CENTRE FOR OPEN AND DISTANCE LEARNING

TEZPUR UNIVERSITY: NAPAAM: SONITPUR

SELF-LEARNING MATERIAL

THE ENVIRONMENT: BASIC UNDERSTANDING

DEM 101

SELF-LEARNING MATERIAL

Course Code: DEM 101

Course Title: THE ENVIRONMENT: BASIC UNDERSTANDING

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March 2012
@ CODL, Tezpur University
Published by
Director, Centre for Open and Distance Learning (CODL),
on behalf of Tezpur University.

COURSE INTRODUCTION

PART -1

COURSE 1: THE ENVIRONMENT: BASIC UNDERSTANDING

COURSE 2: NATURAL RESOURCES AND SUSTAINABLE DEVELOPMENT

COURSE 3: URBAN WATER MANAGEMENT

COURSE 4: FUNDAMENTALS OF DISASTER MANAGEMENT

DEM 101 THE ENVIRONMENT: BASIC UNDERSTANDING

UNIT-1: ENVIRONMENT – GENERAL PERSPECTIVES

UNIT STRUCTURE

1.1 OBJECTIVES

After going through this unit, you will be able to:

Articulate and integrate your existing knowledge about the environment and broad, in-depth overview of components of different biotic and abiotic components of the environments by viewing them as interacting parts of an environment.

Appreciate the complex interactions of physical, chemical, biological, socioeconomic and cultural environment.

1.2 INTRODUCTION

Environment, we can say, is something very familiar with us. It's the whole thing that makes up our surroundings and affects our capability to live on the earth. But when somebody asks, what is environment it is an interrelated subject matter. To give answer of the term environment it depends on for whom we are talking about, means "environment of whom" is it we are talking about the environment of plants, animals, human being, for a home or a pond, etc. Then next question comes, is it a living object or non-living objects? Who is human being, who is animals and what is a plant? so and so.

Literally, the word 'Environment' is derived from a French word "*Environner* – surrounding/ to encircle, to envelope". Etymologically it means ***surroundings***. But by environment we not only mean our immediate surrounding only but also a variety of issues connected with human activity, production, basic living and its impact on natural resources such as land water, atmosphere, forests, dams, habitat, health, energy resources, wildlife, etc. Like other animals man depends on environment and becomes an environmental factor with respect to other members in an ecosystem. Any external force, substance or condition, which surrounds and affects the life of the organism in any way becomes a biotic or abiotic factor of its environment. In relation to man, the environment constitute of air, land, water, flora and fauna because these regulate the man's life. Human society viewed environment in a varied angles according to their need and demands.

1.3 DEFINITION AND CONCEPT

Environment has been defined in several ways, for example:

i) The sum total of all surroundings of a living organism, including power of nature and other living things, which offer conditions for improvement in terms of sustainable development and growth as well as risk and harm or injury to the system resulting in impairment or loss of function.

ii) Environment is the sum of all social, economical, biological, physical or chemical factors which constitute the surroundings of man, who is both creator and moulder of his environment.

iii) Environment is the representative of physical components of the earth wherein man is the important factor influencing his environment. A. Goude

iv) Environment refers to the sum total conditions which surround man at a given point in space and time. C. C. Park

v) Environment is a holistic view of the world as it functions at anytime, with a multitude of special elemental and socio-economic systems distinguished by quality and attributes of spatial and temporal and mode of behaviour of biotic and abiotic varieties.

vi) Environment can be defined as 'the circumstances and conditions that surround an organisms or a group of organisms' or 'the social and cultural conditions that affect an individual or a community'.

We can study environment in two ways: 'natural environment' and 'man-made environment'. By 'natural environment' we meant a complete structural and functional ecological unit that act as a natural system and natural phenomenon within their boundaries without any massive human intervention. It includes all the natural vegetation, wild animals, microorganisms, soil, rocks, water, air, etc. Simply 'natural environment' is referring as the 'environment' which encompasses all living and non-living things occurring naturally on mother earth or some region thereof.

The concept of the *natural environment* is contrasted with the 'man-made environment' or 'built environment' which comprises the areas and components that are strongly influenced and regulated by humans. Man-made environment is made of anthropogenic ecosystems and physical structures. Agricultural land, silvicultural land, aquaculture, culture media, etc. are a few examples of man-made environment.

1.4 COMPONENTS OF THE ENVIRONMENT

Environment is the multitude of a various entity. Environment consists of four spheres namely, *biosphere* (sphere occupied by life or biotic components), *atmosphere (*sphere occupied by air), *lithosphere* (sphere occupied by soil sediments and rocks) and *hydrosphere* (sphere occupied by water). These four spheres can be broadly grouped under two categories like abiotic (physical) factors consist of temperature, humidity, precipitation, water, minerals, air and soil, rock or sediment, etc., and biotic (living or biological) factors which are composed of all the living organisms of plants, animals and micro-organisms. It consists of, producers (autoprophic green plants), consumers (Primary Consumer - herbivores, Secondary Consumer – primary carnivores and Tertiary Consumer- secondary carnivores) and decomposers (soil microorganisms -bacteria and fungi).

The very concept of the different components of environment that we need to understand is that these four different components are not isolated with each other there is always a continuous linkage in terms of their structural and function part for exchange mechanism of matter and energy. Thus, organic or inorganic chemicals on earth are distributed or exchange among these four major environmental conceptual spheres i.e. atmosphere, hydrosphere, lithosphere and biosphere.

The interrelationships among the four environmental spheres are so dynamic, complex (even fragile) and inseparable that if one spheres or linkage alter, all other sphere also react accordingly. In this conceptual framework, every sphere has a two-way linkage to every other sphere, including itself. The two-way linkage signifies that flow matter may from one sphere (components) to another in both directions. There is constantly inter and intra specific transfer of energy and mass in a given environmental sphere.

1.4.1 ATMOSPHERE

The life on the earth exists because it is surrounded by atmosphere. The transparent layer of gases or envelope which surrounds the earth is known as atmosphere. It extends up to approximately 10,000 km above (the extreme edges of the atmosphere lie about 35,000 km above the surface) the earth's surfaces which sustain life on earth and saves it from the hostile environment of outer space. The earth's atmosphere is made of a combination of several gases. According to their relative volumes, nitrogen constitutes the highest proportion (

78.09%) followed by oxygen (20.95%), argon (0.93%), carbon dioxide (0.03%) and minute traces of neon, helium, methane, krypton, hydrogen, xenon, and ozone. These gases reach more than 100 km above the Earth's surface and beyond 100 km they are present in very low concentrations. In addition to this mixture of gases, the lower atmosphere contains varying amounts of gaseous, liquid, and solid water, and various particulates. There are some parameters of the atmosphere that vary considerably with altitude. The density of the atmosphere shows a sharp decrease with increasing altitude. Pressure drops from one atmosphere at sea level to 3×10^{-7} atmospheres at 100 km above sea level, while temperature varies from -100°C to 1200°C. So, at different heights above the earth surface in the atmosphere there is a change in proportion of gases and because of this, most of the atmosphere's mass (99%) lies within 30 km of Earth's surface. The total mass of the atmosphere is approximately 5×10^{15} tonnes, which is roughly one millionth of the earth's total mass.

Atmosphere is a life-giving blanket of air which consists of various gases form and in contact with the earth that are essential for living organisms on earth. It is a reservoir of several elements essential to life and act as a protective shell. It is the source of oxygen (essential for life on earth) and carbon dioxide (essential for plant photosynthesis). It also supplies nitrogen which nitrogen –fixing bacteria and ammonia- manufacturing plants utilize to yield chemically bound nitrogen essential for life. It serves many functions including the flirtation of radiant energy coming from the sun, insulation from heat loss at the earth surface and stabilization of weather and climate owing to heat capacity of the air thus helps to control the temperature.

STRUCTURE OF THE ATMOSPHERE

Atmosphere may be broadly divided into four layers/regions on the basis of temperature profile namely, troposphere, stratosphere, mesosphere, and thermosphere. It extends upto 500 km with temperatures varying from a minimum of -2°C to a maximum of 1200°C. The different atmosphere layers have different characteristics and specific roles. Each layer is important to man and forms an important part of Earth's functioning process.

Troposphere – The troposphere is the lowermost layer of the atmosphere which means most closely to the earth surface and it the layer where we breathe in. It is the layer in which man and other living organisms live. It lies from the surface of the earth to an altitude of 10 to 11 km. From the surface of the Earth, it extends out to about 6-8 kilometers at the poles, 11 km in mid-latitudes and 17 kilometers at the equator. Temperature ranges in this layer is between 15^0C to -56^0C and important chemical species are N_2, O_2, CO_2 and H_2O.

In respect to composition, the troposphere is more or less homogeneous, in the absence of air pollution, mainly due to the constant circulation of air masses in this region, with both horizontal and vertical air currents. It is also a turbulent due to the global energy flow arising from imbalances of heating and cooling rates between the equator and the poles. The entire weather phenomenon of the earth takes place within this atmospheric layers and is known as birthplace of the weather, storms and rain. The amount of water vapour decreases gradually with increase in attitude, maximum amount is present in the lowest level of atmosphere and is entirely absent above 8 to 10 km. Density decreases exponentially with increasing altitudes. And as we move away from the surface of the Earth, the air becomes thin and temperature of the troposphere decreases by 6.5ºC per kilometer. However, the temperature stabilizes at 12 kilometer. This area is called the tropopause which is considered as a thin buffer zone between the troposphere and the next atmospheric layer, stratosphere. Tropopause is the upper layer of troposphere which gradually merges with the next atmosphere layer, which marks temperature inversion, i.e. transition from positive lapse rate to negative lapse rate.

Stratosphere – The second layer of air masses is known as stratosphere, which start from the tropopause extending between altitudes of 10 and 60 kilometers above the surface of the Earth and temperature increases with height from -56ºC to -2ºC at upper limit of the stratosphere. This behaviour of temperature changes is exactly the opposite of the troposphere, where temperature decreases with increasing altitude.

The increases in temperature are due to O_3 formation under the influence of UV rays of solar radiation. Ozone is a special form of oxygen, made up of tri-atomic oxygen rather than the usual di-atomic oxygen. It is the important species in the stratosphere, acting as a protective radiation shield for protoplasm or living organisms on earth from injurious effects of the harmful sun's high energy ultra-violet radiations. Ozone confined largely in the atmospheric zone of 25 km to 30 km height and this particular zone of the stratosphere which contains abundant quantity of O_3 is known as 'ozonosphere", the life saving jacket. Ozone content of stratosphere is constant which means that ozone is being produced from oxygen as fast as it is broken down to molecular oxygen. The maximum ozone concentration is around 10 ppm in the stratosphere at an altitude of 25 – 30 km.

O_2 + hν -------2O

O_2 + O ----------- O_3

Ozone is usually formed from oxygen by a photochemical reaction in which solar energy separates the two atoms in an oxygen molecule (O_2) to form atomic oxygen which then recombines with other oxygen molecule (O_2) to form ozone (O_3). The ozone layer absorbs ultra-violet radiations of sun and thus, protects the life on the Earth from various skin cancers. And at the same time, supplies the source for partitioning the atmosphere into a quiescent stratosphere and turbulent troposphere. The boundary between the stratosphere and the mesosphere above is called the stratopause.

Because of negative lapse rate, there is little convection and mixing in the stratosphere, so air of this layers are quite stable. If any material/pollutants get into the stratosphere, they pose long term global hazards compared to the impact in the much denser troposphere. These is due to the lack of vertical convection in the stratosphere and the residence times of molecules or particles in this region are quite long.

Commercial jet aircraft fly in the lower stratosphere, where air flows almost horizontally, to avoid storms or air turbulence which is common in the troposphere below.

Ozone in stratospheric is good, but ozone in troposphere is bad as it causes breathing problems for some people, and usually occurs in the summertime when the pollution over a city builds up during stagnant air conditions associated with high pressure areas.

Mesosphere – The mesosphere is the third layer of atmosphere that lies beyond the stratosphere. Stratosphere and the mesosphere together forms the middle atmospheric layers of the Earth. It extends from the stratopause to about 80 kilometers above the Earth's surface and major constituents of ions present are chemical species of N_2, O_2, CO_2, O_3, Ar, O, etc. Mesosphere layer does not have the capacity to absorb the sunlight due to low level of UV absorbing species, particularly ozone hence the temperature falls down drastically with increasing altitude (-2 to -92) and ice crystals can form in this layer. The air in this layer is very thin because the air particles are farther apart which results in low atmospheric pressure, so it very hard to breathe. At its maximum height, the mesosphere is bounded by the mesopause - the upper limit of the mesosphere, which separates the atmosphere layers of the mesosphere and the thermosphere.

In the mesosphere layer meteorites either gets vaporize or melt down due to the friction with the molecules present in the mesosphere layer while entering the earth atmosphere. Transfer of energy take place as the meteors fall at a very high speed, which they colloid and it's seen as a glow like a falling star.

There is a zone of atmosphere known as **ionosphere,** stretches from 80 to 550 kilometers, above the Earths surface, comprising portions of the mesosphere, thermosphere and exosphere. The structure of the ionosphere is strongly influenced by the charged particle wind from the Sun, which is in turn governed by the level of solar activity. It is distinguished with other layer because of the presence of high concentration of electrically charged particles (ions), particularly oxygen and nitric oxide, split into atoms and also undergoes ionization after absorption of solar radiation in the far UV region. This layer is very thin, but it is where aurora takes place, and is also responsible for absorbing the most energetic photons from the Sun, and for reflecting radio waves/signals, thereby enabling long-distance radio or telecommunication.

Thermosphere – The next layer after mesosphere is the **thermosphere,** which is also referred to as the upper atmosphere, extends upward to about 640 km and it can be said as the beginnings of outer space found in the exosphere. Its temperature increases rapidly with altitude giving a negative lapse rate and temperature can be as high as 2,000ºC because of the absorption of shortwave radiation by ionization processes. However, the air in the thermosphere would feel cold, because of the thinness of the air and molecules of nitrogen and oxygen, which absorb the Sun's energy, are so far apart that the heat concentration is ineffective and thus little heat energy is available. The thermosphere includes the regions in which UV radiations and cosmic rays cause ionization of molecules like oxygen and nitric oxide. This region is called *ionosphere* (as discussed above). The outer extremely rarefied fringe of the atmosphere is called exosphere which is gradually merged with the outer space.

Exosphere – The final layer of the atmosphere beyond the thermosphere is the exosphere. It cover very high temperature due to intense solar radiation and the air is very thin because the air particles are widely separated. It is the outer space, which lacks atoms except, those of hydrogen and helium. The exosphere stretches from the 550 kilometers onwards into the space for thousands of kilometers extending upto 32,190 km from the earth. In this layer of atmosphere, the earth's magnetic field becomes more important than gravity in distribution of atomic particles in the exosphere. Beyond the exosphere lies outer space, where there are almost no air particles and no weather. Satellites performing different functions occupy this layer.

Role of atmosphere:-

Atmosphere supplies O_2, CO_2, and N_2 essential for living organisms and most of its biological activity which utilize them. Without air we (human being) and animals can't transmits sound for communication among each other. Air act as a medium for locomotion of avifauna and insects, and as well as for speedy aviation transport of man and material. The ozonosphere protects the earth's living organisms from the harmful ultraviolet rays of sun while, the ionosphere helps for long distance communications. Day-to-day or long-term average state of the atmospheric environment is largely determined based on the environmental variables exists in the atmosphere. The motion of wind is responsible for specific climatic condition and water cycle. Atmosphere also provides a good space for research and monitoring. Many man made satellites used for communication, weather monitoring and research move around or are stationed in the thermosphere at particular altitude.

1.4.2 LITHOSPHERE

The lithosphere is the solid layer of inorganic materials at the surface of the Earth that forms the base layer of Earth's sphere. It includes all big and small landmasses which are found on the Earth. Lithosphere consists of three layers namely, crust (oceanic and continental), mantle and core. Crust is composed of soil particles and major three elements are oxygen, silicon and aluminum which contributes of about 1% and extends down to a depth of 50 km. Yet, lithospheric thickness varies from about 50 kilometers under ocean bottoms to about 100 kilometers below continental surfaces. It is the upper region of earth crust and part of the upper mantle that behaves more or less rigid shell of the solid earth. The high velocity with which seismic waves propagate through the lithosphere suggests that it is completely solid. The lithosphere is underlain by the asthenosphere weaker, hotter, and deeper part of the upper mantle that behaves elastically on time scales of thousands of years or greater. The boundary between the lithosphere and the underlying asthenosphere is defined by a difference in response to stress: the lithosphere remains rigid for very long periods of geologic time in which it deforms elastically and through brittle failure, while the asthenosphere deforms viscously and accommodates strain through plastic deformation. The outer, rigid, lithosphere consists of several individual segments called tectonic plates. Plates are moved by convection currents. Some plates are entirely underwater which is known as Nazca Plate while plates which are above water are called continents and there are some plates which are composed of both areas under water and areas above water.

With the exception of volcanic activity, however, transport of materials through the lithosphere is relatively slow. Physical, chemical and biological processes interact with the outermost land surfaces of the lithosphere to form soil, ultimately providing materials essential for vegetative growth.

The uppermost part of the lithosphere that chemically reacts to the atmosphere, hydrosphere and biosphere through the soil forming process is called the *pedosphere*. On the other hand, the soil layer is also referred to as the pedosphere, a mixture of inorganic and organic solid matter, air, water and microorganisms. Soil is the uppermost layer of Earth's crust capable of supporting life. It is a major source of food, clothing, minerals, building material, fuels such as coal, petrol, etc. serves as a habitat to all the life-forms on the Earth and help in making many useful products. Soil is a stratified mixture of inorganic and organic materials. The inorganic or mineral constituents of soil are derived from some parent materials by physical, chemical and biological weathering from the soil forming rocks and the organic constituents of the soil are derived form the living or dead biomass of plants and animals through metabolic activities of microorganisms organisms present in the soil. Within the soil, biochemical reactions by microorganisms are responsible for most of the chemical changes of matter and energy. However, soil and rock are mainly storage compartments for deposited matter of very large amounts. Exact lithospheric compositions vary spatially, for example between oceanic and continental areas, however it is largely composed of oxygen and silicon, with aluminum, iron, calcium, magnesium, sodium, potassium, and other elements contributing lesser amounts.

1.4.3 HYDROSPHERE

Water exists on the earth in all three material states: gas, liquid, and solid. The hydrosphere in the liquid form may be fresh water or saline water which are the major component of the earth. It includes the oceans, seas, lakes, ponds, rivers and streams. The hydrosphere covers over 70% of earth's surface and is the home for many plants and animals hence it can be said that Earth is truly a water planet. Most water (97%) resides in the oceans and the remainder is found in the ice sheets of Greenland and Antarctica (2%), and in freshwater lakes, rivers, ground water below the surface, and water vapor in the atmosphere (1%). Among the fresh water in the earth system, streams, rivers and lakes only comprise 0.02%. Groundwater and soil water together make up about 0.5% of all water (by volume). Atmosphere contains only about 0.0001 % of the water in the form of gases (Water vapour). Though 2% of water stored as ice in glaciers seems to be a small amount, it would have a great impact on the environment if it happens to melt into a liquid due to any environmental stress related to climatic conditions. The present 'global warming' is a great threat of melting and collapsing of large ice sheets that result in raising sea level. Rising sea levels is a source of various problems, that it could inundate coastal areas/cities, displaces millions of people which will augment to social and security warning, and cause disaster on freshwater ecosystems and habitats.

Considering the global climate patterns, the hydrosphere is an important component and is a large reservoir for materials and energy. Transformation between the three states of water captures and releases significant amounts of energy. Water, materials, and energy contained in the hydrosphere are continually transported within the hydrosphere and through other spheres by ocean circulation, the hydrologic cycle of evaporation and precipitation, tectonic subduction, and biologic respiration. Like the atmosphere, hydrosphere is always in motion. The motions of water in the form of currents move the warm waters in the tropics toward the poles, and colder water from the polar regions toward the tropics. These currents exist on the surface of the ocean and at great depths in the ocean up to about 4km.

Water is essential for life and plays an important role in atmospheric and lithospheric processes. In fact, the abundance of water on Earth is a unique feature that clearly makes a distinction our "Blue Planet" from others planet in the solar system. WE all know, other planets of the solar system did not have a drop of liquid water. The amalgamation of certain factors of earth like the right mass, the right chemical composition, the right atmosphere, and the right distance from the Sun permits water to exist mainly as a liquid state. However, variation of surface temperatures and pressures of our planet at different levels of atmosphere permit water to exist in all three states: solid (ice), liquid (water), and gas (water vapor). The high heat capacity of ocean containing huge volume of saline water, buffers earth surface temperature from large fluctuations and maintained appropriate for living organisms.

WATER CYCLE OR HYDROLOGICAL CYCLE

When we talk about the water cycle or hydrological cycle, we couldn’t able to say any definable start or finish. Because there is always a continuous storage and movement in terms of different states of water and their functions among different compartments, or reservoirs, of the Earth's hydrosphere, by different physical processes. The primary physical processes involved in the water cycle are the evaporation of water from the oceans and landmass, the transport of water in the atmosphere, condensation, precipitation over the oceans and land, and the flow of water from land to the oceans. However, water does not necessarily cycle through each compartment in order. Before reaching the ocean, water may have evaporated, condensed, precipitated, and become runoff multiple times. The hydrologic cycle or water is used to model the storage and movement of water molecules between the four spheres of environment. Water is stored in the following reservoirs: atmosphere, oceans, lakes, rivers, glaciers, soils, snowfields, and groundwater. It moves from one reservoir to another by processes like: evaporation, condensation, precipitation, deposition, runoff, infiltration, sublimation, transpiration, and groundwater flow.

Water in liquid form is the universal solvent and the basis of all life on our Planet. It is an essential life-sustaining resource and major constituent of almost all life forms which led Benjamin Franklin to comment "When the well's dry, we know the worth of water." Most animals and plants contain more than 60% water by volume. Without water life would probably never have developed on our planet.

1.4.4 BIOSPHERE

The biosphere is the life zone of the earth (in air, water, soil, rocks and sediments and other living organisms) and includes all living organisms, including man, and all organic matter that has not yet decomposed. Representing all life on earth exists in different components of the environment, the biosphere can be thought of as the space in which organisms live. There are many factors that affect the biosphere and our life here on Earth. There are big factors such as the distance between the Earth and the Sun and small factors may be work on a molecular level. We can think, if our earth is too far from or too close towards the sun, what could be the environment of the earth, whether similar live on present earth may able to show or may be something beyond our the imagination…

The term "biosphere" originated with the geologist Eduard Suess in 1875, who defined it as "the place on earth's surface where life dwells". Vladimir I. Vernadsky, Russian scientist, coined the term "Biosphere" in the 1929. Biosphere is about what we talk about life or living beings. In other words, biosphere we can express as Biosystem" or "life". Life can be convey as biosystems organized by interactions between biological components interacting with physical environments, and become a unified whole with capacity to maintain homeostasis and self-perpetuation. Life may also be said to be simply the characteristic state of organisms. Although there is no universal agreement on the definition of life, many scientists accept that the biological manifestation of life is characterized by highly complex organization, Self-homeostasis, metabolism, growth and development, adaptation, response to stimuli and reproduction (*Self-perpetuation*). All the biotic components cannot survive in isolation and they must interact with physical (abiotic) or a biotic environment. Life evolves as a result of the interaction between organisms and their environments through energy, matter, and information produces characteristic functional system and it adjusts itself to the environment.

The biosphere has evolved since the first single-celled organisms originated 3.5 billion years ago under atmospheric conditions resembling to the Mars and Venus, which have atmospheres composed primarily of carbon dioxide. Life evolved on earth during its early history between 4.5 and 3.8 billion years ago and the biosphere readily distinguishes our planet from all others in the solar system like hydrosphere distinguished from all other in the solar system with the presence of water. Life is found abundantly in oceans, lakes and rivers (hydrosphere), extending down to various depths into the soil surface (pedosphere) and land surface (lithosphere), and up into the lower atmosphere.

Biosphere has the direct links to other components of environment in different functional pathways which vary spatially and temporally**.** A key component of earth systems, the biosphere interacts with and exchanges energy and matter (mass) with the other spheres, helping to drive the biogeochemical cycling/nutrient cycling of carbon, nitrogen, phosphorous, sulphur and other elements. From an ecological point of view, the biosphere is considered as a 'giant global ecosystem" comprising the totality of biological diversity in all forms of levels on earth and performing all way of biological functions, including photosynthesis, respiration, decomposition, nitrogen fixation, nitrification and denitrification.

1.4.5 SOCIOECONOMIC AND CULTURAL ENVIRONMENT

Human being is one of the dominating species on earth which is governs by their respective set of socio-economic and cultural values towards their survival on earth by extracting natural resources. We human being normally try to create our own cultural and social environment. Our associated culture, religious practices and traditions for survival and development with response to the prevailing environment are passes down from our forefathers. The society what we are living now is not made by us, it is the result of the various phase of transition roll by our ancestors by analysis and understanding the power of the various environmental factors essential for our survival and fulfilling our need from the surroundings. In this line of development, we, the members of a particular society where we belonged become competent enough to admit certain fact about the relationship of life around us and their presence with the physical conditions.

In more than one way, humans are part of the biosphere. Human activities had a great involvement in the function of biosphere and their interaction with other spheres. Every organism forms a social environment is the natural developing base habitation which is directly influences by the activities and behaviour, and their social characteristics and interactions. A given social environment is likely to create a solidarity milieu among its members only by developing beliefs, help and co-operation with each another and think in similar manner. This milieu is largely influenced and altered by the cultural and economic. The socioeconomic context refers to the social, economic, and cultural connections of nearby communities. There are several communities on earth recognized by their unique asset of culture and their individual's livelihood that also reflects the nature of the social system with respect to their habitat. A particular social system integrates the region's social history, and tells community appraisal and response to resource management issues. The social mix of individuals and groups affects community cohesiveness, power for support and problem solving, and other social variables that influence the identity and resource utilization and management. The overall social-cultural environment is largely determined by everything of the individuals excluding the economy or the political system. Economic life is organized primarily through a market in which individuals relate to one another as buyers and sellers and the purpose is production. The socio-cultural environment consists of the whole range of behaviours and relationships in which individuals engage in their personal lifestyles and relationships. It includes the characteristics of the population (e.g. age, sex, ethnicity, category, birth, death, etc.), values and attitudes.

When we talk about the culture, it is a characteristic of groups, and this can signify a particular society as a whole, groups within society, or even groups of societies and nations. Cultural perspective values about natural resources, and world views about nature influence how groups identify management issues and build acceptable solutions for certain environmental problems.

1.5 SUMMING UP

Environment can be defined as a sum of complex set of biological, physical, chemical factors and social factors in which a living organism or community exists. This all factors work together and there is a close interrelationship among them. The totality of surrounding environment and conditions determined the survival, growth and development, atmosphere and ambience, happiness and quality of any form of life. By now, you must understand what is environment and why we are talking about and the interrelation of the different components of the environment. We all know, among the four components of the environment, the biosphere is the one place where all of the other spheres of the planet work together. Let's think about the interactions of different components for a few second. Soil and sediments interacts with water; air interacts with the soil and sediments; living organisms interacts with water, soil, air; so and so. In these interactions some kind of forces are involved along with the transfer and exchange of energy and matter. Thus, we can say all of those forces, energy and mass work together to create our living world. The following text will give you a summarize note of the whole thing we had learnt as of now in this unit.

Environment is a multi-dimensional system of complex interrelationship in a continuing state of change. It may be accomplished that environment consists of an inseparable whole system constituted by physical, chemical, biological, social and cultural elements which are interlinked independently and jointly in innumerable ways.

A large number of chemical reactions of life processes undertake in the atmosphere some of which either use or release gases from and to the atmosphere. The chemical reactions of life for example photosynthesis-respiration, carbonate precipitation, etc. have also imparted a strong signal on the chemical composition of the atmosphere, transforming the atmosphere from reducing conditions to and oxidizing environment with free oxygen. Green plants undergo photosynthesis during the presence of sunlight and produces oxygen by consuming carbon dioxide from the atmosphere whereas respiration releases carbon dioxide using oxygen. Other examples of biogenic gases in the atmosphere include methane, dimethylsulfide (DMS), nitrogen, nitrous oxide, ammonia, etc.

Water played a key role in the evolution and sustenance of life on earth. The biosphere as we all know it would not exist without liquid water. Water act as an important conveyor (a river or stream system collects the substances within the water shed) and transporter of soluble nutrients (phosphate and nitrate) that are needed for plant growth, and for transporting the waste products of life's chemical reactions. It also may be envisaged as delivers them water collected from different sources are ultimately reached to the oceans.

The lithosphere and biosphere are intimately connected through soils, which consist of a mixture of air, mineral matter, organic matter, and water. Soil is the most characteristic feature of the terrestrial environment, which act as the reservoir of biogenic salts and minerals which are essential for the living organisms. Soils at different places vary considerably in their structure, components and properties. These difference in the soils are often largely responsible for differences in vegetation within the same climatic region, consequently they are of great significance in the distribution of plant communities. The soil is one of the most important ecological factors called edaphic factor. Soil plays a very important role as it produces food fro human beings and animals. In fact, one could consider soil as composed of all four spheres of environment. Root growth of plants and generation of organic acids are important for the mechanical, chemical and biological fragmentation or break down on weathering of rock mass.

The biosphere with other spheres is responsible for the magnificent level of exchanging and recycling of energy and matter on earth. The mobilization of energy and matter is not restricted to small geographic regions, in fact, it is spread all over the earth since the function of atmosphere, hydrosphere and lithosphere are link with each other and it's a continuous processes. In urban area we can see the falling of burnt biomass, which is burnt far away from the urban areas in a forest. It indicates the long-range atmospheric transport and deposition of burnt biomass or fly ash. Similarly, there is always the redistribution of chemicals, minerals and gases in a continental and global scale depending on the atmospheric residence times.

Today, when we talk about the environment of human being we meant everything outside us affecting us. Environment refers to the biological, physical and social conditions in which we live, especially as it influences our attitudes, feelings and development. The socio-economic and cultural environment refers to the environment of the concern people, community, culture, family life, institutions and others element that interacts and shape the society. Any society will need enough unpolluted space for habitation, clean air to breathe, clean water for drinking and other purposes, hygienic food to eat, etc. But there may be wide difference in terms of cultural and social environmental values with respect to different social communities. And all the segments of the environment, the atmosphere, hydrosphere, lithosphere and biosphere are damage to a larger extend by the incalculable human activities may be in the name of development or management or due political pressure or security measures. This damage makes a permanent impairment in the structural and functional process of the natural phenomenon where the entire spheres are involved directly or indirectly. Therefore, a new culture need to develop and emerge to reduce the gap between the pace of development and alarming rate of environmental degradation for bringing a healthy environment, and maintaining and preserving the natural environmental components. We should change our lifestyle towards the sustainable development, a kind of reused and recycle livelihoods and should develop a scale of scientific understanding without miscalculating the traditional indigenous knowledge of the communities .

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1.7 PROBABLE QUESTIONS

What is environment? What are the four major components of the environment?

What is abiotic environment?

What is biotic environment?

Write short notes on troposphere.

Write short notes on stratoposphere.

What are the functions of natural environment?

How atmosphere is stratified (vertically stacked components)?

What is the effect of the ozone in the Stratosphere?

Can life exist without water? Is there any planet with water in the solar system?

How does climate change affect permanent ice on earth’s surface?

What is the air you breathe composed of?

What is lithosphere? Is it a solid shell or liquid sphere?

Define soil. How the soil is form?

UNIT-2: ENVIRONMENT- THE CAPITAL

UNIT STRUCTURE

2.0 OBJECTIVES

After going through this unit, you will be able to:

1. discuss the resources of earth and it's structure and function.
2. define sustainable yield so that we can manage our resources or environment (which is degrading day by day due to our activities) such a way that our future generation can sustain on it.
3. describe the concept of sustainable yield.
4. discuss the different hypothesis related to economic development and environmental degradation.
5. describe ecological security and how it relates to food security.

2.1 INTRODUCTION

Before going to the main topic we should have the very knowledge that what is 'environment'. Environ means surrounding; so environment is everything that surrounds human or surround us. The environment as capital concept has become widely adopted because it is both simple and appealing.

2.2 EARTH CAPITAL

All values supporting life on earth are called earth capital.

We can classify earth capital as

Earth Capital

Natural Earth Capital | Man-Made Earth Capital

Fig. 1.1 Solar and natural capital taken from
T. Miller (*Environmental Science*)

Natural capital is thus the stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future.

Besides the natural resources a variety of ecosystem functions are also provided as natural income. Forest for example not only act as wood production unit they also perform many other important ecosystem functions like preventing soil erosion, absorbtion of rain water and flood controling, providing habitat for a diversity of plant and animal species which may serve as foods or medicines for other species, absorbing the natural wastes of diverse life forms, generating oxygen and sequestering carbon from the atmosphere, they also affect the microclimate of their area, they are a key component of the hydrologic cycle, as well as providing aesthetic enjoyment and spiritual inspiration. The overall health of the forest environment and the creatures in it are maintained by the forest ecosystem. Ecosystem functions having particular value to human are called ecosystem services.

Services from Natural Capital

The general services provided by natural capital can be categorized into four divisions:

- *Provisioning Services* – provide resources used in production (timber, fish, etc.)
- *Regulating Services* – regulate ecosystem processes, such as decompositing organic wastes, purification of the air (by oxidation, etc.)

- *Cultural Services* -providing benefits of a spiritual, aesthetic, recreational or psychological nature; giving meaning to place, etc
- *Supporting Services* - regulate processes necessary to support all the other ecosystem services.

Examples of Natural earth capital:

Climate, recycling of vital chemicals, renewable energy resources, non-renewable energy resources, non-renewable mineral resources, potentially renewable resources, biodiversity and gene-pool, natural pest and disease control, waste removal and detoxification, soil formation and renewable, water resources and purification, air resources and purification, degradation mechanisms of microbes, hydrological cycles.

Examples of Man-made earth capital:

Built heritages, dams, academic institutions, highways, hospitals and schools, cultural heritages.

Based on the short human time scale, natural resources are classified into three categories. Table 1.1 lists the three categories of natural resources.

Table 1.1 Kinds of Resources

Categories	Description	Examples
1. renewable resources (perpetual resource)	Can be renewed, replenished or regenerated	Solar energy Geothermal energy Water power
2. potentially renewable	Can be replenished fairly rapidly (hours to decades) through natural processes	Forest trees, grassland grasses, wild animals, fresh lake and stream water, groundwater, fresh air and fertile soil
3. nonrenewable resources (exhaustible resource)	Exists in a fixed quantity and can de depleted much faster than they are formed New stores of these resources may not be available again for several thousands or even millions of years	Energy resources such as coal, oil, natural gas and uranium Metallic mineral resources such as iron, copper and aluminum which can be recycled Nonmetallic mineral resources such as clay, sand salt

We have a lot of resources around us to fulfill our needs. Some of them are finite, some are renewable but it takes time to replace or replenish them. Unfortunately, the unmanaged and rapid consumption of these resources has led to the exploitation of the natural resources and thus reducing the availability of these resources.

2.3 SUSTAINABLE YIELD AND ENVIRONMENTAL DEGRADATION

Common property resource: Resource that people normally are free to use Examples are clean air, fish in parts of the ocean not under the control country, migratory birds, gases of the lower atmosphere and the ozone content of the upper atmosphere (stratosphere).

Sustainable yield: The maximum volume of resource that can be extracted from a potentially renewable resource so that the resource remains renewable or the highest rate at which a potentially renewable resource can be used without reducing its availability.

In other words the sustainable yield of natural capital is the ecological yield that can be extracted without affecting the base capital itself, i.e. the surplus required to maintain ecosystem services overtime.

Environmental Degradation: When extraction volume of resources exceeds sustainable yield, it is termed as environmental degradation.

If a potentially renewable resource such as soil, grassland, forest or wildlife is extracted faster than it is naturally replenished and when such extraction continues, the resource becomes nonrenewable (on a human time scale) or nonexistent (extinct). Then it is considered as environmental degradation or depletion of resources.

Tragedy of commons

The concept of the Tragedy of the Commons is extremely important for understanding the degradation of our environment. The concept was clearly expressed for the first time by Garrett Hardin in his now famous article in Science in 1968. It unveils a new era of thinking for the first time among the social and environmental scientists, especially in relation to the over-exploitation of natural and economic resources, pollution of the environment, and over-population.

The basic idea of the concept is that if a resource is held in common for use by all, then ultimately that resource will be destroyed. "Freedom in a common brings ruin to all." To avoid the ultimate destruction, we must change our human values and ideas of morality.

Examples of Common Resources

1. Air. No one owns the air, it is available for all to use, and its unlimited use leads to air pollution.
2. Water. Water in the seas, estuaries, and the ocean is a common resource. But, water in lakes and rivers is often owned by cities, farmers, or others, especially in the western US.
3. Fish of the sea.

Hardin used a parable to illustrate the Tragedy of the common where a pasture is considered as common by herdsman to graze their animals. They can graze as many as and as long as the

number of men and animals are sustained by the carrying capacity of the land, as by disease, poaching or war. But in absence of these stresses, numbers can increase which in turn generates tragedy unless steps are taken to prevent it.
Sustainability is maintained in the pasture as long as the number of sheeps is below its carrying capacity. But going through general human nature and being rational to have more profit, more animals will be added. As result of this soon through free access to the commons, the pasture will be overgrazed and ruined.

In an oft-quoted passage, Hardin said: "Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destination to which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all".
Hardin also noticed that oceans of the world are subject to the Tragedy of the Commons.Due to overexploitation of fishes, turtles and other sea-foods; many species are reported to be threatened and in the verge of extinction.
Although many traditional societies are still there who act sustainably in well-defined areas, but on the high seas fishermen may see no point in throwing back undersized fish or breeding stock if other fishermen will come along and take them anyway.

Environmental degradation - loss of biodiversity

The Tragedy of the Commons, in various aspects underlies much of the degradation of our forests, soils, rivers, wetlands, coral reefs and oceans leading to massive losses of biodiversity of native flora and fauna. In each instance, the gain to the exploiter is much greater than any individual's share of the loss. There is urgent need to take proper steps to tackle the problems of our mis-use of rivers, estuaries and artesian water reserves by sharing but not polluting a common resource.

Pollution

In case of global pollution the tragedy acts in a reverse direction where it is not a matter of taking something out of the commons but of putting pollutants like seawage, chemicals and radioactive wastage into the soil or water, and noxious fumes, or gases such as oxides of sulfur(SOx) and oxides of nitrogen(NOx), dumped into the atmosphere. Moreover, the so-called "rational man" thinks that his share of cost in creating pollution is much less than the cost to rectify it. Thus we all are locked into a system of "fouling our own nest".

Since the air and seas around us cannot be fenced off, so the Tragedy of the Commons has been approached by other means - like laws or taxes which make it cheaper for the polluter to treat his pollutants than to discharge them untreated. The "greenhouse effect" and the ozone hole are global Tragedies of the Commons.

The major challenges facing the world today are to meet the demands of an increasing population and to reverse environmental degradation. As a result of which our land are degrading like soil erosion, salinization, water logging, loss of organic matter, decreasing biodiversity and desertification and thus reducing the productivity of our crop land.

Environmental degradation can occur in many forms either naturally or through anthropogenic means. When habitat is destroyed biodiversity get lost or natural resources are depleted and the environment is degraded. But now days the rate of environmental degradation through natural means is very few; most of them are directly or indirectly through human processes. Loss of rain forests, air pollution and smog, ozone depletion and the destruction of the marine environment are the largest area of concern.

After urbanization has taken pace, in many areas natural environment has been exposed to unmanaged waste which ultimately leads to deterioration of soil and water quality. In some places major disaster like oil spills have degraded the local environment.

Deforestation and logging industry have destroyed many tropical rain forests around the world. This has destroyed many natural habitat and the plants and animals endemic the area.

Increasing rate of industrial processes and automobile emission are the major source of air pollutants that results into photochemical smog, acid rain, stratospheric ozone depletion and global warming. CFCs or chlorofluorocarbons are the primary cause of ozone depletion which escapes from vehicle air conditioners.

Increasing runoff and decreasing infiltration over large area is another result of growing urbanization. Decreasing runoff in turn results into depletion of ground water, drying of springs and waterways, saltwater encroachment and others.

Ecosystem Degradation

Excessive use of fresh water, reduction in habitat and introduction of alien species leads to ecosystem degradation in fresh water. Overuse of water for industrial, personal, and agricultural needs causes habitat reduction and increase in pollution of the same. In China alone, over three quarters of 50,000 km of main waterways are so polluted that they no longer support fish life. Thailand's Chao Phraya River has enough heavy metals from industry, sewage from Bangkok and pesticides from agriculture to exceed the government norms of water pollution by a factor of 100.

Overexploitation of fresh water species results into an unsustainable ecosystem.

Alien species affect the ecosystem by population explosion and thus utilizing the resources required by the other native species as they are not evolutionally adapted. For example, lampreys have destroyed much of the native commercial fisheries of Canada's Great Lakes. Zebra mussels, an alien species, not only decrease local biodiversity, but also cause the American power plants about $100 million in damages annually.

Case study:

Saravanan.P, Arun Prasad.K, Sudha.G, Ilangovan.P, An assessment of environmental degradation: Case study of Avaniyapuram town panchayat, Madurai, International Journal of Environmental Sciences, Volume 1, No 7, 2011.

Land and water are the primary natural resources and improper management of such resources leads to severe environmental problem. The most common reason for the problem is the rapid population growth and unplanned urban expansion. The cities are expanding in all directions resulting in large scale urban sprawl and changes in land use. The spatial pattern of such changes is clearly noticed on the urban fringes, than in the city centre. Hence, the city fringe experience sudden growth but lacks in infrastructure facilities leading to various environmental issues.

The present attempt has been made to study the environmental degradation of the southern fringe area of Madurai city. The investigation is focused on Avaniyapuram town panchayat which comprises of three villages namely Avaniyapuram, Ayyanpappagudi and Kalkulam. Here, the geomatic technique is used to analyze the environmental issues as it gives an apparent spatial dimension of the problem, which otherwise cannot be achieved through a traditional approach. The major environmental problems identified are the unplanned residential expansion, ground water depletion and improper solid waste disposal. The analysis is carried out sequentially in three stages. Initially the land use change detection is done for two time points through remote sensing and cadastral data for the region and secondly the quality of the ground water is assessed by collecting water samples and testing its chemical parameters in laboratory. Finally, the solid waste disposal site has been surveyed and the ground water around the site is tested. It is inferred from the analysis that water bodies has been encroached for residential use and drinking water has been depleted in western and south part of the study area and improper solid waste disposal has made 32 % of ground water unfit for domestic purpose.

