MGEOS -13

M.Sc., - Geography

Semester - I

ENVIRONMENTAL GEOGRAPHY

Department of Geography
School of Sciences
Tamil Nadu Open University
Chennai - 600 015

MASTER OF SCIENCE IN GEOGRAPHY

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577, Anna Salai, Saidapet, Chennai - 600 015
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Course Design:	Dr. K. Katturajan Assistant Professor, Department of Geography, School of Science, Tamil Nadu Open University, Chennai -600 015
Course Writer:	**Dr. V. Rengan** Guest Lecturer, Department of Geography, Government Arts College (Autonomous), Salem -636 007.
Course Coordinator & Editor:	Dr. K. Katturajan

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TAMIL NADU OPEN UNIVERSITY

(A State Open University Established by Government of Tamil Nadu, Recognized by UGC & DEB,
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No.577, Anna Salai, Saidapet, Chennai - 600 015. Tamil Nadu.

Professor K.Parthasarathy
Vice Chancellor

11.02.2022

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At this momentous juncture, I wish you all bright and future endeavours.

With warm regards,

(K. PARTHASARATHY)

Email:tnouvc@gmail.com
:drkpsbard@gmail.com

Ph: 044-24306633 / 24306634
Fax:91-44-24356767

URL:www.tnou.ac.in

MGEOS-13: Environmental Geography

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MGEOS-13: Environmental Geography

UNIT 1

Nature and Scope of Environmental Studies and Role of Geography

Structure

1.1 Overview

The evolution of human beings creates many changes in our environment. Ancient people mainly depended on nature for survival, the development of science and technology to help to human's sophisticated life and this creates many disturbances on the environment. The normal cycle of the ecosystem is affected, and it creates many problems among living and non-living organisms. The environment is a combination of many variables. the combination of physical and biological aspects is referred to as the environment. It is also determining the climate and weather, which are extremely important to all the biological forms. The environment is derived from the French word "Environner" which means "surround". The term 'environment' is widely used and has a broad range of definitions, meanings, and interpretations. Most people say the term 'environment' means, simply, 'nature': In other words, the natural landscape together with all its non-human features, characteristics and processes are called environment.

However, for other people, the term 'environment' includes human elements to some extent. Many people would regard the agricultural and pastoral landscapes as being part of the environment, whilst others are yet more inclusive and regard all elements of the earth's surface - including urban areas - as constituting the environment. The environment is our basic life support system and is composed of living beings, physical surroundings, and climatic conditions. The term environment includes all biotic and abiotic entities around us. It provides us with the basic elements of air, water, food, and land which are essential for life to flourish on the earth. The biologist Jacob Van Uerkal (1864-1944) introduced the term ‘environment’ in Ecology.

Learning Objectives

After reading this unit, you will learn the following

- Definitions, Nature, and Scope of Environmental Studies
- Significance of Environmental Geography
- Role of Geography in Environment

1.2 Definitions of Environmental geography

Before defining "environmental geography," it might be useful to consider the discipline of geography in general. One common misconception is that geography is simply the study of place names. In other words, geographers study the spatial distribution of things (languages, economic activity, pollution, transportation routes, soils, climates, whatever) to find out why they are distributed as they are. The geographer then tries, to figure out why these distributions matter, and in what ways this understanding can suggest the solution to problems that occur in the world. Environmental geography is the study of the Environment’. The term Environmental geography lays more emphasis on man-environment relationships. Probably K. Hewitt and F. K. Hare first used the term ‘environmental geography’ in Man and Environment. “Environmental geography is the study of systematic description of different components of the environment and interactions of man with these components.”

Savindra Singh defined Environmental Geography in 1989 as follows: “Thus broadly speaking, environmental geography may be defined as the study of spatial attributes of interrelationships between living organisms and the natural environment in general and between technologically advanced

‘economic man’ and his natural environment in particular in the temporal and spatial framework.”

Boring defined ‘A person’s environment consists of the sum of the stimulation, which he receives from his conception until his death.’ It can be concluded from the above definition, that the Environment comprises various types of forces such as physical, intellectual, economic, political, cultural, social, moral, and emotional.

Douglas and Holland defined “The term environment is used to describe, in the aggregate, all the external forces, influences and conditions, which affect the life, natural behaviour and the growth, development and maturity of living organisms”.

Boring defined ‘A person’s environment consists of the sum of stimulation which he receives from his conception until his death.’ Indicating that environment that comprises of the various types of forces such as physical, intellectual, mental, economic, political, cultural, social, moral and emotional

- C.C.Park defined “Environment refers to the total of all the conditions which surround man at a given point in space and time”
- Encyclopedia Britannica defined “The entire range of external influence acting on an organism, both the physical and biological, and other organisms, i.e. forces of nature surrounding an individual”.
- US Council on Environmental quality defined “Total environmental system including not only the biosphere but also his interactions with his natural and manmade surroundings”.
- P. Gisbert defined “Environment is anything immediately surrounding an object and exerting a direct influence on it.”
- E.J. Ross defined “Environment is an external force which influences us.”

1.3 Nature of Environmental Geography

Environmental studies cover every aspect, that affects a living organism, as it interacts with the surroundings in its quest to live. Environmental studies are integrative, but the core of the subject comprises biological sciences like zoology, botany, microbiology, and physiology. Many environmental concerns can be resolved through the application of biotechnology and molecular biology, while bioinformatics can serve as a database at the molecular level.

Environmental studies are therefore multidisciplinary and aim at unravelling how human beings and nature correlate, sustaining life and man's unquenchable thirst for development with limited and finite resources. Physics, chemistry, biology, anthropology, geology, engineering, archaeology, sociology, economics, statistics, political science, law, anthropology, management, technology, and health sciences are all its components. Among these physics, chemistry, geography, geology, and atmospheric science help us to understand the basic concepts of structural and functional organization, as well as the physical characteristics of our environment.

