addition of excess amount of nutrients into the water. This condition resulted in the increase in the population of phytoplanktons, that resulted in low nitrogen and phosphorous ratio which acted as the limiting factor and there was shift in the type of producers i.e., diatoms, green flagellates and dinoflagellates were replaced by small green flagellates of genera *Nannochloris* and *Stichococcus*. This shift in the producer created problem for blue point oyster (that supported profitable industry of the bay) thriving on original phytoplankton populations. The oyster population was unable to utilise small green flagellates as food and gradually disappeared from that place. A major setback for the oyster industry of Great South Bay. Not only this, other shellfish were also eliminated from that place. The reason for their elimination was that the green flagellates (new type of producers) grew well when nitrogen was available in the form of urea, uric acid and ammonia which in this case provided by duck manure. Whereas the diatoms, original inhabitants of the bay required inorganic nitrogen (nitrate) which is a long process.

So, this case study is a very excellent example of how a species exclusive to particular area or region is replaced by another rare species with change in any physical factor. This case study was very well known by “The Duck vs. The Oyster.” (Odum, 1983).

3.6. Summary

Environment of organisms plays very crucial role in the survival. Mostly the physical factors have significant effect on the living components. Living organisms tries to adjust and adapt themselves to different factors of the environment as they have different requirements and tolerance for different factors. The presence or absence

of physical factor(s)decides or limit the actual distribution and abundance of plants and animals geographically. This stress in the organisms to cope up with complex environmental conditions has led to morphological and physiological modifications in organisms in due course of evolutions. Those whichare not able to do so are either limited to certain places or become extinct. Further, the physical factors have different impacts on an organism or population at different time, place and conditions. Environmental condition that exceeds the limits of tolerance of an organism act as a limiting factor. Apart from this, maximum and minimum of an environmental factor too have limiting effect. A range in between these two indicates tolerance level of an organism. The concept of limiting factors helps the environmentalist to know about environmental conditions that are critical and limiting. That is abundance and scarcity of essential nutrients, minerals, physical and chemical nature of the environment significantly decides the existence of organisms on this planet earth.

Thus, above knowledge can be utilized in increasing the production of crops in agriculture and managing pest population without disturbing the ecological balance.

Terminal Questions

Q.1. What do you understand by a limiting factor? Discuss in detail.

Q.2. Discuss the effect ofphysical environmental factors temperature and humidity on an organism.

Q.3. Describe the Shelford law of tolerance in detail with suitable examples.

Q.4. Give an account of Liebig law of minimum.

Q.5. Discuss the role of light as an environmental factor.

Q.6. Write short note on:

(i) Zone of tolerance

(ii) Factor interaction

(iii) Zone of intolerance

Q.7. Define:

(i) Cyclomorphosis

(ii) Environmental factors

(iii) Limiting Factor

Answers of Self-Assessment

1) Temperature, light, humidity, current and pressure, water, soil, fire etc.,
2) Plants that can survive in low temperature.
3) Animals whose body temperature fluctuates with change in environment temperature.
4) Liebig Law of Minimum and Shelford Law of Tolerance.
5) Justus Liebig in 1840.
6) Eurythermal organisms are able to tolerate a wide range of temperature. Stenothermal organisms are able to tolerate small range of temperature.

Glossary

Celestine- It is a mineral consisting of strontium sulphate.

Fecundity- Ability to lay eggs or produce offspring.

Intolerance-Inability to bear or endure adverse environmental conditions.

Limiting factors- Environmental factors whose absence or presence influence the abundance, distribution and limits the growth of an organism.

Poikilothermic- Cold blooded animals whose body temperature fluctuates with change environment conditions.

Thermal stratification- It refers to change in temperature at different layers of large water bodies like lake.

Tolerance- The ability to deal with adverse environmental conditions.

Vegetations- Plants and trees of a specific region is referred to as vegetation.

Strontianite- It is an important mineral containing the chemical element strontium.

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Unit 4: Introduction to Environmental Science

Unit structure

4.0 Learning Objectives

After reading this unit you will be able to:

- Define Environmental science
- Know the history behind the emergence of concept of environmental science
- Understand the multidisciplinary nature of environmental science and about its sub-divisions.
- Describe its scope and importance
- Understand the need of public awareness
- Recognize different environmental challenges
- Understand the need of environmental education

4.1 Introduction

You have already learned in the previous units (1-3) about environment, its types, scope, components, limiting factors and its importance. Through these units you must have understood the importance of environment for the survival, growth, development, reproduction and health of all living organisms. Earth environment is the only home that we have and it provides air, food, water and other needs to us. So, entire life support system depends on the well-being of the environment and its components. You have also gone through the various human activities that are adversely affecting our environment by disturbing the balance of nature.

In this unit we will discuss about Environmental Science, its nature and the reason behind its emergence as a separate field of science. We will also discuss how the integration of environmental science with other fields e.g. biology, chemistry, ecology, statistics, computer science etc. any environmental issues can be handled. A study of this unit will help you to understand the scope and importance of this branch. It also enables us to know why public awareness is required in solving various environmental issues and how the environment education can be useful in doing so.

4.2 Environmental Science

You have studied about environment in Unit-1 and you know that everything that surrounds us comprises environment. It covers all the external forces, influences and conditions that affect the life of living organisms. It is the combination of physical, chemical, biological and social components on Earth that directly or indirectly affects the development and survival of an organism. Among all components, the humans under biological component occupy a central position among other organisms. Therefore, nowadays major focus is on the various anthropogenic activities affecting the environment at global level. Apart from this several socio-economic, cultural and political factors are also simultaneously influencing our environment.

In today's world human perception of nature, natural resources and wildlife has been changed. Now humans have started realizing that he is just a species among other species on Earth and his well-being is linked to well-being of others. Severe environmental problems like climate change, pollution, global warming, ozone layer depletion, acid rain, deforestation, desertification etc. are evident as major threats to the life existing on Earth. For this, general knowledge about life supporting environment, its working and persisting environmental problems has become obligatory. Since no other academic discipline covers the above-mentioned areas completely, therefore new academic discipline i.e.

environmental science has been introduced to fillthis gap. The study which includes various aspects of environment like its quality, its maintenance and conservation of its biotic and abiotic components can be collectively stated as **“Environmental science”**. It can be defined as “the study of all systems of air, land, water, energy and life surrounding the man”. It is an applied science that deals with every issue affecting organism and is mainly concerned with the analysis of human impacts on the physical, chemical and biological environment of Earth. According to some academicians, environmental science is a study of the environment including all biophysical as well as anthropogenic conditions under which an organism lives.

The Environmental science came into existence after the 1960s. Rachel Carson’s environmental science book named “*Silent Spring*” (1962) documented the adverse effect of indiscriminate use of pesticides addressing environmental issues for the first time. Many issues like Santa Barbara oil spill (1969) in California and catching fire incident in the Cuyahoga River of Cleveland, Ohio (1969) increased the visibility of environmental matters. The book named “*Limit to Growth*” by Club of Rome (1972) and the United Nations Conference on the Human Environment (Stockholm Conference, 1972) also drew the attention of the world towards environmental imbalance. As the outcome of this conference, The United Nations Environment Programme (UNEP) was created. Further in 1987, Commission (formerly known as the World Commission on Environment and Development) introduced the term Sustainable Development in its report “*Our Common Future*” focussing on the need of balanced development process for the welfare of nature and future generations. This report influenced the Earth Summit; Rio de Janeiro, Brazil (1992) where the Agenda 21 related to sustainable development was adopted. Similarly, in 2002 at Johannesburg (South Africa), the World Summit on Sustainable Development was held that also emphasized on eco-friendly developmental processes. In the same context, “*The Future we Want*” is the declaration on sustainable development and a green economy adopted at United Nations Conference on Sustainable Development (2012) in Rio.

As discussed above, the concept of environment and environmental problems are no more restricted to a region, country or continent but have become a matter of global concern.

For example, the leakage of a toxic gas in the air from the industry in USA may to some extent also polluted the air of Europe. We Indians were alarmed due to oil spillage in the Arabian Sea and Indian Ocean during Iraqi invasion of Kuwait (Gulf war). These global environmental concern led to the creation of various international environmental agencies and non-governmental organizations (NGOs), including United Nations Environmental Programme (UNEP), Global Environmental Monitoring System (GEMS), World Commission on Environment and Development (WCED), World Conservation Strategy (WCS), International Union for Conservation of Nature and Natural Resources (IUCN), World Wide Fund for Nature (WWF), and Global Environmental Facility (GEF),Scientific Committee on Problems of the Environment (SCOPE), United Nations Conference on Environment and Development (UNCED). Similarly, many scientific forums and conventions were held for settling environmental issues, for example Ramsar Convention for conservation of wetland fauna and flora, Montreal Protocol for protecting the ozone layer, Kyoto Protocol for reducing emission of greenhouse gases, Intergovernmental Panel on Climate Change (IPCC) for quantifying the extent of global warming and Convention on Biological Diversity (CBD) for biodiversity conservation. These developments lead to the emergence of environment science as new academic field to tackle the environmental problems.

Environmental science is driven by three basic aspects i.e (i) need of multi-disciplinary approach to analyse complex environmental problems; (ii) advent of environmental laws needing specific environmental protocols of investigation; (iii) growing public awareness towards various environmental problems. Since 1970s, environmental science has been encouraged worldwide and included in the formal education systems of different countries in order to create awareness among peoples. In India, 2003 onwards environment education has been made compulsory at graduate level in all the universities and colleges.

Check your progress – 1

Q1. Define Environmental science?

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Q2. Name some of the common environmental organizations?

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4.3 Multidisciplinary Nature

The environment and its persisting problems are highly complex due to which it requires interdisciplinary efforts to understand them. It assimilates approaches of various disciplines to fulfil its objective. So, it can be defined as interdisciplinary field that integrate various academics fields (physical, biological, chemical and information sciences etc.) to understand the structure, function and environmental problems of environment. Environmentalists are generally concerned with the understanding of earth processes, assessing different energy systems, pollution control, natural resources and its management and global climate change etc.

Basically, core subjects of Environmental science are biological sciences like zoology, botany, microbiology and physiology etc. But many environmental concerns can be resolved through application of other academic disciplines. Disciplines like physics, chemistry, geography, geology and atmospheric sciences help us in understanding physical, structural and functional organization of our environment. For example, to understand the phenomenon of global warming, computer models are created by physicists for studying atmospheric circulation and infra-red radiation transmission, atmospheric chemicals and their reactions are inspected by the chemists, plant and animal contributions to carbon dioxide fluxes are analysed by biologists whereas meteorologists and oceanographers help in understanding the atmospheric dynamics. Similarly, mathematical science is used in environmental modelling whereas for data interpretation application of statistics and computer science is required. The expertise from the fields of environmental engineering and architecture helps in finding solutions to technical issues like pollution management, waste management, green building, and green energy and focuses on design and technology for improving environmental quality.

The activity of living and non-living component of the environment is governed by laws of physical, chemical, geological and biological sciences whereas; human activity and their behaviour are studied under psychological, political and social sciences. Rules for maintenance of healthy state of environment come under authority of national legislation while agreements related to environmental issues faced by different countries come under international law. International cooperation is an essential aspect for dealing global environmental issues like climate change, ozone layer depletion, environmental pollution, trade in hazardous substances, biodiversity loss, depletion of natural resources, ecological imbalance etc. Economics aids in better understanding of the social background required for achieving growth and development. For the fulfilment of above-mentioned goals management studies will help in formulation and implementation of environment related policies. Apart from this, environment study is also connected with philosophy, ethics and cultural traditions that help in achieving our goal sustainably. Therefore, environment science requires different experts from various fields of science while taking any environment related decisions. Thus, we can say that environmental science has multidisciplinary approach that integrates with various academic fields i.e. physics, chemistry, biology, ecology, anthropology, geography, geology, climatology, atmospheric sciences, archaeology, environmental economics, sociology, statistics, political science, law, economics, philosophy, management, technology, ethics and health science etc. to analyse and manage different complex environmental problems

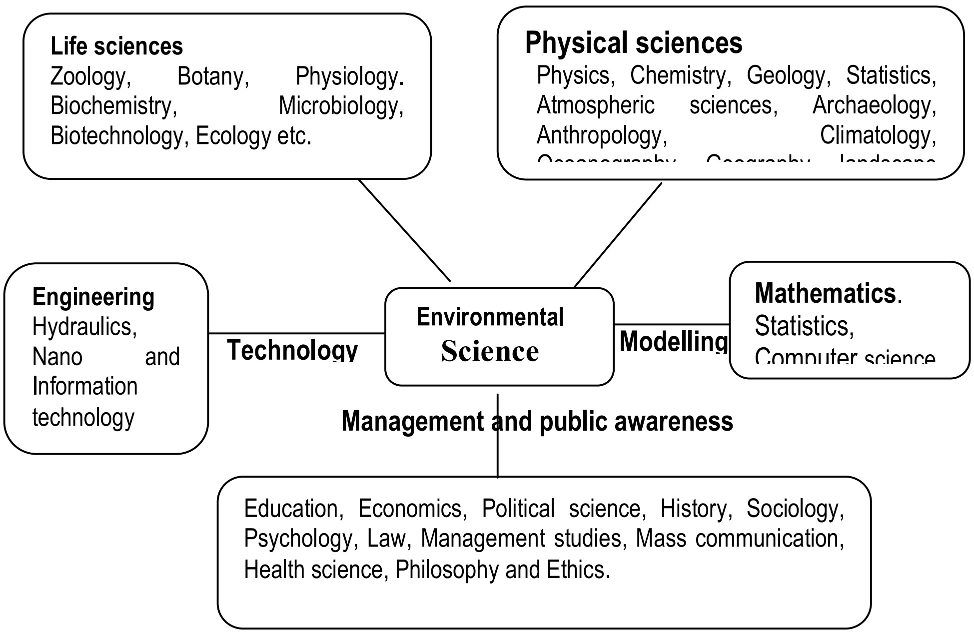

Fig. 1 Multidisciplinary nature of Environmental Science

Environmental science involves the study of several aspects that influence our biophysical environment, earth processes, ecological systems, biodiversity, natural resource, different energy systems, climate change, and different types of pollutions and so on. For this, above-mentioned discipline has been united to develop different subdivisions of environmental science. Its major subdivisions include ecology, geosciences, environmental chemistry, atmospheric science, environmental microbiology, environmental toxicology, and environmental impact assessment. Apart from this, other subdivisions are environmental studies, environmental engineering, environmental economics, environmental ethics, environmental management, environmental sociology, environmental biotechnology etc. These are generally treated as independent academic disciplines parallel to environmental science.

1. **Major subdivision of environmental science**

    (i) **Ecology:** It is the study of relations of organisms to one another and to their biophysical environment that include both biotic and abiotic components. It further includes the study of biodiversity, distribution, abundance, biomass and population of organisms along with competition and cooperation among them. Ecologists as environmental scientists, study the relatioNships between environment and the population of a particular species within that environment and various correlating aspects among them. Ecologists are generally involved in conducting fieldwork to collect and analyse data related to persisting environmental conditions and use the information for planning habitat management or environmental projects.

    (ii) **Geoscience:** It involves the study of environment related areas - geology, soil science, volcanoes and the Earth's crust. For example, for analysing the erosion of the Earth's surface in particular area soil scientists, physicists, biologists, and geo-morphologists are involved. Geo-morphologists can study the movement of sediments, biologists study its impacts to the plants and animals, physicists analyses the light transmission changes in erosion causing water, and the soil scientists can make the final calculations on the water flow when it penetrates the soil causing the soil erosion.

(iii) **Atmospheric science:** It deals with the study of the Earth's atmosphere and analyses its relation to atmospheres of other systems. In involves a wide variety of scientific studies relating to space, astrology and the Earth's atmosphere (meteorology, pollution, gas emissions, and airborne contaminants). For example, for studying Earth's atmosphere physicists analyses its atmospheric circulation at particular part, chemist's analysis the chemicals existent in this part and their relationships with the environment, meteorologists study the dynamics of the atmosphere whereas biologists observe how the plants and animals are affected and their relationship with the environment.

(iv) **Environmental chemistry:** It involves the study of the chemical and biochemical phenomenon that occur in environment. It includes atmospheric, aquatic, soil, and analytic chemistry. It involves in understanding how the healthy, uncontaminated environment works and the optimum concentration of chemicals that present naturally in environment. Above understanding helps in the study of the effect of human activities and release of chemical on the environment. For example, on introduction of chemical object into an environment, chemists study its chemical bonding to the soil or sand of the environment and biologist further analysis the chemically induced soil to see its relationship with the plants and animals.

(v) **Environmental microbiology:** It involves the study of microorganisms, their relationship with one another and with their environment. Microbes being omnipresence affects the entire biosphere and plays important role in regulating biogeochemical system of our environment. Environmental microbiologists study the ways through which microorganisms interact with the environment. They study how microbes could aid plant growth and how the microbes can be used to clean up areas contaminated by heavy metals.

(vi) Environmental toxicology: It is a field of science that deals with the study of the harmful effects of various chemical, biological and physical agents on living organisms and the ecosystem. The environmental toxicologists study the toxic pollutants, its potential source, its effect on biophysical environment and identifying the ways for minimizing their toxic effects on humans and other living organisms. They may further conduct experiments to determine the effects of toxins at different concentrations chemicals.

(vii) Environmental analysis: This is concerned with the analysis of the environment with respect to its basic four components i.e. atmosphere, hydrosphere, lithosphere and biosphere. All these components are dynamic and changes with time and space. Analysis of environment enables us in understanding the current and possible changes in the environment as one must be aware of the existing environment and its future perspective.

(viii) **Environmental monitoring, impact assessment and development:** Studies are designed to help us in understand the natural environment and protect it from the negative impact of extensive human activities. It involves the repeated and regular observations on status of chemical, physical and biological factors of the environment, for example chemical monitoring for various chemicals in the environment as well as bio monitoring for changes in the life forms in different ecosystems. It further includes the studies on risk assessment, safety evaluation and sustainable development.

(ix) **Environmental legislation and education:** Environmental legislation involves the collection of laws and regulations related to environment. This further ensures the consideration of environment while taking any decisions that can impact environment. Some of the Environmental legislations are the Environment Protection Act, the Clean Air Act, the Endangered Species Act, the Montreal Protocol, and the Clean Water Act etc. Environmental education is concerned with creating awareness in general public for environmental problems around them through formal and informal education.

Thus, we can say that today environmental science is acting as an active part of the scientific world that has accelerated the need to address Earth's environmental problems. It encompasses multiple scientific fields and sciences to see how all interchange and relate with one another.

Check your progress 2

Q3. Name the major sub-divisions of Environmental science?

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Q4. What is the role of legislation in environmental matters?

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4.4 Scope and Importance of Environmental Science

In the process of development, the quest of human to control and exploit nature and its services, has literally whacked up everything in this Mother Nature. While doing so we interrupted the complex system of environment and its life forms which in turn can results in severe outcomes, the kind of which have not been witnessed before.An environmental science has a vast scope as it covers a wide range of subject matters or issues related to our complex life-supporting system.

Scope: Scope of the subject can be described in terms of its areas of applicability and career opportunities. There are three major areas of its applicability-

(a) management of natural resources

(b) conservation of ecosystem and biodiversity

(c) prevention and control of human induced pollution.

In addition, environmental science plays an important role in solving environmental issues like climate change, global warming, ozone layer depletion, pollution, energy crisis, desertification, urbanization, population explosion, loss of biodiversity, disposal of wastes and so on. The scope of environmental science is not only limited to studying concepts, components and environmental problems, but also to find out a practical global solution by raising public awareness towards the immediate need for environmental protection. In recent decades, environmental science has been considered to be associated with a number of career opportunities. Following are the major career options related to the subject:

- R&D opportunities in this area include research on various environmental issues, for example studying different types of pollution **Research and development**

(R&D):, their causes and effects. It further involves in development of clean and efficient technologies for future. Some of the common carrier profiles are scientists, researchers, and analysts.

- **Consultancy:** Environment consultancies are hired by governments, industries and NGOs for carrying out laboratory-based environmental analysis or studies that is required for environment impact assessment (EIA) and other compliance processes. Environmental experts are needed by industries to guide them for adopting clean eco-friendly technologies, controlling pollution, disposing the wastes, and carrying out environmental audit. For example, ecological consultancies like RAMKY, ENZEN etc.
- **Green media and Green advocacy:** In order to generate environment awareness, there is an immense need for skilled manpower in the field of print and electronic media. A number of magazines and newspapers regularly publish articles on environmental theme, for example, Down to Earth, a magazine published by Centre for Science and Environment. Other environment related magazines are: Nature Conservancy, National Wildlife, and Mother Earth News etc. Today, lawyers are playing important role in ensuring implementation of environmental norms, laws, and programmes. Public Interest Litigation (PIL) is the important way of using law strategically for social change thus empowering people to fight against anti-environment activity.
- **NGOs:** NGOs plays an important role in environment protection as they constitute a world-wide network interacting with government and intergovernmental organization. Now days, most of the environmental programmes are being implemented through NGOs, with the help of funds from national and international agencies. There are large number of NGOs in India and other countries working for environmental protection, conservation and awareness. Some common examples of environmental NGOs are Green-peace, CI, WWF, CSE, TERI, Kalpavriksh, Tarun Bharat Sangh, and Vatavaran and person can start environment related NGO itself.

- **Government jobs, State, National and International agencies:** A number of conventional jobs are available in government sector like in environmental ministry, pollution control boards, national parks, and biosphere reserves etc. Various states, national and international agencies such as UNEP, IUCN and World Bank require qualified human resources for implementing environment-related projects.
- **Academics:** Environmental science has been encouraged worldwide and included in the formal education systems of different countries. Today it is taught at almost every level of education i.e. from school to university level. For this, large numbers of teachers or academicians are required.

At present world is facing several environmental problems that have grown in size and complexity day by day, threatening the survival of mankind on earth. These problems can be solved only when everyone cares for the environment and have the knowledge regarding causes, consequences, and remedial measures of different environmental problems. In order to achieve this goal, environmental science is promoted and taught at different educational levels from school to colleges and universities. The environment science enlightens us, about the need of protection and conservation of environment and has become **important** for the following reasons:

Importance:

1. To realize that environmental problems are global and are of International importance: Environmental science lets us recognize that environment issues like climate change, global warming and ozone depletion, acid rain, marine pollution and biodiversity loss etc. are not just national problems but are global issues and hence must be tackled with international efforts and cooperation.

2. To understand the impacts of development on environment: It's well known that development results in urbanization, industrial growth, expansion of telecommunication and transport systems and hi-tech agriculture etc this affected our environment in various ways. Environmental science makes us aware of various environmental problems and draws the attention of general population towards the need for different environment friendly steps for example, decentralization of industries to reduce congestion in urban areas that will reduce pollution. The aim is to achieve all this sustainably.

3. To understand the interrelationship between organisms: Environmental science is important because it enables us to understand the interrelationships between the organisms. For example, plants produce and release oxygen to the atmosphere that human's need for respiration while humans breathe out carbon dioxide that plants need for photosynthesis. Plants are sources of food for humans and animals whereas animals' faecal matter is the source of nutrients for plants and other organisms. Thus, organisms are dependent on each other for survival.

4. To focus on the need of biodiversity conservation and how to conserve it: Biodiversity is the richness of biological variations on earth. Environment science helps us to understand how the continuous loss of biodiversity due to over exploitation, habitat degradation, and deforestation and land pollution has posed threat to the existence of mankind.

5. To identify sustainable ways of living and development: Environmental science is concerned with finding out various sustainable ways of living without compromising the future generations need. Environmental sustainability means creating awareness among people about proper consumption of resources and minimizing unnecessary waste. This includes minimizing energy consumption, conserving natural resources; embracing the 3 R's reduce, reuse and recycle, conserving power etc.

6. To develop awareness about environmental problems at local, national and international levels: Environmental science aims to educate and equip learners with necessary environmental skills to pass to the community in order to create awareness. Environmental awareness can be created through social media, creating a blog dedicated to creating awareness; community centred green clubs, women forums, and religious podiums.

Check your progress 3

Q5. What are the three main areas of environmental science applicability?

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Q6. Name some career options related to environmental science?

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4.5 Need for Public Awareness

After the agricultural, scientific and industrial revolution in the recent past, huge human impact has been seen on our environment. Today, earth systems are immensely affected by human activities like extracting materials, using energy and emitting pollution for fulfilling the quest of food, shelter and other products of growing population of the world. Over-exploitation of natural resources, pollution of environment, increasing industrialization every year, introduction of the faster mode of transportation, large crowded cities or urbanization, deforestation, use of insecticides, pesticides, improper use of fertilizers and chemicals etc are the contributing factors that affected the life of man, animals and other organisms. Today, earth is going through major environmental changes and the activity of human has upsets the balance of the ecosystem. The raised concentration of greenhouse gases (carbon dioxide, methane, nitrous oxide and ozone) has been already introduced in the environment and that shall persist for long in atmosphere. The chlorofluorocarbons (CFCs) that released due to humans' activities will continue to deplete ozone layer for centuries to come. Forest cover cleared by us shall take decades to regenerate and extinct species will never come back. All these changes and their outcomes will make our lives more and more difficult. The future of entire humanity is at great risk. So, it is essential to make the public aware of the consequences of the environmental degradation, if the reformative measures are not undertaken in time then this may result in the extinction of life too. Today, we are facing various environmental challenges and need of the time is that every individual should get acquainted with these challenges so that we all realize our responsibilities towards our mother Nature and act accordingly in eco-friendly way.

4.5.1. Environmental challenges

1. **Overpopulation:** In this developing world, human population is increasing day by day. To meet the demand of this uncontrolled growing population, considerable pressure is

developing on nature and its resources. It is exceeding the carrying capacity of Earth ultimately leading to imbalance in nature. Hence, the greatest challenge present today is to limit the population growth by developing awareness among people and society. The possible ways that can be helpful in doing so are-empowering women, promoting family planning, government incentives etc.

2. **Poverty:** In India vast majority of our people are directly or indirectly dependent on the natural resources of the country for the fulfilment of their basic needs of food, fuel, shelter and fodder. Large number of people (about 40%) is still below the poverty line. Environment degradation has adversely affected the life and livelihood of poor and tribal population who depend upon the resources of their immediate surroundings. Depleted natural resources, climate vulnerability, rural-urban migration and growing resource demands are the some of the reasons that has harmed the livelihoods and well-being of the poor. Thus, we can say that the challenges of poverty and environment degradation are two facets of the same challenge.
3. **Urbanisation:**In present scenario, urbanisation and industrialisation has given birth to a large number of environmental problems. Due to rapid industrialization job opportunities in particular areas has increased, that diverted the gigantic concentration of people to the urban areas competing for limited resources. Rapid housing constructions leads to the overcrowding problems or development of slum areas having many issues like poverty, inadequate water, poor sanitation facilities, lack of rubbish disposal, industrial pollution etc. Hence, dealing with problems due to rapid urbanization is a major challenge.
4. **Agricultural growth:** Agriculture plays an important role in growth and development of nation. But just like other forms of human activities, growth in agricultural activities for increasing production also have negative impact on Environment. Hi-tech agricultural activities has led to the various environmental problems like soil degradation and erosion, air, water and soil pollution, loss of biodiversity, deforestation, genetic engineering, irrigation problems etc. High yielding verities have caused soil salinity and damage to physical structure of soil. Need of the hour is to meet the agricultural need of the growing demand in sustainable and eco-friendly way.

5. **Need for water conservation and ground water:** In this rapidly developing world, factors like community wastes, sewage waste, industrial effluents, chemical fertilizers, insecticides and pesticides have polluted our surface water and also affected the quality of groundwater. Therefore, the most important challenge of today's world is to restore and maintain the water quality of our rivers and other water bodies. For this there is immense need of finding suitable strategies for conservation of water, provision of safe drinking water and keeping water bodies clean.
6. **Development and Forests degradation:** Forests serve as main role in catchments for the rivers. Today, for fulfilling the increasing demand of water, large irrigation projects were made in order to harness the mighty river. Surely, these developments have some negative aspect too i.e. forests degradation, displacement of local people, biodiversity loss etc In India, forest cover has been declining due to pressures of agriculture, rapid urbanization process and other uses. Earlier rural people and even today the tribal communities inhabiting forests respects trees, birds and animals and plays important role in restoring and conserving forests. In India there are many sacred grooves where plant species are protected by the local communities' thereby playing role in conservation of species. Thus, it is the need of the time to develop strategies for the joint management of forests where traditional knowledge and experience of the local communities and modern techniques of forest Department can be utilized together.
7. **Reduction of Genetic Diversity:** At present most, wild genetic stocks have been disappearing from nature due to certain reasons like climate change, deforestation, habitat loss, overexploitation, pollution and invasive species etc. For example, Asiatic Lions are facing problem of loss of genetic diversity. Genetic diversity is important as it helps to maintain the population health, as individuals with allele's variations are more suited and adapted to the changing environments. Today, the protected areas network like sanctuaries, national parks, biosphere reserves, declining forest cover etc. have isolated wildlife populations thereby decreasing changes of the group breeding with another. Therefore, remedial steps are needed to be taken to check decreasing genetic diversity.

8. **Air, water and soil pollution:** Majority of our industrial plants are the huge source of air, water and soil pollution due to improper disposal of highly toxic industrial and chemical waste. Large number of cities and industrial areas has been identified as the highly polluted area in terms of air, water and pollution. Various environment legislation like The Air Act (1981), The Water Act (1974), The Environment Act (1986) and The Biological Diversity Act(2002) etc. are enforced in the country, but their implementation needs great resources, technical expertise, political and social will. Again, for solving this problem public awareness about these rules is necessary. Their support is indispensable for the implementation of these rules.

Through the study of above-mentioned challenges, it is clear that our environment is getting degraded day by day due to human activities and we need to do seriously something about it. We often take this issue carelessly and feel that government should take necessary steps. But truth is that we all are equally responsible towards our mother nature and the goal of environment protection can be achieved only by joint efforts.Active co-operation of each and every one, at all level of social organization, scientists, educationists, students, politicians and administrators is needed. A little effort by a single person can cause significant improvement in conditions of the environment. For example, a person can use energy more efficiently, one can prefer bicycle over car thus saving petrol and reducing pollution,minimizing the use of paper, a few grains saved by us can make food affordable to poor and couples may decide to have only one or two children and thus contribute in population control. Hence, we can say that major environmental problems can be resolved if the initiation begins at grass root level with the effort of a single individual.For this, public awareness needs to be created. In this context, various media (social, print and electronic) can strongly influence public opinion and can aid in developing public awareness towards environment protection. Also, awareness among people towards environmental issues can be developed by giving

4.5.2 Environmental Education (EE).

Environment education helps individual to understand how their decisions and actions are affecting the environment and to know how we can keep our environment healthy and sustainable for our future generations. Now it is the high time to manage our behaviour and action towards environment and for this environmental education can act as a milestone.

Check your progress 4

Q7. Mention any four environmental changes.

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Q8. Name some environment related Act?

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4.6 Summary

In this unit we have gone through the concept of environmental science and its various aspects. So far you have learnt that

- ***Environmental science is an applied science dealing with every issue that affect the life of an organism.***
- ***It mainly emphasizes on the analysis of human impacts on the physical, chemical and biological environment of Earth.***
- ***Environmental science has multidisciplinary nature as it integrates various academic fields like physics, chemistry, biology, ecology, anthropology, geography, geology, climatology, atmospheric sciences, archaeology, environmental economics, sociology, statistics, political science, law, economics, philosophy, management, technology, ethics and health science etc. for dealing complex environmental problems.***
- ***Ecology, geosciences, environmental chemistry, atmospheric science, environmental microbiology, environmental toxicology and environmental impact assessment etc are its major subdivisions.***
- ***Major areas of its applicability are management of natural resources, conservation of ecosystem and biodiversity and prevention and control of pollution.***

- ***Some of the career options related to the subject are consultancy, research and development (R&D), academics, green media, green advocacy, NGOs, Government jobs, and jobs in State, National and International agencies etc.***
- ***The environment science plays important role in realizing that the environmental problems are global, knowing the impacts of development on it, identifying sustainable ways of living, understanding the need of biodiversity conservation and the need of developing public awareness about environmental problems.***
- ***Today, world is facing challenges like overpopulation, poverty, agricultural growth, need to ground water, forests degradation, reduction of genetic diversity, urbanisation, air, water and soil pollution etc.***
- ***Through above mentioned challenges, it is clear that environment is getting negatively affected day by day due to increasing human activities. For the betterment of environment eco-friendly efforts of each individual is mandatory. And the people can be made conscious about nature, its importance and their responsibility towards environment by developing awareness among them.***
- ***For creating awareness among people towards environmental and its issues Environmental Education (EE) is important.***

Terminal Questions

1) What is environmental science? Discuss its major areas of study.
2) Give an account on history of environmental science.
3) Discuss multidisciplinary nature of environmental science
4) Describe the scope and importance of environmental science.
5) "The need for public awareness about environment is of vital importance." Discuss.
6) Write notes on:
   (i) Environmental agencies
   (ii) Atmospheric science
   (iii) Environmental toxicology

(iv) Urbanization

(v) Environmental Education

Answers

Check your progress – 1, 2, 3 & 4

1) Environmental science - analysis of human impacts on the physical, chemical and biological environment.

   UNEP - United Nations Environmental Programme

   IUCN - International Union for Conservation of Nature and Natural Resources

   WWF - World Wide Fund for Nature

   SCOPE - Scientific Committee on Problems of the Environment

   UNCED - United Nations Conference on Environment and Development

   IPCC - Intergovernmental Panel on Climate Change

   CBD - Convention on Biological Diversity

2) Sub-divisions of Environmental science - ecology, geosciences, environmental chemistry, atmospheric science, environmental microbiology, environmental toxicology, environmental impact assessment and environmental legislation.

3) Environmental legislation - collection of laws and regulations related to environment. –that are considered while taking any decisions that can impact environment. Examples- The Clean Air Act, The Endangered Species Act, The Montreal Protocol, and The Clean Water Act etc.

4) Management of natural resources, conservation of ecosystem and biodiversity and prevention and control of pollution

5) Consultancy, research and development (R&D), academics, green media, green advocacy, NGOs, Government jobs etc.

6) Environmental challenges are overpopulation, poverty, agricultural growth, need to ground water, forests degradation, reduction of genetic diversity, urbanisation, air, water and soil pollution etc.

7) The Air Act (1981), The Water Act (1974), The Environment Act (1986) and The Biological Diversity Act (2002) etc.

Glossary

Abiotic :non-living factors of the environment.

Acid rain : rain or other forms that have acidic precipitation.

Anthropogenic : man-made, not natural

Atmosphere : Gaseous envelop around earth, the air.

Biodiversity : Variety of life forms

Biotechnology : Use of biological processes on industrial scale to produce useful products.

Biotic : living components of environment; pertaining life.

Climate: variation of weather in a region over long periods of time.

Deforestation : conversion of forest areas into non-forest area for agriculture, urban use or developmental process.

Eco : prefix added to words indicating consideration of environment e.g. eco-friendly

Ecology : The study of the inter-relationships between organisms and environment.

Ecosystem : The structural and functional entity of biotic communities and their environment.

Environment : the external conditions in which an organism lives and interacts.

Environmental ethics : ethical decisions with respect to the environment or man's belief about what is right or wrong environmental behaviour.

Environmental science: the study of interactions of physical, chemical and biological components of the environment.

Erosion: displacement of solid/sediments or soil due to agents like wind, water or ice.

Forest: land with canopy cover

Genetic diversity: total number of genetic characteristics.

Groundwater: water located beneath the ground surface.

Global warming: the observable increase in global temperatures mainly due to human activities

Insecticides:a chemical or pesticides used to control insects in all developmental forms.

Intergovernmental Panel on Climate change (IPCC): established in 1988 by World Meteorological Organization and UN Environment programme and is dedicated to providing the world with objective, scientific information related to climate change.

Kyoto Protocol: an international agreement adopted in December 1997 in Kyoto, Japan for reducing emission of greenhouse gases.

Montreal Protocol: an international treaty (1987) designed to protect the ozone layer by phasing out the production of ozone depleting substances especially CFC's.

Natural resources: valuable naturally occurring substances.

Ozone hole: Thinning of the stratospheric ozone layer.

Pollution: introduction of impurities in the environment which is harmful to living organisms.

Silent Spring: environmental science book by Rachel Carson published in 1962.

Sustainable: able to be maintained at a certain rate or level.

Toxicology: Study of the harmful effects of toxic substances on living organisms.

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Unit 5: Environmental Education

Unit Structure

5.0 Learning Objectives

After reading this unit you will be able to:

- Define Environmental Education
- Know the evolutionary history of Environmental Education.
- Understand goals, objectives and guiding principles of Environmental Education.
- Know about the various approaches of Environmental Education and programmes related to it.
- Know about number of Environmental Organizations and Agencies
- Understand the role of adult and women education.
- Describe the advantage of Environmental Education.

5.1 Introduction

From the previous units 4 you are now aware about environmental science, its scope and importance. Through that unit we got the idea that how the multidisciplinary approach of Environment is useful in tackling the environmental issue. Apart from this we also realized that why public awareness is very important regarding environmental problems and for this purpose Environmental Education is necessary.

In this unit we will discuss about Environmental Education and its evolutionary history. We will also discuss about the goals, objective and guiding principles of Environmental Education. As the main aim of Environmental Education is to create general environment related awareness among people which can be achieved through various approaches like formal and non-formal Environmental Education. Today, many environmental related international and national organizations and agencies are involved in environmental activities. For better and healthier future for us and for future generations it is our duty to educate our young generation about environment.

5.2. Environmental Education

Today, we all are facing various environment related problems like climate change, global warming, pollution, ecological imbalance due to biodiversity loss etc. These problems are the outcome of human activities as humans are exploiting mother earth to the core. Now it is very necessary to bring about a sense of awareness related to all environmental issues amongst citizens so that we can understand the value of our life-supporting Earth and its environment. This can be achieved through imparting environment related knowledge to people especially to children and young generation as they are nation's greatest resources and the future of civilization depends on them. For this, teaching Environmental Education in schools, colleges will assist with that. **Environmental Education** is a study of nature, its functioning and persisting environmental problems so that environmental issues can be tackled efficiently. It also involves building of strategies to enhance and sustain nature. Environmental Education creates a positive impact on youth and helps us become conscious of our actions and in making responsible choices. It will regenerate human's interest in conservation and improvement of our environment before it is too late. Environmental Education is not just 'saving the world'. It is also about the development of an appreciation of the wonders and beauty of the world, and a sense of needing to save it or we can say the development of ecological thinking (Palmer, 1998).Several environmentalist and agencies have defined the term in different manner and some of them are as follows-

In "*The Journal of Environmental Education*" written by ***William B. Stapp***(1969) definition of Environmental Education is"Producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of help solve these problems, and motivated to work toward their solution".

Bandhu, Desh (1981) in his paper entitled "*Environmental Education - Needs and strategies*" defines it as "Environmental Education is the process of recognizing values and clarifying in order to develop skills and attitudes necessary to understand and appreciate the inter-relations among man and his bio-physical surroundings. Environmental Education also entails practice in decision making and self-formulating a code of behavior about issues concerning environmental quality."

The International Union for the Conservation of Nature and Natural Resources(IUCN, 1971) has evolved Environmental education definition as "Environmental education is the process of recognizing values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the inter-relatedness among man, his culture and his biophysical surrounding. Environmental education also entails practice in decision making and self-formulation of a code of behavior about issues concerning environmental quality".

Encyclopedia of Educational Research (Mitzel, H. E., 1982) states: "Defining environmental education is not an easy task. Unlike other curriculum areas, the specific content of environmental education has never been well defined. It is universally agreed, however, that environmental education should be interdisciplinary, drawing from biological, sociological, anthropological, economic, and political and human resources. It is also agreed that a conceptual approach to teaching environmental education is best".

A definition of Environmental education first appeared in 1969 in "*The Journal of Environmental Education*" written by ***William B. Stapp***but the need of environmental education was highlighted during seventies period that reflected a growing concern about environmental degradation and world realized that concern and awareness regarding environment can be spread only through environmental education programmes. It mainly emerged from the United Nations Conferences on Human Environment at Stockholm (Sweden) in 1972. This conference emphasized on organization of formal and mass environmental programs and led to the establishment of United Nations Environment Programme (UNEP). In 1975, "*The Belgrade Charter*" was the outcome of an International Workshop on Environmental Education held at Belgrade (Yugoslavia) which was organized by United Nations Education, Scientific and Cultural Organization (UNESCO). Belgrade workshop formulated goals, objectives and guiding principles of environmental education programs to achieve the objectives of Stockholm conferences. UNESCO also launched an environment education newsletter "*Connect*" as an official organ of UNESCO-UNEP International Environmental Education Programme (IEEP). Later in 1977, world's first intergovernmental conference on environmental education was organized by UNESCO in cooperation with UNEP at Tbilisi, Georgia (USSR). The *Tbilisi Declaration* constitutes the framework, principles and guidelines for environmental education at all levels-local, national, regional and international for all age groups both inside and outside the formal school system. In International level, the next initiative for Environmental education was the World Conservation Strategy (1980) by IUCN with funding from UNESCO, UNEP and the World Wide Fund (WWF). In 1987, Moscow hosted the Tbilisi+10 Conference to evaluate the progress of Environmental Education and in the same year, the Brundtland Report "*Our Common Future*" published that states- "Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs."Thereafter, in the same context time to time a series of meetings and conferences were held **(Table – 1)**. In seventh World Environmental Education Congress, Morocco (2013) main topics of discussion include the importance of environmental education, its role to empower, establishing partnership to promote environmental education. In national level various recommendations were made as an outcome of a national seminar, organized by the Indian Environmental Society in collaboration with the International Programme on Environmental management at the Indian National Science Academy, New Delhi in 1979, in which stress was given to integrate Gandhian thought and values as a part of Environmental Education. In 1980, first International Conferences on Environmental Education held in New Delhi, where importance of Environmental Education was observed in developing social consciousness towards harmful effects of ecological disruptions on individual and community.

Table -1: An Evolution of Environmental Education

YEAR	EVENT
1968	UNESCO Biosphere Reserve Conference in Paris-discussion on environmental curricula, training and awareness development.
1969	Definition of Environmental Education first appeared in "*The Journal of Environmental Education*" written by *William B. Stapp*
1970	UNESCO & IUCN – Environmental Education definition. U. S. created the Environmental Education Act.
1972	Human Environment Conference in Stockholm-UNESCO & UNEP funded Environmental Education programme.
1975	Belgrade Charter – proposed initial Environmental Education goals.
1977	First International Environmental Education congress at Tibilisi – goals & Objectives of Environmental Education established.
1980	World Conservation Strategy – declares sustainable development as important for conservation.
1987	Tbilisi+10 Conference in Moscow – to evaluate Environmental Education progress. The Brundtland Report "*Our Common Future*" provides globally recognized definition of sustainability.
1992	Earth Summit in Rio de Janeiro – Agenda 21, a global plan for sustainable development.
2002	Johannesburg Summit – Sustainable development with five target areas.
2005-2014	UN – Decades of Education for Sustainable Development (DESD).
2007	4^{th} International Conference of Environmental Education in Ahmadabad, India, focuses on the DSED.
2013	7^{th} World Environmental Education Congress, Morocco - Discussion on importance of environmental education, its role to empower, establishing partnership to promote environmental education.

Check your progress 1

Q1. Who gave the definition of Environmental Education first time and in which journal?

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Q2. When first International Environmental Education congress was held?

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5.3. Objectives of Environmental Education

Goals of Environmental Education are to develop a world that is aware and concerned about the environment, its components, problems, and has knowledge, skills, attitudes, motivations and commitment towards solution of current problems and the prevention of new ones (UNESCO, 1975). Further, the goals of environmental education as accepted in the Intergovernmental Conference organized by UNESCO/UNEP in Tbilisi, USSR in October, 1977 are as follows: (a) to foster **awareness** and concern about economic, social, political and ecological interdependence in urban and rural areas, (b) to provide every person with **opportunity** to acquire knowledge, values, attitudes, commitment and skills necessary to protect and improve the environment, (c) to create new patterns of **behavior** of individuals groups and society towards the environment.

According **to UNESCO-UNEP** (1978) the main **Objective** of Environmental Education is to develop logical vision among the individual about the local and international societies and encourage participating in resolution of environmental problems through:

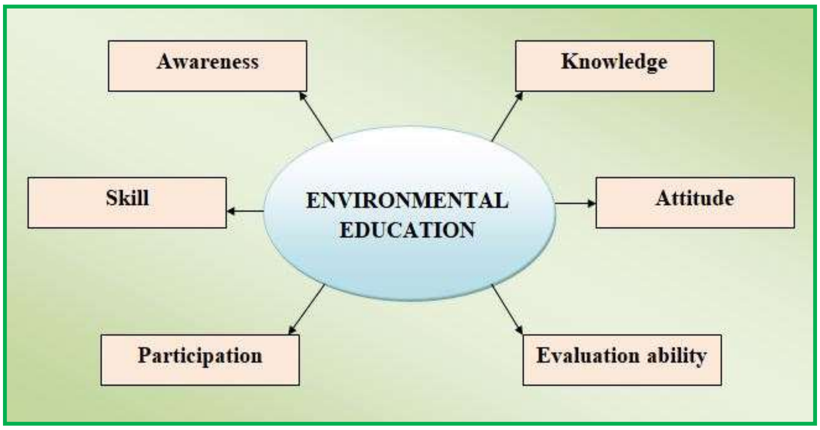

Figure 1: Objectives of Environmental Education

1. **Awareness** – Environmental education helps individual to acquire an awareness of and sensitivity to the total environment and its allied problems
2. **Knowledge** – helps to gain a variety of experiences and acquire a basic understanding of the environment and its associated problems.
3. **Attitude** – helps in acquiring a set of values and feeling of concern for the environment and the motivation for active participation in environmental improvement and protection.
4. **Skill** – helps to acquire skills for identifying and solving environmental problems.
5. **Evaluation ability** – develops ability to evaluate environmental measures and education programmes in terms of ecological, economic, social, aesthetic and educational factors.
6. **Participation** – provide individual with an opportunity to be actively involved at all levels in working towards the resolution of environmental problems.

Further, according to Vidart (1978), the specific aims of Environmental Education fall into three groups:

1. **Cognitive aims:** These include developing environmental knowledge and thinking ability which enable the individual and his social group to work out political solution to the various problems connected with environment.
2. **Normative aims:** These relates to the development of ecological awareness which will be conducive to the creation of modification of value models enabling the individual and the group to identify the factors that disturbs the environment equilibrium and protest against them.
3. **Technical and applicative aims:** This means planning collective practices that preserves, improve or restore the quality of life, as understood by the community through formal and informal education in such a way that the economic development do not conflict with the biological rhythms of the ecosystem.

Check your progress 2

Q3. What are the six main objectives of Environmental Education?

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Q4. How many specific aims of Environmental Education given by Vidart

(1978)?
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5.4. Guiding Principles of Environmental Education

According to the Tbilisi Conference (1977) the following are the **Guiding principles** of Environmental Education:

1) Consider the environment in its totality i.e. natural, artificial or manmade, technological, social (economic, political, moral, cultural, historical, and aesthetic).
2) Consider environment education as continuous life long process (from pre-school to all higher levels-formal as well as non-formal)
3) Be interdisciplinary in approach, in making possible holistic and balanced perspective.
4) Be community based and emphasize active participation for prevention and finding solutions to environmental problems.
5) Examine major environmental issues from world and regional point of view i.e. from local, national, regional and international point of view.
6) Focus on current, potential environmental situations while having account of historical perspective.
7) Consider environmental aspects in plans for growth and development.
8) Emphasize the complexity of environmental problems and need of developing critical thinking and problem-solving skills.
9) Promote the importance and necessity of local, national and international cooperation in the prevention and solution of environmental problems.
10) Utilize diverse learning about environment and different educational approaches to teaching and learning about environment along with practical activities.
11) Help learners to find the symptoms and the main causes of environmental problems.

12) Relate environmental sensitivity, knowledge, and problem solving and values clarification at every grade level.

13) Enable learners to have a role in planning their learning experiences and provide an opportunity for making decisions and accepting their consequences.

Check your progress 3

Q5. Write any two guiding principles of Environmental Education given in Tbilisi Conference, 1977?

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5.5. Environmental Educational Programmes

Based on different discipline, Newman (1981) proposeda three-fold classification of Environmental Education programmes.

Environmental studies: It is concerned with the issues of environmental disturbance and minimization of their impacts through changes in the society (social sciences).

Environmental sciences: It deals with the study of the processes in water, air, soil and organisms which lead to pollution or environmental degradation and to know a scientific ways for establishing a standard that can be acceptably clean, safe and healthy for the natural ecosystem and organisms living within it (physical and natural sciences).

Environmental engineering: This is the study of the technical processes which are used to minimize the pollution and the assessment of impact of this on environment (engineering sciences).

Check your progress 4

Q6. Who proposed the three-fold classification of Environmental Education programmes?