In this study, apart from landuse change detection analysis two problems have been identified as major reason for environmental degradation. The identified environmental problems are ground water depletion in the Villapuram tank area and Kalkulam solid waste disposal. This study covers three major aspects

i. Landuse / landcover change detection
ii. Ground water depletion due to tank encroachment
iii. Solid waste disposal and effect of sewage plant on ground water.

2.4 KUZNET'S HYPOTHESIS AND ENVIRONMENTAL KUZNET'S CURVE

According to Kuznets, income inequality increases until a critical income level is attained, after which inequality begins to decrease. The graphical representation of this hypothesis is an inverted U shaped curve.

Researchers have also examined the Kuznets hypothesis in other situations with one of the most well known being the relationship between inequality and environmental factors (such as pollution intensity).

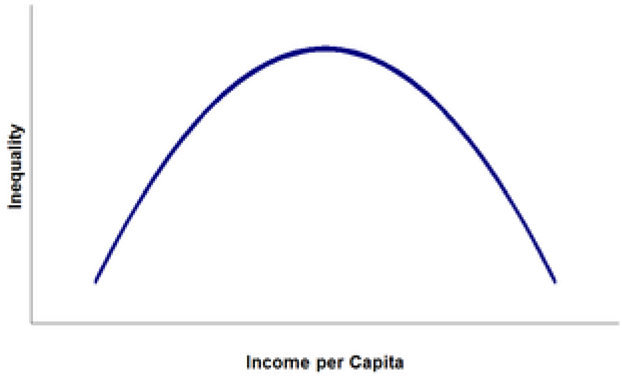


Fig 2: Kuznet's curve – inequality grows with increase in per capita income, which finally falls when income increases further

The environmental kuznet's curve (EKC) hypothesized relationship between various indicators of environmental degradation and income per capital. In the early stages of economic growth both environmental degradation and pollution increases, but beyond some level of income per capita the trend reverses. That is at high income level economic growth make effort to protect the environment. This implies that the environmental degradation (impact indicator) is an inverted u-shaped function of income per capita.

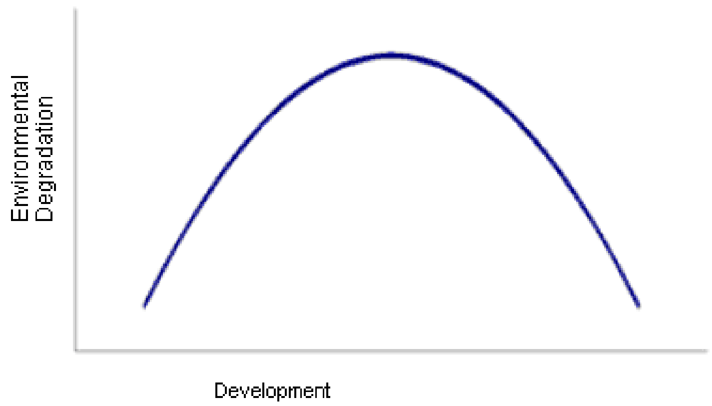


Fig 3: Environmental kuznet's curve (EKC)

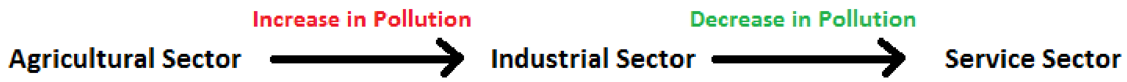
A better understanding of the effect of economic growth and technological changes on environmental quality leads to the fact that most indicators of environmental degradation are monotonically rising in income. But this is not a simple function of income alone. There are certain time related effects which reduce environmental impacts in some countries at all levels of income. However, the increase in pollution and other degradation overwhelms the time effect in rapidly growing middle income countries. But since growth is slower in wealthy countries, the pollution reduction efforts can easily overcome the scale effect. The origin of the apparent EKC effect takes place here only.

Environmental Kuznets Curves

Inverted U shape explained by Nordstrom and Vaughan are as follows –

- Clean environment is assumed to be a normal good so, the demand for a clean environment is income elastic. Pollution generally increases with increase in per capita GDP, but after a certain per capita GDP achieved pollution decreases with the increase in per capita GDP. Because, higher the per capita GDP, more people care about a clean environment.

- There are also some structural changes with increasing trade. Developing countries shift from agriculture sector to industrial sector (increase in pollution) during process of development and after reaching certain per capita GDP, they move from industrial sector to service sector (decrease in pollution).



Empirical evidence has shown that some pollutants follow environmental Kuznets curve and some do not. Mani and Wheeler (1999) found that the industrial water pollution first rises sharply with income and after a certain level of income it remains constant. Rothman (1998) showed that in the case of consumption based pollution like CO_2 and municipal waste, doesn't follow environmental Kuznets curve.

Suri and Chapman (1998) believed that the shape of environmental Kuznets curve influenced by exports and imports. If increase in per capita GDP leads to stricter environmental regulations and a comparative disadvantage in pollution intensive industries and if international trade flows are determined with these factors, then developed economies will change the composition of their production in favour of the environment. Pollution haven hypothesis can be seen as a possible explanation of decreasing segment of the environmental Kuznets curve. If the production is determined by these many factors, it is very natural that developed country will take the upper hand and thus some country must be the recipient of the polluting industry.

2.5 POLLUTION HAVEN HYPOTHESIS

Pollution haven hypothesis denies the environmental kuznet's curve and thus the hypothesis says that developed countries have clean environment only because they have shifted pollution causing industries to developing countries.

In today's world, in all countries liberalization become a common agenda to promote trade and foreign direct investment (FDI) for the development of the nation. While looking to the one aspect of the nation they become blind to the other most important site; as their concerned to environment become very less, mainly the least developed and developing countries. On the other hand developed countries are having strict environmental regulations. So, Pollution haven hypothesis says that highly pollution intensive industries have been migrating from developed countries to the developing countries as the cost of production of such industries increases at the home country. But in developing countries there are not such strict environmental regulations, so dirty industries of developed countries find these countries more attractive with lower wage rates. So, the cost of production is quite low in comparison with the developed countries. At the same time developing countries also get benefits because they need financial resources for industrial development. Consequently, developing countries provide pollution havens for pollution intensive industries. I addition to this due to these migrations developed countries are becoming net importer of some environmental goods, where previously they were exporter of those goods.

Various definations of pollution haven hypothesis given by various authors-

Field identifies two parts of this hypothesis –

1. Developed countries having strict environmental standards encourage pollution intensive industries to
   move to developing countries with less strict environmental standards.
2. On the other hand, developing countries also try to attract pollution intensive industries to get FDI and to increase the industrial growth.

According to Liddle Pollution haven hypothesis is simply when low environmental standards become the source of comparative advantages which lead to the shift in trade pattern.

Fredriksson says that reduced trade barriers result in a specialisation in pollution intensive industries by developing countries.

Background study of Environmental Kuznet's curve and pollution Haven Hypothesis:

Free trade is said to have contradictory impacts on environment, both increasing pollution and motivating reductions in it. But many economists are of the opinion that trade is not the root cause of environmental damage. Antweiler et al. (2001) and Liddle (2001) argue that trade may be good for environment. With the help of *technological effect*, trade may improve the environmental quality. Due to the rise in income through trade, environmental regulations are made stringent and this evolves the scope for new innovations for reducing pollution. Thus, according to them foreign direct investment in underdeveloped countries may help in reducing pollution through transfer of technology.

In a high-income country industries generally face higher regulatory costs than its counterpart in a developing country (Mani and Wheeler (1998)). Under these circumstances the pollution intensive industries will have a natural tendency to migrate to countries with weaker environmental regulations (Copeland and Taylor (1995)). This is referred to as the *Pollution Haven Hypothesis (PHH)* (See, Bommer (1999), Cole (2003, 2004)). The *PHH* refers to the possibility that polluting industries concentrate in developing countries with low environmental standards. The *pollution haven hypothesis* (*PHH*) predicts that, taking advantage of free trade and the low environment monitoring, multinational firms have the tendency to relocate the production of their polluting goods to developing countries.
Thus, developing countries become 'haven' for the world's polluting industries and developed countries are expected to benefit in terms of environmental quality from trade, while developing countries will lose. In other words, the *PHH* basically suggests that countries

having strict environmental standard shift all their polluting industries to the poor countries having poor environmental standards. According to Rotham (1998), cleaner environmental quality is also a function of consumer preferences which differs in the rich and the poor countries as people in the developed countries try to distance themselves from environmental degradation associated with their consumption. This phenomenon of *distancing* may be a possible source of *EKC* results. Therefore, the changes in international specialization under which poor countries engage in *dirty* and energy intensive production while rich countries specialize in *clean* and service intensive production might lead to the inverted U-shaped *EKC* curve.

2.6 ECOLOGICAL SECURITY

Dr. Amrita Patel, Chairperson of the Foundation of Ecological Security (www.fes.org.in) and National Dairy Development Board gives definition of ecological security as follows:

"Ecological security is maintaining the natural integrity, and in a state of stability, as far as present circumstances can possibly permit, the optimum functioning of the vital processes of Nature's Biological Systems that sustain the myriad life forms – plant and animal, both macro and micro, which through their symbiotic relationship, complementary interaction and adaptation to their abiotic environment over millions of years, have thus far supported the evolution of all life on Earth, and not the least human. It is the matrix of interlocking biotic and biotic forms, in their totality, that constitutes the critical biological foundations of life on Earth". Her comprehensive definition of ecological security, thus, is an attempt to touch the deeper core of the matrix in which life originated, evolved and in which it is evolving, blossoming and sustaining.

The Netherlands Pugwash Group, together with International Student/Young Pugwash (ISYP), has initiated a Pugwash Study Group on New Challenges to Human Security. In calling their first Pugwash Workshop and ISYP pre-workshop, which were subsequently held in Wageningen, The Netherlands from 16-18 June 2006.

The Wageningen Call offers some helpful commentary on the nature of the 'problematique' as it relates to ecological security.

1. Environmental issues tend to have a long 'incubation' period before they become a threat to human security.

2. Even if appropriate remedial measures are taken, the time for recovery is long and exceeds the time scale of most decision makers.

3. If species are lost or ecosystems are destroyed, recovery within human time scale is impossible.

4. Environmental (ecological) degradation and natural resource scarcity contribute to migration and conflicts and deprive future generations of unique resources of which we cannot know the value.

5. These losses may impose severe constraints on future societies.

6. While a long-term approach to present policy making for ecological security is selfevident, the short-term timeframes of politicians, economic considerations, and a discourse of ‘national interest’ tend to push the ecological agenda down the ladder of policy priority.

7. All the above characteristics contribute to the lack of urgency for environmental (ecological) issues at the present juncture and to the overall trend where they are losing prevalence in policy and public discourses.

8. However serious the costs may be to future generations, these do not form a constituency to which decision-makers feel responsible or which can hold them accountable.

To this assessment it is also added that (a) humans continue to see themselves as being separate and distinct from an ‘environment’ rather than as being an integral part of an ‘ecology’ consisting of the whole community of life on Earth; (b) that humans have no sense of identity as a species and no framework for inter-species ethics, and (c) that the dominant human sense of proper relationship with Earth is that of ‘use’, and (d) that human numbers and expectations continue to grow.

Food security and Ecological security

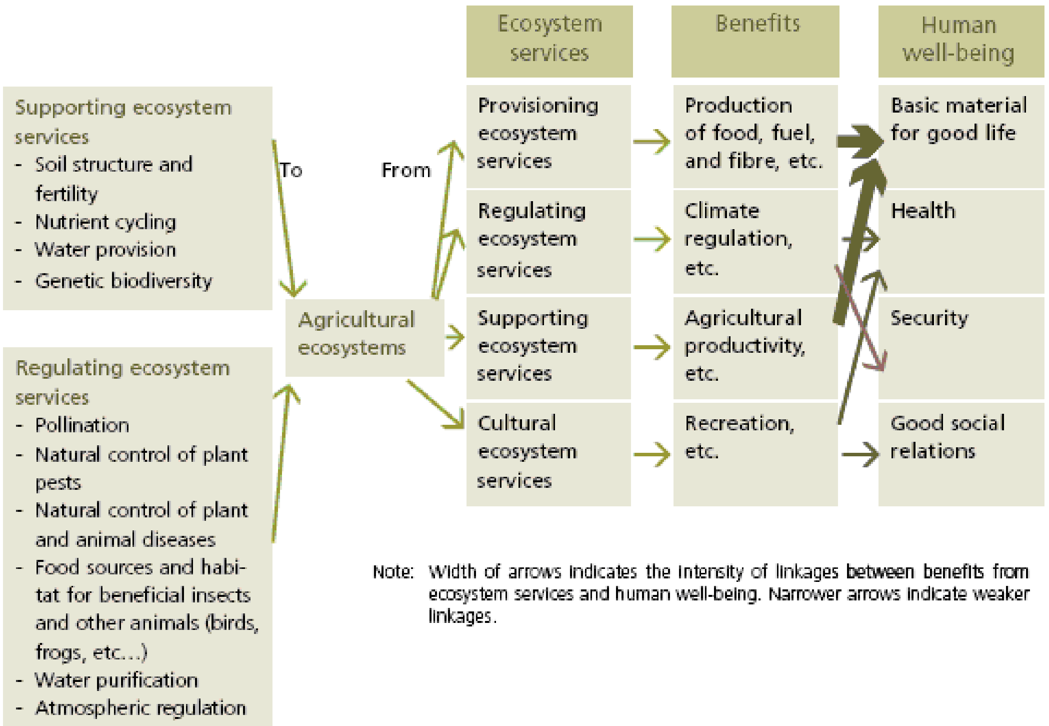
Impacts of accelerated food production on ecosystems and ecosystem services

As a result of increased agricultural production and greater stability of food supply around the world, food security has improved, while this has been accompanied by a significant decline in the state of ecosystems and the services that they provide. Agriculture plays a major role in global environmental changes in terms of changes in land use, land cover and irrigation that affect the global hydrological cycle in terms of water quality and quantity.

Agricultural ecosystems provide many benefits in various aspects of human well-being, such as adequate livelihoods, sufficient nutritious food, health, secure resource access and security from disasters. However, if agriculture is not managed properly, it can lead to reduced productivity or increased production costs as a result of problems such as pest damage, competition for water from other ecosystems, nutrient run-off and sedimentation of waterways and in turn incurred significant societal costs.

Furthermore, there is an increasing risk of ecosystem regime shifts, abrupt reorganizations of ecosystems from one relatively stable state to another, which might lead to catastrophic changes in ecosystem services. The declines in many ecosystem services caused by increase in agriculture might also affect the supply of the services like pollination, which are of high importance to agriculture itself. To design appropriate policy measures and management approaches, however, there is a critical need sufficiently to understand the trade-offs that may occur between provisioning services and other ecosystem services, in addition to their impacts on human well-being and distribution between societal groups.

Fig 4: Ecosystem services to and from agriculture, and linkages between human well-being and benefits obtained from ecosystem services that are provided by agriculture.



Source: UNEP Policy Series, ECOSYSTEM MANAGEMENT ISSUE NO. 4, JUNE 2011, Food and ecological security.

The First Victims of Ecological Insecurity

The poor are directly dependent on nature for their livelihoods. Environmental degradation and ecological disaster put the life of the poor into a kind of mess. Healthy ecosystems supplying fodder, fuel wood, minor timber, medicines, wild foods, etc. on sustained basis provide sustainable livelihoods for the poor. Poor are often accused of causing environmental deterioration and pollution.

Environmental conservation must go hand in hand with economic development because any economic development which destroys the environment will create more poverty, unemployment and diseases and thus cannot even be called economic development. It may just be the transfer of resources from the poor to the rich. This is because the poor depend on nature for their daily survival – for them the Gross *Natural* Product is more important than the Gross *National* product. Environmentally destructive economic development will lead to more poverty of the poor and destroy their livelihood resource base. The environmental problems facing India are different from those facing the affluent countries and have more immediate effects on the health and livelihood of the poor. Ecological poverty may, in fact, be the starting point of dealing with economic poverty.

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2.8 PROBABLE QUESTIONS

A. Multiple Choice: Choose the one best answer for each question.

1. A nonrenewable resource is one that
a. can be used only once.
b. is an element.
c. is involved in a biogeochemical cycle.
d. are depleted much faster than the rate at which they are formed.

2. Which of the following is a renewable resource?
a. uranium as source of energy c. natural gas
b. solar energy d. wood

3. A resource that is destroyed when used, but can be replaced is said to be:
a. recyclable c. renewable
b. nonrenewable d. potentially renewable

4. Which of the following does not belong to the natural capital/natural resource?
a. air b. land c. water d. energy from the sun

5. Which of the following can not be depleted by human activities?
a. trees b. solar energy c. natural gas d. coal

6. Which of the following is potentially renewable?
a. wood b. fish c. corn d. all of them

7. Which of the following practices makes soil infertile?
a. use of fertilizer b. green manufacturing
c. extensive agriculture d. use of compost matter

B. Short Answer/Essay: Be concise and relevant (to environmental science).

1. Give two environmental examples of the Tragedy of the Commons.

2. Explain the difference between an environmentally sustainable society and an unsustainable society.

3.List three root causes of environmental problems. For each, provide one sentence explaining what environmental problems the root cause produces.

4. What are the greatest threats to aquatic biodiversity?

C. Define the following terms:
1. Earth capital, 2. Potentially renewable resources,
3. Sustainable yield, 4. Environmental degradation,
5. Pollution Haven hypothesis, 6. Kuznet’s curve,
7. Ecoligical security

D. Explain :

1. Developing countries working as a dumping ground for developed countries– (pollution haven hypothesis).
2. Differences between renewable and nonrenewable resources.
3. Air pollution (as a case of tragedy of commons).

E. Activity:

1. Make a chart of the resources available in your place and classify of your own way.
2. Analyse a case study of environmental degradation of your region.

UNIT-3: ENVIRONMENT AND POPULATION

UNIT STRUCTURE

3.1 OBJECTIVES

Human population is the inseparable component of the environment. It is evident that human populations can shape and are shaped by their environment. If we observe closely to the present scenario of environment, it is clear that most of the degradations are caused due to increased number of human population. But before understanding the role of population in making or degrading the environment one must know what constitutes the population and their socio-economic status in a particular region. And for that one should know "what is demography?" Demography is the term used to describe the study of human population of a geographic area. After going through this unit, you will be able to:

- Discuss population's size, growth and distribution of the World as well as of our own country i.e. India.
- Describe the dynamic processes of population change namely fertility, mortality and migration. Discuss population Explosion and the factors that contribute to the population explosion.
- Describe the process of urbanization

- Discuss the effects of population growth in the field of resource depletion, human health and food security.

3.2 INTRODUCTION

As we all know that problems arising from rapid population growth have now become worldwide concern. To understand the various phenomena underlying the pattern of population growth and its impact on the society as well as on environment, Demography has been developed. So we are going to study about the Demography of world and India in details. Before starting the Demography chapter let us give a look on the population related problems.

Problems that are arising due high population growth include mainly overpopulation, diseases, unprovoked crime, scarcity of resources, refugee migrations, the increasing erosion of nation states and international borders, and empowerment etc.

This particular unit "**Population and Environment**" emphasizes the issues related to population and its relation to environment. **1.2.1** Will deal with the demography, its definition, sources of demographic data and the processes that bring about changes in population size. **1.3** includes the population growth of world and India. **1.4** deals with the population explosion, urbanization and migration. Fourth chapter describes about the resource depletion, environment and human health and lastly about food security related to the population growth.

Demography or the study of population is scarcely three centuries old. The present, however, is a period of extraordinary activity in the study of population due to the fact that after the Second World War, vast changes have occurred in many aspects of life due to rapid population growth in a large number of countries of the world. The developing countries that became independent generally after the Second World War launched their programmes of economic and social development to raise the standard of living of their people; but, in some countries, the economic development programmes have failed to keep pace with the rising tide of population and they have, therefore, not been able to ensure a higher standard of living standard of living for their people (M.K. Premi; 2003).

DEFINITION OF DEMOGRAPHY:

The term "Demography" is derived from two Greek words, *demos*, the people, and *graphy*, to draw or write. The term was first used by Guillard in 1855. According to the definition given by Cox in 1970, the demography is "The study by statistical methods of human populations involving primarily the measurement of size, growth and reduction of the numbers of people, the proportions living, being born or dying within some area or region and the related functions of fertility, mortality, or marriage."

Some other writers have taken a more comprehensive view in defining the discipline of demography that covers more clearly its nature and scope. Definition given by Hauser and Duncan in 1959 "Demography is the study of size, territorial distribution, and composition of population, changes therein, and the components of such changes, which may be identified as fertility, mortality, territorial movement (migration), and social mobility (change of status)"

In this definition composition of population implies (1) such traits as age, sex, race and ethnic origin (the biological or fixed traits), (2) such life cycle attributes as educational level and marital and household status; and (3) such variable characteristics as occupation, socio-economic status, income, etc.

Population studies can be automatically linked to many other social science disciplines such as Economics and Demography, Geography and Demography, Sociology and Demography, Political science and Demography, History and Demography, Psychology and Population, Law and Population.

SOURCES AND NATURE OF DEMOGRAPHIC DATA

Population size, its distribution, and composition are basically static aspects of demography and data relating to them are usually obtained by taking population censuses at regular intervals. In India, as in many other countries, a large mass of demographic data is collected regularly through nationally sponsored sample surveys. The major sources of demographic information are as follows

1. Population census
2. Civil registration system and population registers
3. Sample surveys
4. Administrative records, and
5. Parish registers and archival records.

3.3 POPULATION GROWTH AND DISTRIBUTION

3.3.1 THE WORLD POPPULATION GROWTH AND DISTRIBUTION

About 3 million years ago existence of human being came into this earth. As time passed, introduction of agriculture among the human population brought about a new era because it leads to a settled lifestyle among them. Day by day new concepts had been developed among the settled population. Concept of community also had developed and it helped a lot in population growth.

Industrial revolution that took place in 18^{th} century in Europe has brought a tremendous change in the pattern of population growth. In that period death rate was considerably low because famines, epidemics had diminished due to increase in the knowledge and evolution of new medical therapies among the people. The twentieth century witnessed an unprecedented rapid improvement in health care technologies and access to health care all over the world.

Population realized these changes and took steps to reduce their fertility but the decline in fertility was not so steep. As a result the global population has undergone an unfold increase and reached 7 billion in 2011.

According to the census done by the United States Census Bureau, the estimated number of world population is 6.976 billion. But according to a separate estimate by the United Nation it has already exceeded 7 billion. According to United Nations Population Fund estimate on 31st October 2011 world population has reached 7 billion which means that the world is adding the largest numbers to its population than in any time in history. Despite the fact that the annual population growth rate has declined to 1.2 percent per year, world population grows by about 83 million annually. If the same growth rate had applied in 1950, only 30 million people annually would have been added to the world total. Both the sixth billion and seventh billion were reached in the same number of years: a record of 12 year. The highest rates of population growth were seen during 1950s and for a longer period during the 1960s and 1970s. The growth rate peaked at 2.2% in 1963, and had declined to 1.1% by 2009. Table 1 shows the population growth from AD I to2011.

Table1: World population growth from AD I to 2011

WORLD POPULATION GROWTH	
Christian era AD I	------ 300 million
1650	------ 1500 million
1750	------ 760 million
1804	------- 1 billion
1927	------- 2 billion
1960	------- 3 million
1987	------- 5 billion
2000	------- 6 billion
2011	------- 7 billion

It is estimated that the population of the world reached one billion for the first time by 1804. It would be approximately another 123 years before it reached two billion in 1927, but it took only 33 years to rise by another billion people, reaching three billion in 1960. Thereafter, the global population reached four billion in 1974, five billion in 1987, six billion in 1999 and finally cross seven billion in October 2011. Growth can be calculated as the following way

Growth rate =(change in population size) / (Base population × Number of years)×100

Table2: Estimated growth rate from 1600-2011.

Following are the estimated growth rates of in between the years

Year	Growth rate
1600-1800	0.3%
1850-1900	0.5%
In mid 1960	2.0%

In mid 1980	1.7%
In mid 2000	1.4%
2009	1.1%
2011	1.09%

Source: Central Intelligence Bureau, US

The explosive growth did not occur in entire world it was in fact almost completely confined to developing countries--- Africa, Asia, Latin America and still continues. Today about 97% of population growth takes place in these developing countries. Amongst the developed nations, US are the only one which already has high birth rate and steady migration (immigration) shows a sizable growth of population. After World War II population growth doubled and increased again and again. It took all the human history to reach a world population of 1.6

DYNAMICS OF POPULATION CHANGE: There are three dynamic processes of population change namely
FERTILITY- Fertility can be measured by the following processes
Crude birth rate b)General fertility rate c)Age specific fertility rate
Total fertility rate e) Gross reproduction rate f) Net reproduction rate
Child women ratio.
MORTALITY- Mortality can be measured by -----
Crude death rate b) Age specific death rate c) Infant mortality rate
d) Cause specific death rate e) Expectation of life at birth.
MIGRATION- we will discuss migration in later chapters.

DEMOGRAPHIC TRANSITION: Historically population passes through different more or less well defined stages in terms of developed fertility and mortality. As a generalized explanation of the process of mortality and fertility these theories referred to a stage of high fertility and high mortality in a simple agrarian society which finally transforms itself into a condition of low fertility and low mortality after passing through different stages----
High Stationary stage--- where birth rate and death rate are very high.
Early expanding stage--- where birth rate continues to be high and death rate reduces.
Late expanding stage--- where death rate falls but more rapidly falling birth rates.
Low stationary stage--- birth rate and death rate both comes down.
Decline stage--- where death rate exceeding birth rate.

billion at the beginning of the 20th century.

POPULATION OF CONTINENTS ACCORDING TO THE 2011 CENSUS

Table 3: Population by continent along with their population density

CONTINENTS	DENSITY (Inhabt/km^2)	POPULATION (MILLION)
ASIA	86.7	4,140,336,501
AFRICA	32.7	994,527,534

EUROPE	70	738,523,843
NORTH AMERICA	22.9	528,720,588
SOUTH AMERICA	21.4	385,742,554
OCEANIA	4.25	36,102,071
ANTARCTICA	0	4,490(varies)

Source: www.cia.gov

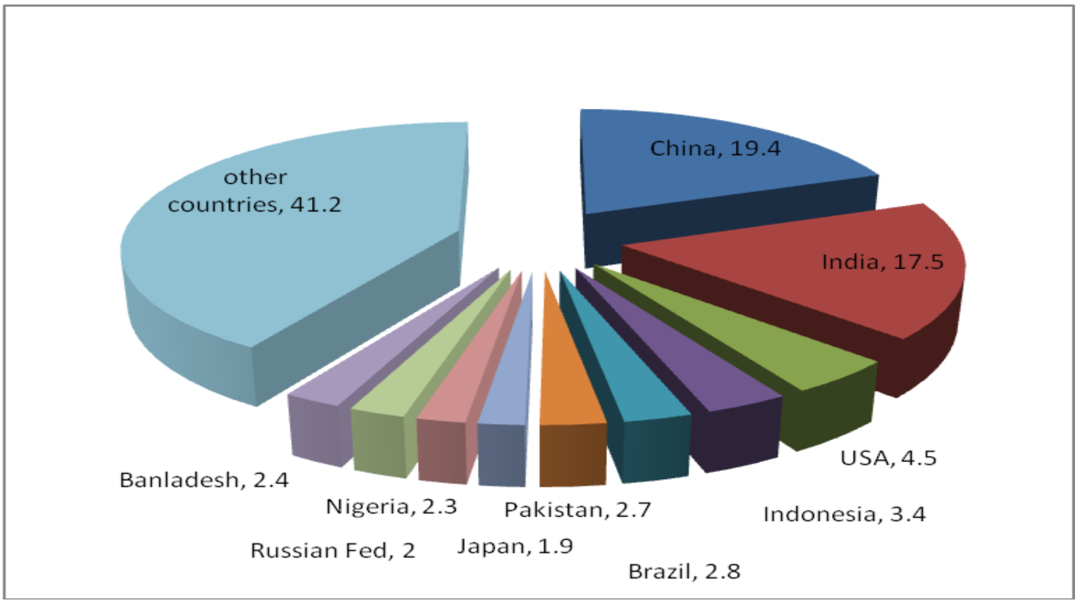
Table 4: Top ten most populous country in the world in 2011

Top ten most populous country in the world

Country	**population (million)**
CHINA	1,336.72
INDIA	1,189.17
UNITED STATES	313.23
INDONESIA	245.61
BRAZIL	203.43
PAKISTAN	187.34
BANGLADESH	158.57
NIGERIA	155.22
RUSSIA	138.74
JAPAN	126.48

Source: Central Intelligence Agency, US (July 2011 est.)

Fig1: PERCENTAGE OF POPULATION SHARE IN TOTAL WORLD POPULATION



Source: Population Division and Department of Economic and social affairs of the United Nation Secretariat.

3.3.2 SIZE, DISTRIBUTION AND GROWTH PATTERNS OF INDIA'S POPULATION:-

India's population rose to 1,210,193,422 billion people over the last 10 years i.e. from 2001-2011, an increase by 181 million, according to the census 2011 and is the second most populous country in the world and comes next only to China. According to the census 2010, India's population growth is slower for the first time in nine decades.

The population, which accounts for world's 17.5% population, comprises 623.7 million males and 586.5 million females, said a provisional 2011 census report. China is the most populous nation accounting for 19.4 % of the global population. At present a little more than one out of every six persons in the world is from India.

Population growth in India during 20th century can be divided into 4 distinct phases

1901-1921--- stage of stagnant population growth
1921-1951--- stage of steady growth
1951-1981--- stage of rapid growth
1981-2001--- stage of high growth with a definite sign of slowing down.

The year 1921 is called great divide because it distinguishes the earlier period of checkered population growth from a period of moderately increasing growth. Between 1896 and 1897 and in the period of 1911-1921 there was wide spread famines and epidemics. In 1907 certain famines in Uttar Pradesh, plague in Bengal and Mumbai. Again 1911-1921 it was an influenza epidemic causing 7% of the total population die. Table 5 shows the population growth rate and decadal increase of population from 1891 to 2011.

TABLE 5: GROWTH OF INDIA'S POPULATION SINCE 1891:

YEAR	TOTAL POPULATION	DECINIAL INCREASE	DECINIAL GROWTH RATE
1891	235.9	-	-
1901	238.4	2.4	1.0
1911	252.1	13.7	5.7
1921	251.3	-0.8	-0.3
1931	279	27.7	11
1941	318.7	39.7	14.2
1951	361.1	42.4	13.3
1961	439.2	78.1	21.6
1971	548.2	108.9	24.8
1981	683.3	135.6	24.8
1991	843.9	160.6	23.5
2001	1027	180.6	21.34
2011	1210	181.4	17.64

Source: census of India

Table 6: Provisional census 2011(Govt. of India)

	POPULATION

PERSONS	1210.2 million
MALES	623.7 million
FEMALES	586.5 million

SOME FACTS FROM POPULATION CENSUS 2011

The percentage decadal growth during 2001-2011 has registered the sharpest decline since independence. For 2001-2011, this decadal growth has become 17.64% a decrease of 3.90 percentage points from 21.34% for the period 1991-2001.

2001-2011 is the first decade (with the exception of 1911-1921) which has actually added lesser population compare to the previous decade.

Uttar Pradesh continues to be the most populous State in the country with almost 200 million people.

3.4 POPULATION EXPLOSION

If we observe the current trend in population growth that we could see that in most of the developing countries the populations are increasing in an exponential way. That is the **population explosion** which is a curse for the developing countries like India. The literal meaning of **population explosion** is a “pyramiding of numbers of a biological population” (Webster’s dictionary).

Followings are the possible reason for such population explosion happening in the developing countries.

1. The increase in birth rates due to medical improvements.
2. Decrease in death rates due to better medical facilities and advancements in the field of medicines.
3. Immigration to better developed countries due to several reasons like better job opportunities, war, and natural causes like flood, earthquakes etc.

Let’s discuss about some of the reasons in brief---

3.4.1 REASONS FOR INCREASE IN POPULATION

BIRTH RATE—

Poverty: - Unfortunately as the population increases the resources of a particular place do not increases. India is currently facing a vicious cycle of population explosion and poverty. One of the most important reasons for this population increase in India is poverty. The people, who have to struggle to make two ends meet, produce more children because more children mean more earning hands. The infant mortality rate among such families is higher due to lack of facilities like food and medical resources. Thus they produce more children assuming that not all of them would be able to survive.

Religious beliefs, Traditions and Cultural Norms:-

The educational facilities are not increasing as the population increases, so most people still strictly follow ancient beliefs. India's cultural norm is for a girl to get married at an early age. At an early age one girl child hardly gets an opportunity to be educated. So, in most of the cases it is seen that girls start bearing children throughout their lifetime. This results in the increase of the global fertility rate.

DEATH RATE

It is seen that decrease in the death rate also helps in the population explosion. Possible reasons are:

In developed countries economic developments, improvements in the supply of food and nutrition and rising levels of income levels, better methods of food storage, sanitary reforms and public health measures contributed towards the decline in the mortality rate.

In developing countries major decline in the mortality rate in past decade attributed by technological advances in the prevention and control of diseases and advanced public health and medical services.

MIGRATION

Migration plays an important role in the population growth in both developed and developing countries. In countries like the US immigration plays an important role in the population increase. However, in countries like India, immigration plays a very small role in the population change. Although people from neighboring countries like Bangladesh, Pakistan and Nepal, migrate to India. During the 1971 war between India and Pakistan over Bangladesh, the immigration rate increased tremendously.

We will discuss about the affect of population explosion in the following segments such as urbanization, resource depletion and environment and human health.

3.5 URBANIZATION

Around 3 billion people virtually half of the world's total population now live in urban settlements as cities are playing dominant role in the global economy as centers of both production and consumption. Before going details into the topic urbanization we should first discuss about what is called urban? And what are the factors that influence the process of urbanization.

3.5.1 DEFINITION OF URBAN

According to the census 1951, India; a place was considered as urban if it follows some criteria. Those are 1. If the area had Municipality, Cantonment Board, Notified Area Committee, Town area committee, etc.

2. Population size should be 5000 or more per square km.

In addition to these criterions a lot of discretionary powers are given to census officers to declare other places as urban if they exhibit urban characteristics. In 1961 Census, the Census Commissioner for India has made some changes to the Urban definition. The definition of Urban has included some changes such as (a) a place should have a population of 5000 or more persons. (b) Its population density should be more than 1,000 persons per square mile and (c) at least three fourths of the working population should be engaged in non agriculture activities.

In 1981 the definition was again changed now includes these points—1. The population density should be 400 persons per km^2. 2. At least three fourths of the working population should be engaged outside Primary Sectors. In the 1991 and 2001 censuses, conditions are (a) at least 75% of the male working population should be engaged in non- agricultural pursuits.

3.5.2 URBANIZATION IN INDIA

Urban population has been growing at a faster rate than that of rural population. This growth has been higher between 1941-1951 and 1971-1981.

In 1941-1951 periods, early phase of Industrialization takes place and again growth of war industries and partition of India also takes place in that period only. Low growth of rural population in 40's is due to exodus of few millions Muslims from India to Pakistan. In 1971-1981 a large number of new towns appeared and there was substantial rural to urban migration.

GROWTH OF CITIES:

In India, settlements with population of 100000 or more are termed as cities in comparison to towns that have population of less than 100000.the former is also known as class I city.

In India depending on size of population we have 6 classes of urban cities---------

Class 1--- population 1 lakh or more
Class 2--- population 50,000 to 99,999
Class 3--- population 20000 to 49,999
Class 4--- population 10,000 to 19,999
Class 5--- population 5000 to 9,999
Class 6--- less than 5000

The Census Organization introduced the concept of "Urban agglomeration" in the 1971 census. The number of urban agglomerations and cities with population of one lakh and above increased from 300 in 1991 to 393 in 2001.

In 1991 there were 393 cities and urban concentration in India. It is further observed that there are 23 metropolies in 1991. In 2001 these million plus cities have increased to 35 with a total population 107.9 million compromising 37% of total urban population.

This concentration of population is largely due to the fact that big cities provide greater job opportunities. This leads to heavy congestion of population leading to many fold urban problems including city and environment. 30% of metropolitan people live in squattering settlement.

Table 7: Population of India by residence

Source: Various Census reports of India

CENSUS YEARS	NUMBER OF URBAN AGGLOMERATION/TOWN	TOTAL POPULATION	URBAN POPULATION	RURAL POPULATION
1901	1827	238396327	25851873	212544454
1911	1825	252092290	25941633	226151757
1921	1949	251321213	28086167	223235046
1931	2072	278977238	33455989	245521249
1941	2250	318660580	44153297	274507283
1951	2843	361088090	62443709	298644381
1961	2363	439234771	78936603	360298168
1971	2590	598159652	109113977	489045675
1981	3378	683329097	159462547	523866550
1991	3768	844324222	217177625	627146597
2001	5161	1027015247	285354954	741660293
2011	7935	377 millions	833,087,662	377105,760

Table 8: Percentage distribution and population by rural-urban residence

Year	Rural (%)	Urban (%)
1901	89.16	10.84
1921	88.82	11.18
1941	86.14	13.86
1961	80.92	19.08
1981	76.64	2336
1991	74.29	25.71
2001	72.22	27.78

Table 9: The rural-urban distribution of India's population from 1901 to 2001

Percentage distribution of			Decadal growth rate	
Year	Rural	Urban	Rural	Urban
1901	89.16	10.84	-	-
1911	89.71	10.29	6.40	0.35
1921	88.82	11.18	-1.29	8.27
1931	88.01	11.99	9.98	19.12

1941	86.14	13.86	11.81	31.97
1951	82.71	17.29	8.79	41.43
1961	82.03	17.97	20.49	26.41
1961	80.92	19.08	19.01	34.21
1971	80.09	19.91	21.86	38.23
1981	76.64	23.34	19.32	46.14
1991	74.29	25.71	20.01	36.47
2001	72.22	27.78	17.97	31.13

3.5.3 ENVIRONMENTAL PROBLEMS ASSOCIATED WITH URBANIZATION

Urban centre creates environmental hazards both for itself and surrounding rural areas, by bringing about large scale imbalance and in ecological setup. In India & many developing Nations, Urban centres are already unable to provide adequate houses, potable water, drainage system, growing energy needs and efficient systems of waste management. As town grows into cities, it spreads horizontally destroying its own open space and green areas.

One third of the World's poor population lives in Urban areas. Urban poverty leads to environmental problems. They live in urban slums, plagued by serious lack of infrastructure such as adequate water supply, poor sanitation and housing etc.

As the cities spreads & spills outwards it decimates the surrounding agricultural land and natural resources. Unplanned urban sprawls, environmental insensitive industrialization and motor vehicles exhaust fumes leads to a high incidence of respiratory diseases affecting 100's of millions of people.

Sewage in big cities pose a great problem especially after a few decades. Water stays and flood the cities. Flooding, besides damage to building disruption transportation and lead to outbreak of epidemics.

Industrialization and urbanization have resulted in propound deterioration of urban air qualities. People in urban areas are exposed to more pollutants in terms of quantities and types.

Waste management is already a pressing environmental issue in almost all urban areas in India.

3.6 MIGRATION

Migration is one of the variable among the others eg fertility, mortality etc which is regarded as the third variable in bringing changes in the size and structure of the population of any given area. Hence, it becomes an important component of population studies.

Every member of a population resides at some time-point or a series of time-points in space. A change in the location of his/her residence is termed as spatial mobility. This mobility can take place in three different ways:

- When the change of residence is across national boundaries. This leads to international migration.

- When the changes of residence is from one community to another while remaining within the country. This is called internal migration.
- When the change of residence is within the same community. This is called local movement.

3.6.1 DEFINITION OF MIGRANT:

There are several questions that are involved in defining a migrant. When we will define a migrant then we will have to consider the following aspects

First one relates to migration boundaries. This include three levels

- Provincial or state boundaries
- Distinct boundaries
- The boundaries of the civil divisions, like city, town, village, etc.

If the internal migration is defined across state boundaries only many moves within the state will not be considered as migration and hence, the estimates of migration will be much too small. On the other hand, if migration is defined on the basis of boundaries of each city, town or village, it will give the total estimate of migration.

Secondly relates to time or duration meaning that how long a person should stay in a place or change in residence.

The definition of Migrant can be given as “A person who has changed his residence from one geographically well defined area to another area with the intension of permanently or semi-permanently settling at the new place.”

3.6.2 DEFINITION OF CERTAIN TERMS ASSOCIATED WITH MIGRATION

Outmigration: The place at which the migrant lives is called place of origin and for that place a person that is an out migrant and the place where the migrant arrive is known as place of destination and the person is called in-migrant. When the migration takes place across international boundaries, the terms used are emigration and immigration to describe migration phenomenon, and emigrant and immigrant to define a person.

Migration interval: In order to analyze migration, demographers break down the total time period into a series of interval and collect data separately for each of these intervals. So such time series is known as migration intervals.

Migration Stream: A body of migrants that depart from a particular area of origin and arise at a specific area of destination during a specific period or interval is known as migration stream.

Methods of measuring migration

The volume of migration in any country or state can be determined during any two time-points if the information on births and deaths between those time-points is available. For example, if Po and Pt represents the total population at the beginning and at the end of the interval and if B and D represent the total births and deaths respectively, then we estimate net migration, M, as

$$\boxed{M= (P_t- P_o)-(B-D)}$$

MIGRATION RATES

Net Migration rate can be defined by the following formula

$m=(M/P)\times 1000$

Where m= migration rate during a specified migration interval

M= number of net migrants, and

P= average population of the area during migration interval.

In a similar manner we define

Inmigration Rate = $(I/P)\times 1000$

Outmigration Rate = $(O/P)\times 1000$

Gross Migration rate = $(T+O)/P\times 1000$

Where I = Inmigration during the interval, O = outmigration during the interval.

As we have sex-age specific death rates, we can have migration rates specific of certain characteristics of the population if the relevant data to determine the number of migrants possessing those characteristics are available. Thus,

$$m_1= (M_1/P_1)\times 1000$$

Where m_1= migration rate for population of a specified geographical area characterized by trait I

(e.g. sex, age, marital status, etc)

M_1= Number of migrants characterized by same trait i.

P_1= total population of the area possessing the same trait i.

3.6.3 MIGRATION TRENDS IN INDIA

The size of migration in India is not large. According to the 1961 census, out of a total population of 438.9 million, 144.8 million persons (109.4 million in rural areas and 35.4 million in urban areas) or 33.0% of the people were enumerated at places other than the place of birth and hence considered as migrants. These migrants are called as lifetime migrants since the period for which they have moved out from their respective birthplace is not known, it can be just a few days or several years.

According to the 1971 census, 30.4 % of the people were enumerated in places other than their place of birth. This proportion of lifetime migrants was 30.7% in 1981 census but fell down to 27.4% in the census 1991 census. From the migration data from 2001 it can be concluded that from the past four censuses, there has been slowing down of internal migration in India.