Data simulation and interpretation need the application of statistics and computer applications, while mathematical science is often used in environmental modelling. The technical solutions for pollution management, waste management, green building and green energy can be found with expertise from the fields of engineering and architecture. e achievement of sustainability at all levels is interwoven with and dependant on international cooperation which in turn rests on international relations. Principles of sustainable development, determine the drafts and negotiation of the international accords and security issues. International cooperation is an indispensable factor in dealing with global environmental issues like climate change, transboundary pollution, trade-in hazardous substances, ozone layer depletion, biodiversity loss, etc. Economics enables us to gain a better understanding of the social background needed to achieve growth and development.

Keeping all these in mind, management studies will enable us to formulate policies, followed by legislation for their implementation. The study and treatment of the environment are very much connected with philosophy, ethics and cultural traditions that help us achieve our goal sustainably.

The air that we breathe, the water that sustains our lives, the food that gives us energy, the towns, and the cities that we live in, in fact, everything around us constitutes the environment. It is the sum of all life support systems. Therefore, it is essentially a multidisciplinary approach that brings about an appreciation of our natural world and human impacts on its integrity. It is an applied science as it seeks practical answers, to make human civilization sustainable on the earth's finite resources.

Environment studies is a multi-disciplinary science because it comprises various branches of studies like chemistry, physics, medical science, life science, agriculture, public health, sanitary engineering etc.

It is the science of physical phenomena in the environment. It studies the sources, reactions, transport, effect, and the fate of physical and biological species in the air, water, soil and the effect of human activity upon these.

As the environment is complex and made up of many different environments like natural, constructed and cultural environments, Environmental studies is interdisciplinary including the study of biology, geology, politics, policy studies, law, religion engineering, chemistry and economics to understand humanity's effects on the natural world.

This subject educates the students to appreciate the complexity of environmental issues and citizens and experts in many fields.

By studying environmental science, students may develop a breadth of interdisciplinary and methodological knowledge in the environmental fields that enables them to facilitate the definition and solution of environmental problems.

1.4 Scope of Environmental Studies

Environmental science has a vast scope since it covers a wide range of subject matters or issues related to our complex life-supporting system. Environmental studies teach us about deforestation, forest conservation and diversified ecologies. The scope of the environmental study is diverse dealing with the areas such as the geo-ecosystem or simply ecosystem as a study unit. The scope of the subject can be described in terms of major areas of applicability as well as career opportunities related to the subject. The environmental studies discipline has multiple and multilevel scopes.

The scopes are summarized as follows:

- The study creates awareness among the people to know about the various renewable and nonrenewable resources of the region. The endowment or potential, patterns of utilization and the balance of various resources available for future use, in the state of a country are analysed in the study.
- It provides knowledge about the ecological systems and cause and effect relationships.
- It provides necessary information about biodiversity richness and the potential dangers to the species of plants, animals, and microorganisms in the environment.
- The study enables one to understand the causes and consequences due to natural and man-induced disasters (flood, earthquake, landslide,

cyclones etc.,) pollution and measures to minimize the effects.

- It enables one to evaluate the alternative responses to environmental issues before deciding on an alternative course of action.
- The study enables environmentally literate citizens (by knowing the environmental acts, rights, rules, legislations, etc.) to make appropriate judgments and decisions for the protection and improvement of the earth.
- The study exposes the problems of overpopulation, health, hygiene, etc. and the role of arts, science, and technology in eliminating/ minimizing the evils from society.
- The study tries to identify and develop the appropriate indigenous eco-friendly skills and technologies for various environmental issues.
- It teaches the citizens the need for sustainable utilization of resources as these resources are inherited from our ancestors to the younger generating without deteriorating their quality.
- The study enables theoretical knowledge into practice and the multiple uses of the environment

1.5 Significance of Environmental Geography

It is a branch of geography that describes the spatial aspects of relations between man and the earth. Environmental changes at any scale, from global to local, are of crucial importance for life on planet earth. In addition to climate change, current challenges include changes in biodiversity, soil degradation and increases in mass movements. Often, the dynamics of such environmental processes require an understanding of the spatial and temporal couplings between the atmosphere, biosphere, relief sphere, pedosphere, and hydrosphere.

Environmental study is based upon a comprehensive view of various environmental systems. It aims to make the citizens competent to do scientific work and to find out practical solutions to current environmental problems. The citizens acquire the ability to analyze the environmental parameters like the aquatic, terrestrial and atmospheric systems and their interactions with the biosphere and astrosphere.

The world population is increasing at an alarming rate especially in developing countries.

- The natural resources endowment in the earth is limited.

- The methods and techniques of exploiting natural resources are advanced.
- The resources are over-exploited and there is no foresight of leaving the resources to the future generations.
- The unplanned exploitation of natural resources leads to pollution of all types and at all levels.
- The pollution and the degraded environment seriously affect the health of all living things on earth, including man.
- The people should take a combined responsibility for the deteriorating environment and begin to take appropriate actions to space the earth.
- Education and training are needed to save biodiversity and species extinction.
- The urban area, coupled with industries, are major sources of pollution.
- The number of areas under the protected areas should be increased so that the wildlife is protected at least in these sites.
- The study enables the people to understand the complexities of the environment and the need for the people to adopt appropriate activities and pursue sustainable development, which is harmonious with the environment.
- The study motivates students to get involved in community activities and to participate in various environmental and management projects.
- It is high time to reorient educational systems and curriculum towards these needs.
- Environmental studies take a multidisciplinary approach to the study of human interactions with the natural environment. It integrates different approaches of the humanities, social sciences, biological sciences and physical sciences and applies these approaches to investigate environmental concerns.
- Environmental study is a key instrument for bringing about the changes in the knowledge, values, behaviours, and lifestyles required to achieve sustainability and stability within and among countries.