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5.6. Environmental Education in India

India is a country which is highly diverse climatically, geologically, ethnically, socially and economically etc., so Environmental Education has to be location-specific. At the basic beginning level, special attention must be paid to school going children and women that comprises about 50% of the population. They are to be made aware of health, family planning, nutrition, rural development, slum improvement, sanitation, hygiene, water and food contamination, fodder, fuel wood, nature etc. For this purpose, Non-government organizations can play a significant role. There are more than 200 non-governmental organizations, out of which 150 work in the area of Environmental Education and awareness (Sharma, 2018).

The main objective of Environmental Education is development of awareness and knowledge, attitudes, skills and abilities to participate in solving real life environmental problems. The challenge of achieving these goals requires effective educational strategies. The Environmental education has four main interrelated components (i) awareness, (ii) real life situations (iii) conservation, and (iv) sustainable development. The perspective should be integrated, inter-disciplinary and holistic in nature and lay mass in rural, tribal, slum and urban areas, women and students and teachers in schools, colleges and universities as well as planners and decision policy makers, programme implements and R & D workers need to be educated about environment and issues related to it. For this, there is need for a new **approach** in education which cuts across various subjects at schools and higher levels. Some recommendations according to Peyton *et al.* (1997) that can be offered to guide teachers and curriculum developers in designing approaches to environmental education are (a) Infusion of environmental issues in school/colleges curriculum, (b) Designing environmental awareness or educational programmes, (c) Exhibitions and (d) Establishment of environment clubs and societies. India adopted the infusion approach to Environmental Education throughout the formal education system. Here, Environmental Education is compulsory at all levels of formal education from 2003 onwards.

Environmental Education is generally divided into two major sub- areas i.e. **Formal and Non-Formal education**. Formal Environmental Education is in organized form where students, teachers and institutions are involved whereas non-formal Environmental Education is designed for any age group, working in social, economic and cultural development of the community. They form groups or clubs and arrange exhibitions, public lectures, meetings, environmental campaigns. The following constitute main content of this education.

Table -3: Formal & Non-formal Environmental Education:

FORMAL ENVIRONMENTAL EDUCATION	NON-FORMAL ENVIRONMENTAL EDUCATION
Primary school: In this platform emphasis should be mainly on building up awareness, followed by real-life situations and conservation). Main purpose should be to sensitive the child about environment. The content to be used are surroundings from home to school to outdoor situations and teaching includes audio-visual and field visits.	Adult education: Adults may influence other members for better ways of life. In local language, information packs, posters, slides, audio, audio-visuals etc. may be generated.
Lower secondary school: At this level level, objective must be real life experience, awareness and problem identification. The study contents include general science, teaching, practical and field visits.	Children activities: This can be ensured through essay competitions of different age groups. Ministry of Environment & Forest with the help of India organize such activities. On the spot painting, modeling and poster design contests are conducted for children by the National Museum of Natural History. Short term courses are also given by NMNH in EE every year.
Higher secondary school education: Here emphasis must be on conservation, assimilation of knowledge, problem identification and action skills. There should be proper teaching, practical and field work with science-based and action oriented work.	Eco-development camps: They help in sound rural development involving youth. A set of guidelines has been prepared by Ministry of Environment & Forests. The main objectives are : to create awareness in students and non-student youth about basic ecological principles; to identify root cause of ecological problems as related to human activities; to take steps to solve

	local ecological/environmental problems and to develop a spirit of national integration.
Tertiary (College) stage: In this levelmaximum emphasis would be on knowledge regarding sustainable development followed by conservation, real life situations and awareness. The content must be College or University based on Science and Technology. Teaching, practical and action-oriented field work is to be done.	Non-governmental organization: There are over hundreds of NGOs, of which most are involved in EE and awareness, others in nature conservation, pollution control, afforestation and social forestry, floristic and faunal studies, rural development, wildlife conservation and waste utilization and eco-development.
University Education: Environmental education at this level is being looked after the University Grants Commission. There is a high-powered committee to suggest areas of EE at postgraduate level. There are about 10 Universities teaching courses in environmental area. Besides these, there are also research institutes and professional institutions as Indian Institute of Technology, Engineering Colleges, Schools of Planning and Architecture, which offer courses in environmental engineering. The University education has three major components: teaching, research and extension. At postgraduate level, four major areas are recognized. Environmental engineering: It includes the subjects like architecture, civil engineering, town and country planning, including human settlements, slum improvement, landscape architecture, industrial design, regional science and urban ecosystem studies. Conservation and management: It includes fields like	Various schemes and activity conducted by Government Like - Training senior executives/administrators, Foundation courses for the probationary selected for the I.A.S., I.F.S., I.P.S. and cadets of three wings of Armed Forces, Research and Development Programmes supported by Ministry of Environment, Ministry of Environment & Forests has established Centres of Excellence in the country that generate knowledge and methodology and training in areas of Tropical Ecology (Bangalore) and Environmental Education (Ahmedabad).

land use, forestry, agriculture, energy, waste management, wildlife management, national parks, biosphere reserves, biological diversity, water management, mining management, non-polluting renewable energy development etc. Environmental health: This deals with public health and hygiene, sanitary and chemical engineering, occupational health, toxicology, nutrition and drug use etc. Social ecology: It includes subjects like ecology, sociology, social planning, cost-benefit, community organizations and services, psychology and counseling, environmental ethics and related areas of humanities.	
There are some institutes, centres assisted by Ministry of Environment and Forests which provide formal education/training in environmental areas. For instance, Centre for Environment Education (CEE), Ahmedabad, Indian Institute of Forest Management, Bhopal and Indian Gandhi National Forest Academy, Dehradun.	Apart from above mentioned non-formal education, there are many ways of developing sense of responsibility towards environment. For e.g. Public representatives (M.Ps and M.Ls) may build up sound public opinion and stimulate public interest; Conducting educational programmes for Tribal/forest dwellers; Organizing suitable activity on "World Environment Day", International Biodiversity Day, Earth Day etc.

Check your progress 5

Q7. What are the four interrelated components of Environmental Education? ……………………………………………………………………………………………………

Q8. What are the two major sub-areas of Environmental Education?

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5.7. Environmental Organizations and Agencies

There are several international and national organizations, agencies and programmes involved in different areas of environment, forestry, wildlife and other relevant aspects. These organizations are playing the key role in sorting out environmental issues. Some of the important bodies of this type are as follows:

Table -3: List of International Organizations:

NAME OF ORGANIZATION	ABOUT
Earthscan	Founded by UNEP in 1976, commissions original articles on environmental matters
Convention on International Trade in Endangered Species (CITES)	It is a multilateral treaty to protect endangered plants and animals. The convention was opened in 1973 and entered into force on 1 July 1975. For Indian, the Ministry of Environment and Forests function as nodal agency for participation in international agreements.
Environmental Protection Agency (EPA)	An independent Federal Agency of the U.S. Government established in 1970. It deals with protection of environment by air, water, solid wastes, radiation, pesticides, noise etc.
European Economic Community (EEC)	It is a community of 12 European nations and has programmes of framing and implementation of policy for environmental improvement and conservation of natural resources. CPCB, India has taken up projects on air quality monitoring with assistance of EEC.
Human Exposure Assessment Location (HEAL)	The project is a part of the Health Related Monitoring Programme by WHO in co-operation with UNEP with three components viz air monitoring, water quality monitoring and food contamination monitoring on a global basis.
International Council of Scientific Unions (ICSU)	A non-government organization (Paris) - encourages exchange of scientific information, initiates programmes requiring international scientific cooperation and studies and reports on

	matters related to social and political responsibilities in treatment of scientific community.
International Union for Conservation of Nature and Natural Resources (IUCN/WCU)	An autonomous,founded in 1948(Headquarters at Morges, Switzerland) - initiates and promotes scientifically based conservation measures. Now re-named as World Conservation Union (WCU).
International Marine Consultative Organization (IMCO)	It regulates the operation of ships in high seas from marine water pollution viewpoint.
South Asia Co-operative Environment Programme (SACEP)	Set up in 1982 for exchange of professional knowledge and expertise on environmental issues among member countries – Afghanistan, Bangladesh, Bhutan, India, Iran, Pakistan and Sri Lanka.
United National Educational, Scientific and Cultural Organization (UNESCO)	United Nations agency (Headquarter-Paris, 1945) to support and implement the efforts of member states to promote education, scientific research and information, and the arts to develop the cultural aspects of world relations. It also holds conferences and seminars, promotes research and exchange of information and provides technical support.
United Nations Environment Programme (UNEP)	UN agency (Headquarters - Nairobi, Kenya 1972), responsible for co-operation of inter-governmental measures for environmental monitoring and protection. It was founded to study and formulate international guidelines for management of the environment. UNEP is assisting many such programmes in India.
World Commission on Environment and Development	Set up in 1984 in pursuance to re-examine the critical environmental and development issues and to formulate proposals for them. The commission makes an assessment of the level of understanding and commitment of individuals, voluntary organizations and governmental bodies on environmental issues.

Earthwatch Programme	Established in 1972 under the terms of the declaration on the Human Environment. It monitors trends in the environment, based on a series of monitoring stations. Its activities are coordinated by UNEP.
Project Earth	Developed in collaboration with UNEP to inspire interest and educate young people worldwide on the crucial issues facing the Earth's Environment.
Earthwalks	A series of expeditions designed to draw international attention on environmental issues. First such walk was taken by R. Swan and six young people were presented by him on 6th June, 1992 at UNCED, Earth Summit (3-14 June, 1992), held at Rio de Janeiro (Brazil).
Man and Biosphere Programme (MAB)	It is the outcome of international Biological Programme (IBP). MAB was formelylaunched by UNESCO in 1971. There are 14 projects areas under this programme.
United Nation Framework Convention on Climate Change (UNFCCC)	International environmental treaty adopted on 9th May 1992 and open for signature at Earth Summit (1992). Its ultimate objective is to stabilize greenhouse gas concentration in the atmosphere.
Convention on Biological Diversity (CBD)	It is multilateral treaty (1992) having three main goals-conservation of biological diversity, sustainable use of its components, fair & equitable sharing of benefits from genetic resources.
Global Environmental Facility (GEF)	It was established in 1992 for tackling most environmental problems. It unites 183 countries in partnership with international institutions, civil society organizations & private sector to address global environmental issues.
Greenpeace	A non-profit organization, with a presence in 40 countries across Europe, the America, Asia and the Pacific. Greenpeace focuses on the most serious worldwide threats to our planet's biodiversity and environment. It campaign to: stop climate change, protect ancient forests, save the oceans, stop whaling, say no to genetic

	engineering, stop the nuclear threat, eliminate toxic chemicals and encourage sustainable trade.
Institute for Global Environmental Strategies (IGES)	Established in 1998, IGES is an independent and non-profit think tank based in Japan. Its mission is to more human society to become more environmentally and socio-economically Sustainable. Goal of IGES is to create a new paradigm for the global community so that the unsustainable production and consumption patterns currently observed can be changed into sustainable ones. It comprises four components: Strategic research, information outreach, multi-stakeholder dialogue, and capacity building.
Environmental Investigation Agency (EIA)	An international campaigning organization in U.K - investigating and exposing environment crime.

National Organization:

Apart from International organization, there are a number of governmental as well as non-governmental organizations, agencies and programmes engaged in environmental studies. Most of the governmental bodies involved in environmental studies are under the administrative control of, or assisted by the ***Ministry of Environment and Forests (MoEF*)**,Government of India which was set up in 1980 for planning, promotion and coordination of environmental programmes. After this, an integrated Department of Environment, Forests and Wildlife (D.O.En) was created in September 1985. The Ministry in 2014 was re-named as ***Ministry of Environment, Forests and Climate Change (MoEF & CC)***to stress upon India's stand on the issue of global climate change at international summit. It is mainly concerned with the implementation of policies and programmes related to biodiversity, forests and wildlife, ensuring the welfare of animals and prevention and abatement of pollution and climate change. The Ministry also acts as the nodal agency for the **United Nations Environment Programme (UNEP)**, **South Asia Cooperative Environment Programme (SACEP)**, and **International Centre for Integrated Mountain Development (ICIMOD)** and for the follow-up of the **United Nations Conference on Environment and Development (UNCED)**. The Ministry also deals with the issues relating to multilateral bodies like the **Commission on Sustainable Development (CSD)**, **Global Environment Facility (GEF)**, and of regional bodies like **Economic and Social Council for Asia and Pacific (ESCAP)** and **South Asia Association for Regional Co-operation (SAARC)** on matters pertaining to environment.

The main objectives of the Ministry are:

- Conservation and survey of flora, fauna, forest and wildlife,
- Prevention and control of pollution and impact of climate change
- Afforestation and regeneration of degraded areas.
- Protection of the environment
- Ensuring the welfare of animals.

These objectives are supported by legislation and regulatory measures, aimed for the preservation, conservation and protection of the environment. Besides the legislation measures, a National Conservation Strategy and Policy Statement on Environment and Development (1992), National Forest Policy (1988), a Policy Statement on Abatement of Pollution (1992) and a National Environment policy (2005) has also been evolved.

Check your progress 6

Q9. Write the full form of following organizations - CITES, IUCN, UNESCO & CBD?

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5.8. Role of Adult and Women Education

Educating men and women are a key for sustainable development of nation and conservation of nature. Environmental Education increases better understanding of environment and the environmental challenges among men and women. It develops the knowledge, skills and commitment among them which is needed to take responsibility for addressing these environmental challenges.

Environmental adult education develops a link between the environment and other aspects (social, economic, political and cultural) of people’s lives. Environmental adult education uses engaged, participatory methods based on the understanding that learning is a far more complex, extensive and important process than information transmission. Environmental adult education begins with recognizing people's with ecological knowledge and bringing them together through dialogue and debate for developing new ecological understandings of our world. Women play an important role in managing natural resources on family and community levels as women manage various activity like water, sources for fuel and food, as well as both forests and agricultural terrain. Educated women provide plan-document to be used for physical development of the human habitat. Therefore, the presence of educated women is needed to play as a system for sustainable environmental development. In the same context, a statement was given by U.N. Secretary-General Ban Ki-moon in the Earth Institute's State of the Planet meeting at Columbia University (New York, 2010) that" The world's women are the key to sustainable development, peace and security". Women's are not only get affected by environmental disasters or degradation but also their activities have an impact on natural resources and the environment. Therefore, it is the need to promote and develop environmentally friendly behaviours among women.

Major sustainable development treaties have also accepted the specific need and importance of women's participation. In 1992 United Nations Earth Summit (UNCED) produced two key conventions i.e. one on biological diversity and other on combating desertification which served as guides for implementation of environmental actions from a gender perspective. Agenda 21 (UNCED document), included a chapter on gender that highlighted the role of women as sustainable consumers in industrialized countries. Studies related to the women's link to environment are concentrated not only in developing countries but also in developed countries and have shown that women have a smaller carbon footprint than men, making the majority of environment friendly or "green" decisions at the household or base level.

This can be further assisted by various movements and activities leaded or conducted by women's that have made great strides in preserving and protecting the resources around them. Women took the lead in the Chipko Movement of India in the 1970s, where activists stopped the felling of trees by surrounding it or hugging the trees. They also protected water sources from corporate control. Similarly, another famous effort initiated by women was the

Green Belt Movement, which was the conservation and forestry movement that originated in Kenya on Earth Day in 1977. Previously and even today many women around the world continue the fight against climate change, making sustainable consumption choices, and improving access to, control over and conservation of resources. Their voices must continue to be integrated into policy and implementation efforts at every stage for the well-being and better survival of future generations. Thus, we can say that the adult and women education add an ecological lens to Environmental Education through which we can address environmental problems and give voice to the needs of those who are most affected.

Case Study

- Barefoot College trains (1972) women in Tilonia, Rajasthan, in solar engineering and ensure that this scientific knowledge remains, grows and circulates within the community. It is revolution that brings solar energy and clean technology to the poorest rural development.
- Chipko movement was ecological nonviolent movement by rural villagers, particularly women in Uttarakhand, India (1973) aimed at protecting or saving trees by the act of hugging trees to protect them from being cut down.
- Green Belt Movement (1977) in Kenya encouraged the women to work together to plant trees for preventing soil erosion, harvesting rainwater, to restore their source of fuel for cooking and generate income.

Check your progress 7

Q10. Mention the name of any one environmental movement led by women?

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5.9. Advantages of Environmental Education

Environment education is a process that creates awareness among individuals towards their responsibility for environment, allows them to explore environmental issues and engage then in solving environmental problems. If water gets polluted, what are we going to drink? How will we enjoy nature if every forest is cut down? All this questions are persisting today and actions are required. If our children and young generations who are the future of nations aren't taught how to preserve our ecosystem, the earth will be doomed. This is why Environmental Education is important and it has following advantages-

- **Encourages individual to respect mother earth and every life forms** - By teaching individual, how to respect our nature, will definitely pave way for a brighter future. Environmental Education teaches us to be kind towards every life forms living in this world. This will have a positive impact on our nature.
- **Cultivates critical thinking** – Environmental Education also develops critical thinking amongst people. We become mindful and responsible of our actions and their magnitudes and this will ultimately shows positive or healthy sign in nature.
- **Promotes a healthy way of life** - Nowadays everyone is restricted to their phones, TV's and homes, and people hardly move their muscle. Environmental education encourages people especially kids and young mass to participate in outdoor environmental activities. It teaches us about the benefits of the environment and how we can use it to our advantage.
- **Restoration of Environmental balance** - By teaching kids and everyone how their actions impact nature, we can suppress the environmental degrading activities and can maintain environmental balance. For instance, in today's developing world where large area of forest is cut down, motivating people to plant more and more plants will definitely aids in balancing the nature. It helps in creating a sustainable future.

In conclusion, Today world is facing many numerous crisis and critical environmental issues like climate change, global warming, loss of biodiversity and environmental pollution etc. These issues are the outcomes of human activities like genetic modification, deforestation, soil erosion, water and air pollution, toxic waste, over exploitations of natural resources, fisheries collapse, oil spills, militarization, deregulation, trade, marketing and urban decay. Thousands of animals and forests are dying due to human activities creating ecological imbalance. Steps must be taken to preserve our life supporting mother Earth. Environmental Education is the need of the hour and is vital for our future. It will be the most important thing that we teach our people. Societies and politics and belief systems and ideologies change and evolve subjects and disciplines also changes and evolve and priorities for people and countries change. The future belongs to young generations and upcoming generations and Environment Education helps in building up a healthier and greener environment for future generation.

5.10. Summary

In this unit we have gone through the concept of Environmental Education and its various aspects. So far you have learnt that

- ***Environmental Education is a study of nature, its functioning and persisting environmental problems so that environmental issues can be tackled efficiently.***
- ***A definition of Environmental education first appeared in 1969 in "The Journal of Environmental Education" written by William B. Stapp but the need of environmental education was highlighted during seventies period***
- ***It mainly emerged from the United Nations Conferences on Human Environment at Stockholm (Sweden) in 1972.***
- ***The Belgrade Charter (1975) was the outcome of an International Workshop (Belgrade, Yugoslavia) organized by UNESCO that includes formulated goals, objectives and guiding principles of environmental education programs to achieve the objectives of Stockholm conferences.***

- ***The Tbilisi Declaration constitutes the framework, principles and guidelines for environmental education at all levels-local, national, regional and international for all age groups.***
- ***In seventh World Environmental Education Congress, Morocco (2013) main topics of discussion include the importance of environmental education, its role to empower, establishing partnership to promote environmental education.***
- ***The main Objectives of Environmental Education (UNESCO-UNEP, 1978) are to develop awareness, knowledge, attitude, skill, evaluation ability and participation among individuals.***
- ***According to Vidart (1978), the specific aims of Environmental Education are – Cognitive aims, Normative aims and Technical and applicative aims.***
- ***Newman (1981) proposed a three-fold classification of environmental education programmes i.e. Environmental studies, Environmental sciences and Environmental engineering.***
- ***Environmental education can be further divided into two major sub- areas i.e. Formal and Non-Formal education.***
- ***There are several international and national environmental organizations, agencies and programmes like Earthscan, CITES, EPA , EEC, IUCN/WCU, UNESCO, UNEP, Earthwatch Programme, Project Earth, Earthwalks, MAB programme, UNFCCC, CBD, Greenpeace and Ministry of Environment, Forest and Climate Change, Govt. of India (MoEF & CC) etc.***
- ***Educating men and women are a key for sustainable development of nation and conservation of nature.***
- ***Women took the lead in the Chipko Movement of India in the 1970s, Green Belt Movement in Kenya on Earth Day in 1977; Barefoot College trains (1972) women in Tilonia, Rajasthan, in solar engineering etc.***

- ***Environmental Education has many advantages i.e. encourages individual to respect mother earth and every life forms, cultivates critical thinking, promotes a healthy way of life and restoration of Environmental balance.***
- ***Environmental Education is the need of the hour and is vital for developing healthier and greener environment for future generation.***

Terminal Questions

1) Define Environmental Education with its brief account of its evolutionary history.
2) Discuss the main objective of Environmental Education as per UNESCO-UNEP, 1978.
3) What are the guiding principles of Environmental Education?
4) Discuss briefly the formal and non formal Environmental Education.
5) What are the advantages of Environmental Education?
6) Write notes on:

i) Tbilisi Declaration
ii) Cognitive aims of Environmental Education
iii) Chipko Movement
iv) Ministry of Environment, Forests and Climate Change (MoEF & CC), Govt. Of India

Answers

Check your progress –1, 2, 3, 4, 5, 6 &7

1) William B. Stapp (1969)
2) In 1977 at Tibilisi, Georgia (USSR)
3) The main Objectives of Environmental Education (UNESCO-UNEP, 1978) are to develop awareness, knowledge, attitude, skill, evaluation ability and participation among individuals.
4) According to Vidart (1978), there are three specific aims of Environmental Education– Cognitive aims, Normative aims and Technical and applicative aims.

5) Guiding principles given in Tbilisi Conference, 1977 are – (a) Consider the environment in its totality i.e. natural, artificial or manmade, technological, social (economic, political, moral, cultural, historical, and aesthetic). (b) Consider environment education as continuous life long process (from pre-school to all higher levels-formal as well as non-formal)
6) Newman (1981)
7) Interrelated components of Environmental Educations are (i) awareness, (ii) real life situations (iii) conservation, and (iv) sustainable development.
8) Formal and Non-formal Environmental Education
9) CITES – Convention on International Trade in Endangered Species

   IUCN – International Union for Conservation of Nature

   UNESCO – United Nations Educational, Scientific and Cultural Organization

   CBD –Convention on Biological Diversity

   Chipko movement (1973)

Glossary

Attitude: A way of thinking or feeling about something.

Biodiversity: Variety of life forms

Behaviour: A response of an individual towards any action, environment or stimulus.

Belgrade Declaration: it was the outcome of an International Workshop on Environmental Education held at Belgrade (Yugoslavia) in 1975that was organized by United Nations Education, Scientific and Cultural Organization (UNESCO). In this, goals, objectives and guiding principles of Environmental Education programs were formulated to achieve the objectives of Stockholm conferences.

Climate: variation of weather in a region over long periods of time.

Climate Change: the slow change in climatic conditions over a time at a given place.

Deforestation: conversion of forest areas into non-forest area for agriculture, urban use or developmental process.

Eco: prefix added to words indicating consideration of environment e.g. eco-friendly

Ecology: The study of the inter-relationships between organisms and environment.

Ecosystem: The structural and functional entity of biotic communities and their environment.

Environment: the external conditions in which an organism lives and interacts.

Environmental ethics: ethical decisions with respect to the environment or man's belief about what is right or wrong environmental behaviour.

Environmental science: the study of interactions of physical, chemical and biological components of the environment.

Erosion: displacement of solid/sediments or soil due to agents like wind, water or ice.

Forest: land with canopy cover

Global warming: the observable increase in global temperatures mainly due to human activities

Intergovernmental Panel on Climate change (IPCC): establishedin 1988 by World Meteorological Organization and UN Environment programme and is dedicated to providing the world with objective, scientific information related to climate change.

IUCN: International Union for Conservation of Nature, global international organization working in the field of nature conservation and sustainable use of natural resources. It's headquarter is in Gland, Switzerland.

Natural resources:valuable naturally occurring substances.

Pollution: introduction ofimpurities in the environment which is harmful to living organisms.

Skill: ability or expertise to do something well.

Sustainable: able to be maintained at a certain rate or level.

Tbilisi Declaration: In 1977, Intergovernmental conference on environmental education was organized by UNESCO in cooperation with UNEP at Tbilisi, Georgia (USSR). The *Tbilisi Declaration* constitutes the framework, principles and guidelines for environmental education at all levels-local, national, regional and international for all age groups both inside and outside the formal school system.

UNESCO: United Nations Educational, Scientific and cultural Organizations, founded in November 1945. It is the United Nations organization for the promotion of international cooperation in education, science, culture and communication. The seat of UNESCO is in Paris, France.

UNEP: United Nations Environmental Program, established as an outcome from the UN Stockholm Conference in 1972. It is responsible for coordinating the UN's environmental activities and assists the developing countries in implementing environmental policies and practices.It's headquarter is in Nairobi, Kenya.

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UNIT 6: Basics of Environmental Protection

Unit Structure

6.0 Learning Objectives

In this unit you will able to understand the basics of environment protection and various agencies involved in protection work. The unit will explain:

- Basics of Environment Protection
- Difference between Protection and Conservation
- Various agencies (Local/ National/ International) involved in resource conservation
- Role of information Technology in resource conservation.

6.1. Introduction

In a broader sense environment protection means protection of environment as well as other resources from any adversely affecting agency. The damaging agency can be individuals, industry, organization etc. The objectives of environmental protection include conservation of resources as well as repairing of damaged ones. The main reasons behind the depleting and damaging resources are high population growth, overconsumption and unsustainable utilization. Considering this alarming situation now the governments have begun placing restraints on activities that cause environmental degradation. Since the 1960s, environmental movements have created more awareness of the multiple environmental problems.

The environmental protection may involve:

(a) Changes in characteristics of goods and services,
(b) Changes in consumption patterns,
(c) Changes in production techniques,
(d) Treatment or disposal of residuals in separate environmental protection facilities,
(e) Recycling, and
(f) Prevention of degradation of the landscape and ecosystems.

6.2 Different Approaches to Environmental Protection

Basically there are two different approached for environmental protection-

Voluntary environment agreements

Ecosystem approach

6.2.1. Voluntary Environment Agreements

In the era of industrialization there are many voluntary environmental agreements which are followed by many companies on voluntary basis. Under this agreement the companies follow the minimum regulatory standards and thus support the development as well as conservation for the best environmental practice. For instance, in India, Environment Improvement Trust (EIT) has been working for environmental and forest protection since 1998.

6.2.2. Ecosystem Approach

In ecosystem approach **of** resource management rather than taking a specific resource for decision making the completer ecosystem should be taken under consideration. It is more collaborative approach of planning and decision making. Under this approach all the stakeholders are taken under consideration s a unit. This approach ideally supports a better exchange of information, development of conflict-resolution strategies and improved regional conservation. Religions also play an important role in the conservation of the environment

6.3. Role of Government in Environment Protection

Commonly it is a general perception that environment protection is the responsibility of government, legislation and law enforcing agencies. But in real sense it is the responsibility of every citizen along with the government to conserver the available resources. It is an ideal condition to involve different stakeholders including industry, indigenous groups, environmental group and community representatives for decision making in environment related issues.

The Constitution of India has a number of provisions demarcating the responsibility of the Central and State governments towards Environmental Protection. As per the article 48-A of our constitution it is the duty of state to protect and improve the environment and to safeguard the forest and wildlife of the country. By Article51-A (g) environmental protection has been made a fundamental duty of every citizen of India. As per article 21 of the constitution is a fundamental right, which states that "No person shall be deprived of his life or personal liberty except according to the procedure established by law".

6.4 Protection vs Conservation

6.4.1. Protection

Protection means shielding something against dangers which tend to destroy it. Thus resource protection means shielding the resources against the dangers which may either completely destroy it or at least damage it to such extent that it may not be able to confer benefits it is expected to give (Negi, 1993). As protection requires efforts as well as money, its intensity is directly proportional to the value of and the benefits conferred by, the resource to be protected. The more valuable there source the more likely it is to be damaged by humans and consequently greater is the effort and more resources required to protect it.

6.4.2 Conservation

Environmental conservation is the practice of us humans saving the environment from the loss of species, and the destruction of the ecosystem, primarily due to pollution and human activities. Conservation is vital in saving and helping both animals and trees as all are dependent on one another for survival. For maintaining the supply of resources, it is important to use the resource at or below its sustained yield. The resource conservation aims to-

- Maintain ecological processes and life support systems
- Ensure continuous yield of plants, animals and materials
- Preserve the quality of environment
- Conserve biological diversity
- Achieve sustainable use of species and ecosystems

The collective resource management programmes with the involvement of local social groups have been found to be effective for the management of watershed, forest, fishery, agriculture etc as well as for improving community wellbeing

Environmental conservation and protection are two terms that are often used interchangeably, although they are quite different. Conservation refers to the responsible management of the environment and its resources for present and future use and protection, on the other hand, is a much stricter approach where the environment, lands and natural resources are put away, not to be consumed by humans, but are instead maintained in their pristine form. If the land is to be used by humans, it should only be utilized for its natural beauty and inspiration.

In short on one hand conservation includes the responsible use of natural resources whereas in protections the environment is protected from all harmful human activities.

6.5 Institutional apparatus (Local/ National/ International)

Environment Conservation is not a matter which can be single handed managed by the Government agencies. For the sustainable development it is the need of the hour that different government and non-government agencies must work together. To address this diverse and critical issue many institutions and organization have been setup at international, national and local level. An environmental organization is an organization seeks to protect, analyze or monitor the environment against misuse or degradation or lobby for these goals. Environmental organization may be a government organization, a nongovernment organization, a charity or trust which can act at global, national, or local level.

India's approach to protect the environment and to restore it, exists from the vedic and post-vedic times But after independence it took a back seat and economic growth became the priority in our day to day life. Only after 1972 with the formation of the National Committee on Environmental Planning and Coordination (NCEPC) the focus on environmental conservation again restarted. In 1985 a full-fledged department, Department of Environment and Forest was set up by the government. Initially the Constitution of India did not contain any provision towards the promotion/protection of environment. However, the 42nd amendment of the constitution in 1977 added some important clauses that entrusted the government the responsibility of providing a clean and well-protected environment.

6.5.1. Local Agencies (In India)

There are many Non Governmental Organizations (NGOs) which are actively involved in the area of resource conservation. A NGO is mostly privately funded organization with no active involvement of any government agencies. Therefore NGOs are independent of governments. In our country there are many active NGOs which are working in the field of environment conservation, sustainable development, resource conservation, wildlife conservation etc.. Some of them are as follows:

Centre for Science and Environment (CSE)

The Centre for Science and Environment (CSE) is New Delhi based a research organization. The main objective of CSE is to maintain a balance between exploitation of the available natural resources and growing industrialization. The CES try to create awareness among people regarding the day today environmental issues and propose solutions of these issues. The main target group of CSE is the youth and students of our country With this in mind, CSE has been developing non-formal environmental education. Their tools for creating awareness are periodicals publications, films, exhibitions and other products.

Kalpavriksh

Established in the year 1979 Kalpavriksh is an Indian NGO actively working in the field of Environmental awareness. The area in which Kalpavriksh is involved in creating awareness among people, promoting research, litigation etc. For environment related issues they go upto protest letters to street demonstration etc. Kalpavriksh is actively involved in protest against the destruction of largest green area in Delhi and also actively involved in studying the impact of Narmada dam project on environment and many more. Kalpavriksh believes that a country can develop meaningfully only when ecological sustainability and social equity are guaranteed, and a sense of respect for, and oneness with nature and fellow humans is achieved. In this NGO all the

decisions are taken after appropriate debate and discussion within the organization and with the community.

Development Alternatives

Development alternatives is an Indian based non-governmental organization with the aim of sustainable development without damaging the available resources. This NGO was established in the year 1983. The agenda of development alternatives is focus on a cordial interrelationship between social and environment component of the country. In short it includes the balanced relation between nature, technology and people living in the country. The development alternatives believes in sustainable development must support the economy, environment and most importantly the society. The Development Alternatives

Group is, therefore, dedicated to bring about a better balance among the basic prerequisites of sustainable development: social equity, environmental quality and economic efficiency. The mission of the Development Alternatives Group is to promote sustainable national development. The development alternatives believes in generating sustainable livelihood to eradicate poverty on one hand and conservation and proper regeneration of the resources on other.

Tropical Research & Development Centre (TRDC)

Established in 1994, the vision of TRDC is to make natural resources available to all, with no discrimination. This NGO, headquartered at Bengaluru, aims to nurture development practices through education, awareness and conservation. The TRDC – Paryavaran project launched in some districts of Karnataka addresses the adversities of environmental degradation and climate change. The project also aims at conservation and betterment of local flora and fauna, revitalization of water resources, and involving the younger generation and farmers in their efforts to help in the preservation of natural resources.

Sankalp Taru Foundation

This environmental NGO is a classic example of how digital channels can be used in protection and conservation of the environment. SankalpTaru is an e-NGO, which aims at promoting tree plantation across the country. The NGO is active in 21 states in India. The plantation drive is run on a digital platform, allowing SankalpTaru to use innovative technologies such as GPS-tagging and others. This way, the volunteers can track the progress of plantation drives. So far, millions of trees have been planted since SankapTaru's inception by Apurva Bhandari in 2013. The NGO involves all the aspects of environmental protection – rural development, cleaner schools, tree plantation in cities and community-based land protection. Their principal aim is to create a greener, cleaner and healthier environment so that our future generations get a better and greener planet with even richer bio-diversity and abundant natural resources.

Chintan Environmental Research and Action Group

Focused on promoting sustainable and equitable growth for every member of the society, Chintan works towards ensuring responsible and sustainable consumption, thus protecting the environment. Founder Bharati Chaturvedi is an avid writer with several powerful articles promoting environmental protection. At Chintan, they endeavor to lessen surplus waste, promote sustainable consumption and facilitate better waste management. They also raise their voice against air pollution by creating awareness. The primary purpose of promoting sustainable consumption and waste management is to provide resources for the vulnerable sections of the society.

6.5.2. National Agencies

There are many national level agencies in our country which are actively involved in the protection and conservation of natural resources. Some of them are The Ministry of Environment and Forest, Central Pollution Control Board, Indian Board for Wildlife, National Biodiversity authority, Animal welfare board of India, Forest survey of India etc.

Ministry of Environment and Forest: In India the Ministry of Environment and Forests (MoEF) is one of the most important department of central government. The ministry mainly focuses on planning and promoting the matters related with environment and forest in the country. The main activities undertaken by the ministry include conservation and survey of the flora and fauna of India, forests and other wilderness areas; prevention and control of pollution; afforestation and reducing land degradation. All national parks of the country are administered by the ministry. It provides the financial support the different organizations for research, capacity building and for creating awareness among common peoples in the country. The Ministry is also the nodal agency in the country for the United Nations Environment Programme.

Central Pollution Control Board

In India to conserve the various resources against the rising pollution a statutory body namely “Central Pollution Control Board” was established in the year 1974. This body was constituted under the Water (Prevention and Control of Pollution) Act, 1974. Further, CPCB was entrusted with the powers and functions under the Air (Prevention and Control of Pollution) Act, 1981.

It is an apex body which provides the technical inputs to the Ministry of Environment and Forests of the provisions of the Environment (Protection) Act, 1986. The thrust areas of CPCB, is proper implementation of the Water (Prevention and Control of Pollution) Act, 1974, and the Air (Prevention and Control of Pollution) Act, 1981. CPCB promotes the cleanliness and improvement of water and air quality in thecountry.

Indian Board for Wildlife (IBWL)

The IBWL is the apex body for wildlife conservation in India. The IBWL is headed by the honorable Prime Minister of India. The IBWL has been reconstituted w.e.f. 7.12.2001. The XXI meeting of the IBWL was held on 21.1.2002 under the Chairmanship of the Honorable Prime Minister of India at New Delhi.

National Biodiversity authority

It is a statutory autonomous body under the Ministry of Environment and Forests, Government of India established in 2003, after India signed Convention on Biological Diversity (CBD) in 1992. Its head quarter is situated in Chennai. The main objective of the authority is implementation of Biological Diversity Act, 2002. it acts as a facilitating, regulating and advisory body to the Government of India "on issues of conservation, sustainable use of biological resources and fair and equitable sharing of benefits arising out of the use of biological resources." Additionally, it advises State Governments in identifying the areas of biodiversity importance (biodiversity hotspots) as heritage sites.

Animal Welfare Board of India

Animal welfare board was established in 1962 under Section 4 of The Prevention of Cruelty to Animals Act, 1960. Its head quarter is in Chennai. The board gives advice to Government on Animal Welfare Laws and promotes animal welfare in the country. The Board issues publications to raise awareness of various animal welfare issues. The Board's Education Team gives talks on animal welfare subjects, and trains members of the community to be Board Certified Animal **Welfare** Educators.

Forest Survey of India:

Forest survey of India is a government organization in India under the Union Ministry of Environment, Forest and Climate Change for conducting forest surveys and studies. The organization came into being in, 1981. Its headquarter is in Dehradun, Uttarakhand. The objective of FSI is the monitoring periodically the changing situation of land and forest resources and present the data for national planning; conservation and management of environmental preservation and implementation of social forestry projects. FSI prepares State of Forest Report biennially, providing an assessment of the latest forest cover in the country and monitoring changes in these and conduct an inventory in forest and non-forest areas and develop a database on forest tree resources. Forest Survey of India assesses forest cover of the country every 2 years by digital interpretation of remote sensing satellite data and publishes the results in a biennial report called 'State of Forest Report'(SFR).

6.5.3. International Agencies

IUCN (The World Conservation Union)

The world conservation union was founded in the year 1948. The union brings together states, government agencies and a diverse range of nongovernmental organization in a unique partnership covering some 81 countries. Its headquarter is in Gland, Switzerland. IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and sustainable use of natural resources. The union has helped many countries to prepare National Conservation Strategies, and demonstrates the application of knowledge through the field projects it supervises. The world conservation union builds on the strengths of its members, networks and partners to enhance their capacity and to support global alliances to safeguard natural resources at local, regional and global levels. The IUCN Species Survival Commission (SSC) represents the world's most complete source of scientific and management expertise on species and their conservation.

Convention on Biodiversity

The Earth summit held in 1992 at Rio de Janeiro resulted into a Convention on Biodiversity, which came into force on 29 December 1993 and has been ratified by 183 countries. The Convention on Biodiversity has three key objectives- (i) conservation of biological diversity, (ii) sustainable use of biodiversity (iii) fair and equitable sharing of benefits arising out of the utilization of genetic resources. This convention has stimulated many countries to develop National Biodiversity Strategy and Action plan.

United Nations Environment Programme (UNEP):

The UNEP, stands for United Nations Environment Programme was established in the year 1972. It is a global authority that set ups the global environment agenda for protecting the different natural resources. The UNEP advocates environmental protection along with sustainable development without compromising the life quality of future generations. Headquartered in Nairobi, Kenya, UNEP works through its divisions as well as regional, liaison and out-posted offices and a growing network of collaborating centres of excellence. UNEP works closely with its 193 Member States and representatives from civil society, businesses, and other major groups and stakeholders to address environmental challenges through the UN Environment Assembly, the world's highest-level decision-making body on the environment.

The organization hosts the secretariats of many critical multilateral environmental agreements and research bodies.

6.6. International Programmes on Conservation

World Conservation Strategy

In 1980, the International union for conservation of natural resources (IUCN), the United Nations Environmental Programme (UNEP) and World Wide Fund for Nature (WWF) developed the world conservation strategy, a long term plan for conserving the world's biological resources (IUCN/UNEP/WWF, 1980). This plan was expanded and followed by "Caring for the earth: a strategy for sustainable living" ((IUCN/UNEP/WWF, 1991). This report enlisted a set of principles and strategies of a sustainable society based on practical integration of environment, social and economic, concerns. Its primary goal was to maintain essential ecological processes and life support systems to preserve species and genetic diversity to ensure the use of species and ecosystems in a sustainable manner to improve the quality of human life.

World Commission on the environment and development:

In 1983 the United Nations established a commission called the World Commission on the Environment and Development. The commission is often called Brundtland Commission after the name of head of the commission. The commission proposed a global agenda to address the world's environmental problems and people's concerns relating to living conditions, resources, population pressures, international trade, education and health. This commission favors sustainable development as sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987).

United Nations Conference on Environment and Development (UNCED):

At the time of the United Nations Conference on Environment and development (the Earth Summit) held in Rio de Janeiro most of the leaders of the world signed the frame work convention on climate change and the convention on biological diversity. The Rio summit adopted Rio declaration and Agenda 21 for achieving sustainable development in the 21 century (UNCED, 1992). This declaration includes equal consideration of environment, society and economy.

Besides these the Agenda 21-UNCED, The Rio Summit Follow-up, Commission on Sustainable Development (CSD), Global Environmental Monitoring and Assessment are some other international programmes on environmental conservation.

6.7 Importance of Information and Technology for Conservation of Environment

Information generally has an advantage over those to whom such access is denied. The evolution of information technology, has generally led to dispersal of information to increasing broader audiences. Advances in telecommunications and other forms of information technology have contributed to the creation of new patterns of work and human association. Information technology has also increased the pace of discovery. The capacity of establishing and maintaining worldwide databases has linked environmental, researches around the globe. These information is utilized for developing and early warning system and to forecast any eventuality much earlier. A large amount of information is easily available through Remote Sensing technology, Geographical Information System (GIS) and Global Positioning System (GPS) that is being used for various environmental studies.

Realizing the importance of Environmental Information, the Government of India, in December, 1982, established an Environmental Information System (ENVIS) as a plan programme. The focus of ENVTS, is been on providing environmental information to decision makers, policy planners, scientists and engineers, research workers, etc. Total 25 ENVIS Centers have been functional in our country to cover the broad subject areas of environment. ENVIS is a decentralised system with a network of distributed subject oriented Centers ensuring integration of national efforts in environmental information collection, collation, storage, retrieval and dissemination to all concerned. Presently the ENVIS network consists of Focal Point at the Ministry of Environment and Forests and ENVIS Centers set up in different organizations/establishments in the country in selected areas of environment. These Centers have been set up in the areas of pollution control, toxic chemicals, central and offshore ecology, environmentally sound and appropriate technology, bio-degradation of wastes and environment management, etc. ENVIS focal point ensures integration of national efforts in environmental information collection, storage, retrieval and dissemination to all concerned.

Global Environment Database:

The United Nations Environment Programme (UNEP) has set up the global environmental database (GRID) within the frame work of the Global Environmental Monitoring system (GEMS). The main function of GRID are environmental data management and to establish a global network on environment using GIS and image processing technology. GRID is useful to examine interactions between different environmental databases and to provide models and scenarios. The international Geosphere and Biosphere programme uses GRID as a useful data management system for studying global change. The activities of

GRID also focus on problems of land degradation, forest depletion and loss of biological diversity.

6.8 Summary

There is a serious concern about the growing fragility of the Earth's life support system. Ever growing human population and its activities are adversely affecting the various resources of the earth. Human population and economic wealth of people have significantly increased the degradation of natural resources which need to be controlled immediately. Resource protection and conservation is the need of the hours. One should protect the available resource by focusing on changing the consumption patterns, recycling, and prevention of degradation of the landscape and ecosystems. Environmental conservation and protection are two terms that are often used interchangeably, although they are quite different. Conservation refers to the responsible management of the environment and its resources for present and future use and protection, on the other hand, is a much stricter approach where the environment, lands and natural resources are put away, not to be consumed by humans, but are instead maintained in their pristine form. If the land is to be used by humans, it should only be utilized for its natural beauty and inspiration. The matter on environmental protection often focuses on the role of government, legislation, and law enforcement. However, in its broadest sense, environmental protection may be seen to be the responsibility of all the people and not simply that of government. There are many agencies which are working on local, national and international levels. There are many Non Governmental Organizations (NGOs) which are actively involved in the area of resource conservation at local level. Sustainable development emphasizes that the rate of consumption and use of natural resources must approximate the rate at which these resources can be substituted or replaced. At the same time it requires that society is able to satisfy social, economic and other needs without affecting the interest of future generation.

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Terminal Questions

Q.1. What is environment protection and explain various approaches of environment protection.

Q.2. Write a note on role of Government in environment Protection.

Q.3. Differentiate between Protection and conservation.

Q.4. Discuss in detail the various local agencies involved in environment Protection.

Q.5. Discuss in detail the various national agencies involved in environment Protection.

Q.6. Explain different International Programmes on Conservation

Q.7. Write a note on ENVIS and Global Environment Database.

UNIT 7: SUSTAINABILITY

Unit Structure

7.0. Learning Objectives

After studying this unit students will be able to learn:

- The origin, definition, concept and history of sustainability
- Pillars and principles of sustainability.
- Goals of sustainable development
- Criteria and indicators of sustainability
- Approaches to study the sustainable development
- Environmental ethics, theories and its role.

- Impact of globalization on sustainable development

7.1. Concept of Sustainability

Sustainability means meeting our own present needs without compromising the ability of future generations to meet their own needs of resources including environmental, social, economic, cultural and political resources. Therefore, it is a complex concept and linked with the sustainable development. The most often quoted definition comes from the UN World Commission on Environment and Development (WCED 1987): "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Thus the term sustainability may be defined as "the integration of environmental health, social equity and economic vitality in order to create thriving, healthy, diverse and resilient communities for the present generation as well as generations to come". It emphasizes that rate of consumption and use of natural resources must approximate the rate which those resources can be sustained or replaced. It presumes that resources are finite and should be used conservatively and wisely with a view to long-term priorities. To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in a productive harmony to support present and future generations. In simplest terms, sustainability is about our children and our grandchildren and the world we will leave them.

7.2. Origin and History

The concept of sustainability is relatively a new idea but it has roots in social justice, conservationism, internationalism and other past movements with rich histories. It gain momentum at the beginning of the 80s, when by a small group of environmentalists and environmental economists coined the term and concept of sustainability. In the year 1987 a report on "*Our common Future*" was published by the World Commission of Environment and Development, popularized the term sustainable development. This report is also known as the Brundtland report. Due to this report sustainable development has been put on the international political agenda by the UN via linking it with the human development. Therefore, it is a notable and visionary development paradigm adopted by UN to increase life expectancy by providing healthier living conditions and better healthcare, to all people.

Sustainable human development may be defined as ‘the capacity of all human communities, including the most deprived, to meet their fundamental needs for accommodation, drinking water, food, satisfactory health and hygiene, participation in decision-making, social cohesion, a social fabric, cultural and spiritual expression, etc. This entails the adaptation of technologies and lifestyles to the social, economic and environmental potential of each region, internalizing costs and establishing systems that are compatible with the biosphere. It seeks a balance between the ecological, economic and social spheres, while also taking account of political (participation and democratisation), ethical (responsibility, solidarity, social justice and sufficiency) and cultural (local diversity and artistic expression) considerations. Various milestones in the evolution of the sustainable development approach is given in Table 1.

Table 1.Evolution of sustainable developmentconcept.

Year	The main event	The main aspects
1972	Stockholm united Nations Conference	113 nations present expressed their concerns about how human activity affects the environment. he conference put in evidence the indissoluble link between the quality of life and environmental quality for present and future generations and recognized that human activities contribute to the deterioration of environment which endangers our future.
1985	Vienna Convention	As the ozone hole over the Antarctic was discovered, the Convention began seeking solutions to reduce consumption of substances harmful to the ozone protective layer surrounding the Planet.
1986	World Commission’s work on Environment and Development	Studying the dynamics of environmental deterioration and offering solutions on long-term sustainability of human society.
1992	Conference on Environment and Development, organized by the united Nations in Rio de Janeiro	Nations present agreed on a plan for sustainable development called Agenda 21 and the two sets of principles: the Rio Declaration on Environment and Development and the forest principles
2001	Millennium development Goal	192 United Nations member states adopted the United Nations Millennium Declaration which laid out eight major development goals to be achieved by

		2015.
2002	Summit on Sustainable Development.	The main issues discussed were: reducing the number of those who have no access to drinking water reserves, halving the number of those who have unhealthy conditions corresponding to 1.2 billion, increased using sustainable energy sources and rebuilding herds exhausted ish
2005	Commission started a process to revise the Sustainable Development Strategy	It was pointed out that the actions of non-sustainable development had negative effects: climate change, public health threats, increased poverty and social exclusion, natural resource depletion and damage to biodiversity. Commission presented a proposal for Revision, which is focusing on 6 priorities: climate change, health, social exclusion, transport, natural resources and poverty. He ways to be followed to solve these problems were identified.
2006	Sustainable Development Strategy was adopted in 2006 for the enlarged European union	The Sustainable Development Strategy was adopted in June 2006 for the enlarged European union based on the Gothenburg strategy and outcome of the process that begun in 2004.
2009	15th Session united Nations framework Convention on Climate Change held in Copenhagen	The most important topics of the negotiations were the targets for reducing the emissions of greenhouse gases, especially by the developed countries, financial support for developing countries, to adapt to climate change, stop destroying the planet's forests
2012	UN Rio+ 20 submit	The most important topics was to commit the governments to create a set of sustainable goals (SDG) that would be integrated into the Millennium Development Goals (MEA)
2015	Agenda 2030	The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The 17 SDGs are integrated—they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability.