MIGRATION STREAMS:

Based on birthplace and place of enumeration, migration can be classified into four migration streams which are as follows—

- Intra-district migrants: persons born outside the place of enumeration but within the same districts.
- Inter-districts migrants: persons born outside the district of enumeration but within the same state.
- Interstate migration: persons born outside the state of enumeration but within India.
- Immigration: persons born outside the country.

3.6.4 FACTORS INFLUENCING MIGRATION AND CONSEQUENCES

Factors that influence migration most are both economic and non economic. Migrants move out from areas where employment opportunities are stagnant, where income is low and where the rate of population growth is high. The major factors that drive out the population of a place can be divided into “push” and “pull” factors. These “push” and “pull” factors have some adverse affect on the society as well as environment.

PUSH FACTORS:

Major push factors in areas of origin that can result in migration causing environmental damage include the following:

- Scarcity of or inadequate access to land and resources.
- Lack of employment opportunities.
- Poverty
- High population pressure
- Environmental degradation, including loss of soil productivity
- Natural disaster
- Civil unrest and conflict
- Rites of passage when young people leave home to make their way in the world.

PULL FACTORS

- Pull factors are those which attract the migrants to live in that particular place. These pull factors have direct or indirect adverse affect on the biodiversity of that place. These include
- Access to land and natural resources (renewable and nonrenewable).
- Employment opportunities
- Access to markets
- Access to facilitate and amenities, such as social services and transport.
- Safety and security
- Family reunification and networks.

3.6.5 MAGNITUDE OF MIGRATION

MIGRANTS BY PLACE OF BIRTH

The census that held in 2001 had collected migration details for each individual by place of birth and last residence. Data on last residence along with details like duration of stay in the current residence and reason for migration provides useful insights for studying migration dynamics of population.

As per 2001 census, Maharashtra received largest number of migrants (7.9 million) by place of birth from other states and other countries, followed by Delhi (5.6 million) and West Bengal (5.5 million). During the last decade (1991-2001), the number of migrants in India (excluding J&K) rose by 32.9%, high in comparison to India's population, which recorded a growth of 21.5% this decade (2001-2011).

MIGRATION BY PLACE OF RESIDENCE

Total number of migrants by place of last residence in India (excluding J &K) grew by 34.7% between 1991- 2001. High growth (53.6%) among interstate migrants is also observed.

MIGRATION STREAMS DURING 1991-2001

Rural to rural migration within the country	53.3 million
Rural to urban migration	20.5 million
Urban to rural migration	6.2 million
Urban to urban migration	14.3 million

It may be important to note that in case of intra-state migrants majority of the migration is from one rural area to another, due to marriage in case of females and in search of work in case of males. For interstate migrants, however, the flow is mainly towards urban areas.

MIGRATION BY LAST RESIDENCE FROM NEIGHBOURING COUNTRIES

In 2001 census about 5.1 million persons reported as migrant by last residence from across the International border. In comparison to 1991, there is 31.6% decline in international migration to India (excluding J & K) in 2001. This may be due to substantial decline in the number of recent migration and death of earlier migrants due to old age.

3.7 RESOURCE DEPLETION

In this present scenario of population explosion or overpopulation, resource depletion as well as environmental degradation is a big issue. All of us are aware of how the populations are increasing in a faster rate. As population increases tremendously along with that some questions also raised. These include a place where a pocket of population will live, what will be their main source of income, on what they will depend for their food etc.

Population growth and human activity is placing unprecedented and unsustainable demands on the natural resources. Increasing demand for natural resources, the intensification of agriculture, the production of hazardous waste, a rapidly growing and globalizing economy, and urbanization, all contribute to environmental degradation. These changes may reduce the fertility of, and access to, arable land, and affect air quality.

3.7.1 WHAT ARE THE RESOURCES AFFECTED MOST?

In most of the cases it is seen that due to increase in the population number natural resources are affected most. Degradation as well as depletion of natural resources is maximum in a particular area. Depletion of natural resources can lead to some adverse changes in the climate as well as health of population. Among natural resources forests, biodiversity, air, lands and water resources are the most affected one.

Land resources: Land resources include the forests, biodiversity present on land, agricultural lands, quality and quantity of land used for habitation. Land degradation includes soil erosion, chemical deterioration, desertification etc some of the consequences of the population explosion.

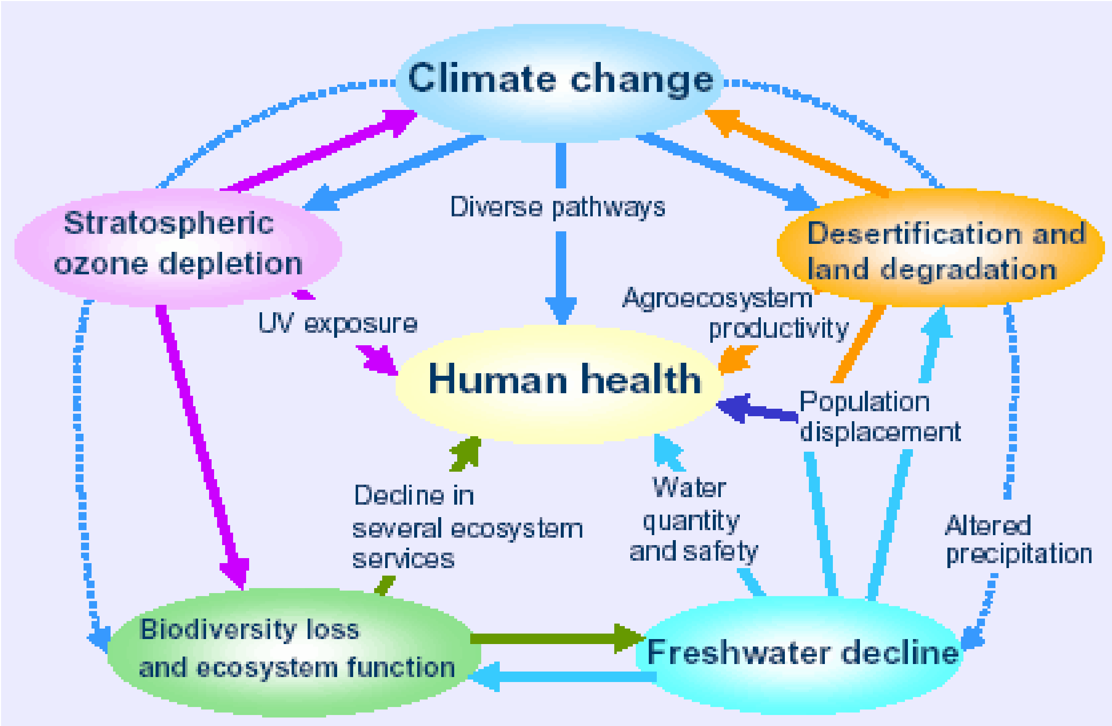
Water resources: Water resources mainly includes ground water resources, surface water resources e.g. river, lake, sea etc. Pollution in the water resources are caused by the population growth and it inversely put pressure on the drinking water quality of a region.

Air: Air or atmosphere being the one of the common property resource is affected the most due to population growth. As the population increases, industries as well as the automobiles also increases. Results in the increase in the emissions from the vehicles and industries increase substantially which causes the pollution and many other health related issues. Global warming and climate change are the ultimate consequences of these emissions.

3.8 ENVIRONMENT AND HUMAN HEALTH

Environment and human health are two inseparable issues. In present day situation egradation of the environment is a big issue caused by growing population as well as the industrial growth. The main issues related to environmental are discussed in the earlier chapters. From the above discussions we come to know about the factors that are responsible for the degradation of the environment. Now we will discuss only how human health is affected by such environment.

Fig 2: Figure showing the factors affecting human health



Source: World health organization

World health organization reported that degradation in the environment combined with the growth in world population, is a major cause of the rapid increase in human diseases.

- Malnutrition among the children is prevalent due to lack of access to adequate and balanced food supply.
- Epidemics such as measles, influenza etc.
- Spread of Waterborne diseases such as malaria, cholera.
- Air borne diseases such as asthma, lung diseases etc.
- Diseases caused due to soil contamination.
- Diseases caused due to air pollution.
- Global warming also increases the risk of some diseases.

3.9 FOOD SECURITY

According to the definition adopted by World food Summit people are considered food secure when they have all time access to sufficient, safe, nutritious food to maintain a healthy and active life.

Food security is built on three pillars:

❖ Food availability: sufficient quantities of food available on a consistent basis.

❖ Food access: having sufficient resources to obtain appropriate foods for a nutritious diet.

❖ Food use: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

As the population increases access to balanced as well as adequate food is becoming a question among the populations living in the poverty line. Food security is a complex sustainable development issue, linked to health through malnutrition.

FACTORS THAT AFFECT THE FOOD PRODUCTION

- Population growth
- Climate change
- Land degradation
- Crop and cropland losses to non-food production.
- Water scarcity
- Desertification
- Resource depletion
- Urban expansion etc.

3.10 SUGGESTED READINGS

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13) www.cia.gov

14) www.fao.org, (World Food Summit, 1996).

15) www.prb.org, (The world at 7 billion, July 2011).

16) www.unhabitat.org

17) www.who.org, Department of Public Health and Environment, November 2011.

18) **www.worldwildlife.org**

3.11 PROBABLE QUESTIONS

1. Multiple choice question

a) What is last decadal population growth rate of India?

i) 24.8% ii) 23.5% iii) 21.5% iv) 17.64%

b) What is the decadal growth rate of population in world in 2001?

i) 1.09% ii) 1.7% iii) 0.5% iv) 1.4%

c) What is the population number of a class I city?

i) 50,000 ii) 1,00,000 iii) 5,00,000 iv) 10,000

d) What is the decadal migration rate during 2001-2011 ?

i) 5.6% ii) 7.9% iii) 21.5% iv) 21.5%

2. Answer in brief

a) Give a brief illustration about the population growth in India since 1991.

b) What is population explosion and how it affects the environment. Discuss in details.

c) How human health and environment is related to each other?

d) What is resource depletion? How human populations are affecting the resources?

UNIT 4: ENVIRONMENTAL SUSTAINABILITY

UNIT STRUCTURE

4.1. OBJECTIVES

After going through this unit, you will be able to:

- Discuss the ideas of sustainability and sustainable development.
- Get acquainted with some basic concepts of EIA and CPR

It is expected of the learners to concentrate on the concepts well to build a strong base.

4.2. SUSTAINABILITY – BASIC CONCEPTS

In you carefully notice you will find that some systems endure for a very long time while some do not. If you carefully notice the world around us many systems (be it a community, administrative structure, social belief, an ecosystem or a network of activity) perish with time. Some of these systems, of course endure for a very long time. If we take the endurance of a system with respect to time, then the system that persists for the longest time period is the most sustainable system.

So, sustainability is the capacity to persist. Sustainability, therefore, may broadly be referred to as the persistence of the integrity and structure of any system over time.

For human kind, sustainability may be considered as the long-term maintenance of well being, which has socio-economic, political and environmental dimensions.

In ecology, sustainability may be described as to how biological systems remain diverse and productive over time, which is a necessary prerequisite for life and well-being. Wetlands, grasslands and forests, that are healthy and long-lived, are examples of sustainable biological systems.

Sustainability is an ongoing process and, therefore, while assessing the sustainability of a system it is imperative to scrutinize the interacting processes involved among participants. Also, there is a need to assess whether the processes increase physical, social and human capital involved or slowly erode that capital.

The whole world, today, is talking about **environmental sustainability**. Environmental sustainability is the key to the human existence on the earth. This is because all the basic needs of human life come from the environment – be it food, water, cloth or shelter. Environmental Sustainability does infer to the long support, by every faculty of the environment, towards human needs for existence. The various faculties of the environment means – the physical, socio-economic and cultural environment.

Among economists, it is well accepted that environment must be seen in the context of development and that environmental sustainability is maintained in the development processes.

Optionally there are three major indicators of environmental sustainability:

1. Groundwater table
2. Deforestation
3. Carrying capacity of land to animals.

Ground water is a potentially renewable resource. It is actually meteoric in origin. This means, every rain recharges the groundwater. When there is more withdrawal than recharge then the water table dips. As the water table dips, we understand the groundwater consumption rate is not sustainable.

Similarly, deforestation is an obvious indicator; that there is so much of pressure on our forests that the forest cover is shrinking.

There is considerable debate about how to define sustainability and, therefore, critics often argue that the concept of sustainability is meaningless if it could not be satisfactorily defined. The word sustainability is derived from the Latin word *sustinere* (*tenere*, to hold; *sus*, up). The term *sustainability* has been used more in the sense of human sustainability on planet Earth since the beginning of the discourses on sustainability. The most widely quoted definition of sustainability and sustainable development is that of the Brundtland Commission's definition of 1987: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The definition is highly flexible which has given rise to numerous definitions and the thousands of interpretations.

The measurement of sustainability, involving the sustainability of environmental, social and economic domains, both individually and as communities, are evolving and they include indicators, benchmarks, audits, sustainability standards and certification systems like *Fairtrade* and *Organic* indexes and accounting. This also includes assessment, appraisal and other reporting systems. The metrics of sustainability are applied over a wide range of spatial and temporal scales.

4.3. SUSTAINABLE SOCIETY

We human beings have been trying to build an ideal society where we could live and enjoy. Only until recently, many of them started to wonder whether our society could last long enough to see its perfection. With this in mind, many began to ask the question "What is a sustainable society?" Based on experience, knowledge, and vision of the world, different people have offered different answers to this question.

A society will be called a sustainable society that can progress without catastrophic setbacks in the foreseeable future. This means that the progress is forward without any breaks and hardship. It does mean that a society which can make necessary changes within its structure and behaviour while progressing can remain a sustainable society. Therefore, there is a lot of learning involved. As soon as a society learns and reacts to the knowledge and comes back to the natural path, the hurdle or the imminent catastrophe is overcome.

For example, the societies all over the world have recognized and developed knowledge about the ill effects of chemical pesticides. There is a kind of revolution all over the world to go in for organic agriculture. So, the societies that can comeback to the natural and organic way of agriculture are more sustainable than the others. It does also mean that the societies that learn faster and implements faster are more sustainable societies.

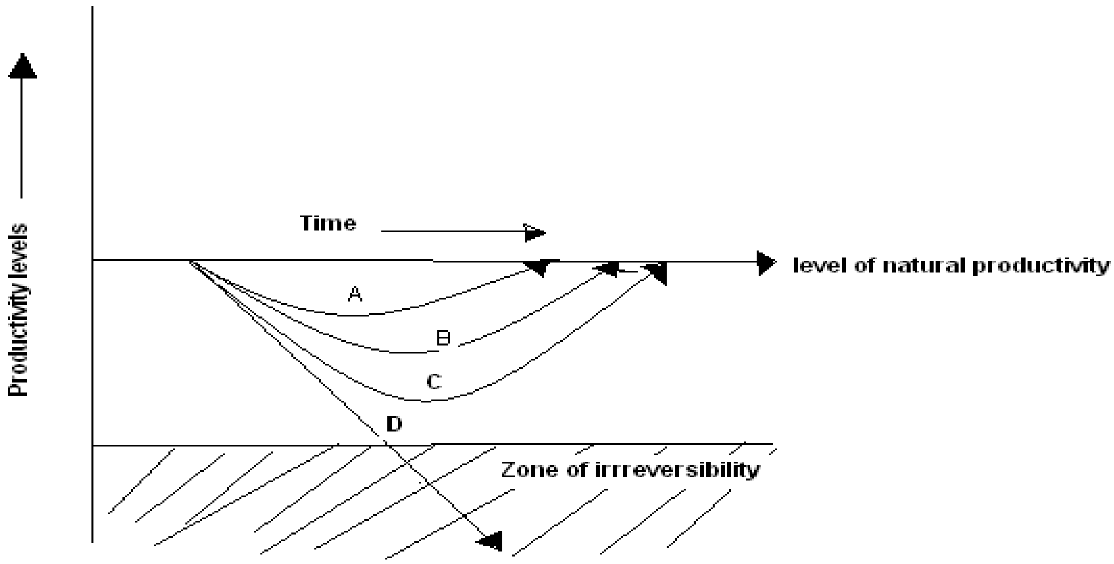

Fig 1: Learning process of the societies and returning to the level of natural productivity

The figure 1 illustrates how societies A, B and C leave the level of natural productivity, learn, react and come back to the level of natural productivity. These 3 societies are sustainable; however, the society 'A' is more sustainable than 'B' and the society 'B' is more sustainable than 'C'. The society 'D', on the other hand, does not learn and breaks the elastic limit of the natural system and enters into the zone of irreversibility. Therefore, the society 'D' could not be called a sustainable society.

For, there is a lot of learning processes in attaining sustainability, we have to give that space to every society so that it can learn about the sustainable use of its resources. A society running on a huge resource deficit is not sustainable. If it is allowed to continue, future generations have to pay the price of it.

To build a sustainable society, a delicate balance between current needs and future needs has to be reached. In the past, the law of nature ensured this balance. Today, the law of nature still applies. However, with our capability to utilize the reserved resources, human beings have a choice to make. We could continue to use up all the reserved resources and let our children suffer the consequence of resource starvation. Or, we could aggressively move away from non-renewable resources and put ourselves on a sustainable footing once and for all.

"Earth provides enough to satisfy every man's need, but not every man's greed" - Mahatma Gandhi had said. The Earth has vast resources to satisfy our needs. The only reason we are running on a resource deficit is that we did not keep our greed in check. At the same time, we have allowed our resource consumption per capita to rise rapidly. To make things even worse, we treat natural resources as a free giveaway. Our efforts have been focusing only on how to retrieve it fast and with minimum cost to us, regardless of what impact it could have on others or future generations.

4.4 PREREQUISITES OF SUSTAINABILITY

As we have discussed above, there is a lot of learning process and application of knowledge, which helps a society to be sustainable. Also, that we have to provide that space so that a society could learn and react in the right direction.

Therefore, there are certain preconditions which are essential to be there in the society; only then we can expect a society to learn and condition its needs to attain sustainability. They are as follows:

- Democracy
- Decentralisation
- Resource self-sufficiency, and
- Culture

Democracy in the every spare of development is very essential for a society to attain sustainability; that, I you and every one of us take part in the development process. Democracy should not only restrict to only voting for electing representatives of the people. When I you and everyone (people) take part in the decision-making of the development projects then the true aspirations of the people will be reflected in the process of development. And, therefore, the development will be just and will address the needs and aspirations of the people. Many a time, when people are not involved in the decision-making of the development processes, projects do not give fruits to the locals and, therefore, such projects seem unwanted and sheer wastage of resource.

Decentralisation helps to make our decisions quicker and appropriate with respect to the needs and aspirations of the local people. For example, if we need to have a water harvesting project in a village in Gujarat and an officer sitting in Delhi decides the technology and modalities of the project then, I am sure, you will agree with me, the project will face the following:

- Wrong positioning – because the decision maker is sitting far from the site and therefore will not have any idea of the local setting.

- Wrong budgeting – because the decision maker will not have the idea as to that dimension the project should be and, therefore, the budget will be too small or too big.
- Time-taking procedures - the project will have to go through the time-taking official procedure, trickling down from Delhi, and a lot more.

Such inconvenience can be avoided if the decision –making process is decentralized and people themselves decide as to what – how and which kind of the project has to be implemented in that Gujarat village. Decentralisation saves time in such situations and gives the opportunity to the people to choose the right kind of technology.

Resource self sufficiency does mean managing with whatever resource a development unit – be it a village or a block or a district or a state - has. When one economic block depends on some other's resources then there is no control of resource use within that block. If the resources are to be generated within the unit then the question of rational use and conservation comes into play. The best example would the Indian villages of the past, which were self sufficient with the resources and managed everything within the village except the salt which came from outside. Those were the times when the Indian villages conserved the resources for future use. Suppose a country 'A' is fully dependent on the oil resource of another country 'B', then the country 'A' will never have control over its oil consumption. The USA is one of such countries that get oil of the Middle East. Therefore, if you see the consumption pattern of the USA, it says that the pattern is certainly not sustainable.

Culture of affluence and wastage of resources is not something that is sustainable. The volume of food that the northern countries throw can feed all the hungry people of the world. The overproduced food grains are often thrown in the grasslands, to control the global food price, by some of the northern countries. This overproduction putting pressure on our natural resources is not required at the first place and the wastage adds to the pressure on the earth capitals. A culture of optimum production and wastage is the key for sustainability and, therefore, society that learns to minimize wastage would be called sustainable.

Therefore, a society must provide the space of learning and implementing. These are the essential prerequisites a society must possess to initiate the learning process justly and quickly. As discussed earlier, a society that learns faster and implements faster is a more sustainable society. Therefore, these prerequisites are the facilitators of learning and implementation.

4.5 SUSTAINABLE DEVELOPMENT

Sustainable development is a model of growth in which resource consumption aims to meet human needs keeping the health of the prevailing environment intact for the present needs and the future needs for the generations to come.

The term was first used by the Brundtland Commission in 1987 in its report, *Our Common Future*, and defined sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". The definition is highly flexible. It does not say any method or rule to attain a development that is sustainable. However, the definition stresses on the intergenerational equity with respect to the environmental conditions and resource availability. The intergenerational equity was then more elaborately expressed in the Rio summit in 1992 as "we have not inherited this earth from four forefathers but borrowed it from our future generations". Therefore, the concept of sustainable development allows growth but with giving sufficient respect to the environment that takes care of all human needs and wants. The field of sustainable development, thus, can be conceptually divided into three elements:

(a) environmental sustainability
(b) economic sustainability and
(c) sociopolitical sustainability.

Environmental sustainability is the process of making human behaviours as environment friendly as possible, and the environment as pristine as naturally possible. An "unsustainable situation" occurs when natural capital (the sum total of nature's resources) is consumed faster than it could be replenished. Sustainability requires that human activity only uses nature's resources at a rate lower than the rate at which the resources get replenished naturally. Here comes a concept of 'sustainable yield'- the maximum resource one could extract from a resource pool so that the pool supports for a very long time. However, estimation of sustainable yield is often considered difficult and unnecessary. The thumb rule, therefore, is that the minimum resource use is the option for sustainability.

In a way environmental sustainability is inherently linked with the concept of 'carrying capacity', which is the maximum support a system can support. Theoretically, the long-term result of environmental degradation will mean inability of the 'capitals' to sustain human life.

As mentioned above there is no prescribed rule as to which kind of economics will ensure sustainability. Economist Paul Hawken puts forwards a list of dos for converting to earth sustaining economics as per the following:

- Reward earth sustaining behaviour.
- Discourage earth degrading behaviour.
- Full-cost accounting to include the ecological value of natural resources in their market process
- Use environmental and social indicators to measure progress towards environmental and economic sustainability and human well being.
- Use full-cost pricing to include external costs of goods and services in their market prices.
- Replace taxes on the income and profits with taxes on throughput of matter and energy.
- Establish public utilities to manage and protect public land and fisheries.
- Make environmental concerns a key part of all trade agreements and of all loans made by international agencies
- Reduce waste of energy, water and minerals
- Preserve biodiversity
- Reduce future ecological damage and repair past ecological damage
- Reduce poverty
- Ensure slow population growth.

Rewarding earth sustaining behaviour refers to subsidizing an action and rebating taxes. For example, there could be more subsidies on organic agriculture, greener and low energy technologies, water conservation programmes, etc. This subsidy will encourage such activities and more and more such activities will grow preferentially. Discourage earth degrading behaviour refers to taxing heavily on the activities and products so that people, by a choice avoid such activities and such products.

Ecological value of natural resources is an important aspect to look at things. If you consider a timber log from a tree which might cost about only Rs 1000.00, however, the ecological value of the tree will be several times higher. You can appreciate this when you consider the other services the tree was rendering as a living tree – providing oxygen, hosting birds, contributing to regulate climate, contributing to the rain formation and so many other services.

If you do a costing of all such services of a tree then it would be much higher than the actual market price of the tree as timber. Therefore, our actions should take account of the ecological services of plants and animals, and for that matter, all such products. Then you will find it easy to choose which action will be a sustainable one.

With the increase of purchasing power of the people all over the world, including Indians, waste of resources has become inevitable. Sustainable economics points at three *R*s – reduce, re-use and recycle. This would then put minimum pressure on our resources.

Paul Hawken puts forward his simple golden rule for a sustainable economics as – "Leave the world better than you found it, take no more than you need, try not to harm life or the environment and make amends if you do". Amendments in this context refer to learning from the mistakes fast and implementing in an earth sustaining way.

A global consensus was achieved on the issue of sustainable development in the Rio summit in 1992. Agenda 21, a comprehensive blueprint of the action to be taken globally, nationally and locally by organizations of the UN, governments, and major groups in every area in which humans directly affect the environment, was taken as the action plan of the United Nations (UN) related to sustainable development.

There are 40 chapters in the Agenda 21, divided into four main sections.

1. Social and Economic Dimensions- which deals with combating poverty, especially for developing country, changing consumption patterns, promoting health, change population and sustainable settlement in decision making.

2. **Conservation and Management of Resources for Development** - Includes atmospheric protection, combating deforestation, protecting fragile environments, conservation of biological diversity (biodiversity), control of pollution and management of biotechnology and radioactive wastes.

3. **Strengthening the Role of Major Groups** -Includes the roles of children and youth, women, NGOs, local authorities, business and workers and strengthening the role of indigenous peoples, their community and farmers.

4. **Means of Implementation**- Implementation includes science, technology transfer, education, international institutions and financial mechanisms.

India has been consistently playing an important role in the evolution of an international consensus to tackle major global environmental issues. It was an active participant in the process leading up to and culminating in the convening of the United Nations Conference on Environment and Development in Rio, 1992 and the Earth Summit held in Johannesburg (Rio+5) in 2002.

The sustainable development concept is, however, not new to India. The principles of sustainable development are interwoven in the people's culture, tradition, behaviour, and life-style of Indians.

The most articulate advocate of sustainable development in the modern context in India was undoubtedly Mahatma Gandhi, who not only had a vision for independent India's development, but also had a philosophy, strategy and tools for it. His vision of development was sustainable development. E. F. Schumacher has discussed elaborately the Gandhian economics in his book ***Small Is Beautiful: Economics As If People Mattered*** in the early 1970s.

In India, we have a five-year plan and, therefore, India did not feel the need to have a separate strategy for Sustainable development. The Five Year Plans provide medium-term strategies for overall development.

India presented its perspective on sustainable development before the World Summit for Sustainable Development (WSSD) in 2002 as a detailed study "Empowering People for Sustainable Development" (EPSD). It was brought out by the Ministry of Environment and Forests.

The EPSD (published in 2001 by Ministry of Environment and Forest, GoI) introduces the essential framework for sustainable development in India: democratic continuity, devolution of power, independent judiciary, and civilian control of the armed forces, independent media, transparency and people's participation. It follows multidimensional, sectoral and cross-sectoral approaches.

Since the 10^{th} 5-year plan, sustainable development strategies have formed an integral part of the plans. Large number of laws and polices have been in force in India to handle the environmental issues. India now has a matured Environmental Impact Assessment (EIA) regime in place since 1994.

4.6. ENVIRONMENTAL IMPACT ASSESSMENT (EIA) AND SUSTAINABLE DEVELOPMENT

A broad definition of EIA is the need to identify and predict the impact on the environment and on human health and well being of development actions like legislative proposals, policies, programmes, projects and operational procedures, and to interpret and communicate information about the impacts prior decision making. By having said 'prior decision' making means that the entire process is completed before a decision is taken whether we are going to go ahead with the development or not. EIA was first formally established in the USA in 1969 and has since spread, in various forms, to most other countries. The US National Environmental Policy Act of 1969, NEPA, was the first legislation to require EIAs to be carried out. Consequently it became an important model for other EIA systems, both because it was a radically new form of environmental policy, and in the success and failures of its subsequent development.
In essence, EIA is a process, a systematic process that examines the environmental consequences of development actions, in advance. This emphasis, compared with many other mechanisms for environmental protection, is on prevention. Planners, of course, have traditionally assessed the impacts of developments on the environment, but invariably not in the systematic, holistic and multidisciplinary way required by EIA.

The process involves a number of steps, such as

- Project screening narrows the application of EIA to those projects that may have significant impacts. Usually the large projects are screened out for mandatory EIA. The requirements of being 'large', however, vary from country to country. The NEPA model suggests a preliminary environmental assessment of the project to ensure that the project does not pose significant impacts. A report of 'finding of no significant impacts' (FONSI) is required for a clearance for EIA. Projects failing to produce a FONSI need to conduct an EIA before the start of the project. In India, the screening of the projects have been done by the EIA authority – the ministry of Environment and Forest, GoI – and, according to the first guideline in 1994, identified 29 categories of development activities having resource involvement of Rs.5 crore more. In 2006, the list was extended and the resource involvement limit too was raised.

- Scoping identifies all the possible issues associated with the project at the early stage.

- Consideration of alternatives ensures that the proponent has considered other feasible approaches, including alternative project locations, scales, processes, layouts, operating conditions and the ‘no action’ options.

- Description of the project/development action includes a clarification of the purpose and rationale of the project and an understanding of its various characteristics – including stages of development, location and processes.

- Baseline studies include establishment of both the present and the future state of the environment, in the absence of the project, taking into account changes resulting from natural events and from other human activities.

- Identification of the key impacts brings together the previous steps with the aims of ensuring that all potentially significant environmental impacts are identified and taken into account in the process.

- Prediction of the impacts aims to indentify the magnitude and other dimensions of identified changes.

- Evaluation and assessment of the significance of the impacts seek to assess the relative significance of the predicted impacts to allow a focus on key adverse impacts.

- Mitigation involves application of measures to lower the impacts.

- Public consultation and participation – public hearing is a mandatory step in the EIA process. Traditionally the findings of the process is compiled and a draft EIS (Environmental Impact Statement) is placed in front of the public.

- EIS presentation – compilation of the final EIS. Structure of the EIA is generally official. It is a legal process and therefore, it is better to follow the structure provided by the regulating agency. The EIS has a mandatory section called the non-technical summary of the project for making it easy to understand for the general public.

- Review involves a systematic appraisal of the quality of the EIS, as a contribution to the decision making process.

- Decision making – based on the reviewer’s comments the decision maker
- Post decision making monitoring
- Auditing

The order of the steps may vary and at times these steps are overlapping.

EIA is a process with several important purposes. It is an aid to decision-making. For the decision maker, it provides a systematic examination of the environmental implications of a proposed action, and sometimes alternatives, before a decision is taken.

It is also an aid to the formulation of development action. Many developers no doubt see EIA as another set of hurdles for them to jump in order to proceed with their various activities; the process can be seen as yet another costly activity in the permission process. However, EIA can be of great benefit to them since it can provide a framework for considering location and design issues and environmental issues in parallel.

Underlying such purposes is of course the central role of EIA as one of the instruments to be used to achieve sustainable development – a development that does not cost the earth!

Existing harmful developments have to be managed as best they can. In extreme cases, they may be closed down, but they can still have residual environmental effects for years to come. It would be better to mitigate the harmful effects of a project in advance, at the planning stage, or in some cases, to avoid the particular development. Prevention is better than cure.

The procedure of EIA enables common people to participate in the development process. Decentralised and democratic development process only ensures sustainable development. EIA offers such an environment to take right decision, taking note of the likely environmental damage right at the planning stage itself.

For large projects, there is a clearance regime in India. The clearance for such large projects is given by the ministry of Environment and Forest, GoI. The State Pollution Control Boards coordinate the process of EIA and Public hearing, which is a mandatory step. In the public hearing, local people, interest groups, civil societies and all other groups get information of the project and express their aspirations of the project. The notification of the public hearing is served by the chairman of state pollution control boards in at least two leading news papers of the region where the project is due. One of the notifications must be in a local language widely spoken in the region. For example, if we need to have a public hearing for a dam project in Assam then at least one notification of the public hearing must be in Assamese.

4.7. COMMON PROPERTY RESOURCES (CPRS)

In ancient times humans used to live in community. Even now many tribal communities and nomads live in community. The system of CPR was developed from this communitarian use of resources. Since then it has been in use. So in due time people learnt to how to use the CPR judiciously. A common resource is a resource readily accessible to all members of the public who wish to obtain benefits from it. Some examples are natural, like forests, rivers, and lakes.

Resources accessible to and collectively owned\held\managed by an identifiable community and on which no individual has exclusive property rights are called common property resources. Common property resources are also called common pool resources, commons or public goods. Generally these are the resources that people are free to use. Some examples of CPR are Ocean, river, lake, forest, grazing field irrigation systems, fishing grounds, pastures, forests and so on. It is important understand what is community in relation to CPR. For instance, all inhabitants of a village form an identifiable community. Apart from this, a community may be a caste-based or religion-based or occupation-based group of people or a group constituted according to the traditional social order.
There is a popular idea that if the CPR is used without any control then there is a danger that each user's consumption of the CPR will deplete and degrade the supply. Because of this idea, governments seek to have control over the CPR.

CPR is renewable but sometimes depletion occurs faster than the renewal. A common property regime is a conscientious social understanding of people from the community residing near a resource. It regulates the preservation, maintenance, and consumption of a CPR.

CPRs have been defined in a number of ways. The element that is common to most of these definitions characterizes primary importance to the nature of access in identification of CPRs. The common one is all that is not private property as common property. Also people differentiate between open access or free access and CPR. CPR is supposed to have a well defined rule. A community which has the right to its collective use is properly defined and the rules that govern their use are clearly mentioned. Traditionally, a very large part of the country's natural resources was common property in the sense that it was widely used by the rural population. The process of extending state control over the common resources, began with the declaration of "reserved" and "protected" forests by the colonizers in India. It has resulted in the exclusion of villagers' access to common resources by law. As a result, the systems of community management gradually disintegrated.

The rural population, particularly the poor, depends greatly on the goods and services available from CPR. Government for its own interest tries to generate revenue. So it brands areas as reserved forests which were earlier used by community without any cost.

Common Property Regime

In common property regimes, access to the resource is not free. In this system resources accessed by the community is not entirely free and it is monitored by the regime. And there are also mechanisms through which the regime excludes outsiders from using its resource. Thus, in a common property regime, a common-pool resource looks like private property resource from the outside and as a commons from the inside of the community.

Some of the examples and definition of CPR

- Pasture land- Traditionally, grazing and pasture land has been the most important constituents of CPR land. Many villages have land earmarked as permanent pastures land/grazing land.

- Village forest-This includes all land under village forest. This also includes the area notified as forest within the village which may belong to the forest department, or any other government department.

- Government forest- Forests in India are classified into three categories such as reserved forest, protected forest, and unclassified forests.

- Reserved forest: Reserved forests are constituted under the Indian Forest Act. The government holds absolute rights of ownership in reserved forests. Access to these forests is generally restricted.

- Protected forest: Protected forests too are constituted under the Forest Act. The locals are permitted to gather all produce except those items which are specifically prohibited. Other privileges to the local population are also permitted. The privileges commonly enjoyed by the local population include collection of leaves, firewood, fodder and other minor forest produce, grazing of cattle, etc.

- Unclassified forests: According to the classification by legal status, this category includes all other forests. Some of these forests are privately owned. All village forests are included in this category. In the hill States of the North-east, forests are owned by district councils, village community and even by individual households. All these come under the category of unclassified forests.

Let us stop and think

People think that the problem with common resources is that greed on the part of individuals can ruin the resource for the community. As an example we can think of a public pastureland. If one person uses to pasture more animals than his fair share, they will deplete the pasture faster than the normal use, harming other people's livestock in the community. If a people in the community use the pastureland sustainably and determine the number of livestock to be grazed in the land, everyone can enjoy the common resource, in addition to preserving it for future generations.

In a situation known as the tragedy of the commons, common resources are destroyed by acts of greed or a poor understanding of the limitations of that resource. This concept was developed by Garrett Hardin and was first published in the journal *Science* in 1968. In this case some people use more than their fair share of a common resource and everyone suffers because their over-exploitation of the resource diminishes the amount available to the community. But it has been criticized by Ian Angus as useful political myth (http://www.socialistvoice.ca/?p=316). He accuses Hardin of proposing for privatization and spreading myth about the capitalistic idea.

Privatization of common resources is also a matter of concern in many areas of the world. While some resources are protected for use by members of the public, others may be purchased by private firms. In Bolivia people protested against the privatization of water. The fear of privatization is that people previously enjoyed a resource for free and later they may have to pay for it. In this case access to resources will be limited to the wealthiest individuals who can pay for it.

4.8. PROBABLE QUESTIONS

I. Choose the correct answers

1. A sustainable system functions for
(a) a limited period (b) unlimited period (c) a specific period.

2. Which of the following is more sustainable agriculture?
(a) crops grown on organic manure
(b) crops grown on chemical fertilizers
(c) crops grown in water stress conditions

3. Which of the following is/are indicators of environmental sustainability?
(a) water table (b) forest cover (c) rainfall

4. Who coordinates the public hearing of EIA?
(a) Minister of Environment and Forest, GoI
(b) Minister of Environment and Forest of the respective state governments
(c) Chairman of Pollution control Board of the respective states

5. Which of the following is are common property resources
(a) Government hospitals (b) grazing land (c) fishing wetland
(d) Public school (e) groundwater

II. Write short Answer questions

1. Explain the concept of sustainable development.
2. What are CPRs? Do you think our governments should focus on reviving the common property regime? Explain.
3. What is the need to conduct an EIA for large projects?

Activity

1. Go around your hometown/ native village and list all the earth degrading and earth sustaining activities going around.
2. Look for a public hearing notice on the local dailies of your city/ state. If you find any, then attend the hearing.

UNIT-5: ECOSYSTEM PROCESSES

UNIT STRUCTURE

5.1 OBJECTIVES

After going through this unit, you will be able to:

- improve basic understanding of ecosystem and the theory and process in ecosystems
- apply this knowledge to important biological questions such as the flow of energy and matter in ecosystem, maintenance of diversity and responses to global climate change.

5.2 INTRODUCTION

Biogeography reveals that living organisms that may range from large animals and plants to microscopic bacteria are found practically everywhere on this earth. The distribution and abundance of living organisms and one biological structure of the community vary in response to various physical conditions of the environment. Living organisms (plants and animals) and their non-living environment like soil, air water and nutrients are inseparably interrelated and interact upon each other. In fact, these physical and chemical components support the organisms living within them. Biotic and abiotic components of the environment are the basic functional unit in ecology. Ecology is the branch of biology that studies the interaction between living organisms and their environment. All living things including human being need appropriate environments for their survival and growth. The complex system, in which interactions between the different components of environment occur whereby there is the continuous flow of energy and matter, is referred to as an ecosystem.

It can be expressed as a unit that includes all of the living organisms in a given area. These living organisms interact with the non-living environment. As a result a flow of energy specifically directs to a definite trophic structure, forming different types of food chain and food -web, biodiversity, and biogeochemical cycles within the systems. This is an ecological system or ecosystem. Thus, ecosystem can be described as any spatial or organizational unit which includes both the living and non-living constituents and which interact with each other resulting in an exchange of energy and materials.

The concept of the ecosystem is a broad one. It covers all the components to form functional unit, and emphasizes various main functions of ecology such as obligatory relationships, interdependence, and causal relationships among the living and non-living components of the given environment. Keeping this in view, we may think of our planet Earth as a giant ecosystem. Here all the physical and other living organisms, irrespective of their biomass and metabolism, are constantly acting and reacting upon each other. In doing so they bringing about some kind of structural and functional changes in it.

- Biosphere or ecosphere is considered as a vast ecosystem (largest of all possible ecosystems). It is too large to handle and thus for convenience, we generally study the whole biosphere by making its spatial simulated subdivisions into units of smaller ecosystems. Therefore, an ecosystem may be aquatic or terrestrial, temporary (a rain-fed pond) or permanent (lake, forest), natural (forest, lake

, ocean, etc.) or man-made (cropland, aquarium, space station, pots of house plants, etc.). However, all these subdivisions of the biosphere, acting as a small unit of ecosystem, are simply separated from each other spatially or temporally and these boundaries of separation are often difficult to define. Practically there is no functional boundary. In fact, all the units are linked with each other forming as whole or an integral one. There are no theoretical restrictions on the area of space as to how large or small an area must be to host an ecosystem, nor on the minimum numbers of species or individual organisms to be present there.

5.3 ECOSYSTEM

An ecosystem is a biotic assemblage of plants, animals and microorganisms living together in a certain space in which they interacts with their physico-chemical environment, ensuing a structural and functional role giving a system-level processes of flow of energy and cycling of minerals in a steady state system. Biological environment in fact determines and defines the physical environment also.

Roy Clapham in 1930 first coined the term "ecosystem" to mean the combined physical and biological components of an environment. Later, British ecologist Arthur Tansley fully redefined the ecosystem concept , describing ecosystems as "The whole system, … including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment" (Tansley, 1935). The inseparable link between the biological environment and the physical environment was emphasized by Sir Authur G. Tansely.

The ecosystem is a core concept in biological sciences and ecology, serving as the level of biological organization in which organisms interact simultaneously with each other and with their environment. The study of ecosystems mainly consists of the study of certain processes like, e*nergy transformations* and *biogeochemical cycling* that link the living, or biotic, components to the abiotic or non-living components. Altogether, these two basic components and their interactions with and relationships to each other form a dynamic and complex new whole, functioning as an "ecological unit", with additional characteristics that can't be found in the individual components. Any organism can not survive completely by itself for long without its population or without involving any environmental conditions. Likewise, any community cannot exist without the cycling of elements and flow of energy in the ecosystem.

5.3.1 DEFINITION

There are number of definitions of ecosystem as given by several scientists. But certain common elements are found in these definitions. These are- living organisms, non-living organism and their interaction. Thus, we can sum up and define an ecosystem as 'a structural and functional unit of biosphere or segment of nature consisting of community of living beings and the physical environment, both interacting and exchanging materials between them'.

Let's learn some of the definitions given by some of the scientists:

A. G. Tansley (1935) 'An ecosystem is the result of interaction between the living and non-living components of the environment."

Clarke (1954) "The organisms and the physical features of the habitat form an ecological complex or more briefly an ecosystem."

Woodbury (1954) "Ecosystem is a complex in which habitat, plants and animals are considered as one interesting unit, the materials and energy of one passing in and out of the others."

E. P. Odum (1959), Living organisms and their nonliving (abiotic) environment are inseparably interrelated and interact upon each other. Any area of nature that includes living organisms and non-living substances interacting to produce an exchange of materials between the living and non-living parts is an ecological system or ecosystem.

According to S. Mathavan (1974), 'an ecosystem is a sum total of living organisms, the environment and the process of interaction between the various components of the ecosystem.'

"Ecosystem" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Convention on the Biological Diversity, 1992).