Environmental studies deal with every issue that affects an organism. It is essentially a multidisciplinary approach that brings about an appreciation of our natural world and human impacts on its integrity. It is an applied science as it seeks practical answers in making the human civilization sustainable on the earth's finite resources. Its components include

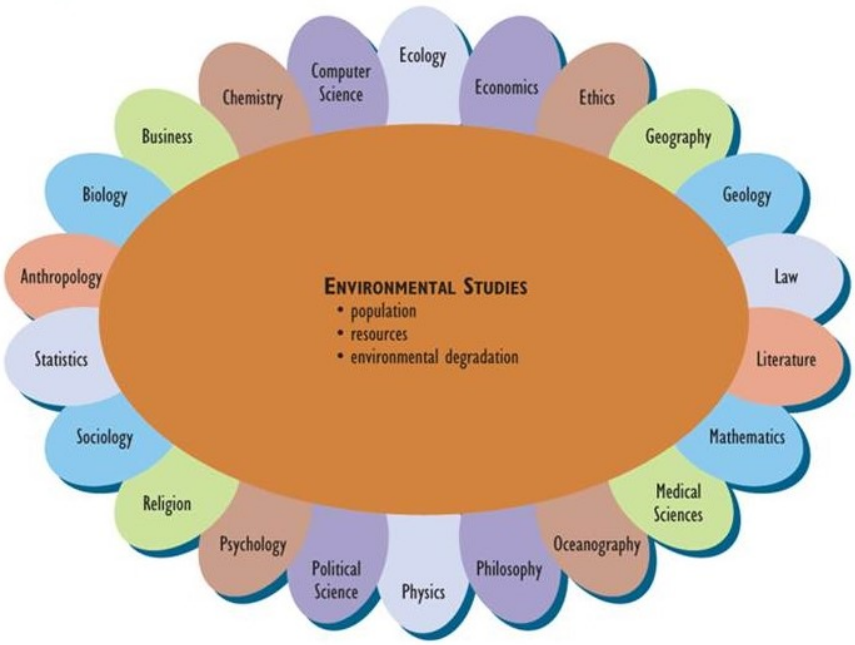

Fig.1.1. Environmental science is an interdisciplinary character. All disciplines are relevant to the identification and resolution of environmental issues. Credits: https://ecampusontario.pressbooks.pub/app/uploads/sites/801/2020/05/fig1_1.jpg.

1.6 Role of Geography in Environment

The subject of geography is a bridge between the physical and the social sciences. The study of the natural environment and its relationship with the human environment is closely associated with geography. Geography as a holistic discipline deal with the natural mechanism, investigates human and economic activities together, with the interaction between man and nature and helps individuals adopt a holistic viewpoint.

Geography seeks to understand where things are found, why they are there, and how they develop and change over time It is the science that studies the human-space interaction according to the principle of cause and effect, and it deals with space and human who uses it for economic purposes. What matters in this human-environment interaction is that benefits should become permanent and sustainable. This phenomenon is extremely important for future generations if we desire them to continue to benefit from the geographical environment. When we look at the current perception of the environment and the related application, the present state is not very encouraging. I'll give you a few examples; field grabbing race in polar regions under the pretext of researching, construction of technological cities in desert areas, destruction of tropical forests for

agriculture and settlement purposes, oil drilling practices in the open seas, increasing presence of nuclear facilities and so on. Such human activities lead to irreversible damages to the natural environment. Also due to the misapplication of human activities such as settlement and industrialization, mankind confronts such an unhealthy environment where the soil lost all contact with the sky, global warming, extreme pollution in the atmosphere and hydrographic elements. With effective environmental education, it is possible to prevent excessive and improper use which nature cannot compensate for anymore.

The ever-increasing world population creates the biggest problem that prevents the sustainable use of scarce resources. Undoubtedly protecting the natural environment does not mean disuse. In this respect, the question of how to use the natural environment, how to plan and how to ensure environmental awareness in large populations come to the fore. To answer these questions, it is necessary to know the structure and the properties of the natural environment in the first place. At this point, the place of geography comes to the fore in an effective environmental education. This study emphasizes effective environmental education and attempts to explain the functions of geography and how it should be utilized in environmental education.

Let Us Sum Up

Environmental geography is the branch of geography that describes the spatial aspects of interactions between humans and the natural world. It requires an understanding of the dynamics of climatology, hydrology, biogeography, geology and geomorphology, as well as how human societies conceptualize the environment. Environmental geographers are familiar with how natural systems function, but, they also know that humans are a dominant agent of change in nature. They realize that it is not possible to understand the environmental problems without understanding the physical processes as well as the demographic, cultural, and economic processes, that lead to increased resource consumption and waste. Environmental geographers fan out along a variety of academic paths, and these paths will cross, mingle, or converge with those of other disciplines.

Glossary

Geography: Geography is the study of places and the relationships between people and their environments. Geographers explore both the

physical properties of Earth's surface and the human societies spread across it.

Ecosystem: An ecosystem includes everything at a particular location: plants, animals, microorganisms, air, water, soil and human-built structures. Natural ecosystems are formed entirely by natural processes. Agricultural ecosystems are created by people to provide food or other materials. Urban ecosystems are dominated by human-built structures.

Environment: Environment includes the living and nonliving things that an organism interacts with or influences. Living elements that an organism interacts with are known as biotic elements: animals, plants, etc., abiotic elements are nonliving things that include air, water, sunlight etc.

Nature: "Nature" refers to the phenomena of the physical world and life in general. The term is often referring to the "natural environment" or wilderness wild animals, rocks, forest, beaches, and in general areas that have not been substantially altered by humans, or which persist despite human intervention.

Check Your Progress

1. Define Ecosystem

   Answer: An ecosystem is a geographic area where plants, animals, and other organisms, as well as weather and landscapes, work together to form a bubble of life

2. Write the importance of the environment?

   Answer: It provides food, shelter, air, and fulfils all human needs whether big or small. Moreover, the entire life support of humans depends wholly on environmental factors. In addition, it also helps in maintaining various life cycles on earth.

3. Write the significance of environmental geography?

   Answer: It is a branch of geography that describes the spatial aspects of relations between man and the earth. Environmental changes at any scale, from global to local, are of crucial importance for life on planet Earth.

4. Mention the role of geography in the environment?

   Answer: It is the science that studies the human-space interaction according to the principle of cause and effect, and it deals with space and human who uses it for economic purposes.