7.3. Drivers of change

In the developing countries extreme poverty still affects the lives of millions of people and in 1993 more than 1.3 billion people were earning less than US$ 1 per day (UNEP 1999). High rate of poverty and mal-distribution of wealth associated with various social evils like diseases, serious crime, family breakdown and use of narcotic drugs.

Climate change, environmental pollution, natural resource deterioration, loss of forest and biodiversity has complex interaction with socioeconomic systems (Singh et al. 2005). Climate poses numerous challenges for sustainable development. We have maximized our ability to extract fossil oil in an era of probably far higher prices for oil-based products in one side and emission of pollutants in the environment, is a threat to the high quality of life enjoyed on the other side. Loss of Biodiversity due to deforestation, especially in rainforests which comprise just 6 percent of the world’s land but contain more than 5,00,000 of the planet’s species. In arid and semiarid regions land degradation results in desertification, acid rain or acidification is the process of forming acids from various air pollutants viz. ammonia, sulphur dioxide, nitrogen oxides and Eutrophication of water bodies are forms the sound basis of sustainability.

Sustainability is, thus, a framework upon which can be built specific strategies for guiding decision making. It encourages more responsible manufacturing and production, covering the industrial side of waste and pollution. It also encourages companies, industries, and governments to make decisions based on long-term consequences, rather than taking the easiest, cheapest option. This entails the adaptation of technologies and lifestyles to the social, economic and environmental potential of each region, costs and establishing systems that are compatible with the biosphere.

7.4. Pillars of Sustainability

Sustainability is a framework upon which can be built specific strategies for guiding decision making. Increasing population and consumptions of the resources are the main hurdles in achieving the sustainability. Developed countries (world’s wealthiest countries), with less than 20 percent of the world's population, contribute roughly 40 percent of global carbon emissions and they are responsible for more than 60 percent of the total carbon dioxide that fossil fuel combustion has added to the atmosphere since the industrial revolution began, but now it changing rapidly. Consumption is another side of the problem, especially per capita consumption of key natural resources which varies greatly around the world. Typically, the citizens of rich industrialized nations use more of the world's resources and produce more waste. As a result they sometimes deplete their own resources and often the resources of other countries. A typical example is meat. China, with the world's largest population, is the highest overall producer and consumer of meat, but the highest per-capita consumption in the world is that of the United States. The average United States citizen consumes more than three times the global average of 37 kilos per person per year. Africans consume less than half the global average, and South Asians consume the least, under 6 kilos per person per year (Thomas 2002).

Sustainability is a holistic approach that considers ecological, social and economic dimensions. It recognized all must be considered together to find lasting prosperity. A popular method of considering the sustainability state of mind is the triple bottom line approach. Sustainability is measured by assessing performance of the three main principles altogether, in particular a balanced treatment. These three terms are also known as the three pillars of sustainability or concept of sustainability concepts or three dimensions of sustainability. These three bottom lines, or pillars are:

Economic Sustainability- Economic sustainability takes into account the social and ecological consequences of economic activity. Societal wellbeing would have to be maximized and poverty eradicated through the optimal use of natural resources. Additionally, it also means that human communities across the globe are able to maintain their independence and have access to the resources that they require, financial and other to meet their needs.

Social Sustainability- A socially sustainable society is one in which all members have equal rights, all share equitably in societal benefits and all participate equally in the decision-making process. Universal human rights and basic necessities are attainable by all people, who have access to enough resources in order to keep their families and communities healthy and secure. Thus, it is based on the distribution of equity, uplifting the welfare of people, improving access to basic health and education services, gender equity, political accountability and participation.

Environmental Sustainability- this sustainability empathized that all of earth's environmental systems are kept in balance while natural resources within them are consumed by humans at a rate where they are able to replenish themselves. Environmental sustainability has a main focus on maintenance of biological diversity, atmospheric stability and ecosystem function and services.

As far as the priorities of these three terms are concerned the environmental sustainability comes first. The social and economic sustainability and beneficiaries are all the organisms are depending subsystems. In the recent years following two new pillars of sustainability also emerged out. These are:

Cultural sustainability - it refers maintaining cultural beliefs, practices, heritage conservation, morals and collection of human knowledge and relates with the economic, social, and environmental dimensions of sustainability. Cultural sustainability has always been categorized under the social pillar of the three pillars of sustainability, but with recent developments within this field considerations are being made in order to make Cultural Sustainability its own pillar, due to its growing importance within social, political, environmental, and economic sphere

Political sustainability - refers to a stable political system in order to apply various policies and practices for the change to transform economy monitory dependent development to environmentally sustainable and also negotiate, support an item on the political agenda locally, regionally and globally.

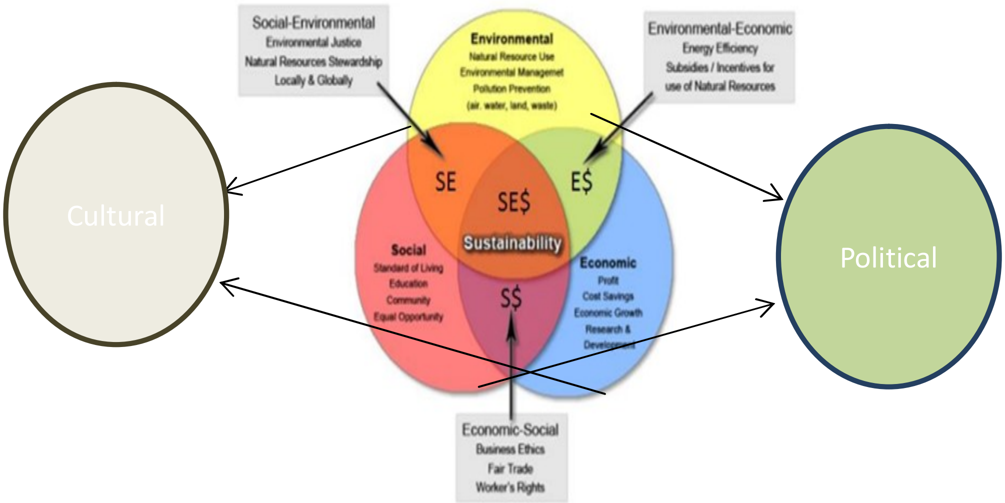

Figure: 1. Different pillars of sustainability

7.5. Guiding principles of sustainability

Sustainability is largely relying on conservation based development needs. To protect the structure and function as well as diversity of natural ecosystems it focuses on following aspects:

- **Integration of environmental and economy -** The environment and the economy are very closely related. Various economic tools and policies may promote sustainable development, or at least lead to a more environmentally conscious use of resources. These tools or policies may be applied equally to producers, consumers and taxpayers and to enable the market to determine the correct overall cost of using resources. The integration of the environment and the economy is as advantageous for poorer countries as for rich ones because, if production models adhere to economic and environmental rules, there may be a better balance of comparative production advantages. The result could be a softening of world trade rules whereby poorer countries would be enabled to lay claim to greater economic development.

- **Conservation of Biological Diversity and sustainable use of Natural Resources-** Achieving sustainable development presupposes that we can preserve biological diversity, maintain ecological processes and life support systems and use the world's species and ecosystems in a sustainable manner is necessary to achieve sustainability. These measures must focus on species and ecosystems as well as on their genetic heritage. Consequently, the limits, on and the capacity for renewal of, natural resources such as soil, wild and domesticated species, forests, pasture and farm land, fresh water and marine ecosystems, must not be compromised. The life of non-renewable resources should be extended by developing and using more effective and cleaner technologies and by encouraging re-use and recycling.

- **Cooperation, Partnership and Participation-** Achieving sustainable development has become a collective responsibility that must be fulfilled through action at all levels of human activity. Consultation and cooperation in all decision-making are essential to the sustainable management of terrestrial, aquatic and marine ecosystems. It is incumbent upon all states and all nations to cooperate in good faith and in a spirit of partnership in implementing effective strategies to protect, preserve and restore the environment. All must take an active part and do their fair share in accordance with their capabilities and the means at their disposal. All governments must accept their responsibilities by introducing economic growth policies and programs compatible with the protection of their own environment and that of others. They must ensure the protection of ecosystems of particular importance for agriculture and the way of life of the populations that depend on it.
- **No to exceed the earth carrying capacity**
- **To improve the quality of life including the social and economic concerns**
- **To develop a national framework code to integrate development and conservation.**

The principles of sustainability can be linked with the goals of sustainability.

7.6. Sustainable Development Goals or goals of sustainability

One of the main outcomes of Rio+20 Conference is the agreement by members to launch a process to develop a set of sustainable Development Goals (SDGs). The Sustainable Development Goals are a universal call to action by all countries, poor, rich and middle-income to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere (www.un.org). These goals stressed on the eradication of poverty by increasing economic growth and job opportunities while conserving the environment, increasing education, health, social and climatic protection. In the year 2017 UN members adopted Agenda 2030 for sustainable development, in which 17 goads are defined. These are as follows:

7.6.1. Goals of Agenda 2030 for sustainable development

Source https://www.un.org/sustainabledevelopment

Goal 1: End poverty in all its forms everywhere- More than 700 million people, or 10 per cent of the world population, still live in extreme poverty today, struggling to fulfill the most basic needs like health, education, and access to water and sanitation to name a few.

Goal 2: Zero Hunger- According to the World Food Program, 135 million suffer from acute hunger largely due to man-made conflicts, climate change and economic downturns. The COVID-19 pandemic could now double that number, putting an additional 130 million people at risk of suffering acute hunger by the end of 2020.

Goal 3: Ensure healthy lives and promote well-being for all at all ages-Ensuring healthy lives and promoting well-being at all ages is essential to sustainable development. Currently, the world is facing a global health crisis COVID-19 which is spreading human suffering, destabilizing the global economy and upending the lives of billions of people around the globe.

Goal 4: Quality education- Education enables upward socioeconomic mobility and is a key to escaping poverty. Despite a significant progress made in the last decade still 260 M children were still out of schools.

Goal 5: Achieve gender equality and empower all women and girls- Gender equality provides necessary foundation for a peaceful, prosperous and sustainable world. There has been progress over the last decades: More girls are going to school, fewer girls are forced into early marriage, more women are serving in parliament and positions of leadership and laws are being reformed to advance gender equality. Despite a lot of gains still many challenges remain as suchlike discriminatory laws and social norms, poor representation in political leaderships and sexual violence.

Goal 6: Ensure access to water and sanitation for all - Worldwide, 33 % people do not have access to safe drinking water, 40 % people do not have a basic hand-washing facility with soap and water, and more than 673 million people still practice open defecation.

Goal 7: Ensure access to affordable, reliable, sustainable and modern energy- The Energy Progress Report provides global dashboard to register progress on energy access, energy efficiency and renewable energy.

Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all – This candrive economic progress, create jobs for all and improve living standards.

Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation- Inclusive and sustainable industrialization, together with innovation and infrastructure, can unleash dynamic and competitive economic forces that generate employment and income. They play a key role in introducing and promoting new technologies, facilitating international trade and enabling the efficient use of resources.

Goal 10: Reduce inequality within and among countries - Reducing inequalities and ensuring no one is left behind to achieving the Sustainable Development Goals

Goal 11: Make cities inclusive, safe, resilient and sustainable- Cities and metropolitan areas contributing about 60 per cent of global GDP. However, they also account for about 70 per cent of global carbon emissions and over 60 per cent of resource use. This increasing the expansion of cities and growing number of slum dwellers leading to inadequate infrastructure and services, worsening the pollution and unplanned urban sprawl.

Goal 12: Ensure sustainable consumption and production patterns - Worldwide consumption and production have destructive impacts on the planet natural environment and resources. This leads to environmental degradation which is endangering the very systems on which our survival depends. One third of all food produced rotten every year due to poor harvesting, storage, and transport facilities.

Goal 13: Take urgent action to combat climate change and its impacts- Climate change is affecting every country on every continent. It is disrupting national economies and affecting lives. Weather patterns are changing, sea levels are rising and weather events are becoming more extreme. 2019 was the second warmest year on record and the end of the warmest decade (2010- 2019) ever recorded. Carbon dioxide (CO_2) levels and other greenhouse gases in the atmosphere rose to new records in 2019. The Paris

Agreement, adopted in 2015, aims to keep temperature rise globally below the 2 ^{0}C compared to preindustrial level.

Goal 14: Conserve and sustainably use the oceans, seas and marine resources - The oceans and sea provides many products and regulate of many services including the climates of the world. Thus, careful management of marine resources is essential for sustainable future. However, at the current time, there is a continuous deterioration of coastal waters owing to pollution, and ocean acidification is having an adversarial effect on the functioning of ecosystems and biodiversity recalls putting more efforts to conserve these.

Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss – Forest and wildlife is critical to our survival but it is under increasing stress due to high anthropogenic activities. Human activity has altered almost 75 per cent of the earth's surface, squeezing wildlife and nature into an ever-smaller corner of the planet. Investing in land restoration is critical for improving livelihoods, reducing vulnerabilities, and reducing risks for the economy.

Goal 16: Promote just, peaceful and inclusive societies – This goal addresses the social insecurity, justice system because social insecurity, weak institutions and limited access to justice in the world is still a great threat to sustainable development particularly in the developing countries.

Goal 17: Revitalize the global partnership for sustainable development- The SDGs can only be realized with strong global partnerships and cooperation. A successful development agenda requires inclusive partnerships to build principles and values; and to share vision and goals placing people and the planet at the global, regional, national and local levels of centers.

7.7. Criteria and indicators of sustainability

Sustainability can be regulated by adopting different criteria in order to assess opportunities, risk derived from the pillars and linking them with sustainability. Simply, sustainability criteria are requirements to the sustainable quality of a product and its sustainable production, which have to be fulfilled in order to acquire a sustainability status or certification (Pavlovskaia 2012). Bell and Morse (2001) have recommended the following criteria of sustainable development:

a) Social justice;
b) Local government, public participation, democracy;
c) Sustainable balance between local and imported resources consumption;
d) Use of local economic potential;
e) Environmental protection;
f) Protection of cultural heritage,
g) Protection and regeneration of a new environmental quality,

7.7.1. Indicators for sustainability criteria

An indicator is parameters which provideinformation about and describe the state of a phenomenon. Indicators are,thus, quantified information which helps to explain how things are changing over time. Indicators of sustainable development have been developed to measure identiiable economic, social and environmental conditions. Indicators for sustainability criteria are the tools used to check and evaluate the fulfillment of sustainability criteria, as well as progress towards sustainability. Indicators can provide quantitative measurement and qualitative assessment of human activities and their impact on the surrounding world (Annon. 2010). These correspond to policy goals, informative, easy to understand and compute logical, effective, practical, reliableand accessible data. United Nations Commission on Sustainable Development (CSD) revised in 2007 the set of indicators of sustainable development to serve as reference for countries to develop or revise national indicators of sustainable development (Table 2).

Table 2.CSD Indicators of Sustainable Development–3rd edition

Theme	Sub-theme	Core indicator
Poverty	Income poverty	Proportion of population living below national poverty line
	Income inequality	Ratio of share in national income of highest to lowest quintile
	Sanitation	Proportion of population using an improved sanitation facility

	Drinking water	Proportion of population using an improved water source
	Access to energy	Share of households without electricity or other modern energyservices
	Living conditions	Proportion of urban population living in slums
Governance	Corruption	Percentage of population having paid bribes
	Crime	Number of intentional homicides per 100,000 population
Health	Mortality	Under-five mortality rate
		Life expectancy at birth
	Health care delivery	Percent of population with access to primary health care facilities
		Immunization against infectious childhood diseases
	Nutritional status	Nutritional status of children
	Health status and risks	Morbidity of major diseases such Prevalence of tobacco use as HIV/AIDS, malaria, tuberculosis
		Suicide rate
Education	Education level	Gross intake ratio to last grade of primary education
		Net enrolment rate in primary education
		Adult secondary (tertiary)
		schooling attainment level
	Literacy	Adult literacy rate
Demographics	Population	Population growth rate
		Dependency ratio
	Tourism	Ratio of local residents to tourists in major tourist regions and destinations
Natural hazards	Vulnerability to natural hazards	Percentage of population living in hazard prone areas
	Disaster preparedness and response	Human and economic loss due to natural disasters
Atmosphere	Climate change	Carbon dioxide emissions
	Ozone layer depletion	Consumption of ozone depleting substances
	Air quality	Ambient concentration of air pollutants in urban areas
Land		Land use change
	Land use and status	Land degradation
	Desertification	Land affected by desertification
	Agriculture	Arable and permanent cropland area
	Forests	Proportion of land area covered by

		forests
	Coastal zone	Percentage of total population living in coastal areas
Oceans, seas and coasts	Fisheries	Proportion of fish stocks within safe biological limits
	Marine environment	Proportion of marine area protected
Freshwater	Water quantity	Proportion of total waterresources used
		Water use intensity by economic activity
	Water quality	Presence of faecal coliforms in freshwater
Biodiversity	Ecosystem	Proportion of terrestrial area protected, total and by ecological region
	Species	Change in threat status of species
Economic Development	Macroeconomic performance	Gross domestic product (GDP) per capita
		Investment share in GDP
	Sustainable public finance	Debt to GNI ratio
	Employment	Employment-population ratio
		Labor productivity and unit
		labor costs
		Share of women in wage
		employment in the non- agricultural sector
	Information and communication technologies	Internet users per 100 population
	Research and development	Gross domestic expenditure on R&D as a
		percent of GDP
Tourism		Tourism contribution to GDP
Global economic partnership	Trade	Current account deficit as percentage of GDP
	External financing	Net Official Development Assistance (ODA) given or received as a percentage of GNI
Consumption and production patterns	Material consumption	Material intensity of the economy
	Energy use	Intensity of energy use, total and by economic activity
	Waste generation and management	Generation of hazardous waste
		Waste treatment and disposal
	Transportation	Modal split of passenger transportation

In 2017 the global indicator framework for Sustainable Development Goals was developed by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) and adopted by the General Assembly on 6 July 2017 and is contained in the Resolution adopted by the

General Assembly on Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development (A/RES/71/313). According to the Resolution, the indicator framework will be refined annually and reviewed comprehensively by the Statistical Commission at its fifty-first session in March 2020 and its fifty-sixth session, to be held in 2025. The global indicator framework will be complemented by indicators at the regional and national levels, which will be developed by Member States. The global indicator framework includes 231 unique indicators. The details can be obtained from the link https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202020%20review_Eng.pdf.

7.8. Approaches to sustainable development

Nowadays, “sustainability” is a very widely used terms in policy contexts, businesses and organisations. However, the unfortunate paradox is that environmental degradation and destruction are occurring at unprecedented levels. It involves economic as well as social and environmental changes, thus requiring an interdisciplinary approach. International organizations and institutions uses three main approaches to Sustainable Development (SD) have been analyzed: -

- The first approach is the integration of economic, social and environmental systems, all of which must be simultaneously sustainable, because each of the three pillars is independently crucial and because the three pillars are interconnected.

- The second one is ecosystem health approach which considers the economic and social systems as subsystems of the global environment. This approach implies focusing on the pressures placed on ecosystems by human activities (material and energy extraction, physical restructuring, pollutant emissions, human appropriation of space and ecosystem productivity). These pressures are often the cause of reduced ecosystem health as manifested in degraded service lows and reduced management options.

- The third one is the resources or capital approach, which views sustainable development as development that ensures non-declining per capita national wealth by replacing or conserving the stocks of produced, human, social and natural capital. It broadens the concept of economic capital by integrating concepts from physical and social sciences to include measures of human, social, natural and environmental capital.

In the above approaches following methods are used:

1. Appraisal of the Environment
2. Estimation of the Environmental Impact
3. Natural Resource Accounting
4. Government Policies and Economic Outlook.

7.8.1. Appraisal of the Environment

Assessment of environmental conditions is prerequisite for initiation of any sustainable development project. In this system symbiotic relationship between local ecology, social structure and economic conditions of the area concerned should be taken into account for assessing the sustainability. Bio-physical condition of the area is intricately related with the economic order of the region which, in turn, influences societal development. The assessment report recommends action plan.

7.8.2. Estimation of the Environmental Impact

Environment and its positive use is a key factor for sustainable development. Negative impact on environment through unplanned development may harm the sustainability as a whole. Estimation of environmental impact is the study of interrelationship with natural systems and development process The development which creates complete social and environmental harmony is only classed as sustainable. To achieve this goal, identification of the major positive aspects and its optimum utilization and monitoring is necessary. Thus, in this method different ecological inputs along with climate, soil, vegetation and drainage resources should be properly assessed and monitored and how development process affects these natural systems should be critically examined.

7.8.3. Natural resource accounting

In this system of natural resources like clean air, soil, water, forests, ecotourism, wildlife, livestock, etc. taken for accounting of sustainability. This is opposed to the traditional accounting system which ignores the economy of natural systems. This system is a new one and therefore, no unified methodology exists for evaluation of resources.

7.8.4. Government Policies and Economic Outlook

In this method the government policies and economic matters taken in the accounting system as the Government policies play an important part in the conservation and allocation of resources between poor and rich, reducing inequality among individuals etc.

7.9. Ethics

7.9.1. Definition and concept

Ethics or morality has to do with the principles, standards, rules, norms of conduct that make cooperation, justice, and freedom possible. It provides a philosophically based touchstone for an ideal of justice, right relationship and the proper use of power and authority. Ethics is grounded on the ethical commitment to the well-being not only of contemporary populations but also the wellbeing and enhanced opportunities of future generations. According Jennings (2010) the ethical analysis typically has the following four central components:

- A**n evaluation of the character and intentions of the agent—what** virtues/vices does the agent exemplify?
- **An evaluation of the inherent properties of an action—**what rights or duties does the action fulfill or violate?
- **An evaluation of the consequences of an action**—what benefits or harms are brought about by the action?
- **Evaluations of the context within which actions take place**—does the action support or undermine the system or context which makes the action possible and meaningful in the first place?

In sum, virtue, rightness, consequence, and context are all ethically important in navigating sustainability. A sustainable society lives within the carrying capacity of its natural and social system. It has a system of rules and incentives that promote replenishing and limit depletion and pollution. A sustainable society builds upon the commitment of its members to conform to these rules voluntarily, and it enforces them when necessary.

Environmental ethics is the study of value, moral relationship of human beings to the environment and its non-human contents. Environmental ethics believe that humans are a part of society as well as other living creatures, which includes plants and animals. These items are a very important part of the world and are considered to be a functional part of human life. Human values are the things that are important to individuals that they then use to evaluate actions or events and become a factor when looking at environmental ethics. Human values are unique to each individual because not everyone places the same importance on each element of life. For example, a person living in poverty in an undeveloped country may find it morally acceptable to cut down the forest to make room for a farm where he can grow food for his family. However, a person in a developed country may find this action morally unacceptable because the destruction of forests increases carbon dioxide emissions into the atmosphere, which can negatively impact the environment.

Depletion of natural resources, global climate change, biodiversity loss, degradation and destruction off ecosystems, air, waterpollution are the challenging aspects of anthropogenic activities and directly related with environmental ethics and human values. Therefore, it exerts influence on a large range of disciplines including environmental law, environmental sociology, ecological economics, ecology and environmental geography. Its emergence was the result of increased awareness of how the rapidly growing world population was impacting the environment as well as the environmental consequences that came with the growing use of pesticides, technology and industry in the 1970s. The first academic conference concerning environmental ethics was held at the University of Georgia in 1971; the first journal, Environmental Ethics, was founded in 1978. The International Society for Environmental Ethics was founded in 1989 and the International Association for Environmental Philosophy in 1997. From the 1980s onward, research, publication and teaching in environmental ethics rapidly expanded. Environmental ethics are now a key feature of environmental studies that establishes the relationship between humans and the earth. With environmental ethics, you can ensure that you are doing your part to keep the environment safe and protected. Environmental ethics builds on scientific understanding by bringing human values, moral principles and improved decision making into conversation with science.

7.10. Theories of environmental ethics

Environmental ethics is a huge field and so vast therefore, difficult for one principle to cover all the aspects. Many theories have emerged over the years, and each one has stressed on various principles of environmental ethics. These are:

7.10.1. Anthropocentrism

The term anthropocentrism can be used to refer to worldviews and attitudes, to intrinsic value, or to moral status and significance. It suggests that human beings are the most important beings. All other living beings are but accessories that would assist in their survival. The argument that anthropocentric attitudes, such as that humans have dominion over nature, lie at the root of our environmental problems has historically been influential in environmental ethics. Now, there are two further divisions of anthropocentrism. These are: weak anthropocentrism and strong anthropocentrism.

a. **Weak anthropocentrism-** believes that human beings are the centre because it is only through their perspective that environmental situations can be interpreted.
b. **Strong anthropocentrism-** believes that human beings are at the centre because they rightfully deserve to be there. .

7.10.2. Environmental Justice and Sustainability

Environmental justice is a key concern of environmental ethics. It is defined by the US Environmental Protection Agency as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Global and intergenerational justice issues have recently gained greater attention because of their centrality to the ethics of global climate change. Affluent people living today are disproportionately responsible for anthropogenic climate change because of their high-consumption (and so high-emissions) lifestyles. However, poor people in low-income countries are, and will increasingly be, disproportionally exposed to the ecological hazards associated with climate change, being more dependent on their local ecological systems and having a lower adaptive capacity (e.g., less wealth and mobility).

7.10.3. Non-Anthropocentrism

As opposed to anthropocentrism, this principle gives value to every object, every animal in nature. It is a principle that believes in everything that sustains itself in nature.

a. **Ethics and Sentient Animals-** One key approach to environmental ethics focuses on the moral status, and ethical treatment, of individual animals. Most commonly, moral status is attributed on the basis of animals' subjective experiential welfare, particularly animals' capacity to feel pain. The basic idea that sentience is a sufficient condition for moral status is widely accepted in environmental ethics, even by those who do not regard it as a necessary condition.
b. **Ethical Biocentrism-** Ethical biocentrism is used to describe ethical positions in which all living things have moral status. A number of biocentric approaches have been systematically developed these approaches disagree about what characterizes a living thing and why those characteristics might be thought of as morally relevant; whether some living things are more morally significant than others; and whether the value of life is just one among a broader, plural set of values conveying moral relevance, or is the only such value.
c. **Ecocentrism –** In this theory moral sphere outward from the human community to the biotic community and suggest ethic was not systematic. It, thus, enlarges the boundaries of the community to include soils, waters, plants and animals and their preservation for the integrity, stability and beauty of the earth.
d. **Species**-According to this theory species have value distinct from that of the individual organisms that comprise them Species, and populations, are certainly instrumentally valuable. They provide food, medicine, shelter, recreation, enjoyable experiences, knowledge, and more. The question here is whether they have value not based on their usefulness to us. There are two ways in which both ecosystems and species might have non-instrumental value. They might have interests or a good of their own that we ought to care about (moral status) or they might be valuable in their own right even if they lack interests (another form of intrinsic value).
e. **Wildness Value-** Wildness is defined as "in contrast with those areas where man and his works dominate the landscape...where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." Wildness or naturalness is significant in environmental ethics.
f. **Hybrid or Value-Pluralist Views**- this theory says that moral status of many different kinds of beings and things have defended a variety of values. Some positions in environmental ethics are value monist—arguing that there is ultimately only one kind of master value (e.g., positive sentient experience, or flourishing) and that other apparent value can be analyzed in terms of or be reduced to that

one value. pluralist view may adopt where one can consistently rank values and apply some kind of lexical priority rule on one value (or amount of the value) over another value (or amount of the value).

7.11. Role of ethics

The environmental ethics plays a key role in the recognition of the human- environment interactions. Modern environmental ethics is the philosophical re-thinking of modern human race's environmental behavior. Sustainable development implies harmony on human-environment interactions and inters- generation responsibility, with emphasis on a harmonious relationship among population, resources, environment and development, so as to lay a sustainable and healthy foundation of resources and environment for future generations. The role of environmental ethics in regional development consists of cognition, criticism, education, inspiration, adjusting, legislation and promoting environmental regulations. Environmental ethics plays big role in conservation of natural resources. It largely relies on making human communities and ecosystems better, protecting important resources for the present and future. Its role can be categorized into following:

- In the management of natural resources to meet our increasing needs and wants.
- To build a scientific understanding by bringing humans values, moral principles
- To improve decision making into conservation based sustainable development.
- In helping sustainable developmentat regional and local level
- In the harmonizing relationship of population, resource, environment and economic development
- In the behavior selection, social and political system transformation
- In strengthening the legal system
- In raising environmental awareness.
- In the Protection of environmental rights of animals.
- In the conservation of traditional value systems
- In the equitable utilization of natural resources.
- In the equity among the people of rural and urban areas and also between males and females.

7.12. Globalization and sustainable development

Globalization refers to market liberalization, shifting profits up the value chain and the interconnectivity of global markets. Globalization gave fresh importance to spatial economics along with the significance of financial and monetary layouts. Globalization, when well-managed, can provide better results to everyone or most of us. There are a lot of confusion and differences over discussions as the process of globalization has diverse implications to various people (Antonucci and Varriale 2020). Globalisation started to influence all aspects of community life, from culture to crime and from finance to religion. Due to globalization, the world is turning into a single social space, shaped by complex economic and technological forces. Globalisation is characterized by four major trends which entailed new problems and challenges for society. These are:

a. Increased flows of commodities and persons,
b. Expansion and diversification of financial activities;
c. Development of communication networks, knowledge and relationships;
d. Increasing disparities.

The impact of these changes is so immeasurable that governments and individuals can do little to contest or resist them. The main challenge is the growing disparities between developed and other societies and within societies themselves, leading to a high degree of economic stratification between rich and poor, at regional, national and global levels. Unfortunately, this difference is not shrinking, it is growing and sometimes manifest in violent outbursts causing considerable human and material damage. Further, sustainability of globalization may or may not flow in a similar way for all countries. Some of them like the United Kingdom and Japan might experience a better local atmosphere due to the globalization process, while others like Bangladesh and Mexico can experience a declining and fading environment(Ushakov and Chich-Jen 2020).

Though there are various ways to define the complexity of the processes related to globalization(Sano 2020; Goel et al. 2020). Following indexes are mainly used to analyse the overall impact of globalization on the countries' sustainability also to assess its significances in a scientific manner. These are:

a. **The KOF Globalization Index (KOFGI)-**The KOF Globalization Index (KOFGI) is used in this study as a measure of globalization which is calculated on a yearly basis from 1970 to 2015 (Gygliet al. 2019). This index measures the economic, social and political dimension to globalization. It is used in order to monitor changes in the level of globalization of different countries over extended periods of time. The data are normalized implying that each variable is transformed to an index with a scale from one to one hundred, where 100 is assigned to the maximum value of a specific variable over the whole sample of countries and the entire period of time which is the analogue to a transformation of the series according to the percentiles of its original distribution. The procedure is called panel normalization which is different to annual normalization where data are normalized across all countries in the same year only. The resulting data are well-behaved in terms of sensitivity to outliers (Tang et al. 2020). Economic, social and political globalizations are assessed giving equal weight. The economic globalization consists of trade globalization and financial globalization, of which each gets a weight of 50 %. Social globalization consists of interpersonal, informational and cultural globalization each of them gets 33 % weights. Political globalization is measured with reference to the number of embassies and international non-governmental organizations (NGOs), along with participation in UN peacekeeping missions. Economic, social and political globalizations are aggregated to the Globalization Index using again equal weights.
b. **Sustainability Indices-**Sustainable development is a challenging concept, its fundamentals are very clear which states the maintenance of the integrity of bio-physical and natural systems. It ensures that a proper functioning economy must be present and cultivating or upholding human wellbeing and health is of utmost importance. Sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfill their aspirations for a better life (Tang et al. 2020).
c. **Human Development Index (HDI)-** HDI highlightsnot only the economic development but also individuals and their abilities in the measurement of growth of a country. It incorporates three important areas of human development i.e. healthy and long life, knowledge accessibility and standard of living for evaluation of sustainability. Healthy living is measured by life expectancy at birth; knowledge is determined by an average of expected and mean years of schooling and standard of living by the gross national income per capita (Annon. 2018).
d. **Environment Sustainability Index (ESI)-** It has been constructed by taking into account four areas (i) energy consumption, (ii) carbon dioxide emission, (iii) forest area and (iv) mortality rate attributed to household and ambient air pollution. Environment Sustainability for 189 countries has been prepared by UNDP to construct the index by ranking countries based on their performance in the above

four areas with the most efficient receiving rank one and so on. The ranks across all indicators are aggregated, attaching equal weights to obtain the Environment Sustainability Index. Lower values of ESI indicate greater efficiency in terms of environmental sustainability (Tnag et al. 2020).

e. **Environmental Performance Index (EPI)-** EPI focuses on two main environmental goals viz. (i) reducing environmental stresses to human health; (ii) endorsing ecosystem vitality and comprehensive natural resource management. Both of the goals also replicate the policy significances of environmental specialists around the globe and the international community's intentions for the adoption of Goal 7 of the Millennium Development Goals (MDGs) for ensuring environmental sustainability. These two goals are evaluated by combining 25 different performance indicators(Wendling 2018).

f. **Red List Index (RLI) –**RLI is a measure of the aggregate extinction risk of species across the globe. It is based on the "Red List of threatened species" published by International Union for Conservation of Nature. The range progresses varied from 0 to 1. 0 indicates the species is extinct whereas 1 indicates the species being least concern (IUCN 2019; Salvia et al 2019).

g. **Sustainable Development Goal Index (SDGI)-** The 2030 Agenda for Sustainable Development) was adopted in 2015 by the UN and therefore, applicable to all the member countries of United States. In this index all the indicators of sustainability for each member are given a comparable scores and a highest ranking of 100 is given in order to develop this index. The global SDG Index score by goal can be interpreted as the percentage of achievement. The difference between 100 and countries' scores is, therefore, the distance in percentage that needs to be completed to achieve goals. For example Sweden's overall Index score 85 suggest that the country is on average 85% of the way to the best possible outcome across the 17 SDGs.

7.13. Summary

Sustainability is a complex term related with the sustainable development, which envisages meeting ourown needs of the present generation without compromising the ability of future generations. The term integrates environmental, social, economic, cultural and political resources in order to create thriving, healthy, diverse and resilient communities for the present as well as generations to come. The concept was emerged in the year 1987 when World Commission of Environment and Development published report on "Our common futures". Later United Nations linked it with human development in order to eradicate poverty, equitable

distribution of wealth, reduce environmental pollution, prevents natural resource deterioration, conserve forests and biodiversity and climate change adaptation. In 2015 UN Member States adopted 17 goals as a part of Agenda 2030 for sustainable development. Sustainability is a holistic approach encourages companies, industries and governments to adopt environmentally sound, energy efficient technologies and recycling of waste and pollution in order to establish systems that are compatible with the biosphere while integrating the social, economic and environmental potential of each region.The sustainability approach is difficult to tie down in analytical terms, since it is concerned with tremendous variety of development objectives and achievable only, if taken seriously and implemented on a global scale. Therefore, varioussustainability criteria have been devised to assess opportunities and risks derived from economic, environmental, social, cultural and political dimensions of sustainability. To check and evaluate the fulfillment of sustainability criteria, as well as progress towards sustainabilityindicators tools used. In order to assess the sustainable development goals the UN General assembly in 2017 adopted global indicator framework includes 231 unique indicators. There are three main approaches used to analyze sustainability at the international organizations and institutions level. These approaches are based on appraisal of the environment, estimation of the environmental impact, natural resource accounting and government policies and economic outlook methods of assessment. Sustainable development implies harmony on human-environment interactions and inters- generation responsibility, with emphasis on a harmonious relationship among population, resources, environment and development. Increasing population and consumptions of the resources are the main hurdles in achieving the sustainability. Thus, ethics can play an important role in attaining sustainability because sustainable society has a system of rules to limit depletion and degradation of resources and incentives facility to promote replenishment of resources. Environmental ethics is a huge field and exerts an influence on a large range of disciplines including environmental law, environmental sociology, ecological economics, ecology and environmental geography. There are three important theories viz. anthropocentrism, environmental justice and

sustainability and non-anthropocentrism of environmental ethics. Further, in the recent years globalization on one side has increases the significance of financial and monetary layouts but on the other side it has started to influence all aspects of community life, from culture to crime and from finance to religion. The overall impact of globalization on sustainability may be analysed using various indexes.

TERMINAL QUESTIONS

Section A - Fill in the blank spaces with appropriate words

i. Sustainability means ---------------------------------- (See concept section)
ii. The most used definition of sustainability is given by __________ in the year __________ (see concept section
iii. The title of Brundtland report was _________
iv. Sustainability is based on _____ ________ and ________ principal pillars
v. Sustainable Development Goals were adopted and the IN in the ____________

Section B- Subjective question

i. Describe the origin of sustainability term in brief (See origin and history section)
ii. Explain the drivers of global environmental change.
iii. Discuss the guiding principles of sustainability.
iv. What are goals? Discuss the UN goals for Agenda 2030.
v. Discuss the different approaches to sustainable development.
vi. What is ethics? Elaborate the theories of environmental ethics in detail.
vii. Discuss the impact of globalization on development and environment.

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Unit 8: Ecology

8.0 Learning Objectives

After the study of this unit you will be able to:

- know all about the ecology vis-à-vis human beings
- understand the philosophy of ecology
- highlight the importance and scope of ecology for sustainable development
- interlink the relationship with discipline of science and humanities

8.1 Introduction

None of the living entity is independent and associated to environment in terms of light, energy, shelter, or any other environmental factors. The study of interrelation between living entity and to its environment is called as Ecology. For example, the adopted methodologies, theories and frameworks to develop the understanding the relations of human to its environment are human ecology. The human is the most intellectual organism and revealed higher resilience to adapt the environment. The hunting and gathering activities are the examples for adaptation against the environment in ancient era. However, in present era, potable water, clean air, food, and energy are the major ingredients of a livable environment. To target the supply of these ingredients a variety of evolving changes like reverse osmosis filter water, air purifier, and organic food stuffs etc. has been adopted. In this context, the study of foraging (hunting and gathering) activity and other modifications in order to survive and thrive consider as human ecology.

The ecology was on track with the human evolution on earth. The study of relationship of organism to its environment was initially termed as Ethology by a French Zoologist, Geoffrey Saint Hilaire, 1859 which is today in limelight due to the huge crisis of natural resources. Further, a German biologist Reiter, 1866 coined term Oekologie. Afterward, in 1867 E. Haeckel introduces the term firstly in literature **(Egerton, 2013).**

8.2 Ecology

As we know, if you make a sound in front to a well the sound will revert as eco sound. Now you may understand the meaning of Eco. Eco reflects reaction in response to any action. Etiologically eco means “to house” (originated from Greek word oikos meaning house) and logos means “to study”. Here, it is important to understand that the all the things around

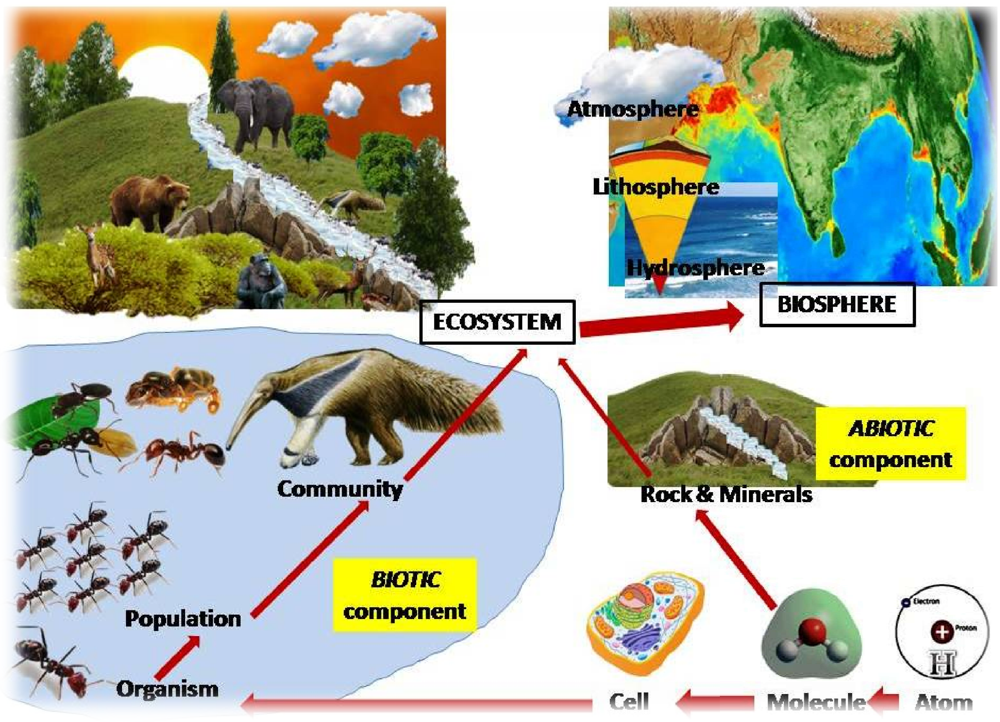


Fig 1. Ecology: Interactions in biotic and abiotic component

us or surrounding is considered as an environment. Basically the environment is originated from two words *i.e.* 'environrer and ment'. Where, 'environer' indicates to the surrounding and 'ment' means action. Thus, the environment means the action of surrounding that influences to the organism. The environment has two components i.e. biotic and abiotic. Further, it has three domains i.e. lithosphere (sphere of landmasses and soils), hydrosphere (sphere of water bodies) and atmosphere (sphere of air masses). The sphere of living beings is considered as biosphere. The biosphere interactive to all the three spheres of land, water and air, these interactions and interrelations form the ecosystems. The ecosystem is the structural and functional unit of Ecology. Ecology is defined as the scientific study of interactions and interrelations of biotic and abiotic factors.

Ecology is the branch of biology to study the organism in reference to living place such as household, habitat and circumstances of dwelling place. Basically, the life of an organism is existed, connected and influenced by the other organism and the surrounding abiotic environment. In our environment, we connected with non-living factors closely like temperature, and other climatic factors e.g. we, human beings, put the cloths according to the ambient temperature woolen during winter, light cotton cloths during summer, our life style is according to temperature.

In case of plants the vital activity of plants including flower bloom etc. are dependent to temperature. In another end if we considering the biotic interaction it may be in between same species (population), between different organisms (community). The biotic community along with the abiotic component is called as ecosystem. A biosphere is an ecological region of characteristic climate and share the highest level of ecological hierarchy. To sum up the things, the life of a living being is associated with the biotic community and non-living factors in a space. Basically, the study the interactions with the biotic community of the individuals along with the abiotic factors in relation to its habitat. The leaf litters decomposition recycled back the nutrients to the soil from where it obtained for their growth and development. The leaf litter decomposition returned back the nutrients to soil. The decomposition of leaf litter also depends on the environmental abiotic conditions. Hence, the environmental conditions are helpful to maintain the stability of the nature **(Monika *et al.*, 2017).**

8.2.1 Definition

A branch of biology dedicated to study the interactions and interrelationship of biotic communities and abiotic factors in relation to the physical space is called ecology. In nutshell, the study of interrelationship between habitat and inhabitants' biotic community is called as ecology e.g. the interrelationship of a lake and its algae, fishes other organisms.

The cluster of ecosystems is called ecology and ecosystem is an integral part of ecology. It is considered as the structural and functional unit of ecology. Ecology is extensively studied by researchers and they have defined it in different flavor. But the gist is to study of living beings along with its biotic and abiotic interactions at its living place.

The organism exists in their ecological favorable environment and as the environmental condition is deviating from the desired environmental condition the population of organism started to decline gradually in response to the environmental condition. The decline in the population reflects that the organism is in stress environment and not able to tolerate the stressful environmental condition. If population survives in environmental condition means either the condition if favorable or organism has the ability to adapt and acclimatize the prevailing condition. These environmental variable are numerous mainly water stress, thermal (temperature) stress and light etc.

When organism is out of their optimum range of tolerance certainly they effort to change or modify their characteristics and features to survive in harsh or intolerant environmental condition as physiological response to environment. The effort may be temporary and reversible for time being and it may be for permanent, irreversible and genetically too. Adaptation is a permanent genetically determined physiological response to environmental stress. Acclimatization is a temporary, reversible, short durational physiological change (adjustment) / response to the environmental stress.

The atoms together form a molecule. Different molecules are the constituents of a living cell. A number of cells organize an organism. Organism is a basic entity of an ecosystem. The total number of an organism of same individuals in an area is population. Two or more than two populations together form a community. The community of living being live in a surrounding place (abiotic) collectively called as ecosystem. The ecosystem is a basic and functional unit of ecology Fig 1.

The ecology comprises all the interactions among living beings and with abiotic components. Apart from abiotic component, the biotic relations are also a part of living place and influence the organism's life. All the interactions, either among biotic or abiotic that influence life of living beings are ecology. Thus, the abiotic factors or physical environment are crucially significant in maintaining ecosystem. The healthy environmental conditions tree improves the tree growth and ultimately develops the higher carbon sequestration **(Bijalwan *et al.*, 2017).**

8.2.2 Biotic interactions

Biotic interactions are playing a crucial protagonist to decide the existence and survival at a specific place in long run. The biotic interactions are very dynamic component and directly influence the life of habitat. These interactions are also time dependent and changes with time of maturity of the prevailing landscape. There are certain examples of biotic interactions like prey-predator relations, allelopathy and symbiosis. However, the biotic interaction influences the life of each and every living being direct or indirect mode. The study of biotic interaction in the field of ecology is very crucial and complex too. Keep in this view the biotic interactions are tabulated here in summarize format.

Table 1: Biotic interactions and its effects in Ecology

Interaction	Type of Interaction	Effect of biotic interaction	Example
Amensalism	-/0	One population is inhibited but second one is not affected by this association.	Tagetes prevent the growth of nematodes by secreting allelochemicals. Salvia and Parthenium are other examples
Predation	+/-	One species prey on another species	Frog prey on Grasshopper
Parasitism	+/-	One species is inhibited and second one is affected by this parasitism.	Fungi, Bacteria, Cuscutta, Broom grass, Rafflesia
Competition	-/-	The populations are not affecting directly to each other but they fight for using the resources	Langurs & Monkeys, African lions & cheetahs, Woodpeckers &

		available like for light, moisture etc.	Squirrels
Commensalism	+/0	One population is benefited but second one is not affected.	Vines, Epiphytes, Orchids, Climbers, Lianas
Mutualism	+/+	Both of the species are get benefitted and they essentially required this association for survival.	Biological Nitrogen Fixing Bacteria (Rhizobium) & Actinomycetes (Frankia), Lichen, Coroloid roots of Cycus with fungal hyphae, Mycorrhzae & Plants, Ant with Acacia
Neutralism	0/0	Two populations living together but neither affecting nor benefiting to each other.	Tarantulas and cacti in desert.

8.2.3 Ecological Pyramids

The ecological pyramid represents trophic structure and function of an ecosystem. The pyramid may be for Numbers, Biomass, Energy and Productivity. The hierarchical level is the outcome of consequences of the entire role played by individuals. Due to the high production found at lower of trophic levels, consequently the "upright" pyramid is usually obtained for biomass, energy, and numbers except the Forest pyramid for Numbers and Aquatic system pyramids for Biomass. The inverted pyramid in tree reveals (a single tree- → numerous birds → uncountable parasites) the increasing numbers individuals with successive trophic levels. However, generally the numbers of individuals decrease with successive trophic levels e.g. pyramids of grassland and aquatic ecosystem. Likewise, the biomass of individuals is also decrease with successive trophic levels (except aquatic ecosystem) e.g. pyramids of biomass for forest and grassland ecosystems. Owing to the unidirectional flow of energy in successive trophic levels all the pyramids of energy and all the pyramids of productivity are always upright.

8.2.4 Ecological Niche

The organisms live at a place and also play some role. The ecological niche concept propagate the theory of specialized microenvironment distinctly provide specific characteristic to (re)produce, to grow and proliferate. The role is also connected with or assign by the position of the organism *e.g.* the position of any organism in a trophic level determine the role of organism. The growth of a tree and the contribution of tree are depended to the existing place of tree. The prevailing xeric, hydric and other environmental conditions of a soil influence the growth parameters of existing tree and design the growth and dynamics of the tree and ultimately also scale the role and contribution of the tree. Although, the study of niche is confined or restricted to, in term of physical space only. However, niche is beyond the physical space of an organism. As the 'n' numbers of factors influence the specialized living place, the 'n' number of variable are linked to the niche of an organism. Summarily, the ecological niche is not just physical space occupied by an organism it also includes the functional role, idea, and attributes of an organism at specialized habitat.

8.3 Types of ecology

The life on earth system is dependent to numerous factors either biotic interactions or abiotic components. The ecological study as is very complex to interpret. The species-wise study in this regard has a tremendous potential. The species specific initially started ecologist for animal study. Afterward it becomes popular especially in field of agronomy, horticulture, floriculture, orchard, viticulture, plantation crop etc. as it is a source of economic and cash crop. The species specific

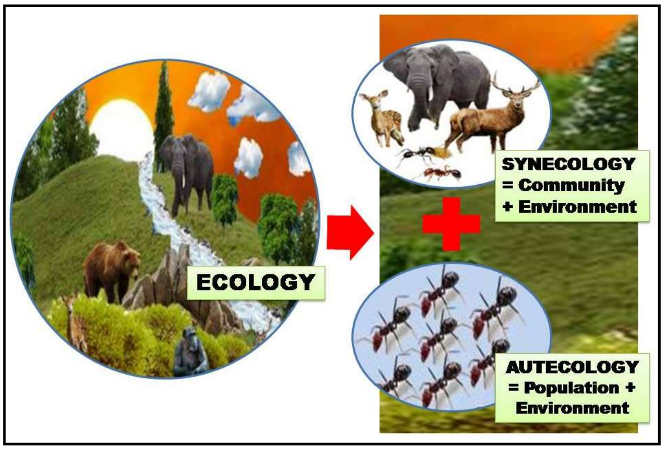


Figure 2: Types of Ecology

ecological study of single population is called as autecology. In simple sense, it is study of individuals of same species in relation to its habitat and distribution Fig 2. Synecology: The ecological study in relation to a multiple species with habitat is called as Synecology.