Christopherson (1997) defined it as “An ecosystem is a natural system consisting of all plants, animals and microorganisms (biotic factors) in an area functioning together with all the non-living physical (abiotic) factors of the environment.”

Further Eugene Odum, definined ecosystems as: "Any unit that includes all of the organisms (ie: the "community") in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles (ie: exchange of materials between living and nonliving parts) within the system is an ecosystem." Central to the ecosystem concept is the idea that there are mechanisms for continuous absorptions of materials by organisms from surrounding environment for the production of organic matter and, then decomposed and released into inorganic form. Ecosystems can be conceived and discussed in the habitat of various sizes with tremendous variety of scope. It can describe any location where there is interrelationship between organisms and their environment. Besides, an ecosystem usually has a boundary within which the component parts function together as one unit.

5.3.2 STRUCTURE AND TYPES

The characteristic structure of an ecosystem is accomplished by the systematic organization of biotic components and abiotic components or the physical features of that particular ecosystem. The biotic components of an ecosystem provide the biological diversity or species richness of an area with respect to the physical characteristics like, minerals, air, water, sunlight, temperature, etc. All ecosystems in this earth, consists of two basic components i.e. abiotic component and biotic component and their basic source of energy is sun. The relationship between the biotic components and the abiotic components of an ecosystem is called 'holocoenosis'. They exist together and interact with each other in building up or retrieving the system. The biotic components vary from one ecosystem to another ecosystem. The distribution and abundance of species is largely determined by the climatic factors. The structure of an ecosystem provides information about an array of climatic conditions prevailing in that area.

5.3.2.1 ABIOTIC COMPONENT

The abiotic or non- living component of an ecosystem are the inert matter found on earth. This consists of the soil and its constituents, sediments, particulate matter, mineral nutrients, atmospheric temperature, light, water, gas, wind, rainfall, etc., which surround, influence and shape the living or biotic component. These abiotic components are the characteristic features of the climatic condition which determines the species composition of an area. Solar energy is e tonly significant source of energy for light on earth for any ecosystem. The amount of organic or inorganic nutrients present in the soil, at any given time, reflects the standing quantity of biomass. The inorganic elements which are largely incorporated in biogeochemical cycling are CO_2, H_2O, N_2, Ca, P, S, etc. and these elements keep on moving from one compartment to another of the environment. Carbohydrates, lipids, amino acids, proteins which are synthesized by the living components are transfer from lower trophic level to the higher level through food chain and food web and ultimately reached to the soil as their wastes materials and dead remains which again make it available as nutrient for the plants.

Broadly abiotic factors are classified under three categories.

i) Climate factors (atmospheric temperature, relative humidity, intensity of light, rainfall, wind, and other physical factors).

ii) Inorganic substances (carbon, sulphur, nitrogen, phosphorus, water and so on) that are involved in material cycling of an ecosystem.

iii) Organic components (proteins, carbohydrates, lipids, humic substances, etc) that link the biotic and abiotic components of an ecosystem.

All the physico-chemical characteristics of soil related to the structure and composition like soil and its types, texture, soil profile, minerals, pH, organic matter, soil water, soil organisms, etc are called edaphic factors.

5.3.2.2. BIOTIC COMPONENT

Biotic component of an ecosystem comprises all the living part of the environment (*constitutes the biomass or living components*), which are associated through adjustment, adaptation, interaction in a common environment for various resources. Biotic community is distinguished into autotrophs, heterotrophs and saprotrophs based on the function and the general manner in which organisms obtain their food material. However, biotic components vary from one system to another. The biotic factors in an ecosystem may affect an individual organism depending on the type of organism.

i) Autotrophic organisms (Autotrophs) – Autotrophs of different types can produce energy either through photosynthesis or chemosynthesis. Autotrophs are the organisms known as producers of chiefly the green plants which can manufacture food items through photosynthesis, by using the solar energy that they use as sources of energy and nutrients. It is composed of the number of chlorophyll bearing plants, microscopic phytoplanktons, algae, different types of terrestrial and aquatic plants including, forbs, ephemerals, climbers, herbs, shrubs, trees, etc. This process of food synthesis (photosynthesis) begins when sunlight is absorbed by chlorophyll and other pigments in the plant. Sunlight is used as a source of energy to combine CO_2 from the atmosphere with H_2O from the soil to make organic compounds like carbohydrates, starches, and cellulose. This process converts the radiant energy into chemical energy, energy stored in chemical bonds releasing O_2 as a by-product. This stored energy is the direct or indirect source of energy for all organisms in the ecosystem.

There are also certain organisms that can synthesize food minerals in the absence of sunlight by oxidizing simple inorganic compounds from the environment and converting them to organic nutrients. This process is called chemosynthesis. The organisms that use chemosynthesis like chemosynthetic bacteria are found in those areas where sunlight can never reach, for example around hydrothermal vents on the deep ocean floor. All those bacteria use chemosynthesis, manufacture carbohydrates and other organic molecules from the oxidization of sulfates or ammonia. These bacteria use hydrogen from hydrogen sulphide which is pourd out in hydrothermal vents along with boiling hot water and they get nitrogen from ammonia or nitrates.

Only producers provide food for the consumers and decomposers, and they play a substantial role in the movement of mineral nutrients in ecosystems. Under anaerobic conditions the chemosynthesizers “rescue” energy in the form of organic compounds, otherwise it would be “lost” through storage in sediments. Thus, producers are the source of the energy that drives the entire ecosystem.

ii) Heterotrophic organisms (Heterotrophs or phagotrophs or macroconsumers) – Organisms which are not able to synthesize their own food material and whose nutritional and energy needs are met by feeding on other organisms are called heterotrophs, or other-feeders. The term heterotroph can refer to single or multi-cellular organisms. Many bacteria, fungi and animals are heterotrophs. These are the organisms which use the organic compounds produced by the autotrophs. Depending upon the type of food habit and consumption the heterotrophs are classified as primary, secondary and tertiary consumers. The primary consumers are those organisms that feed directly on living plants or plant remains to meet their nutritional requirements and are referred to as herbivores. Herbivores are of two types i.e. zooplankton (animals) and benthos (botton form) feed on plant remains. The secondary consumer also known as carnivores is a heterotroph, deriving its energy indirectly from the producer by feeding on the herbivore. Some ecosystems may contain tertiary consumers that feed on the carnivores or secondary consumers. Organisms that feed on both producers and herbivores and carnivores and derive their energy are called omnivores. Heterotrophs are the consumers of the food chain.

iii) Decomposers (saprotrophs or microconsumers saprophytes or osmotrophs) -

Organisms that feed on the non-living organic matter, usually faecal matter, exudates and excreta of plants, dead and decaying plants and animal matter by absorbing soluble organic compounds are called saprotrophs or decomposers. They cannot synthesize their own food, like fungi, bacteria, protozoa and animals such as dung beetles, vultures etc. These comprise of a community of decomposers which bring the complex constituent element of the plant and animal bodies back to the surrounding medium or to the soil as a decomposed and simple compound.

The driving force of the system is the energy of the sun. The survival of any individual organism in an ecosystem depends on how matter and energy flow through the system and through the body of the organism. This radiant energy of the sun is harvested by the producers, then it flows from producers to consumers to decomposers and eventually dissipates as heat.

5.3.3 ECOSYSTEM TYPES

Ecosystems may be divided into different types based on their species composition, climatic characteristic, sizes, major habitat, human pressure, etc. However, in general ecosystem is broadly classified into two major types based on their habitat namely, *terrestrial* and *aquatic*. Under these there may be sub ecosystems depending on structure and functional characteristics. Terrestrial ecosystem operates on land mass which are not based on water while aquatic ecosystem operates in aquatic habitats. On the other hand, on the basis of human influence, ecosystems can be classified as natural ecosystems and man made or modified ecosystems or man-engineered ecosystems. Both terrestrial and aquatic ecosystems may be natural as well as man – made ecosystems. The natural ecosystem covers all kinds of natural components like plants, forest, grassland, river, rocks, sea, ponds, lakes, deserts, etc, where there is no involvement of human beings. All types of ecosystems introduced and managed by man are artificial ecosystems. For example, garden, aquarium, villages, cities, etc.

Here, I would like to say that many people get confused about the "types of ecosystem" and "component of ecosystem" and even about "biome". The components of ecosystem we had studied just before these sections reveals the biotic component and abiotic component. Thus, the components of ecosystem and the types of ecosystem are two different terms. Biome is an ecosystem or we can say as biosystem which is quite a large distinct landscape characterized by a particular major vegetation type influenced by climatic conditions. It is a major regional group of climax species composition in terms of plants and animals communities that are best adapted to the physical natural environment, latitude, elevation and terrain of the particular region. Biomes are distributed over the surface of the earth as broad belts from the equatorial region to the Polar regions. Biomes are broadly classified into two namely, terrestrial biomes and aquatic biomes.

Terrestrial Ecosystems can be further classified as follows:

1. Forest ecosystem
2. Grassland and Savannah ecosystem
3. Desert and shrubland ecosystem
4. Tundra ecosystem

Aquatic Ecosystems can be divided into two types:

1. Freshwater ecosystem

Freshwater ecosystems includes

a) Lake and Ponds (confined)

b) Rivers and Streams (continuous)

c) Wetlands such as Bogs, Marshes, Fens, and Swamps (fed by water and nutrients leaching from surrounding catchments area).

2. Marine ecosystem

5.3.3.1. FOREST ECOSYSTEMS

Forest is one of the largest ecosystems of the terrestrial ecosystem. The type, composition and stage of forest largely depend on various climatic conditions like rainfall, temperature, humidity and amount of sunlight received, and latitude or altitude. Forests tend to have a high net primary productivity and also a high biomass.

Forest ecosystems are classified into three major types,

a) **Tropical forests**, found in the equatorial region with higher temperature, frequent heavy rainfalls and soils having poor nutrient content with low pH. Tropical forest harbors a tremendous amount of species diversity. Complex associations of plants and animals species in terms of food and habitat are found in the tropical forest leading to a close structural and functional phenomenon of the system

b) **Temperate forests** occur at lower latitudes receiving sufficient amount of rainfall. Temperatures may falls below 0^oC in winter and it may be warm and humid during summer. Soils are well developed and rich in nutrient. Climate of the tropical forest shows non-seasonal while in temperate it shows seasonal pattern. Broad leaved, deciduous tree species and the complex layered structure of the vegetation are the characteristics of the temperate forest, results to high primary production

c) **Alpine forest** shows the characteristics of cold climates and high elevation with acidic and humus rich soil. The vegetation is dominated by coniferous tree species having needle like structure leaves that help to reduce the evapo – transpiration and tissue damage from freezing injury.

The major forest biomes found in India are:

- Tropical evergreen forests / Tropical rain forests.
- Tropical deciduous forests.
- Temperate coniferous forests / Temperate needle leaf forests.
- Temperate broad - leaf forests

5.3.3.2 GRASSLAND AND SAVANNAH ECOSYSTEMS

Grassland ecosystems are water-limited by nature which bears intermediate characteristic of forest and desert ecosystem. It occurs in those landscapes where annual rainfall (150 and 1200 mm/year) is intermediate between the deserts and forests, and it is associated with droughts occurring at least once in a year. The vegetation is mainly dominated by several grass species but frequently includes some trees species like Acacia, Eucalyptus, etc. It has relatively low biomass compared to forest ecosystem but gives high primary productivity. Grasslands of the world are differentiated on the basic type of grasses and non-grasses plant species. Depending on the temperature gradient, grassland ecosystems are divided into two major types:

a) Temperature grasslands – occur across large areas of Europe and Asia, Central North America, and South America. Temperature grasslands are also referred as 'Steppes' in Europe and Asia, 'Prairies' in Canada and North America, 'Pampas' in South America, 'Tussocks' in New Zealand and 'Veldts' in Africa. Hot summers and cold winters with 250 and 600mm rainfall per annum show the climate condition of Temperate grassland. The amount of rainfall however determines the height of grasses in the grassland. For example, in North America, rainfall gradient helps to divide the temperate grasslands into tall grass prairies (in wetter areas) and short grass steppes (in dryer habitats). Soil is rich with large amount of organic matter, helping them for better growth and production of arable crops. The characteristic of

Temperate grasslands also shows the presence of broad – leaved perennials which either flower early in the season or after the grasses have died down. The ecosystem supports large populations of grazing (bison, antelope, zebra, bighorn sheep, deer, etc) and browsing (rodents, rabbits, prairie dogs, etc) animals. Those herbivores in turn support large number of mammalian carnivores. Very less diversity of bird and amphibians could be found in this grassland because of the absence of stratified trees and the short growing season of grasses. However, temperate grasslands are of tremendous economic importance to mankind because these are mainly grain growing and cattle raising areas.

b) Tropical grassland or Savannah– It is primarily located in equatorial and sub - tropical regions comprised with scattered trees. It is found in Central Africa, South America, Southern Asia and also in Australia. Temperatures remain high throughout the year. Maximum temperature reaches up to 30°C, but minimum temperature ranges from 12-14°C. Temperature may drop slightly at the start of the rainy season and the highest temperatures coincide with the summer rains.This ecosystem is characterized by warm climatic plains with coarse grass species and the margins with scattered trees. This grassland may receive up to 1200mm of rain in the wet season, but no precipitation during dry season. Nutrient cycling is largely hindered due to low soil moisture content and this reduces nutrient availability. The vegetation is characterized by drought-resistant shrubs and grasses. Common trees include *Acacia, Phoenix and Eucalyptus*. Kangaroos are found in the Savannah of Australia.

5.3.3.3 DESERTS AND SHRUBLAND ECOSYSTEM

The desert in its most typical form consists of drought resistant shrubs covered land with scanty vegetation, spatially quite dispersed, consisting of mainly thorny bushes. Many species are short lived annuals that complete their life cycles during infrequent and short rainy periods. Many deserts across the globe receive annual rainfall of less than 50 mm consisting of hot days and cold nights which is influenced by descending air currents which limit the formation of precipitation. In deserts because of low productivity, the litter layer is comparably limited and organic content of surface soil layers is very low, soil is thin and freely drained. Also, evaporation tends to concentrate salts at the soil surface. Due to loose texture, rainfall easily and very quickly penetrates the soil or runs over the surface in temporary streams. Thorny shrubs, ephemeral animals, underground corms and bulbs and succulents plants such as cacti are the major vegetation of hot desert. All the plants have certain morphological adaptations allowing them to survive long periods of drought. Reptiles and insects are most able to survive in desert conditions. However some mammals, including rodents and camels, have evolved means of coping with arid conditions.

Deserts are classified as hot and cold temperate deserts. The hot deserts are found in the Sahara in Northern Africa, Kalahari in Southern Africa, Thar in India, Atacama in South America, deserts of Mexico and Australia. Whereas, cold deserts are found in deserts of Iran and Turkey, Gobi desert of Mongolia, some deserts of Argentina and mountainous region where the climate is too dry for grassland. Hot deserts are found around latitudes 30ºN and 30ºS. Semi-desert ecosystems occur in less arid regions, but where water remains limiting. Cool deserts have denser shrub vegetation and abundant microflora.

Shrubland ecosystem has a very specific spatial distribution located in a narrow zone between 32 and 40° latitude North and South on the west coasts of the continents. Temperate shrubland formed around the shrubs of the Mediterranean Sea is known as "Maquis" and the shrubland found around Southern California is called "Chaparral". This biome is sometimes also called Mediterranean Scrubland or sclerophyll forest. This area has a dry climate and precipitation falls mainly in the winter months. Annual averages range from about 300 to 750 mm and most of this rain falls during a period between 2 to 4 months long. Trees and shrubs living in this zone tend to be small, thick, hard, drought-resistant evergreen leaves that can withstand arid conditions. And many of the plant species have thorns to protect themselves from herbivore damage. The rate of leaf decomposition in the soil is slow due to dry climate. As a result, the soil is poor of nutrient and plants couldn't get sufficient nutrient requirements to produce new leaves, and quick growth occurs during wet season. Instead, the plants of the chaparral develop leaves that can withstand arid conditions. Representative species of the Shrubland ecosystem include cork oak (*Quercus suber*), olive (*Olea europaea*), eucalyptus, arbutus (*Arbutus unedo*), acacia, maritime pine (*Pinus pinaster*), shrub oak (*Quercus dumosa*), and live oak (*Quercus agrifolia*). Shrublands are important habitats for reptiles, small mammals and birds.

5.3.3.4. TUNDRA ECOSYSTEMS

Tundra ecosystem lies north of 60^o N latitude between the Arctic ocean and the polar ice caps to the north and the Coniferous forests to the South. There is no tundra biome in the Southern hemisphere. It covers about 8 million km^2 extending across North America, Europe and Asia. The regions found above the tree line on high mountains are called alpine tundra. The word 'tundra' means 'North of the timber line'. These are superficially barren land, treeless regions where extreme environmental conditions severely limit plant growth. Low temperature (-30^oC to -40^oC in winter and only about 10^oC in summer only for a very short period) and short growing season (3 to 4 weeks) prevent the development of forest in tundra region.

The plains of tundra are covered with snow, ice and below a certain depth the ground remains permanently frozen soil most of the year forming permafrost. Therefore ground surface is spongy, uneven as a result of freezing and thawing. Precipitation is low usually below 250mm and occurs mainly as snow. The low productivity and limited microbial activity result in thin soils. Vegetation in tundra is very sparse and consists of low growing plants. Hence, it is also called 'arctic desert'. It exhibits very low species diversity. Plants are mostly shallow rooted and they often possess xerophytic adaptations. Lichens and mosses form the main vegetation along with dwarf birches and dwarf willow trees, bilberries, dwarf huckleberries, and low flowering herbs. The extreme seasonality of tundra couldn’t harbour any amphibians and reptiles which mean that some animals are only present as summer migrants. Migratory birds such as geese, sandpipers, ducks and other water fowl breed on tundra in summer feeding on the vegetation and on the emergent insects. Insects like biting flies, dipteran flies (black flies), mosquitoes etc. are found here. The caribou, musk ox, arctic hare, arctic fox, lemming, polar bear and weasels are the mammalian residents of tundra. Some of them hibernate in winter in caves and others migrate to coniferous forests.

5.3.3.5 AQUATIC ECOSYSTEMS:

1. Freshwater ecosystems: Freshwater ecosystems includes

a) Lake and Ponds (Lentic; Stagnant, sessile)

b) Rivers and Streams (Lotic; continuous, running)

c) Wetlands such as Bogs, Marshes, Fens, Shrub-Carr and Swamps

(fed by water and nutrients leaching from surrounding catchments area).

a) Lakes and Ponds

Lakes and ponds ecosystem are more or less stagnant, confined one with little or no current. Many ponds are seasonal, lasting just a couple of months (particularly during rainy season) while lakes may exist for hundreds of years or more. Depending upon the temperature and chemical composition, and depth and distance from the shoreline ponds and lakes can be classified into different zones. For example, on the basis of water depth and types of vegetation and animals there may be three zones in a lake or pond namely, Littoral, Limnetic and Profundal.

Littoral zone are the topmost zone near the shore of a lake or pond usually occupied by rooted plants. Limnetic zone found near-surface open water surrounded by the littoral zone is characterized by shallow to the depth of effective light penetration and associated organisms are small crustaceans, rotifers, insects and their larvae and algae. And profundal zone in deep-water part of the lake/pond where there is no effective light penetration. The associated organisms are snails, mussels, crabs and wounds.

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Temperature varies in ponds and lakes seasonally and depth-wise. In shallower lakes the temperature stratification persists during the summer when surface waters are warm. The portion of water body which is well illuminated and warm is called the epilimnion. The cooler water below, the metalimnion or thermocline, becomes colder with depth. This bottom layer of stagnant water with little or no fluctuation of temperature is called the hypolimnion. In between the epilimnion and hypolimnion, there is a narrow zone called the thermocline, this is the zone where temperature of the water changes rapidly.

Depending upon the chemical composition of the substrate and the geology of the surrounding catchments, ponds or lakes can be categorized as Eutrophic (water with rich nutrient status and high productivity), Mesotrophic (water with moderate nutrient status and productivity) or Oligotrophic (water with poor nutrient status and productivity). Eutrophic pond or lakes may be natural, characterized by natural nutrient enrichment or cultural which is generally speeded up by human activities. Which are responsible for the addition of 80% nitrogen and 75% phosphorous to lakes and streams.

b) Rivers and Streams

Rivers and streams are bodies of flowing water moving in one direction differing greatly, depending on their size. Rivers and Streams are places where water is transported from one place to another. Streams and rivers can be found everywhere—they get their starts at headwaters, which may be springs, snowmelt or even lakes, and then travel all the way to their mouths, collects in a watershed and ultimately deposits that water in the ocean. Their length varies from their source in upland and to the sea. All along the way, the characteristics of a river and streams change. Rivers serve as an important life-giving source to many plants and animals.

In general, the temperature is cooler at the source than it is at the mouth. The water is also clearer, has higher oxygen levels, and freshwater fish such as trout and heterotrophs can be found there. Towards the middle part of the stream/river, the width increases, as does species diversity-numerous aquatic green plants and algae can be found. Toward the mouth of the river/stream, the water becomes muddy from all the sediments that it has picked up upstream, the water becomes less turbulent, light penetration and oxygen level falls down. Since there is less light, there is less diversity of flora, and because of the lower oxygen levels, fish that require less oxygen, such as catfish and carp, can be found.

High in the catchment areas the water is unpolluted, too turbulent and nutrient poor but enough o support aquatic mosses, liverworts and algae, and caddis fly (*Trichoptera*) and balckfly (*Simulium* spp.) larvae feeding fine organic particles. The volume of moving water is increased having accumulated as the river passes through its catchment and the current is reduced. Plankton communities consisting of algae, photosynthetic bacteria, crustaceans, and rotifers develop and fish, reptiles, birds and mammals may be present. The energy of the river decreases, particularly at the edges of a growing channel, plankton communities become more complex and sediment is deposited, providing a rooting medium for benthic organisms such as oligochaete worms, plants which grow up beyond the water's surface provide physical habitat for invertebrates, fish and epiphytic organisms. Consequently, human influences increase for harvesting water resources.

c) Wetland ecosystems

Wetlands are areas of marsh, fen, peatland or water (permanent or temporary), with water that is static or flowing. These are the areas lying along the banks of rivers and lakes and the coastal regions. The soil must remain water logged or submerged for whole or part of the year and support hydrophytic biota (hydrophytic vegetation) that depends upon and is adapted to this waterlogging or submergence during atleast part of their life cycle. Fresh water wetlands can be grouped as bogs, Marshes, Fen, Shrub – land and Swamp.

5.3.3.6 MARINE OR OCEANIC ECOSYSTEMS

Marine or oceanic ecosystems are the largest of Earth's aquatic ecosystems covering 70% of the earth's surface. Marine ecosystems contain several unique qualities that set them apart from other aquatic ecosystems, the key factor being the presence of dissolved compounds in seawater, particularly salts. Marine waters cover two-thirds of the surface of the Earth. Such places are considered ecosystems because the plant life supports the animal life and vice-versa. Like other aquatic ecosystems, marine ecosystems require nutrients and light to produce food and energy. However, both nutrients and light are limiting factors in marine ecosystem productivity. Marine ecosystems harbour different species ranging from microscopic planktonic organisms that comprise the base of the marine food web (i.e., phytoplankton and zooplankton) to large marine mammals like the whales, manatees, and seals. Some examples of important marine ecosystems include salt marsh, estuaries, coastal and lagoons mangroves and coral reefs.

5.3.4 TROPHIC LEVELS

As we all know, the central theme of ecosystem is to release and exchange of minerals and flow of energy between the living organisms and physical conditions of the system. All the existing living organisms in any ecosystem can be grouped into producers, consumers and decomposers. In view of the structural components, a characteristic of all ecosystems can also be described according to their feeding preferences of each organism, in other words depending on the way that organisms get energy. Thus, each group of organisms with similar feeding habits constitutes a trophic level. “Trophic” means trophe – nourishment or feeding. The relationship between the trophic levels depicts “trophic structure” of and ecosystem wherein each animal population forms the various trophic levels. Trophic structure of an ecosystem can be described in terms of its total amount of nutrients or the amount of living material. The amount of nutrients in the soil at any given time is referred as 'standing state' whereas the amount of living material is referred to as 'standing crop'.

In an ecosystem, there may be three or four trophic levels. Trophic levels remains the same in any types of the ecosystems, but its representative’s species can vary. For example, in forest (terrestrial ecosystem) all the plants (trees, shrubs and herbs) being the producers occupy the “first trophic level” while in the ponds, rivers, lakes and streams (aquatic ecosystem) the producers, the first trophic levels are phytoplankton and aquatic plants. First trophic levels are the ‘producers’ that able to manufacture its own food and which indirectly provide all food and energy requirement to the maintenance of the ecosystems. Animals that feed exclusively on producers are the “second trophic level”. Small invertebrates to great mammals represent the “second trophic level” i.e. primary consumers in forest but in ponds, rivers, lakes and streams they are represented by small crustaceans, the zooplankton, and for some species of fish that feed on phytoplankton. Depending on the food habits and availability secondary consumers or the “third trophic level” are mainly the animals that feed on herbivores and tertiary consumers which occupied the “fourth trophic level” are carnivorous that feed on carnivorous in forest, mainly, carnivorous mammals, reptilian, birds, amphibians and insects, while in the rivers and lakes secondary and tertiary consumers are represented mainly by fishes and birds.

Some primary/secondary or secondary/tertiary consumers display a mixed feeding preference, characterized by availability and choice of the food material and nutrient requirement, eating animals and plants. These consumers eating everything are called omnivorous (*omnis*= everything). They occupy more than one trophic level and, some organisms occupy different trophic positions in different food chains. Since man is an omnivore, so occupy all trophic levels for food chain.

Decomposers or detritivores forms a special class of consumers, because they obtain their energy by degrading dead organisms or absorbing excreted or extracted organic matter from other organisms.

The sequence of trophic levels represents the pathway in which energy is transferred from one trophic level to another in an ecosystem. The amount of energy in a trophic level is always higher than the amount transferred to the following higher trophic level. This is because of the fact that energy obtained by organisms is used in activities and great part of dissipated in heat form or eliminated in feces or excreta which is unable for further use or consumption.

5.3.5 FOOD CHAIN AND FOOD WEB

The transfer of energy and nutrients from the first trophic level 'autotrophs' through a series of organisms of higher trophic levels through repeated process of consumption and being consumed by others is known as **Food Chain**. Food chains are not isolated and they forms complex pattern of consumption in a natural ecosystem and thus form a **Food Web**.

Characteristics of Food Chain

Food chains signify a feeding relationships and nutritive interaction between the biotic components of an ecosystem whereby there is repeated eating in which each group eats the smaller one and is eaten by the larger one. In general, it consists of four or five trophic levels where producers and consumers depend successively on one another, forming the network of a food chain. Shorter food chains provide greater available energy and vice- versa. It figures out the major source of solar energy on which the entire organism depends and also specifies the non-cyclic or unidirectional energy flow mechanism, and matter circulation in ecosystems. It helps to understand the movement of toxic substances and the problem of 'Biological magnification' in the ecosystem.

Two types of food chain operate in nature.

i) Grazing food chain and

ii) Detritus food chain.

Grazing food chain starts from green plants (producers) and through herbivores to the primary carnivores, secondary carnivores, etc. A herbivore based food chain is generally seen in ecosystems such as grassland, pond or lake where a substantial part of the net primary production is grazed on by herbivores.

Illustration of grazing food chain

	Autotrophs -	Herbivores -	Primary carnivores -	Sec. carnovores – etc.
E.g.	Phytoplanktons, –	zooplanktons, -	rabbit, -	Lion,Tiger
	grass	fish	fox	

Detritus food chain starts from detritus, the dead organic remains including metabolic wastes, exudates derived from grazing food chain, which is consumed by detritus feeding microorganisms (detritivores) such as micro arthropods, oligochaetes, protozoans, bacteria, fungi, etc., which is turn eaten by some other predators. The detritus feeding organisms process the detritus in their gut by reducing it into small pieces, digesting it partially or completely, thus making organic material available for bacterial or fungal attack. These microorganisms also act as food for many soil animals.

Illustration of detritus food chain

Detritus	**Detritivores**	**Detritivores Consumers**	**Small Carnivores**	**Large Carnivores**
Mangrove Fallen leaves and dead bodies	Fungi, bacteria and protozoans	Insect larvae, crustaceans, molluscs and fishes	Minnows, small game fish, etc.	Large fish, birds

Differences between grazing and detritus food chains lie primarily in the source of energy, solar radiation for grazing food chain while detritus for detritus food chain. There is a long-sized chain in grazing while detritus food chain is a shorter chain. Grazing food chain is herbivore based while detritus is based on decomposers.

Food web

The complex pattern of interrelated food chains in a natural ecosystem is called a food web. In other words, the complex network of food chains that maintains the stability of the ecosystem is termed as food web. Food web can be defined as, "a network of food chains which are interconnected at various trophic levels, so as to form a number of feeding connections amongst different organisms of a biotic community".

Food webs are indispensable in ecosystems as they allow an organism to obtain its food from more than one type of organism of the lower trophic level. It indicates that greater the number of alternative pathways the more stable in the community of living things. Normally, a food web functions according to taste and choice of food preferences of the organism. Nevertheless availability of food source and other compulsions are equally important. For example, in Sunderbans tigers are found to eat fish or crabs though these are not their normal food, but non-availability of enough food/prey forced them to feed on them.

5.3.6 ECOLOGICAL PYRAMIDS

The graphical representation of an ecological parameter like members, biomass and energy content of the primary producers, consumers of the first and second orders and so on to top carnivores of a food chain in any ecosystem with producer represented the base and top carnivores at the tip are referred to as ecological pyramids. Charles Elton in 1927 first developed the concept of ecological pyramids who noted that "…the animals at the base of a food chain are relatively abundant while those at the end are relatively few in number…". Ecological pyramids are also called 'Eltonian pyramids' after C. Elton.

On the basis of the ecosystem species characteristic, an ecological pyramid may be upright (tapering towards the tip), or inverted (widens towards the tip) or spindle shaped (broader in the middle and narrow above and below).

Depending on the parameters used, there are 3 categories in ecological pyramids

i) Pyramids of number

ii) Pyramids of biomass

iii) Pyramids of energy

Pyramids of number

It depicts the number of individuals per unit area in producers and in different order of consumers in an ecosystem. The shape of the pyramid of numbers may be upright, inverted and spindled shaped depending on the type of the ecosystem

Pyramid of numbers in grassland and aquatic ecosystem show upright pyramid while a parasitic food chain gives inverted pyramid and an adult tree of forest which supports larger number of herbivorous birds which in turn are eaten by smaller number carnivorous birds forms a spindle shaped pyramid.

Pyramids of Biomass

“Pyramid of biomass is the graphic representation of biomass (the total amount of organic materials produced by organisms in an ecosystem at any time) present in each trophic level per unit area, with producers at the base and top carnivores at the tip". Pyramid of biomass may be upright or inverted or spindle shaped depending on the total amount of organic matter present in each trophic level. Almost in terrestrial ecosystem pyramid of biomass shows upright, due to the maximum biomass occurring in producers, and there is progressive decrease in biomass from lower to higher trophic levels. We can find inverted or spindle shaped pyramid in an aquatic ecosystem where the biomass of trophic level depends upon the reproductive potential and longevity of the member. In general, the first trophic level “producers’ of the aquatic habitat are microscopic in size which hold small amount of biomass, but they have high biotic potential compared to the other higher trophic level.

Pyramids of Energy

“Pyramid of energy represents the amount of energy trapped per unit area and time in different trophic levels of a food chain with producers forming the base and the top carnivores at the tip". It depicts not only the amount of total energy utilized by the organisms at each trophic level of food chain, but more important is the actual role of the various organisms play in the transfer of energy. Pyramid of energy is always upright because of the fact that, there is no 100% transfer of enrgy from one trophic level to another trophic level as per Lindemann's ten percent rule. About 80 - 90% of the energy available at lower trophic level is used up to overcome its entropy and to perform metabolic activities. Only 10% of the energy is available to next trophic level.

5.4 ECOSYSTEM SERVICES

Have you ever thought of how we get clean water and air, what is the importance of trees growing in our home, at the roadsides, where from we get our food, our cloths, how plants get beautiful flowers, etc.? Natural ecosystems perform numerous fundamental life-support ‘services’ to sustain human welfare and upon which our civilization and development depend. It not only provides our basic needs like the food, fibre, shelter, water, livable atmosphere and other raw materials and services necessary for subsistence, also contributes to protecting us from the elements, satisfying our needs, providing us opportunities to think about the creator, and giving us a sense of identity. The services of nature (environment) to households, communities, societies and economies are the ecosystem services. The health and welfare of human populations depend upon the services provided by ecosystems and their components.

The services provided by ecosystems to humans are products of the complex interactions among different species and with the non-living components of the environment. Ecosystem services are the processes by which the environment produces resources that we often take for granted such as clean water, timber, and habitat for fisheries, and pollination of native and agricultural plants. Whether we find ourselves in the city or a rural area, the ecosystems in which humans live provide goods and services that are very familiar to us.

Some other examples of ecosystem services that come from nature include:

i) regulation of climate - moderate weather extremes and their impacts by the presence of trees

ii) pollination -pollinate crops and natural vegetation

iii) disperse seeds - reduces seedling mortality under mother plants and helps to distribute the plant species in different areas

iv) maintain biodiversity in terms of species and genetic level.

v) regulation of river flows and groundwater levels

vi) prevention of soil erosion, maintain soil fertility and soil health

vii) mitigate drought and floods by maintaining of healthy waterways

viii) purify the air and water

ix) detoxify and decompose wastes through waste absorption and breakdown

x) cycle and move nutrients

xi) protect people from the sun’s harmful ultraviolet rays

xii) Water filtration, recharge ground water and aquifers

xiii) protect stream and river channels and coastal shores from erosion

xiv) control agricultural pests

xv) regulate disease carrying organisms and vector borne diseases

xvi) fulfill people's cultural spiritual and intellectual needs

xvii) maintain and regeneration of habitat

xviii) provide shade and shelter

5.5 BIOMES

Biome is a large, regional or sub continental bio-ecosystem characterized by a dominant vegetation type or other distinct climatic characteristics in which organisms are well adapted through the succession forming a climax stage. Biomes are defined as "the world's major communities, classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment" (Campbell 1996). The climate and geography play very important role in determining the type of biome that can exist in a particular region. Biomes are distributed over the surface of the earth as broad belts from the equator to the poles. However, the extent of a biome is determined by climatic and edaphic factors, barriers, latitude and altitude. Each biome consists of many ecosystems whose communities have adapted to the small differences in climate and the environment inside the biome. The importance of biomes cannot be overestimated. Biomes have changed and moved many times during the history of life on Earth. More recently, human activities have drastically altered these communities.

Broadly, on earth we have two types of biomes *terrestrial* and *aquatic* biome. The terrestrial biomes are classified into Taiga, Temperate forest, Tundra, Desert, Grassland (Chaparral, Temperate Grassland and Tropical savanna), Tropical rainforest. The earth's coldest biome is the tundra which has permanently frozen subsoil, called permafrost.

Freshwater and Marine ecosystems make the aquatic biomes. Freshwater biomes are extremely important because water is the basis of all life.

The general features and characteristics of the **Tundra, Desert, and Grassland** biomes may be seen and revised from the section of ‘ecosystem types’.

The Taiga biomes

Taigas are the 'northern coniferous forests' which are also referred as 'North Woods', very common in Siberia. The word taiga means, "marshy pine forest" in Russian. It is one of the most fragile biomes. Taiga extends as an east - west band across North America, Europe and Asia, just to the south of tundra (between 45^oN to 75^oN latitudes). In southern hemisphere it is found in the south island of New Zealand. In India, such forests are found in the Himalayas.
In taiga winters are very long and snowy, temperature reaching a low of about 6^oC. Summers are very brief with the average temperature of 20^oC. Summer is mild and provides a short growing period (of about 60 - 150 days). Precipitation occurs as both rainfall and snow. Soils are thin, acidic and poor in humus as the fallen needles (coniferous leaves) form a thick zone on the surface and decomposition / decay is very slow due to low temperature and poor growth of decomposers.

Temperate deciduous forests

It is found in temperate regions of North central Europe, Eastern Asia and Eastern United States and in the southern hemisphere in Australia and New Zealand. The area is characterized by warm summer (20 - 27^o C) and moderately cold winter having 12^o C. Precipitation is abundant ranging from 75 cm to 150 cm. Soil is rich in organic matter and minerals. Vegetation shows distinct five layers, namely overstory of deciduous trees, deciduous tree stratum, shrub layer, herbaceous layer, and moss and lichen. Trees occupies in overstory reach 15 - 55 meters above the ground while deciduous tree stratum with crown tops around 6 - 12 meters above the ground. The shrub layer is up to 3 meters high and rhizomes and bulbs of herbs or spring perennials form the herbaceous layer. On rocks and fallen logs abundant moss and lichen layer grow. The common trees are beech, hemlock, buckeyes, basswood, oak, maple and hickory.
Important consumers are deer, fox, bear, wild turkey, salamander, turtles, lizards, snakes, etc.

Tropical rain forest

Tropical rain forests occur in regions with plenty of moisture and heat. Temperature and humidity are high. Annual rainfall is around 200 - 225 cm and evenly distributed throughout the year. The forest soil is rich in microorganisms and soil fauna.
birds, monkeys, lemurs, sloths, ant-eaters, bats,
. Crowns of large trees (canopy trees) are covered by epiphytes - non - parasitic plants. Dominant epiphytes are orchids and ferns. Tropical rain forest is also rich in ‘lianas’, the woody climbers with roots in the ground and their leaves and flowers in the canopy of trees are found.

5.6 SUMMING UP

An ecosystem is basically self-sufficient which is usually defined as a large area where materials and energy flow takes place between different organisms and non-living things. The biotic (living organisms) and abiotic components like soil, air, water, sunlight, minerals, and nutrients are important for a healthy ecosystem. All kinds of life forms on this planet are interconnected in some way or the other. Some may be part of a food chain, while others may help in production and pollination and contribute to reproduction. There is a fine balance between living things, non-living things, food webs, and environmental conditions of an area. This balance ensures that none of these are disturbed in any way and that they can live, nourish and reproduce in that system. This is the 'web' of life, the fragile ecosystem that we are just beginning to understand.

Producers, consumers and decomposers are the various trophic levels, which are linked by their food relationship forming a 'food chain'. Several food chains are interrelated and interconnected to form a network called 'food web'. Graphical representation of ecological parameters like number of individuals, amount of biomass and amount of energy results in the trophic structures pyramid of number, pyramid of biomass and pyramid of energy respectively.

The major terrestrial ecosystems of the world with their groups of climax biotic community are called 'biomes'. Essentially, biomes are regional ecosystems, and the biosphere is the largest of all possible ecosystems. The major terrestrial biomes are - tundra, tropical forests, savannah, grasslands and deserts. The survival and well being of a biome and its organisms depend on ecological relationships throughout the world.

Ecosystems sustain human societies and allow them to prosper, due to the nutritional, environmental, cultural, religious, recreational and aesthetic resources they provide. We all depend directly or indirectly on the products and services of ecosystems, including crops, livestock, fish, wood, clean water, oxygen, and wildlife.

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5.8 PROBABLE QUESTIONS

- What is an ecosystem, and how can we study one?
- What are different types of ecosystem?
- Is the earth an open or closed system with respect to energy and elements?
- What are the major factors responsible for the differences between ecosystems?
- What is the difference between the ecosystem and biome?
- Describe the characteristic features of the Tundra biome.
- Define trophic level.
- What is ecological pyramid? Why does the pyramid of energy always remain upright?

UNIT-6: EARTH PROCESSES

UNIT STRUCTURE

6.1 OBJECTIVES

After going through this unit, you will be able to:

- discuss the various geomorphic processes that shape the earth's surface
- study the various geological agents responsible for geomorphic processes
- describe the various biogeochemical cycles

6.2 INTRODUCTION

We know that the earth's crust is dynamic. The differences in the internal forces operating from within the earth which built up the crust have been responsible for the variations in the outer surface of the crust. The earth's surface is being continuously subjected to external forces induced basically by energy (sunlight).The external forces are known as exogenic forces and the internal forces are known as endogenic forces. The actions of exogenic forces result in wearing down (degradation) of relief/elevations and filling up (aggradations) of basins/depressions, on the earth's surface. The phenomenon of wearing down of relief variations of the surface of the earth through erosion is known as gradation. The endogenic forces continuously elevate or build up parts of the earth's surface and hence the exogenic processes fail to even out the relief variations of the surface of the earth.

6.3 GEOMORPHIC PROCESSES

The endogenic and exogenic forces causing physical stresses and chemical actions on earth materials and bringing about changes in the configuration of the surface of the earth are known as geomorphic processes. Diastrophism and volcanism are endogenic geomorphic processes. Weathering, mass wasting, erosion and deposition are exogenic geomorphic processes. Any exogenic element of nature (like water, ice, wind, etc.,) capable of acquiring and transporting earth materials can be called a geomorphic agent. When these elements of nature become mobile due to gradients, they remove the materials and transport them over slopes and deposit them at lower level.

6.4 LANDFORMS

Landforms are natural features of the landscape, natural physical features of the earth's surface, for example, valleys, plateaus, mountains, plains, hills, loess, or glaciers which are created with the physical agents such as water, wind etc.

6.4.1 FLUVIAL LANDFORMS

Rivers have been eroding, transporting, and depositing sediment since the Earth's hydrosphere came into existence, and have had a major influence in changing the landscape. The landforms either carved out (due to erosion) or built up due to deposition by running water are called fluvial landforms. Deposition of fluvial sediment has occurred in river channels, floodplains, lakes, alluvial fans, and deltas as well as in the sea. These deposits are a record of the geometry, flow, and sedimentary processes of past fluvial environments, and these can be related to past climates, tectonic activity, and eustatic sea-level change.

6.4.2 EROSIONAL LANDFORMS

The significant landforms resulting from fluvial erosion by streams include river valleys, water falls, pot holes, structural benches, river terraces, meanders, peneplains etc.

6.4.2.1 RIVER VALLEYS

The valleys carved out by the rivers are significant erosional landforms and the shape and dimension of fluvially originated valleys change with the advancement of the stages of fluvial cycle of erosion. The valley in the youthful stage of fluvial cycle of erosion is called the V-shaped valley. The valleys gradually widened due to lateral erosion with the advancement of the stage of cycle of erosion.