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Suggested Online Readings

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2. https://aissmschmct.in/wp-Structure/uploads/2020/08/BSC-HS-Sem-III-Environment-Science-I-HS-307-Chapter-1.pdf
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UNIT 2

Man, and Environment Relationship

Structure

2.1 Overview

The combination of land, water, air, fire, and sky are called Pancha Poothas in the early period. Without these five aspects, there is no surrounding environment. Changing weather and climate create a different lifestyles for the survival of living and nonliving things. The fundamental spatial unit for

the study of such interrelationships is the biosphere (agroecosystem) or part thereof. The abiotic components (physical components-land, air, water, and energy) are closely related to geography particularly physical geography (geomorphology, climatology, soil geography etc.) geology (quaternary studies, physical geology, petrology etc.) geophysics and atmospheric sciences (meteorology), all of which belong to the major field of earth sciences. Physics and chemistry (main biochemistry is also related to the abiotic/ physical components via geology and geophysics. These subfields of earth sciences are related to each other and provide vital information about the composition and characteristics of the various aspects of physical or abiotic components of the biosphere geo-ecosystem. Since physical geography studies all the elements of abiotic components based on its resources and the information derived from geology, geophysics, and atmospheric sciences, it is more closely related to environmental studies and therefore to environmental geography.

Further, geography is the only discipline that can pursue the study of the environment in totality because

a) It studies the spatial attributes of all the phenomena including the man in each space and highlights the complex man-environment relationships at different stages and phases in a time-space continuum while other sciences study the individual phenomenon and do not bother for the spatial organization.

b) Being integrating science geography synthesises all the elements and components of planet earth into one body and links social science with natural sciences.

c) It lays stress on the 'synthesis of all near-surface spheres into one interacting system'. That is to say that, geography studies the biosphere (the interface of air, land, and water) in total (all components of biosphere abiotic and biotic –their characteristics and interrelationship)

d) As regards the physical system, it is geography that excels other sciences because geographers know structure (of geomaterials), geomorphic processes, climate, vegetation, and soils while other scientists specialize in only one of these aspects.

e) Geographers besides identifying the complex relationship between man and the physical environment have the capability of locating the distribution of such relationships in space, mapping them, and exploring the cause of variations.

f) Geographers recognize that the quality-of-life layer varies from place to

place in terms of richness or poverty of life-form capable of being supported. Geographers are the only scientists who can recognize and identify the environmental regions, locate them in space and present them on maps.

Learning Objectives

After reading this unit, you will learn the following

- Geography as a Science of Relationship between Man and Environment.

2.2 Geography as a Science of Relationship between Man and Environment

The concept of geography as the study of man and the environment relationship is quite old. The Greek, Roman, Indian, Chinese, and Arab geographers attempted to establish a relationship between man and the natural environment. Kant, at the end of the 18th century, advocated the impact of the environment on the lifestyle and physical constitution and lifestyle the equatorial, hot deserts, Mediterranean, coastal, and mountainous regions. According to Kant, the inhabitants of the Torrid Zone are exceptionally lazy and timid, while the people of the Mediterranean region living in mild temperature conditions are industrious, hardworking, and progressive.

The environmental causation continued throughout the 19th century. Humboldt asserted that the mode of life of the inhabitants of the mountainous countries of the Andes mountains differs from that of the people of the Amazon basin, coastal plains and islands like Cuba and West Indies. Ritter attempted to establish the cause variations in the physical constitution of body, physique and health of people living in the different physical environmental conditions.

The idea of defining the geography in terms of man and environment relationship developed on scientific lines in the later part of the 19th century after the publication of Origin of Species (1859) by Charles Darwin. This seminal work gave a new direction to the discipline of geography. The theory of evolution held that all living species have evolved from pre-existing forms. His geological observations and theories had one thing in common: the idea that things in nature change with time.

He also believed that the face of the earth also changes with the change in the environment over the period. In this book, Origin of Species, Darwin presented his idea that species evolve from more primitive species through

the process of natural selection. In his account of natural selection occurs, known as Darwinism, he pointed out that not all individuals of a species are the same but have variations and some of these variations make their bearers better adapted to the ecological conditions.

He theorized that well-adapted individuals of a species have more chance of surviving and producing young than does the less adapted and that over time the latter are slowly weeded out. Through his theory, Darwin showed how the multitude of living things in our world could have come into being without any recourse to a divine master plan, in a plain, causal, naturalistic way. Darwin argued that a struggle for existence must take place. It followed that those who survived were better adapted to their environment than the competitors. This means that relatively superior adaptations increase while relatively inferior ones are steadily eliminated.

2.3 Darwin's concept of man and environment relationship

1. Organisms vary, and these variations are inherited (at least in part) by their offspring.
2. Organisms produce more offspring than can survive.
3. On average, offspring that vary most strongly in the direction favoured by the environment will survive and propagate.

Darwin's theory had a far-reaching impact on the growth and development of geography. It assumed that variations in animals were random. In this way, the older teleological conception (the religious belief that God has a plan and all phenomena of the earth have been created to perform certain functions for man) of nature was profoundly challenged.

Darwin's book upset many established patterns of thought, contradicted firmly held religious tenets (teleological concept) and brought into focus the concept that humans are one species among many that have evolved more primitive ones. In his subsequent book, The Descent of Man and Selection about Sex (1871), Darwin provided evidence of human evolution from one primitive species and discussed the role of sexual selection in evolution.

The concept of defining geography, in terms of relationships became quite popular in Germany. The work of Darwin influenced Friedrich Ratzel, who published Anthropogeography in two volumes in 1882 and 1891 respectively.

In the first volume, he organized the material to show the influence of the physical environment on history, culture, and the mode of life of the people,

while the second volume deals with the geographical distribution of men in the world. It was because of this book in which he discussed the man and environment relationship of the different tribes of the world that he is considered as the ‘founder of human geography.

Ratzel, by applying the organic theory to political geography, developed the concept of lebensraum (literally living space or the geographical area within which an organism develops). While developing the man and environment relationship, Ratzel, in his book Political Geography (1897), equated a nation with a living organism, and argued that a country’s search for territorial expansion was like a growing organism’s search for space. The conflict between nations was thus seen as a contest for the territory within which to expand, with the fittest surviving.

The concept was appropriated by the German School of Geopolitik in the 1920s and 1930s and used to justify the Nazi programme of territorial expansion. In the opinion of Dickinson and Gumplovicz, “Ratzel’s work contains more and more important knowledge concerning the state, than the entire theoretical political science literature of the last 100 years”.