8.4 Importance of Ecology

The ecological effects are the crucial factor that is responsible for survival and growth of biotic community in its environment. Ecological factors affect the essential physiological processes are including the light, temperature, humidity, precipitation, wind, fire, edaphic factors, topographic factors and biotic factors.

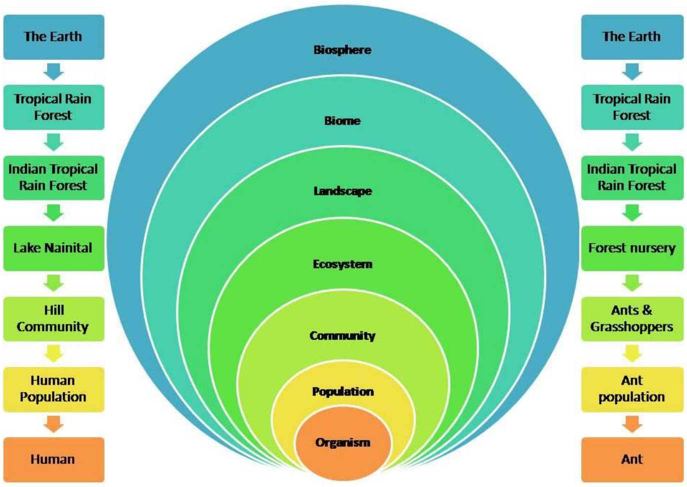


Figure 3: The hierarchical levels in Ecology

Light may affect the following processes that have direct significant role in plant growth and survival: photosynthesis, transpiration, movements, flowering, and seed germination.

Temperature may affect the following processes that have direct significant role in plant growth and survival: metabolism, flowering, growth and development, desiccation, chilling, freezing.

The vegetation architectures of plant are ecological attributes of the climatic environment mainly influenced or designed by precipitation. On the basis of the rainfall distribution the type of vegetation propagates into the region are as follows: Xerophytic vegetation, evergreen forest, grassland, sclerophyllous forests.

The most important edaphic factor is soil that has tremendous role in plant growth as it supplies the water, essential nutrients and support to grow. Thus on the basis of soil condition the growing plants are categorized as: Oxylophytes (acidic soil), Halophytes (on salty/saline soil), Lithophytes (rocks), Chasmophytes (rock crevices), Psammophytes (sandy soil).

Ecological factors affect the essential physiological processes including the following: photosynthesis, transpiration, movements, flowering, and seed germination.

Check Your Progress 1

Choose the appropriate option of following

1. **Choose the oxylophytes related word in given list**
   (A) Acidic soil
   (B) Salty soil
   (C) Saline soil
   (D) Sandy soil
2. **Choose the chasmophytes related word in given list**
   (A) Salty soil
   (B) Sandy soil
   (C) Rock crevices
   (D) Marsh land
3. **The short-lived plants those are not true xerophytes**
   (A) Epimeral Annuals
   (B) Succulent Plants
   (C) Non-succulent Plants
   (D) Xeric Plants
4. **The environmental induced changes in traits fix for permanently then the individual is called:**
   (A) Ecad
   (B) Ecotype
   (C) Genotype
   (D) Phenotype
5. **Identify the interaction type -/0 in following**
   (A) Amensalism
   (B) Commensalism
   (C) Predation
   (D) Neutralism

The feeding habit of individual is a specific characteristic which categories and place the individual into a hierarchical arrangement to form a trophic structure and the level of this food structure is called as trophic level. The linear arrangement of individuals through successive trophic levels forms a chain and called as Food Chain. The assemblage of multiples food chain together form a web like structure called as Food Web.

8.5 Ecological Responses

The physiological response (adaptation) of plant to water stress

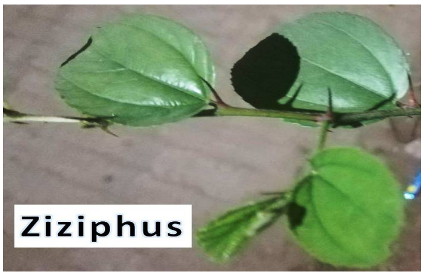
The plant exists in dry habitat and able to tolerate the dry condition (xeric) are called as xerophytes.

The environmental gradient addressing the soil water interaction and its availability to plant soil is studied in terms of xeric, optimum and hydric condition of soil. The xeric and hydric condition is directly linked with the nutrient availability and unavailability. Moreover, these conditions reduce the biodiversity of existing region by the vanishing the plants incapable to tolerate the condition of specialized microhabitat and also influence the extent of biotic interactions. The organism capable to tolerate the environmental gradient only will survive to the locality. The diminishing out of one species from a tolerance range will pitch for another species which will be adaptive to the environmental variable. During the process of adaptation and acclimatization the organism may change, loose and/or acquire some characteristic e.g. xeric plants modify their body tissue to capture water for longer storage, xeric plants have specialized leaves structure to reduce the transpiration loss.

Table 2: Xeric plants and its response to drought

Xeric Category	**Adaptive Features**	**Physiological response to drought stress**	**Example**
Epimeral Annuals	Draught evaders or draught escaper plants	Epimeral annuals are the short-lived plants and are not true xerophytes. These plants escape to the actual dry/xeric condition by completing life cycle in short period.	*Agremone maxicana*, *Cassia tora*, *Solanum xanthocarpum*
Succulent	Draught enduring plants	These plants modify their body structure against the draught condition for permanently. During the adaptation, the plant has developed the structure to store the water into their root tissues. They face the prevailing dry condition externally and internally survive due to stored water into fleshy tissues.	*Opuntia*, *Aloe*, *Euphorbia*

Non-succulent	Draught resistance plants and true xerophytes	These plants considered as true xerophytes as they face and tolerate the dry condition externally and internally. These plants are capable to tolerate the xeric conditions due to several adaptations.	Calotropis procera, *Casurina equisetifolia, Ziziphus zuzuba*



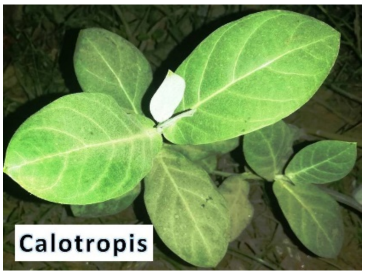


Table 3: Morphological, anatomical and physiological response to thermal stress

Animal	**Adaptive features**	**Morphological, Anatomical and Physiological response to thermal stress**	**Example**
Homeothermic (homo = same; therme = heat)	Warm blooded	The animals are capable to maintain their body temperature at a certain level constantly without affected by the environmental temperature fluctuations. In order to maintain their temperature they expanses their entire energy.	Birds and mammals
Poikilothermic (poikilos = variable; therme = heat)	Cold blooded	The animals are incapable to maintain their body temperature at constant level and their body temperature change with the fluctuation of environmental temperatures.	Reptiles, fishes and amphibians

8.6 Relationship with discipline of science and humanities

The ecology is a comprehensive science dealing the relations, interactions and exchange between the organisms in context to habitat. Habitats are distributed diversely in nature with coverage to the sea, terrestrial and atmosphere. Thus, ecology stretched to entire biosphere and linked with many disciplines of animal, plant, marine and many more. As per the linkage with diverse field ecology may be specialized with different name discussed in Fig 4.

The famous quote "Protecting nature and the wilderness for its own sake" describes deep ecology.

Fig 4: Ecology in relation to disciplines of science and humanities

8.7 Scope of Ecology

The limitless energy of Universe emitted from the Sun is scattered which reach to earth in form of quanta. The radial energy in form of quanta is abundantly present which is converted by green plants to chemical energy. This chemical energy is flow in all biotic community through food chain and food web. The photosynthesis process depends on the accessibility and availability of light and in organic nutrients. The photosynthesis is one of the prime ecological process that essentially significant for life on earth. As, it is an ecological process hence the biotic component (green pigment of leaves) interdependent to some abiotic factors too (sunlight, nutrients and water). In an ecosystem, the flow of energy is a unidirectional. The typical example energy flow in an ecosystem is as follows: Sun's energy $\rightarrow$ Primary producers $\rightarrow$ Herbivores $\rightarrow$ Carnivores. Similarly, the energy flow in a grassland ecosystem is as follows: Grasses $\rightarrow$ rabbit $\rightarrow$ wolf $\rightarrow$ tiger.

In contrast to photosynthesis, some organism exhibits chemosynthesis activity the CO_2 fixation using energy derived from inorganic and organic compounds is called chemosynthetic organism.

In lake ecology, the study of eutrophic condition of shallow lake, the above mentioned abiotic factors may acts as deciding (limiting) factors and regulated the process by their extent of presence. For example, in eutrophic lake the presence of inorganic nutrient (especially phosphorus) is the deciding factor for growth of algae instead of light. The presence of inorganic Phosphorus is directly proportional to the algal bloom in lake.

As per the Gaia hypothesis (the environment facilitate to organism and/or microenvironment for evolution and this intricate, auto-regulatory ecosystem supports make the condition favorable for life) the abiotic environment play the crucial determining role to decide the existing biotic life in an ecosystem. Ecad are genetically similar forms of the same organisms but morphologically distinct in response to the prevailing environmental condition. The changes are temporary and reversible when the environmental condition reverts. The individuals are same genotypes and environmental induced phenotypic differences in vegetative traits like size, shape, height etc. e.g. *Plantago maritina, Euphorbia hirta*. Sometime the environmental induced changes in traits fix for permanently and interbreed then the individual is called Ecotype. Similarly, an ecotype is genetically different forms of the same organisms but in response to environmental factors, the physiological, behavioral and structural changed permanently *e.g. Arabis fecuda*

The different parameters like precipitation, temperature, solar radiation & wind speed in different types of forest ecosystem determine the growth of tree as well as it also deciding factors for litter fall. Research has concluded the trend of litter mass production in pattern (with maximum in Mangrove forest and minimum in Boreal needle-leaved forest) as follows:

Mangrove forest > Tropical evergreen forest > Tropical rain-green forest > Temperate broadleaved evergreen forest > Temperate summer-green forest > Temperate needle-leaved forest > Boreal needle-leaved forest

The emergent property principle sets the segment in different levels according to the outcome of their interactions and role of the segment. Afterward due to this emergent property principle, the hierarchical arrangement of ecological levels reveals that each upper level depicts a new property that was not available in at its lower hierarchical level(s).

The biosphere is the physical space on lithosphere, hydrosphere and atmosphere where life exists. Biosphere is the top position in hierarchical levels of ecosystem. As we know, the ultimate source of energy on earth is Sun. The photosynthetic activity harnesses this energy after converting to make utilizable to mankind through food chain and food web. The diverse forest type exists on earth like Tropical, Subtropical, Temperate, Humid etc. The warm humid climate is the characteristics of tropical rain forest which supports broadleaf evergreen trees. Tropical rain forest confined to equatorial region and stretched to South East Asia, Amazon forest-scapes of South America, Central America and Africa. Tropical rain forest claim maximum productivity and this biome retain the maximum diversity of species composition as it characterized as multi-layered vegetation. The five stories of vegetation are herb, shrubs, tree, climbers and creepers. It located in Andman and Nicobar Island, Western Ghat, Assam and coastlines of India.

The 'n' number of variables is responsible for the growth and development of ecological life. The nature has designed the feedback mechanism to balance the population of organisms in a particular place / habitat / microhabitat with some sort of environmental gradient. As the human population explosion, the ecological disruption took place and hamper the ecology in terms of habitat loss, habitat fragmentation etc. In this regard habitat fragmentation is described here in details in perspective of other discipline of science and humanities.

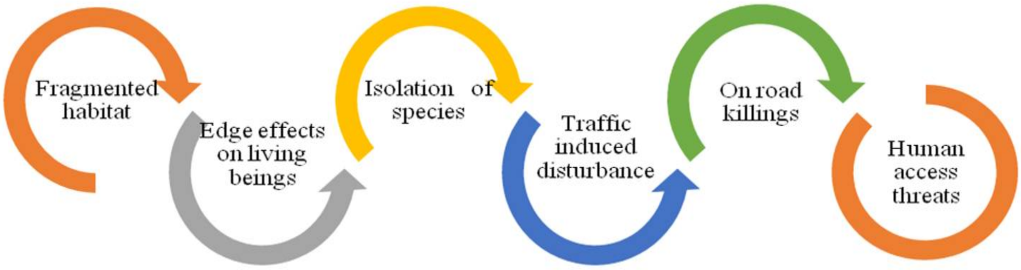


Fig 4. Habitat fragmentation and its consequences

The new construction of road or other project in forest area always results the habitat fragmentation and scarifies the life of wilds animals, plants, insects and other organisms in many terms. The road construction activity in natural habitat is explained here to understand the impacts on natural habitat and their life. The fragmented habitat exposed extensively and changes the soil micro-biota by the beating action of wind. It accelerates the impacts of temperature fluctuation by breaking up the temperature regulating capacity / buffer of forest habitat. Intrinsically, woodland have regulated the temperature naturally by the activity of supply more oxygen through photosynthesis, the multi-layered vegetation prevents the direct penetration to forest soil. The temperature stabilization and wind flow regarding edge effect for the creation of new microhabitat that is delicately distinct from original one. The new microhabitat will definitely less suitable to the previous flora and fauna however it may be suitable to some of species and will helpful to establish that species only in this region. This event creates an isolation of some species that further reduce the no of other species due to allelopathic and several other responses. Further the traffic induced disturbance will hamper to the destruction of the sensitive species at early stage and later on effects on other species too. The traffic induced activity of will also trigger the encroachment and on road killings. Ultimately the human accelerated access will destroy the entire ecosystem.

Terminal Questions

1. **What are the types and effects of biotic interactions in Ecology?**

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2. **Discuss the term Ecological Niche in relation to trophic level.**

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3. **Highlight the physiological (adaptive) response of cold blooded and warm blooded animal to thermal stress.**

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4. **What are the hierarchical levels in ecology and its role?**

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5. **Explain the habitat destruction and its impacts in relation to road construction in wild area.**

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Answers

Check Your Progress 1

1. A, 2. C, 3. A, 4. B, 5. A.

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Unit 9: Ecosystem

9.0 Learning Objectives

After the study of this unit you will be able to:

- know all about the ecosystem vis-à-vis an essence of life
- understand the philosophy of ecosystem
- highlight the chronic ill effects of industrial development on ecosystem disruption
- ecological conservation for sustainable development

9.1 Introduction

Think about the lake, you will imagine about a water-body, think about desert, you will imagine a sand dune with scattered vegetation. Likewise, if you will think about forest, the landscape image of tree dominated landscape will appear in mind. Seeds cannot grow until and unless the presence of moisture. Moreover sapling is not able to proliferate into a tree without availability of sunlight, water nutrients etc. Plant and animal are living beings but totally dependent directly or indirectly to abiotic factors *e.g.* the opening of leaves stomata is depend on presence of sunlight. Likewise, the formation of vitamin A, D in human body and carotene in tomato is also dependent to the presence of sunlight. The elevation and temperature have crucial role in plant distribution e.g. alpine forest (3600-4000 m) and timberline (4000 m) is the outcome of elevation. The survival of plant and animal without its non-living surrounding is not possible. Both living and non-living factors are essential component, intermingled closely and form together an ecosystem. As you know, the earth encompasses the living and non-living entities that interact each other. The utility of the nonliving surroundings is to supply the shelter, nutrient and energy to the inhibiting living organism. As a source for nutrient, shelter and energy the abiotic component is called as ecotype. Summarily ecosystem is biotic component with its ecotype.

9.2 Man and Biosphere

Nature incorporates itself infinite numbers of creatures within & between several direct & indirect linkages. Human is also one entity of the nature evolve continuously. The existence and progress of human depend upon understanding the diverse linkages of environment and creating equilibrium (*i.e.* homeostasis). At present the human has pulled over the destructive transformation in name of civilization with a huge negligence of nature behavior and intervention. Most of the creation of man for comfort and pleasure has sit on volcano. In current era, 91% of global human inhabitants live in pollution zone (WHO, 2018) and are facing death and detrimental effects of pollution. The unparallel leverage of population and negligence to role of environment are root cause to destructive unsustainable development. The need to understand the environment, its role and functions are first and foremost liability of human society.

9.2.1 Atmosphere

Atmosphere is the largest chunk of biosphere mainly encompass of gases, droplets and solids. It also acts as a medium for flow of energy in ecosystem, conductive values of biological and other materials. The typical behavior of temperature with its co-parameters in plays significant role in climate of ecosystem. The temperature is the deciding factor at different stages of plant growth like seed germination, flowering and fruiting etc. Organisms on the basis of temperature profiling are categorized as psychrophile, mesophile, thermophile, steno- and eury-thermic. The temperature gradient in water body at different depth controls the dissolve oxygen content of water body and regulates the biotic composition of water body. The profiling of temperature is crucial to determine the physiological response of temperature. The interaction of plant behavior and distribution regarding environmental factors are known as physiological response. Likewise, the temperature plays different role in soil and atmosphere. The science of atmosphere is Meteorology and Climatology.

9.2.2 Lithosphere

Simply lithosphere denotes to the land masses and land where soil biota exists called as soil. Soil is three-dimension body in contrast to land i.e. two-dimensional body. The soil type and properties is crucially essential for the growth of plant, construction of building and other construction like runway for aircraft. The soil type determines through the soil physical properties

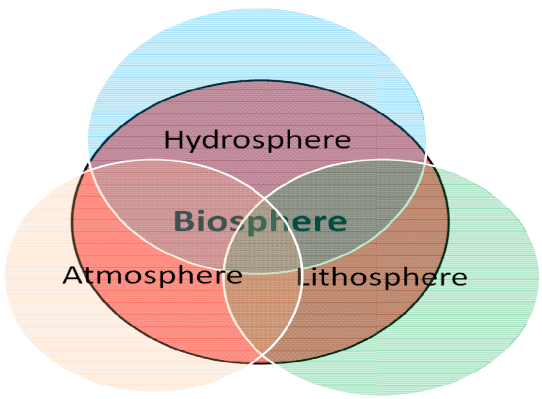

Figure 1: Biosphere and other segments on earth where organism lives.

like texture, structure, B.D., P.D., heat storage effect etc. and thermal property of soil like conductivity, diffusivity, heat flux and mass transfer in soil. The ecosystem is interconnected system and some water related issues are specifically discussed in soil segment as they are so connected with the soil properties e.g. soil water and types, field capacity, water stress and wilting coefficient, saturation of water, water holding capacity and retention, forces on water, water potential, seepage, infiltration, percolation and soil water flow devices. The science of solid earth is called as Geology, science of soil is Pedology and science of landforms is Geomorphology. The tree stands sequester the CO_2 and maintain the gaseous exchange and temperature on earths **(Bijalwan *et al.*, 2017).**

9.2.3 Hydrosphere

The realm constituting water is called hydrosphere. The water is in 2/3 of the earth but little fraction (1%) only is potable water available and rest of water is with high salt content hence called as marine water and unfit for drinking purpose. Now earth is at alarming state due to dwindling water resource especially in India. Hydrosphere is very essential segment of biosphere as the life can exist only with the water on earth. The science of sea and ocean is Oceanography **(Shankhwar *et al.*, 2012).**

The living beings exist in all the three spheres (atmosphere, lithosphere and hydrosphere) collectively called as biosphere.

9.3 Ecosystem

Ecological system (ecosystem) is the connection or relation of living and non-living constituents in a physical space (imaginary boundary). As the ecosystem constitute with two factors interconnected to each other namely biotic and abiotic factors. The ecosystem is assemblage of biotic and abiotic resources and associated with the humans since time immemorial in every phase of life. The realm of ecosystem consist the biotic and non-biotic in its complex interactive forms. These two factors organize the ecosystem but their cumulative effects still need to discover. In typical sense, the ecosystem governs with abiotic or environmental condition, distance and proximity with surrounding, and biological interactions. The biological interactions reveal the competition (inter- and intra-specific competition), mutual relationship and trophic levels of biological entity. The interaction and interrelation regulates the nutrient cycles and energy run of system among organism and communities. It is a complex and open system in which the flow of energy and nutrient cycles organize the system in self-regulated, hierarchically and self -organized mode *e.g.* forest ecosystem, pond ecosystem, desert ecosystem etc. A.G. Tansley in 1935 has given the term ecosystem. He redefined the term as the interactive arrangement of biocenosis (association of living system) and biotope (physical environment).

Check Your Progress 1

Choose the appropriate option of following

A. The non-living surroundings supply shelter, nutrient and energy to the inhibiting living organism is called _______________.

i) Ecotope ii) Ecosystem iii) Habitat iv) Abiotic

B. The active form of abiotic component in relation to an ecosystem is ______

i) Edaphic factor ii) Ecesis iii) Ecotone iv) Ecotope

C. Summarily ecosystem is biotic component with ________________.

i) Ecotope ii) Energy iii) Ecology iv) Ecotone

D. The sum of abiotic contributions to ecosystem is called ___________________.

i) Edaphic factor ii) Ecesis iii) Ecotone iv) Ecotope

E. The physical environment is also known as _________________.

i) Ecotope ii) Lithosphere iii) Psammosereiv) Edaphic factor

9.4 Structure of Ecosystem

For the better understanding of ecosystem one need to understand the hierarchical levels of organism in nature, prior to the ecosystem, living system starts from elemental level *i.e.* atom of element (till today 94 naturally occurring elements on earth are known to science) to molecule (the assemblage of two or more than two atoms), and to cell (the assemblage of micro- and macro-molecules to organize a cell). The cell also considered as the basic unit of organism and on the basis of cell, the organism may be categories into uni-cellular and multi-cellular organisms. The next level after cell is the organism; population and community are the biotic component of an ecosystem (see the Fig. 2 & 3). The assemblage of the organism forms population and two or more than two different populations comprise the community. The biotic component is the integral part of ecosystem and form an ecosystem after inclusion of abiotic component. Basically the ecosystem reflects how the biotic and abiotic component interacts with each other (see the Fig. 2). The ecosystem of same land regime is called the landscape. The large land regimes with same landscape create a biome e.g. Tundra biome, Taiga biome etc. The assemblage of all biome form atmosphere, lithosphere, and hydrosphere is called Biosphere. The abiotic element of environment is so influencing so the name of hierarchical level like ecosystem, landscape and biome is designated behind the abiotic factors.

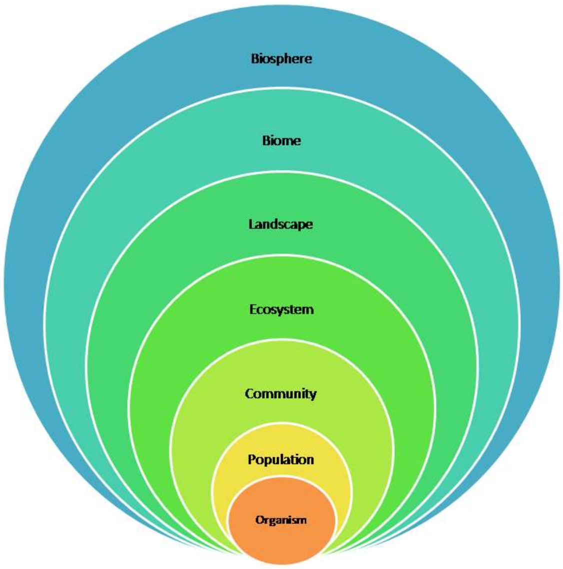

Figure 2: Hierarchical system of living system in nature

The biosphere establishes of numerous pockets or patches or ecosystems comprising together biotic constituents with abiotic realms. These ecosystems have their own microenvironments however, all of these ecosystems are interlinked and interdependent and collectively form biosphere. The abiotic realms broadly consider as environmental factors. The environmental factors are also interconnected to these ecosystems and as per feedback from the interactions of living organisms and their micro-environment, theses environmental factors respond to life and microenvironment of the ecosystem.

These interlinking connections in homeostasis balance to interdependent components of ecosystem and responsible for further modifications/alteration of ecosystem too. These interactions are very complex to understand and in matrix form.

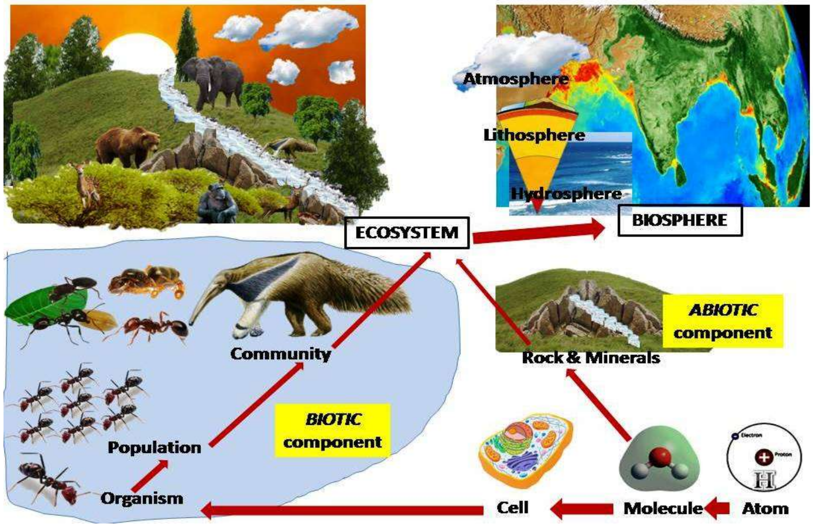

Figure 3: Structure of Ecosystem: atom to biosphere level

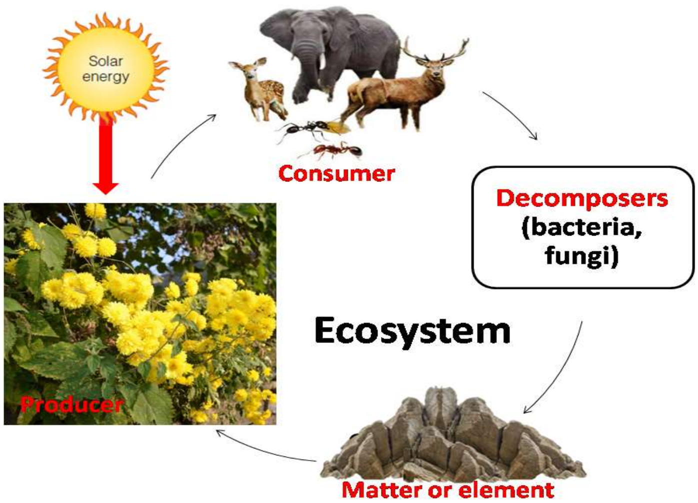

Figure 4: Components of Ecosystem

The two scenario for better understanding the role of abiotic factor in ecosystem are as follows: In first scenario, after the summer season, when the first rain comes down to ground it simple activate the soil enzymes for intake of the nutrients after converting it into readily available form. The supply of nutrients to the plant makes it greener and enhances the growth. But the nutrients were already present over there into soil and the water makes it available through numerous activities for positive growth. Moreover, if the rain is for longer time to stagnant water or absence of proper drainage, the water reduces the nutrients present over there and ultimately ill-impact to plant growth. Likewise, in this second scenario impact of rain on seed germination by introducing the rainwater to ecosystem the seed already present over there start to germinate out by the activity of various enzymes in presence of water. If the rain is for longer duration to stagnant water or absence of proper drainage, the water degenerate the seed or germinated root system and ultimately ill-impact to plant growth. Thus the single parameter of environment (i.e. water) has the impact to ecosystem and likewise several other simultaneously impacted on ecosystem at the same time. However, prior to change in ecosystem various interconnected attributes are changed. Thus the energy and mass transfers in the soil-plant-atmosphere system is govern and interdependent to various abiotic components. For better management of soil-plant-atmosphere systems, the biophysical methods and engineering process need to be understood in term of soil-plant interactions. The soil-plant interaction in reference to plant growth is dependent to the abiotic components like water, heat and gas flows, energy budgets and nutrient dynamics etc.

9.5 Components of Ecosystem

Across the hierarchical levels all the components may group in to the following living (biotic) and non-living (abiotic) components. However the ecosystem functioning require energy for different vital activities. The ecosystem constitutes two main constituents biotic and abiotic components along with energy. The living or biotic component further categorized in to producer, consumer and decomposers (Fig 4).

The producer are chlorophyllous plants, they produce the food through the photosynthesis activity, hence called producer. The consumer is living organism who depends on the producer for their food. The consumers are further categorized into primary, secondary and tertiary consumers in hierarchical level in different food chains and food webs. The living organism grows with the various interactions in their environment and completes their life. When they die, they attract some micro-organisms (bacteria, fungi etc.) to break down the body of dead organism and decompose it to the soil. Thus the lives in ecosystem start from the producer and the food and energy transfer to consumer and after death the organism decompose to the soil and energy release to the environment. The ultimate source of energy on earth is Sun; producers during the process of photosynthesis utilize this radiant energy and transfer to the ecosystem as per hierarchical levels. Thus the whole system is interconnected and interdependent for food, energy and water & nutrient cycling in ecosystem. The system is complex and invariably changes with the varying components of the ecosystem.

9.6 Characteristics of Ecosystem

As earlier discussed, the ecosystem is complex and invariably changes in changing environmental factors. Hence, it is difficult to define the ecosystem characteristic in single line. The ecosystem characteristics are as follows:

- It is a structurally (living and nonliving) and functionally organized (actively transfer of food, energy in hierarchy) system
- Ecological system is the interrelated and interdependent dynamic system, the dynamic activity results the natural resources and includes all of its natural resources in to ecosystem
- The vital activity of ecosystem fueled by the radiant energy of sun and the transfer of energy in to the trophic levels results to the productivity of ecosystem
- The ultimate source of energy on earth is sun, and the flow of energy in ecosystem is uni-directional, however, different types of ecosystem run through the existing energy movement
- The interconnectivity and interactions of ecosystem made it an open system with continuous input and output of mass and energy

9.7 Types of Ecosystem

The realm altogether with its all resources is considered as ecosystem. Mainly the ecosystem is categorized into natural and man-made ecosystem. In current era, none of the ecosystem is inaccessible to human interruptions. However, for study purpose the ecosystem is grouped into different ecosystem types as follows:

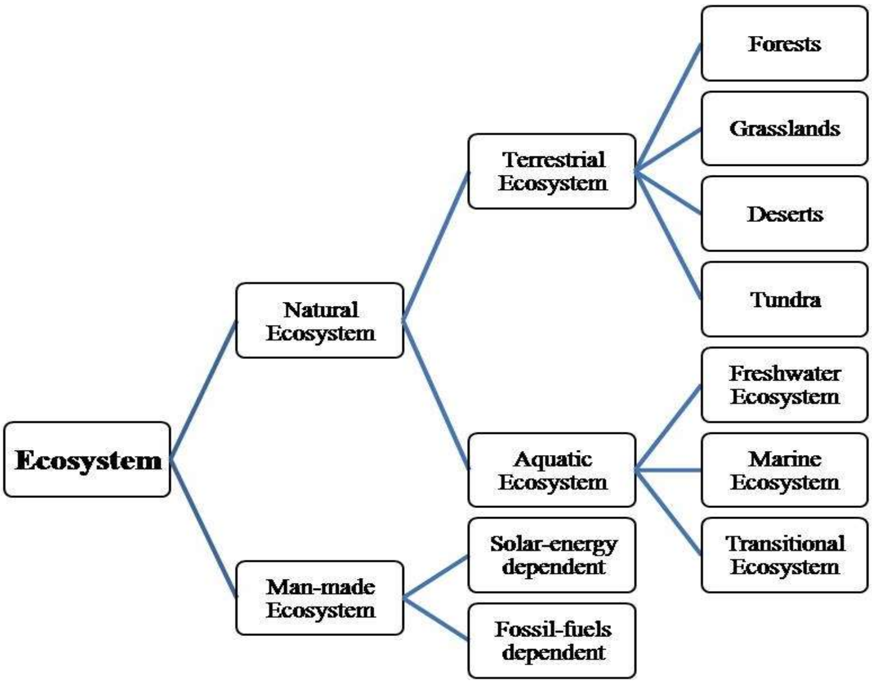

Figure 5 Types of Ecosystem

Table 1: Description about Biome/Ecosystem

Ecosystems	**Definition**	**Problem facing**
Forest	Tree dominating ecosystem is considered as forest ecosystem. This terrestrial ecosystem is richest in biodiversity.	Deforestation and deterioration
Grassland Biome	The grassland ecosystem has grasses in majority and it sub-divided into Savana (tropical grassland with scattered tree) and Temperate grasslands (dominant grasses, trees and large shrubs are absent)	Over-grazing and encroachment
Desert Biome	Geographically desert biome prevails in 15^0 to 30^0 North and South equator. The desert biome is dominated with sand and very less annual rainfall. Thorny vegetation is characteristics with ephemeral, succulent and non-succulent.	Water scarcity is prominent
Tundra Biome	The treeless land above timberline with snow cover in winter and abandoned in summer with wild flowering plants. Arctic and Alpine type tundra exists and actually it is polar desert.	Treeless land with short vegetation season

Freshwater	Water body containing the water lesser salt content (less than 3%). Pond, lake, swamp, river and wetlands are the freshwater bodies. The freshwater body is lentic (still water) or lotic (running water) and the study of freshwater is called as Limnology.	Water pollution and disappearing waterbodies
Marine	Water body containing the water higher salt content (more than 3%). Sea, Oceans and Lake are the saltwater bodies.	Ocean acidification
Transitional	The ecotone between two ecosystems e.g. region between freshwater and marine ecosystem is considered as transitional ecosystem. Likewise marsh is also an example of the transitional phase between water-body and terrestrial ecosystem and considered as transitional ecosystem.	Like other ecosystem the transitional ecosystem also in danger.
Note: Tropical savanna ecosystems are ecotone of woodland and grassland characterized by the coexistence of tree and grass.		

The hierarchical level of an ecosystem starts from organism at basic level and after several levels attains the biosphere at highest level. The biosphere is the ultimate ecosystem on the earth and confines all the biological entity with its non-biotic constituent altogether. Mostly ecosystems are natural but manmade ecosystem also exist in nature *e.g.* Agroecosystem, aquarium etc.

Man-made Ecosystem

The human involvement and intervention has changed or modified the ecosystem at great extent as per their requirement and utilization of the ecosystem. The result of this excessive influence has turned out the ecosystem so they considered as man-made ecosystem or artificial ecosystem e.g. cropland, aquarium, arboretum, lawn, water-park etc.

Natural Ecosystem

The forest ecosystem is one of the most diverse ecosystems. Indian forests are classified into six major groups namely Moist Tropical, Dry Tropical, Montane Sub-tropical, Montane Temperate, Sub Alpine and Alpine Scrub Forest.

9.8 Importance of Ecosystem

The ecosystem has a leading role in nature. Its significance can be study under the categories of Ecosystem services and Revenue generation.

9.8.1 Ecosystem Services (ES)

A number of human derived benefits (HDBs) obtained from the environment/nature/ecosystem directly or indirectly, knowingly or unknowingly and these human-derived benefits are called as ecosystem services (ES). These HDBs may due to the function, positioning, characteristics, and/or processes of ecological-system and in pertinent to the necessity of human-being for their facility, comfort and wellbeing. Ultimately the term ES denotes to HDB from the ecosystem. These HBDs may further categorized under provisioning, regulating, cultural and supporting services. Any HDBs obtained from the ecosystem naturally may be considered as ES and enlisted in Fig 6.

9.8.2 Revenue generation from ES

All the natural resource on earth confine in pockets called ecosystems. Ecosystem is the ultimate source of all revenue and it satisfies the human demands since immemorial time. The ecosystem services are exchanged in form of revenue or monitory term as per the human need and resource availability.

9.8.3 Flow of energy

The two components of ecosystem are also dependent to sunlight for the energy. The energy move from the ultimate source of energy (sun) to the producers (green plants) in form of small pockets (quanta). The green plants accomplish the photosynthetic activity by the virtue of chlorophylls presence. The photosynthetic activity is the entry point of energy flow to biotic community and energy transfer from producer to consumer and ultimately to decomposers. The energy flow universally follows this pattern of energy flow and hence, it is called as unidirectional flow of energy.

9.8.4 Nutrient cycling

The flow of energy into ecosystem ensures the growth of biotic community at different hierarchical levels. After the maturity time the plant and animal got death and decay and shred down to ecosystem and finally decompose out by the activity of tiny microbes. The small microbes help to disintegrating the dead body of animals and plants releases nutrients back to the soil (ecosystem). Thus the nutrient flow in different segments of ecosystem and this flow are called as nutrient cycling.

9.8.5 Himalayan forest of Uttarakhand

The forest of Central Himalaya in Uttarakhand region is stretched from tarai, bhabhar at lower elevation approximately less than 300m. The upper hill of Uttarakhand forest attains up to 2800-3400 m elevation. The forest is rich in biodiversity and changes with the elevation situated characteristically considered as tropical, sub-tropical, temperate, cold

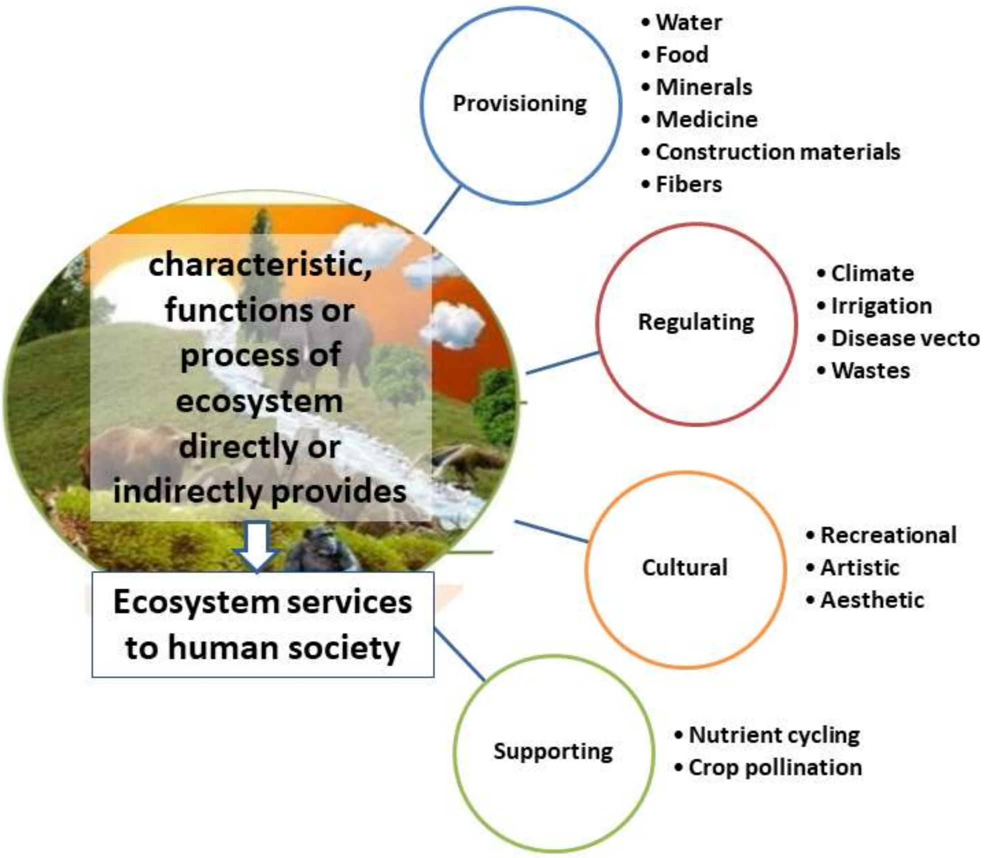

Fig 6: Ecosystem Services

and frigid (winter). In the tarai region the Sal, Shisham, Teak and Mahogany trees are dominating, the valley region comprises broad leaf deciduous forest and grass patch are also available in this region. In the mid altitude the main tree species of Oak, Banj, Buransh, and Kafal along with Chirpine exist in this region and Uttrakhand forest are known for this species. In high hill region the coniferous tree species like deodar, spruce and fir are found dominantly **(Shankhwar *et al.*, 2020).** Afterward in alpine meadows only some medicinal and wild plants exist which freeze out in winter seasons.

9.8.6 CO_2 fertilization in forest ecosystem and carbon sequestration

The forest area decided to cover at least the 33% to its geographical area the hilly terrain are fragile in nature hence for conservation strategy, forest area in hilly terrain is decided to 66% of geographical area. India is rich in biodiversity due to its geographic diversity from Himalaya to desert area of Rajasthan. Indian Himalaya is enriched with biodiversity and forest resources. Locally the Himalayan ecosystem supplies the fuel, fodder, timber, clean water, and hydroelectricity but globally it contributes to the carbon sequestration and hydrological cycles.

9.9 Concepts in Ecology

9.9.1 The emergent property principle

The ecosystem is a hierarchical set-up of distinctly different levels. Each level has its own characteristics feature that is the outcome of that particular level in hierarchy and it has no existence without hierarchy. The characteristics are emerging out due to that particular level so it called as emergent property. The emergent property describes the factors that cannot be explained individually, as intermingled with numerous factors.

9.9.2 Homeostasis

A state of balance in an ecosystem is called homeostasis. The homeostasis is like a balance of two factors of promotion and reduction. E.g. plant in a pot drying due to absence of irrigation water will dry up gradually. However the over constant irrigation to that plant-pot will lead to rotting down of the plant. In between two situations, another situation of controlled irrigation will flourish the growth of plant in pot. Here the balanced irrigation reveals one of example of homeostasis. The unavailability of irrigation water to pot results to wilting before drying up is a sort of negative feedback. The negative feedback is like a warning system that helps to balance the ecosystem through feedback mechanisms.

9.9.3 Gaia hypothesis

The temperature and rainfall influence the climate, agriculture and ultimately the human life in many ways. However, it is very important to understand that the ecosystem is solely co-existence of biotic and abiotic factors and biotic factor also responsible to regulate/change the environment (abiotic). We may consider all living being as biotic factor that interdependent to its environment (abiotic factor). These biotic factor also influence/regulate/change its environment. James Lovelock proposed in Gaia hypothesis that the biosphere is as self-regulating system and biotic component regulate to its abiotic factor (environment).

Example: The exploding human population exerts the higher concentration of CO_2 that ultimately climate change (the global problem) a threat to human society. The most drastic threat to human being is depleting water resource is also the outcome of increasing population and mismanagement of human. In Precambrian age, the photosynthetic bacteria also influence the global environment and evolved the environment to aerobic.

9.10 Cybernetics and Stability

The ecosystem is so interconnected and interdependent that the sequential events are also controlled by previous step or the primary steps have the controlling power to final step. This complex interconnection and inter-dependence is sum to cybernetics e.g. in a grassland if grasses grow more it can feed more grasshopper and grasshopper will maintain the grass abundance. More growth of grasshopper population attract frog who feed on grasshopper and frog population will control the population of grasshopper. Likewise, the frog population is controlled by the snake. Thus, ultimately, the population of snake in grassland is dependent on grass indirectly (Grass → Grasshopper → Frog → Snake). The increasing number of snake leading to decreasing number of frog and if lesser numbers of frog then higher number of grasshopper that lead high infestation on grass. The same concept of cybernetics is also applied in agroecosystem. The agriculture crop is highly affected by the rat. The population of rat can be easily controlled by the snake (Crop → Rat → Snake) and may be concluded that the higher snake population is helpful for agriculture production.

In Grass → Grasshopper → Frog → Snake, the higher growth of grass leads to higher growth of grasshopper too. But after a certain point, the increasing population of grasshopper will diminish the growth of grasses. This limiting of growth of grass, ultimately will limit the growth of grasshopper too, as higher growth of grass promotes the higher growth of grasshopper too. Likewise, in next step, the higher population of grasshopper led to higher growth of frog, but after a certain time the increased population of frog will limit the population of grasshopper by feeding up upon grasshopper. Decreasing population of grasshopper will ultimately result decreased population of frog. Likewise, the leaf litters of tree growing in the soil are recycled back the nutrients to the soil. Thus the nutrients obtained from the soil solution to the tree for their growth and development and leaf litter decomposition returned back the nutrients to soil and hence maintain the stability of the nature **(Monika *et al.*, 2017).**

This mechanism of controlling population through feedback is responsible for constant population of organism in an ecosystem after a certain period of time, hence, called as stability through feedback mechanism.

Terminal Questions

1. Discuss the role of abiotic component in relation to ecosystem.

   ………………………………………………………………………………………………

2. After a certain time, the number of living being become constant explain why?.

   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   …

3. Justify the term “**Cybernetics and Stability**” in agriculture management.

   ………………………………………………………………………………………………

4. Explain the terminology of following: i) Gaia hypothesis, ii) Homeostasis, iii) Emergent property principle.

   ………………………………………………………………………………………………

5. Briefly explain how the increasing population of peacock may promote the growth of grass in a grassland ecosystem.

   ………………………………………………………………………………………………

6. Define the ecosystem services and its role in mankind.

   ……………………………………………………………………………………………

Answers to Check Your Questions 1

A i, B iv, C i, D iv, & E i.

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Unit 10: Ecosystem Functions

Unit structure

10.0 Learning Objectives

After the study of this unit you will be able to:

1. Identify the functions of natural ecosystem vis-à-vis human society
2. understand the concept of ecological self-replenishing control
3. realize the ecological significance of energy flow and information flow
4. highlight the ecosystem services in reference to sustainable development

10.1 Introduction

In the modern era of science, the most addressed problems are pollution, climate change and global warming. The air, water and noise pollution in India is at the extreme and devastating state. These problems of pollution have culminated the human life more than any other issue, like terrorism, accident, natural disaster, hunger or anything else. The pollution is a silent killer which has killed the highest number human in India. The earth has self-replenishing ability that resist against the disruptions. The self-replenishing ability is due to the cyclic process naturally governing phenomenon like in the water cycle, the water evaporates from rivers and sea, the forest transpires the water to ambient environment and after condensation return to earth in form of rain. Likewise, in the nutrient cycling processes, after decay and decomposition of body of living beings, the nutrients are return back to soil and restore it for continuous supply of nutrients to green plants for their growth and development. The self-replenishing property of earth system has tremendous potential for its sustenance through generating the resource continuously. The earth ecosystem is sufficient to tackle the hunger and other consumptions, ultimately sufficient to human need. But self-replenishing property or power will fail to gratify the human greed. As the need may be utilize through the judicious use of natural resources and greed will disrupt the cycle first and discontinue the supply sustainably. e.g. the forest has the tremendous potential to utilize the elevated CO_2 liberated naturally to the atmosphere. But it unable to cope up the CO_2, as in one hand the urbanization has deteriorated, damaged and deforested the forest and on the other hand the urbanization has introduced the exceeding level of CO_2, to the environment. Ultimately it derailed the cyclic processes and debar the self-replenishing property of ecosystem on earth.

10.2 Biogeochemical cycles (C, N, P & S)

In biogeochemical cycles, the carbon cycle is most studied and has unlimited significance in field of ecology and environment. Carbon cycle is directly linked with photosynthesis, climate change, global warming, carbon sequestration and deforestation

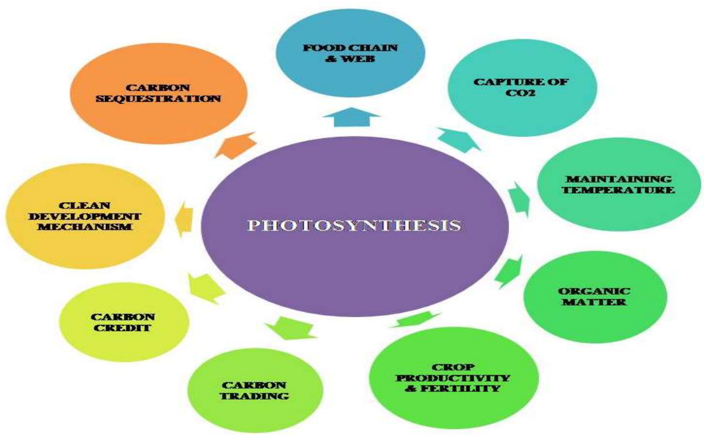

Figure1: The ecological significance of photosynthesis in reference to Carbon Cycle

research. Other applied sciences like agriculture, forestry, horticulture etc. are directly and indirectly linked with carbon cycle. Carbon farming and carbon trading is the emerging field in this reference that need to boost up for redressing of the current global problems. The importance and prospects of Carbon cycle in modern research is increasing in manifold. Therefore, a brief description of carbon cycle is displayed below.