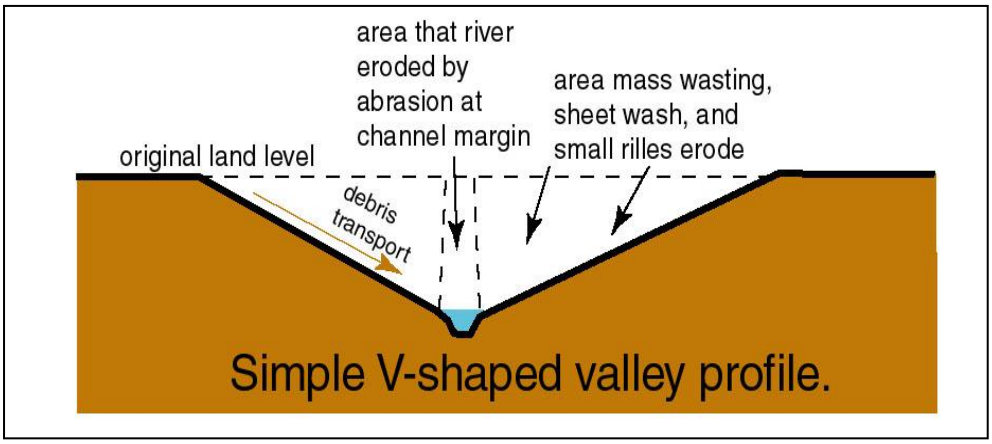

Fig 6.1: River Valley(source : http://maps.unomaha.edu/maher/geo117/part2/117fluvial.html)

There are 3 types of v-shaped valleys:

(i)Gorge - Steep precipitous wall within which a narrow river is confined (e.g.-Indus, Sutlej, Brahmaputra, Rhine, Zambezi)

(ii)Canyon - A very deep and extended gorge.

(iii) Structural benches - Differential erosion of alternately arranged hard and soft rocks forming step-like valleys known as structural benches.

6.4.2.2 WATERFALLS

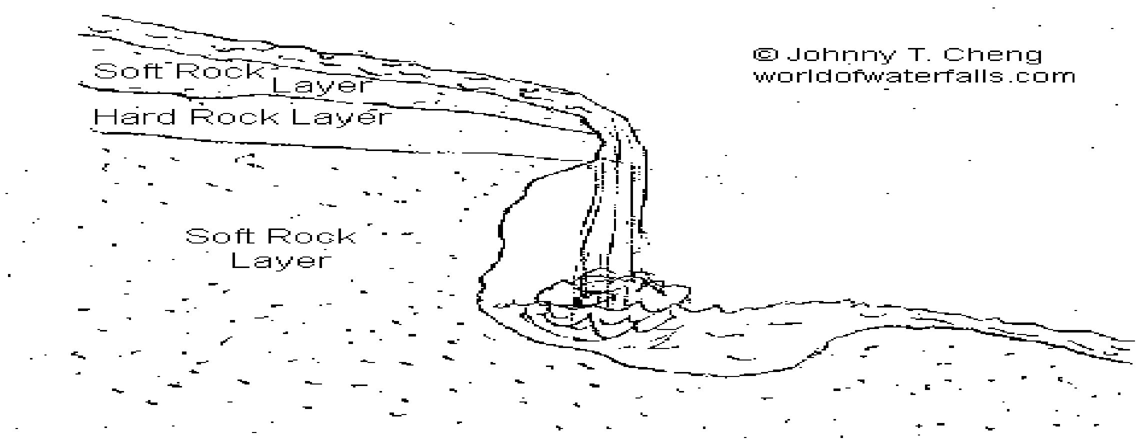

Fig 6.2: Formation of waterfall

Waterfalls are caused because of sudden descents or abrupt breaks in the longitudinal course of the rivers due to a host of factors e.g. variation in the relative resistance of rocks ,relative difference in topographic relief, fall in sea level etc. Waterfalls are formed due to:-

(i)Differential erosion of hard and soft rocks

(ii)Plateau scarp formation (Livingstone, Aughrubies, Gersoppa falls)

(iii)Because of fault scarps (Victoria fall on Zambezi River)

(iv) Due to Glacial Hanging valley (Yosemite fall)

(v)Fall in sea level and related rejuvenation

(vi) Other topographical reliefs and earth movements.

(vii)Due to formation of knick point in a rejuvenating stream

6.4.2.3 POTHOLES

The kettle-like small depressions in the rocky beds of the river valleys are called potholes which are usually cylindrical in shape. Potholes are generally formed in coarse grained rocks such as sandstones and granites. Potholing is the mechanism though which the grinding tools (fragment of rocks etc) when caught in the water eddies moves in a circular manner and they grind and drill the bed rocks and thus form small holes which are gradually enlarged.

6.4.2.4 STRUCTURAL BENCHES

The step- like flat surfaces on either side of the present lowest valleys are called terraces. The benches or terraces are formed due to differential erosion of alternate bands of hard and soft rock beds. River terraces are generally formed due to dissection of fluvial sediments of floodplains deposited along the valley floor.

6.4.2.5 RIVER MEANDERS

River meanders refers to the bends of longitudinal courses of the rivers. Meanders are normal for rivers flowing on low slope in plains or lowlands where sediment is fine sands, silt or mud.

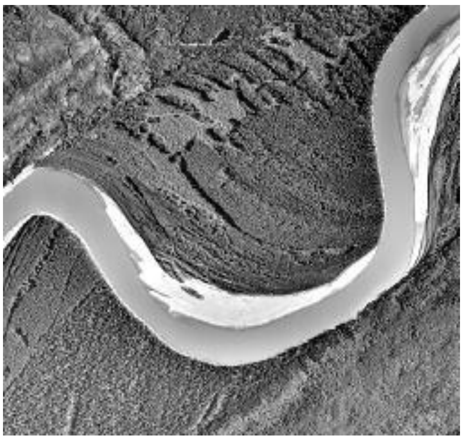

Fig 6.3 meandering river (source NASA)

6.4.2.6 OX-BOW LAKES

These are formed due to impounding of water in the abandoned meander loops.

6.4.2.7 PENEPLAIN

It represents featureless low lying plain having undulating surface and remnants of convexo-concave residual hills and is the end product of normal cycle of erosion. Usually frequented with low residual hills called Monad nocks.

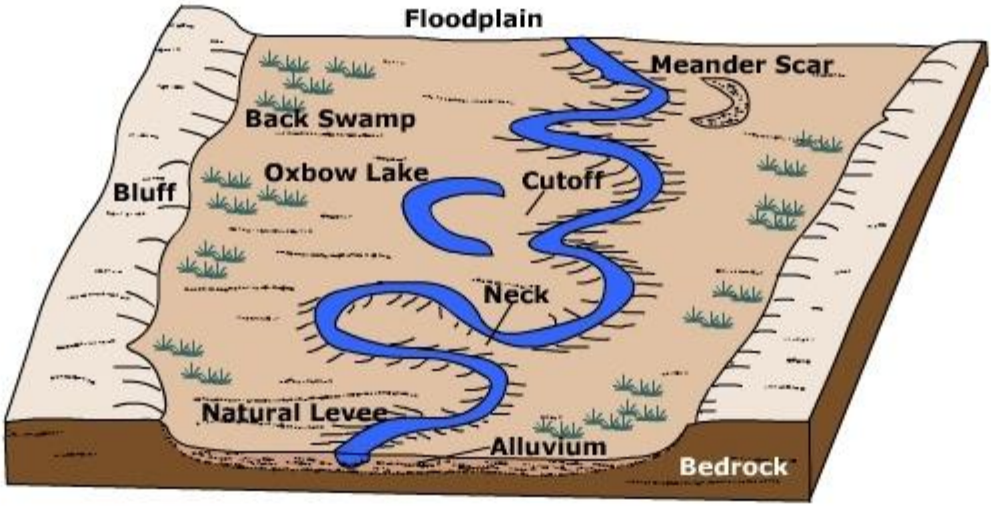

Fig: 6.4 Fluvial Land Forms

(Sourcehttp://www.geography.hunter.cuny.edu/~tbw/ncc/Notes/chap3.landforms/river.stream.landscapes.outline.htm)

6.4.3 DEPOSITIONAL LANDFORMS

6.4.3.1 ALLUVIAL FANS AND CONES

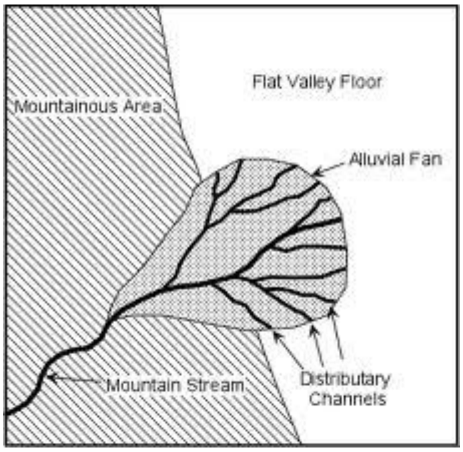

Fig 6.5 : Alluvial fan

(source : http://maps.unomaha.edu/maher/geo117/part2/117fluvial.html)

These are formed due to accumulation of materials in the form of fan and cones respectively at the base of foot hills. Alluvial Cones are made of coarse materials than the alluvial Fans.

6.4.3.2 NATURAL LEVEES

Narrow belt of ridges of low height built by the deposition of sediments by the spill water of the stream on its either bank.

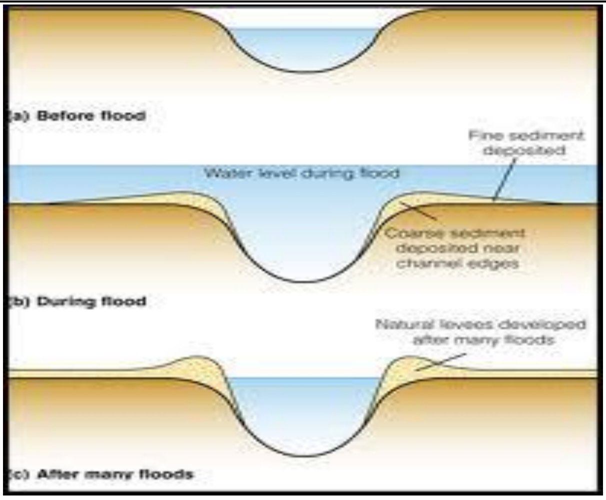

Fig6.6 Formation of natural levees

6.4.3.3 FLOOD PLAIN

Surfaces on either side of a stream that are frequently inundated by channel water.

6.4.3.4CREVASSE SPLAYS - Formed by breaching of levees when water escapes through a series of distributary channels.

6.4.3.5 DELTA -Triangular deposition at the mouth of a river debouching in a lake or a sea.

Factors that help in Delta formation –

(1) Long Courses of rivers

(2) Medium size sediments

(3) Calm or Sheltered Sea

(4) Suitable place (shallow sea and lake shores)

(5) Large amount of sediments

(6) Accelerated erosion

(7) Stable condition of sea coast.

On the basis of shape delta can be

1. Arcuate
2. Bird-Foot
3. Estuarine
4. Truncated

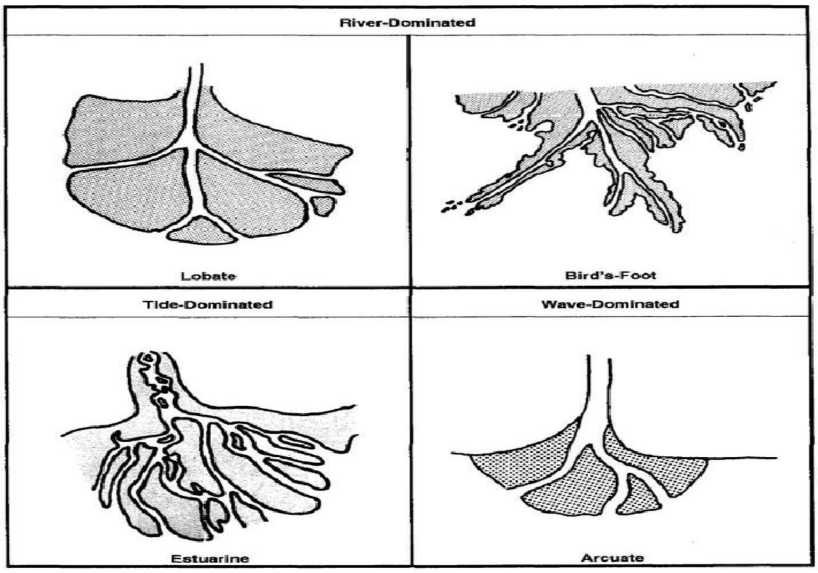

Fig 6.7 Types of deltas

6.4.4 AEOLIAN LANDFORMS

In aeolian processes wind is the agent for the transport and deposits the sediments. Wind is the primary source of erosion and the particles deposited are of sand, silt and clay size.

The particles are transported by the following processes:

Creep is when a particle rolls or slides across the surface.

Lift is when a particle rises off the surface and carried by wind.

If the airflow is turbulent, larger particles are trajected by a process known as **saltation**.

Impact transport occurs when one particle strikes another causing the second particle to move.

6.4.4.1 EROSIONAL LANDFORMS

There are several types of landforms associated with erosion: lag deposits, ventrifacts, yardangs and pans etc.

DEFLATION BASINS-Depression created through deflation, also known as Deflation hollows e.g. Quattara depression (Egypt), Buffalo Hollow (American Great Plain)Big Hollow (Wyoming, USA), Pong Kiang Hollow (Mongolian Desert)

MUSHROOM ROCKS- Rocks having broad upper part and narrow base formed due to abrasion at base.

Fig: 6.9: Mushroom Rock

(source : http://en.wikipedia.org/wiki/Mushroom_Rock_State_Park

Isenberg- Sharply rising residual hills due to wind erosion.

Demoiselles- Rock pillars having relatively resistant rocks at the top and soft rock below. These are formed due to differential erosion.

Zeugens- Abrasive action of wind acting on exposed weakness of horizontally bedded rocks (hard above and soft below) thereby producing a tabular mass of resistant capping upon softer rocks beneath.

Yardangs- Sinuous ridges and parallel depressions formed due to differential abrasion of vertically arranged thin alterations of hard and soft strata. Typical of Turkistan Desert and also in Tibesti Massif (Sahara)

Ventifacts-Faceted rock boulders, cobbles and pebbles formed due to prolonged wind abrasion (one abraded face-Einkanter, two abraded faces-Zweikanter, three abraded faces-Dreikanter).

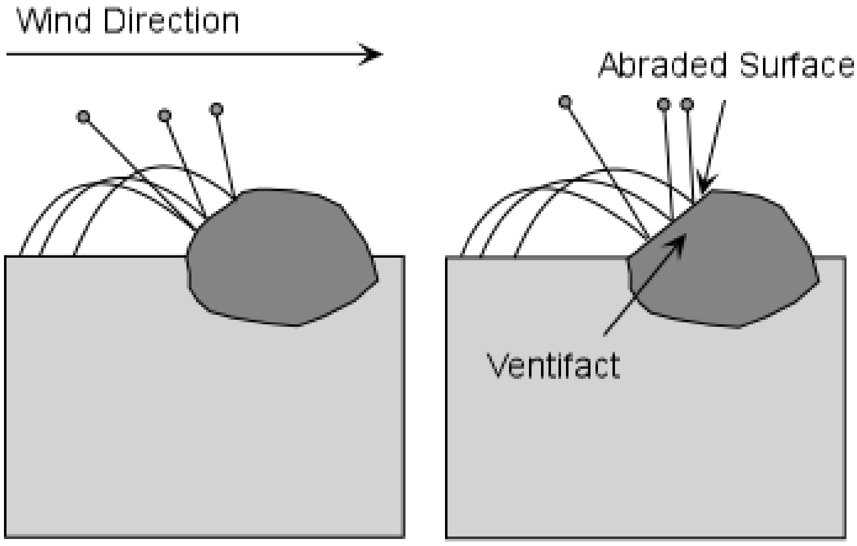

Fig : 6.10 Ventifacts

6.4.4.2 DEPOSITIONAL LANDFORMS

Deposition is the laying down of sediment transported by wind, water or ice. A depositional environment occurs when there is a reduction in velocity in the transport medium whether it's wind, water or ice. The three types of depositional landforms are ripples, dunes and mega dunes.

6.4.4.2.1 RIPPLES

Wave like features formed by saltation impact. They may be transverse or longitudinal.

6.4.4.2.2 SAND DUNES

Heaps or mounds of sands. They are mobile landforms and may be coastal dunes, riverine dunes, and lacustrine dunes.

Formation of Sand dunes requires:

1. Abundance of sand
2. High velocity of wind
3. Obstacles such as tree, bushes, rocks, forests etc.
4. Suitable places for the accumulation of sands.

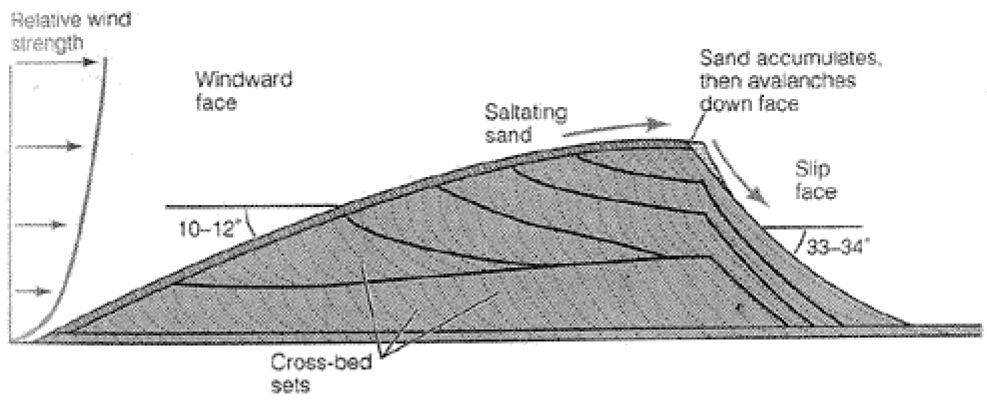

Fig. 6.11 : A barchan dune (crescent shaped)

(source : http://search.datapages.com/data/doi/10.1306/212F7C16-2B24-11D7-8648000102C1865D)

Process of Formation	Type	Description	Wind Direction
Deposition	Ripples	Range in height from 1 mm to 500 mm with wavelengths from 0.01 m to 5m.	One
	Barchan Dunes	Crescent shape dunes form whose long axis is transverse to dominant wind direction. Barchan form where the sand supply is limited	One
	Transverse Dunes	Asymmetrical ridge form at right angles to the wind direction. Transverse form when sand supply is abundant and winds are weak.	One
	Star Dune	Pyramidal peak with three or more arms. Each arm corresponds to a wind direction.	Three or more

		Star dunes do not migrate but grow vertically.	
	Nebkhas	Dunes formed due to shrubs as obstacles	One
	Longitudinal	The dune ridge is symmetrical, aligned parallel to the net direction of the wind, and has slip faces on either side.	At least two

Table : Different types of sand dunes

6.4.5 GLACIAL LANDFORMS

Glaciers have played an important role in the shaping of landscapes in the middle and high latitudes and in alpine environments. Their ability to erode soil and rock, transport sediment, and deposit sediment is extraordinary. During the last glacial period more than 50 million square kilometers of land surface were geomorphically influenced by the presence of glaciers.

6.4.5.1 EROSIONAL LANDFORMS

Two major erosional processes occur at the base of a glacier. First, at the base of a glacier, large amounts of loose rock and sediment are incorporated into the moving glacial ice by partial melting and refreezing. The second process of erosion involves the abrasive action of the held rock and sediment held by the ice on the surface underneath the glacier. This abrasive process is known as scouring.

A number of distinct erosional features can be observed in mountainous regions that have experienced the effects of glaciation.. (fig 6.12)

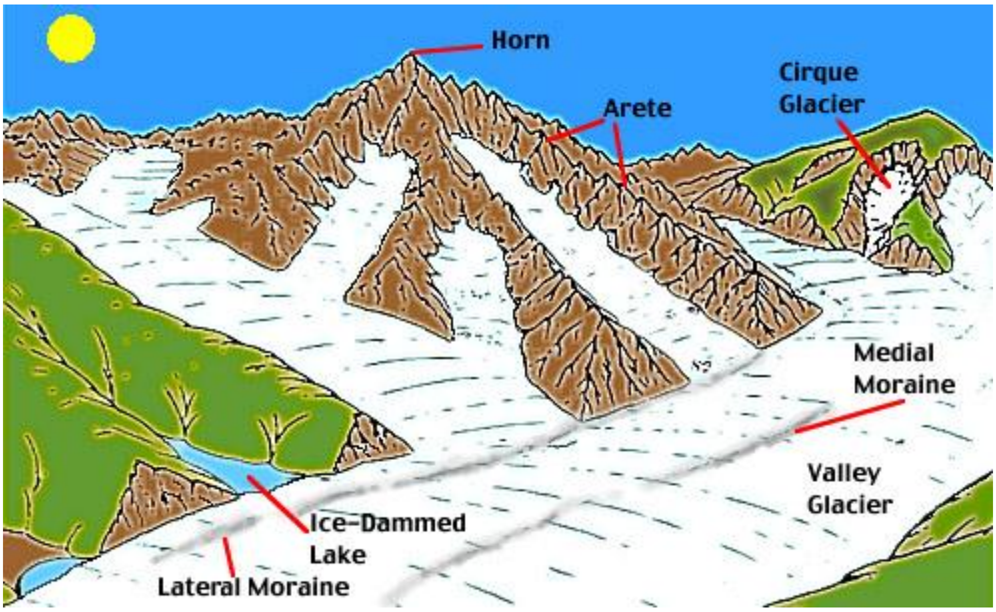

Fig. 6.12: Glacial landforms

Cirque

A scooped-out, amphitheater shaped basin at the head of a glacier.

Arêtes: (knife-edge in French)

A sharp sawtooth or serrated ridge that divides two cirque basins.

Horn

A pyramidal, sharp-pointed peak that results when several cirques glaciers gorge an individual mountain summit from all sides.

Bergschrund

These are formed when a crevasse or wide crack opens along the headwall of a glacier; most visible in the summer when covering snow is gone.

Tarns

A small mountain lake that collects especially in a cirque basin.

Hanging Valley

Valleys carved by tributary glaciers that are left standing high above the primary valley floor.

Fjord

A drowned glaciated valley or glacial trough along a seacoast.

Erratics

A unique rock carried by a glacial formation that deviates in size and/ or type relative to the native area.

Truncated Spurs

Occur where a glacier carves its way though rock, cutting off the edges of interlocking spurs.

6.4.5.2 DEPOSITIONAL LANDFORMS

Moraines

French word that refers to any glacier-formed accumulation. There are different types of moraines:

• Lateral Moraines: A deposition of sediments along both sides of a glacier.

• Medial Moraine: A deposition of sediments between two lateral moraines.

• Terminal Moraine: Eroded debris that is dropped at the glacier's farthest extent.

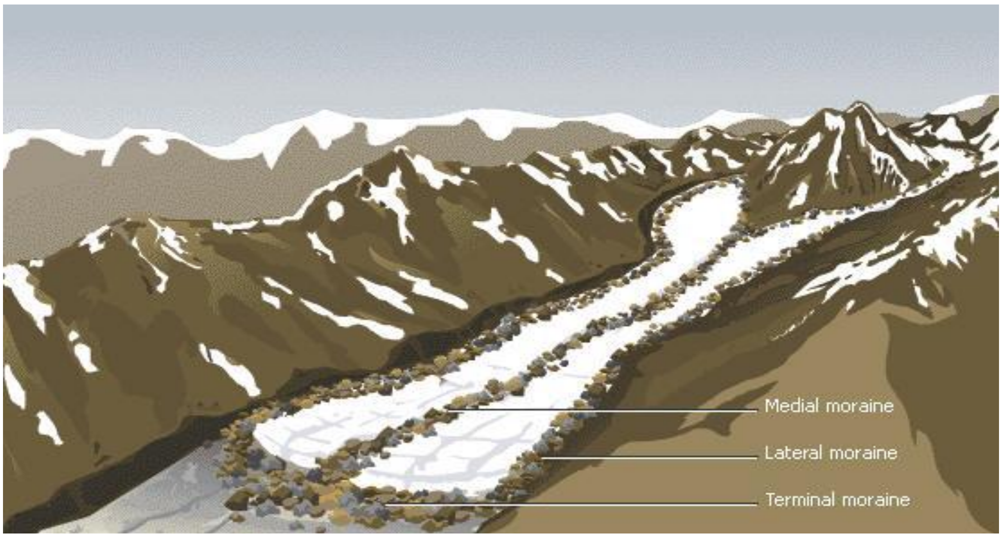

Fig. 6.13: Glacial Moraines

Till Plain

Forms behind an end moraine; it features unstratified coarse till, has low and rolling relief, and has a deranged drainage pattern.

Esker

A sinuously curving, narrow deposit of coarse gravel that forms along a melt-water stream channel, developing in a tunnel beneath a glacier.

Kettle

Forms when an isolated block of ice persists in a ground moraine, an outwash plain or valley floor after a glacier retreats; as the block finally melts, it leaves behind a steep sided hole that frequently fills with water.

Kame

A depositional feature of glaciation; a small hill of poorly sorted sand and gravel that accumulates in crevasses or in ice caused indentations in the surface.

Drumlin

Composed of till (unstratified, unsorted) and is streamline in the direction of continental ice movement-blunt end upstream and tapered end downstream with a rounded summit.

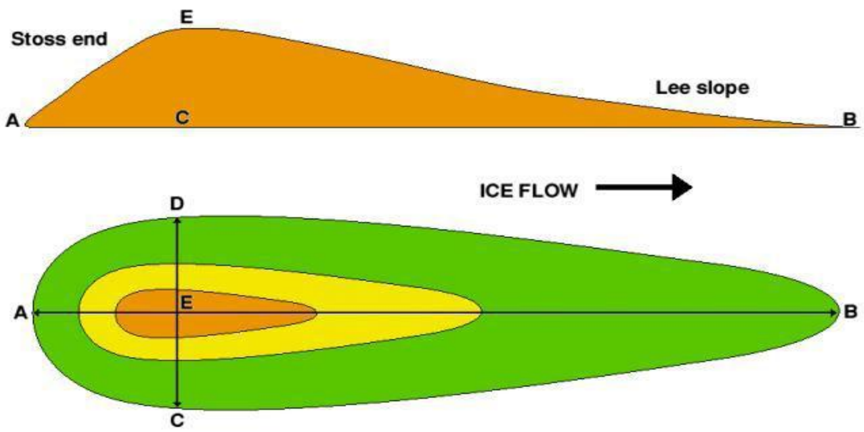

Fig 6.14: Drumlin

Loess

Loess is a geologically recent deposit of silt or material which is usually yellowish or brown in color and consisting of tiny mineral particles brought by wind to the places where they now lie. It is a product of past glacial activity in an area. It is a sedimentary deposit of mineral particles which are finer than sand but coarser than dust or clay, deposited by the wind. Loess is a type of silt which forms fertile topsoil in some parts of the world. Loess deposits are usually a few meters thick.

6.5 BIOGEOCHEMICAL CYCLES

There is a continuous interaction between the abiotic components in the environment and the living organisms in the biosphere which are accompanied by continuous matter cycle in nature.

Different species of living organisms assimilate substances needed for their growth and life support emitting to the environment products of metabolism and other complex mineral and organic compounds of chemical elements in the form of non-assimilated food or dead biomasses. As a result of biospheric evolution, a stable chain of global biogeochemical cycles has been formed whose violations have led to serious alterations in the environment affecting all the species.

Land ecosystems play an important role in the dynamics of the biogeochemical cycles. The most well known and important cycles are carbon, nitrogen and sulfur.

6.5.1 THE GLOBAL CARBON CYCLE

Carbon is the key of life on earth. The carbon atom's ability to form long covalent chains is the foundation of organic chemistry and biochemistry. The biogeochemical cycle of carbon is complex since it includes all life forms on earth as well as the inorganic carbon reservoirs and link between them. Carbon is present in the Earth's atmosphere, soils, oceans, and crust. If we consider Earth as a system, these components can be referred to as *carbon pools* (or reservoirs) because they act as storage houses for large amounts of carbon. Any movement of carbon between these reservoirs is called a flux. In any integrated system, fluxes connect reservoirs together to create cycles and feedbacks. An example of such a cycle is seen in Figure 6.15 where, carbon in the atmosphere is used the plants in photosynthesis to create food material. On a global basis, these processes transfer large amounts of carbon from one pool (the atmosphere) to another (plants). Over time, these plants die and decay or are burned either for energy or in wildfires. All of these processes are fluxes that can cycle carbon among various pools within ecosystems and eventually releases it back to the atmosphere. Viewing the Earth as a whole, individual cycles like this are linked to others involving oceans, rocks, etc. on a range of spatial and temporal scales to form an integrated global carbon cycle (Figure 6.15).

Now if we consider shortest time scales (of seconds to minutes) plants take carbon dioxide from the atmosphere through photosynthesis and release it back into the atmosphere via respiration. On longer time scales, carbon from dead plant material can be incorporated into soils, where it might reside for years, decades or centuries before being broken down by soil microbes and released back to the atmosphere. On still longer time scales, organic matter are buried in deep sediments and are slowly transformed into deposits of coal, oil and natural gas, the fossil fuels. When we burn these substances, carbon that has been stored for millions of years is released once again to the atmosphere in the form of carbon dioxide (CO_2).

Globally, the carbon cycle plays a key role in regulating the Earth's climate by controlling the concentration of carbon dioxide in the atmosphere. Carbon dioxide (CO_2) is important because it contributes to the greenhouse effect, in which heat generated from sunlight at the Earth's surface is trapped by certain gases and prevented from escaping through the atmosphere without which the Earth would be a much colder place. But an unnatural buildup of greenhouse gasses can lead to a planet that gets unnaturally hot. The Earth's carbon reservoirs act as both sources of as well as sinks, removing carbon from the atmosphere. If all sources are equal to all sinks, the carbon cycle can be said to be in balance and there is no change in the size of the pools over time. Maintaining a steady amount of CO_2 in the atmosphere is important to maintain a stable average temperature at the global scale.

6.5.2 CARBON POOLS

In order to understand how carbon is cycled and how atmospheric CO_2 changes we must know the places in which carbon is stored (pools), how long it resides there, and processes that transfer it from one pool to another (fluxes). Collectively, all of the major pools and fluxes of carbon on Earth comprise what we refer to as the global carbon cycle.

The Earth's Crust: The largest amount of carbon on Earth is stored in sedimentary rocks within the Earth's crust. In all sedimentary rocks on Earth store 100,000,000 PgC. (1Pg is equal to a trillion kilograms) Another 4,000 PgC is stored in the Earth's crust as hydrocarbons formed over millions of years from ancient living organisms under intense temperature and pressure. These hydrocarbons are commonly known as fossil fuels.

Oceans: The Earth's oceans contain 38,000 PgC, most of which is in the form of dissolved inorganic carbon stored at great depths where it resides for long periods of time. A much smaller amount of carbon, approximately 1,000 Pg, is located near the ocean surface which is rapidly exchanged with the atmosphere through both physical processes, such as CO_2 gas dissolving into the water, and biological processes, such as the growth, death and decay of plankton. Although most of this surface carbon cycles rapidly, some of it can also be transferred by sinking to the deep ocean pool where it can be stored for a much longer time.

Atmosphere: The atmosphere contains approximately 750 PgC, most of which is in the form of

CO_2, with much smaller amounts of methane (CH_4) and various other compounds. The relatively small size of the atmospheric C pool also makes it more sensitive to changes caused by an increase in sources or sinks of C from the Earth's other pools. In the context of global pools and fluxes, the increase that has occurred in the past several centuries is the result of C fluxes to the atmosphere from the crust (fossil fuels) and terrestrial ecosystems (via deforestation and other forms of land clearing).

Organic carbon

We often refer to carbon occurring in "organic" versus "inorganic" forms. This is a simple way of grouping different forms of carbon into biologically derived compounds (complex substances produced only by the growth of living organisms) and mineral compounds that can be formed in the absence of biological activity (but can sometimes be formed with the assistance of living things, as in the case of sea shells). Organic compounds includes such things as sugars, fats, proteins and starches and are contained in both living organisms and the material that remains after their death and partial decomposition (including the organic matter in soils as well as the deposits of coal and oils we refer to as fossil fuels). Note that complete decomposition of organic matter results in a return to mineral forms, often as CO_2. Mineral forms of carbon include carbonates contained in rock and seawater as well as CO_2 itself.

soils and microorganisms (bacteria and fungi).Unlike the Earth's crust and oceans, most of the carbon in terrestrial ecosystems exists in organic forms. Plants exchange carbon with the atmosphere relatively rapidly through photosynthesis, in which CO_2 is absorbed and converted into new plant tissues, and respiration, where some fraction of the previously captured CO_2 is released back to the atmosphere as a product of metabolism. Collectively, terrestrial ecosystems contain approximately 560 PgC, with the wood in trees being the largest fraction.

The total amount of carbon in the world's soils is estimated to be 1500 PgC. Most of the carbon in soils enters in the form of dead plant matter that is broken down by microorganisms during decay. The decay process also releases carbon back to the atmosphere because the metabolism of these microorganisms eventually breaks most of the organic matter all the way down to CO_2.

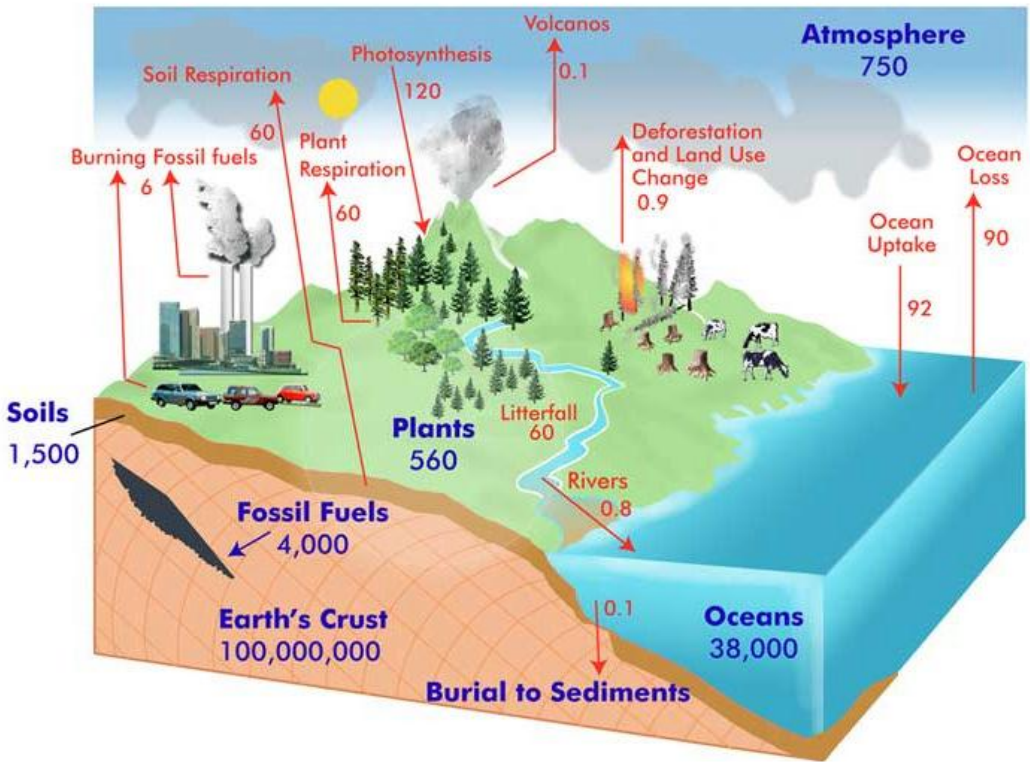

Figure 6.15 . A simplified diagram of the global carbon cycle. Pool sizes, shown in blue, are given in petagrams (Pg) of carbon. Fluxes, shown in red, are in Pg per year. (www.globe.gov/projects/carbon)

6.5.1.2 CARBON FLUXES

The movement of any material from one place to another is called a flux and so a carbon flux is a transfer of carbon from one pool to another. Fluxes are usually expressed as a rate with units of an amount of some substance being transferred over a certain period of time (e.g. g cm-2 s-1 or kg km2 yr-1). For example, the flow of water in a river can be thought of as a flux that transfers water from the land to the sea and can be measured in liters per second, cubic meters per minute or cubic kilometers per year.

A single carbon pool can often have several fluxes both adding and removing carbon simultaneously, the sizes of which can vary widely. For example, the atmosphere has inflows from decomposition (CO_2 released by the breakdown of organic matter), forest fires and fossil fuel combustion and outflows from plant growth and uptake by the oceans.

Photosynthesis: During photosynthesis, plants use energy from sunlight to combine CO_2 from the atmosphere (carbon removed from atmosphere) with water from the soil to create carbohydrates (stored in the structure of plants). Virtually all of the organic matter on Earth was initially formed through this process. Because some plants can live to be tens, hundreds or sometimes even thousands of years old (in the case of the longest-living trees), carbon may be stored, or sequestered, for relatively long periods of time. Current estimates suggest photosynthesis removes 120 PgC/year from the atmosphere and about 610 PgC is stored in plants at any given time.

Fossil Fuels

Fossil fuels are the transformed remains of ancient organisms: terrestrial plants and drifting plankton that once lived in oceans and lakes. Over millions of years of accumulation and burial, the borganic material undergoes a chemical change, resulting in what we now recognize as fossil fuels and a variety of intermediate substances. All of the energy fossil fuels contain was initially captured by plants during photosynthesis and has become concentrated in various solid or liquid forms. The most common forms are petroleum, coal and natural gas, but other hydrocarbon deposits have also been recognized (oil shale, tar sands, and gas hydrates). Combustion of fossil fuels releases a great deal of energy, which is why they have been used in transportation, manufacturing, home heating and electricity generation. Globally, fossil fuels account for approximate three-quarters of total energy production. The primary product of this hydrocarbon combustion is carbon dioxide.

Plant Respiration: Plants also release CO_2 back to the atmosphere through the process of respiration (the equivalent for plants of exhaling). Respiration occurs as plant cells use carbohydrates, made during photosynthesis, for energy. Plant respiration represents approximately half (60 PgC/year) of the CO_2 that is returned to the atmosphere in the terrestrial portion of the carbon cycle.

Litterfall: In addition to the death of whole plants, living plants lose some portion of their leaves, roots and branches to the ground which acts as a transfer of carbon (a flux) from the plant to the soil. Dead plant material is often referred to as litter (leaf litter, branch litter, etc.) and undergoes decomposition on the ground.

Soil Respiration: The release of CO_2 through respiration is not unique to plants, but is something

all organisms do, including microscopic organisms living in soil. When dead organic matter is broken down or decomposed (consumed by bacteria and fungi), CO_2 is released into the atmosphere at an average rate of about 60 PgC/year globally. Because it can take years for a plant to decompose (or decades in the case of large trees), carbon is temporarily stored in the organic matter of soil.

Ocean—Atmosphere exchange: Inorganic carbon is absorbed and released at the interface of the oceans' surface and surrounding air, through the process of diffusion. Once in a dissolved form, CO_2 goes on to react with water in what are known as the carbonate reactions. These are relatively simple chemical reactions in which H_2O and CO_2 join to form H_2CO_3 .The formation of carbonate in seawater allows oceans to take up and store a much larger amount of carbon than would be possible if dissolved CO_2 remained in that form. Carbonate is also important to a vast number of marine organisms that use this mineral form of carbon to build shells.

Fossil fuel combustion and land cover change: The modern-day carbon cycle also includes several important fluxes that results from anthropogenic activities. The most important of these is combustion of fossil fuels: coal, oil and natural gas . Since the days of the industrial revolution, these fuels have been mined and combusted at increasing rates and have served as a primary source of the energy that drives modern industrial human civilization. The main byproduct of fossil fuel combustion is CO_2, and these activities are acting as rapid flux to the atmosphere of large amounts of carbon. At present, fossil fuel combustion represents a flux to the atmosphere of approximately 6-8 PgC/year. Another human activity that has caused a flux of carbon to the atmosphere is land cover change, largely in the form of deforestation. With the expansion of the human population and growth of human settlements, a considerable amount of the Earth's land surface has been converted from native ecosystems to farms and urban areas. Because forests and other native ecosystems generally contain more carbon (in both plant tissues and soils) than the cover types they have been replaced with, these changes have resulted in a net flux to the atmosphere of about 1.5 PgC/year.

Geological Processes: Geological processes represent an important control on the Earth's carbon cycle over time scales of hundreds of millions of years. The processes involved include the formation of sedimentary rocks and their recycling via plate tectonics, weathering and volcanic eruptions.

Carbon Budgets: the balance between sources & sinks

The Earth's carbon cycle is in a constant state of motion. Through processes that take place over time, carbon is constantly being transferred between all the various pools discussed above. In fact, if the amount of carbon moving into a given pool is matched by an equal amount of carbon moving out, the pool size remains constant. If this condition were true for all carbon pools, the global carbon cycle would be said to be in a state of dynamic equilibrium; "dynamic" because the carbon itself is moving, and "equilibrium" because the equal size of all inputs and outputs keeps the system in balance. The size of all carbon pools remains unchanged. Presently, a budget of the Earth's carbon cycle shows that it is far from being in a state of balance. While random variation in natural processes such as climate and forest fires often results in some degree of imbalance on an annual basis, the very large imbalance in today's carbon cycle is due to the processes of fossil fuel combustion and land cover change, as discussed earlier. Although CO2 is indeed building up in the atmosphere, the rate at which it is accumulating is less than the rate at which it is being emitted and the difference is difficult to account for through present estimates of uptake by the land and oceans.

6.6 GLOBAL NITROGEN CYCLE

Few elements are as complex and interesting as nitrogen. Firstly, this complexity is reflected in the highly intricate biogeochemical cycle, where nitrogen occurs in valence states from -3 to +5 and where many of the transformations are carried out by a few organisms only, at normal temperatures and pressures. Secondly, nitrogen is an element which is abundant on earth, but only a very small proportion of it enters into the biogeochemical nitrogen cycle at significant rates. The atmosphere where nitrogen occurs abundantly in its molecular form only contains six per cent of all nitrogen on earth. Of all nitrogen taking part in the biogeochemical nitrogen cycle only 0.04 per cent occurs in compounds potentially available to living organisms. In the terrestrial system only four per cent occurs in biomass, the remainder forming a large reservoir as dead organic matter (96 per cent). The unavailability of the 99.96 per cent occurring as nitrogen gas, combined with the major role played by nitrogen-containing substances in all forms of life, has caused nitrogen to be one of the key elements limiting the primary production.