Ratzel’s book Anthropogeography had a great influence on the geographic thought of America, France, Britain, Russia, and Sweden. Ratzel’s most important disciple was Ellen Churchill Semple. Semple, in the Overview of her book, Influences of Geographic Environment declared “man as the product of earth’s surface”. The influence of the physical environment on the history of people of the region in any part of the world can be found in her writings. The main cause of variations in the history, culture, and lifestyle of the people of plains and mountains can be traced to the physical environment.

Subsequently, the French geographers, especially Vidal de Lablache, Brunhes, Martone, etc. The concept of pays (micro-region), developed by Lablache, was also based on the concept of relationship. He also coined the concept of genres de vie (lifestyle). Lablache was convinced that genres de vie were themselves reflective of nature (physical environment), even as they transformed it. He always conceived human geography as natural, not social science.

Ultimately, geography as the science of relationships appeared in the form of environmental determinism. Environmental determinism is the doctrine according to which human activities are controlled by the physical environment. The environmentalists considered the natural environment as the ‘geographic factor’ and their geography was known as ‘pure geography’.

In the opinion of environmental determinists, human geography is the study of the influence of the physical environment on man.

Barrows, in his presidential address (1922), recommended that relationships in geography should be studied “from man’s adjustment to environment, rather than the reverse”. Hettner (1907) also supported the concept of geography as the study of relationships. Thus, both the physical factors and the human factors (cultural environment) are to be studied in their relations to each other. Geography is, therefore, exclusively human geography, or as Barrow stated, geography is ‘human ecology. Geography is a natural science in the same way as plant ecology is biological science. Sauer, in his book Agricultural Origins and Dispersals (1952), focused upon the patterns of human culture about the natural environment. He also tried to explain how the human interactions with the physical environment have resulted in various cultural patterns in the different parts of the world.

While examining the lifestyle and history of the people in the different regions of the world, it may be said that there is a close relationship between the environment and the mode of life of the people. Undoubtedly, terrain, topography, temperature, rainfall, natural vegetation, and soils have a direct bearing on the culture, economy, and society of the people, yet the role of man as the transforming agent of his physical surroundings cannot be ignored. Works of man reveal many facts for which the environmental forces alone can give no satisfactory explanation. For example, similar locations may not lead to a similar life.

The Eskimos of the Tundra region differ markedly in their economic activities and cultural practices from the Tungus, Yakuts Yukaghirs, etc. The Khasis and Nepalis, living in Meghalaya (India) in the same physical environmental conditions, have different cultural ethos. The same is the case with the Gujjars and Bakkarwals of Kashmir Valley and the Kashmiris in the state of Jammu and Kashmir. Likewise, the Hanjin (water dwellers) of Dal Lake and Jhelum River in Srinagar have different attitudes and modes of life from the inhabitants of Srinagar city. Geography, as the discipline of relationship, though was quite a prominent approach, lost its position after the Second World War. The advocates of spatial science, locational analysis, behaviouralists, radicalises and humanists criticized this approach and declared it just deterministic and unscientific.

The history of geographical ideas, clearly depicts how through ages, the man environment relationship has been perceived, deliberated upon, and established as one of the focal themes in geographical thinking. The whole idea is to get more and more logical and useful knowledge of the human

habitat as the humans spread over the earth's surface. Before we investigate the historical background and doctrines established on this theme, we need to have a clear perspective on a man-environment relationship which is discussed in the next section.

2.4 Man and Environment Relationship – A Perspective

For the understanding of this relationship, one has set the limits on how one defines the environment. The most basic definition was given by Einstein who states that *the environment is everything that isn't me*. In simpler words, everything beyond me is the environment. Thus, one should not debate on the dualism of physical and cultural environment rather take both as two halves of the same whole. Both physical (biotic, abiotic and energy) and cultural (Mentifact, socio facts, and artifartefacts) components influence man's actions in adapting to the environment to transform it for satisfying his needs. The basic premise is that this relationship is not direct or static rather it is dynamic and multifaceted.

In the ancient and Middle Ages, Greek, Roman, Indian, Chinese, and Arab geographers attempted to establish a relationship between man and the natural environment. Kant, in the latter half of the 18th century, advocated the impact of the environment on the lifestyle and physical constitution and lifestyle the equatorial, hot deserts, Mediterranean, coastal, and mountainous regions. According to Kant, the inhabitants of the Torrid Zone are exceptionally lazy and timid, while the people of the Mediterranean region living in mild temperature conditions are industrious, hardworking, and progressive.

The environmental causation continued throughout the 19th century. Humboldt asserted that the mode of life of the inhabitants of the mountainous countries of the Andes mountains differs from that of the people of the Amazon basin, coastal plains, and islands like Cuba and the West Indies. Ritter attempted to establish the cause variations in the physical constitution of body, physique, and health of people living in the different physical environmental conditions.

2.4.1 Impact of Darwinism

The idea of defining the geography in terms of man and environment relationship developed on the scientific lines in the latter part of the 19th century after the publication of *The Origin of Specie*s (1859) by Charles Darwin. This seminal work gave a new direction to the discipline of geography. The theory of evolution held that all living species have evolved

from preexisting forms. His geological observations and theories had one thing in common: the idea that things in nature change with time.

Most of the writers in the pre-Darwinian period discussed the man-environment relationship as a cause-effect relationship. They did not ponder the processes involved in this relationship. Ratzel for the first time took up this issue in the first volume of *Anthropogeographie* (1882) which was later developed by his students Semple and Demolins. In France, Blache's ideas dominated so this rigid framework of harmony and relationship was not accepted. But in America, this was carried out by Davis who tried to incorporate this idea of causality into the definition of geography itself. This notion was not accepted by many scholars as they were of opinion that no science can be confined to the study of a specific relationship. Moreover, this causal relationship provides an unsound methodological approach as the intensity of the influence of the environment becomes a major problem.

Flere was deeply influenced by Darwinism and opined that the man-environment relationship should be studied from the physiological point of view while delineating human regions. He applies Darwin's ideas of natural selection through environmental influence on human groups. Huntington too investigated this theme and applied it to the human population while studying it at the global level. Taylor investigated this idea in his studies on race, population, states, and cities. He concluded that these are directly influenced by environmental factors as their development over time is regulated by these conditions. Determinists, therefore, raised certain questions but could not possibly find suitable answers within the geographical framework. Hartshorne tries to seek answers by stating that the whole determinist-possibilist debate within the discipline was unreal and futile which led the whole debate on a philosophical level rather than at an empirical level.