10.2.1 Carbon cycle

Senescence of a leaf is a process to define the falling down of leaf after a completing the biological age. After senescence, the leaf starts to decay and decompose means started to release the nutrients accumulated in its tissues during the growth and development. The nutrients are retuned back to the soil through the process of leaf litter decomposition. For this reason, the leaf decomposition is considered as one of the crucial phenomena in biogeochemical cycles. The nutrients, initially absorbed from soil system through roots incorporated for the growth and development of plant by numerous vital activities and at the end the leaf senescence to earth.

The terrestrial ecosystems like forest enjoy this movement of nutrients from soil to plans and further from plants to soil continuously like a cyclic process. The cyclic movement of nutrients, from one phase to another phase is called as the biogeochemical cycle. The recycling back of nutrients to the soil system perpetuates the plants growth and development for ensuring the further consumption. Hence the nutrient cycling phenomenon contributing in the way of perpetuation the nutrient and soil organic matter by nutrients leaching, immobilization and net nutrient litter mineralization. The nutrient cycling and adding of soil organic carbon to soil system through the litter decomposition enhance the soil quality and buffering capacity by attracting the soil microbes. The soil microbes convert the unavailable form to the available form of soil nutrients to plant uptake. Thus, the soil system has a self-replenishing power of nutrients cycling for the continuous supply the plant nutrients in nature.

10.2.2Nitrogen Cycle

The nitrogen (N) is required in high amount to plants / agricultural crops and supplied by the chemical fertilizer urea widely for the growth and development. The nitrogen is the most abundance nutrient available in atmosphere in elemental form. The elemental form of nitrogen has triple covalent bond that hard to break up thus it is not readily available to for its uptake by the plants. For breaking down this triple covalent bond high energy is required and some of the microbes have the potency to convert the elemental nitrogen into readily available forms.

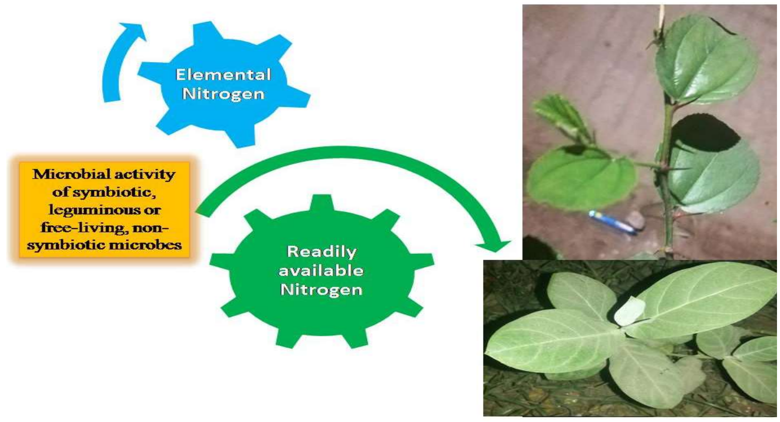

Figure 2: The conversion of elemental nitrogen to readily available form of nitrogen

The microbial conversion takes place through the enzyme nitrogenase and makes it available to metabolize by the plants. These microbes are symbiotic leguminous and non-symbiotic or free-living soil. The excreta and urine wastes from human and animals are the main source of soil nitrogen. The cow dung, manure and FYM (farm yard manure) are applied the agricultural soil have nitrogen as major soil nutrients. Nitrogen is the one of the main constituents of chlorophyll and it also part of DNA. The prime role of nitrogen is to produce the protein and responsible for the vegetative growth of plant. As it is also the part of chlorophyll, the presence of adequate amount of nitrogen promotes the photosynthesis activity.

10.2.3 Phosphorus and Sulfur cycles

The presence of phosphorus is essentially needed for the strengthening the skeleton in human and animals. In plant phosphorus is responsible for the vigorous growth of stem against the lodging of crops and provides the high yields. The sulfur containing amino acids are essential nature nutrients and limiting factor for protein synthesis. The Co-enzyme A regulates the synthesis of amino acids. The adequate amount of sulfur availability will promote the synthesis of Co-enzyme A.

10.3 Productivity and Energy Flow

All the nature gifted resources, contributions and services are considered as the ecosystem functioning. In general, the ecosystem functions are ecosystem services, energy flow, Nutrients Cycling and Productivity. However, the ecosystem functioning is 'N' number of activities at a same time including the vital activity of plant. For example, the photosynthesis process is an essential activity for plant existence and in turn it provides the oxygen to the ecosystem which has utmost importance for vital activity of other life on earth and ecosystem including human beings. The four sub category of ecosystem functions described in Fig 10.1. As we know the ecosystem is the interplay of interactions among biotic, abiotic components and their complexes. The ecosystem services (ES) are described in detail in previous unit (Unit 9.8.1).

The ES are provisioning, regulating, cultural and supporting. The ultimate source of energy on earth is Sun and the green chlorophyllous vegetation is capable to convert the radiant energy to chemical energy with the help of dehydrogenase enzymes which flows unidirectional in ecosystem through food chains and food webs. The energy flowed is utilized to produce the plant biomass and productivity (production per unit of time). In an ecosystem, the productivity is studied in term of primary productivity (PP), net primary productivity (NPP) and gross primary productivity (GPP). Afterward the completing the biological age the plants and animals are dead and decay. During the decaying the plant and animal biomass release back the nutrients to the soil and helps in to the nutrient cycling. The nutrient cycling is the connecting end of the cycle in an ecosystem and ensures the flow of material biotic component to abiotic components. While, the flow of nutrients and water are required from the soil system to plants through absorbance are essentially required for the growth and development of plants.

Examples for ecosystem function is not only the services provided by a river, forest but functions like pollination in flowers with the help of pollinator insects; rain to an ecosystem or region; abstraction of micro-nutrients from soil; seed dispersal through waterways; ensuring the dew moisture to quench bird thirst; mixing of soil layers by earthworm through casting the Vermicast etc. also considered as ecosystem functions.

As we know, the sun is the prime and first source of energy, due to radiation activity the energymoves to earth system, where after transforming the radial energy supports the vital activity of life. The energy emitted from the Sun, due to the nuclear fission reaction. The flow of energy in an ecosystem is crucial as it is a heart of life in an ecosystem. The radiation energy moves to earth as an electromagnetic wave in form of energy pockets called quanta. The radiation energy moves from the Sun to earth abundantly but a minute portion of this radiation energy is tapped for energizing the ecosystems on earth naturally.

The radiation energy is trapped through leaves green plants through the photosynthetic activity, afterward it called a chemical energy. The flow of energy (chemical energy) in an

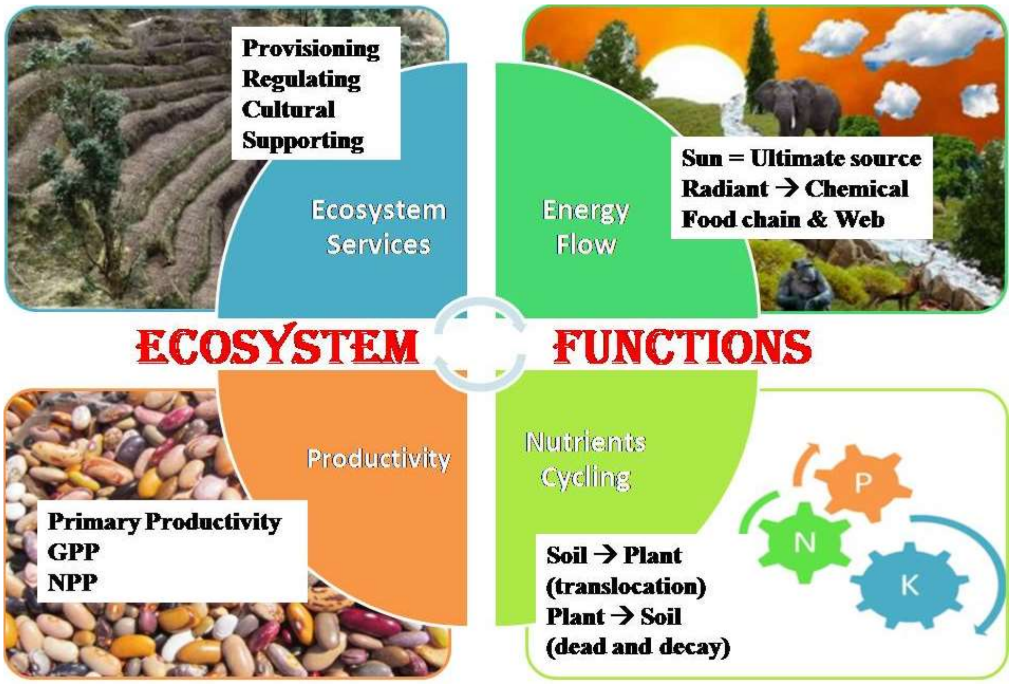

Figure3: A brief display of Ecosystem Functions

ecosystem is complex however it flows in uni-direction. It has very less efficiency, require huge energy to dissipate during transfer and that is why it flows in unidirectional pattern. As per the 10% rule, the energy sieved only 10% of one trophic level to next tropic level. The almost 90 % of energy is dissipate to environment during the transfer. The sequential arrangement of organism in linear format to transfer the energy is called food chain and the stage where the energy level changes are called trophic level. The first trophic level is characterized by the green auto-tropic plants who harness the radiation energy through photosynthesis. The green plants are called a producer as they produce the chemical energy by using the radiation energy. Afterward the organisms in next trophic levels (trophic level second onward) are called hetero-trophs. The second trophic level is characterized by herbivores (herbs eaters) dependent on the first trophic level (chlorophyllous plants) for their energy through feeding the green plants. Further, the third trophic level is characterized by small carnivores who dependent on the herbivores for the food and energy. Then, the next trophic level is also carnivores but they depend on carnivores for their food and energy. Summarily, the organisms are arranged in order their food habits and formulate segmented system of unidirectional flow of energy (food resource) and each segment represents a trophic level and complete set of segments is a food chain. In nature, a number of food chains exist together and form a web like structure. The assemblage of two or more than two food chains is called a food web. The flow of energy is through successive trophic levels only. Hence, it is considered as the unidirectional flow of energy in an ecosystem.

Check Your Progress 1

Choose the appropriate option of following

1. ***Choose the free-living nitrogen fixer (FLNF) in given organisms list***
   (A) ***Azotobacter***
   (B) ***Dorylimes***
   (C) ***Frankia***
   (D) ***Rhizobium***

2. ***The reduction reaction of N2 to NH3 is called as***
   (A) ***Ammonification***
   (B) ***Nitrogen fixation***
   (C) ***Denitrification***
   (D) ***Eutrophication***

3. ***The most critically limiting element/nutrient in agriculture***
   (A) ***Nitrogen***
   (B) ***Phosphorus***
   (C) ***Potassium***
   (D) ***Sulfur***

4. ***Identify the ecosystem which is the most diverse on the planet***
   (A) ***Tropical forest***
   (B) ***Savanna grassland***
   (C) ***Marsh land***

(D) ***Coral reef***

5. ***The enzyme is required for the biological nitrogen fixation***
   (A) ***Dehydrogenase***
   (B) ***Nitrogenase***
   (C) ***Proteases***
   (D) ***β-glucosidases***

Check Your Progress 2

Choose the appropriate option of following

A. The photosynthesis process involves the enzyme _______________.

i) Dehydrogenase ii) Nitrogenase iii) Proteases iv) β-glucosidases

B. In the ecosystem, the flow of energy is________.

i) Zigzag ii) Random iii) Unidirectional iv) Uncertain

C. Typically the energy transferred from one trophic level to another trophic level is about ________.

i) 10 % ii) 20 % iii) 30 % iv) 40 %

D. After the photosynthesis process, the radiant energy is called as________________.

i) Photon ii) Photo energy iii) Quanta iv) Chemical energy

E. The systematic arrangement of trophic levels is also known as _________________.

i) Food chain ii) Food web iii) Ecological pyramid iv) Ecosystem

10.4 Information flow

Usually data reflects some numerical values but it is beyond the numerical values and may be in non-numerical or figure form too. The data mean gathering or collection of relevant facts, the meaning contained in facts is information and the conclusions drawn from the information is knowledge. Like other fields of science, Ecology is also deal with numerous data, information and of course a set of knowledge that flows or exchange in an entire environment. Information ecology emphasize on the interactions of environmental components trough interpretation of data, information and knowledge. The biotic component of environment influences the environment and being influenced by the environment. The ultimate aim of study about the interactions of environmental components is to provide the information facts and services. The information in ecology is dynamic and complex in nature as it is based on numerous interactions between living and nonliving beings.

As we know the ecosystem's biotic and abiotic factors interact and influence to the each other and ultimately the outcome these interactions form the ecosystem. The natural phenomenon involves all the associated existing components due its connectedness together or as response of action (change in a factor) trigger the certain changes that further proceed the natural process to completion. This is the interconnected, interdepended and governs through the interactions. In nature, the interactions are the cluster of 'n' number of simple processes running in same piece of time and many of times even they overlap and reflect the natural interaction complex. The understanding of the interaction required the keen observation. To understand the complex ecosystem, the observation of single factor and associated activity need to study. As a case study, we will discuss the impact of soil water availability to plant and growth of insect larvae. Let us observer the addition of water through rain to a natural plant system. As the water availability ensure, the soil system will stimulate to optimize the soil nutrients and will boost up the plant growth. The plant growth helps to spouts more plant leaves that will cool down the ambient temperature of that particular area as the more leaves will helpful to conserve the soil moisture. Moreover, this event will enhance the relative humidity and ultimately create new microhabitats that optimize the growth of specific leaves eater larvae. Now, it is important to note that if the moisture content is at optimum to plant it will proliferate the growth of green leafy plant. If the water content is exceeding the optimum condition it will attract the growth of the leaf eater larvae too. It will promote the growth of larvae that further the growth and development of the larvae will affect the plant growth due to its feeding activity. Thus, normally the addition of water to soil system boost the plant growth but it may also diminish the plant growth by infestation effects of insects. Now focus on the question, how the information flow to insect this the time to grow on this plant. In this phenomenon the exceeding water content is the action that triggers the reaction or the turning point to develop the insect larvae. If the water content is in control and only sufficient to plant growth only and the soil system is in dry condition instead of wet, humid condition the information or signal or stimulation will not carry forward for the growth of insect. Thus, the information flow in an ecosystem is the activity of stimulation or feedback mechanism. For monitoring the flow of information in an ecosystem, the ecosystem needs to be segmented in to pieces and the stimulation or signals are as appears in the adjoining segments will be considered as the flow of information. Thus, the information flow may be map out in a natural ecosystem. The mapping activity of the flow of information in an ecosystem is considered as the modelling of information flow. A number of models for assessing the flow of information are suggested and the field of ecosystem modelling for information flow is growing on in different horizons including its precision and other crucial factors.

10.5 Ecological pyramids

The ecological pyramid represents trophic structure and function of an ecosystem. The pyramid may be for Numbers, Biomass, Energy and Productivity. The hierarchical level is the outcome of consequences of the entire role played by individuals. Due to the high production found at lower of trophic levels, consequently the "upright" pyramid is usually obtained for biomass, energy, and numbers except the Forest pyramid for Numbers and Aquatic system pyramids for Biomass. The inverted pyramid in tree reveals (a single tree- → numerous birds → uncountable parasites) the increasing numbers individuals with successive trophic levels. However, generally the numbers of individuals decrease with successive trophic levels e.g. pyramids of grassland and aquatic ecosystem. Likewise, the biomass of individuals is also decrease with successive trophic levels (except aquatic ecosystem) e.g. pyramids of biomass for forest and grassland ecosystems. Owing to the unidirectional flow of energy in successive trophic levels all the pyramids of energy and all the pyramids of productivity are always upright.

10.6 Ecosystem perturbation

Ecosystem is a dynamic system and it need to be assisted or ordered toward productivity and promotion for the welfare of humans and society. The numerous causes like overpopulation, over-exploitation of natural resources, overgrazing of grassland, monoculture plantation, introduction of new chemicals, air & water pollution and mis-managements are available to deteriorate the environment and ecosystem to an alarming situation **(Shankhwar and Srivastava, 2015).** The ecosystem perturbations like storms, eat-waves, droughts floods, melting glaciers, bleaching of coral reef and forest fires are affect the life of humans, plants and animal drastically. The perturbation may be quick assaulted and it may be chronic too like wastes generation, environmental un-hygiene, nuisance pollutants etc. consequently responsible for diseases and disruptions.

Ecosystem perturbations- grazing and browsing: The animals that garner foliage, fruits, soft bark, green stems and twigs from plants and does not depend on eating the grasses and eat the higher height growing vegetation are called **browsers**. The examples of browsing animals are as follows: Goats, wild Goat, Deer, Markhor, Sulaiman Markhor, West Caucasian Tur, Alpine - , Iberian - , Nubian - , Siberian - and Walia - ibex. While the animal who pieces the grasses and other vegetation like dicots and herbaceous woody plants near or at ground levelare called **grazers**. The examples of grazing animals are as follows: Horses, Sheep, Bison, Geese, Giant Panda, Hippopotamus, Cattle, Rabbits, Grasshopper and Green Sea Turtle.

The grazing and browsing animals are the subcategories of herbivory animal. The food resource partitioning in the way of segregation the food harnessing habits of herbivory animals enables them to co-exist into same region and share the food resource without competition. It is a mechanism against the competition for food and ultimately it favours and allows grazing and browsing species to harness the green vegetation without inter-species competition. Thus, it is important to understand the grazing and browsing animals and their food regimes. Finally, the particularly the competition for food in this region is intraspecific competition among the herbivory animals.

The browsers are taking up the advantages of the geographical landscape which is not suitable to grazing animals. In the Mountainous Rocky landscape, during the snow fall the area covered of snow and the ground-level green vegetation & other grasses, are become inaccessible to grazing animals, a browser such as the white-tailed deer may take the advantage of being browser for harnessing the green foliage at a height. The grazers are taking up the advantage of the geographical landscape i.e. not suitable to browsing animals, such as the height of vegetation may be inaccessible to browsing animals. The high height of vegetation may be suitable only to the selective browsing animals that have a long neck like giraffe. Moreover, many times the browsers depend on the portions of the vegetation with low in nutrients and/or chemically less active substances. While the grazer can feed on the meristematic region of grasses, when face the inaccessibility of grasses.

The traditional tropical forest is the best utilized habitat that is a house for diverse trees including herb, shrubs, tree lianas, climbers and epiphytes. Due to high diversity, the tropical forest contributes differently to human beings and society. The diversity among living beings and organisms in habitats form stronger and more stable ecosystem. The most diverse ecosystem means more stable and with higher buffering capacity. But due to the extreme events of pollution in wide array of impacts has affected all the system. The tropical forest is also experiencing the problems exerted through the pollution and face the deterioration and degradation of forest. The mass degradation and deforestation of tropical forest has resulted to reduce the forest to half of the forest at the time after nineteenth century. The deforestation and declined forest are the cascade effect of different mismanagement and over-exploiting events. Therefore, it is difficult to blame to a single reason for the declined forest in tropical region. The changes observed in the diversity of forest tree and animal community are studied in term of biological diversity. The reduction in biodiversity is one of the outcomes of manmade activities on ecological activities. However, it is only a small segment of anthropogenic activities and manmade activities have more potential impacts on nature and ecosystems.

10.7 Fire and burning

While the study of an ecosystem, the study of fire as a natural and/or manmade factor that determines the shape of an ecosystem. Fire is crucial component that influence both animal and plant community and their interactions with the physical environment. The forest fire is often devastating and hazards but it may also be a beneficial event for ecological development, if it is a controlled fire. For example, the most significant role of fire is to breaking up the seed dormancy which is an essential for regeneration of forest. The fire in the forest called as forest fire may different source of origin. The regular controlled fires are being done in forest as a tool to prevent the spreading up of the forest fire. The controlled fire enables the germination of new propagules in forest by burning out the leaves litters which is a major hindrance of the seeds to contact with the ground soil and moisture. Moreover, the controlled forest fire is the process of fast mineralization which enables availability of phosphorus and micronutrients and escape out the load of carbonaceous substances. It is also the cheap method of dispose-off the agricultural waste on the agricultural on-site. In one hand it burns the litter which results the organic humus and another hand it may be beneficial as a source of phosphorus and micronutrients due to the addition of ash content and charcoal. Ash content enriches the soil micronutrients; however, the charcoal shoots out the extreme pH and ultimately enhances the microbial activity of soil. The charcoal acts as natural chelators that helpful to adhering the micro-nutrients. It may improve the soil condition, which favors the growth and development of soil microbiota. The controlled way of a fire operates as land management practices to enhance the biodiversity in forest by eradicating the non-native, invasive species and weeds for the promotion of timber.

The above-mentioned facts are associated with the advantages of forest fire. But still it is a Universal truth that forest fire engulfs a huge forest year by year. The devastating forest fire may continue till several months and spreads out many miles once started to burn and cause loss uncountable amount of money. The forest outbreak changes the ecosystem dynamics by changing the land use pattern along with other disturbance like insect infestation and disease etc. The changes in species composition of forest also triggered the succession and may induce early maturity or climax of forest.

10.8 Industrialization

As we know, the natural feedback mechanism regulates the populations of different community in an ecosystem and enables them to continue the different functions of ecosystem. But gradually through the population explosion, the human beings have disrupted the different mechanism of homeostasis on earth. For the satisfying the need of this population requires mass scale production of various goods and articles in interest of human population. Ultimately, a new era of industrialization has emerged out in large part of the earth surrounding the human society. The Industry and manufacturing have led to generated associated waste year by year. Some of wastes are biodegradable and recycled back the nutrient to the earth. But numerous of waste are non-biodegradable, recalcitrant in nature are started to pile up on earth here and there. Finally, these non-biodegradable wastes are gradually bio-accumulating in solid & liquid phase and exert pressure to disrupt the natural state of homeostasis on earth. Likewise, the urbanization is also exhibiting to settle the human population and alter the land use pattern. For example, the forests are cleared out to grow the agricultural commodities and agricultural land converted to residential colonies to settle out the growing human populations. Thus, the changes in land use pattern are owing to human demand year by year. Further, the residential colonies continue discharge the effluent that disintegrate, disrupt and damage the vegetation at a large scale. Moreover, this discriminate discharge ultimately joins and vanishes out the water body due to activity of different pollutants present in discharged effluents. As the effect of pollutants on human, biodiversity and property are gradual and chronic but it is long-lasting and irreversible. Several death causing diseases, extinction loss of biodiversity and Stone leprosy to historical monuments are the prominent examples of pollution. Furthermore, the industrialization and urbanization activities harness the natural resources available and trigger the imbalance in presence of natural resources.

10.9 Over-exploitation of natural resource

The resources like forests, minerals, waters etc. are given by the nature traditionally are called natural resource. The natural resources are optimum to supply the nutrients and water when they are use in judiciously and sustainably. In general, the sustainable use of natural resource means the use of the natural resource at present without compromising the future generation to use the same. The sustainable use of natural resource has the virtue to use it long lasting in sufficiency. However, the overuse of the natural resources decreases and depletes the natural resources drastically. The over-exploitation means the exploiting the species without ensuring its supply in constant rate for future and ultimately cause the extinction of the species. The animal poaching for their body parts results the extinction of animal globally *e.g.* the killing or hunting of elephant for its ivory tusks; the killing of lions for its hide etc. The mining activity of coal supplies it for power generation. The over-exploiting of coal consequently led to extensive mining that destroy the forest ecosystems. The over-exploitation of natural resources always leads to destructions of nature and natural resources.

10.10 Habitat fragmentation and destruction

The habitat is essential part of living beings and the inhabitants living in are in accordance with that habitat conditions. Although, the most of the factors associated are indirect and complex to interlink. Still the impacts of climate change are the well understood in reference to habitat fragmentation. The global warming and climate change widely responsible for habitat destruction and fragmentation by the melting glaciers and frequent flood events. The habitat fragmentation and destruction are consequently leading towards the devastating impacts on glaciers, forest, grasslands and other landscapes. If in response to changing climatic condition converting the hilly terrain to xeric climate the sensitive tree species like Oak will be replaced by adaptive tree species of Chirpine. The further retrospect of this event will eventually promote the xeric condition as the chirpine have fire resistance and most suitability in xeric hill conditions. The extinction of water conserving Oak species, which was responsible to conserve the water will dry up the hill station and will spread the new recruits of chirpine mono-culture. Thus, the habitat destruction damages the tree biodiversity and tree extinction also will destruct the habitat **(Shankhwar *et al.*, 2020).**

10.11 Deforestation and fragmentation

The land use pattern is a pattern to use the land resources. The anthropogenic activities are the direct input to change and/or design the land use pattern. The change in land use pattern led to deforestation and fragmentation. The various activities like agriculture, human settlement and construction of roads, factory etc. are supporting to the human habitat and habitation profuse huge pressure to clear the forest. Tree based ecosystem play crucial role in carbon sequestration **(Bijalwan *et al.*, 2017)** and retaining tree based land use. Hence, the clearance of forest declines the plant and animal community drastically. The change in land use pattern from forest ecosystem to agricultural system led to reduce the diverse plant community to monoculture. The ultimate effect of change in land use pattern lead to deforestation, fragmentation and reduction of biodiversity result the fragile ecosystem instead of stable ecosystem. The fragmentations of forest are mainly due to the activity of construction of new road, dam, mining activity etc. The fragmentation of the forest area drastically reduces the biodiversity by changing the property of micro-habitat. The fragmentation of forest split out the forests into small patches of forest. The larger forest is extensively attributed to the more diverse forest and as smaller forest area will lead to the less divers' forest. The species richness prevails in larger and diverse forest. The fragmentation of forest deteriorates and deforests the forest due to edge effect of forest segments.

10.12 Invasive species

The interactions of biotic community are the main determining factors to existing the biotic community in the prevailing ecosystem. The biotic community compete for various resources like food, shelter, moisture and light etc. The biotic community are either eury- or steno - in nature which help to tolerate the competition in adverse climatic condition. As the outcome of competition in adverse situation, the steno species will diminish out and the only the eury species will proliferate. The eury species has the capacity to survive in wider ranges and trigger the extinction of the steno species which can survive in a small micro-habitat. The invasive species are the eury species that can move to new place and may survive there too due to its eury nature. The invasive species have some extra characteristics that help it to survive in wider range environmental variables *e.g.* the seeds of Parthenium are so tiny and may disperse easily to the wider area. Moreover, the short lifespan of Parthenium help to produce its seeds in short duration of time and boost its dispersion largely. Thus the eury species spreading to new spaces and diminish out the native steno species is the devastating activity of eury species and act as a danger for mass extinction of steno species. The mass extinction of native steno species will deteriorate the micro-habitat due to extinction and disruption of the biotic species in ecosystems. As the biotic component disappears due to extinction it also affects the abiotic factors of ecosystem.

10.13 Climate change

The climate is the condition of a region characterised by rainfall, temperature etc. The anthropogenic activity influences the environment at an extent that it also alters the climatic condition. The noted activities that change the environment globally are greenhouse gas emission through the anthropogenic activity **(Shankhwar *et al*., 2012).** The greenhouse gas namely H_2O, CO_2, CH_4, NO_2, O_3, CFC & SF_6 are directly responsible for global warming through greenhouse effect. The global warming induced climate change is one of the most devastating consequences of anthropogenic activity. The climate change influences the human beings, plant & animals and ecosystem tremendously. It is globally addressed problem generated by the cascade effects of anthropogenic inputs. The global warming consequently increases the temperature on earth which has the destructive impacts on glacier and promotes the melting of polar icecaps. One side it shrinks the glacier and other hand the melting glacier affect the coastal area with the disparaging motion of flood. Summarily, it destructs the habitat of polar bear and damages the human settlements in coastlines and port lands. The climate change activities alter the climatic conditions that regulate the agricultural production. Thus, the climate change reduces the production of agricultural commodities and staple food. The microbiota is ultra-sensitive towards the temperature and pH; hence the climate change affects the living microbiota in soil. The microbial change may change the ecosystems and even the land use patterns. Thus, as we know that in ecosystem all the components are interlinked and closely associated. Therefore, the detrimental impacts may also lead to damage the nature the vanishing the ecosystems. The climate change first attack on the stenothermic plants and animals and indirectly support to the eurythermic plants and animals. The changing effects on biotic community is to promote the eurythermic plants and animals and withdraw stenothermic will ultimate create a homogeneous population. The reduction of biological diversity will lead to destruct a number of plants and animals.

Terminal Questions

1. Briefly discuss the following:

   a. Herbivory

b. Trophic level
c. Ecological pyramids
d. Information flow in ecology
e. Energy perturbations

2. Differentiate between the following:

a. Food chain and food web
b. Grazers and browsers
c. Herbivores and carnivores
d. Autotrophy and heterotrophy in food chain
e. Steno and eury in reference to invasive species

3. Outline the role of nitrogen cycle in agriculture.

4. Highlight the carbon cycle in reference to sustainable development.

5. Explain the contributions of ecosystem service in present era.

Answers

Check Your Progress 1: A i, B ii, C i, D iv, E ii.

Check Your Progress 2: A i, B iii, C i, D iv, E i.

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Unit 11: Global Ecosystems and Ecosystem Development

11.0 Learning Objectives

After the study of this unit you will be able to:

- know all about the ecology vis-à-vis human beings

- understand the philosophy of ecology
- highlight the importance and scope of ecology for sustainable development
- interlink the relationship with discipline of science and humanities

11.1 Introduction

It is worth to understand that Autecology denotes to the study of individual species. In the ecosystem different organism live together in form of community and interrelated together due to their functional position which is called as ecological niche. The food habit joint together the organism of ecosystem and construct a hypothetical pyramids shaped structures showing food responses. The food behaviour of different animals in an ecosystem is depicted in form of upright or inverted pyramid e.g. the pyramid of energy is always upright; the upright pyramid of numbers of species is not found in forest ecosystem. Thus, the presence of any plant or animal species in any location is not due to a random occurrence, but this assemblage is the outcome of different ecological selection phenomenon. Hence, the study of different species occurrence in different geological location is important. After the study of this unit you will able to understand the different biomes, its types, distribution, characteristics, ecosystem development – concept, types, process and applications in evolution of ecosystems.

11.2 Definition

A giant realm of ecosystem characterized by distinct plants, animals, and its assemblage typically present due to the adaptive consequences in correlation with the topography, soil and climate is called as biome. Biome reflects the totality of biotic community and its connecting stages of succession exist in particular climatic region.

The different patches of the same forest may reveals the distinctly variation in animal and plant species distribution. The variation in animal and plant species is also due to the adaptive consequences including the climatic interrelation and succession stage at a particular region is common in nature. The assemblage of this variation in reference to location or location identified with distinctly different biotic component is considered as the biome. The variation or diversity may promote speciation or trigger the distinction of species.

11.3 Biomes types, distribution and characteristics

This is a fact that if we transact to a forest and cover a significant distance; we will observe a distinct variation in vegetation and even the characteristics of the same variation. The noted variation reveals the impact of attributes due to geographical location and consequences of interrelated activity and environmental factors etc. The environmental factors involved are the biotic components and abiotic components as the topography, soil and climate. Therefore, the collection of existing distinct biotic component differs with change in locations as a response to the adaptive consequences is considered as the distribution of biome types. The same species of plant and / or animal species may also undergo in distinct variation due to the adaptive consequences at different in particular environmental regimes and considered as the characteristics of biome.

As you know that we are more closely surrounded with the terrestrial biome and that's why the terrestrial biome is more studied or become popular. The ocean also reflects a huge variations as a whole and species evenness in particular zone. Therefore is also characterized into different biomes. Before discussing the frequently studied biome *i.e.* the terrestrial biome, a quick look on the oceanic biomes is as follows:

11.3.1 A snapshot of Oceanic Biome

In the ocean, the biome is considered as partitioning and the oceanic region is recently divided into four distinctive biomes namely. The divided zones are representing distinct latitude level or any other specific characteristic like polar region, coastal front etc.

Oceanic Biome	**Characteristics features**
Westerly wind	high latitude, complex herbivore ecology
Easterly trades	low latitude, taxonomically most diverse group of climax community
Polar fronts	low diversity
Coastal zone	enriched with coral reef and diverse plankton zooplankton

The high and low latitude is designated as the westerly wind and easterly trades. The biotic communities are dramatically distinct in these two biomes. At the polar region the diversity is drastically low and the biome is known as Polar fronts. After all, the coastal zone is also distinct with other zones and greatly influenced due to transition phase and come under the Coastal zone.

11.4 Types of Terrestrial Biome

Early in plant ecology, a distinct relationship was observed between climate and the physiognomy of the existing plant species called as biogeography. The terrestrial biomes on the basis of vegetation are mainly either forest biomes or grassland and other unique biomes.

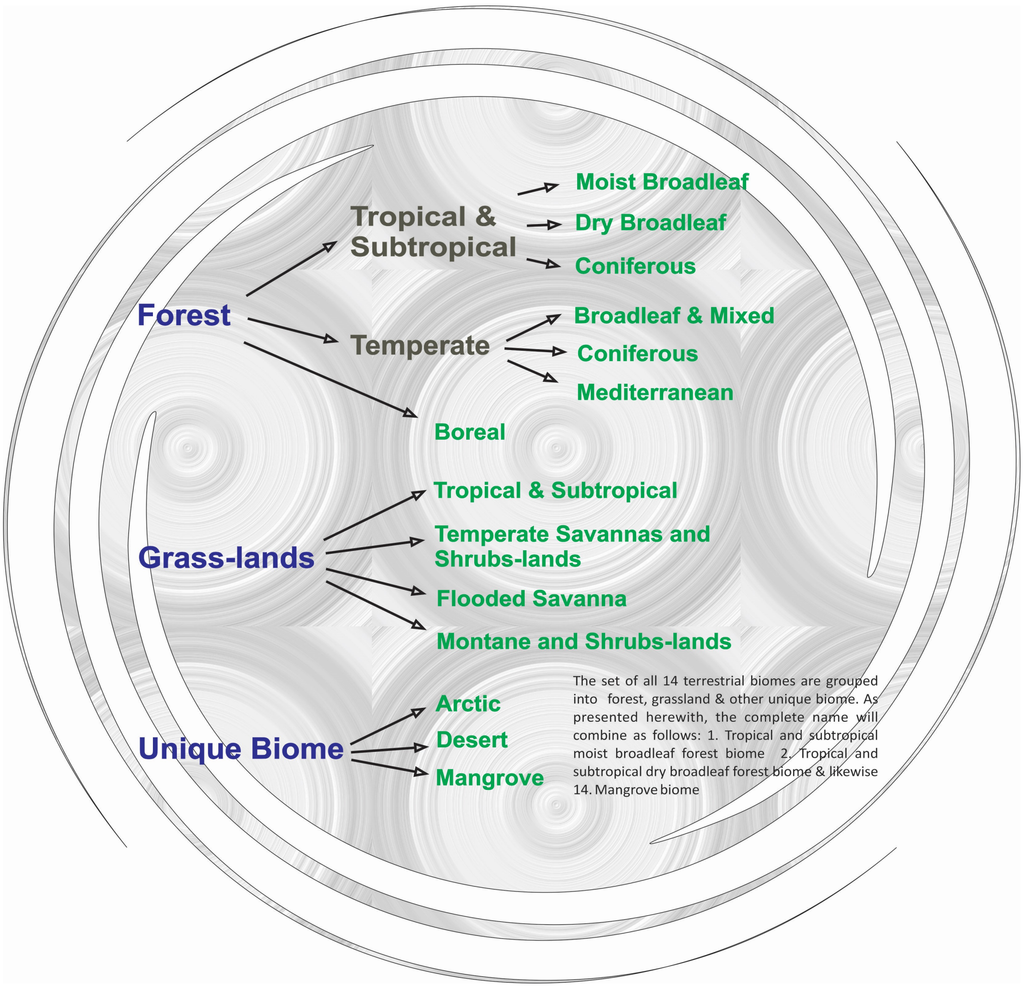


Fig 11.1 Types of Terrestrial Biomes

11.5 Biome distribution

The environmental variables including temperature and precipitation have a strong cascade impacts in the biological diversity of vegetation and animals. The natural flora and fauna of a region is a direct outcome of the environmental variables essentially of temperature and precipitation. The distribution of biome is directly linked with the temperature and precipitation. If only two environmental variables namely temperature and precipitation is arranged in systematic sequence, it will able to define the distribution pattern of biomes on the full stretch of world-wide. Here you may know about the nine biome distribution explained by Whittaker in 1975 on the basis of mean annual temperature and mean annual precipitation. The lowest mean annual precipitation (150-250 mm) with lowest mean annual temperature (-28° C) is a feature of *Tundra biome* and the lowest precipitation (150-250 mm) with higher mean annual temperature (20-25° C) is to *Hot Desert biome*. Likewise, the temperature range (-20°C to 30°C) above the tundra biome with slightly higher mean annual precipitation (mm) and highest mean annual precipitation (51–127 cm) are the characteristics of *Grassland and Shrubland Biome,* and *Savannah* (also known as tropical seasonal forest) biome respectively. The savanna grassland biome is designated with lower annual rainfall and long spells of dry season. The savanna grassland is ecotones of tropical forest and desert. The scattered dry deciduous tree in grassland is the characteristic features of Savanna. Further the higher mean annual precipitation (mm) is designated as *Boreal and Alpine Forest Biome*, *Temperate Forest Biome*, *and Dry Tropical Forest Biome*. The tropical forest biome is stretched on central part of equator and is also known for the highest biodiversity of terrestrial species. The tropical forest biome is a home for nearly half of terrestrial species on earth. The tall trees and shrubs are the dominating vegetation and characterized as Phanerophyte plants types. The variation in rainfall patterns as per the seasons; altitudinal variation and soil parent material is characteristic feature of tropical forest biome. These variations has created diversified sub-category of biome namely i. Evergreen Rainforest, ii. Seasonal Deciduous Forest, iii. Tropical Cloud Forest, and iv. Mangrove Forest that integrated together to form the Tropical Forest Biome. The forest existing in the central and south part of America is chiefly the tropical forest. At last the highest mean annual precipitation (125 to 660 cm) is characterized to *Temperate Rainforest Biome* with higher mean annual temperature (20^{o}C) and *Tropical Rainforest Biome* with the highest mean annual temperature (20^{o}C to 34^{o}C).

Ecosystem in India is endowed with vast resources for forests, hills, surface water resources etc. Ecosystem is dynamic, its attributes and boundaries are constantly changing and consequently, interactions with human uses also are dynamic. The emerging shift of ecosystem is owing to the ecological interactions, especially those of trophic nature including the impact of exotic species, invasion, pollution, and other management aspects. The modification in ecosystem is mainly due to the biomass flow between different elements of the exploited ecosystems information on health of the ecosystem as well as the capacity to support biological production and trophic functioning. The climatic variability is recognized as one of the major environmental challenges affecting ecosystems and economies globally. The multiple benefits arise out from the ecosystem services for food security, and

Check Your Progress 1

Match Section A and Section B appropriately

A	B
i. Westerly wind	**a. low latitude, taxonomically most diverse group of climax community**
ii. Easterly trades	**b. enriched with coral reef and diverse plankton zooplankton**
iii. Polar fronts	**c. high latitude, complex herbivore ecology**
iv. Coastal zone	**d. low diversity**

11.6 Characteristics of Biomes

The large landscape with its vegetation and wildlife including the all the living organisms are called as the biome. Basically the biome differs to each other on basis of their environmental attributes and physiographical characters which favor some specific plants and animal in the region. Collectively, considered as the biomes, therefore the characteristics are the fundamental criteria for selecting the plant and animals and ultimately designing the biodiversity. Hence the characteristics of biome are the crucial factor that determines the biome.

11.6.1 Forest Biome

The forest biomes are basically defined on the basis of the dominated characteristic of existing forest vegetation like broadleaf, coniferous characters etc. It is notable that the climatic conditions (like humid, sub-humid, arctic & subarctic etc.) of region regulate the vegetation type and growth. Forests play crucial role in carbon sequestration **(Bijalwan *et al.*, 2017).**

11.6.1.1 Tropical and Subtropical Moist Broadleaf Forest Biome

Predominantly humid climatic condition prevails in Tropical and Subtropical Moist Broadleaf Forest Biome. Tropical and Subtropical Moist Broadleaf Forest Biome prevails in area that have Rainfall less than 2000mm. Tropical and Subtropical Moist Broadleaf Forest Biome is characterized by high β diversity.

The concept note on Beta Diversity

The diversity is measured in different level of scale. The Beta diversity is use to estimate the variation in the diversity of any tree, animal or any other species from one location to another location e.g. lake, pond, field to another lake, pond, field. For simple understanding, β diversity use to quantify the number of fish varieties that are not the present in two different water body e.g. ponds.

Two ponds have a total of 12 fish varieties: a, b, c, d, e, f, g, h, i, j, k, l.

In pond X there are total 10 fish varieties: a-j.

In pond Y there are only 07 fish varieties: f-l.

Both ponds X&Y) have f-j; they have 5 fish varieties in common.

Therefore the β diversity of both ponds= (No of Species in pond X - No of Common Species)+ (No of Species in pond Y - No of Common Species) = (10-5) + (7-5) = 7.

Hence, there are seven fish varieties are either only in pond X or only in pond Y.

11.6.1.2 Tropical and Subtropical Dry Broadleaf Forest Biome

The part of central India is enriched with the Tropical and Subtropical Dry Broadleaf Forest Biome. Predominantly semi-humid climatic condition prevails in Tropical and Subtropical Dry Broadleaf Forest Biome.

Tropical and Subtropical Dry Broadleaf Forest contained the trees with maximum level of diversity of tree species. Tropical and Subtropical Dry Broadleaf Forest full of diversification as it has five layers of tree canopy which can be divided into the following:

i. Overstorey canopy: large trees are established woodlots with emergent crown cover and the forest seems grand forest *e.g. Quercus leucotrichophora, Cedrus devdara, Pinus roxburghii.*

ii. Medium layer: the tree is medium sized and in growing and expanding phase of growth *e.g. Bahunia verigata, Morus nigra.*

iii. Lower canopy: the trees are at early stage of growth *e.g.Grawia optiva*.

iv. Shrub level: the bushy structure of plants highly favorable by browsing animals *e.g. Rhododendron arboretum*.

v. understory: grasses and seedlings are the dominating vegetation.

11.6.1.3 Tropical and Subtropical Coniferous Forest Biome

Predominantly semi-humid climatic condition prevails in Tropical and Subtropical Coniferous Forest Biome. Generally Tropical and Subtropical Coniferous Forest prevails in high altitude and tree leaves are generally needle shaped and tree form cone like structure. Coniferous trees species are common in the region *e.g. Pinus wallichiana, Pinus roxburghii, Cedrus devdara.*

11.6.1.4 Temperate Broadleaf & Mixed Forest Biome

Predominantly humid climatic condition prevails in Temperate Broadleaf & Mixed Forest Biome. The following tree species may available in mixed forest area *Aegle marmelos, Albizia lebbeck* L., *Artocarpus lacucha, Bahunia purpurea* Linn., *Bahunia verigata, Bauhinia racemosa* Lam., *Bauhinia semla* Wunderlin., *Bauhinia vahlii* Wight &Arn, *Blood Orange, Boehmeria regulosa* Wedd., *Bombax ceiba, Cassia fistula* L., *Cedrus devdara, Celtis australis, Cupressus torulosa, Eucalyptus, Ficus auriculata, Ficus auriculata*Lour, *Ficus glomerata, Ficus palmata, Ficus religeosa, Ficus semicordata, Ficussubincisa, Grawiaoptiva, Grewia asiatica* L, *Grewia oppositifolia Buch*.-Ham, *Holarrhena pubescens Buch*.-Ham, *Jacaranda mimosifolia, Litsea monopetala* Roxb. *Lyonia ovalifolia* Wallich, *Mallotus phillippensis* Lam., *Milletia extensa* Benth, *Moringaoleifera Lam., Morus nigra,* *Neolitsea cuipala* Buch – Ham*, Ougeinia oojeinensis* Roxb*., Phoenix humilix* Royle*.,* Vern, *Phyllanthus emblica, Pinus wallichiana, Populous ciliata, Populous ciliata, Pinusroxburghii, Prunus persica, Punica granatum, Quercus leucotrichophora, Rhododendron arboretum, Sapindus mukorosis, Toona cilita, Zizyphus mauritiana*

11.6.1.5 Temperate Coniferous Forest Biome

Predominantly humid to semi-humid climatic condition prevails in Temperate Coniferous Forest Biome. The following tree species may available in mixed forest area *Aegle marmelos, Albizia lebbeck* L., *Artocarpus lacucha, Bahunia purpurea* Linn., *Bahunia verigata, Bauhinia racemosa* Lam., *Bauhinia semla* Wunderlin., *Bauhinia vahlii* Wight & Arn, *Blood Orange, Boehmeria regulosa* Wedd., *Bombax ceiba, Cassia fistula* L., *Cedrus devdara, Celtis australis, Cinnamomumm tamala, Cupressus torulosa, Eucalyptus, Ficus auriculata* Lour, *Ficus glomerata, Ficus palmata, Ficus religeosa, Ficus semicordata, Ficus subincisa, Grawia optiva, Grewia asiatica* L, *Grewia oppositifolia Buch*.-Ham, *Holarrhena pubescens Buch*.-Ham, *Jacaranda mimosifolia, Litsea monopetala* Roxb. *Lyonia ovalifolia* Wallich, *Mallotus phillippensis* Lam., *Milletia extensa* Benth*, Moringa oleifera Lam., Morus nigra, Neolitsea cuipala* Buch – Ham*, Ougeinia oojeinensis* Roxb*., Phoenix humilix* Royle*.,* Vern, *Phyllanthus emblica, Pinus wallichiana, Populous ciliata, Populous ciliata, Pinus roxburghii, Prunus persica, Punica granatum, Quercus leucotrichophora, Rhododendron arboretum, Sapindus mukorosis, Toona cilita, Zizyphus mauritiana*

11.6.1.6 Temperate Mediterranean Forest Biome

Predominantly subarctic, humid (taiga) climatic condition prevails in Temperate Mediterranean Forest Biome.

11.6.1.7 Boreal Forest Biome

The Boreal forest biome is also known as Taiga Biome. The vegetation is enriched with cone bearing tree canopy that have predominantly needle shaped leaves.

11.6.2 Grasslands Biome

The Biome predominantly has grasses as a major constituent is considered as Grassland Biome. The grassland biome is further classified into following groups namely- Tropical and Subtropical Grasslands Biome; Temperate Savannas & Shrubs-land Biome; Flooded Savanna Biome; Montane & Shrubs-lands Biome.

11.6.2.1 Tropical and Subtropical Grasslands Biome

Tropical and Subtropical Grasslands Biome mainly characterized by prevailing semiarid climatic condition. The rolling grasses are predominantly present with very less spotted tree at lower density. The alternate wet and dry condition is the specialty of this region.

11.6.2.2 Temperate Savannas & Shrubs-land Biome

Predominantly semiarid climatic condition prevails in Temperate Savannas & Shrubsland Biome.

Characteristics of the Savanna

Savanna is clearly characterized by the dominant grasses with scattered other vegetation either tree or shrubs or both tree and shrubs. The seasons around the year maybe divided into two spells one is rain dominant and another rain scanty. The rainy season also cover the summer season however, the winter and some part of summer is come in dry spells. As the precipitation in summer season is also common in the savanna terrestrial zone. Thus this region is characterized by the hot humid conditions. The dry seasons only is characterized by the cool climate. The savanna is also supports the herds grazing animals at a large scales. The savanna is prominent region to support the grazing animal and the browsing animals supported by the other terrestrial biomes.

11.6.2.3 Flooded Savanna Biome

Predominantly temperate to tropical climatic condition and characterized by fresh or brackish water inundated prevails in Flooded Savanna Biome.

11.6.2.4 Montane & Shrubs-lands Biome

Predominantly Alpine or Montane climatic condition prevails in Montane & Shrubs-lands Biome.

11.6.3 Unique Biomes

The terrestrial biomes are divided into forest biome and grassland biome and remaining biome are come under the category of unique biome. The unique biome constituted Arctic, Dessert and Mangrove Biome.

11.6.3.1Arctic Biome

The area is highly cold and characterized by very less vegetation.

11.6.3.2 Dessert Biome

The area is highly hot and very less vegetation characterized by thorny.

11.6.3.3 Mangrove Biome

The marshy land area exist some trees specialized pneumatophores root system e.g. *Avicennia germinans*, *Laguncularia raecemosa*.