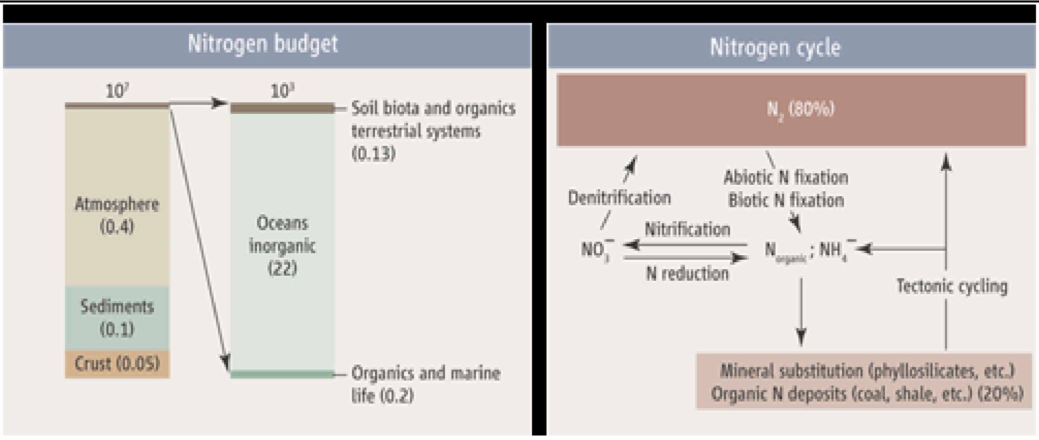

Fig 6.16 (left) Budgets of nitrogen in the major reservoirs on Earth. (Right) Major changes in redox chemistry catalyzed by biota. Budget values are in pedagrams (1015 g).

(source : http://www.starsandseas.com/SAS%20Ecology/SAS%20chemcycles/cycle_nitrogen.htm)

Thirdly, the nitrogen cycle is easily manipulated by man, and it has been estimated that, by the end of this century, man-made additions of combined nitrogen will equal the amounts fixed annually through biological nitrogen fixation (Soderlund and Svensson, 1976). This increased addition from fertilizers, together with nitrogen oxides emitted into the atmosphere as a result of combustion, is undesirable since nitrogen compounds are a direct environmental hazard (Bolin and Arrhenius, 1977).

6.6.1 NITROGEN METABOLISM IN ECOLOGICAL SYSTEMS

The biogeochemical cycle of nitrogen includes such processes as fixation, mineralization, nitrification, assimilation and dissimilation.

6.6.1.1 Nitrogen Assimilation: Plants and most microorganisms are dependent on ammonium or nitrate salts for growth, though they seem generally to prefer ammonium as a nitrogen source. All plants, except certain bog species, are able to utilize nitrate as well as ammonium. Nitrogen assimilation is the process by which NH3 or NH4+ is taken up by an organism to become part of its biomass in the form of organic nitrogen compounds. If no other factors limit microbial growth, microorganisms will efficiently scavenge the surroundings for available ammonium nitrogen. Since ammonium oxidation through nitrification proceeds rapidly in most soils, nitrate is probably the most important nitrogen source for most plants.

6.6.1.2Mineralization: Ammonium is liberated through mineralization, mainly by microorganisms, from organic compounds. In soil microorganisms, the balance between mineralization and immobilization of ammonium nitrogen, i.e. positive or negative nitrogen net mineralization, is regulated primarily by the C/N ratio of the substrate (parnas, 1975, 1976). Microbial biomass in soil has been estimated to contain four per cent nitrogen (Rosswall, 1976), and if the carbon content is 50 per cent, the microbial biomass has a C/N ratio of 12.5. When an organic substrate is broken down by microorganisms, the quality of the substrate will determine the relative proportion of carbon assimilated and respired. Soil animals may play an important role in regulating nitrogen mineralization in at least two ways. The effect of grazing on microorganisms may increase mineralization rates (Rosswallet aI., 1977; Colemanet al., 1977). It also seems that soil invertebrates may play an important role through their excretion of significant amounts of simple nitrogenous substances, such as uric acids, urea, and also ammonia.

6.6.1.3 NITRIFICATION-DENITRIFICATION: Nitrogen also plays an important role in generating energy in certain groups of microorganisms. Autotrophic nitrifying bacteria obtain energy from the oxidation of ammonium or nitrite, while denitrifying bacteria use nitrate, nitrite, or nitrous oxide as terminal electron acceptors during the oxidation of organic substrates. There seem to be very close couplings between nitrification and denitrification. Nitrification is the oxidation of NH_3 or NH_4^+ to NO_2^- or NO_3^- by an organism a means of producing energy and denitrification is the reduction of NO3- to any gaseous nitrogen species, generally N2 or N2O.

1) $NH_3 + O_2 + 2\ e^- \longrightarrow NH_2OH + H_2O$

2) $NH_2OH + H_2O \longrightarrow NO_2^- + 5\ H^+ + 4\ e^-$

Nitrification

1) $NO_3^- \longrightarrow NO_2^- \longrightarrow NO + N_2O \longrightarrow N_2$

2) $2\ NO_3^- + 10\ e^- + 12\ H^+ \longrightarrow N_2 + 6\ H_2O$

Denitrification

Unlike nitrification, denitrification is an anaerobic process, occurring mostly in soils and sediments and anoxic zones in lakes and oceans. Similar to nitrogen fixation, denitrification is carried out by a diverse group of prokaryotes, and there is recent evidence that some eukaryotes are also capable of denitrification (Risgaard-Petersen et al. 2006). Some denitrifying bacteria include species in the genera Bacillus, Paracoccus, and Pseudomonas. Denitrifiers are chemoorganotrophs and thus must also be supplied with some form of organic carbon.

Ammonification: When an organism excretes waste or dies, the nitrogen in its tissues is in the form of organic nitrogen (e.g. amino acids, DNA). Various fungi and prokaryotes then decompose the tissue and release inorganic nitrogen back into the ecosystem as ammonia in the process known as ammonification. The ammonia then becomes available for uptake by plants and other microorganisms for growth.

6.6.1.4 NITROGEN FIXATION: Nitrogen fixation is any process in which N2 in the atmosphere reacts to form any nitrogen compound. Biological nitrogen fixation is the ultimate source of nitrogen in all living organisms, in the absence of industrial fertilizers. In terrestrial ecosystems, the symbiotic bacteria, particularly strains of genus *Rhizobium,* are a significant source of nitrogen fixation. These bacteria are found in the roots of many leguminous plants and have been used agriculturally as a means of replenishing soil nitrogen.

$$N_2 + 8\,H^+ + 8\,e^- \longrightarrow 2\,NH_3 + H_2$$

(aided by symbiotic bacteria of genus *Rhyzobium*)

Genus	Phylogenetic Affiliation	Lifestyle
Nostoc, Anabaena	Bacteria (Cyanobacteria)	free-living,aerobic, phototrophic
Pseudomonas, Azotobacter, Methylomonas	Bacteria	free-living, aerobic, chemoorganotrophic
Alcaligenes, Thiobacillus	Bacteria	free-living, aerobic, chemolithotrophic
Methanosarcina, Methanococcus	Archaea	free-living, anaerobic, chemolithotrophic
Chromatium, Chlorobium	Bacteria	free-living, anaerobic, phototrophic
Desulfovibrio, Clostridium	Bacteria	free-living, anaerobic, chemoorganotrophic
Rhizobium, Frankia	Bacteria	symbiotic, aerobic, chemoorganotrophic

Table 6.2: Different genus of nitrogen-fixing bacteria

6.6.2 NITROGEN POOLS

The pools of nitrogen includes: terrestrial, oceanic and atmospheric. 99.96% of the crustal nitrogen exists as uncombined atmospheric N2 and it is this fact that causes nitrogen to often be limiting in the condense phase.

The principal form of nitrogen in terrestrial systems is as dead soil organic matter , with biomass accounting for only 4% and inorganic nitrogen about 6.5% on a global average(Sonderlund and Svensson, 1976). There is however a large difference in the distribution of nitrogen in the tropics and the polar regions, with the tropical regions having a larger proportion of nitrogen contained as biomass.

The dissolved N2 is the principal form of nitrogen in the oceans, accounting for 95% of the total oceanic nitrogen. The remainder of the oceanic nitrogen is principally N03- and dead organic matter. The oceans hold about .05% of the total non-crustal nitrogen. In contrast to C02 where the ocean is a significant reservoir, the oceans contain only about 15% of the total N2O due to its low solubility.

In the atmosphere, N2 is the principal nitrogen component and over 99% of the remaining nitrogen is found as N2O.

6.6.3 FLUXES OF NITROGEN

The largest source of atmospheric ammonia is ammonification and volatilization from animal excreta (Frenzy et al., 1983) direct anthropogenic emissions including combustion and fertilizers are much smaller. The majority of this NH3 is returned as NH4+ in precipitation or via dry deposition. The ammonia is then available again to the biosphere and the cycle is repeated. In the NOx cycle (fig 6.17) gaseous emissions of NO, and much smaller emissions of NO2 are balanced by dry deposition of NO2 and HNO3 and wet deposition of N03-.the principal sources of NOx are anthropogenic combustion. Microbial processes in soils, lightning and natural forest fires are much smaller NOx sources. In the atmosphere NOx is converted to HNO3 via photochemical oxidation and therefore has a short residence time (of the order of few days).

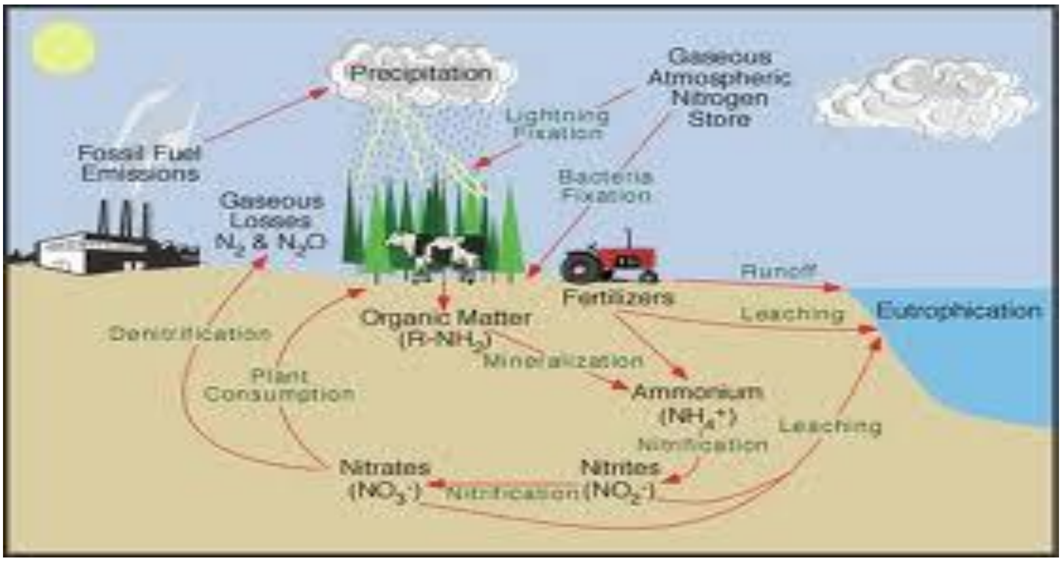

Fig 6.17 Global Nitrogen Cycle

(source : http://www.physicalgeography.net/fundamentals/9s.html)

6.6.4 HUMAN IMPACTS

Many human activities have a significant impact on the nitrogen cycle. Burning fossil fuels, application of nitrogen-based fertilizers, and other activities can dramatically increase the amount of biologically available nitrogen in an ecosystem. And because nitrogen availability often limits the primary productivity of many ecosystems, large changes in the availability of nitrogen can lead to severe alterations of the nitrogen cycle in both aquatic and terrestrial ecosystems. Industrial nitrogen fixation has increased exponentially since the 1940s, and human activity has doubled the amount of global nitrogen fixation (Vitousek et al. 1997).

In terrestrial ecosystems, the addition of nitrogen can lead to nutrient imbalance in trees, changes in forest health, and declines in biodiversity. With increased nitrogen availability there is often a change in carbon storage, thus impacting more processes than just the nitrogen cycle. In agricultural systems, fertilizers are used extensively to increase plant production, but unused nitrogen, usually in the form of nitrate, can leach out of the soil, enter streams and rivers, and ultimately make its way into our drinking water. The process of making synthetic fertilizers for use in agriculture by causing N2 to react with H2, known as the Haber-Bosch process, has increased significantly over the past several decades. In fact, today, nearly 80%

of the nitrogen found in human tissues originated from the Haber-Bosch process (Howarth 2008).

Much of the nitrogen applied to agricultural and urban areas ultimately enters rivers and nearshore coastal systems. In nearshore marine systems, increases in nitrogen can often lead to anoxia (no oxygen) or hypoxia (low oxygen), altered biodiversity, changes in food-web structure, and general habitat degradation. One common consequence of increased nitrogen is an increase in harmful algal blooms (Howarth 2008). Toxic blooms of certain types of dinoflagellates have been associated with high fish and shellfish mortality in some areas. Even without such economically catastrophic effects, the addition of nitrogen can lead to changes in biodiversity and species composition that may lead to changes in overall ecosystem function. Some have even suggested that alterations to the nitrogen cycle may lead to an increased risk of parasitic and infectious diseases among humans and wildlife (Johnson et al. 2010). Additionally, increases in nitrogen in aquatic systems can lead to increased acidification in freshwater ecosystems.

Nitrogen is arguably the most important nutrient in regulating primary productivity and species diversity in both aquatic and terrestrial ecosystems (Vitousek *et al*. 2002). Microbially-driven processes such as nitrogen fixation, nitrification, and denitrification, constitute the bulk of nitrogen transformations, and play a critical role in the fate of nitrogen in the Earth's ecosystems. However, as human populations continue to increase, the consequences of human activities continue to threaten our resources and have already significantly altered the global nitrogen cycle.

6.7 SULFUR CYCLE

Sulfur occurs in a variety of valence states, ranging from –2 (as in sulfide and reduced organic sulfur) to +6 (as in sulfate). Sulfate is the most stable form of sulfur on today’s toxic Earth; weathering and leaching of rocks and sediments are its main sources. In addition, the reduced inorganic forms of sulfur, with oxidation states of –2 and 0 (as in elemental sulfur) are quite common in anoxic environments, with sulfur compounds of mixed valence states (e.g., thiosulfate and polythionates) produced transiently.

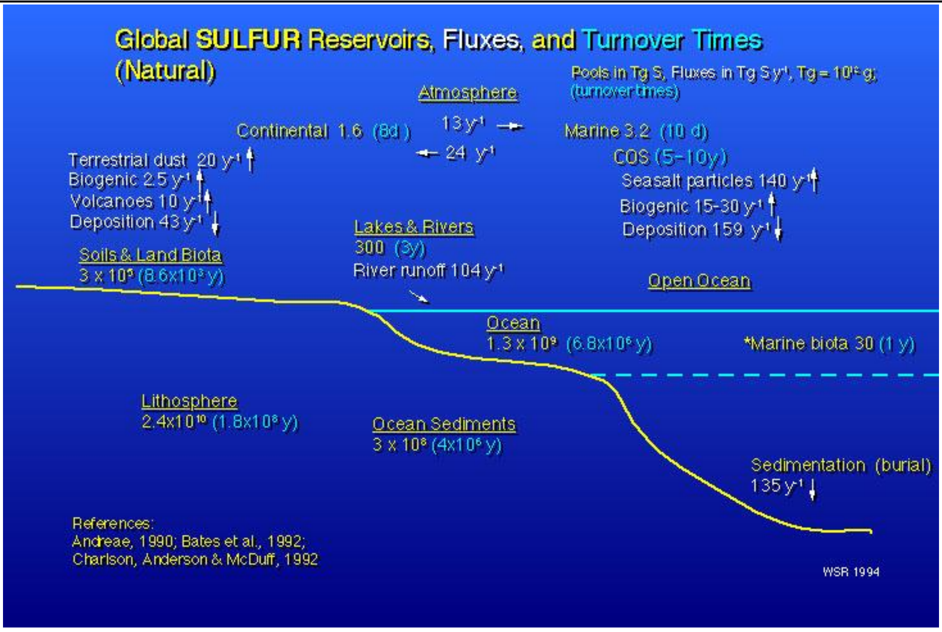

Fig 6.18 Natural (pre-industrial) global sulfur reservoirs, fluxes and turnover times. Major reservoirs are underlined; pool sizes and fluxes are given in Tg (1012 g) S and Tg S yr-1. Turnover times (reservoir divided by largest flux to or from reservoir) are in parentheses. (Source: http://www.physicalgeography.net/fundamentals/9s.html

6.7.1SULFUR POOLS (RESERVOIRS)

The lithosphere is the largest reservoir, with turnover times of ~109 yr. Ocean waters, where sulfate is a major constituent, and ocean sediments, where sulfide and sulfate are the major forms, have similar reservoir sizes and turnover times of >106 yr.

Carbonyl sulfide (COS) is the longest-lived gaseous sulfur compound. Large particulate fluxes of sea salt and terrestrial dust are added to the atmosphere, but their abundance is restricted to altitudes of < 1km. The particles have residence times of days, close to rainout times, reflecting their control by precipitation. Some volcanic emissions are injected into the stratosphere, where they have much longer residence times.

Sulfur fluxes

Microbial transformations between valence states drive the global Sulfur cycle

• Under anaerobic conditions, SO4 is substrate for sulfate reduction

Sulfate reduction:

$2H^+ + SO_4^{2-} + 2(CH_2O) \longrightarrow 2CO_2 + H_2S + 2H_2O$ (Desulfovibrio sp. or Desulfotomaculum sp.)

H2S reacts with Fe2+ to precipitate FeS, which can be converted to pyrite FeS2:

$FeS + H_2S \longrightarrow FeS_2 + 2H^+ + 2e^-$

H2S diffuses though zone of F3+

$2Fe(OH)_3 + 3H_2S + 2H^+ \longrightarrow FeS_2 + 6H_2O + Fe^{2+}$

Sulfur-based photosynthesis (thought to be one of first forms of photosynthesis on the Earth)

Plant uptake of sulfate is followed by assimilatory reduction and incorporation of carbon bonded sulfur into the amino acids cysteine and methionine. The molecular structure of S-reducing protein contains Fe as a cofactor .When soil sulfate concentrations are high, plants may accumulate SO4 in leaf tissue. In most soils, majority of Sulfur pool held in organic forms. However, despite predominance of organic S forms, the pool of SO4 2- in most soils is not insignificant. To maintain charge balance, plant uptake and reduction of SO42- consumes H+ from the soil, whereas mineralization of organic sulfur returns H+ to soil solution, producing no net increase in acidity.

6.7.2 Global Sulfur Cycle

Sulfur is released into the atmosphere through the burning of fossil fuels --especially high sulfur coal--and is a primary constituent of acid rain. Thus, sulfur gas is not a long-lived or major constituent of the atmosphere. Short mean residence time for atmospheric sulfur compounds as a result of their oxidation to sulfate.

Episodic events (volcanic eruptions, dust storms) contribute to global cycling of Sulfur.

Volcanic eruptions: volcanic eruptions eject sulfur from the mantle which are carried by the wind etc.

Soil dusts: Large particles usually deposited locally, whereas small particle can be transported long distances e.g., dust from deserts of Middle East contributes to sulfate in northwest Indian Ocean carrying sulfur with it. The average annual flux from dust transport in troposphere is about 8 X 1012 g S/yr .

Forest fires emit an additional 3 x 10^{12} g S/yr

Direct emissions from **human industrial activities** largest source of S gases to atmosphere which is estimated to be in the range between 50-100 x 10^{12} g S/yr but owing to reactivity of S gases in atmosphere, most of anthropogenic SO2 emissions deposited locally in precipitation and dry fall.

The Marine Sulfur Cycle

Sulfur-metabolizing archaea are mainly restricted to high-temperature environments, such as deep-sea hydrothermal vents. Sulfur cycling in the biosphere is very rapid, and microorganisms in the ocean play an essential role in sulfur cycling. Grazing by zooplankton seems to be important to release of DMS to seawater and production of DMS increases as a function of increasing salinity, as river water mixes with seawater in estuaries. Oxidation of DMS to sulfate aerosols increases abundance of cloud condensation nuclei in atmosphere, leading to greater cloudiness

6.8 WEATHERING AND SOIL FORMATION

The surface of the earth is a dynamic place. Over geologic time, the rocks uplifted above sea level break down and are converted into soils by weathering processes. Soils release soluble components into rivers and can be eroded and transported across landmasses until both soluble and particulate components are eventually deposited in marine sedimentary basins which get gradually converted to rocks which are again exposed to surface through tectonic processes. This is called rock cycle which continually modifies the earth surface.

Soil is a key component of the rock cycle because weathering and soil formation processes transform rock into more easily erodible material. Rates of soil formation may even limit the overall erosion rate of a landscape. Erosion processes are also key linkage in the rock cycle between soil production and the filling of sedimentary basins. When water falls onto the Earth's surface it can seep into the ground and percolate down to the water table or it can run off down slope to collect into streams that ultimately combine to form rivers.

The material transformations and interactions hat occur between oil, sediment, rock, water and the atmosphere during geological cycles of uplift and erosion are important in global biogeochemical cycles.

6.8.1 WEATHERING

Weathering occurs because rocks and minerals become exposed to physical and chemical conditions under which they are formed. Rocks form at higher temperatures and pressures than that of surficial environment so they are unstable at the temperatures and pressures of the earth's surface and thus susceptible to weathering. The inorganic solid phase of any soil consists of a number of minerals displaying different degrees of weathering susceptibility. the extent of weathering of these minerals are expose in the soil or at the surface condition ,including supply of water and the removal or transport of weathering products.

Weathering can be separated into two types: physical and chemical. Physical weathering involves changes in the degree of consolidation with little or no chemical and mineralogical changes of rock and minerals. Chemical weathering involves changes in the chemical and mineralogical composition that generally act on the surfaces of rocks or minerals. Physical weathering increases the surface area of rocks and minerals such that chemical weathering can proceed at a faster rate.

6.8.2 PHYSICAL WEATHERING

Rocks and minerals break when stressed above their tensile strength. Commonly, rocks fracture along joints, fissure, or planes that have developed during cooling, tectonics and sedimentary processes or along lines of weakness at the boundaries between mineral grains. When previously buried rocks are exposed at the earth surface, the lowering of the over burden pressure or unloading allows the rocks to expand. This expansion induces fracturing that aids in the conversion of rock to soil. Physical weathering processes expand these fractures or cause the development of new ones.

Frost wedging is the prying apart of materials by expansion of water when it freezes. The pressure produced by freezing water is well above the tensile strength of many rocks and repeated freeze –thaw cycles can break down the rock.

In arid environments, where the soluble products of weathering are not completely removed from the soil, saline solutions may circulate in the soil a well as in rock fractures. The growth of salt crystals in crevices can force open fractures. Salt weathering occurs in cold or hot deserts or areas where salts accumulate.

Thermal expansion induces by insolation may be important in desert areas where rocky outcrops and soil surfaces are barren. In a desert , daily temperature excursions are wide and rocks are heated and cooled rapidly. Each type of mineral in a rock has a different co efficient of thermal expansion. Consequently when a rock is heated or cooled , its minerals differentially expand and contract , thereby inducing stresses and strains in the rock and causing fractures.

Plants and animals disrupt and disaggregate rocks and fracture or abrade individual grains or minerals. Endolithic algae growing in deserts may be capable of disintegrating rocks through sinking and swelling. Lichens are effective agents in physical weathering by extending fungal hyphae into rocks and by expansion and contraction of thalli. Higher plants grow roots in rock crevi8ces and eventually the increased pressure breaks and disrupts the substratum. Earthworms digest and abrade a considerable amount of soil. Similarly rodents, moles etc. break down rocks and create fine particles.

6.8.3 CHEMICAL WEATHERING

Chemical weathering involves chemical changes of rocks and minerals under near-surface conditions. The dissolution of these minerals depends on a number of factors. The composition of the mineral to be weathered (strength of chemical bonds within the lattice).second, the temperature affects the arte of weathering reactions. Third, the composition of soil solution surrounding the minerals grains (Ph, acids, complexing ligands etc.) and lastly physiography (slope, topography etc.).

There are six fundamental processes that chemically weather minerals. These are dissolution, hydration, acidolysis, chelation and oxidation/reduction.

Dissolution

Dissolution of a mineral occurs when the crystal lattice breaks down and separates into its component ions in water.

$$CaCO_3 + H_2O \rightarrow Ca^{2+} + CO_3^{2-}$$

In this case the two ions, Ca^{2+} and CO_3^{2-} , are released into the soil solution are able to released into the solution and are able to react with water (to form bicarbonate or carbonic acid) or other solution components , or be removed from the soil by leaching. The dissolution of $CaCO_3$ is regulated by the following reactions:

$H_2O + CO_2\,(g) \leftrightarrow H_2CO_3$

$H_2CO_3 \leftrightarrow HCO_3^- + H^+$

$H^+ + CO_3^{2-} \leftrightarrow HCO_3^-$

Overall:

$CaCO_3(s) + H_2O + CO_2 \leftrightarrow Ca^{2+} + 2\,HCO_3^-$

Dissolution of CaCO3 is a congruent reaction; the results completely in soluble products.

Hydration and hydrolysis

Hydration is the incorporation of water molecules into mineral, which results in a structural as well as chemical change. For example, hydration of anhydrite results in the formation of gypsum:

$CaSO_4 + 2H_2O \leftrightarrow CaSO_4.2H_2O$

(anhydrite) (gypsum)

Acidolysis

Acidolysis is a similar weathering reaction to hydrolysis in that H+ is used to weather minerals, but in this case the source of H^+ is not water but organic or inorganic acids. humic and fulvic acids , carbonic acid , nitric or sulfuric acid and low molecular-weight organic acids such as oxalic acid can all provide H^+ to weather minerals.

Chelation

Besides attacking minerals by providing H^+ , organic acids can also cause weathering by chelation. A chelator is a ligand capable of forming multiple bonds with a metal on such a Fe, Al, or Ca, resulting in a ring-type structure with the metal incorporated into the complex.

Oxidation and Reduction

Oxidation and reduction reactions weather minerals by the transfer of electrons. For example in an oxidizing environment an electron can be removed from Fe2+ at mineral edges causing disruption in the crystal structure due to charge imbalance , making the mineral susceptible to weathering.

$4FeO + O_2 + H_2O \leftrightarrow 4FeOOH$

(Goethite)

6.8.3 FACTORS INFLUENCING SOIL FORMATION

There are five major factors that control the formation of soils

1. *parent materials* (geological or organic precursors to the soil)
2. *climate* (primarily precipitation and temperature)
3. *biota* (living organisms, especially native vegetation , microbes , soil animals)
4. *topography* (slope, aspect and landscape position)

5. *time* (the period of time since parent materials became exposed to soil formation)

Soils are often defined in terms of these factors as "dynamic natural bodies having properties derived from the combined effects of climate and biotic activities, as modified by topography, acting on parent material over periods of time.

Parent materials

Geological processes have brought to the earth's surface numerous parent materials in which soils form. The nature of the parent material profoundly influences soil characteristics. For example a soil might inherit a sandy texture from a coarse-grained, quartz-rich parent material such as granite or sandstone. The chemical and mineralogical composition of parent material also influences both chemical weathering and natural vegetation. For example; the trees growing in the limestone region will produce litter rich in calcium.

Climate

Climate is perhaps the most influential of the four factors acting on parent material because it determines the nature and intensity of the weathering that occurs over large geographic areas. The principal climatic variables influencing soil formation are effective precipitation and temperature.

Precipitation: We have already seen that water is essential for all the major chemical weathering reactions. To be effective in soil formation, water must penetrate into the rock. The greater the depth of water penetration, the greater the depth of weathering soil and development. In areas with high rate of precipitation, the rate of chemical weathering will be more.

Temperature: for every 10^oC rise in temperature, the rates of biogeochemical weathering reactions are more than double. This is the reason why the very modest profile characteristics of cold areas contrasts sharply with the deeply weathered profiles of the humid areas.

Biota

Role of natural vegetation: Plants influence the amount of organic matter buildup in the soil. For example, soil developed under grassland vegetation has organic matter incorporated into the rooting zone, while in forest soils, organic matter accumulates on the surface. In general, deep rooted plants contribute more to soil development than shallow rooted plants because the passages they create allow greater water movement, which in turn aids in leaching.

Role of animals: Leaves, twigs, and bark from large plants fall onto the soil and are broken down by fungi, bacteria, insects, earthworms, and burrowing animals. These organisms eat and break down organic matter releasing plant nutrients. Microscopic organisms and the humus they produce act as a kind of glue to hold soil particles together in aggregates. Well-aggregated soil is ideal for providing the right combination of air and water to plant roots.

Animals living in the soil affect decomposition of waste materials and how soil materials will be moved around in the soil profile.

Topography

Steepness, shape, and length of slope are important because they influence the rate at which water flows into or off the soil. If unprotected, soils on slopes may erode leaving a thinner surface layer. Eroded soils tend to be less fertile and have less available water than uneroded soils of the same series.

Time

Time is required for horizon formation. The longer a soil surface has been exposed to soil forming agents like rain and growing plants, the greater the development of the soil profile. Soils in recent alluvial or windblown materials or soils on steep slopes where erosion has been active may show very little horizon development. Soils on older, stable surfaces generally have well defined horizons because the rate of soil formation has exceeded the rate of geologic erosion or deposition. As soils age, many original minerals are destroyed and many new ones are formed. Soils become more leached, more acid, and more clayey.

Project Work

1. Depending upon the topography and materials around you, observe and record climate, possible weathering process and soil contents and characteristics.
2. Describe the landforms on which you live.

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6.10 PROBABLE QUESTIONS

1. Are physical and chemical weathering processes independent of each other? If not, why? Explain with examples.
2. What is the result of anthropogenic intervention in the global carbon cycle?
3. How does the movement of water shape landforms?
4. What is a delta? What are the major deltas in India?

UNIT-7: ATMOSPHERIC PROCESSES

UNIT STRUCTURE

7.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the various atmospheric processes that controls the earth's environment, including earth's energy budget, atmospheric circulation, winds etc
- discuss the tropical weather pattern
- give a brief overview of the climate of India

7.2 HEATING PROCESS OF THE ATMOSPHERE

The earth-atmosphere system is sustained by the supply of energy from the sun. Solar radiation is the ultimate source of energy that results in the varied atmospheric processes. Thus the study of energy transferred and exchanged in the earth-atmosphere system is necessary to study the basics of climatology.

Energy is the capacity to do work on some form of matter. It can exist in various forms and change from one form to another. The transfer of energy from place to place is of importance in climatology. There are basically three ways in which this transfer can take place: conduction, convection and radiation.

Conduction consists of energy transfer directly from molecule to molecule where the molecules are densely packed and contact one another. Heat transferred in this way always flow from warmer to colder regions.

Convection involves transfer of heat by the mass movement of fluid (such as water and air). This type of heat transfer takes place in liquids and gases because they can move freely and it is possible to set up currents within them.

Radiation is the only means of energy transfer through space without the aid of a material medium. The energy from the sun travels in the form of waves that release energy when they are absorbed by a surface.

7.2.1 THE ATMOSPHERE AND SOLAR RADIATION

Three atmospheric processes modify the solar radiation passing through our atmosphere destined to the Earth's surface. These processes act on the radiation when it interacts with gases and suspended particles found in the atmosphere. The process of scattering occurs when small particles and gas molecules diffuse part of the incoming solar radiation in random directions without any alteration to the wavelength of the electromagnetic energy (Figure 7f-1). Scattering does, however, reduce the amount of incoming radiation reaching the Earth's surface. A significant proportion of scattered shortwave solar radiation is redirected back to space. The amount of scattering that takes place is dependent on two factors: wavelength of the incoming radiation and the size of the scattering particle or gas molecule. In the Earth's atmosphere, the presence of a large number of particles with a size of about 0.5 microns results in shorter wavelengths being preferentially scattered. This factor also causes our sky to look blue because this color corresponds to those wavelengths that are best diffused. If scattering did not occur in our atmosphere the daylight sky would be black.

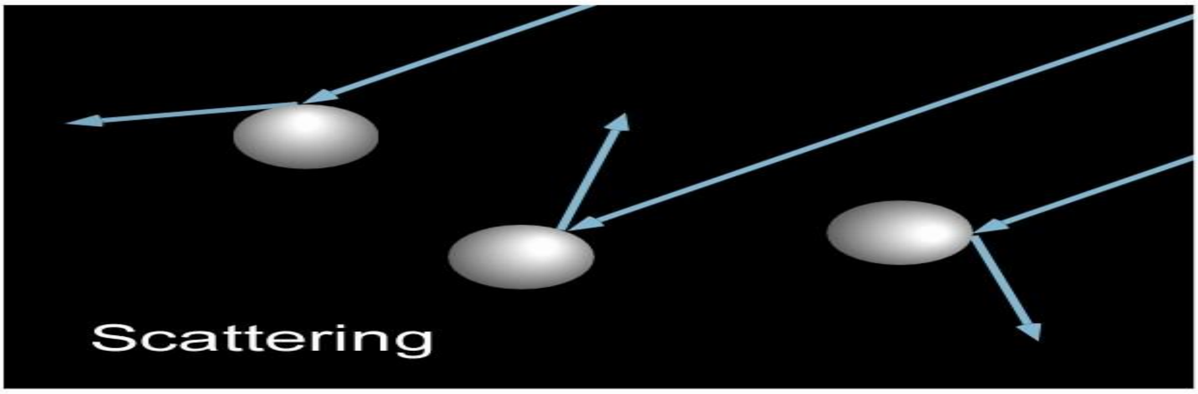


Figure 7-1: The process of atmospheric scattering causes rays of sunlight to be redirected to a new direction after hitting a particle in the atmosphere.

If intercepted, some gases and particles in the atmosphere have the ability to absorb incoming insolation. Absorption is defined as a process in which solar radiation is retained by a substance and converted into heat energy. The creation of heat energy also causes the substance to emit its own radiation. In general, the absorption of solar radiation by substances in the Earth's atmosphere results in temperatures that gets no higher than 1800° Celsius. According to Wien's Law, bodies with temperatures at this level or lower would emit their radiation in the long wave band. Further, this emission of radiation is in all directions so a sizable proportion of this energy is lost to space.

Sunlight reaching the Earth's surface unmodified by any of the above atmospheric processes is termed direct solar radiation. Solar radiation that reaches the Earth's surface after it was altered by the process of scattering is called diffused solar radiation. Not all of the direct and diffused radiation available at the Earth's surface is used to do work (photosynthesis, creation of sensible heat, evaporation, etc.). As in the atmosphere, some of the radiation received at the Earth's surface is redirected back to space by reflection.

The reflectivity or albedo of the Earth's surface varies with the type of material that covers it. For example, fresh snow can reflect up to 95% of the insolation that reaches it surface. Some other surface type reflectivities are:

* Dry sand 35 to 45%
* Broadleaf deciduous forest 5 to 10%
* Needle leaf coniferous forest 10 to 20%
* Grass type vegetation 15 to 25%

Reflectivity of the surface is often described by the term ‘surface albedo’. The Earth's average albedo, reflectance from both the atmosphere and the surface, is about 30%.

7.2.2 THE PLANETARY ENERGY BUDGET

The amount of solar radiation reaching a unit area of the surface – the insolation-is made up of energy transmitted directly through the atmosphere and scattered energy. The earth’s overall average equilibrium temperature changes only slightly from one year to the next which indicates that each year the earth and atmosphere combined must send off into space as much energy as they receive from the sun. The same type of balance must exist between the earth's surface and atmosphere.

Fig 7-2 is a simple model of earth energy balance model.

Suppose 100 units of solar energy reaches the top of the earth atmosphere, the amount reflected and scattered back to space by the clouds ,the earth and atmosphere is 30 units. The atmosphere and clouds together absorb 19 units which leave 51 units of direct and indirect solar radiation to be absorbed at the earth's surface. Out of the 51 units reaching the surface a large amount (23 units) is used to evaporate water and about 7 units are lost through conduction and convection, which leaves 21 units to be radiated away as infra red energy. The earth surface radiates upwards 117 units in the form of infra red energy both during day and night. But the atmosphere allows only a small faction of this energy (6 units) to pass through space. The majority of this (111 units) is absorbed mainly by green house gases, water vapour and CO2 and by clouds. Much of this energy (96 units) is radiated back to earth producing the atmospheric green house effect. Hence the earth receives nearly twice a much long wave infra red radiation from the sun as it does short wave radiation from the sun. Thus the energy lost at the earth surface (147 units) is exactly balanced by the energy gained.

A similar balance exists between the earth's surface and the atmosphere. From the fig 7-2 the energy gained by the atmosphere (160 units) balances the energy lost. The solar energy received at the earth's surface (51units) and that absorbed by the atmosphere (19 units) balances the infra red energy lost to space by the earth surface (6 units) and its atmosphere (64 units).

The earth surface receives 147 units of radiant energy from the sun and its own atmosphere while it radiates away 1117 units producing a surplus of 30 units. The atmosphere, on the other hand, receives 130 units (19 units from the sun and 111 units from the earth) while it loses 160 units, a deficit of 30 units. The balance is the warming of the atmosphere produced by heat transfer processes of conduction and convection and by the release of latent heat.

And so in all the energy transfer a delicate balance is maintained.

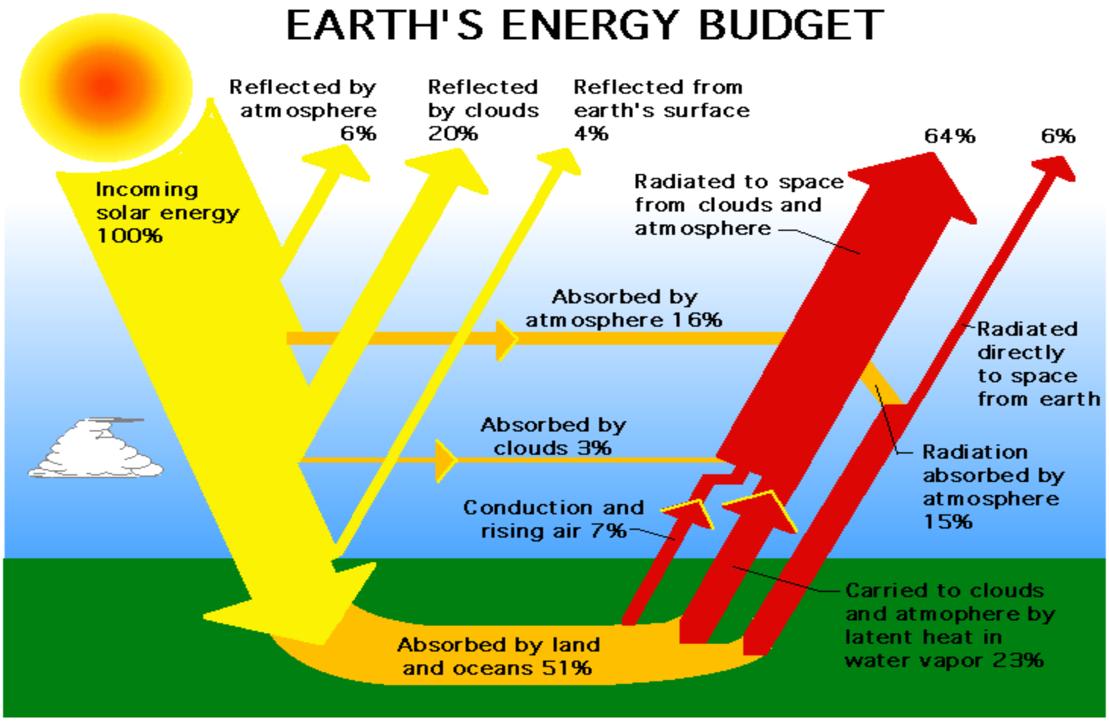


Fig 7-2 : Diagram of Earth's energy budget.
(Courtesy NASA's ERBE (Earth Radiation Budget Experiment) program.)

7.3 ATMOSPHERIC STABILITY AND MIXING HEIGHT

When we speak of atmospheric stability we are referring to a condition of equilibrium, thus air is in stable equilibrium when after being lifted or lowered, it tends to return to its original position-it resists upwards or downwards air motions. Whereas air which is in unstable equilibrium will, when give a little push, move further away from its original position –it favors vertical air currents.

7.3.1 ADIABATIC LAPSE RATE

The ease with which pollutants can disperse vertically into the atmosphere is largely determined by the rate of change of air temperature with altitude. For some temperature profiles the air is stable i.e. the dispersion of pollutants is discouraged. For other temperature profiles the air is unstable where rapid vertical mixing takes place.

Imagine a parcel of air with an imaginary boundary around them. If this parcel of air moves upwards in the atmosphere it will experience less pressure causing it to expand and cool. On the other hand if it moves downwards, more pressure will compress the air and its temperature will increase. If a parcel of air expands and cools or compresses and warms with no exchange of heat with its surroundings this situation is called adiabatic process. As long as the air in the parcel is unsaturated the rate of adiabatic cooling or warming remains constant. This rate of heating and cooling is about 10^{o}C for every 1000 m of change in elevation and applies only to unsaturated air. For this reason it is called dry adiabatic lapse rate. Thus if the air temperature decreases faster with increasing elevation than adiabatic lapse rate, the air will be unstable and rapid mixing will take place. Conversely if the actual air temperature drops more slowly than adiabatic lapse rate, the air will be stable and air pollutants will concentrate. If water vapor is present then condensation occurs when the parcel is raised and cooled releasing latent heat. The added heat means a saturated air parcel will not cool as rapidly as a dry one. Unlike the dry adiabatic laps rate saturated adiabatic lapse rate is not a constant since the amount of moisture air can hold before condensation begins is a function of temperature. An average value of moist adiabatic lapse rate in the troposphere is 6 ^{o}C/km

7.4 TEMPERATURE INVERSION

Temperature inversions represent the extreme cases of atmospheric stability, creating a virtual lid on the upward movement of pollution. There are several causes of inversions, but the two that are most important from an air quality standpoint are *radiation inversion* and *subsidence inversion*.

7.4.1 RADIATION INVERSION: The surface of the earth cools down at night by radiating energy towards space. On a cloudy night, the earth's radiation tends to be absorbed by water vapour which in turn reradiates some of that energy back to the ground. On a clear night however the surface more readily radiates energy to space and so ground cooling takes place much more rapidly. As the ground cools, the air in contact with the ground also cools. Thus on clear winter nights, the temperature of the air just above the ground becomes colder than the air above it and so inversion takes place. Radiation inversion begins at about dusk; as the night progresses reaches few hundred meters in height before the sun warms up the ground again and breaks the inversion.

7.4.2 SUBSIDENCE INVERSION: Subsidence inversion is associated with high pressure weather systems known as anti-cyclones. Air in the middle of the high pressure zone is descending and on the edges it is rising, air near the ground moves outward from the centre, while aloft moves towards the centre from the edges. The result is a massive vertical circulation system. As air in the centre of the system falls it experiences higher pressure and is compressed and heated. Since the subsiding air gets warmer it is able to hold more and more moisture but in the absence of moisture its relative humidity drops and there are chances that clouds are formed. The result of subsidence and surface warming is an inversion located anywhere from several hundred meters above the surface to several thousand meters that lasts as long as the high pressure system exists. At night the surface can cool quickly by radiation which may result in radiation inversion, located under the subsidence in version.