In America, the concepts of Spencer and Darwin, the survival of the fittest and the struggle for life, respectively were positively used in the disciplines of political science and economics to justify laissez-faire. Darwinism, though, had a limited influence on classical equilibrium economics.

In geography, particularly, political geography, these ideas of struggle and selection were used significantly. Ratzel (1896) applied this concept to his seven laws for the growth of state which later developed as the concept of *Lebensraum.* He states that as plants and animals struggle for their existence, a nation too, clash for their struggle to capture more territory. The organic analogy derived by Ratzel along with the theme of struggle and selection provided a strong model in analytical political geography which

had scientific justification in man's political behaviour. Semple tried to omit the concept of organic analogy in her writings, but it seemed that she was still touched by it, as these themes penetrated in her writings.

Kjellen (1942) in his work on states was highly influenced by Ratzelian ideas. His *Geopolitik* is an example where he writes that states are biological manifestations not only morally but also organically as they experience lust. He was also supportive of Spencer's writings which are visible in his *Staten sam Lifsfarm* (1944). The over-dependence of political geography on the organic analogy, the ideas of struggle and *Lebensraum* brought disgrace to this branch, especially in the 1930s.

To sum up, Darwin contributed by making science more empirical and inductive; this dismisses the role of teleology also. The biggest contribution of Darwinism in geography is in establishing man's place in nature and at the same time making a study of man scientific learning.

2.4.2 The Deterministic Perspective

In the history of geographical thinking, human–nature dialogue has been studied and analyzed from several different perspectives and views. The first amongst these approaches to deliberate on the human-nature relationship was determinism. In the words of Platt (1948) determinism, refers to the idea that everything in human life is caused certainly by preceding events or conditions. The primary initial source of determinists for an explanation was the physical environment, and the theoretical order was centred on the belief that human activity was solely regulated and controlled by their environment. Determinism, as a paradigm is one of the most significant beliefs, which continues in one form or another. In the context of this concept, it is believed that due to the difference in the natural environment, the variations in human behaviour in different parts of the world can be described. The spirit of deterministic ideology is that the level of development of history, culture, lifestyle and social group or nation is solely ruled by the physical components of the environment at any scale.

Determinists consider humans as passive agents on whom the physical factors are working continuously determining their approach and decision-making process. In short, they believe that most of the activities of man can be elucidated as a response to the environment. In the context of the effect of natural conditions, the first attempt was made by Greek and Roman scholars to explain the physical characteristics and character traits of different people and their cultures. At that time, this effort was not contained only among geographers rather included scholars from different fields like the doctor **Hippocrates**, philosopher **Aristotle**, and Historians

Thucydides, Polybius, and **Herodotus**. In the Greco-Roman era, regional studies were closely tied with the study of history. Thucydides and Polybius saw Athens's natural conditions and geographical position as factors for its greatness. For example, **Aristotle** explained the difference between Northern Europe and Asian people in the context of climate causes, while explaining the greatness of Rome, while mentioning similar incidents of **Strabo**. Strabo argued that the cold weather in Europe was the reason for their bravery.

Aristotle thought that people living in hot weather in Asia were wise but there was a lack of soul and therefore time to time subjected to slavery. As humans often consider their home as the best place, it is not surprising that Aristotle believed that the best combination of all possible worlds was in the centre of space, Greece (Glacon, 1967). Aristotle strongly advocated the progress of some countries is the result of their favourable environmental conditions.

In the Middle Ages, **Montesquieu** explained that in cold weather people are less physically strong, more courageous, clear, less susceptible, and less cunning than those in hot weather. He quotes that people in hot weather are terrible, weak in body, dull and inactive. The deterministic approach dominated the writings of Arab scholars. They divided the world into seven terrestrial zones based on climate and highlighted the physical and cultural characteristics of the castes and castes of these regions. **Al-Baruni, Al-Masudi, Ibn-Hawkal**, **Al-Idrisi** and **Ibn Khaldun** attempted to correlate the environment with human activities and living conditions within the conceptual domain of determinism.

Deterministic reasoning continued in the 19th century when geography itself was related to other sciences. **Carl Ritter**, a German geographer adopted an anti-human approach and laid the philosophical base of determinism in geography. Ritter tried to make a difference in the physical constitution of the body, body, and health of men living in different physical environments. Many of his students considered geography as "*a study of the relationship between people's density and the nature of their land*". Many geographers of their school had declared that their main task was to identify the influence of physical cultural geographical conditions and the political fortunes of residents of any area in both East and present. Alexander von Humboldt, one of the founders of 'Modern Geography' and a contemporary of Ritter, also said that the life of the residents of a hill country is different from those in the plains.

Friedrich Ratzel, the founder of 'new' determinism, supplemented the 'classical' geographical determinism with the elements of 'Social Darwinism' and developed the state's theory as an organism. He believed in the existence of qualification and saw the 'man' as the end product of the development. Development was a natural selection of type according to the ability to adjust itself to the physical environment. He along with his disciple Ellen Churchill Semple became the most vocal expression of the deterministic approach in geography. Semple in her book Influences of Geographical Environment (1911) writes: Man is a product of the surface of the Earth. This book had widespread, long-lasting use in geographic education. She dominated the environmentalist period of the discipline in the early twentieth century and "trained a large proportion of those who became leaders of the profession during the period between the two World Wars". Her methodological statement cannot be questioned as at one time she points out that the influence of climate on man both as a direct and indirect effect cannot be questioned. She further elaborates that man was a passive subject who bears direct environmental influence at the early stages of development.

2.4.3 The Possibilistic Perspective

The doctrine of possibilism tries to explain the relationship of a human being with the environment differently. It puts humans at a higher level and regards them as active agents. It is a principle that claims that the environment provides opportunities and man being an economic man chooses from those possibilities. Febvre (1932) in ‘A Geographical Overview to History’ stated ‘there are no necessities, but everywhere possibilities; and man, as the master of these possibilities, is the judge of their users’.