Check Your Progress 2

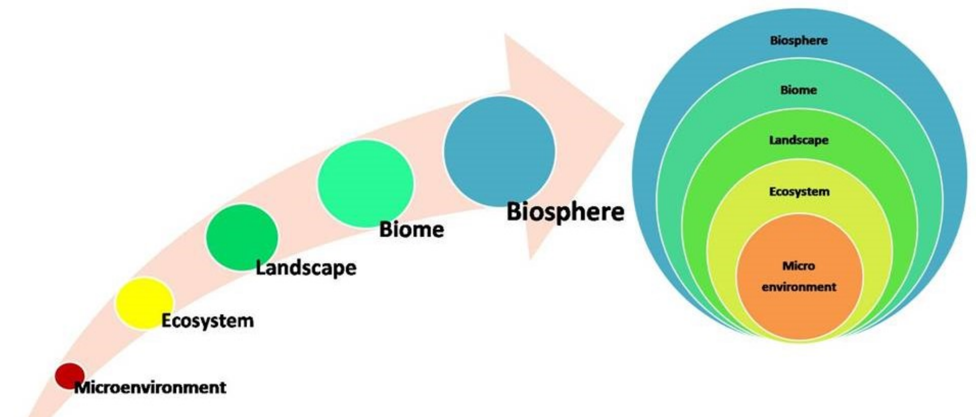
Match Section A and Section B appropriately

A	B
i. Broadleaf Forest	a. Grasses with scattered tree vegetation
ii. Coniferous Forest	b. highly cold and very less vegetation
iii. Savanna	c. *Quercus leucotrichophora, Cedrus devdara*
iv. Arctic Biome	d. *Pinus roxburghii, Cedrus devdara*

11.7 Ecosystem development-concept, types, process and applications

The successive growth of ecosystem is the activity of change in community structure more loosely change in composition. The continuous and consistent trend of changing in the community arose out of the competition of the biotic community either knowingly or unknowingly at different age and stage of life. This activity is the principle cause of species replacements mechanism of nature. The prediction of ecological attributes in speciation and extinction of species are highly complex and remain unclear due to the ‘n’ number of factors involvement simultaneously or stepwise during the ecological interventions. However, a number of models, enumerations have been developed so far to explain the ecological role in evolution. Like, Lotka and Volterra model is based on logistic equations describes apparently the inter- and intra- specific completion of species. This model summaries that if the higher population strength, it will be higher the intra-specific completion. This model efficiently explains all the possible outcome of interaction and which species is going to increase or going to decrease at different competition levels.

Likewise, Shannon and Weaver diversity index elaborates the biological diversity traits such as species richness and evenness. Similarly, the ecological succession discloses the species dynamics in changing ecological conditions and describes different interactions that are the cause and consequences of ecosystem development dynamics. The three factorial outcome of ecological interaction is responsible for the species replacement in an ecosystem.



The pockets of space with specialized characters create microenvironment. The abiotic components along with biotic community form an ecosystem. The ecosystem of same land regime is called the landscape. The large land regimes with same landscape create a biome e.g. Tundra biome, Taiga biome etc. The assemblage of all biome form atmosphere, lithosphere, and hydrosphere is called Biosphere.

11.7.1 Global shift in Lake Ecosystem

The small amount of freshwater is available in water body like lake and river i.e. around <0.5%. Despite the scarcity, the lake water body remains under influence of multiple anthropogenic activity of habitat destruction, human settlement, industrialization, over-fishing, climate change and eutrophication. The impacts of increased human population, industrial development, deforestation and depletion of land resources have had serious adverse impacts on lakes and resulted decline seen in number of lakes and other small water bodies.

11.7.1.1 Bioaccumulation

The tissues are generally rich in lipid and have high affinity with the lipophilic compounds. This high affinity force to capture the entering xenobiotics compounds into the adipose tissues of cells and results the bioaccumulation of lipophilic compounds. The bioaccumulation of the compounds increases the concentration of xenobiotics in an organism. Most of the time being the xenobiotics compounds are due to its toxic nature and results the toxicity to the organism. Thus, the presences of xenobiotics compounds even in minute concentration affect the life of biotic community and also mold the environmental conditions for some selective living organisms. The organisms have the high tolerance against the toxicity of environmental xenobiotics compounds may only proliferate and other organisms will filter out of the location. Thus, the bioaccumulation tendency is one of the selection criteria of organism in a particular ecosystem.

11.7.1.2 Biomagnification

Like the bioaccumulation, the bio-magnification that means the increase of xenobiotics compounds due to its lipophilic in successive trophic levels. The concentration of lipophilic compounds may rise up from very minute level to higher toxic levels through the biomagnification. Thus the exogenous addition of persistent organic pollutants (POPs) affects potentially to the aquatic environment and turns the livable environment to a death chamber. Biomagnification process is required very less time as different trophic levels are available in water body in parallel. The multifold rising of pollutants in lake leads to the toxicity of food chain.

11.7.1.3 Eutrophication

Eutrophication process is the cascade effect of nutrient enrichment, algal bloom and anoxia. The pollution from household to water body mainly nitrate and phosphate as an excessive nutrient. The nitrates and phosphates especially in lentic water body like Lake gradually enhances the nutrient load that is called as nutrient enrichment. The source of nutrients from household on daily basis may be the soap,

detergent, kitchen residues etc. However, in farmland the leachates fertilizer, pesticides, and other chemical that enhances the nitrates and phosphates content **(Monika *et al*., 2017).** Although the nutrient enrichment adds the plant growth in water body, but due high fecundity rate of algae like water hyacinths, the water hyacinth cover the upper layer of Lake. The high fecundity rate help water hyacinth to compete with other aquatic plants vigorously and mono species richness occur into the water body.

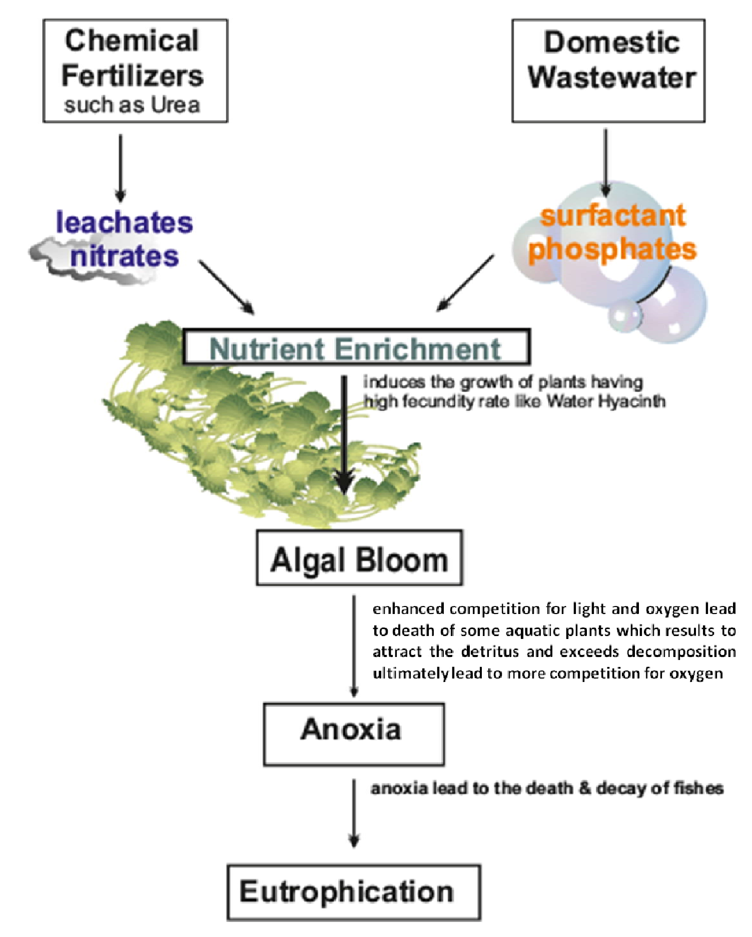


Fig 21.2 The processes of Eutrophication

This high growth of algae helps to vanish out the other aquatic plant species and is considered as the algal bloom. As result of algal bloom, mono-culture dominating intra-species competition starts in lake **(Shankhwar et al., 2012).** Moreover the mono species growth and development enhanced competition for availability of light and space. The intra-specific completion among algae results rapid addition of organic residue by death and decay of algae as algae has short life span. The addition of organic matter in the water body attracts the detritus and the detritus consume the dissolve oxygen in order to degrade the decayed organic matter. Ultimately, due to activity of detritus the dissolve oxygen content in lake water is depleting fast. As the water body is stratified into different layers *i.e.* epiliminion, thermolimion and hypoliminion on basis of water temperature. The hypolimetic layer suffers more due to oxygen depletion as it also facing the more competition for light. Thus the hypolimnetic layer faces the drastic oxygen depletion due to excessive nutrient load, decomposition organic matter, turbidity and algal bloom is called as Anoxia. The anoxic condition involved for decreasing the floral diversity as death of aerobic organism, adverse environmental condition and changing in temperature, presence of toxic or inedible phytoplankton and leads to killing of small fishes. During addition of dead organic residues the biochemical oxygen demand of water body also increases.

11.7.2 Ecological succession

At the first the land has no soil moisture, organic matter, and other constituents essentially required for the growth and development of plants. On this barren land Lichen (A primitive organism on earth) appears at first, hence it is called as the pioneer species. The pioneer species grow first and create the environmental condition for the growth of another organism. Lichen has the capability to grow on new substratum which has the minimal nutrient media, this beauty of lichen is due to its associating power of algae and fungi. In true sense, the lichen is the lichenized fungi. Algae provide food & shelter to fungi and fungi produces the secondary metabolites that helpful in succession.

11.8 Evolution

The permanent change with the time heritable traits results the evolution. The change is the outcome of the completion within and between species and with the abiotic factors as well. Ultimately, the species selection for next generation is on the basis of 'the survival of the fittest'.

11.8.1 Evolution of Ecosystems

The evolution is a measureless word as it is use describes a series of changes. The evolution begins with change in small patch and the small patch is often considered as microenvironment. The microenvironment is a desired change to boost up the growths.

e.g. a seed of a tree fall on the ground if it gets the moisture and other environmental variables at optimum condition, the seed start to germinate. The only germination is not an assurance for growth and development of new seedling. Soil condition, water availability, temperature and weather condition are the other factors to determine the growth and development of sapling. In a nutshell, the microenvironment is the venue for change and responsible for evolution. The microenvironment initiates the growth of biotic component through interaction with abiotic factors to facilitate as an ecosystem. The building of new ecosystems modify the abiotic components along with the biotic component growth and ultimately it form large land-holding *i.e.* landscape. The landscape and its vegetation and biotic assemblage also influence the climatic condition of landscape. The modified climatic condition will promote the same vegetative structures and create the same landscape at larger scale that ultimately. The environmental disruption, degradation and deterioration can be checked through planting more trees and transforming the ecosystem **(Shankhwar and Srivastava, 2015).**

11.8.2 Theory of Evolution

The selection of individuals from the nature was the determining characteristics for the growth and development of the particular species. The growth and development of the species also plays a key role in complex ecological interactions in biotic community that fueled the ecological dynamics. The ecological dynamics is solely responsible directly or indirectly for ecological evolution. Hence, the theory of evolution explained below is the outcome of ecological interactions:

1. The group of individuals forms a population, however, the individuals of the species are not exactly same, and they are un-identical.
2. Not all but some characteristics pass from one generation to next generation and these characters are heritable to next generation and therefore the basis for genetic pool.
3. The environmental condition plays significant role in the growth and development of population of a species. Due to environmental condition most of the individual fail to

produce their progeny and to contribute to population continuum at their maximum rate of production ability.

4. Thus, the different forebear contributed different number of their descendents which was outcome different ecological interactions. Ultimately the contribution for the next generation was notably incomparable. Hence, the consequently the contribution in population most have the more prominent role in further generations.

Terminal Questions

1. Briefly discuss the following:
    a. Biome
    b. Oceanic Biome
    c. Savanna Biome
    d. Evolution of Ecosystem
    e. Global Shift in Lake Ecosystem
2. Differentiate between the following:
    a. Forest and Grassland biome
    b. Ecological Succession and Ecological Evolution
    c. Biomagnification and Bioaccumulation
    d. Algal Bloom and Anoxia in Lake ecosystem
    e. Taiga and Boreal Forest
3. Outline the role of Ecological Succession in Ecological Evolution.
4. Highlight the Types of Terrestrial Biomes.
5. Explain the contributions of Eutrophication in Ecological Succession.

Answers

***Check Your Progress 1*:** i. c, ii. a, iii. d, iv. b.

Check Your Progress 2: i. c, ii. d, iii. a, iv. b.

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Unit 12: Interactions

Unit Structure

12.0 Learning Objectives

After completing this unit, you will be able to:

- Understand the importance of ecological interactions in the ecosystems.
- Describe different types of ecological interactions existing between various organisms.
- Learn about the defense mechanisms by prey and predators.
- Distinguish between a habitat and an ecological niche of a species.
- Learn about the relationship between competition and the niche, and its consequences.

12.1 Introduction

You might have already learnt about the ecosystem in the previous units. Ecosystem is defined as, *a system where biotic and abiotic components interact to function as a single* *unit.* Since, all organisms depend on resources (food, pace, mates and so) or the services provided by ecosystems for their survival, growth and reproduction, no single species can exist in a complete isolation. This tendency of organisms has resulted in a relationship between the species and the ecosystems.

In order to grow, survive and reproduce, every individual on earth requires some sets of environmental conditions. These set of favorable conditions are essential to maximize the role of species in its habitat. Since resources are not uniformly distributed across the landscapes, species cannot utilize the entire available resources. They occupy a part of it which is often competitively dominant region of entire niche.

In this unit, you will learn about the above mentioned categories of interactions with their examples along with their applications in the real world. Besides the niche concepts and it significance.

12.2. Ecological Interactions and its applications

In everyday life, we use the term *symbiosis* which means *"living-together".* However, in ecology, symbiosis is a close ecological association occurring between the individuals of two or more different species for the long period of time. This term can be used to describe all types of biotic interactions. Like most ecological interactions, symbiosis is recognized as one of the essential forces behind evolution.

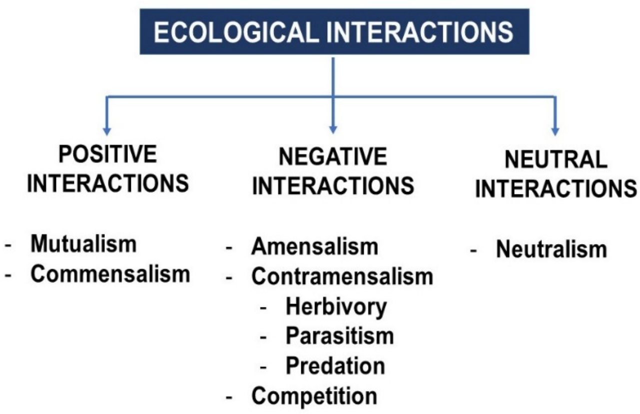


Fig. 12.1. Types of ecological interactions existing in various ecosystems

We can define *ecological Interaction* as a direct or indirect association between organisms in an ecosystem. These interactions can between plants-plants, plants-animals or animals-

animals. These interactions influence the population of interacting species. Sometimes, the effect could benefit mutually or can have detrimental impact on the interacting individuals. When it neither benefits nor harms the individuals, known as neutral interactions. Depending upon the nature of effects on the interacting organisms, these interactions can be classified into three broad categories- positive, negative and neutral as illustrated in the fig 12.1.

12.3. Types of Interactions

As mentioned in the figure 12.1. the three broadly classified categories of ecological interactions can further be divided into several types of biotic interactions. These may include mutualism, commensalism, amensalism, competition and contramensalism (herbivory, parasitism and predation). An overview and nature of these interactions can be understood from the table 12.1. Obtained from Odum (1959) and Haskell (1947).

Table 12.1 Concise description ecologicalinteractions existingbetween species.

Type of Interaction	Species A	Species B	Nature of Interaction
Competition	-	-	Each population inhibits the other.
Predation, Parasitism, Batesian mimicry	+	-	Population A, the predator, parasite, or mimic, kills or exploits members of population B, the prey, host, or model.
Mutualism, Mullerian mimicry	+	+	Interaction is favorable to both (can be obligatory or facultative).
Commensalism	+	0	Population A, the commensal, benefits whereas B, the host , is not affected.
Amensalism	-	0	Population A is inhibited, but B is unaffected.
Neutralism	0	0	Neither of the populations affects the other.

We will discuss each of these interaction in coming sections in more detail.

12.3.1 Positive Interactions

When two organisms living in a defined geographic area, they interact with each other. During the interaction, either individuals of one species benefits the individuals of the interacting species or both species benefit in the partnership. Such interactions are known to be positive in nature. There are two kinds of such interactions exist in ecosystems. These may include mutualism and commensalism.

i. Mutualism

You may have learned about the nitrogen cycle in previous units. As illustrated in the fig. 12.2. nitrogen-fixing bacteria, rhizobium dwells in the root nodules of leguminous plants such as beans, lentils, peas, etc. These microorganisms convert atmospheric nitrogen into an ammonia-like substance to be utilized by the leguminous plants. In exchange, legumes supply bacteria safe environment and sufficient nutrition. This illustrates a beneficial mutualistic beneficial relationship between legumes and nitrogen-fixing bacteria.

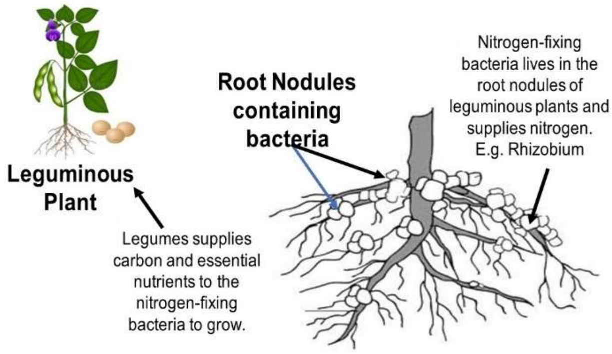


Fig. 12.2. Symbiotic relationship between legumes and nitrogen-fixing bacteria.

From the above example, we can define mutualism as *a symbiotic relationship occurring between the individuals of two different species, in which both the individuals of association benefit.* Individuals of each interacting species grow, survive and reproduce more effectively in the presence of the other interacting species. Since, both interacting species benefit from the interaction, it is a win-win (+ +) condition, neither of species is harmed by the other. Benefits may include essential resources such as food, space, defense against predators, pollination, dispersal and so on.

The number of species involved in the interaction is determined by how each species benefits from it. It can be species- specific or different species. When interaction is exclusive between the two species, it is species specific, like formation of mycorrhiza which is formed due to a close association between fungi and plant species. But, sometimes interactions may involve several species as in case of pollination, where several pollinators interact with several species of plants to derive their food. The coexisting species and their interaction become so significant in mutualism that at least one species it become completely dependent on the other. In other words, sometimes, interactions become so important for some species that they completely dependent on the interaction for their existence. Based on this dependency of one species on the other, mutualism can be classified as obligatory and facultative.

a. Obligate Mutualism

You might have studied about the classic example of lichens, formed due to a close association between photobiont algae and mycobiont fungi to form a thallus (lichen), an entirely different species from the interacting species. During the association, fungi obtains nutrients from the photosynthetic algae, and in return, fungi provides protection and stability to algae as shown in fig. 12.3.

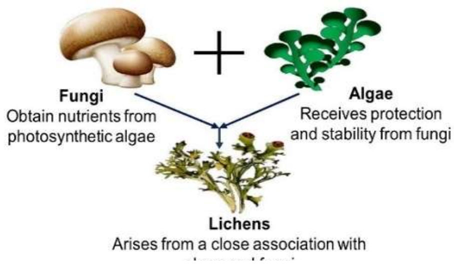


Fig. 12.3. Obligatory mutualism

Such interactions where species are forced or compelled to depend on each other for their survival are known as *obligatory mutualism.* These interactions show very high degree of interdependency as the absence of either of species can result in the death of other species or both. Hence, these interactions are exclusively species-specific in nature as well.

A similar kind of relationship can be observed between coral polyps and zooxanthellae too. As we know coral polyps are small, soft-bodied organisms. They produce carbon dioxide and water during the cellular respiration. And, zooxanthellae are algae living in the tissues of coral polyps. While interacting, zooxanthellae uses this carbon dioxide and water to carry out photosynthesis. During the process, zooxanthellae produces sugars, lipids and oxygen as its byproducts. Coral polyps, then utilize these byproducts to grow. This continuous recycling of the byproducts between the cells of coral polyp and zooxanthellae force them to remain in a close association. Since, in the absence of zooxanthellae for long period of time will result in the death of coral polyps. Other such examples may include the mutualistic relationship between fungi and roots of higher plants; between termites and protozoans and so on.

b. Facultative Mutualism

Facultative mutualism, on other hand, is a relationship between two or more species in which the species benefit from the interaction but may also survive without it, independently. Such interactions are also known as proto-cooperation. Unlike obligate mutualism, facultative mutualism can exist between multiples of species, but benefits obtained from it are less than that of obligate one.

A well-documented example of facultative mutualism is between hermit crab and sea anemone as shown in fig. 12.4. During their lifespan, a young hermit often carries a young sea anemone on its back. Even when a hermit crab outgrows its shell, it transports or takes sea anemones to fresh feeding sites with plenty of food. In exchange, hermit crabs are protected from predators by sea anemone. Since, sea anemone attached to the shell, crabs become undetectable by their predators. This is because predators avoid attacking the crab due to the presence of cnidoblasts (cells that are often toxic, tubule to capture prey) in sea anemones.

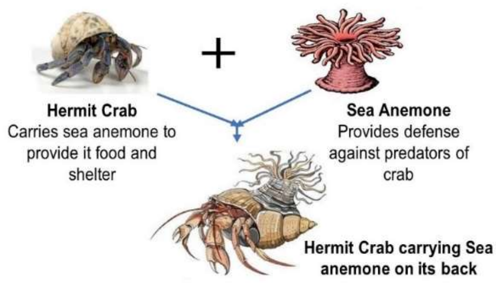


Fig. 12.4. Facultative Mutualism

Facultative mutualism can be described in three ways based on the benefits as,

- **Resource-resource mutualism:** both species provide a resource to the other species. e.g. association between coral polyps and zooxanthellae.
- **Service-resource mutualism:** one species provides service, while the other provides a resource. E.g. a relationship between honey bees and flower.
- **Service-service mutualism:** both species provide service to the other species. E.g. an interaction between an anemone and a clownfish.

Since, species growth and survival are not interdependent, facultative mutualism is non-obligatory in nature.

Applications of Mutualism

1. **Transfer of nutrients.** Mutualism plays a significant role in obtaining nutrients from plants and animals during the interaction. As can be seen in,

- **a.** Nitrogen-fixing bacteria derive its nutrients from the legumes.
- **b.** Coral polyps uses byproducts of zooxanthellae for cellular respiration
- **c.** Fungi and algae provides essential nutrients to each other.
- **d.** In mycorrhizae, fungi provide nutrients to the host plant.

2. **Defense**. Mutualistic relationships often provide protection against the parasites and predators of the interacting species.
   - **a.** A wasp-like ants provide protection too acacia trees from the herbivores.
   - **b.** Cleaner fishes feed on ecto-parasites of their host fish.
3. **Ecosystem services.** Mutualism also provide regulating ecosystem services to the interacting species.
   - **a.** Honey bees and flowers during pollination
   - **b.** Dispersal of seed by animals
4. **Impacts population dynamics.** Some symbiotic mutualistic relationships, especially where obligatory mutualism came to its role, it can influence the population density of interacting species, since they are interdependent for their existence. And, as removing one species may change the dynamics of the other species or both.

i. Commensalism

Commensalism term was coined by Pierre-Joseph van Beneden in 1876, which means "sharing a table". Commensalism is a positive interaction, but it is not the same as mutualism. It can be defined as *an ecological interaction between two or more species in which one of the species benefits while the other remains unaffected*. i.e. neither suffers nor benefits. It often exists between a larger host (an organism that provide the benefit but are unaffected) and a smaller commensal (an organism which is benefited from the interaction). Such interactions may exist between the individuals of the same species or

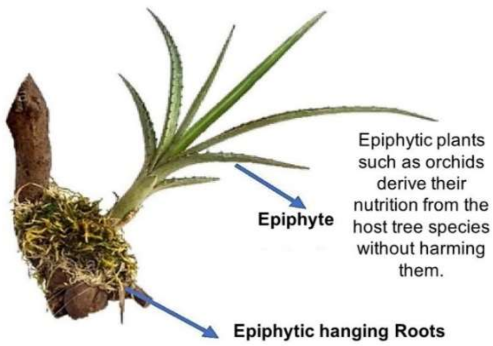


Fig. 12.5. Commensalism in Epiphytes

different species.

For instance, you might have seen epiphyte plants that grow upon another plant or object for physical support. Since, they do not possess any attachment to the ground, they obtain their food from the host plants. It is often that small epiphytes grow on the surfaces of large trees and attach themselves on the branches of trees. From there, they derive nutrition that flow down the branches without harming the host tree. A similar kind of association is common in cattle egret and cattle.Commensalism is a long-term interaction where some species remain in the relationship for their entire life. And, depending on the relationship, the commensal may exhibit various morphological and functional adaptations. Since these adaptions accumulate over time, commensalism also plays a crucial role in the evolution, like other ecological interactions.

12.3.2 Negative Interactions

Symbiotic associations are not always beneficial to the interacting species; in certain circumstances they can be harmful or detrimental too. Negative interactions are the ones that have a direct or indirect negative impact on the interacting species. Amensalism, parasitism, predation and competition are examples of antagonistic interactions. Let us learn about the various kinds of such antagonistic ecological interactions that exist in ecosystems.

i. Amensalism

Amensalism is a symbiotic relationship between individuals of different species in which one species gets harmed or destroyed while the other either benefits or remains unaffected. Generally, it is considered to be exist between the individuals of two different species, however it can be seen within the same species as well. Amensalism is often confused with the term antagonism and used as its synonym which is ecologically incorrect. This is due to the fact that in antagonistic interaction, one species actually benefits at the expense of the other. While, during amensalism one of the species either harmed, and the other species either benefits or remains unaffected. Since, sometimes, neither of the species profits from the interaction, amensalism also referred as asymmetrical competitive interaction.

It is one of the processes of evolution, which involves defensive strategies including as chemical or physical barriers to protect themselves or to derive nutrients from the environment. One such phenomenon occurring in the ecosystem is allelopathy. It is a process of inhibiting the growth of the other interacting species by releasing toxic chemical compound into the environment.

ii. **Allelopathy.**

Allelopathy term was coined by Hans Molisch in 1937, deriving from two Greek words, “allelon” means of each other and “pathos” means to harm. It can be defined as *the biological phenomenon in which species interacts to influence the growth, survival, and reproduction of the other interacting species by secreting certain chemical compounds”.*The synthesis or the production of such chemicals do not occurs as in response to the interaction, but as part of the species usual functioning. It is a form of chemical competition in which one species inhibits the growth of another in order to take advantage of all available resources. Since, it limits the competition for resources among the species, it is considered to be most critical factor in determining abundance and distribution in the plant communities. For instance, as shown in the fig. 12.6.a black walnut produces a non-toxic, colorless chemical substance known as hydro-juglone. It is secreted by leaves, stems, fruit-hulls, inner barks and roosts of black walnut tree. The chemical hydro-juglone on exposing to the environment gets oxidized into a highly toxic allelochemicals, called juglone. Juglone inhibits the growth of nearby vegetation including grasses, shrubs and trees.

Applications of Amensalism

1. **Sustainable weed management**. Extracts of allelopathy often utilize in organic weed management.
2. **Straw mulching**. Agrochemicals from decomposed straws are used to suppress the growth of unwanted plants including weeds and invasive species. It also helps in reducing pest and diseases.

Fig.12.6. Black walnut (*Juglone nigra*)

3. **Crop allelopathy**. Intercropping of field crops to control weeds in the fields.
4. **In medicine**. Penicillium spp. secretion, penicillin is extensively used as antibacterial drugs to kill wide range of bacteria.

Contramensalism

One of the approach to classify interaction is, on the basis of the net effect of one species on the other interacting species. With the combinations of positive (+), negative (-), and neutral (0) effects, this classification provides six hypothetical outcomes as illustrated in the table 12.2.

However, there is issue with this classification, (+, -), because predators and herbivores do not have a significant negative effect on the dynamics of prey population. Furthermore, the trophic mechanisms do not describe accurately all possible ways in which their results can be achieved. Therefore, in 1986, Arthur on the basis of their non-trophic mechanism to represent predation, parasitism and herbivory under contramensalism.

Table 12.2. Interactions on the basis of interspecific effects between two species

	Positive (+)	Negative (-)	Neutral (0)
Positive (+)	Mutualism(+ +)	Contramensalism (+ -)	Commensalism (+ 0)
Negative (-)	Contramensalism (- +)	Competition (- -)	Amensalism(- 0)
Neutral (0)	Commensalism (0 +)	Amensalism (0 -)	Neutralism(0 0)

Continue reading to learn more about contramensalism through various examples from existing ecosystems.

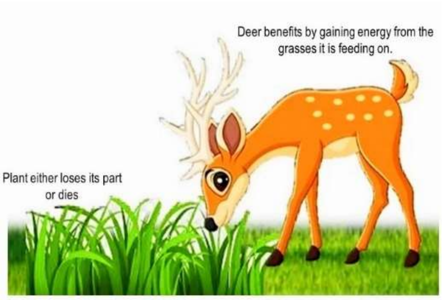


Fig. 12.7. an antagonistic relationship: herbivory

a. **Herbivory.** In nature, plants and animals have evolved together. During the process of co-evolution, they had built a close relationship between them. Plant-pollinator interactions have been beneficial to both plants and dispersers. However, this is not the case in plant-herbivore relationships, as it is antagonistic in nature. That means herbivores benefits at the expense of plant species.

As you know, herbivore are the animals which feed on plant species. Hence, it can be defined as an interaction between plants and herbivores species in which herbivorous animals consume plants to derive nutrition and energy. Since, plant species either loses part of itself or dies during the interaction, it is considered to be an antagonistic type of relationship.

Previously, the herbivory was thought to be unequal, favoring herbivores and against the plants. However, in recent studies reveals that herbivory is beneficial to plants as well. For instance, a gypsy moths grazing on the canopy of trees. This allows penetration of more sunlight to reach ground, which benefit plants with more diversified and productive ground layer.

Besides developing a strong relationship with herbivore, plants as well as herbivores have also adapted defense to balance their relationship. In plants, development of thorns, production of allelochemicals, etc. While in herbivores, they have evolved to recognize plants with high nutritional values and fewer defensive chemical compounds.

Parasitism. The term parasite is a Greek word "parasitos" means one that eats at the table of another. It can be defined as the relationship between species in which one species benefits from the interaction at the expense of the other, often without killing the host species. An individual that derives the benefit from the interaction is termed as a parasite, while an individual that is harmed during the interactions is termed as the host. Generally, parasites are smaller in size than their host with high fecundity to ensure their survival. But, unlike predators, parasites do not kill their host and usually live in (tapeworm and hookworm) or on (ticks and mites) them for a period of time. Parasite live in association with the host to use it as habitat and a source of nourishment. Since, some of these interactions are highly specialized, a parasite of one species may not be parasitic on another. E.g. humans are primary host for trypanosomes.

Despite the fact that most parasites feed on their host for nutrition, some parasites may use some species as their secondary hosts for the transmission of one primary host to another. Parasites, often do not impact their primary host as much as they do in secondary hosts. E.g. Humans are secondary host of tsetse-flies.

Brood Parasitism. Brood parasitism is a kind of social parasitism in which, parasites rely on hosts to raise their offspring and conserve their energy for locating food and producing more offspring. It can often be seen in certain species of birds, insects and fishes where parasitic species manipulate the host to provide parental care to their young ones on their own. The true parents place their young ones under the foster care of host species. They do so by replacing host eggs and killing them. In order to reduce the chances of rejections, females of parasitic species usually select a species as the potential host whose eggs resembles their eggs. For instance, brood parasitism existing in cuckoo and a great reed warbler.

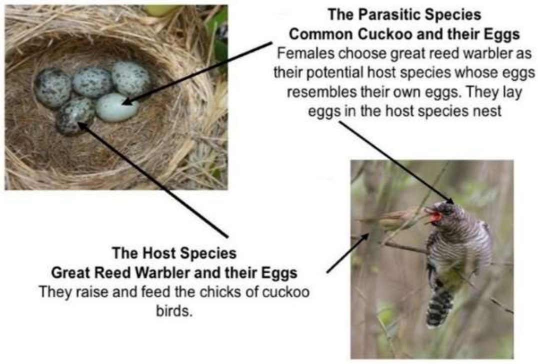


Fig. 12.8. Brood-parasitism in common cuckoo

Predation. Predation is an antagonistic relationship as predators gain energy, while the prey suffers. It can be defined as an act of capturing, killing and eating of one organism by another for obtaining nourishment. Predators are the organism that kill and feed on the other organism, while the organism that gets killed is called the prey. Predators are highly specialized organisms with keen senses that allow them to capture their prey. As, these animals actively search for their prey, once identified, they attack it. The most common type of predation can be seen between two species from different trophic levels in the food chain. A competition between predators may develop in a complex ecosystem where multiple predators feed on the same prey. However, there are some exceptions. Predation is not as same as scavenging for dead organisms. Predators do often scavenge, but as a part of their feeding strategies. Similarly, it cannot be categorized under symbiosis as it results from the short-term interaction.

Being at the top of a food chains, they play a vital role in ecosystems. It helps in maintaining ecosystem at equilibrium by regulating the prey population, while promoting biodiversity. Since, the population of prey-predator are not constant over time. It changes with time in a cyclic manner, and thus influences the dynamics of population of each other. Prey population is directly proportional to the predator population. That means as the population density of prey increases, food availability for the predators also increases. In such environment, the population of predators expands in an exponential manner. With the decrease in prey population, predators' numbers also start reducing due to shortage of the food. Again, with the increase in the availability of food, prey population flourishes in the absence of predators. Hence, a new prey-predator cycle starts like in case of lynx-snowshoe interaction.

In order to provide defense against the predators, the prey unlike predators has develop various anti-predatory adaptations such as, mechanical and chemical defense, camouflage, and mimicry. Let us examine the various types of defense mechanisms evolved by prey and predators in detail.

Mechanical Defense. It is a physical defense against predators to avoid being attacked/eaten. It includes development of the thorns on plant species like Acacia spp. trees; the hard shell on turtles

Chemical Defense. It is the process of releasing or injecting toxic chemical compounds to protect themselves from predation. E.g. allelochemicals juglone secreted by black walnut to reduce competition by inhibiting the growth of nearby plant species.

Camouflage. It is the phenomenon in which individuals of prey change their color or pattern of the body to their surrounding environment to avoid being detected by their predators. For instance, chameleon. There are five various kinds of camouflage exist in nature. These are:

Cryptic Coloration. This is the most basic way of animal camouflage. In cryptic coloration, animals change their body shape, color, and patterns according to their surroundings to avoid being detected by their predators. E.g. a flat fish living in the ocean blend so well into a variety of surroundings (imitates the colors and textures of the seafloor), that makes difficult to spot prey and thus, allows it to flee or hide from their predators.

Descriptive Coloration. In this, animals disguise themselves by using more than one color or patterns. They often conceal themselves with the spots, stripes and shapes on their bodies in order to keep the outline of their body shape consistent. Leopards, as predators use this type camouflage technique. They hunt using their coloration and marks as a hunting tool.

Self- Coloration. Sometimes, animals make use of the opportunities available in their environment. For instance, some turtle species that live in shallow water hide by growing algae on their hard shells to protect themselves from being attacked by their enemies.

Aposematic Coloration This is often known as warning coloration. Aside from disguising, some animals usually do the exact opposite. They change their skin color tone to a brought and vibrant that is easily visible, along with a foul odor or taste, a toxic chemical, and the ability to sting or bite, and so on. Such coloration allows animals to warn predators and reduce the chance of being eaten. If predators eat them despite the coloration, they will have a terrible taste or be exposed to a toxic chemicals and will learn to avoid such organisms in future. E.g. insectivorous birds can remember the unpleasant experience and likely to avoid eating them in future.

Mimicry. Not all organism in nature do have the defense mechanisms. Some species confuse their predators by imitating its surroundings or something else. Such animals may imitate leaves, twigs, and other objects that predators would avoid. There are two types of organisms that mimic others. These are:

Batesian mimicry. A harmless species imitates the warning coloration of a poisonous one in this type of mimicry. E.g. Monarch butterflies consume toxic chemicals from milkweed plants and store them in their bodies. When an insectivores bird tries to eat them, it gets sick. Thereafter, the bird not only avoid eating monarchs, but also similar-looking butterflies.

Mullerian mimicry. In such mimicry, two or more harmful or unpalatable aposematically colored organism that resembles each other. It often found in mimetic species that are unpleasant or obnoxious. It is important that all of the species be identical in appearance and color. E.g. wasps and bees.

III. Competition

Competition is an ecological relationship between two or more organisms of same or different species, where one species competes with each other for different resources. Majority of competition arises due to increased demand of food supply among the individuals. However, individual may nevertheless, be in competition for other resources such as space, light, mates and so on.

In nature, when two individuals of the same or different species compete for the same resources, there is often a winner (+) and a loser (-). The weaker of the two competing species must either adapt or die out, whereas the stronger species acquires the resources. However, if the competitors struggle to the death and kill each other, the interaction becomes antagonistic in nature and affects both individuals adversely (-, -). Even though it is commonly believed that competition favors the stronger species, since weaker species tend to become extinct due to unavailability of resources. However, there are instances, when even the number of the stronger species has declined. There are several factors influencing the intensity of competition between the individuals. Some of these are:

Population density. When population expands rapidly, it increases the demand of natural resources which are limited in the environment. As the available resources decline or deplete, competition among the individuals will occur.

Resource sharing or partitioning. the degree of competition can also be determined by how individuals share resources. When two different species compete for the same resources, the competition becomes more intense.

Classification of Competition

Based on the different classifications, competition can be grouped into three major categories. These are:

On the basis of taxonomical relationship

Intraspecific. This competition involves individuals of similar size competing for the same resources. It can be defined as, the form of competition in which individuals of the same species competes for the same limited resources, known as intraspecific competition. It becomes intense in rapidly growing population, where resources availability decline as the number of individuals increases due to increase in the demand of resources. Intraspecific competition regulates the growth of population and also act as selective force during the evolution, and often, results in both individuals reducing fitness. For instance, some plant species produces various kinds of chemical compounds that inhibits other plants of the same species from growing around them.

Interspecific. It involves individuals of different sizes with significant differences in their abilities. That means that the competition occurs between the individuals of two different species for the same resources. Thus, can be defined as the form of competition in which two individuals of two or more different species competes for same limited resources, called as interspecific competition. It can also be intense with the increase in the size of population, like intraspecific competition. Since, two different species usually differ in fitness which influences the intensity of completion, interspecific competitions are more intense than intraspecific ones. It plays a vital role in regulating ecological communities and also serves as an agent of natural selection during evolution. For example, coral covers large surfaces of the oceans to obtain enough sunlight for autotrophic bacteria, along with other aquatic organism for the availability of nutrients and sunlight.

On the basis of mechanism.

Interference A form of competition in which competing individuals have a direct control over the process of hunting, growth, or reproduction of a species in a particular environment. It may include attacking, grabbing and killing while competing for resources. It often occurs when two species existing in the same habitat come in contact with others to defend their territory, or utilize the available resources.

For example, in case of allelopathy, one plant releases a toxic allelochemicals to poison the soil for others, so that it would prevent others plants from deriving nutrients from that soil.

Exploitative Sometimes, one species exploits resources such as food, space, etc., in common with another species without coming in its direct contact. Exploitative competition is a kind of indirect competition in which two or more species are interacted through a limiting resources such as space, water, sunlight, nutrients or other similar resources that acts as a mediator. As, the individual's consumption and use of limited resources makes it challenging for others to access them.

Apparent Like exploitative competition, apparent competition is one of the form of indirect competition, in which both the individuals of competing species are preyed upon by the same predator. For instance, imagine Species A and B are preyed upon by Species C, the predator, any change in the population of species A may affect the population of species B. Thus, suggesting that as predator feeds on species A and become more viable and fit at the expense of the population of species B.

On the basis of influence

Direct It occurs in the ecosystem directly influence each other by affecting the availability of resources in the ecosystem. Generally, it can be seen where the two species share the same niche or community. E.g. deer inhabiting and competing for same limited resources, i.e. grasses and leaves in the same ecological niche.

Indirect It influences the resource availability indirectly. It often occurs where the two species occupy different niche or communities. E.g. presence of deer near to the pond may affect other deer nearby, by decreasing the amount of water in the pond.

Direct and indirect competition can be observed in both interspecific and intraspecific competitions. Such forms of interactions enable us to study the behavior of the species along with their life styles.

Like other ecological interactions, competition is conserved to be one of the driving forces in evolution. It often results in change in the fitness of interacting species. Along with the change in the community structure, it also exerts evolutionary pressures on the development of adaptations at a community level.

12.3.3. Neutral Interactions

In ecology, an ecosystem, *a relationship exists between two species that interact but do not affect one another,* called as Neutralism. It is a form of an interaction in which one species' fitness does not impacts/ influence the fitness of the other. That means having no or very insignificant effect on both populations. It differs from predation and mutualism, since one or more species gain from their interactions. Similarly, neutralism is not same as commensalism, in which one of the species gains profit without affecting the other interacting species. For instance, cacti, a plant species and tarantulas, species of spider live together in the desert. Another such example can be some species of bacteria, lactobacillus and streptococcus can coexist without affecting each other.

As we know, all life is interconnected to some extent, i.e. a complex networks of interactions exist in an ecosystem, it is impossible to affirm that there is no competition or benefit to either species. Since, true neutralism is uncommon or non-existent, it often used to circumstances where interactions are either insignificant of negligible. Hence, it is almost impossible to demonstrate true neutralism.

12.4. Ecological Niche

The term habitat is derived from a Latin word "habitare", meaning to inhabit. We can define a habitat as *a natural environment where a particular organisms live and utilize the resources of that place for its survival, such as food, shelter, defense and mates.* It is determined by its physical (soil, sunlight, temperature and climatic conditions) and biological (food and predators) characteristics, and comprises of four components including space, food, water and shelter. It may change over a period of time due to environmental changes (like volcano, climate change and so on) and anthropogenic activities (like deforestation, urbanization, etc.).

Since,every individual on the planet has a position and role to play in its environment, such as how it obtains food, survives, and reproduces, to name a few, there are certain essential sets of environmental conditions required for its existence. It includes the sum total of all resources and physical environmental conditions required by an individual to survive, function and reproduce indefinitely in an ecosystem.This is the area within a habitat occupied by an organism, and known as the ecological niche.

12.4.1 Niche Concept

In 1957, a zoologist introduced the term, "niche". According to him, *a niche is a model with a multidimensional hypothetical space with several components in it.* Each component exhibits

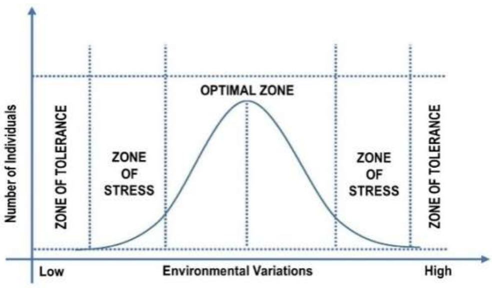


Fig. 12.10. Hutchinson's niche

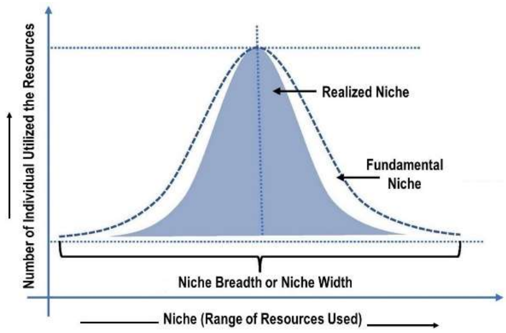
the tolerance ranges of certain essential environmental conditions that are critical for the survival of the species. These components include:

i. **a habitat.** a physical space that a species occupies within its habitat, where all essential conditions are present for an organism to grow, survive and reproduce infinitely.
ii. **a trophic position**. a fundamental position of an organism in its community or the food chain.
iii. **a multidimensional hypervolume**. It comprises of the basic concepts of niche along with the limiting factors. That means that all sets of environmental conditions (physical, chemical, biogeographical) required by an organism for its existence.
iv. **an interaction**. a relationship of an organism with other organisms and with its environment.

So, fundamentally, an ecological niche is a multidimensional representation of available resources, habitat requirements and environmental limitations of a species.

Sometimes, a niche remains unoccupied for a long period of time that can be filled by another species. Some species, on other hand, create a special niche for themselves. Having a specialized unique niche is always advantageous for the species. It always minimizes the chances of two more species competing for the same limiting resources.

The number and types of factors that affects an ecological niche varies with species. And, the relative significance of these factors may also vary depending upon the geographical and biotic conditions. Since it is important for a species to be able to adapt to the changing ecosystem to avoid extinction, they evolve to expand in a wide range of environmental conditions.



12.4.2 Classification of Niche

On the basis of occupancy of habitat, niches can be classified as:

12.4.2.1 Fundamental and Realized Niche

Fundamental niche can be defined as *a hypothetical set of physical (abiotic) and biological (biotic) conditions which is occupied by* *a species or an organism*as shown in the fig. 12.11. It is actual entire space that is occupied by an organism when they are not in competition for the same resources. In other words, fundamental niche is the total range of the environmental variations that are suitable for the survival of an organism, without being influenced by antagonistic interactions such as competition, predation, and parasitism. This allows an organism to expand, survive and reproduce more effectively.

However, in nature species do not occupy the entire niche due to uneven distribution of resources across the landscape. Resources are present in the form of patches that are occupied by species. Furthermore, species are often under biotic controls such as competition, predation, biogeography. Since, they cannot utilize their entire niche due to presence of other species, they usually remain in competition. In such circumstances, a species uses only a part of its niche and becomes relatively dominant. This small *subset of fundamental niche occupied by species is known as their realized niche*.Since the resources are unevenly distributed across the habitat, presence of competitors and predators may vary. Hence, realized niche varies with the populations of same species.

Subsequently, each species possesses both fundamental and realized niche. And since realized niche are part of a fundamental niche, they are smaller than fundamental niche.

12.4.2.2 Alpha and Beta Niche

A niche can further be divided into two categories namely, *alpha* and *beta* niches.

Alpha Niche. These are resources specialized niches occurs in the habitat, in which several species co-exist. Presence of two different alpha niches means the two species are using different resources. In other words, they are using similar resources in such a way that overlap in their used is reduced.

Beta Niche. Due to variations in the environmental tolerances, some species prefer to inhabit in separate habitats. Such species rarely get together to interact physically. This is due to the fact that these species are exposed to a different set of environmental variations-including physical, chemical and biological factors.

12.4.3 Niche Width

Niche breadth as illustrated in the fig 12.12.is also known as niche width. It is an environment that encompasses all of the appropriate sets of conditions including physical, chemical, and biological. To be more specific, *it is the habitable range between the maximum and minimum values of each parameter that constitute of tolerance limits for an individual life.* It includes suitable physical (temperature, precipitation, pressure, humidity), chemical (salinity, pH), and biological (Inter and intraspecific interactions) for the existence of an individual.

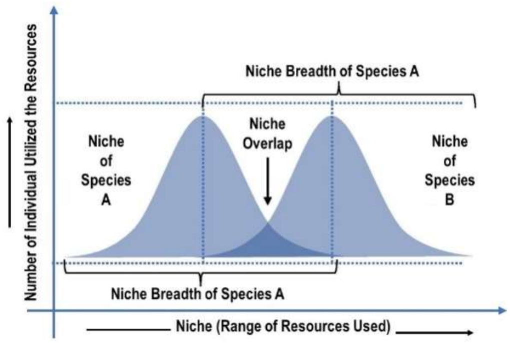


Fig. 12.12. Niche Breadth and Niche Overlap

12.4.4 Niche Overlap

When two or more species compete for the same niche space, it leads to the overlapping of niches. Generally, it occurs when the resources used by the several species are identical or similar in nature. The degree or the intensity of competition between coexisting species determines the width of the niche. It is an index of similarity between the resource utilization by several species.

Niche overlap increases when the two peaks of species distribution move closer to one another.Based on the intensity of competition occurring between or among the species, overlapping as depicted in the fig. 12.13. These are:

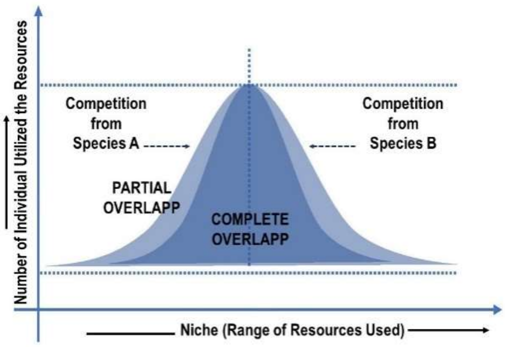


Fig. 12.13. Types of Niche Overlapping

i. Partial Overlapping. When the curves of two competing species partially cover each other. It occurs when the intensity of competition is low, the stronger or the dominant species acquires the niche from other species, thus reducing the niche width of weaker species.

ii. **Significant Overlapping**. When the curves of two species completely cover each other. It occurs when one of two competing species for the same resources eliminates other species from the niche. It often occurs in realized niche where the degree of competition is more as compared to the fundamental niche.

12.4.5 Competition and the Niche

As you have learnt, the resources are finite in the constant environment. When population expands at an exponential rate, demand for the limited resources also increases. In an unavailability or shortage of resources required by species for their survival, species competes with other species. Furthermore, situation gets worsen when the resources required by two different species are similar or identical in nature. Consequently, several impacts can be observed in an ecosystem. These impacts can broadly be categorized as,

- **Short-term Effects**. It operates on the ecological time scale. It eliminates or removes one of the competitive species from the niche through Competition Exclusion Principle. However, there are several ecological processes exiting in nature to minimize the impact of competition exclusion or to avoid it. This can be done by competitive species through Resource Partitioning, Competitive Release.
- **Long-term Effects**. It operates on the evolutionary time scale. It splits or divide closely related species into multiple by changing their characteristics through character displacement.