7.5 ATMOSPHERIC CIRCULATION.

The underlying cause of the general circulation of atmosphere is the unequal heating of the earth's surface. We know from above that the average incoming solar radiation is roughly equal to the outgoing total average earth radiation. However this energy balance is not maintained for each latitude since the tropics experience a net gain in energy and Polar Regions a net loss. To balance these inequalities, the atmosphere transports warm air pole ward and cool air equator ward. Although seemingly simple, the actual flow of air is complex and we shall try to understand with the help of two models.

7.5.1 SINGLE CELL MODEL: **T**he single cell model was proposed by an eighteenth-century English meteorologist George Hadley. it is called thermally direct cell because it is driven by energy from the sun. The first model was founded on the following simplifying assumptions:

- The Earth is not rotating in space.
- The Earth's surface is composed of similar materials.
- The global reception of solar insolation and loss of long wave radiation cause a temperature gradient of hotter air at the equator and colder air at the poles.

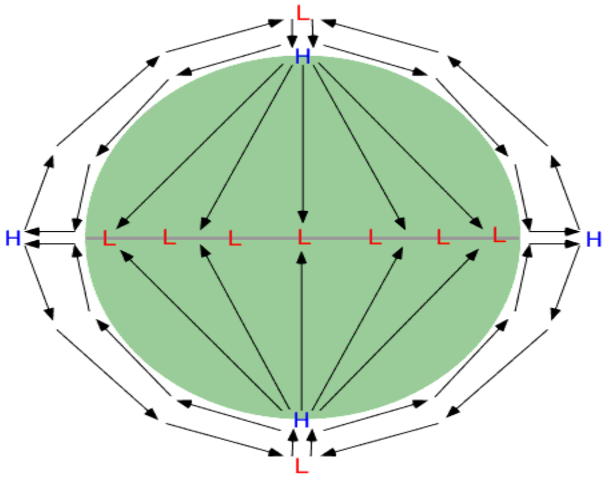


Fig. 7-3 Hypothetical circulation for a non-rotating Earth. Source: National Weather Service, Southern Regional Headquarters - USA.

Since the Earth rotates, its axis is tilted and there is more land in the Northern Hemisphere than in the Southern Hemisphere, the actual global air circulation pattern is much more complicated. Instead of a single-cell circulation, the global model consists of three circulation cells in each hemisphere. These three cells are known as the tropical cell (also called the Hadley cell), the midlatitude cell and the polar cell.

1. Tropical cell (Hadley cell) - Low latitude air moves towards the Equator and heats up. As it heats it rises vertically and moves pole wards in the upper atmosphere. This forms a convection cell that dominates tropical and sub-tropical climates.
2. Mid latitude cell (Ferrel cell) - A mid-latitude atmospheric circulation cell for weather named by Ferrel in the 19th century. In this cell the air flows pole wards and towards the east near the surface and equator ward and in a westerly direction at higher levels.

3. Polar cell - Here air rises, spreads out and travels toward the poles. Once over the poles, the air sinks forming the polar highs. At the surface, the air spreads out from the polar highs. Surface winds in the polar cell are easterly (polar easterlies).

Although still oversimplified, this three cell model can describe the main features of atmospheric circulation.

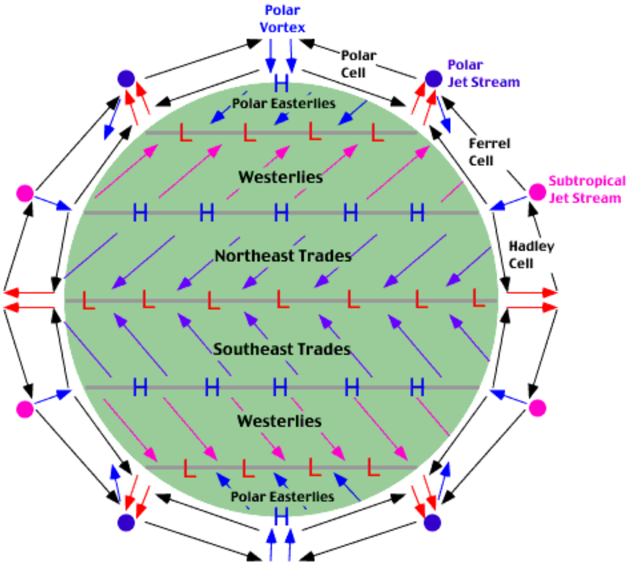


Figure 7-4 : Simplified global three-cell surface and upper air circulation patterns.
(source : http://www.physicalgeography.net/fundamentals/7p.html)

7.6 ATMOSPHERIC PRESSURE

Atmospheric pressure is the force per unit area or the weight exerted by the atmosphere on the surface. As we climb in elevation above the earth's surface, there are fewer air molecules above us; hence atmospheric pressure always decreases with increasing height. Atmospheric pressure decreases more rapidly with elevation in a cold column of air as compared to a warmer less dense air. Thus warm air aloft is normally associated with high atmospheric pressure , and cold air aloft is associated with low atmospheric pressure.

The pressure difference due to temperature establishes a force (called *pressure gradient force*) that causes the air to move from higher pressure towards lower pressure.

7.6.1 PRESSURE MEASUREMENTS

Instruments that detect and measure pressure changes are called barometer.

A common pressure unit used in aviation is inches of mercury. At sea level standard atmospheric pressure is

1019.25 mb =29.92 in Hg =76 cm

The units of pressure as designated by the International System (SI) of measurement is the Pascal, named in honour of Blaise Pascal(1632-1662).

1hPa=1mb

Isobars are lines connecting points of equal pressure.

Forces that influence wind:

In order to identify in which direction the wind will blow; we must identify and examine all the forces that affect the horizontal movement of air. These forces include:

1. Pressure gradient force
2. coriolis force
3. Centripetal force
4. Friction

Pressure gradient force

If we find out the amount of change in pressure that occurs over a distance, we have pressure gradient.

Pressure Gradient = difference in pressure/ distance

If Δp be the change in pressure and d be the horizontal distance between the two places then,

$PG=\Delta p/d$

Thus due to the differences in pressure a net force is acting on the air; this force called the pressure gradient force is directed from the region of higher pressure towards the region of lower pressure. The magnitude is directly proportional to the pressure gradient and is at right angles to the isobars.

Coriolis force

The Coriolis force is due to the rotation of the earth. It is an inertial force described by the 19th-century French engineer-mathematician Gustave-Gaspard Coriolis in 1835. Coriolis showed that, if the ordinary Newtonian laws of motion of bodies are to be used in a rotating frame of reference, an inertial force--acting to the right of the direction of body motion for counterclockwise rotation of the reference frame or to the left for clockwise rotation--must be included in the equations of motion. The effect of the Coriolis force is an apparent deflection of the path of an object that moves within a rotating coordinate system. The object does not actually deviate from its path, but it appears to do so because of the motion of the coordinate system.

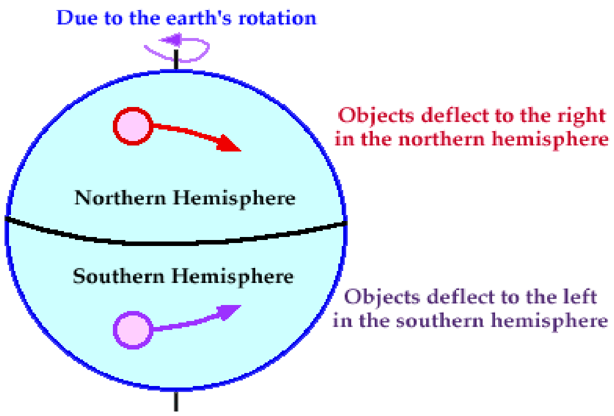


Fig. 7-5 : Coriolis effect due to rotation of the earth (source : http://ww2010.atmos.uiuc.edu/%28Gh%29/guides/mtr/fw/crls.rxml)

7.6.2 PRESSURE BELTS

Two factors leading to the formation of high and low pressure are thermal and dynamic.

(i) Thermal Factor Low pressure is caused by heating. Heating results in expansion of air, resulting in low density and-I thus 'leading to low pressure, e.g., equatorial lows in North America and North India during summer. High pressure is the result of contraction of cooled air and increase in density, e.g., polar highs which occur in North Asia and North America during winters. The main processes in the formation of thermal highs and lows are (a) latent heat of condensation, (b) conduction and radiation, and (c) advection of air masses (advection: horizontal movement of air or liquid transferring heat).

(ii) Dynamic Factor: It operates through a fractional drag and centrifugal force. The centrifugal force is very high along the equator, where the velocity of rotation is high. Hence, the air masses tend to be thrown out, resulting in low pressure. Examples of dynamically produced pressure systems are sub-tropical highs and sub-polar lows. Atmospheric pressure decreases with height. The distribution of pressure is characterised by its zonal or belted nature. Each zone or belt constitutes elongated or circular cells of high or low pressure. There are seven pressure belts on the earth's surface.

The equatorial belt separates the three pairs of belts in the northern and southern hemisphere, namely, the polar high, the sub-polar low and the sub-tropical high. Location of belts is based on the annual average. Pressure belts shift seasonally as the sun moves apparently from one hemisphere to the other, due to the relationship between insolation, heating, expansion, density and air pressure. The pressure belts comprise cells in the northern hemisphere, where all belts shift a little north of their annual average location during summer and a little south of the annual average location in winters. In the southern hemisphere, the belts comprise isobaric bonds and opposite conditions prevail seasonally.

In both high and low pressure belts, the winds are light, blowing in all directions. As the air bodies of different properties meet, they rise up and become unstable, result-ing in rainfall. The air in high pressure belts sinks and spreads and is therefore stable and dry while in the low pressure belts, the air converges and is humid.

7.6.2.1 EQUATORIAL LOW PRESSURE TROUGH

Within a few degrees of equator is a belt of pressure, somewhat lower than the normal pressure 1013 mb, between 1011 mb and 1008 mb, which is known as the Equatorial Trough or Low Pressure Belt. This is an area of high temperature and high humidity, commonly known as the Doldrums, where the air near sea level is stagnant or sluggish. The low pressure is due to heating; as the pressure of a volume of air decreases when its temperature increases. It lies entirely north of the equator during July, because this is the summer hemisphere (Northern Hemisphere). The trough is by no means uniform in width, depth or position. It is deepest and most pronounced when it lies farthest from the equator, such as over an area extending from the Persian Gulf eastward to north-western India, and also over northern Mexico and the south-western United States. It is least distinct over the western and central pacific. Such continental, thermal lows are relatively shallow and have influence only on surface wind patterns.

7.6.2.2 SUB-TROPICAL HIGH PRESSURE BELTS

At about latitude 30 degrees North and South occurs the sub-tropical high pressure belts, sometimes known as the "Horse Latitudes", zones of calm and descending air currents. In the Southern Hemisphere, this belt is clearly defined but contains centers of high pressure termed as "pressure cells". In the Northern Hemisphere in summer, the high pressure belt is dominated by two oceanic cells, one over the eastern Pacific and the other over the eastern north Atlantic. Average pressure exceeds 1026 mb in the centers of the cells. The sub-tropical highs are largely developed by dynamic, rather than thermal causes. Subsidizing air from high levels is largely responsible for their great pressures. Variations in their strength and form are among the most important features of the global energy balance, since the air that diverges from them comprises a large part of the entire air circulation system on the surface.

The summer hemisphere (northern hemisphere) shows only the large oceanic, high pressure centers. The winter hemisphere has a greater number of anti-cyclonic highs and the most active day by day pressure changes along the general sub-tropical pressure zones.

7.6.2.3 SUB-ANTARCTIC LOW PRESSURE BELTS

Pole-wards of the sub-tropical high pressure belts are the broad belts of low pressure, extending roughly from the middle latitude zone (35o to 55o north and south) to the Arctic zone (60o to 75o north and south) but centered and intensified in the sub-Arctic zone (55o to 60o north and south) at about 60th parallel to latitude (horizontal). In the southern hemisphere, over the continuous expense of southern ocean, the sub-Antarctic low pressure belt is specially defined with average pressure as low as 984 mb.It is one of the deepest and most persistent low pressure troughs in the world bordering the Antarctic continent. It is present, however, at all seasons shifting slightly southwards in January. This low pressure trough marks the zone of energy transfer between warm and cold air. It is a strong frontal zone, and the dynamics of air interchange, implemented by the upward displacement of warmer air, the high condensation, great angular momentum, rotational deflection, and other factors produce an almost continuous succession of deep cyclones that move around the world through this zone. Anticyclones, or high pressures accompanied by descending diverging air, sometimes, occupy positions within the trough and at rare intervals may persist for several days.

7.6.2.4 SUB-POLAR LOW PRESSURE BELTS

Nearer the poles occur the sub-polar low pressure belts. One reason for this pressure distribution is that the rotation of the earth causes a polar whirl and therefore a tendency toward low pressure at the poles. But the intense cold around the poles causes the thermal effect to overcome the dynamic one, with the result that the low pressure belts tend to be around just outside the polar circles.

Since the frontal activity between cold and warm air in these latitudes is weak during the summer season, strong sub-polar lows do not develop.

7.6.2.5 POLAR HIGHS

The polar zones have permanent centers of high pressure known as polar highs. Both high and low pressure centers are present, which change in intensity and shape seasonally, with the low (located near the continental margin) dominant during most of the year, but less strongly developed during the winter months. A high pressure ridge tends to occupy the highest portion of the continent but is extremely shallow and not well developed.

7.6.3 WIND(S)

When the movement of the air in the atmosphere is in a horizontal direction over the surface of the earth, it is known as the wind. Movement of the wind is directly controlled by pressure.

7.6.3.1 THE EQUATORIAL BELT OF VARIABLE WINDS

Over the equatorial trough of low pressure, lying roughly between 5° S and 5° N latitude, is the equatorial belt of variable winds and calms or the Doldrums. There are no surface winds here, but a fair distribution of directions around the compass. Calms prevail as much as a third of the time. Centrally located on a belt of low pressure, this zone has no strong pressure gradients to induce a persistent flow of wind.

7.6.3.2 TRADE WIND BELT

North and south of the doldrums are the trade wind belts, covering roughly the zones lying between 5° and 30° north and south. The trade is a result of a pressure gradient from sub-tropical belts of high pressure to the equatorial trough of low pressure. In the northern hemisphere, air moving equator-wards is deflected by the earth’s rotation to turn westwards. Thus, the prevailing wind is from the north-east and winds are termed as the north-east trades. In the Southern Hemisphere, deflection of the moving air to the left causes the south-east trades. Trade winds are noted for their steadiness and directional persistence. Most winds come from one quarter of the equator. The trades are best developed over the Pacific and Atlantic oceans, but are upset in the India Ocean region by the proximity of great Asiatic land mass. The trade wind belts are not altogether favorable for navigation or flying, because over certain oceanic portions, at certain seasons of the year, terrible tropical storms known as hurricanes or typhoons occur.

7.6.3.3 SUB-TROPICAL BELT OF VARIABLE WINDS AND CALMS

Between latitudes 30° and 40° north and south are what has long been called the sub-tropical belt of variable winds and calms or horse latitudes, coinciding with the sub-tropical high pressure belt. Instead of being continuous even belts, the high pressure areas are concentrated into distinct anticyclones or cells, located over the oceans.

The apparent outward spiraling movement of air is directed equatorward into easterly trade wind system; polewards into the westerly wind system. The cells of higher pressure are most strongly developed in summer. There is also a latitudinal shifting following the sun's declination. This amounts to less than 5° in the Southern Hemisphere, but is about 8° for the strong Hawaiian high latitude in the north-eastern Pacific.

Winds in the high pressure cells are distributed around a considerable range of compass directions. Calms prevail as much as a quarter of the time. The cells have generally fair, clear weather, with a strong tendency to dryness. Most of the world's great deserts lie is this zone and in the adjacent trade wind belt.

7.6.3.4 BELT OF WESTERLIES

Between latitudes 40° and 60° north and south, is the belt of westerlies or prevailing westerly winds. Within the westerly wind belt, winds blow from any direction of the compass, but the westerly components are definitely predominant. Storm winds are common in this belt, as are frequent cloudy days with continued precipitation. Weather is highly changeable.

In the Northern Hemisphere, land masses cause considerable disruption of the westerly wind belt, but in the Southern Hemisphere, between the latitude 40° and 60° south, there is an almost unbroken belt of ocean. Here the westerlies gain great strength and persistence.

The belt was extensively used for selling vessels travelling eastwards from the South Atlantic Ocean to Australia, Tasmania, New Zealand and the Southern Pacific Islands. Although the westerly wind belts no longer exert a strong influence over the routes of modern ocean vessels, they are important in long distance flying. Transoceanic and transcontinental flights in the easterly direction require less fuel and shorter time. On westward flights, strong headwinds may eat dangerously into the fuel supply on the plane and in any event necessitate reduced payload.

7.6.3.5. POLAR EASTERLIES

A wind system termed polar easterlies has been described as the characteristic of the Arctic and the polar zones. The concept is greatly over simplified, if not actually erroneous, for winds in these regions take a variety of directions, as dictated by local weather disturbances. Perhaps in Antarctica, where an ice-capped land mass rests squarely upon the pole and is surrounded by a vast oceanic expense, the outward spiraling flow of polar easterlies is a valid concept. Deflected to the left in the Southern Hemisphere, the radial winds would spiral counter clockwise, produce a system of south-easterly winds.

7.6.4 JET STREAMS

Atmospheric jet streams are swiftly flowing air currents thousands of kilometers long, a few hundred kilometers wide and only a few kilometers thick. Wind speeds in the central core of the jet streams often exceed 100 knots and occasionally 200 knots. Jet streams are usually found at the tropopause at elevations between 10 and 15 km although they may occur at both higher and lower altitudes. There are two jet streams both located in the tropopause gaps, where mixing between troposphere and stratospheric air takes place.

The jet stream situated at nearly 13 km above the subtropical high is the subtropical jet stream. The jet stream situated at about 10 km near the polar front is known as the polar jet stream or simply polar jet.

7.6.5 MONSOONS

The term monsoon refers to the seasonal change in the wind in the stratosphere and mesosphere and its associated climatic effects, namely the high variability and unpredictability of rainfall. South Asia experiences two monsoons: the north-west monsoon where the winds blow from the north-east and bring dry weather during October-May and; the south-west monsoon where the winds from the oceans of South-East Asia bring wet weather during June-September.

The monsoon is a result of three physical processes:

(i) the uneven heating of land and sea, which causes a pressure differential that drives the winds from high pressure to low pressure;

(ii) the rotation of the earth, which forces moving wind to veer towards the right in the northern hemisphere and to the left in southern hemisphere;

(iii) the transition in the state of water from liquid to vapour, which determines the strength and location of the monsoon rains.

Originally, theories of the causes of the monsoon in the nineteenth and eighteenth century were based on an understanding of the effects of the non-uniform heating of the land and sea. The earliest propounder of this line of thought, Edmund Halley, an astronomer influenced by Newtonian physics, showed in his ‘sea breeze-land breeze’ model of 1686 the tendency for the northeasterly trade winds on the northern side of the equator and the southeasterly trades to the south of the equator to converge towards the most strongly heated regions of the globe. Differential heating creates pressure differences in the atmosphere, and thus the effect of winds blowing from high pressure to low pressure. As the land is heated to a temperature higher than that of surrounding oceans, the ascending warm air causes an indraft of cooler sea air towards the land interior, bringing the rains associated with the monsoon. Consequently, in the summer, cooler, oceanic air would blow towards warmer land masses, while in winter as the continents cool to temperatures lower than the surrounding oceans, the wind flow would reverse, blowing from the land toward the ocean. This theory was refined by George Hadley, who observed that the wind flow between land and ocean was in an oblique direction (southwest in summer, northwest in winter). Hadley explained that moving air is deflected as a result of rotation of the earth on its axis, veering towards the right in the northern hemisphere and forming the monsoon southwesterlies, and to the left in the southern hemisphere, creating the monsoon north westerlies. While this theory of the monsoon was further refined during the 1950s and 1960s, the development of space observatory technologies and upper-air measuring devices has lent weight to theories that emphasize the seasonal shifting of thermally produced belts of pressure and winds due to a differential heating of air over the Tibetan High Plateau. As this differential heating creates warm air, which then rises and spreads out southwards and gradually sinks over the equatorial regions of the Indian Ocean, it generates a reverse circulation of air in the lower troposphere, creating a low-level poleward flow known as the easterly jet stream. As this flow gains momentum, the winds pick up the moisture from the warm sea surface during their northward movement across the Indian Ocean, bringing the rains of the south-west monsoon. For this reason, the onset of the southwest

7.7 TROPICAL WEATHER

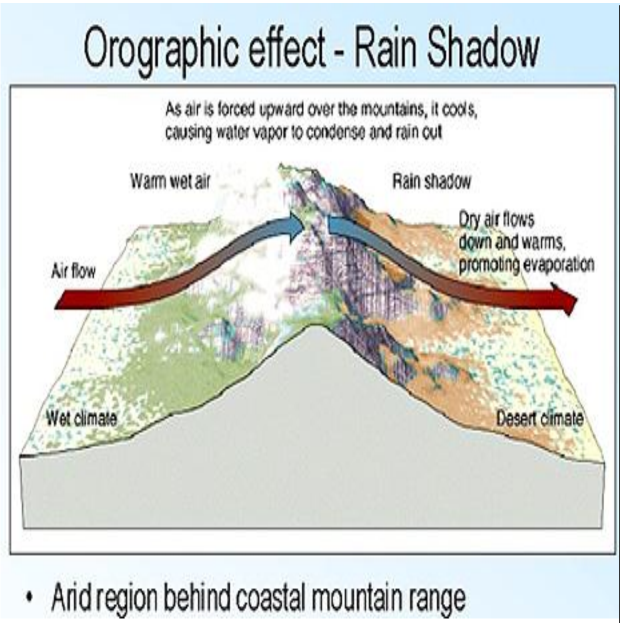
How can we define the tropics?

The most commonly used definition of the tropics is the zone within which the Sun is directly overhead at some time during the year, i.e. the zone between the tropics of Cancer and Capricorn (23.45°N and 23.45° S, respectively).

7.7.1 WINDS IN THE TROPICAL ZONE

Within the tropics, winds are often relatively light, in particular at upper levels. Over the Atlantic and much of the Pacific, these are westerlies throughout the year. Over the western Pacific, Indian Ocean and Africa, there are high-level easterlies close to the Equator (Figures 2 and 3). At low levels, Trade-Wind flows predominate, originating in the sub-tropical high-pressure systems (the areas of the ‘doldrums’) centred near30°N and 25° S. North-easterlies in the Northern Hemisphere converge near the Equator with south-easterlies in the Southern Hemisphere providing the additional forcing necessary for deep convection within the tropics, forming a belt of convective cloud: the inter-tropical convergence zone (ITCZ). However, significant reversals in the low-level wind flow occur over and around the tropical continents during the change from winter to summer. Summer monsoon circulations have westerlies at low levels, but middle- and upper-tropospheric easterlies strengthen as the troposphere warms and deepens to form an upper high over the continents, on the equatorward rim of which there is a steep temperature and height gradient. The greatest strengthening occurs as the equatorial high migrates away from the Equator and deepens. Close to the Equator, these winds may reach jet stream strength in a

shallow layer near 15 km altitude. This jet stream is found only about 1000m below the tropical tropopause. During the Northern- Hemisphere summer, these winds stretch all the way from South-East Asia to Africa's Gold Coast, although the main activity and highest speeds are generally across the southern tip of India, where speeds occasionally reach 60 ms–1* and there is a local minimum over eastern Africa (Hastenrath, 1991). A similar, but weaker, jet stream forms over New Guinea and Indonesia in response to the warming of Australia during the southern summer. The easterly winds at high levels diverge north and south away from the upper high that forms close to the Equator. North and south of 15° latitude, they become westerlies (Figure 2). The upper westerlies may reach jet stream strength to form the subtropical jet stream (STJ) along the poleward edge of the tropical air mass, close to 30°N and 30° S. The STJ is present throughout the year in the Southern Hemisphere, but has large speed changes between winter and summer in the Northern Hemisphere. In the northern winter, its speed may reach 110ms–1 or more over east Asia and the western Pacific. However, its speed is rarely more than 50 ms–1 in high summer with a mean closer to 25 ms–1. At medium levels, winds of moderate strength often form wave trains, known as easterly waves, which form in response to temperature differences and convective development. These have a strong association with severe weather, notably summer mesoscale weather systems over India, and the squall lines of Africa and parts of the Pacific Ocean (Atkinson, 1971; Leroux, 2001). Over the Atlantic, easterly waves are intimately associated with the development of tropical revolving storms (Emanuel 2005). The low value of the Coriolis force close to the Equator presents a difficulty in the assessment of wind speed and direction, so streamline analysis, rather than conventional pressure analysis, is generally used in the tropics, as described in Box 1.



Box 1 : Orographic precipitation is a straightforward process, as depicted below. Moist air moves toward higher terrain - usually large mountain chains but smaller block mountains can also induce the effect. This wind-driven air is forced up the slopes to elevations where both P and T are reduced. At the lower temperatures, the moist air mass becomes saturated and precipitation ensues - usually as thunderstorms in the summer or as widespread snow storms in the winter. This air then becomes "dried out" - most of its moisture has precipitated in the pass over. The air mass that moves down the opposite slope is now drier and warmer. This side is said to be in a "rain shadow", i.e., general storms are infrequent and arid conditions, with their characteristic vegetation, prevail. As it moves on, the air mass may gradually pick up moisture.

Fig : 7-5 : Orographic effect

7.6 .2 The weather patterns and climates of the tropics:

The tropical region experiences only gradual changes in weather patterns and variations are generally small, even between seasons. The main changes are between dry and wet seasons, marked by:

(i) the northward and southward movement of the inter-tropical convergence zone (ITCZ) in the central (equatorial) portion and

(ii) the winter incursion of cooler air at altitude near the pole ward extremes.

Even with this movement, there is almost no seasonal weather fluctuation within about 5–10° latitude of the mean position of the ITCZ. However, since most of the world's hot deserts have their equatorial flank within 20° of the Equator, marked by transition to savannah vegetation (e.g. the Sahel of West Africa), seasonal variations can be large close to these latitudes.

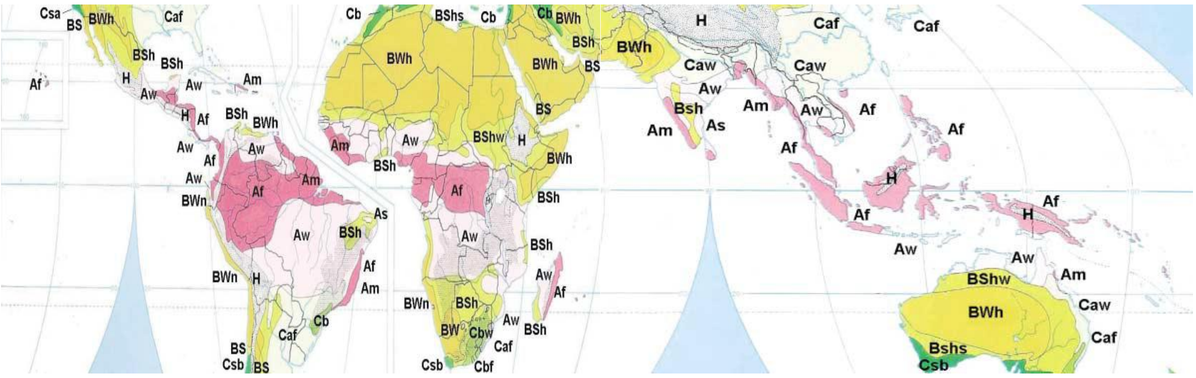


Figure 7-6 Climatic zones of the tropics: Af, Am – tropical rainforest; Aw – savannah; BSh – tropical steppe; BWh – tropical and sub-tropical desert; Cs – dry-summer sub-tropical; H – highlands; Cf – warm temperate with no dry season; Cs – warm temperate with dry summer; Cw – warm temperate with dry winter; stippled– modification due to altitude. The effect of high ground has a profound influence on climate in the tropics, particularly above about 2km. (Using the system devised by Wladimir Koppen.)

As can be seen in Figure 7-7 , the predominant climates of the tropics are dry ones: the hot deserts, semi-desert scrub and expansive savannahs. These lie towards the periphery of the tropical zone, in regions where anticyclonic subsidence predominates and rainfall is either seasonal or ephemeral. The hot deserts are noted for a high diurnal range of temperature. A maximum of more than 40°C in places by mid afternoon may fall as much as 30°C by morning. This range is solely due to the effects of a dry atmosphere with little or no cloud and such a low vapour pressure that diurnal temperatures can vary greatly. Over continental areas, the periphery of the humid zone is dominated by monsoon wind regimes. These bring wet humid weather in summer and predominantly dry weather in winter. Characteristically, there is a seasonal reversal of wind at low levels. In the northern summer, southeasterly winds cross the Equator and recurve to become south-westerlies (north easterlies become north-westerlies in the Southern Hemisphere), bringing moist oceanic air across the Equator into areas that are under the influence of dry continental easterly winds during the winter. West Africa, southern Asia and northern Australia all experience these monsoon reversals. Although still seasonal, the situation is more complex over the Amazon basin and Caribbean, where moist westerlies cannot become established, due to the Andes-Sierra Madre mountain barriers. Thus the motion of convection is dependent on more complex changes in the atmospheric circulation and the influence of the Caribbean Sea, which warms and cools more than the neighboring Atlantic Ocean. Over the warmest ocean areas, the tropics are characterized by the development of tropical revolving storms, associated with strong lower-troposphere winds and (perhaps more importantly) heavy rainfall. Although a relatively narrow zone(no more than about 1500km wide, except in South-East Asia), it is the humid equatorial zone that many associate with the tropics. In this zone, rainfall can be relied upon year round, as the ITCZ is never far away. Maxima are generally limited to the mid 30 Celsius over land by the high water-vapour content of the air and minima are similarly restricted by cloudiness or the overnight formation of dew, mist or fog. Over the sea, temperature changes little day by day. Thus, throughout the tropics, the diurnal range of temperature is relatively small. Nevertheless, this climate is uncomfortable for most humans, who find it difficult to lose excess body heat in these conditions. Where seasonality is the main effect on rainfall, savannahs predominate. In these areas of extensive grassland, annual evaporation exceeds precipitation and trees grow only in stunted groves. These areas are home to relatively large populations in some parts of the world and agriculture is critically dependent on the summer rains (both locally and to re-charge river flows), so any reduction or failure of seasonal rainfall often causes notable famines, especially in recent years. Some areas that have some seasonality, but a predominantly maritime climate, such as the northern Caribbean, have an intermediate climate with extensive forest, as well as grassland. Elsewhere, steppe surrounds the arid deserts. Here few plants can grow, but there is sufficient rainfall or run-off to support agriculture and moderate-sized populations. Included in this climatic zone are the highlands of much of Arabia. However, within each climatic zone there are important variations, due to orography, latitude and longitude. Some of the world’s hot deserts receive most of their (meagre) rainfall in summer, others in winter – here the variation is mainly by latitude and altitude, with equator ward regions having a summer rainfall peak. Examination of the mean annual rainfall in the tropics reveals that there are significant differences on a broad scale within climatic zones, as shown in Figure 4. In general, the desert areas generally see less than 200mmyr–1, though Australia’s dry interior is defined by annual rainfall less than 600 mm. The monsoon zones see between about 1000 and 2500mmyr–1, occurring in summer. The semi-deserts and oceanic areas under the influence of the sub-tropical anticyclones have a total rainfall between 200 and about1000mmyr–1. Areas under the influence of upper-tropospheric troughs (see Parts 2 and3) see about 1000mmyr–1 and the ITCZ experiences totals above 1000 mm yr–1 with some areas seeing more than 3000 mm yr–1.Orographic effects add further local detail. High ground has two main effects: it lowers the mean temperature (although nights may be less cool, if the mountains are modest and the observation is not in valley) and increases the rainfall, increasing the likelihood of precipitation by ‘forced’ convection or convergence. For instance, copious rainfall is generated by the Ethiopian Highlands and India’s Western Ghats. These highlands have a relatively equable climate within the almost universally hot tropical zone and their climate is markedly different from that of their surroundings. Along the western margins of Africa and the Americas, there are cool currents as result of the upwelling of cool deep water under the influence of the Trade Winds. The effect is most marked along the south-west coast of South America, as well as the northwestern and south-western coasts of Africa. This brings a surprisingly cool and usually dry climate north to only a few degrees south of the Equator, although this climatic zone, comparatively equable for the population, is narrow, extending only a few tens of kilometers inland. Populations are comparatively high in these zones, largely due to the excellent fishing available, due to the upwelling of plankton-rich deep waters. Heating and cooling have a significant effect on air pressure throughout the tropics, the pressure falling in response to diurnal heating and rising in response to nocturnal cooling. As pressure rarely changes due to synoptic-scale weather systems in the tropics, the diurnal changes are significant, as shown in Table 1.

7.7.3. EL NIÑO AND THE SOUTHERN OSCILLATION

The El Niño phenomenon is generally accepted to have a profound underlying effect in the tropics, changing the broad scale circulation patterns as pressure changes across the Pacific to form the Southern Oscillation. The Southern Oscillation is a relative change of pressure in the eastern tropical Pacific basin (usually measured at Tahiti) compared with that in the west (measured at Darwin). El Niño is a warming of the eastern equatorial Pacific Ocean and causes mean sea-level pressure to fall over the eastern Pacific, whereas over the western Pacific, pressure rises. The consequence of the changes is to increase precipitation in the eastern Pacific (and over the Atlantic and western Indian Ocean basins), while decreasing it across South-East Asia and Australia (as well as, perhaps, east Africa). Relatively strong westerlies are associated with the development of the El-Niño anomalies in the eastern Pacific (Verbickas, 1998;Fedorov, 2002) and their formation mechanism seems to be directly linked with the El-Niño phenomenon. In view of the mass transport associated with such a change in wind velocity, accompanied by the vast amount of water vapour that can be carried by such tropical winds, it is easy to see how El Niño has global consequences. La Niña is an amplification of the westward flow of the Trade Winds and associated creased warmth of the western Pacific. It is measured as an increase from the normal pressure difference Tahiti–Darwin. Its consequences are an increase in west Pacific tropical storm activity and copious additional rainfall across South-East Asia and north-eastern Australia.

7.8 CLIMATE OF INDIA

India is home to an extraordinary variety of climatic regions, ranging from tropical in the south to temperate and alpine in the Himalayan north, where elevated regions receive sustained winter snowfall. The nation's climate is strongly influenced by the Himalayas and the Thar Desert. The Himalayas act as a barrier to the frigid katabatic winds flowing down from Central Asia keeping the bulk of the Indian subcontinent warmer than most locations at similar latitudes. As such, land areas in the north of the country have a continental climate with severe summer conditions that alternates with cold winters when temperatures plunge to freezing point. In contrast are the coastal regions of the country, where the warmth is unvarying and the rains are frequent. The country is influenced by two seasons of rains, accompanied by seasonal reversal of winds from January to July. During the winters, dry and cold air blowing from the northerly latitudes from a north-easterly direction prevails over the Indian region. Consequent to the intense heat of the summer months, the northern Indian landmass becomes hot and draws moist winds over the oceans causing a reversal of the winds over the region which is called the summer or the south-west monsoon. This is the most important feature controlling the Indian climate because about 75% of the annual rainfall is received during a short span of four months (June to September). Variability in the onset, withdrawal and quantum of rainfall during the monsoon season has profound impacts on water resources, power generation, agriculture, economics and ecosystems in the country. The variation in climate is perhaps greater than any other area of similar size in the world. There is a large variation in the amounts of rainfall received at different locations. The average annual rainfall is less than 13 cm over the western Rajasthan, while at Mausinram in the Meghalaya has as much as 1141 cm. The rainfall pattern roughly reflects the different climate regimes of the country, which vary from humid in the northeast 2 (about 180 days rainfall in a year), to arid in Rajasthan (20 days rainfall in a year). So significant is the monsoon season to the Indian climate, that the remaining season are often referred relative to the monsoon. The rainfall over India has large spatial as well as temporal variability. A homogeneous data series has been constructed for the period 1901-2003 based on the uniform network of 1476 stations and analyzed the variability and trends of rainfall. Normal rainfall (in cm) pattern of the country for the four seasons and annual are depicted in Fig 1 and Fig 2 respectively. Normal monsoon rainfall more than 150cm is being observed over most parts of northeast India, Konkan & Goa. Normal monsoon rainfall is more than 400cm over major parts of Meghalaya.

Annual rainfall is more than 200 cm over these regions. For the country as a whole, mean monthly rainfall during July (286.5 mm) is highest and

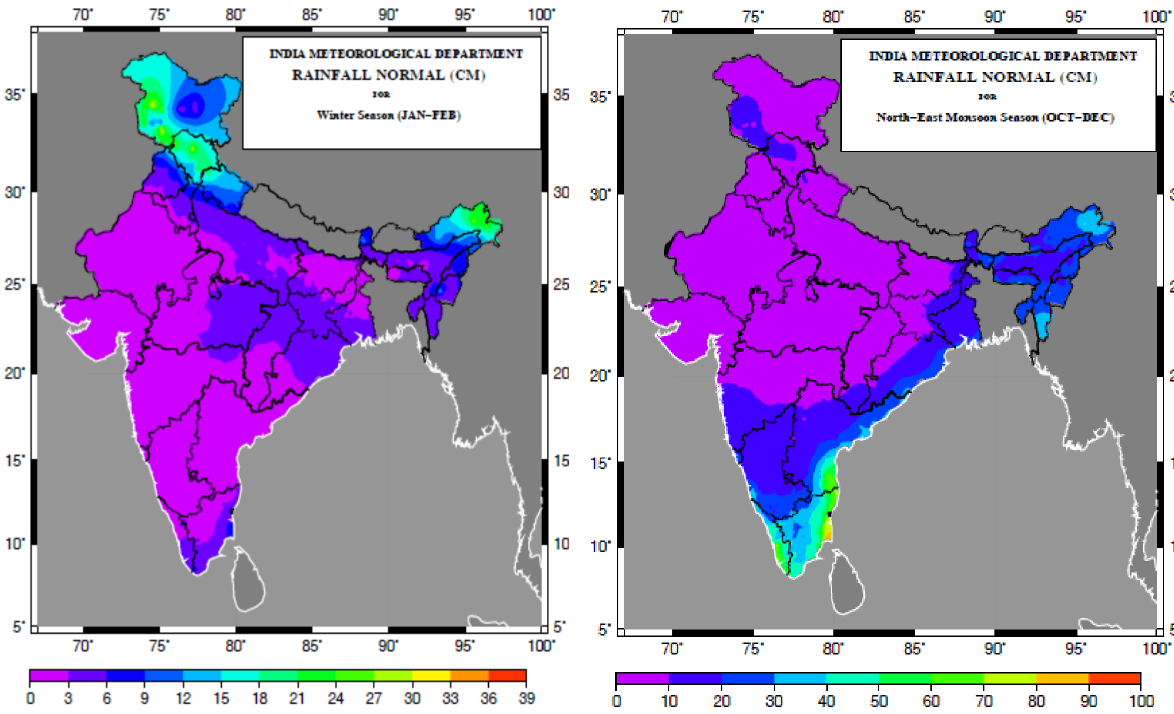


Fig 7-7 : Normal rainfall pattern (cm) during (a) Winter (b) Pre-monsoon (c) Monsoon and (d) Post-Monsoon seasons for the period 1941-90

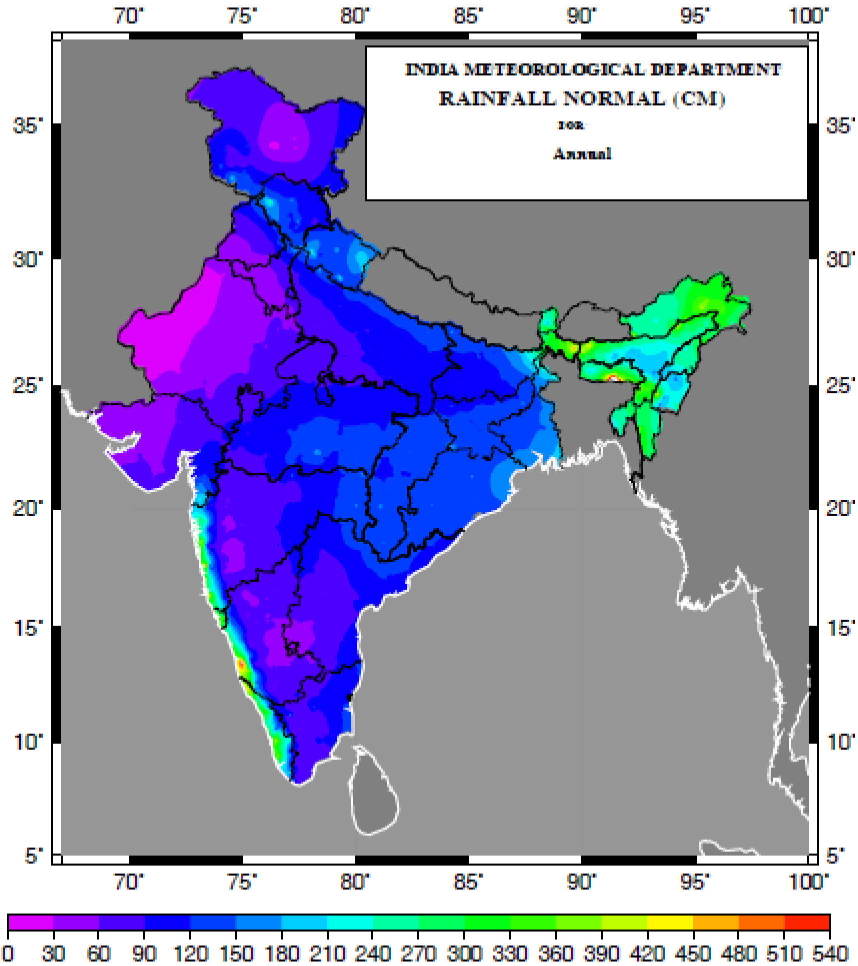


Fig 7-8 : Annual normal rainfall pattern (cm) during 1941-90

contributes about 24.2% of annual rainfall (1182.8 mm). The mean rainfall during August is slightly lower and contributes about 21.2% of annual rainfall. June and September rainfall are almost similar and contribute 13.8% and 14.2% of annual rainfall, respectively. The mean south-west monsoon (June, July, August & September) rainfall (877.2 mm) contributes 74.2% of annual rainfall (1182.8 mm). Contribution of pre-monsoon (March, April & May) rainfall and post-monsoon (October, November & December) rainfall in annual rainfall is mostly the same (11%). Coefficient of variation is higher during the months of November, December, January and February. India is characterised by strong temperature variations in different seasons ranging from mean temperature of about 10°C in winter to about 32 °C in summer season.