The roots of possibilism can be traced back to the works of Plato, who is considered the master of deductive reasoning. Though his idea went into gloom for hundreds of years; the contrasting doctrine of determinism continued to grow and flourished. It got support in the writings of French scholars of the eighteenth century. Montesquieu is credited with developing a doctrine analogous to the modern paradigm of possibilism. He opined that man possesses free will and can choose from a series of opportunities. Similar thoughts were also put forward by another eighteenth-century French philosopher, Comte de Buffon. He believed that man was ordered to conquer the earth and even transform it. Their views laid the base for the crypto-possibilistic hypothesis (Adhikari, 2010). It was only in the latter half of the nineteenth century that under the leadership of Vidal De la Blache

(1845 – 1918), a possibilistic view of man-environment developed. The focus of this philosophy was “Nature has set boundaries and has provided possibilities for human settlement, but the way a person responds to these conditions or adjusts it depends on the traditional way of life." Vidal rejected the concept of material determinism and advocated favourability. He even rejected Durkheim’s opinion of human geography as social morphology rather insisted that man was a partner and not a slave of the environment (Dikshit, 2009). He was critical of Darwinian-Ratzelian heritage which proposed environmental determinism and put forth the concept of possibilism. He sought a scheme for understanding the interaction of nature and culture that eschewed both environmental determinism and radical possibilism to seek answers or solutions for the dichotomy between the human and the environment.

In the twentieth century, possibilism got a stronghold after the publication of Blache’s article in 1913 where he categorically states that geography as a discipline seeks to measure and role of man in modifying the earth surface. This was further strengthened when his book was published in 1921 (English translation in 1926), though posthumously. He observes that nature gives man materials that have their inherent needs as well as limitations thus leading them to limited uses.

Possibilism was further flourished by acclaimed historian Lucien Febvre (1878-1956). He puts forward - “Whatever the men do in their environment, they cannot completely get rid of themselves completely." Febvre emphasized the human initiative and motivation against the environment, destroying the environmental deterministic reasoning and as part of the environment of any group, as well as other humans, because they belong to the next group's cultural surroundings, or the constraints of the environment are influenced by such thinking. He stated that in the view of possibilists, a homogeneous region does not necessarily result in a homogeneous society. This is because people residing in any area have the choice of possibilities from time to time and in the quantity they want. Bruhnes followed Blache’s ideas and took them to the next step, he not only transmitted Blache’s philosophy in France but also disseminated it to different parts of the world. In 1910, his monumental work La Geographie de L'Histoire was published. Barrows, in his presidential address (1922), recommended that relationships in geography should be studied “from man’s adjustment to the environment, rather than the reverse”. Hettner (1907) also supported the concept of geography as the study of relationships. Thus, both the physical factors and the human factors (cultural environment) are to be studied in their relations to each other.

2.4.4 Probabilism

The concept of probability was put forward by the O H K. Spate (1957) is the idea that the physical environment does not specifically determine human activities, yet it gives some reaction to others. This word was proposed as a mid-route between Ratzel's complete environmental determinism and a revolutionary prospect of Febvre, Lablache, and Sauer. While the environmental determinants, influenced by the cause and effect of Darwin, said that human activities are controlled by the physical environment, according to the possibilities, the physical environment provides the opportunity for many possible human reactions and enough conscience to choose people is among them.

According to Spate, "human action was not said in the case of all or some kind of compulsion, but rather the balance of the possibilities". For example, there is a possibility that the use of land in the Sutlej-Ganga field decreases intensity from market centres; Population density decreases away from metropolitan centres in all directions; With the settlement of the village, the crop yields less than a few walking distances. However, there can be exceptions for each of these generalizations, and in many cases, there is a limit to the boundaries that they keep right. Exception and boundary demand details After this concept, probability theory is considered as an essential component of geographic analysis because "a general mode of discussion" was provided for " the scientific study of the scenario". This view is completely consistent with the original Vitalian concept. Geologists started using the probability theory to determine the human and environmental relations and carried out scientific studies of the landscape.

The probability theory was criticized on many grounds. For example, complete knowledge about the environment cannot be available; The available data about the resources and their use cannot be reliable; The perception about resources (environment) differs from humans to the community, community to region, and country to country, prospective model's application, due to these constraints, can be difficult and thus the results obtained cannot be authentic and close to the ground reality.

2.4.5 Cultural or Social Determinism

Cultural or social determinism emphasizes the human element: "Our thoughts determine our actions, and our actions determine the nature of the world's last" (James, 1932: 318). Since there is a difference in human interest, desires, prejudices, and group values, therefore there is a difference in the level of the cultural landscape and socio-economic development. The amendment of an environment depends on our

perception, thoughts, and decision-making processes. This philosophy made by American scholars can be explained in principle, according to which "the significance of man's physical and biological features of his residence is an act of man's views, objectives, and technical skills". For example, a country that is financed by a hunter's perspective can be poor for an agricultural person; The importance of coal is not the same as those who cannot use it. All these truths are self-evident. It is also true that as technology develops, the importance of the environment is not reduced, but the change becomes more complex.

The philosophy of cultural determinism is quite broad among American geographers. For example, Eduard Wellman wrote that "the environment is essentially neutral, its role depends on the level of technology, the type of culture and the other characteristics of the changing society". For example, mountain pass estimation, which is for horses, automobiles, aeroplanes, will be different for them. Assessment of fertility of the soil will not be like the perspective of a Japanese farmer, on the other hand, or an Amazonian Indian. Similar natural conditions can say different reactions on the human part, and in similar circumstances, different cultures can occur. George Carter is out of three fundamental factors in human geography, he has given more emphasis on cultural forces and wrote that "staying as a primary reason for changing the ideas, these are the ideas that determine the human use of the physical world. He also said that human beings are the decisive factor.