Gauss Competitive Exclusion Principle

Imagine populations of two species inhabiting in the same habitat with an identical niche. Initially, when the size of the populations of both species is very small, they may coexist in the same niche for some period of time. But, as soon as the population starts expanding, demand for the identical resources also increases and due to unavailability or insufficient of limited resources, competition prevails. During the competition, the weaker species will either go extinct, or shift to other resources where they adapt and evolve. Sooner or later, both species comes out of that competition.

In 1934, a Russian ecologist conducted an experiment in the laboratory on two species of paramaecium competing for the same resources. In experiment, he grew the two species of paramaecium, *Paramaecium aurelia and Paramecium caudatum* separatey (different habitats or niche) in the lab, both species thrive. But, when grown in the same test tube (same habitat or niche) with the same amount of nutrients (food resources), both species grew poorly. And eventually, *P.aurelia* outcompetes *P.caudatum* for ood resources, resulting in the elimination or extinction of *P.caudatum species,* as shown in the fig. 12.4.From this experiment, he concluded, "*closely related species cannot coexist for long one single limiting resources; the competitively superior or stronger species survives, while the weaker ones geteliminated*".

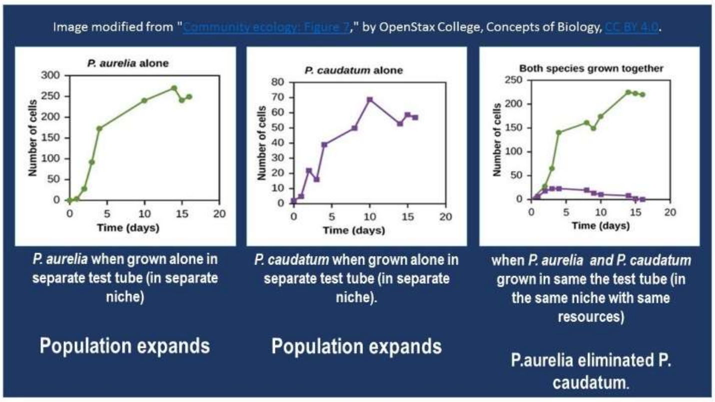
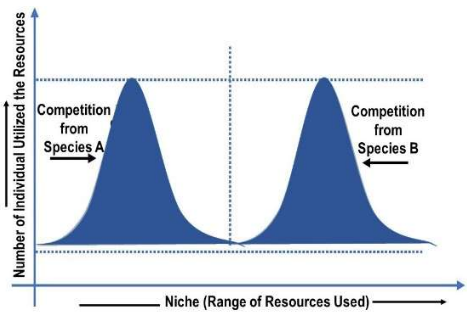


Fig. 12.14. Example of Competitive Exclusion Principle

In nature, it is difficult to observe that two species occupy exactly the same niche. However, larger the overlap between the species niche, more intense the competition between them tend to be. In order to reduce the overlapping of niche, it becomes necessary to minimize the degree of competition between the species. This can be done through resource partitioning, character displacement and competitive release. Let us discuss each of these in detail.

a. **Resource Partitioning** Although individuals compete for the limited resources, coexisting species must evolve themselves to become more specialized and narrow their focus in their use of those resources. This can be achieved by species through the



utilization of different resources, occupying separate region of niche, or feeding during different times of the day to reduce the competition for the similar resources. This is known as resource partitioning, as illustrated in fig. 12.14. In other words, competing species for the similar resources can coexist by minimizing the competition intensity through the niche separation. Thus, resulting in the large non-overlapping and separation of the niche. Hence, we can define resource partitioning as *a phenomenon of dividing or partitioning of the limited resources by coexisting species to avoid competition in an ecological niche.* It is an evolutionary change in the species occurs when two species coexist despite competing for the same resources.

For instance, an anole lizards found on the island of Puerto Rico. Natural Selection, an evolutionary force divided single species of anole lizard into 11 different species. Each species has its own preferred habitat, which is characterized by factors such as plant type and height; penetration of amount of sunlight and moisture.

b. **Character Displacement.** When two similar species with an identical niche come in contact, they are likely to compete more aggressively. Different species under the influence of competition may develop certain traits to utilizeavailable resource in their partition more efficiently. And, individual's adaptation to these traits in the species minimizes the competition in the other partition, causing the divergence of traits and thereby, resulting in the shifting of the niche. When such a shift is related to the morphological changes in the species, it is known as character displacement or niche shift.

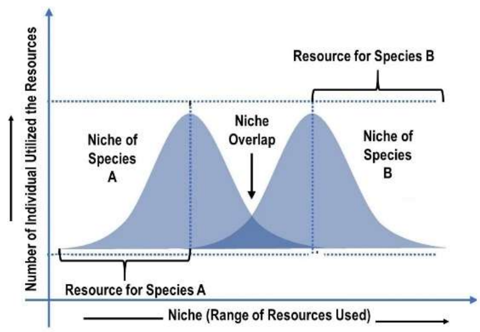


Fig. 12.14. Niche Shifting

c. **Competitive Release**. Individuals often confine themselves to a small geographic region in the presence of competitively superior species. However, when stronger competitors are experimentally removed from the ecological niche, the other species tend to expand their distributional ranges. Thus, competitive release can be defined as *a mechanism in which a species tends to expand its distributional range in the absence of competitively superior species.* In brief, an expansion of the ecological niche in the absence of a competitors. It often occurs in a habitat where one of the two species competing for the similar resources, usually the stronger one, is removed from the habitat. This allow the remaining competitor species to utilize the resources more efficiently than they did when the first one was present. In the process, there occur a significant increase in the population of a less widely distributed species.

When two closely related species coexist, they are quite different. But, when one of the two species occurs alone, it converges towards the other species, appearing virtually similar in some characteristics. Thus, acts as a mirror of character displacement.

For example, Balanus and Chthamalus. According to Connell, Balanus spp. often prefers the intertidal zone, whereas Chthamalus spp. lies in the shoreline above the high tide. When the balanus spp. was experimentally removed, Chthamalus colonized the intertidal zone and outgrew balanus, thus effectively preventing balanus from establishing itself again in intertidal zone. The removal of balanus species allowed Chthamalus to undergo competitive release. In the presence of balanus spp. Chthamalus could occupy only its realized niche, while in its absence Chthamalus can occupy its fundamental niche.

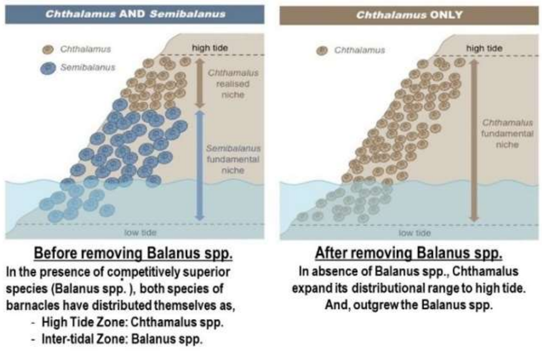


Fig. 12.16. Competitive Release in Barnacles

12.5. Summary

In this unit you have studied various aspects of ecological interactions. So far you have learnt that:

- ***In ecology, symbiosis is a close ecological association occurring between the individuals of two or more different species for a long period of time.***
- ***A mutualism is a win-win situation in which both the individuals of two different species benefit from each other. Obligate mutualism shows very high degree of***

interdependency as neither of two populations, can survive or grow in the absence of the other organism.

- ***Allelopathy is a form of chemical competition to inhibit the growth of other species in order to utilize all available resources by itself.***
- ***Brood parasitism is a strategy developed by one species to trick another species into raising their offspring.***
- ***Predator-predator populations are intrinsically linked and undergo cyclic changes throughout time.All organisms have their own defense mechanism against their enemies or predators to survive themselves***
- ***Competition is a relationship between organisms in which one species inhibits another from gaining access to resources, affecting fitness beyond the cost of resources.***
- ***Total range of environmental conditions, suitable for the existence of a species without being influenced by competition, predation and parasitism,called as fundamental niche.***
- ***Niche overlapping is an index of similarity between or among the resources utilization of different species. The intensity of competition between co-existing species is proportional to the degree of overlapping.***
- ***Two species with distinct ecologies cannot coexist in the same environment.***
- ***Competitive exclusion may be avoided if one or both species evolves to use a different resource, called as resource partitioning, it helps the species coexist more effectively.***

Terminal questions

True /false

Indicate whether the statement is true or false

1. Symbiosis is when neither population affects each other.
2. A prey-predator relationship tends to keep the population of both species at equilibrium
3. Interspecific competition sometimes leads to greater specialization in both interacting species.
4. The relationship between the protests that cause malaria in humans is an example of amensalism.
5. In symbiotic relationship, two species are in obligatory relationship.

Multiple Choice Questions

Identify the choice that best completes the statement or answers the questions.

1. Which of the following interactions will not promote co-evolution?
   a) Competition
   b) Commensalism
   c) Parasitism
   d) Interspecific competition
2. A relationship between two organisms in which one organism benefit on the expense of other organism.
   a) Mutualism
   b) Competition
   c) Predation
   d) Commensalism
3. Barnacles provide habitat to whales by attaching themselves. This neither harm nor benefits the whales. What type of relationship is this?
   a) mutualism
   b) Parasitism
   c) Allelopathy
   d) Commensalism
4. Collectively, physical factors such as light, temperature and moisture that affect an organism life and survival are called as,
   a. Biotic environment
   b. Ecosystem
   c. Abiotic environment
   d. Niche
5. Which of the following would not be included in a description of an organism's niche?
   a. Its color
   b. Its trophic level
   c. Humidity it prefers
   d. When it reproduces

Short Notes

- *Briefly answer the following questions*
- How ecological interactions are classified? Write short note on any two major types of interaction.
- Write short notes on intraspecific and interspecific ecological interactions.
- Describe different mechanism of defense in predator populations.
- What is difference between brood parasitism and allelopathy

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UNIT 13: Populations

Unit Structure

13.0 Learning Objectives

After the completion of the unit, you will be able to:

- Describe the various characteristics of the population.
- Determine the importance of population dynamics and explain how the changes occur over time.
- Explain, individuals belonging to same species have different dispersal pattern.
- Discuss different types of population growth curves and factors that influence population growth.
- Determine the relationship between population growth and available resources.

13.1 Introduction

In unit 13, you will focus on the properties characterizing the population, growth curves and population structure. Ecological interactions occurring between organisms and their surrounding environment helps in adapting traits or characteristics at community level.Therefore, individuals of the same species living in a particular area share many traits. Each and every population has its own demographic characteristics, such as birth rates, death rates, sex ratios, and age structures, and many more. A population can be described using population size, density and distribution. All populations are regulated by number of factors influencing their survival and reproductive success.

Our journey the chapter will begin from the basic understanding of population characteristics and its dynamics.

13.2 Population

Population is a Latin word which literally means “people”. In ecology, a population is defined as *a collection of individuals of the same species that occupy a specific area.*In definition, there are two important components. *First*, individuals of the same species. That means a group of individuals capable of interbreeding among the members of the same population. *Second*, a well-defined boundary, i.e. population must inhabit in a definable space. For example, a herd of deer in Pench Tiger Reserve, Madhya Pradesh.

13.3 Properties

Every population has its own set of characteristics. These includes size, density, dispersion and, demography like birth rates, death rates, age structures, sex-ratios, growth rates, life tables and so on. The characteristics of a population are not the same as those of an individual. As, an individual deer can only have birth or death, it cannot have density. It is important to determine baseline demographic statistics to assess the present and future state of any population.

13.3.1 Population Size

The total number of individuals of the same species inhabiting a particular area is termed as *population size.* It is the product of population density and the geographical area that is occupied, and expressed as,

Population Size = Density X Area.

The size of the population may vary from few cubic centimeters (like micro-organisms) to the millions of kilometers, depending on how the population has arranged itself within a particular geographical range. Since, it is a fundamental parameter of demography, it influences species' chances of survival or being extinct. The larger populations are less likely to get extinct due to any changes in the environment. Whereas, individuals in a small population are more vulnerable to random mortality due to catastrophic events like flood, disease, cloud burst, and so on.

Ecologists use several methods to determine size of population,one such method is

Capture-mark- Recapture Methodto determine population size of mobile animals such as birds, lions, etc. It is based on trapping, marking, releasing and recapturing technique. Individuals are captured, marked (M) within tags and released into the population (N). After the mixing of marked individuals with rest of the population, some randomly selected individuals are again captured from the population (n), including the marked ones i.e. recaptured one (R). By this using the given formula, population size can be estimated.

$$\mathbf{N} = \frac{\mathbf{nM}}{\mathbf{R}}$$

13.3.2 Population Density

You might have observed in nature a great variation in the densities of same species at different places. For instance, the number of tigers per unit are in Ranthambore National Tiger, Rajasthan is different from the number of tigers per unit area in Sariska Tiger Reserve, Rajasthan. From this, several questions may arise like, why does it happens? What factors are responsible for such variations in populations in two different areas? What is an exact meaning of population density? And, how it is significant to any environment? Let us continue reading and get answers to all of these questions.

Suppose, 300 trees of same species cover an area of ten hectares. The population density of that tree species would be the total number of trees (300) per unit area (10 hectares). Thus, we can define population density as *the number of individuals per unit area or per unit volume of any environment.* It is measured as,

$$\mathbf{D} = \frac{\mathbf{N/A}}{\mathbf{T}},$$

Where, N is the total number of individuals, A is area, and T is time.

The body size and population density are usually negatively correlated. That means as the size of the body increases, the density of population decreases. Small plants and animals have higher densities than the larger ones, as can be observed in nature too. For example, the number of insects in one kilometer area and the number of elephants inhabiting in the same area is not similar.

Similarly, population density also depends on the habitat occupancy by individuals. Since, all landscapes are not uniform, not all of the area is suitable for individuals to live. Population density can be categorized as crude density and ecological density.

Crude Density and Ecological Density

Individuals are rarely uniformly distributedover the geographic range. They do not occupy or utilize all of the available area/resources. This could be due to the fact that not all areas have the same environmental and resource conditions. Consequently, population densities of even same species vary at different geographical area, with the availability of resources such as food, shelter, mates, or the climatic conditions.

The total number of individuals present in a unit area or volume of total space is termed as the *crude density*. It occupies or utilizes all the total available area/resources of that geographic area.

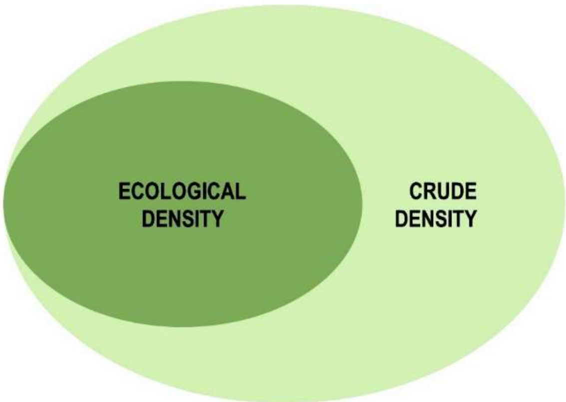

Fig. 13.1 Types of population density

While, *ecological density* is the number of individuals per unit area/ volume of space occupied by the population. Ecological density considers only the ecological niche occupied by individuals, unlike crude density taking the entire ecosystem into its account as shown in fig 13.1.

Since, ecological density can be used to determine the average growth rate, immigration and emigration of individuals in and out of the geographic area, it is considered to be more accurate. It can also be used to study the impacts of change in environmental conditions on organisms. Despite this, it is rarely used in ecological studies, due to the difficulties in determining what is livable during different seasons of the year.

13.3.3 Dispersion

Imagine a population of plant species let say *Prosopis juliflora*, an invasive species distributed across a habitat. Being an observer some of the basic questions that you could ask can be, how individuals in a population have distributed themselves across the area? Why the distribution structured in the way it is? What factors could be behind such patterns of distribution? And so on. Continue reading to learn more about these concepts.

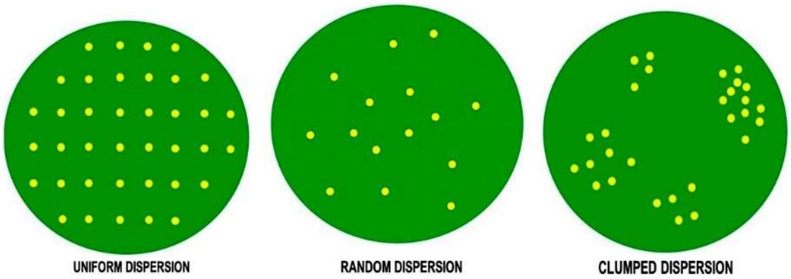

Figure 13.2. types of dispersions- uniform, random, and clumped

As you all know individuals are not evenly distributed across an area. It can be less or more equally spaced in a random manner or can be in the groups. Since, individuals respond to variety of environmental factors such as climatic conditions, resources, interactions, and so on, they can inhabit an area only when those factors are within their tolerance range that can meet their needs. The availability of resources and favorable environmental conditions influence population distribution favoring reproduction and survival in both time and space. Hence, we can define dispersion as *the arrangement of individuals within a habitat at a particular point of time, and space.* Individual movements also can have impact on the spatial pattern of their dispersion. On scales, where environmental change is less significant, populations distribute themselves in three different patterns- uniform, random, and clumped as illustrate in fig. 13.2. a, b, and c.

a. **Uniform or Regular Dispersion.** Regular type of distribution pattern occurs in an environment where all the resources are evenly distributed. They are the consequences of a regular and random pattern of environmental changes caused by the negative interactions such as competition and resource depletion. Individuals have a tendency to avoid or ignore other individuals during such interactions. They keep some minimum distance between themselves and the rest of the population. Subsequently, it results in more or less evenly spaced pattern of distribution. For example, bird nesting on small island such as penguins often spaced uniformly defending their territories.

b. **Random Dispersion.** Random dispersion is a spontaneous distribution occurring in the environment, where factors such as climatic conditions and resources are evenly distributed with frequent and random pattern of disturbances. In such environment, all the individuals in a population have an equal chance of inhabiting at any point in the space. Subsequently, individuals distribute themselves randomly, irrespective of the positions of other individuals. Resulting in the uneven distribution pattern to chance event can be seen. For instances, dandelions grow from wind-blowing seeds that fall into ground randomly and later germinate.

c. **Clumped Dispersion.** The most common type of distribution occurring in environment is clumped dispersion. This pattern of dispersion arises when individuals are drawn to specific areas of the environment. Since, resources are not homogenously distributed across the landscapes and available only in patches, individuals occur in groups. This size and location of these groups or aggregations vary depending on the availability of the resources. As a result, some places have a higher chance of have individuals than others. Such individuals living in groups have better opportunity of encountering patches of resources, enhancing their survival chances. For example, herd of cattle.

On larger scales where changes in environmental conditions are more significant, individuals often distribute themselves in a clumped manner only. For example, flock of migratory birds.

13.3.4. Demography

The interactions of population with their environment and other individuals change over time as the size and composition of population changes due to several factors influencing the present and future dynamics of populations. Consequently, a need has arisen to study changes in population and its causes. Demography, it a term use for the *statistical study of populations and their changes over time.* It is a tool to determine the size, structure and movement of populations over time and space. It helps in analyzing and forecasting social, cultural, and economic trends related to the population. It mainly focuses on three aspects- population size, population structure and distribution of population.

Generally, the size of population is influenced by the changes occurring in environmental conditions. It may increase, decrease or remain constant in response to the changing environmental variations. As a result, the relative number of individuals added or removed is taken into consideration while determine the size of any population. As you already known by now that population size increases by number of births and immigration whereas, it decreases by number of deaths and emigration. Mathematically, it can be expressed as,

Population Growth = (Birth –Deaths) + (Immigration - Emigration)

Let us get into details of each aspects of demography to predict the changes in the population due to environmental variations.

a. **Birth Rate or Natality** It is the total number of individuals added to the population through reproduction. Technically, *it is the number of individuals born per year.* There are two major factors influencing the birth rate. These are:

   i. **Fertility:** It is the capability of an individual to produce its offspring.

   ii. **Fecundity:** It is the total number of offspring produce during a period of time.

b. **Generation time** It is *the average time between two successive generations in a population's lineages.* It often ranges between 22 to 33 years in humans. Generation time can be determined as,

$$\mathbf{g = \frac{N}{t}}$$

where, g is generation time, N is total number of individuals, and t is time.

Figure **13.3. Immigration and emigration**

c. **Death Rate or Mortality** It is the total number of individuals removed from the population due to death. It is defined as *the total number* *of individuals died per year.*

d. Dispersal. As we know, when unfavorable conditions such as, unavailability of resources, change in environmental conditions, inbreeding, and so on prevail, a population confined to a small area is more likely to become extinct. To avoid such adverse conditions, individuals spread themselves across the geographic regions to minimize inbreeding, competition and loss of evolutionary adaptability. Such *movement of an individual or a group of individuals away from their main population* is defined as Dispersal. Dispersal is an important ecological element in population dynamics. Because it can result in changing patterns of distribution and densities over time and space. It can influence population dynamics either by increasing or decreasing the densities of local population. Since, dispersal involves both the local movements of individuals and long-distance migrations, it often results in the expansion of population across a geographic area. Majorly, there are two forms of dispersal events exist in any population as shown in fig 13.3. They are:

i. Immigration is the movement of individuals from different area into a sub-population. In other words, the inward movement of individuals which increases the population density of the sub-population.

ii. Emigration is the movement of individuals out of sub-population to another sub-population. It is the outward movement of the sub-population which decreases the population density of sub-population.

Overall, it can be concluded that population size and density increases by immigration, while decreases by emigrations as shown in the fig 13.3. given below.

e. Age Structure is also known as age structure is the number of individuals of different age groups in a population. It is defined as, *the proportion of the total population in each age group.* Basically, it is the product of natality and mortality of the individuals. It determines how rapidly or slowly a population expands. Also, it represents the history of survival, reproduction and future growth potential of a population. An ecologist, Bodenhelmer in 1938 described three ecological ages as:

i. Pre-reproductive It ranges from 0 to 14 years in humans, when individuals are not mature enough to reproduce.

ii. **Reproductive** Individuals belonging to the age 15 to 44 years are capable of reproducing offspring. The population will likely grow, if it is primarily composed of individuals who are in or about to enter their reproductive age.

iii. **Post reproductive** It varies from 45 to 85+ years, individuals of this age group are too old reproduce. Population dominated by this age group tends to decline over the period of time.

Age structure varies with different species. For instance, in human, all three age groups are of more or less similar, while in some plants and animals' pre-reproductive period is relatively longer than reproductive and post reproductive period, such as in insects. This could be due to the fact that the reproduction is limited to certain age groups, while mortality is prevalent in others. Population size tends to remain stable with uniformly dispersed age groups, except in dispersal events like immigration and emigration. This is because the deaths of older individuals are balanced by the reproduction of younger individuals.

Life expectancy, *is the average number of years an individual is expected to live from the time of its birth.* It is used to calculate age-specific life expectancies of populations.

f. **Age Pyramids**are the representation of population's age structure. *It is a geometrical form of vertical bar graphs that represents the number and proportion of individuals in various age groups at any given time*. The youngest individuals are at the bottom of the graph, while the oldest ones are at the top. Based on the above mention ecological ages, the age pyramids can be of following types as shown in the

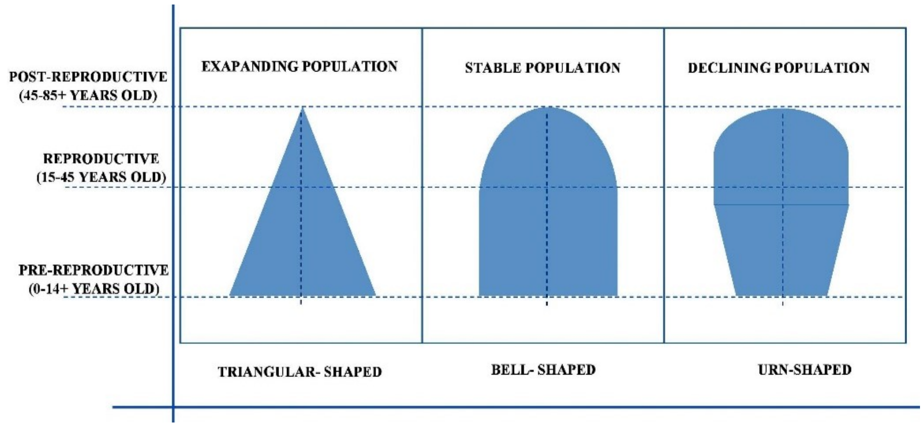

fig. 13.4.

Fig.13.4. Different types of age pyramids given by Bodenhelmer in 1938

i. **Triangular-shaped** When the population expands rapidly with high proportion of young individuals and few old individuals, the age pyramid looks like triangle in shape. It occurs where the pre-reproductive period is longer than the reproductive and post-reproductive period. The birth rate is quite high and population expands in exponential manner. Such populations structures can be seen in countries like Nigeria, Saudi Arabia and so on.

ii. **Bell-shaped** This type of pyramid form when an equal number of young and middle-aged individuals are present in a population. In such population, pre-reproductive and reproductive periods are of almost same length, while post reproductive period remains the smallest one. The growth of the population is usually very slow. They have stable type of population with equal number of births and deaths. This kind of population is significant in developed countries like Japan, America, Australia.

iii. **Urn-shaped** It exist where the deaths rate is relatively more than the births rate. Populations tends to decline over the time. In such population, pre-reproductive period is often of very short time period. Population growth rate is very slow due to less birth rates. This age pyramid represents the population of countries like Germany, Russia, and Bulgaria.

g. **Sex Ratio:**Sex ratio is the percentage of the males to the females in a population. Demographically, *it is the proportion of males to females in a population.* In humans, sex ratio is around 1: 1 Statistically, it can be expressed as,

$$\textbf{Sex Ratio} = \frac{\textbf{total number of males in a population}}{\textbf{total number of females in a population}}$$

Sex ratios can be categorized into two

i. **Primary Sex Ratio** is the ratio of males to females in a population at the time of fertilization. Basically, it is a theoretical sex ratio in which a sexually reproducing individuals have equal tendency of producing males and females, i.e. 1: 1 like in humans. Since, it is difficult to confirm, it cannot be accepted universally.

ii. **Secondary Sex ratio** is the ratio of males to females at the time of birth. Generally, males have shorter life expectancy than females. Since, the mammalian populations tend towards males, but as individuals grow older, the population switches females. Shorter life expectancy in females can be due to physiological or behavioral factors, as common among birds. In birds, males tend to outnumber females. The nesting females are more prone to predation and attacks, resulting in a higher number of deaths in females than males.

13.3.5 Life Tables

Life tables are representations of a population at a particular time. It represents birth and death rates of individuals at different stages of their life. Life tables starts with a cohort. Cohort *is a group of individuals born at the same time.* In order to determine the pattern of survival in a population, there are three major ways. These are:

i. **Dynamic life table,** it categorizes a large number of individuals that are born about the same time. Besides, it keeps records of individuals from birth to death.
ii. **Static life table,** used to determine the pattern of survival in wild populations. You can record the age at the time of death of a large number of individuals. It is done through tagging individuals at the time of their birth and recovers tags after their death after recording the age at death, such in case of tiger monitoring.
iii. **Age-distribution table,** comprises of the proportion of individuals at different ages within a population. You can use age structure to estimate survival of individuals. It can determine the variations in the proportion of individuals in successive age classes or groups.

The age structure life table tends to be less accurate than cohort life, as most of the assumptions usually occur in natural populations. Generally, static life tables are valuable, as they may be the only information available to the ecologists. Hence, life tables act as an important tool to describe the present status of any population and forecast its future growth.

13.3.6. Survivorship Curves

To understand the fundamentals of survivorship curve, imagine a population of 100 individuals born at the same time in a particular area. With the passage of time, some

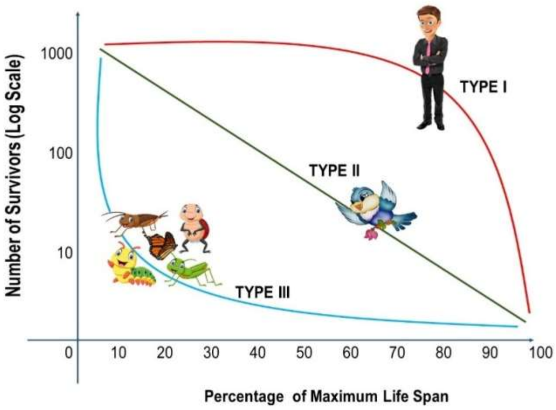

Fig. 13.5. graphical representation of survivorship curves

of those individuals die, leaving few individuals behind each year. Here comes the role of survivorship curves to represent or depict the maximum number of died individuals. Survivorship curves *are graphical representations to depict the proportion of a population that survives.* It shows the pattern of life and deaths within a population. The graphs are obtained by plotting the number of survivors per 1000 births against age. It allows the comparison of generations, populations and, even species. According to Deevey 1974 and Pear 1994, survivorship curves can be of three types as illustrated in the figure. 13.5.

i. **Type I,** survivorshipcurve is slightly convex shaped. When young and middle aged individuals have high survival rates followed by older individuals with high mortality rates represents type I survivorship curve. The key characteristics includes, a low reproductive rate and low mortality due to high parental care in juveniles. The individuals prefer to grow in a stable environment, where there is intense competition for resources and space among individuals. For example, humans.

ii. **Type II,** survivorship curve shows the intermediate patterns of reproductive rate, parental care and survival of juveniles. It produces a straight line pattern depicting the constant rates of survival throughout life. It means, the proportion of individuals dying over time in a population remains constant. In such populations, the mortality of individuals is independent of their age. All have an equal probability to die at any age. For example, in case of adult birds, rodents and reptiles.

iii. **Type III** populations have high rate of mortality at very young ages. Individuals often produce larger number of their offspring, most of them die soon after due to lack of parental care. Once this initial phase is over, survivorship is relatively constant for the rest of the one’s life. They are usually exposed to the disturbances experiencing in their environment. Hence, individuals produce larger number of offspring to compensate the environmental variations. The curve obtained are of concave shapes. For example, fishes, oysters, insects.

In real world, populations are composed of all three types of survivorship curves, with almost every sort of intermediate form of it, between the curves.

13.3.7 Life Histories

As you know, all living organism require energy in order to grow, sustain, and reproduce. Since, energy is crucial limiting factor in the survival of an organism, they have energy budget to balance their survival. During the course of time, every individual experiences a number of offs in terms of growing, surviving, and reproducing. The causes of these trade-offs can be found in individual's life history.

Life History, *is the sequence of events from birth to death, essential for the survival and reproduction of an organism*. It can be classified based on the population characteristics such as, size, sex ratio, growth pattern, fecundity, age structure and so on. However, life histories are categorized on the basis of three main factors- age at which individual begins to reproduce; frequency of an individual to reproduce; and number of offspring per reproduction event. Let us discuss each of these factors

a. **Reproductive age.** You might have noticed, in organisms like small fishes, reproduction starts in very early stage of life. While, the larger fishes like sharks and whales, reproduce at a later stage of their life cycle. Now, several questions may arise as why does it happens? What is its significance in the population dynamics?

   Reproductive age, i.e. the timing of first reproduction, or a stage when an organism starts to reproduce. It is an important life history trait of an organism that plays a crucial role in the dynamics of the population. Since, small fishes start reproducing early in their life, they spend all their energy in the reproduction. They do not invest their energy in their growth or maintenance. Consequently, they become vulnerable to their predators. These organisms are less likely to produce no offspring at all. However, this may come at the expense of their growth, maintenance, and survival.

   Whereas, larger fishes use their energy to grow in size, which provide them defense against their predators. They reproduce at a later stage of their life cycle, thus increasing their chances that may even die before reproducing. These organisms provide parental care to their offspring to ensure their survival. However, they are more likely to die while reaching reproductive age.

   In brief, short-lived organisms are more likely to reproduce early, while long-lived organisms are more likely to postpone reproduction.

b. Fecundity. Sea-snails, like many other marine invertebrates produces hundreds of eggs in a single reproductive event. In contrast, mammal species produce fewer offspring. This life history strategies of different organisms are important in population dynamics, like reproductive age. Fecundity, *is the number of offspring produced in a single reproductive event.* It is one of the major trade-off in life history strategies. This is because parental care is inversely proportional to the number of offspring. That means higher the fecundity of an organism, less energy to be invested in each offspring and vice versa.

Organisms with higher fecundity are less likely to provide parental care to their offspring. They often tend to be small in size with low energy reserves. In such organisms, offspring are generally self-sufficient at an early stage. Since, they have low energy reserves, they are more vulnerable to predation. As a result, only the fewer individuals are likely to survive.

Similarly, that is the case with above illustrated sea-snail. They use their energy budget in producing a number of offspring, each of which is relatively small in size. They provide little or no parental care to their offspring. While, mammals produce fewer offspring and provide extensive parental care to them. Such organisms invest their energy budget to care for their offspring. Sometimes, at the expense of their own health and life.

c. **Reproductive event**. Last, but an important characteristics of life *history is the number of times an organism reproduces over its life time*, called reproductive events. On the basis of the reproductive events, organisms can be classified into two categories. These are semalparity and iteroparity.

i. **Semalparity,** small organisms like spiders die soon after mating, reproducing once in its life. Such organisms use most of their energy budget in a single reproductive event. They concentrate all of their reproductive energies into a single mating before dying. This is most prevalent among bacteria, plants and invertebrates.

ii. **Iteroparity,** unlike spiders, humans, reproduces multiple times throughout their life. They do not spend their energy into a single reproductive event. Such characteristics are found in mammal species like, primates, reproducing many times during their reproductive period.

13.4 Population Growth

Imagine a population of bacteria with a simple life history, growing in one cubic centimeter of tube under an ideal condition. You will notice that initially the population is small and the food supply within the tube is much more than sufficient to support the present population. Now, can you determine what would be the pattern of growth in the bacterial population? We know, all populations have capacity to expand in an ideal condition. And, births and deaths are continuous process in the population growth. Since, there is no dispersal event taking place from either sides of the tube, the number of bacteria is more likely to increase only via new births. From this, we can conclude, *an increase or a decrease in the number of individuals in a population with time* is termed as population growth. We can calculate the size of population at any time using,

$$\mathbf{N_t = N_0 e^{rt}}$$

where, N_t is the number of individuals at time t, N_0 is the initial number of individuals, e is the base of natural logarithms, r is the per capita rate of increase, and t is the number of time intervals or generations.

13.4.1Population Growth Curve

As long as the resources are available to sustain them, all populations have a tendency to grow in exponential manner. And, as these resources become insufficient to hold the expanding population, it collapses. In order to determine the growth pattern of the population and forecast the changes in population size, population growth curves act as very efficient tool. Population growth curves are *graphical representation of how a population size increases over time.* There are two forms of population curves: exponential growth curve and logistic growth curve based on the types of organisms and environmental conditions. You will learn more about these two in in coming sections.

Biotic Potential

All organisms have different capacities to reproduce under ideal conditions. Population of large mammals often have low reproductive capability than small individuals, as described in the previous sections of the chapter. Hence, biotic potential can be defined as, the maximum reproductive capacity of an organism under favorable environmental conditions. Biotic potential of a population can be represented through its constant growth rate under ideal conditions. And, mathematically can be expressed as,

$$\mathbf{g} = \frac{\mathbf{dN\ /dt}}{\mathbf{N}}$$

where, g is growth rate of a population, N is the population size, t is time and d is constant. Let us continue with the types of population growth curves.

Carrying Capacity and Environmental Resistance

When the resources in an environment becomes limited, population stops declining and ultimately stops. The maximum number of individuals at which their growth stops is known as carrying capacity of that environment. It is *the maximum number of individuals that an environment can sustain i*s termed as carrying capacity. It is expressed by letter K. It is often not fixed, it varies with time and space due to limited resources. It is determined by factors like, climatic variations, competition, predation and so on. These factors are known as *the environmental resistance* to population growth.

On reaching carrying capacity due to environmental resistance, the population becomes constant. i.e. birth rates become equal to death rates and population growth becomes zero (equilibrium). The per capita birth decreases with the depleting resources and ultimately population collapses.

a) Exponential Growth: Imagine an unsaturated environment, where population has been significantly reduced due to some catastrophic events like flood, earthquake, etc. Under such conditions, in the presence of plentiful vast resources population grows exponentially at the constant rate. Since, no competition exists among the individuals of the population for the resources, there is net increase in the population size. From this, it can be inferred that a population keeps on growing in an exponential manner until they run out of the resources.For instance, during the rainy season insect's population increases exponential. This is because the environmental conditions become favorable to their reproduction and food supply becomes sufficient. And, when at the end of the season, population collapses suddenly, leaving only a few individuals behind.

As you already know, when birth rates exceed death rates, population tends to expand. When the population runs out of the resources, the death rates increases due to unavailability of resources, population growth stops abruptly and starts to decline. Consequently, when the graph of population size is plotted against time, it produces J-shaped curve. And the size of exponentially growing population at any time can be estimated using,

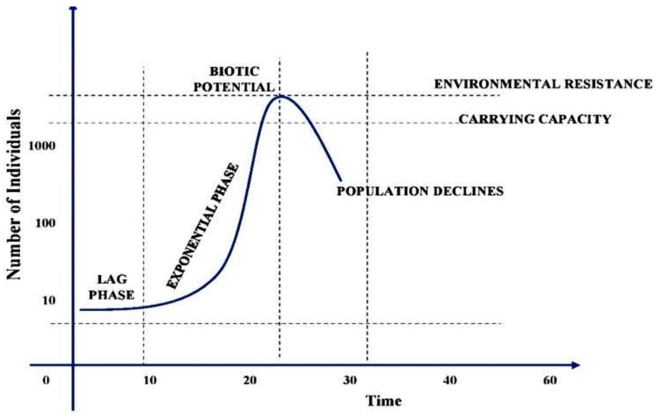

Fig. 13.6 Exponential growth curve of population

$$\mathbf{N_t = N_0 \lambda^t}$$

where, N_0 is initial number of individuals, N_t is number of individual at time t, λis average number of individuals left during one-time interval and t is time intervals in hours, days, years, etc. In above mentioned example of the growth of bacteria, new individuals born per unit of time (b), number of individuals die per unit of time (d). Suppose, we start with (N) number of bacteria at time (t), the number of individuals added to the population through birth, over the time period will be denoted as,

N (t)

And, total number of bacteria reproduced over a given period will be expressed as,

$$\mathbf{b\ N(t)\Delta t}$$

If, **B(t) =** $\mathbf{b\ N(t)\Delta t}$is the total number of birth, and **D(t) =** $\mathbf{d\ N(t)\Delta t}$the total deaths, any change in the population during the time interval can be estimated using the formula,

Change in population size = births – deaths

i.e. $\mathbf{\Delta N = b - d}$

Mathematically, the population size at the next time period (t +Δt), can be expressed as,

N (t + Δt) = N(t) + [(b N(t) Δt) – (d N(t) Δt)]

Substituting the values in the equation, we can write it as

N (t + Δt) = N(t) + [B(t) –D(t)] or ΔN / Δt = (b-d) N(t)

As, when time interval Δt approaches value zero, the rate of change is instantaneous. Thus, the term ΔN / Δt can be replaced by dN / dt expression. Additionally, as *b* and *d* are constant, we can define intrinsic rate of population growth *r* as,

r = b-d

and, can rewrite the equation for continuous population growth as dN / dt = (b-d) N; or

$$\frac{dN}{dt} = rN$$

This equation is known as the model of exponential population growth.

By this, the rate of change in the population during the time interval can be forecasted. Populations with high intrinsic rate of increase expands rapidly. The maximum growth rate of population is known as the intrinsic rate of increase or the biotic potential and mathematically as,

$$\frac{dN}{dt} = r_{max}\, N.$$

b) Logistic Growth Curve: Exponential growth can occur only in the unsaturated environment, where individuals are few and resources are in surplus amount. Since, resources are very limited and finite in nature, no population can continue to grow in exponential manner. As, when the individuals in population increases, resources start depleting. Individuals' access to the resources become very limited. And population growth rate slowdowns, and eventually, it levels-off. Subsequently, resulting in sigmoidal or s-shaped curve, when plotted against time, and known as logistic growth curve. Logistic growth curve is more realistic population growth model. Logistic curve can be divided into three phases: lag, log and stationary. After that population collapses.

i. **Lag Phase** also known as positive accelerating phase. It occurs where there are few individuals in a population in an unoccupied environmental with plenty of resources. At initial stage, population starts expanding very slowly due to reproduction and growth of offspring. During this phase, population growth is maximum as the limiting factors such as food, mates, etc. are all abundant with little or no competition.

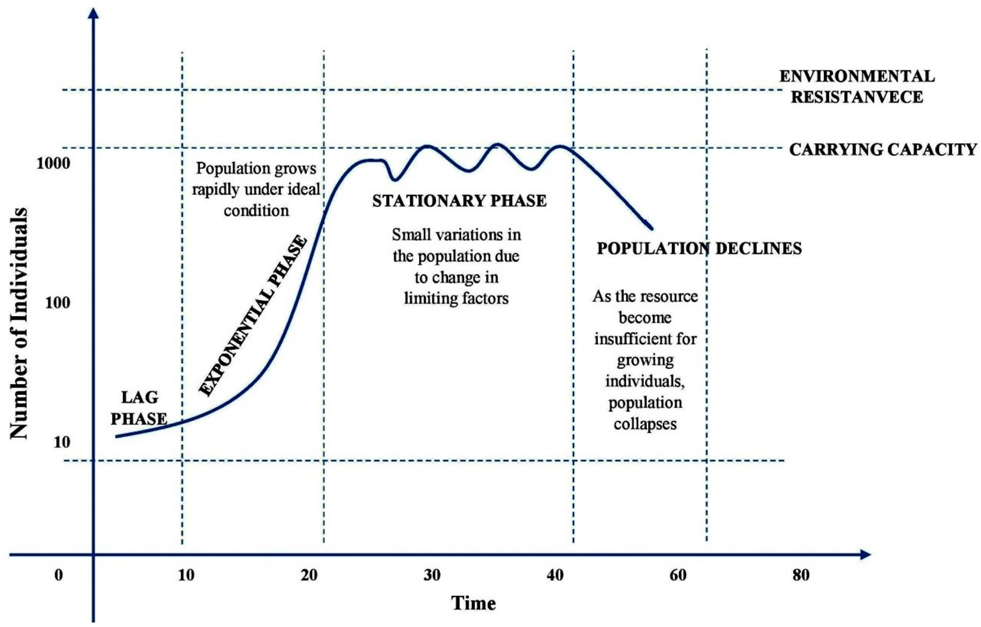

Fig. 13.7. Logistic growth curve of population

ii. **Log Phase** is also called as exponential phase. Since, the environmental conditions are favorable and resources are unlimited, the population expands rapidly. At this stage, total number of individuals in a population reaches reproductive age, and begins to grow exponentially, as long as the birth rates exceed the death rates.

iii. **Stationary Phase** is a negative accelerating stage of the curve. On reaching their biotic potential, i.e. when population reaches its maximum number of individuals that can be supported by an environment, the birth rates and the death rates become equal to one another. Consequently, population stop expanding and remains stable with very small fluctuations due to variations in limiting factors. At this stage, population reaches its equilibrium. Since the resources starts depleting, it becomes insufficient to sustain a growing population, hence it declines at the end.

You can develop logistic growth model by modifying the exponential growth model. You can add the factors that slow down the population growth on approaching carrying capacity. It can be done by multiplying

$$\frac{dN}{dt} = r_{max}\, N \left(\frac{K-N}{N}\right) \quad \text{or} \quad \frac{dN}{dt} = r_{max}\, N \left(1 - \frac{N}{k}\right)$$

On reaching the carrying capacity (K), population is checked by environmental resistance (N / K) factors such as climatic conditions, competition, etc. and slow down the population growth. The rate of population growth (dN / dt) increases slowly, as the difference of [(1-N) / K] becomes smaller and smaller decimal fraction until N = K, where population becomes constant and eventually stops expanding.

In logistic growth model, the per capita rate of increase depends on the size of the population. The per capita rate of increase is inversely proportional to the size of population. i.e.

- Maximum rate of increase max occurs at very small population size.
- If N<K, is r is positive and population expands
- If N=K, r is neutral and population stops expanding
- If N>K, r is negative and population declines.
- When N = K/2, logistic population growth is maximum.

13.4.2. Population Regulation

All populations have a tendency to expand infinitely. However, it is not possible in the real world. Since, resources are very limited in nature and demand of expanding population increases, the population size begins to fall due to inadequate supply of resources and eventually declines. This you might have noticed in the logistic form of population growth as well that on reaching carrying capacity, population ends up facing one or more environmental resistances. This tends the population to fluctuate between the upper and the lower limit of that environment to achieve stability.

As stated above, environmental resistance are the conditions or limiting factors comprising of abiotic and abiotic factors that regulate the growth rate of the population. Depending on the limiting factors, population size is regulated by density dependent and density independent factors. Let us examine those factors in coming sections.

i. **Density dependent regulation.** It can be explained as *when a population growth is increased or decreased by the size of the population.* Denser the population is, greater will be the mortality rate. There are several intrinsic (biotic) factors that influences the size of population. These may include ecological interactions (competition, predation); dispersal events (emigration and immigration); epidemics (pathogenic diseases) and so on. In density-dependent regulation, the population stabilizes on approaching the carrying capacity of the environment. For instance, predators may have better access to their prey, when the population of prey increases. Hence, predators controlling the population of prey by eating the, thereby reducing the size of prey population.

Similarly, some species exhibit inter-compensation characteristics. Suppose, if predators that normally regulates the population of herbivores are removed, the herbivores will increase rapidly leading to increase in the demand of resources. Since resources are finite, individuals in a population may compete for the same resources. This may again limit the growth of herbivore population. Hence, it can be concluded that any change in the environmental conditions while reducing the impact of existing pressure on the population may lead to an increase in the population, till it reaches a point where the second impact takes over.

ii. **Density Independent regulation.**

When a population growth increases or decreases by external environmental factors, regardless of its density, it is termed as density-independent regulation. In such population regulation, growth is not dependent on its density, unlike in density dependent regulation. There are number of extrinsic (abiotic or environment) factors tend to regulate population under various conditions. Such factors may include weather or climatic conditions (rainfall, temperature, pressure); natural calamities (drought, flood, landslides) and so on. For instance, people killed in an earthquake. Regardless of the population density of the area, the survival chances for each individual is same.

Population Regulation Models

In mid twentieth century, the concept of r and k selected organisms was used to study the populations. These are reproductive strategies of organisms to optimize energy and resources to provide parental care to their offspring. Based on these strategies, organisms can be grouped into two categories as illustrated in the table 13.1

i. K-selected: The population of k-selected tend to exist close to their carrying capacity, where intraspecific completion is high. They are adapted to stable and in predictable environments. The population is regulated through density dependent factors. These organisms produce few offspring, have a long gestation period, and often give long term care to their offspring. While larger in size when born, the offspring are relatively helpless and immature at birth and develop skills to compete for natural resources during their adulthood.They have longer life spans. Example: Primates and humans.

ii. r-selected: In contrast, r-selected population tends to exist below carrying capacity, where competition is either low or no competition. They are adapted to unstable and in unpredictable environments. Their population growth is regulation by density independent factors. These organisms have larger number of small offspring.They do not invest resources in long-term parental care and the offspring are relatively mature and self-sufficient at birth.They are short-lived organisms. Example: Jellyfish

Table. 13.1. reproductive strategies of organisms.

	K-selected	r-selected
Climate	Predictable and fairly constant	Unpredictable and variable
Mortality	Density-dependent and more directed	Density-independent; non-directed
Survivorship Curve	Type I and Type II	Type III
Population Size	At equilibrium; at or near carrying capacity; saturated communities; no colonization necessary	Non-equilibrium; often below carrying capacity; unsaturated; recolonization each year.
Competition	Usually keen	Variable, often lax
Selection Favors	Slow development Greater competitive ability Delayed reproduction Larger body size Repeated reproduction Fewer offspring	Rapid development High maximal rate of increase Early reproduction Small body size Single reproduction Many small offspring
Life Span	Longer, usually more than year	Short, usually less than a year
Stage in Succession Leads	Late at Climax Efficiency	Early Productivity

13.5. Population Structure

By now, you know that a population is a group of organisms of same species, inhabiting in a particular area. Populations are often separated by some geographic barriers such as mountains, oceans, deserts and so on. Individuals do not distribute randomly across their ranges, even where there are no such barriers to the individuals' movements. Rather, they prefer to stay near to where they were born. When these large populations are separated, they are sub-divided into various small localized groups and known as *local populations or demes.* They share common gene pool. The group of these local populations linked by migration are called as, *metapopulation.*Since, every individual has a tendency to mate with those who live closer rather than those from the far away, they often mate randomly and have no clear boundaries between them. However, sometimes non-random mating also occurs in a population. It happens when the movement between the populations is restricted by local populations, termed as *continuous population.*

For instance, a self-pollinating plant, a plant growing on one side of meadow prefers to pollinated other nearby growing plants than those are on other sides of meadows. In such populations, genetic variations can be accumulated. And, such geographically separation may result in sub-division of the population, that can inbreed with their respective local populations as well. Thus, we can define population structure as *the patterns in the genetic variations resulting from the non- random mating of a population.* A population can be said to be structured in some way, when migration, inbreeding and natural selection are the reasons of their diversification.