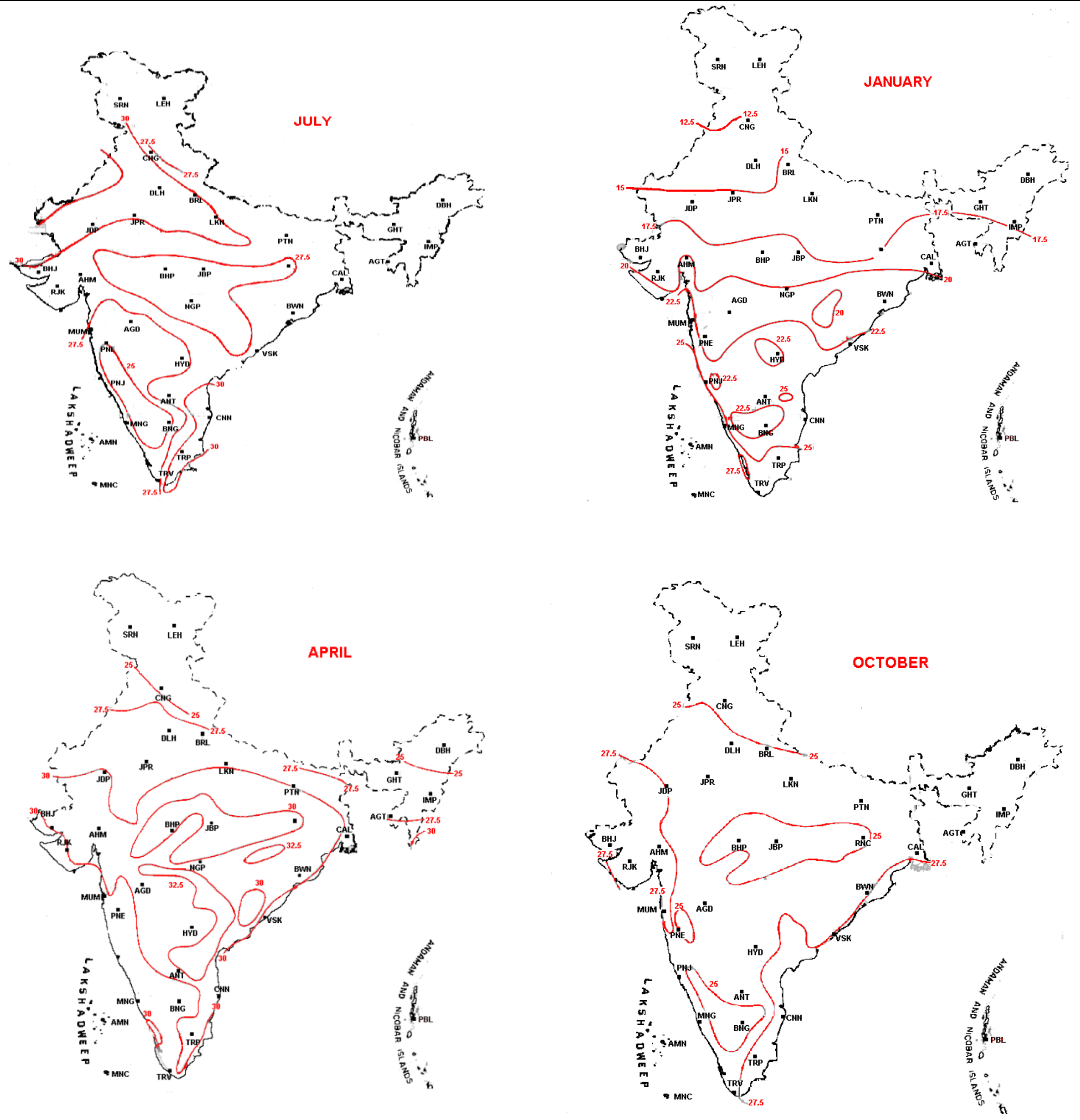


Fig. 7-9 : Seasonal temperature distribution over India

Details of weather along with associated systems during different seasons are presented as under:

1.1 *Winter Season / Cold Weather Season (January and February)*

India Meteorological Department (IMD) has categorized the months of January and February in winter season. However, December can be included in this season for north-western parts of the country. This season starts in early December 3 associated with clear skies, fine weather, light northerly winds, low humidity and temperatures, and large daytime variations of temperature . The cold air mass extending from the Siberian region, has profound influence on the Indian subcontinent (at least all of the north and most of central India) during these months. The mean air temperatures increase from north to south up to 17°N, the decrease being sharp as one moves northwards in the north-western parts of the country. The mean temperatures vary from 14 °C to 27°C during January. The mean daily minimum temperatures range from 22 °C in the extreme south, to 10 °C in the northern plains and 6 °C in Punjab. The rains during this season generally occur over the western Himalayas, the extreme north-eastern parts, Tamil Nadu and Kerala. Western disturbances and associated trough in westerlies are main rain bearing system in northern and eastern parts of the country.

1.2 Pre-monsoon season/ Summer season/ Hot weather season/ Thunderstorm season (March, April and May)

The temperatures start to increase all over the country in March and by April; the interior parts of the peninsula record mean daily temperatures of 30-35°C. Central Indian land mass becomes hot with daytime maximum temperatures reaching about 40°C at many locations. Many stations in Gujarat, North Maharashtra, Rajasthan and North Madhya Pradesh exhibit high day-time and low night-time temperatures during this season. The range of the daytime maximum and night-time minimum temperatures in found more than 15 °C at many stations in these States. Maximum temperatures rise sharply exceeding 45 °C by the end of may and early June resulting in harsh summers in the north and north-west regions of the country. However, weather remains mild in coastal areas of the country owing to the influence of land and sea breezes. The season is characterised by cyclonic storms, which are intense low pressure systems over hundreds to thousands of kilometres associated with surface winds more than 33 knots over the Indian seas viz. Bay of Bengal and the Arabian Sea. These systems generally move towards a north-westerly direction and some of them recurve to northerly or northeasterly path. Storms forming over the Bay of Bengal are more frequent than the ones originating over the Arabian Sea. On an average, frequency of these storms is about 2.3 per year. Weather over land areas is influenced by thunderstorms associated with rain and sometimes with hail in this season. Local severe storms or violent thunderstorms associated with strong winds and rain lasting for short durations occur over the eastern and north eastern parts over Bihar, West Bengal, and Assam. They are called norwesters or “Kal Baisakhis” as generally approach a station from the northwesterly direction. Thunderstorms are also observed over central India extending to Kerala along wind-discontinuity lines. Hot and dry winds accompanied with dust winds (“andhis”) blow frequently over the plains of north-west India.

1.3 South-west Monsoon/ Summer Monsoon (June, July, August and September)

The SW monsoon is the most significant feature of the Indian climate. The season is spread over four months, but the actual period at a particular place depends on onset and withdrawal dates. It varies from less than 75 days over West Rajasthan, to more than 120 days over the south-western regions of the country contributing to about 75% of the annual rainfall. The onset of the SW monsoon normally starts over the Kerala coast, the southern tip of the country by 1 June, advances along the Konkan coast in early June and covers the whole country by middle of July. However, onset occurs about a week earlier over islands in the Bay of Bengal. The monsoon is a special phenomenon exhibiting regularity in onset and distribution within the country, but inter-annual and intrannual variations are observed. The monsoon is influenced by global and local phenomenon like El Nino, northern hemispheric temperatures, sea surface temperatures, snow cover etc. The monsoonal rainfall oscillates between active spells associated with widespread rains over most parts of the country and breaks with little rainfall activity over the plains and heavy rains across the foothills of the Himalayas. Heavy rainfall in the mountainous catchments under 'break' conditions results flooding over the plains. However, very uncomfortable weather due to high humidity and temperatures is the feature associated with the Breaks. Cyclonic systems of low pressure called 'monsoon depressions' are formed in the Bay of Bengal during this season. These systems generally form in the northern part of the Bay with an average frequency of about two to three per month and move in a northward or north-westward direction, bringing well-distributed rainfall over the central and northern parts of the country. The distribution of rainfall over northern and central India depends on the path followed by these depressions. SW monsoon current becomes feeble and generally starts withdrawing from Rajasthan by 1st September and from north-western parts of India by 15th September. It withdraws from almost all parts of the country by 15th October and is replaced by a northerly continental airflow called North-East Monsoon. The retreating monsoon winds cause occasional showers along the east coast of Tamil Nadu, but rainfall decreases away from coastal regions.

1.4 Post-monsoon or Northeast monsoon or Retreating SW Monsoon season (October, November and December)

North-East (NE) monsoon or Post-monsoon season is transition season associated with the establishment of the north-easterly wind regime over the Indian subcontinent. Meteorological subdivisions namely Coastal Andhra Pradesh Rayalaseema , Tamil Nadu, Kerala and South Interior Karnataka receive good amount of rainfall accounting for about 35% of their annual total in these months. Many parts of Tamil Nadu and some parts of Andhra Pradesh and Karnataka receive rainfall during this season due to the storms forming in the Bay of Bengal. Large scale losses to life and property occur due to heavy rainfall, strong winds and storm surge in the coastal regions. The day temperatures start falling sharply all over the country. The mean temperatures over north-western parts of the country show decline from about 38°C in October to 28°C in November. Decrease in humidity levels and clear skies over most parts of north and central India after mid-October are characteristics features of this season (NATCOM 2004, IMD 2010).

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7.10 PROBABLE QUESTIONS

1. How does solar energy influence the atmosphere?
2. How does the atmosphere interact with land and oceans?
3. How is heat transferred throughout the earth system?
4. What is energy radiation budget?
5. How do monsoons affect the Indian weather system? What is the role of jet streams in tropical monsoons?
6. What is the climate of India? What is the role of Thar Desert and the Himalayas in the climate of India?

UNIT-8: CONTEMPORARY ISSUES

UNIT STRUCTURE

8.1: OBJECTIVES

After going through this unit, you will be able to discuss:

- Environmental issues
- Causes and consequences of some important environmental issues
- Case studies related to these issues
- Some measures to reduce these issues

8.2: INTRODUCTION TO ENVIRONMENTAL ISSUES

Environment and its related issues are there from the early age of history. The environmental issues are the result of negative impacts of human on the environment. To fulfill the human desire and need, indiscriminate exploitation of natural resources are going on, resulting enormous environmental issues. To satisfy the necessities of the growing population, use of energy and raw materials become more intensive, generating more waste per unit of wealth and transforming the natural surroundings very rapidly. Rapid industrialization, technological advancement in agriculture, urbanization, energy generation have resulted in indiscriminate exploitation of natural resources disturbing the natural balance of the ecosystems. The proportion of people to land and natural resources is not evenly distributed throughout the globe. For example, India is the 2nd most populous country of the world having only 5% of the fresh water. China, the most populous country of the world has 22% of the world's people but shares less than 10% of its cultivable land area (Elvin, 2004). The unequal sharing of the population and natural resources also helps in enhancing the conflict between the people and the environment.

Environmental issues may be local, regional or global on the basis of how big or small is their sphere of influence in terms of reach and effect. Local issues include soil erosion, pollution of ground water,

Regional environmental issues include acid rain, river water pollution, big dams, desertification, etc.

Global environmental issues include global warming, ozone layer depletion, biodiversity loss, over population

8.3: ENVIRONMENTAL POLLUTION

Environmental pollution can be defined as the adverse effect of a harmful substance i.e. pollutants on the natural environment, including human, animal or plant life. A pollutant may enter into the environment naturally or by man-made activities (anthropogenic). With the increase in population, urbanization, industrialization and developmental activities the problem of environmental pollution is also growing. Pollutants come from two types of sources viz. point source (identifiable) and nonpoint source (non-identifiable).

8.3.1: AIR POLLUTION

Air pollutants	Possible sources	Health effects
Nitrogen oxides, NO_x	Fuel combustion in power plants and automobiles. Natural sources include electrical storms, bacterial decomposition of nitrogen-containing organic matter.	Nitric oxide (NO) causes cellular inflammation at very high concentrations and may be incorporated into hemoglobin in the blood to interfere with the transport of oxygen around the body. Nitrogen-di-oxide (NO_2) causes irritation of lungs and lower resistance to respiratory infection such as influenza.

Sulphur-di-oxide, SO_2	Combustion of S-containing fuel in electric power plants, vehicles. Oxidation of Hydrogen sulphide (H_2S), Oxidation of di-methyl-sulphide.	Produce irritation and increases resistance in the respiratory tract. In sensitive individuals, the lung function changes may be accompanied by perceptible symptoms such as wheezing, shortness of breath and coughing. It may also lead to increased mortality.
Carbon monoxide, CO	Incomplete combustion, biomass burning, methane oxidation, oxidation of non-methane HCs, decay of plant matter	CO enters the blood stream and binds preferentially to hemoglobin, thereby replacing oxygen.
Hydrocarbons, HC	Vegetation emission, domesticated animal and automobiles.	HCs are key ingredients of pho to chemical smog.
Particulates	Natural sources include sea-salt spray, wind-blown dust, volcanic eruption etc. Combustion sources (coal, oil, biofuel etc.) and different industrial processes are main anthropogenic sources.	Cause different respiratory diseases, cancer, eye irritation, visibility disturbance.

The thin layer of gas surrounding the earth is called the atmosphere. Air is a mixture of gases that form the surrounding atmosphere, very essential for all living organisms. Gases are released in to the atmosphere by natural activities (e.g., volcanic eruption, sea-salt spray, vegetation decay etc.) and anthropogenic activities (e.g., emissions from industries, motor vehicle etc.). Air pollution may be defined as the presence of noxious gases and particulates in the atmosphere, for a considerable period which has adverse effects on the environment. Air pollutants may be primary or secondary according to the origin of sources. Primary pollutants are emitted directly into the atmosphere and remain as such for a long period of time e.g., SO2, CO, hydrocarbons etc. Secondary pollutants are result of some chemical reactions in the atmosphere e.g., ozone, peroxy acetyl nitrate (PAN) etc. Acid rain which has devastated many European cities is an outcome of air pollution.

Table 1: Sources and effects of different air pollutants

Acid rain

Presence of strong mineral acids (mainly, sulphuric acid and nitric acid) in rain lowers the pH of atmospheric precipitation making the rain acidic in nature. The threshold pH level of rain water is 5.6, below which rain is considered as acid rain. It was first discovered in the nineteenth century by Robert Angus Smith, a pharmacist from Manchester, England. The acid rain problem is more severe in developed and industrialized countries due to high emission of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) from the industries. Emissions of SO_2 and NO_x from power plants have decreased over the last few decades in Europe and eastern North America due to pollution control measures.

Formation of acid rain

Sulphate and nitrate are formed by various reaction processes of SO_2 and NO_x with other substances. These sulphates and nitrates are the main factors responsible ions of acid rain.

(1) Sulphuric acid in the atmosphere is formed from SO_2 by different reaction processes. Sulphur dioxide is oxidized to SO_3 in presence of metal catalyst (1). Later, SO_3 reacts with water to form sulphuric acid (H_2SO_4)(2). The presence of oxidants and free radicals in the air facilitates production of SO_3 from SO_2 (3 & 4). Sulphur dioxide can also directly react with water to form sulphur trioxide (H_2SO_3) (5) which later gets oxidized to form sulphuric acid. Formation of sulphuric acid also depends upon conditions of light, atmospheric humidity and pH.

$SO_2+O_2 \rightarrow 2SO_3$ (1)
$SO_2+O_3 \rightarrow SO_3+O_2$ (2)
$SO_2+ROO \rightarrow SO_3+RO$ (3)
$SO_3+H_2O \rightarrow H_2SO_4$ (4)
$SO_2+H_2O \rightarrow H_2SO_3$ (5)

(2) Nitric acid can be formed by reaction of NO_2 with water and catalytic oxidation of NO_2 (1). NO_2 oxidation by O_3 yields NO_3 (2) which can react further with NO_2 to form nitrogen pentoxide (N_2O_5)

(3) (3). N_2O_5 is converted to nitric acid (HNO_3) after reaction with water (4). Reactions of NO_2 with NO produce nitrous acid (HNO_2) (5).

$NO_2+O_2+2H_2O \rightarrow 4\ HNO_3$ (1)
$NO_2+ O_3 \rightarrow NO_3+O_2$ (2)
$NO_3+ NO_2 \rightarrow N_2O_5$ (3)
$N_2O_5+H_2O \rightarrow 2\ HNO_3$ (4)
$NO_2+NO+H_2O \rightarrow 2HNO_2$ (5)

Effects of acid rain

The low pH of acid rain has serious environmental impacts on the ecosystems, human health and materials. Effects of acid rain are summarized below-

i. Acidification of water body causes death of aquatic animals. At pH below 4.5, most aquatic life is affected. Toxic metals can migrate to the water body.

ii. Development of acidity in soil can influence the soil characteristics. Essential microorganisms of soil are adversely affected. Acidic soil becomes less productive. Acidic soil can also accelerate the absorption of some metals (e.g., cadmium) by crops, which may be dangerous to human body after consumption of such crops.

iii. Corrosion of building materials and monuments is another serious impact of rain acidity. Probable damage of the historic Taj Mahal of Agra, India is caused by the SO_2 generation from Mathura oil refinery and local sources.

iv. Human health is also affected by acidification of air, water and soil. The small sulphate droplets present in the atmosphere can easily penetrate deep in to the respiratory system causing serious lung diseases. Acidic water consumption is dangerous for human health. Metals are mobilized in acidic soil and can get accumulated in crop plants.

1. Bhopal disaster: The Bhopal disaster took place at Bhopal, Madhya Pradesh, India on the mid-night of 3rd December, 1984 due to the leakage of methyl isocyanate (MIC). The source was the Union Carbide Factory which manufactured Carbonate pesticides using MIC. About 28,000 gas victims have died so far. More than 1,20,000 gas victims are still suffering from diminished vision, respiratory problems, hypertension and anxiety, immune and neurological disorders, cardiac failure, female reproductive difficulties and birth defects.

2. Chernobyl disaster: This disaster is recognized as the worst nuclear accident which occurred at Chernobyl, Ukraine on 28th April, 1986. Radioactive substances spewed out in to atmosphere due to the explosions of nuclear reactor causing deaths of several thousands of people and also premature cancer deaths. About 2000 people died and soil, water and vegetation over 60 sq. km. area around Chernobyl were severely damaged and will remain radioactive for several decades.

3. Photochemical smog: It was first observed in Los Angels through plant damage. It is a mixture of air pollutants [(Nitrogen oxides (NO_X), Ozone, Volatile organic compounds (VOCs) and Peroxyacyl Nitrates (PAN)]. Photochemical smog is an oxidising smog having a high concentration of oxidents an is characterised by brown, hazy fumes which causes irritation of eyes and lungs, plant damge and rubber cracking.

8.3.2: WATER POLLUTION

Water provides a base for all developments. Only 0.76% of total water is available as fresh ground water. With the increase of population demand for water is increasing tremendously resulting in scarcity of water. Apart from water scarcity, the society is also facing the problem of water pollution. Water pollution is a state where it deviates from its pure form and becomes unsuitable for drinking. Polluted water loses its normal function and properties.

Main anthropogenic sources include effluents from domestic and industrial activities. Increasing use of chemicals, soil erosion, radioactive material, heavy metal, agricultural effluents, oil spills etc. adds to this water pollution to a great extent. The untreated waste water discharged from industries contains toxic substances and enter stream, rivers and other water bodies. This results in the contamination of surface and sub-soil water table. Pollutants even can infiltrates into the ground water reservoirs. Polluted water is responsible for several water-borne diseases (cholera, dysentery, jaundice, typhoid etc.). Epidemics of typhoid and cholera killed thousands of people prior to the 20th century. Use of polluted water for irrigation purpose will adversely affect the crop production.

Table 2: Sources and effects of water pollutants

Water Pollutants	Possible Sources	Possible Effects
Biological pollutants Bacteria, fungi, protozoa	Human excreta, plant and animal wastes, industrial wastes	Dissolved oxygen (DO) of water deplete, foul odors
Inorganic chemicals and minerals	Industrial runoff, acid deposition, mining operation, agricultural run-off	Toxic to humans and other animals. Cause genetic and birth defects. Eutrophication is enhanced.
Organic chemicals	Industrial wastes, agriculture, oil spills	Water becomes toxic. Eutrophication of water body is enhanced
Physical agents (heat, particulates etc.)	Power plants, soil erosion, agricultural run-offs, construction activities	High temperature of water body affects survival of aquatic life. Turbidity of water will increase.
Radioactive substances	Nuclear wastes	Cause genetic defects

Eutrophication: A water body with high loading of phosphates and other nutrients leads to eutrophication. Eutrophic water bodies are rich in primary producers, particularly phytoplankton. The phytoplankton, having very high growth and reproduction rate soon reach a maximum population density. Continuing growth and reproduction rate of phytoplanktons are balanced by die-off. The accumulation of detritus on the water body supports an abundance of decomposers, mainly bacteria. Excessive oxygen is used by the bacteria in respiration process, resulting in the depletion of dissolved oxygen level (i.e. hypoxic condition). The hypoxic condition of water becomes unsuitable for high oxygen demanding flora and fauna.

Minamata case

In Minamata Bay of Japan, more than 100 people lost their lives and many thousands became paralyzed from eating fish containing mercury. This incident took place between 1953 and 1960. In a particular village facing the Bay, 15% of the population were either killed or paralyzed. Genetic disorders in new born babies were found whose mothers had consumed the contaminated fish. The source of mercury was the effluent discharged in to the Bay from a vinyl chloride plant of Minamata Chemical Company. Minamata incident was the first known case of bioaccumulation (in fish) of a toxic substance.

8.3.3: LAND POLLUTION

A polluted land area loses its normal properties and function. It becomes unsuitable for crop production. Land pollution can be defined as the "changes in physical, chemical and biological properties of land through misuse of land and resulting in degradation of quality and productivity of land". The pollutants remain in place for longer period than air and water pollution. Possible sources include domestic and municipal wastes, industrial wastes, agricultural wastes, biological agents (bird droppings, excreta of humans etc.) and radioactive materials. Extensive use of fertilizers and water for irrigation is making soil unfertile and less productive. Mining and oil drilling operations are responsible for surface land disruption, acid drainage and oil spills making land unfeasible.

The adverse impact caused by land pollution can be summarized as-

i. Loss of fertility and productivity of land;

ii. By clogging the micro holes of soil, it destroys the micro-organisms of soil.

iii. Soil pollutants may migrate to water bodies causing water pollution.

iv. Ground water also become contaminated from the leaching of toxic materials from dumping of industrial and municipal waste.

8.4: INTELLECTUAL PROPERTY RIGHTS (IPR)

Intellectual property right is associated with new and innovative ideas, products and creations, literary and artistic work etc. The basic objective of IPR is 'to give protection' to human creations. Historically, IPR were applied for mechanical inventions and artistic creations. Its use for the protection of living things is very recent. Intellectual property rights has two main branches. One branch deals with industrial property, useful in commerce and industry and the other branch deals with copyright, which protect literary and artistic works. Patents, trademarks, geographical indications and copyrights are four basic rights related with intellectual property rights.

8.4.1: PATENTS

A patent is an exclusive right granted to an inventor for its product or process. It prevents others from making, using, selling, distributing and importing a new product or a process. This right is given by the government patent office or intellectual property office for a limited period of time. In India, it is usually granted for 20 years time period from the date of patent application. To have a patent on a product or a process, three basic conditions should be met. These are: novelty, inventive step or non-obviousness and industrial applicability. The inventor has to give a detail description of the invention in the patent application. Later, the patent application of an invention is published through an official notification which makes it accessible to the public.

8.4.2: TRADEMARKS

Trademark is a distinctive sign capable of distinguishing and identifying the goods or services of one enterprise from another enterprise producing similar goods or services, provided that it is visually perceptible. Trademarks are getting importance day by day with the development of international trade. A trademark may be a name, word, phrase, logo, symbol, design, image, or a combination of these elements.

8.4.3: GEOGRAPHICAL INDICATIONS

This right is related with the geographical origin of agricultural, natural or manufactured goods and services. It is defined as indications identifying goods as originating in the territory of a country, region, or locality, with a quality, reputation or characteristic attributable to its geographical origin. A registered GI cannot be assigned to others. GI enhance the conservation status of bio-resources including plants, animals, microorganism, their genetic material and by-products. The main economic benefit of geographical indications would be to act as a quality mark which will play a part in enhancing export markets and revenues.

8.4.4: COPYRIGHTS

Copyright of a literary work is different from others as the formality of registration is not needed. The literary and artistic works are protected by copyright law. Copyright law provides the owner the exclusive right to print, distribute and copy the work. Like patent, copyright has a definite time period, which differs from work to work.

8.4.5: TRADITIONAL KNOWLEDGE AND IPR

Traditional knowledge is used in a broader sense. It is the knowledge of local or indigenous community, which has been passed orally from one generation to another in many cases. TK includes a variety of knowledge, scientific, agricultural, technical, ecological, medicinal, folklore, cultural properties etc. Documentation of TK is very limited. TK is a collective knowledge. IPR, especially, Geographical indications help a lot to protect the TK of the indigenous people.TK is the result of past experiences and observations of the people. Legal protection by IPR helps in the preservation of TK and its protection from erosion or negativity effect on the indigenous community that have developed and applied it. Protection of TK will benefit the people and make the knowledge available for the benefit of the society.

8.5: BIO-PIRACY

Bio-piracy is the theft of biological materials by the process of patent. There are many instances of bio-piracy of traditional knowledge of developing country by western developed country.

Turmeric (***Curcuma longa)***

Turmeric is used in medicine, cosmetics and dye. As a medicine, it has been used by our indigenous people to heal wounds and rashes for centuries. In 1995, two Indians at the University of Mississippi Medical Centre were granted a US patent on the use of turmeric in wound healing. Later, the Council of Scientific and Industrial Research (CSIR), India, New Delhi filed a reexamination case on this arguing that turmeric has been used for centuries for healing wounds and rashes by Indians. Their claim was also supported by documentary evidence of traditional knowledge. In 1997, the US patent office revoked this patent, after ascertaining that there is no novelty.

Neem (*Azadirachta indica*):

Neem has tremendous medicinal property. It can be used against many diseases of food crops and human beings. People have been using neem since ancient times. Neem is mentioned in herbal medicine books(Caraka Samhita). India is the country of origin of this medicinal plant. In 1994, a patent was granted to the US Department of Agriculture and US Corporation W.R. Grace Company for a fungicidal medicine. In 1995, NGOs and environmental organizations filed a petition against the patent, saying that the fungicidal properties of neem is being used by people in Indian agriculture to protect crops. The European Patent Office agreed to this claim in 2000.

8.6: BIODIVERSITY LOSS

Biodiversity is the variety and variability of living things. It may be the biodiversity of a small pond or a big forest. All our basic and day to day needs come from biodiversity. Biodiversity is not evenly distributed throughout the world. Biodiversity can be categorized into-(a) genetic diversity, a measure of variety of the same genes within individual species, (b) species diversity, the number of different kinds of organisms within individual communities or ecosystems and (c) ecological diversity, the richness and complexity of a biological community, including the number of niches, trophic levels, and ecological processes.

The definition of biodiversity as given in the Convention on Biological Diversity is, '*Biological diversity' means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.*

8.6.1: BENEFITS OF BIODIVERSITY

Biodiversity benefits us in many ways. It provides us direct use values and indirect use values. Direct use values are concerned with the consumption or production of marketable commodities. These include food, medicine, industrial raw materials and recreational harvesting. Indirect use values are not concerned with the consumption or production of marketable commodities and are more difficult to quantify.

a. Food: All our food comes from wild and domestic plant species. Of the 3000000 or more plant species, 12,5000 are considered to be edible to humans (Rapoport and Drausal, 2001). Animals are also used as food by humans. It is difficult to enumerate the exact number of animal species that are exploited for food.

b. Medicine: Most of the medicines are manufactured from plants for medical treatment. An estimate says that 6% of world's population relies on plant medicine for primary health care (Harvey, 2000). Animals are also used in manufacturing of medicines.

c. Industrial raw materials: A wide range of industrial raw materials (building materials, fibres, dyes, resins, gums, adhesives, rubber, oils, agricultural chemicals, perfumes etc.) are derived from the biological resources.

d. Ecological benefits: Many important ecological services (soil formation, air and water purification, nutrient cycling, solar energy absorption and food production) depend on biodiversity. People of a region having high biodiversity will enjoy this benefit.

e. Aesthetic and cultural benefits: Many people like to enjoy hunting, fishing, camping, watching, and other nature based activities. These activities provide contact with nature. Many indigenous people protect the nature due to their religious beliefs. The U.S. Fish and Wildlife Service estimates that Americans spend 104 billion dollar every year for wildlife recreation.

8.6.2: CAUSES OF BIODIVERSITY LOSS

The rate of biodiversity loss is increasing with time. The reasons for declining of biodiversity are: direct exploitation, habitat loss, fragmentation of habitat, introduced species and extinction cascades.

a. Direct exploitation: Humans can bring a species to an extinction state by exploiting their populations. With the increasing population the exploitation of a species is also increasing. The human exploitation of some species is relatively high.

b. Habitat loss: Habitat loss is especially dangerous for the survival of terrestrial ones. Grasslands are being cleared of for agriculture. Over and illegal extraction of forest products, clearing of forests for developmental activities like mining operation, industrial development, road construction, development of cities are prime causes of habitat loss. At present, almost half of the forest cover exists and only a one fifth of the original forest retains its characteristics.

c. Fragmentation of habitat: Habitat fragmentation, formation of original habitat into small isolated patches is another region for biodiversity loss. Particularly animals are affected by habitat fragmentation because many species (bears, large cats etc.) require large territories to survive; other species (forest interior birds) can only reproduce successfully in deep forest. It makes it easy for the movement of predators and invasive species to move into a new region through the fragmented edges. Availability of food is also affected due to decline of resources.

d. Introduced species: Human activities are introducing non-domesticated species to an area intentionally (for cultivation) or accidentally (transport of soil or ballast, connection of waterways etc.) from the early age of history. Negative effects of an introduced species are far larger than its positive effects. Introduced species can alter nutrient regimes of soil, soil chemistry, hydrology, or energy budgets, change vegetation or habitat, disruption of food chain and ultimately affect the abundance and distribution of native species, leading to extinction.

e. Extinction cascades: The extinction of one species may lead to the extinction of other species, particularly when the species depends on the first one for its food, shelter or pollination.

f. Climate change: Climate change has a tremendous effect on native flora and fauna of a region. Climate change is already having an impact on biodiversity, and is projected to become a progressively more significant threat in the coming decades. For example, Loss of Arctic sea ice threatens biodiversity across an entire biome and beyond. New analyses suggest that 15–37% of a sample of 1,103 land plants and animals would eventually become extinct as a result of climate changes expected by 2050.

8.6.3: MEASURES TAKEN TO PREVENT BIODIVERSITY LOSS

a. Protection, management, connection and restoration of degraded habitat play a major role in prevention of biodiversity loss.

b. Sustainable developmental activities should be our priority to have less adverse impact on the environment.

c. The rare and vulnerable species should be brought into protective custody. Botanical gardens and zoos play important role in this regard. Necessary guidelines should be made for establishment and management of protected areas.

d. Preventing and controlling alien species introduction also serve as a tool for conservation of biodiversity.

e. One should try to respect, preserve and maintain the knowledge, innovations and practices of traditional people relevant for the conservation and sustainable use of biological resources and their wider application.

8.7: OZONE DEPLETION

Ozone is a tri atomic gas found in the atmosphere, mainly concentrated in the stratosphere at about 20 km above the earth's surface. The ozone layer present in the stratosphere serves the important function of blocking harmful UV radiation of the sun from reaching the earth's surface. In the troposphere, it acts as an air pollutant and green house gas. In a clean tropospheric environment, ozone concentration varies between 10-40ppb. The thinning of this layer (called 'ozone hole') in the stratosphere has generated a serious global concerns. The consequence of the thinning of ozone layer is that more UV-radiation will reach the earth's surface, causing damage to protein and DNA molecules at the surface of all living beings.

8.7.1: FORMATION AND DEPLETION OF STRATOSPHERIC OZONE

In the troposphere, ozone is formed due to reactions involving NOx and VOCs in presence of sunlight. But, the formation of ozone takes place in a different process in the stratosphere. It is formed when UV-radiation acts on molecular oxygen (O2) molecules which are known as Chapman Mechanism of ozone formation. In 1930, Chapman proposed that Ozone is formed by photolysis of O_2. The high energy UV-radiation acts on O_2 resulting in the formation of two oxygen atoms (O). These O react rapidly with O_2 to form ozone.

$O_2 + UV \rightarrow O + O$

$O + O_2 \rightarrow O_3$

Again, this produced O_3 molecules go on photolysis reaction, producing one O_2 and one O.

$O_3 + UV \rightarrow O_2 + O$

Thus, the ozone concentration in the stratosphere is dynamic. The equilibrium in ozone concentration is maintained due to its continuous formation and breakdown mechanisms. Seasonal changes of solar radiation alter the concentration of ozone. The ozone concentration in Northern Hemisphere is the highest in summer and lowest in winter. The presence of other chemicals in the stratosphere also upsets the normal ozone equilibrium. The manufacture and use of halogenated hydrocarbons, Chloroflurocarbons (CFCs) are causing serious threat to the stratospheric ozone. CFCs are used in refrigerators, air conditioners and at heat pumps as the heat transfer fluid, in foam insulation, in electronic industry for cleaning computer parts and in aerosols. The released CFCs mix with normal atmospheric gases and have drifted up in to stratosphere. In the stratosphere, CFCs react with UV-radiation, which break down, leasing free chlorine atoms.

$CFCl_3 + UV \rightarrow CFCl_2 + Cl$

The free chlorine atoms then react with ozone molecule to form chlorine monoxide (ClO) and molecular oxygen. At last, two ClO molecules may react to form further chlorine atom and oxygen molecule.

$Cl+O_3 \rightarrow ClO+O_2$

$ClO+ ClO \rightarrow 2Cl+O_2$

8.7.2: CONSEQUENCES OF OZONE LAYER DEPLETION

The stratospheric ozone absorbs about 99% of UV radiation and prevents UV radiation from reaching earth's surface. This is the reason why ozone is commonly referred as ozone shield. But, even the small amount of UV radiation may result in potential damage to the living organisms.

i. Skin cancer is the most obvious damage to human health. Loss of 1% of total ozone leads
to a 3 to 5% increase in skin cancer. In addition to skin cancer, eye diseases like cataracts and temporary disorders such as 'snow blindness'.

The ozone layer is thinnest in Queensland, an Australian region where on the basis of current data, it is estimated that two out of three Australians are expected to develop skin cancer by the age of 70. According to the National Cancer Institute, over 1 million new cases of skin cancer are reported each year in the United States.

ii. Exposure to UV radiation results in stunted plant growth and low crop production. UV sensitive plants are more susceptible to pests and disease.

iii. The photochemical reaction changes the properties of building material.

8.7.3: MONTREAL PROTOCOL

Montreal Protocol came out in 1987 when United Nations reached an agreement in Montreal, Canada, to scale CFC production back 50% by 2000. In 1990, there was an amendment which required the participating nations of the developed countries to phase out major ozone depleting substances by 2000 and by 2010 in developing countries. In that meeting, multilateral fund for developing countries was established with the aim to enable developing countries to implement their commitments under the Montreal Protocol. The developed countries contributed to the fund. The agreed incremental costs to be incurred by developing countries for the phase out of ozone depleting substances are paid by the fund. An executive committee of 14 countries, 7 from developed countries and 7 from developing countries administers it. After knowing the fact that ozone depletion was accelerating more than before, again in 1992, at Copenhagen, parties agreed to complete phase out of CFCs by January 1, 1996.

8.8: CLIMATE CHANGE

Climate can be defined as the average temperature and precipitation expected throughout a typical year in a given region. The type and health of an ecosystem of a region depends on climate and there is a direct relationship between the people of a region with the existing ecosystem. Climate is changing from the early age of world's history, sometimes very rapidly or gradually. The change in the climate system is taking place due to natural and anthropogenic causes.

Climate change affects variables such as the intensity and frequency of flooding, wildfire, severe heat days, and coastal erosion. Other living organisms are not as compatible as human to adjust to a changing climate. A major change in the climate represents a serious threat to the survival of other living organisms and structure and function of the existing ecosystems. As a consequence of such changes human population will be in trouble.

There are a variety of potential causes for global climate change, including both natural and human induced mechanisms. Natural causes responsible for climate change include variations in the Earth's orbital characteristics, atmospheric carbon dioxide variations, volcanic eruptions and variatios in solar output. Anthropogenic causes of climate change mainly include green house gas emitter such as agriculture, deforestation, automobiles, industries such as power plants, chemical producing industries, change in land use patterns, modification in the land cover such as the construction of the concrete buildings, uses of reflective surfaces and even introduction of various harmful pesticides and other chemicals etc.

8.8.1: IPCC REPORT ON CLIMATE CHANGE

The Intergovernmental Panel on Climate Change (IPCC) was formed by the United Nations Environment Programme (UNEP) and World Meteorological Organization in 1988. This panel brings scientists from different region and a wide variety of fields to have a current state of knowledge about climate change.

In its 3rd Assessment report (2001), IPCC said, "recent changes in the world's climate have had discernible impacts on physical and biological systems". The report also declared that "we have altered the chemical composition of the atmosphere through the buildup of greenhouse gases-primarily carbon dioxide, methane, and nitrous oxide ". The increase in greenhouse gas concentration accelerates the natural greenhouse effect, raising the average global temperature of the atmosphere. This results in global warming.

Coral reef: Coral reefs, colonies of tiny living animals found in marine waters that contain few nutrients are termed as "rainforests of the sea". Warm, shallow, clear, sunny and agitated waters are best for their luxurious growth. They occupy less than 0.1% of the world's ocean surface, but harbor 25% of all marine species. Thes diverse and rich ecosystems are in the risk of extinction due to climate change. Charlie Veron, an Australian marine biologist who is widely regarded as the world's foremost expert on coral reefs comments, "There is no hope of reefs surviving to even mid-century in any form that we now recognize. If, and when, they go, they will take with them about one-third of the world's marine biodiversity. Then there is a domino effect, as reefs fail so will other ecosystems. This is the path of a mass extinction event, when most life especially tropical marine life, goes extinct ."

The information given by the 4th Assessment Report (2007) of IPCC are-

- Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture.
- The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005. Methane has increased from a pre-industrial value of about 715 ppb to 1732 ppb in the early 1990s, and is 1774 ppb in 2005. The global atmospheric nitrous oxide concentration increased from a pre-industrial value of about 270 ppb to 319 ppb in 2005.
- The combined radiative forcing due to increases in carbon dioxide, methane, and nitrous oxide is +2.30 [+2.07 to +2.53] W m^{-2}. Anthropogenic contributions to aerosols (primarily sulphate, organic carbon, black carbon, nitrate and dust) together produce a cooling effect, with a total direct radiative forcing of -0.5 [-0.9 to -0.1] W m^{-2} and an indirect cloud albedo forcing of -0.7 [-1.8 to -0.3] W m^{-2}.
- Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes seawater to expand, contributing to sea level rise.
- Mountain glaciers and snow cover have declined on an average in both hemispheres. Widespread decreases in glaciers and ice caps have contributed to sea level rise. Global average sea level rose at an average rate of 1.8 [1.3 to 2.3] mm per year over 1961 to 2003. The rate was faster over 1993 to 2003, about 3.1 [2.4 to 3.8] mm per year.
- At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of

extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones.

- For the next two decades a warming of about 0.2°C per decade is projected for a range of Special Report on Emission Scenarios (SRES). Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.

- Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.

Greenhouse effect: Some atmospheric gases trap some of the outgoing radiation energy, thus retaining heat somewhat like the glass panels of a greenhouse. These gases are known as the greenhouse gases. Greenhouse effect is the process by which the radiation coming back from the earth's surface to the space is absorbed by atmospheric greenhouse gases resulting in the rise in atmospheric temperature. Six main greenhouse gases are carbon-di-oxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and three fluorinated industrial gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Water vapor and ozone are also considered as greenhouse gases.

Greenhouse gases are responsible for the sensitive atmospheric temperature. Without their presence earth will be as cool as -18˚C. These gases are increasing rapidly from the beginning of the industrial era, raising the atmospheric temperature which ultimately results in "global warming".

8.8.2: KYOTO PROTOCOL: a tool to mitigate climate change: In 1997, an agreement was made at Kyoto, Japan to cut greenhouse gas emissions. Annex I countries agreed to cut down the greenhouse gas emission (carbon dioxide, methane and nitrous oxide) at least 5% below 1990 levels by 2012. Three other greenhouse gases (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) would also be reduced. This treaty sets different limits for individual nations, depending on their output before 1990. Developing countries like China, India are exempted from the treaty to allow their development that will increase the standard of living.

An alternative approach was proposed called "Clean Development Mechanism (CDM)". The main concept of CDM is that developed countries can help the developing countries to achieve sustainable development and emission reduction of greenhouse gases. In this way, developed countries can take certified benefit for emission reductions of their own targets.

8.9. PROBABLE QUESTIONS

A. Choose the correct answer from the following:

1. Environmental pollution has-

(a) positive impact on the Environment
(b) negative impact on the Environment
(c) no impact on the Environment
(d) none of the above
2. Climate change is-
(a) a local issue
(b) a global issue
(c) a regional issue
3. Which one of the following is not related-
a) SO_2
b) NO_x
c) CO
d) Particulates
5. Biodiversity is-
(a) the variety and variability of living things.
(b) the variability in living and non-living things.
(c) the variety of living things.
(d) the diversity of manmade structures.

B. Assert whether the following statements are true or false-
I. Industries are contributing to environmental pollution.
II. Acid rain is a product of air pollution.
III. The stratospheric ozone layer protects the Earth from harmful ultraviolet radiation. Sustainable development will increase the environmental issues.
IV. Kyoto protocol is related to ozone depleting substances.

C. Write short notes on the following:
(a) Bhopal disaster (b) Greenhouse effect (c) Eutrophication
(d) Bio-piracy (e) Montreal protocol
D. Answer in brief
a. Define an air pollutant. Is carbon dioxide a pollutant? Explain.
b. Mention possible measures to halt biodiversity loss.
c. Write about the environmental impacts of acid rain.
d. How does introduction of species cause the loss of biodiversity? Explain.
E. Answer the following:
1. What is environmental pollution? Describe briefly the causes and consequences of air, water and land pollution.
2. Describe briefly the causes and harmful impacts of ozone layer depletion.
3. Define biodiversity. Illustrate the benefits of biodiversity.
4. What do you mean by Intellectual property rights (IPR)? Write briefly about the basic rights related with IPR.

8.10. SUGGESTED READINGS

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