Significance of Population Structure

- Sub-populations can evolve independently; it allows population to diversify.
- Provides causes and consequences of restricted migration in natural population.
- Structured population have their own dynamics, like the metapopulation.

13.5.1. Metapopulation

As explained earlier, resources are not uniformly distributed. They are present in the form of patches across the landscapes to support local breeding populations. These patches vary in sizes, shapes and are interconnected through migration within or between the sub-populations. These sub-populations collectively form a single large population with unique population characteristics and dynamics. These sets of sub-populations, occupying distinct habitat patches and interacts through migration within or between the habitat patches, are known as metapopulation.

Assumptions of Metapopulation Theory

i. Habitat patch size should be proportional to the size of population.

ii. Large populations are often less vulnerable to extinct due to environmental and demographical changes.

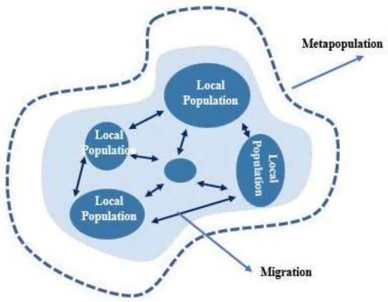

Fig. 13.8. Metapopulation

iii. Increase in the size of habitat patch may reduce the risk of extinction.

iv. Increased migration between habitat fragments reduces the chances of extinction.

Applications

Metapopulation theory helps in planning conservation strategies of both species and their habitat. Several practical applications exist. For instance, an introduction of corridors in forests to facilitates the movement of animals between fragments of the habitat, reducing their risk of extinction.

13.6. Population Resource Relationship

In 1798, an English demographer, Thomas Robert Malthus published an essay, “Principles of population”. He stated that if unchecked, populations grow in a geometric or an exponential manner (as 2,4,8… and so on), whereas the food supplies at arithmetic rate (as 1,2, 3…so on). This creates an imbalance between the available resources and expanding populations. Consequently, the population would outrun of food supply leading to decrease in food per person. Overall, no population can grow infinitely in constant environment.

On the basis on resource exploitation, population can be broadly classified as:

i. **Optimum Population.** When the resources available in a country is an equal its population needs to maintained, known as *optimum population.* It is a theoretically population. It produces the highest standard of living for the people of that area. An increase in individuals do not influence the equilibrium, unless new resources keeping pace with them. In order to achieve this balance, a country needs to keep balance in fertility rate, migration, age distribution and life expectancies of its growing population. If equilibrium establishes between resources and the population, further higher living standards can be improved through better technologies.

ii. **Over Population.** When individuals exceed the carrying capacity of their environment, it is said to be *over populated.* This can be due to the increase in birth rates, decline in mortality rates due to medical facilities, increase in immigration than emigration. For example, countries like China and India. There are several impacts of over-population including, impaired quality of life, depletion of resources, poverty, pollution, and so on. However, some countries like Saudi

Arabia, has managed to increase their carrying capacities through technologies to overcome the impact of over-population.

iii. **Under Population.** When there are few individuals in an area with respect to resource availability, such populations are recognized as under-population. It is a phase of population-relationship where resources and technologies are there, but due to less individuals in a population, they are not being efficiently utilized. For example, countries like Australia has surplus of resources and good living standards.

13.7. Summary

In this unit you have learnt various aspects of population. So far you have learnt that:

- ***Every population has its unique set of attributes, and population characteristics are not the same as those of an individual.***
- ***A population size is a product of population density and geographic area.***
- ***Individuals are not evenly dispersed throughout the geographic range. The most prevalent kind of dispersion is clumped distribution.***
- ***Age pyramids are geometrical depiction of vertical bar graphs that illustrates the quantity and proportion of people in different age groups at any given time.***
- ***Dispersal can result in changing pattern of distribution and density through the time period by increasing or decreasing the local population densities.***
- ***Life tables are summaries of natality and mortality of individuals at various stages of their lives, helping in the prediction of future increase in population of species.***
- ***Survivorship curves are graphs used to compare generations, populations, or even distinct species within a species and time period.***
- ***All populations have tendency to grow in an ideal condition. Population continues to increase at an exponential rate until it runs out of resources.***

- ***In logistic population growth pattern, fluctuations exist in population density between the top and lower limits of the environment in order to achieve stability.***

Terminal Questions

True/False. *Indicate whether the statement is true or false*

1) To determine how many individuals of a population are in a given area, an ecologist would study the population dispersion.
2) Density-independent limiting factor have the strongest influence on a population growth rate when the population is small and widely spread over an area.
3) In log stage of exponential growth curve, the population size increase slowly, but resource use is exponential.
4) Study of demographics helps in forecasting of changes in the human population
5) Human population growth rate has always increased.

Multiple Choice Questions

Identify the choice that best completes the statement or answers the questions.

1. Density, distribution and growth rate are characteristics used to classify which one of the following?
   a) Biomes
   b) Population
   c) Limiting factors
   d) Age pyramids
2. Which of the following does *not* affect the spatial distribution of a population?
   1) the carrying capacity of a population
   2) the distribution of food and other resources
   3) the abiotic conditions like rainfall and sunlight
   4) the existence of predators or parasites
3. Which of the following methods might be used to decrease the rate of approach to carrying capacity by the developed world?
   a) increase birthrate
   b) decrease death rate
   c) decrease resource use
   d) decrease emigration
4. Which characteristic is typical of a K- strategist?
   a) short life span
   b) generally, a small organism
   c) produces many offspring
   d) lengthy parental care
5. Which of the following methods might be used to decrease the rate of approach to carrying capacity by the developed world?
   a) increase birthrate
   b) decrease death rate
   c) decrease resource use
   d) decrease emigration

Short Notes.

Briefly answer the following questions.

1) Define population? Using appropriate examples, describe its various properties.
2) Explain the r and k-selection strategies.
3) Describe various approaches for determining animal population density.
4) Discuss how a population functions as a self-regulating mechanism

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Unit 14: Ecosystem Modelling

Unit Structure

14.0 Learning Objectives

After the completion of the unit, you will be able to:

- Understand fundamental concepts of ecosystem modelling.
- Learn about the modelling techniques.
- Learn about the various types of modelling, based on the approaches.
- Discover how ecological ecosystem modelling can be applied in real world.
- Importance of ecological engineering to humans and the environment.

14.1 Introduction

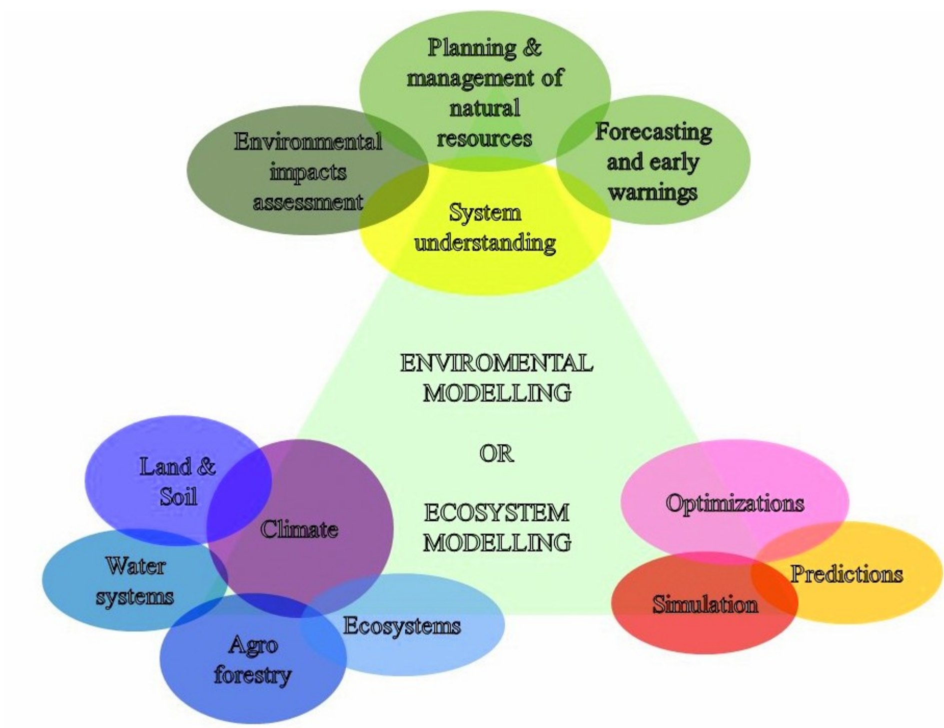
In unit 14, you will learn about the fundamentals of ecosystem modelling and ecological engineering and its applications in real world. You have already learn about the ecology in the previous chapters, ecology is a discipline of science that how organisms interact with their environment. In real world, it is a challenging task to understand, how an organism interacts with other organisms and the surrounding environment. To understand ecological interactions and other ecological processes, it is necessary to first understand the ecosystem in which the they occur.

Ecosystem models are abstract, and mathematical representations of an ecological system that are studied in order to develop better understanding of the real system. Theyare often based on a comprehensive and detailed understanding of the principles that support the natural ecosystems. Ecosystem models minimizes the cost of measures while mitigating the impacts, therefore, they have applications in wide range of disciplines, such as: natural resource management, agriculture, wildlife conservation and so on.

In the present chapter, we will begin our journey from the basic understanding of ecosystem modelling concepts to its process andapplications in real world systems.

14.2. Ecosystem Modelling

As humans, we have a tendency to simplify the complex environments for the better understanding of the systems. Models are used as a tool to simplify a picture of real system and to address problem occurring in it. Although it is difficult to represent all of the attributes of a real system in a model, it contains only the characteristics that are required to solve or describe the problem. Models hold all the information about the



entire system from every aspect as possible as shown in the fig 14.1.

Fig. 14.1. Pictorial description of ecosystem modelling (Ogola 2007)

In 1992, an ecologist, Jorgensen defined ecosystem as "*a natural partition unit that consist of a whole, whose parts include all living and non-living components along with their associated biogeo- and physio-chemical energetic, material, and informational parameters within a time and space region".*Grasslands are the ecosystem accounting for 42% of all vegetation cover on the Earth. You can found grasslandsin every continent except Antarctica. Due to increase in the urbanization and change in the land use, grasslands have been degraded into various systems. Such as, savannas, forests, crop fields, and so on. Besides conversion to cultivation land, environmental factors such as climate change, fire, drought, animal grazing, a shift in the grass species composition and dominance have been observed. However, the relative significance of these environmental factors to the dynamics of ecosystems varies by grassland types.Despite extensive research has been undertaken on the grasslands, it is difficult to measure and identify the major factor influencing the dynamics of grassland ecosystem.

In order to understand ecosystems, researchers often examine them in a controlled environment, experimentally. Experimental setups involve, either the partitioning of a components of a natural ecosystem, known as *mesocosms*, or reconstruction of completely in an indoor/outdoor laboratory environment, known as *microcosm.* However, this approach has its limitation. As when, an individual organism removed from their natural ecosystems or a changes occur in the natural ecosystem due to partitioning, the dynamics of the entire ecosystem may get disrupt. Partitioning and reconstructing of the natural habitats are majorly responsible for the changes in the environment and variations in diversity and abundance of the species. Consequently, these types of experimental approaches aren't always accurate predictors of changes in the ecosystem.

Considering the limitations of the experimental approach, several ecologists suggest to integrate or combine the results of experimental systems with holistic research. Through this integration, the best representative data about the ecosystem structure, functions and dynamics can be gathered. Development and analysis of mathematical models of ecological processes, are known as *Ecological modelling.* It includes both pure biological and integrated biophysical models. An *ecosystem model* is a mathematical representation of an ecological system, that is studied to better understand the real system. Information about the ecosystem from the field data such as relationship between prey and predators; photosynthetic rate of the plants due to availability of sunlight and water are integrated to construct an ecosystem models. Ecosystem models act as a strong tool for interpreting the past dynamics of ecosystem and evaluates the impact of changing environmental factors on future dynamics of the ecosystem. Also depicts the relations between the impact on ecosystems and the consequences as illustrated in fig. 14.2.

Ecosystem model can be considered as useful experimental tools for surveying, to reveal system characteristics, to establish research priorities and to test scientific hypotheses as well. Ecological models mainly comprise of three areas: biogeomorphic, bioenergetics and biogeochemical.

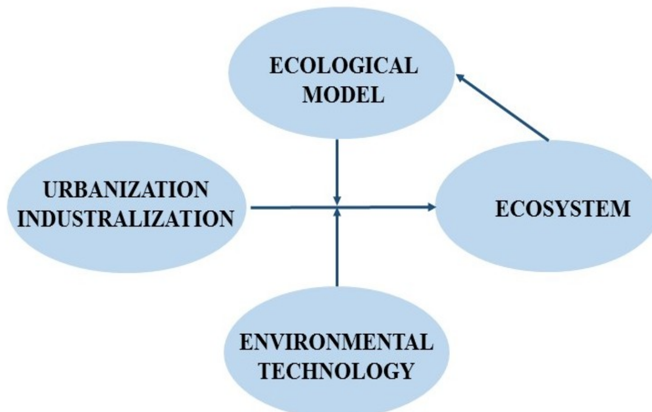


Fig.14.2. Models to find the relationship between the impact on ecosystems and consequences in the ecosystem (*adopted from - Environmental Models and Simulations - S.E. Jørgensen*)

Ecological modelling can be used in the implementation sustainable development. A mathematical model, and system analysis that explain how ecological processes may support sustainable management of resources considering three main aspects: environmental, economic and social domain as shown in fig 14.3.

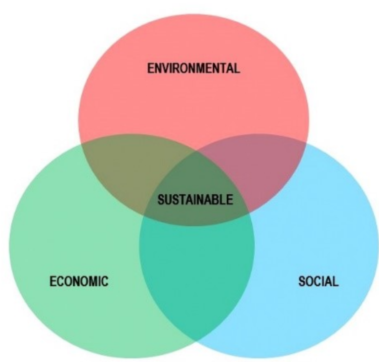


Fig. 14.3. Three domains of sustainability. (*adopted fromYoung-Seuk Park in Development in Environmental or Ecological Modelling 2015*)

Advantages:

- results in the formation of hypothesis about unknown or poorly understood hypothetical relationships.
- allows researchers to replicate/recreate large-scale experiments, that would be too expensive or unethical to conduct in a natural ecosystem.
- helps in the prediction about the dynamics of real systems.
- enables researchers to study ecological processes over a long period of time.

Concepts of Modelling

You must have a basic idea about ecosystem modelling by now. While we go any farther, let us get a better understanding of modelling principles. It is very important to understand the difference between the models and the modelling processes. A *model* is a depiction of something, a concept or a situation, whereas *modelling process* refers to the steps involved in developing a concept into a research model, and then into a quantitative model. Models can sometimes be very complex and detailed. For example, a mathematical representation of the nitrogen transformation within an aquatic ecosystem.

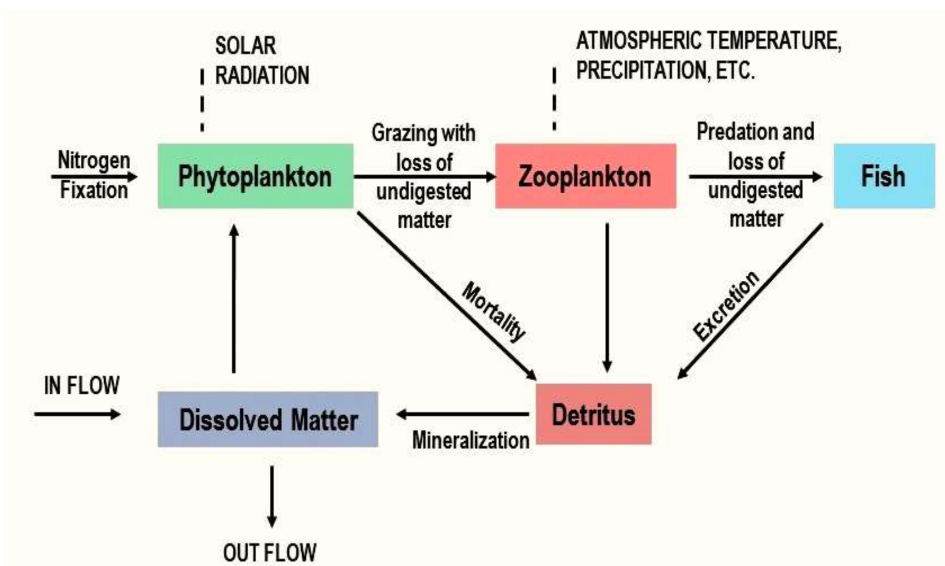


Fig. 14.4. The conceptual diagram of flow of Nitrogen in an aquatic ecosystem.

As ecologists constantly review the concepts and gather new information as a part of their work, the model and picture of the ecosystem or environment it represents keeps on changing.

Components of Modelling

Forcing functions Forcing functions are the external factors that influence the state of ecosystem. They do not get affected by other variables in the system. Forcing variables have some peculiar characteristic such as,

- They are fixed when they enter the system or model
- They are taken as a “given” in the model
- They influence endogenous variables in the model
- They are determined by the model
- They are not explained by the model.

When the forcing functions vary over time, a model is used to anticipate or predict how the ecosystem will evolve accordingly. When these forcing functions are under our control, they often refer as *control variables or control functions.* For example, in eutrophication models, nutrients act as control functions. And, other forcing functions of interest could be climatic variables. These external variables influence biotic and abiotic components and the rate of eutrophication without being affected by other variables in a system.

State Variables In model, state variables are sets of variables that are used to explain the mathematical state of a dynamic system. Although it is often, a very simple process, it is critical to select state variables in modelling. As model has relations between forcing functions and the state variables, the values of state variables anticipated by changing forcing functions can be regarded as the outcome of the model in a management context. In above mentioned example of eutrophication model, state variables will be the concentrations of nutrients and growth of the phytoplankton.

Mathematical Equations Mathematical equations define the relation between the state variables and the forcing functions, and also between the state variables themselves. All the biological, chemical, and physical processes can be represented through mathematical equations.For example, the Lotka-Volterra model can be described using the equation,

$$dx/dt = ax – ßxy$$

$$dy/dy = \delta xy-\Gamma y$$

Where,

x = number of prey y = number of predators

dx/dt and dy/dt = the instantaneous rates of the prey and predators, respectively.

t = time

α, β, δ, γ = positive real constants.

As we know, a similar process can occur in various environments, it means same equations can be used in multiple models. However, it does not suggest that the same process is always expressed using the same equation. This is often because two reasons. First, the influence of additional factors, that may be better expressed using another equation. Second, due to differences in the complexity of either the system or the problem, where the number of details required to be included in model may differ from case to case. Such description and mathematical formulation of the processes are known as *sub models.*

ParametersThe coefficients in the mathematical representation of processes, are known as *parameters.*The parameters are defined scientifically in the conceptual models. In ecology or environmental sciences, various sets of parameters can be found. For instance, the rate of excretion of cadmium in a fish. For some ecosystems or part of ecosystem, parameters can be considered constant. The application of these parameters as constant in model is unrealistic due to various feedbacks in real ecosystems.

Universal Constants These are the constant values accepted universally such as the gas constant, acceleration due to gravity, angular distance of the Earth, atomic weights, and so on are also used in most models.

Let us understand each component of model through example to clear concept. In mass balance model as illustrated above in the fig 14.4. A flow of nutrient (nitrogen) between phytoplankton, zooplanktons, fish, detritus to dissolved organic matter or sediments can be seen. Here, the various components of model can be observed as,

- Forcing functions/ external factors: It includes solar radiation, atmospheric temperature, inflow/outflow of dissolved organic matter, etc. These are environmental factors acting as forcing functions in a model.
- State variables: the concentration of circulating materials such as carbon, phosphorous and/or nitrogen. Carbon acting as most crucial element to describe the actual biomass, whereas phosphorous and nitrogen are nutrients that control the primary production in an ecosystem. In some cases, elements such as silicon also included when it comes a limiting factor of primary production.

- Functions: state variables, kinetic parameters and effects of environmental factors acts as functions of mass balance model.
- Parameters: these are the coefficients of mathematical representation of nutrient cycle. It includes maximum growth rates of phytoplankton; the grazing rate of zooplankton; decomposition rate of detritus.

Modelling Procedure

Modelling process comprises of six steps. They are model *conceptualization, mathematical formulation, parameter estimation, calibration, sensitivity analysis and, validation.* Let us understand each step in a sequential manner.

1. Model conceptualization

This step is the initial stage in developing any model. First, we define a problem and a system of our interest. Thereafter, develop an adjacent matrix to get an overview of the processes, and conceptualize the diagram.

i. **Define a problem**Before starting developing a model, it is necessary to define a problem or develop a research question. Thereafter, a system is defined where all the processes of our interest occur. It should be noted that the problem or the system must be controlled by components of space, time and subsystem.

ii. **Adjacent matrix**After defining a problem, it is important to acquire an overview of the most relevant process in the system. For this, an adjacent matrix is created that lists all the state variables and gather information about the processes. If possible, neighboring/adjacent matrix must be built up before the conceptual diagram. Before developing adjacent matrix, a modeler must enquire about each of the proposed relationships between the state variables. If exist any relationship, "is it significant enough to be included in the model?". If the response is "yes", write 1, and if the response is "no", write 0. Here, value "*1*" represents the availability of a direct relationship between the two state variables, whereas value "*0*" denotes the absence of a relationship between the two components.

iii. **Conceptual diagram** Once the intricacies and significance of the model is identified, it is possible to understand it, at least on the first try. Conceptual diagrams help in understanding such complexities of the model. It reveals all components of the model such as the state variables, forcing functions and processes the model requires.

In an ideal world, one would determine which data are required to develop a model based on a conceptual design. But in practice, most models are developed after data collection. This is a compromising process between model scope and data availability. However, there are several methods to determine the best data collection for a given model, to reduce model uncertainty; but, their applicability or practice is unfortunately very limited.

2. **Mathematical formulation**The next stage in modelling is the formulation of mathematical equations. During formulation of mathematical expressions, a process is described using one or more equations. And, selecting the appropriate equation for the instance at hand can have significant impact on the final model's findings.
3. **Transfer to computer**Once the mathematical equations are provided to the system, verification can be conducted efficiently and quickly. It is a crucial stage in model development process that most developer ignores. By this stage, it is expected from the modeler to answer questions such as, "is the model stable in long run?" "does the model's response is same as expected?" "are the units same on both sides of the equation?".
4. **Verification**Verification is the process for assessing whether a model implementation and its associated data accurately reflect the conceptual description and specifications. In other words, it is an iterative process that determines whether or not the specifications and assumptions meets all of the requirements and is internally complete, accurate enough to reflect the purpose of application with respect to the conceptual model. It focuses on comparing the factors of simulation model of a system with the description of what needs and capabilities of the model were to be. In the verification phase, common questions include such as, is the model stable for long term? Is model built fulfills are requirements of the application? Verification is often carried out during the use of model prior to the calibration phase.
5. **Sensitivity analysis**Verification is always followed by sensitivity analysis. Sensitivity analysis is a process in modelling to determine how values of an

independent variables affects a particular dependent variable under a given set of conditions or assumptions. It examines the extent to which responses are affected by changes in methods, models, values or assumptions. In mathematical equation, it can be expressed as,

$$\mathbf{S = [\Delta x\ x]\ [\Delta P\ P]}$$

Where, *S* is sensitivity, *P* is parameter and *x* is state variables under consideration.

In practical modelling, sensitivity analysis is carried out by changing or modifying the parameter, the forcing functions or the submodels. And, then corresponding responses on the chosen or selected state variable is observed. Sensitivity analysis differentiates between high-leverage variables whose values have a strong impact on the system behavior, and the low leverage variables whose values have limited impact on the system behavior. As, the relationship between a parameter and a state variable is often non-linear, sensitivity must be analyzed for two or more levels of parameter changes. Generally, sensitivity analysis mainly comprises of three major steps. These are

i. Selection of parameters
ii. Estimation of range of variations
iii. Prediction based on the outcomes

Sensitivity analysis determines the significance of various forcing functions as well as the accuracy of the data used to calculate them. Subsequently, it assists in decision making or developing operational strategies by changing variables in an analytical model.

6. **Parameter estimation** Parameter estimation methods are particularly important in modelling. As before conducting calibration, it is always useful to provide the most approximate values for the parameters. In predictive ecosystem models, certain parameters are estimated values or intervals rather than constants. To cover all possible parameters for all possible ecological models, it is important to know more than one billion parameters. This is because if more than a few parameters have been selected for calibration, random calibration is not possible. Consequently, a modeler must learn the behavior of model by modifying one or more parameters at a time and observe the response of the most significant state variables.

7. **Calibration**Calibration is the process of changing or modifying various parameters, in order to choose the most appropriate between the computed and observed data. Calibration adjust the parameters and the forcing functions of the model within margins to obtain a model representation of our interest, satisfying all the pre-determined criteria. The main purpose of the calibration process is to improve estimation of parameters. Calibration can be done using trial and error method or with the use of software designed to determine the parameters that best fit the observed and computed data. An automatic calibration is also possible in models, where it is required to develop objective calibration criteria.

It is important to understand that sometimes calibration is not possible in the model. This does not imply that the model is incorrect or invalid; it could be due to poor data quality also. Thus, it is strongly recommended to examine the dynamics of the state variables before determining the data collection process in detail. In some cases, model calibration is not required like static model or basic models, where only a few well-defined or directly observed parameters are used.

8. **Validation.** Validation should always be done soon after the calibration process. And, it should not be confused with verification. It is the process of determining how well the model outputs, and its associated data are accurate representation of the real world from the intended uses of the model. Validation is a set of activities to verify the performance of the model, as expected or not. In the process we compare the representation of a conceptual model to the real system. And, if the comparison is correct, it is valid; else invalid. However, it only confirms model behavior under a set of conditions represented by the data. Consequently, it is recommended to valid the model with data at a time when conditions other than those of the calibrating data is applied. Even if an ideal validation cannot be achieved, it is still necessary to validate the model.

To validate the model, selection of viable or relevant testing method is required, depending on the scope of the model. However, the standard deviations between model predictions and observations are often used. It compares the observed and anticipated minimum or maximum values of a particular important state variable. And, if there are multiple state variables, they may be assigned different weights.

9. **Approach**Ecopath is a powerful software system that models marine ecosystems using simulation and computational approaches. It's a popular tool among marine and fisheries experts for modelling and displaying the intricate interactions seen in real-world marine ecosystems.

Classification of Models

Based on characteristics and purpose, models can be classified as shown in table 14.1.

Table 14.1. Types of models and its characterization

Type of Model	Characterization
Research Models	Used as a research tool
Management Models	Used as a management tool
Deterministic Models	Predicted values are computed exactly
Stochastic Models	Predicted values depend on probability distribution
Compartment models	Variables declining the system are qualified by means of time-dependent differential equations
Matrix Models	Use matrices in the mathematical formulation.
Reductions tic models	Include as many relevant details as possible
Holistic Models	Use general principles
Static Models	Variables declining the system are not dependent on time
Dynamic Models	Variables defining the system
Distributed Models	Parameters are considered functions of time and space.
Lumped Models	Parameters are within certain prescribed spatial locations and time considered as constants.
Linear Models	First-degree equations are used consecutively
Non-linear Models	One or more of the equations are not first-degree
Causal Models	Inputs the states and the outputs are interrelated by using causal relationships
Black-box Models	Input disturbances affect only the output response. No causality is required.
Autonomous Models	Derivatives are not explicitly dependent on the independent variables (time)
Non-autonomous Model	Derivative are explicitly dependent on the independent variable (time)

14.2.1 Types of Ecosystem Modelling

In ecosystem research and management, researchers use three forms of ecological modelling: conceptual, analytical, and simulation models. A *conceptual model* is an ecosystem model made up of flow charts that depicts the interactions between different compartments of the ecosystem's living and nonliving components. It represents an ecosystem structure and dynamics and demonstrates how environmental disturbances influence the ecosystem.

On other hand, the analytical and the simulation models are mathematical tools for characterizing ecosystems that may, with some limitations, forecast the impacts of future environmental changes without direct research. An *analytical model* is a type of ecosystem model that is developed using simple mathematical formulas to forecast the impact of environmental disturbances on the structure and dynamics of the ecosystem. Whereas, a *simulation model* is a holistic ecosystem model that is produced using advanced computer algorithms to forecast the impact of environmental disturbances on ecosystem structure and dynamics**.** These models are precise enough to detect which ecosystem components are particularly susceptible to disturbances, and used as a reference for ecosystem managers (such as conservation ecologists or biologists) in maintaining ecosystem health in practice. Let us study each of these ecosystem models in more detail.

1. Conceptual Model

The conceptual models are the illustrations used to describe the structure and the dynamics of ecosystem. They are generally represented through diagrams using boxes and arrows in the form of the flow charts. The boxes represent the state variables describing the conditions of components of the ecosystem. And, the arrows show the relationships among the state variables, such as movement of mass and energy, ecological interactions, and so on. In simple terms, in conceptual model, the organisms and their resources are categorized into various compartments, and the arrows indicate the relationships between various organisms and with their environments and energy transfer between them. These diagrams provide a compact and visual statement of the research problem. And, thus aids in determining the questions to ask, as well as the part of the system to study. They provide a balanced required information of ecological structure and processes, while remaining simple enough to aids in the generation of hypotheses and organizing the concepts. Therefore, compartmental models are sometimes preferred to explain these diagrams.

In general, the development of a conceptual model is a continuous process, begins with the formulation of a general research problem or a question. In order to develop a valid conceptual model, an ecologist should first generate hypotheses, assess what data is available and what data is required, and have a clear understanding of the components of ecosystems and ecological processes.

Limitations:

Although conceptual models have numerous advantages, they do have certain limitations. They have inability to predict or forecast the effects of changes in the ecosystem, the species or the environment, as one of its drawbacks.

For instance, ecosystems, as we all know, are dynamic in nature. They keep on changing due to biotic and abiotic factors such as anthropogenic activities (mining, deforestation, etc.), natural calamities (droughts, floods, landslides, cloud bursts, etc.) and diseases (epidemics) and so on. However, ecosystems have resilience property, that means they have ability to recover and return to a state of balance from disturbed, of their own. Sometimes, ecosystems either move towards or away from their equilibrium state due to periodic perturbations and are frequently in a state of change. As humans, we have a power to drastically modify the species composition and the habitat of an ecosystem, it is therefore, a need arises of predictive models in order to understand the adaptation of ecosystems to these changes. And in such cases ecologists often prefer analytical or simulation models. Analytical and simulation are quantitative methods of demonstrating ecosystems that are capable of forecasting the effects of environmental changes without direct observations. Although they are less accurate.

2. Analytical Models:

Analytical models are generally simple and linear system. They are often described using a set of mathematical expressions that have well-defined characteristics. That means, theoretically, analytical models are more complicated. They are developed using simple mathematical formulas to forecast the effects of environmental perturbations on the structure and the dynamics of ecosystem. They operate best when working with relatively simple and linear system such as in the prediction of ecological components like food chains, nutrient cycle, and so on. Hence, these types of models required high mathematical understanding and skill. Although they have a lot of potential and are efficient, they are considered to be relatively less accurate. This may be due to their simplication of ecosystems.

3. Simulation / Computational Models

Simulation model, like an analytical model is a quantitative method of describing an ecosystem. They use computer algorithms to predict changes in ecosystems. This means, in simulation models, we use computational methods to find out the solution, unlike analytical model. They are considered to be ecologically more realistic and accurate model to forecast changes in the dynamics of ecosystem. And, also provide most precise and reliable predictions of ecological responses to the disturbances. This could be due to the fact that computer-based simulation models are better at understanding the complexities of diversified ecosystem, and therefore, used widely. Individual-based simulation is a recent innovation in simulation modeling that not only investigate the behavior of an individual species, but also their impacts on the ecosystem as a whole. Subsequently, we often prefer simulation models over analytical due to its accuracy and feasibility.

14.2.2 Types of Ecological Model

Based on the purposes, ecological models can majorly of four types, as given in table 14.2.

Population models

Population modelling is a tool used by wildlife managers. to predict the outcomes of some management action such as stopping hunting. It also helps to conceptualize the dynamics of a population in a rigorous mathematical notation. Such conceptual models enable ecologists to think more clearly about the dynamics of a population. Third use of the population model is to test hypothesis about population dynamics from observed data. These models are best suitable for measuring scalar abundances of the species or community; life history of organisms; individual based approaches, and in understanding the dynamics of the metapopulation.

Population model is a kind of a system of keeping track of four components of population dynamics. These are birth (natality), death (mortality), immigration and emigration. Mathematically, a population model can be expressed as

Nt+1 = Nt + Bt + It –Et

Where population size (N) at time t+1 is equal to the population at time t plus birth (B) minus deaths (D) plus immigrants (I) minus emigrants (E). For example, Lotka-Volterra prey-predator relationship model.

Ecosystem Models

An ecosystem model is a mathematical conceptual model representing an ecological system ranging from an individual population to an ecological community or even an entire biome to understand the complexity of real ecosystem. These are ecological models describing the structure, functions and dynamics of an ecosystem. Using data collected from the field, ecological interactions such as the relation of sunlight and water availability to photosynthesis; prey-predator relationships and so on. Ecosystem models have numerous applications in real world, such as ecotoxicology and environmental health; agriculture, and wildlife conservation. Ecosystem models are often used to understand ecological processes (food webs, different kind of ecosystems), landscape modelling for predicting changes in the ecosystems, and many more as illustrated in the table 14.2.

For example, the terrestrial ecosystem model (TEM) as illustrated in the fig 14.6. is a process-based ecosystem model that describes carbon, nitrogen and water dynamics of plants and soils for terrestrial ecosystems of the planet.

Terrestrial Ecosystem Models (TEMs) is an approach that represents the movement of carbon and nitrogen in 18 terrestrial ecosystems, that operates on a monthly basis at 0.5 degrees lat/long spatial resolution. It is used to determine the impacts of climate change; increase in the concentration of atmospheric carbon dioxide; availability of nitrogen and change in land use on the terrestrial ecosystems. The changes predicted by TEMs, are often used as measures of terrestrial effects, or as data to analyze the impact of climate change on agriculture and natural ecosystems.

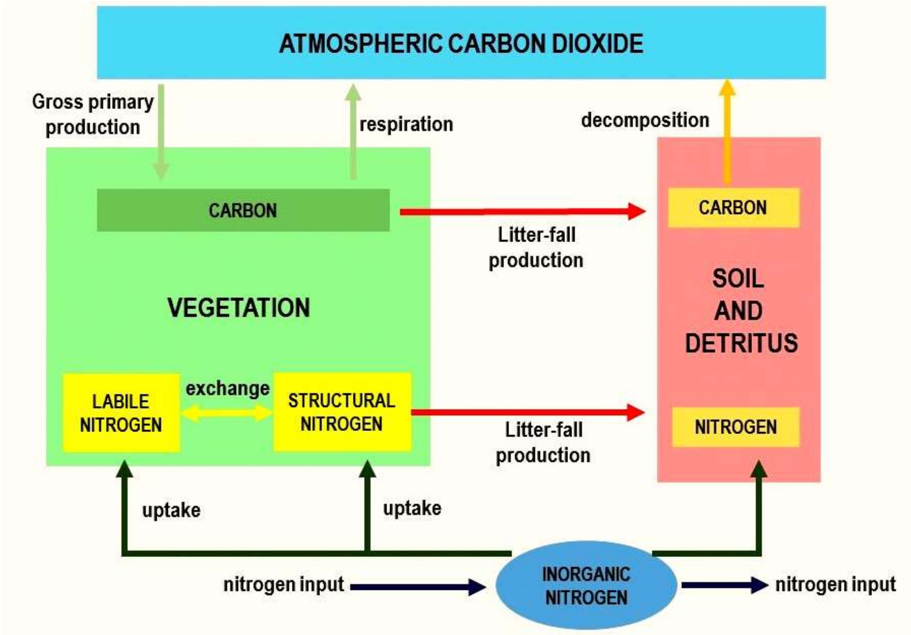


Fig. 14.6. Schematic representation of TEM used for predictions of the future state of ecosystems and movements of carbon dioxide between the atmosphere and terrestrial biosphere.

In TEMs, the forcing functions majorly include monthly average climate (*mean temperature, mean precipitation and mean relative humidity*); texture of the soil (*proportion of sand, clay and silt*); elevation, vegetation and availability of water. To provide hydrological information, the model also includes a water balance model (for instance soil moisture, potential evapotranspiration). The global data sets of terrestrial ecosystem models include soil texture, elevation, long-term average climate, potential natural vegetation.

Applications

- To predict the state of natural ecosystems such as changes in the composition of terrestrial vegetation, movements of terrestrial carbon dioxide, and the composition of soil. The resulting information can be used in developing combined chemistry/climate and natural emission models.
- TEMs-generated representation of change in ecosystems can be used to estimate a crucial relationship between the economic and ecological impacts.
- More problem oriented models can be developed through TEMs, such as impacts of climate change on natural ecosystems and agriculture.

1. Biogeochemical models

Biogeochemical models are generally used to monitor the transport of nutrients and other materials in the hydrosphere and biosphere. They concentrate on the "destiny and conveyance" of these materials, and in some circumstances, they try to explain their impact on organisms.To model the cycling of mineral nutrients, organic and inorganic nutrients are subdivided into those that are bioavailable (ready to be incorporated into biological macromolecules) and those that are not.

Environmental and Ecological Model types and purposes:

Ecological Model Type	Suitable for	Purposes
Population Models	Population Dynamics	• Scalar abundance • Life History • Individual based • Metapopulation
Ecosystem Models	Ecological Processes	• Food-web • Abiotic/biotic ecosystem • Marine, estuarine, lake, river • Wetland • Desert, forest, grassland, island
	Terrestrial Ecosystem	• Plant growth
	Atmospheric	• Plume Dispersion • Air pollution • Acid rain
	Landscape Models	• Analysis and prediction of changes in a region
Biogeochemical Models	Ecotoxicology	• Representation of aquatic ecosystem responses to flow and nutrient, chemical, heavy metals and /or radiological pollution,

Applications of ecosystem modelling

Ecosystem models have applications in a wide variety of disciplines, such as:

1. Natural resource management
2. Ecotoxicology
3. Environmental Health
4. Agriculture
5. Wildlife conservation
6. Archeology with varying degree of success

14.3. Ecological Engineering

Environmental issues are increasing significantly on a global basis. And, the application of environmental technology, alternative technology and ecological engineering is increasingly becoming essential in environmental management.Ecological engineering is the application of technology to ecosystem management that is based on a thorough understanding of ecological principles that supports natural ecosystems. The application of these principles to ecosystem management must be in such a way that minimize the costs of the measures and their impacts on global environment.

Concept of Ecological Engineering

Ecological engineering or ecotechnology is a new approach in the field of applied ecology. In 1960s, an ecologist, H.T. Odum coined the term ecological engineering. It is the process of developing ecosystems that are beneficial to both humans and nature. In other word, it is defined as *the development of long-term ecosystems based on ecological principles that combines humans with its natural environment for mutual benefit.* Ecological engineering is a combination of scientific knowledge, techniques and practices. It includes ecological processes that are used in resource management, equipment design and installation, that ensures conservation of ecosystems. Ecological engineering has two major objectives as,

1. To restore ecosystem that have undergone perturbation.
2. To develop a new sustainable ecosystem with both human and ecological value.

Ecological engineering involves the designing and the restoration of ecosystems through the application of principles learned over the past century. It uses ecology and engineering to predict, design, construct or restore, and manage ecosystems that integrates humans with its environment for the benefit of both as shown in fig 14.7. Ecological engineering and environmental engineering are not same disciplines. Environmental engineering involves the application of scientific principles to solve problem of pollution. Similarly, the term ecotechnology should not be confused with biotechnology, in biotechnology manipulation of genes are carried out to produce new strain or organisms for specific role.

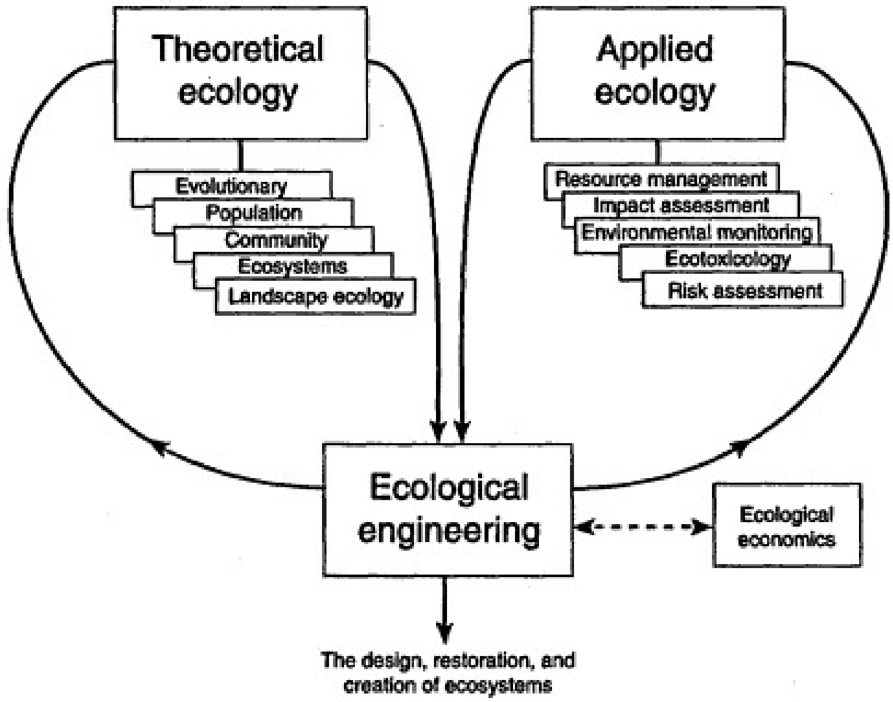


Fig. 14.7. Ecological Engineering: A new Paradigm for Engineers and ecologist. (*adopted from National Academic Press)*

Principles of Ecological Engineering

1. It is based on the self-designing capacity of an ecosystem

Ecological engineering is primarily based on the ability of an ecosystem to restore or reorganize itself as the changes occur. The process of designing an ecosystem involves a quantitative approach based on the fundamental researches.

2. It can be the acid test of ecological theories.

Ecological engineering provides an opportunity to enhance our understanding of ecosystems because of the unique research approach in recreating ecosystems. The restoration of a disturbed ecosystem s defined as "an acid test our understanding of that system". Ecologists have established a clear link between fundamental research and ecosystem restoration so that the system works/functions effectively. Subsequently, ecological engineering is the practice of conducting and implementing fundamental ecological research.

3. **It relies on system approaches**

It is critical to work with entire ecosystems rather than a single species. As system approaches like modelling and cost-benefit analysis are very important and ecosystem design and prediction cannot be anticipated by summing various components to make a whole. It is therefore necessary to consider the entire ecosystem, region by region, but ultimately to make ecosystem. Hence, to comprehend and deal with the designs of ecosystems, ecological engineers must be able to synthesize a wide range of disciplines.

4. It conserves sources of non-renewable energy

Economic growth of modern environmental technology depends on non-renewable sources of energy. Ecotechnology also utilizes some non-renewable energy in the early stages of designing and construction of ecosystem, before switching to solar energy completely. Since most ecosystems relies on solar energy they are self-sustaining in nature. This suggests, once the ecosystem is powered by solar energy, it will no longer be dependent on fossil fuels. If system fails to maintain itself, it does not imply that the ecosystem has failed, as its behavior is eventually predictable.

5. It supports biological conservation.

Acknowledging the ecosystem values serves the purposes to conserve them. Ecological engineering determines ecosystem suitable to human requirements, and also those human needs that are best suited to the existing ecosystem. It considers every component of ecosystem including an individual, species, communities and even biomes. Removal or alternation of any components of a natural ecosystem without an absolute need is considered to be detrimental or harmful. Thus, ecological engineering facilitates in a better environmental conservation ethic than previously recognized.

Applications

The applications of ecological engineering can be categorized into the following three spatial scales as

1. Mesocosms (~0.1 to 100s of meters)
2. Ecosystems (1 to 10s of kilometers)
3. Regional ecosystems (> 10s of kilometers)

Based on the above mentioned spatial scale categories, ecological engineering can be applied in various approaches. Some of those are:

Soil bioengineering Fast growing riparian tree species for bank stabilization and erosion control

Bioremediation Mixes of microbial species and/or nutrient additions for enhanced biodegradation of toxic chemicals

Phytoremediation Hyper accumulator plant species for metal and other pollutant uptake

Reclamation of disturbed lands Communities of plants, animals, and microbes that colonize and restore ecological values

Compost engineering Mechanical and microbial systems for breakdown of organic solid wastes and generation of soil amendments

Ecotoxicology Ecosystems in microcosms and mesocosms for evaluating the effects of toxins

Food production Facilities and species for intensive food production including greenhouses, hydroponics, aquaculture, etc.

Wetland mitigation Wetland ecosystems that legally compensate for damage done to natural wetlands

Environmental education Exhibits and/or experiments involving living ecosystems in aquaria or zoos

Wastewater treatment Wetlands and other aquatic systems for degradation of municipal, industrial, or storm wastewaters

Agroecology Enhancing diversity and activity of soil micro-organisms in favor of plants, regulating pests of crop using natural enemies,

14.4. Summary

- ***Ecosystem models are a strong tool for better understanding historical dynamics.***
- ***Ecosystems are studied using a variety of different research methodologies. The most realistic representation of an ecosystem in its natural condition is a holistic ecosystem model.***

- ***Experimental systems often involve either partitioning a component of a natural ecosystem that may be utilized for research or reconstructing an ecosystem in a laboratory environment.***
- ***Ecological modelling is the development and analysis of mathematical models of ecological processes. They can be analytic or simulation-based.***
- ***A model is a representation of something, a concept, or a situation. It can be as simple as a verbal statement about a topic.***
- ***The coefficients in the mathematical representation of processes are known as parameters***
- ***Calibration is an attempt to discover the best match between computed and observed data by changing a few parameters***
- ***Validation is a method of determining how well the model outputs match the data. If the model structure accurately captures the cause-effect relationship of the real system, it is considered to be structurally valid.***
- ***Conceptual models can be used to show the link between different organisms in a community and their surroundings. Flow charts are commonly used to represent them graphically. Compartmental models are occasionally used to describe them, with arrows indicating the relationships and energy or nutrition transfers.***
- ***Analytical models are mathematically complicated models that excel at forecasting ecological components like nutrient cycling, food chains. Analytical models operate best when dealing with relatively simple, linear system.***
- ***Simulation models are more widely used and are regarded to be more accurate in terms of the environment.***
- ***Sensitivity analysis gives a measure of the sensitivity of parameters, forcing functions, or sub models to the model's most important state variable. It distinguishes between high-leverage variables, whose values have a large impact on system behavior, and low-level average variables.***

- ***Ecological engineering is the application of technological means to ecosystem management that is based on a thorough understanding of the principles that underpin natural ecological systems***

Terminal Questions

True/ False

Indicate whether the statement is true or false

1. Analytical model is an ecosystem model that is created with mathematical formulas to predict the effects of environment disturbance on ecosystem structure and dynamics.
2. In simulation modelling the relationships of different compartments of the living and non-living components of the ecosystem illustrates through flow charts.
3. Holistic ecosystem model study that attempts to quantify the composition, interactions and dynamics of entire ecosystem.
4. Ecological engineering is the formation of long-term ecosystems based on ecological principles that integrate human society with its natural environment for mutual benefit
5. Ecosystem models are generally used to monitor the transport of nutrients and other materials in the hydrosphere and biosphere.

Multiple Choice Questions

Identify the choice that best completes the statement or answers the questions.

1. Eco technology is defined as _ _ _ _ _ _ _ _ _ _ __ _ _ _ _ _ _ _ _ _ __ _ _

a) the use of technological means for ecosystem management based on deep understanding of principle on which natural ecosystem are build.

b) it is the relation between conservation and producer

c) this is an advance technology applied for specific area only

d) it reflects the cycle of ecosystem.

2. What term describes the use of mathematical equations in the modelling of linear aspects of ecosystems?

a) analytical modelling

b) simulation modelling

c) conceptual modelling

d) individual-based modelling

3. Ecosystem model that is created with computer programs to holistically model ecosystems and to predict the effects of environmental disturbances on ecosystem structure and dynamics.

a) simulation modelling
b) conceptual modelling
c) individual-based modelling
d) analytical modelling

4. A re-created ecosystem in a laboratory environment is known as a ____________

a) reproduction
b) microcosm
c) mesocosms
d) simulation

5. Forcing functions are:

   a. fixed at the moment they enter the model
   b. determined within model
   c. the outputs of the model
   d. explained by the model

Short Notes

Briefly answer the following questions.

1. Explain the importance of verification, calibration and validation. Can models without these three steps be developed at all?
2. Write all important components of modelling
3. Write short notes on the procedure of modelling
4. Write real world applications of Ecological engineering
5. Write short note on ecosystem modelling

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