After World War II, schools of social determinism became very popular in Austria, Holland, and Sweden. Social geography relates to the spatial distribution of society. This, however, is not able to gain a deeper understanding of social relations or landscape. Social groups can be isolated in the context of ethnic, religious, professional and some other characteristics, whereas social change is only mentioned, but seldom is associated with any fundamental economic causes or society's class structure. The study of the effects implemented by these groups on the scenario reduces in the definition of purely external factors of the cultural landscape (deployment and deployment of homes, land uses, type patterns etc.), which in the form of morphology and under the functional changes, boundaries of the same road are infinitely the use of such 'macroregional' research is usually used in the character. Motivated and cannot provide any basis of the scientific findings of real importance. Thus, social, or cultural determinism does not adequately assess the environmental factors, that is, the effect of the natural environment on 'cultural geographical differences'.

Thus, social determinism is thus rigorous as environmental fatalism and therefore cannot be accepted in its raw form.

To sum up, the major debate among the geographical thinkers is whether people are active or passive agents in man-nature relationships. The entire debate revolves around two issues. First, resource exploitation is inevitable for the survival of human beings which means that they will take more and return less. Second, there is hope that morality will win as human beings will vote for greater gains than meagre personal benefits. The doctrine of sustainable development leads towards both these issues as it is based on the theme that development means meeting the needs of the present without compromising the ability of future generations to meet their own needs.

2.5 Approaches to the study of the man-environment relationship

The study of relationships between man and environment has always been a focal theme of environmental science and facets of the man and environment relationship changed through time with the development of human society and the dimension of the environment. As man became social, economic and technological, he broadened his environment by creating his environment through his design and skill to have provision for better food, shelter, access and comfort. The man environment relationships, thus, can be perceived and evaluated in a variety of ways and approaches as followings:

2.5.1 Deterministic Approach

This approach is based on the basic tenet of ‘earth made man’ and pays more attention to the complete control of the physical environment on man and his activities. In fact, according to deterministic perspectives of the man-environment relationships, man is subordinate to the natural environment as all aspects of human life viz. physical (health and comfort), social, economic, political, ethical, aesthetic etc. not only depended on but are dominantly controlled by the physical environment

2.5.2 Teleological Approach

The teleological approach is based on the religious faith of man is superior to nature and all other creatures. This school emanated from the teaching of Judeo-Christian religious tradition which preached that ‘man is superior to all creatures, and everything is created for his use and enjoyment. This ideology of man- environment/nature relationship fostered man to exploit

natural resources and to subdue nature without considering the aftereffects of reckless and uncontrolled plundering of natural resources.

2.5.3 Possibilistic Approach

The possibilistic Approach to the study of man-environment relationships emerged through the criticism of environmental determinism and the overtone of the teleological approach. Right from the very inception of the school of environmental determinism, there was a dissenting voice raised by those who believed that 'no doubt physical environment influences man and his activities but there is ample scope for man to change the environment so much so that it becomes suitable for man and his society.' Possibilists were quite aware that man cannot fully tame nature and is not always victorious. Possibilists replaced more deterministic terms 'control' with 'influence' and 'influence' with more moderate terms 'response' or 'adjustment'.

2.5.4 Economic Deterministic Approach

This approach is based on the basic ideology of Man's mastery over the environment and continued economic and industrial expansion through the application of modem technologies. The basic thesis of the growth (affluence) school is that because economic growth is required for political, social, and economic stability, the 'quality of environment' normally assumes lower priority in formulating planning proposals and in long-term planning because the deterioration of the environment is generally protracted and socially less oblique than a deterioration in the economy. It may be pointed out that this extreme concept of economic determinism led to rapacious exploitation of the natural resources in the western developed countries and thus, created most of the environmental and ecological problems of the global dimension.

2.4.5 Ecological Approach

Ecological Approach to the study of man- environmental relationships are based on the basic principle of ecology which is the study of mutual interactions between organisms and the physical environment, on the one hand, and interactions among the organisms on the other hand in each ecosystem. Thus, man is considered as an integral part of nature/ environment It is obvious that the relationship between man and environment is two-directional as the environment affects and influences man and in turn, man also influences and modifies the environment. This type of mutual interaction and relationship between man and environment is symbiotic.

Let Us Sum Up

The relationship between man and the environment has been established in the early periods itself. Human beings live in the kingdom of nature and interact with it constantly. The influence of nature in the form of the air he breathes, the water he drinks, the food he eats, and the flow of energy and information. Over the last four centuries, human activities have transformed the Earth's chemistry, water, soil and air, altered the face of the earth and changed the earth's physical and biological characteristics. These changes have led to massive environmental pollution which has tremendous health implications on the lives of the people. To reduce the problems, conserve our nature.

Glossary

Ecological Approach: Ecological Approach to the study of man-environmental relationships are based on the basic principle of ecology which is the study of mutual interactions between organisms and the physical environment on the one hand and interactions among the organisms on the other hand in each ecosystem.

Ecosystem: An ecosystem includes everything at a particular location: plants, animals, microorganisms, air, water, soil and human-built structures. Natural ecosystems are formed entirely by natural processes. Agricultural ecosystems are created by people to provide food or other materials. Urban ecosystems are dominated by human-built structures.

Energy flow: Movement of energy in the carbon chains of organic matter that passes through a food web as one organism consumes another.

Conservation: The management of human use of nature so that it may yield the greatest sustainable benefit to current generations while maintaining its potential to meet the needs and aspirations of future generations.

Abiotic: An abiotic factor is a non-living part of an ecosystem that shapes its environment.

Check Your Progress

1. When man-environment relationship concept develops?

   Answer: The idea of defining the geography in terms of man and environment relationship developed on scientific lines in the later part of the 19th century after the publication of Origin of Species (1859) by Charles Darwin

2. Who was the author of the Anthropogeography book?

   Answer: Friedrich Ratzel, published Anthropogeography in two volumes in 1882 and 1891 respectively.

3. Who introduces the term Ecology?

   Answer: The term “Ecology” was introduced by Ernst Haeckel (German scientist) in 1869 and involves the study of interactions as well as interrelationships amongst organisms and their environment.

4. Mention the types of Aquatic ecosystems?

   Answer: There are two types, Fresh water and Oceanic/Marine ecosystem

5. Write about the natural ecosystem?

   Answer: There are two types of the natural ecosystem, Terrestrial Ecosystem and Aquatic Ecosystem.

Books for Reference

1. Environmental Geography, (2007), H.M. Saxena, Rawat Publications, New Delhi.
2. Environmental Geography, (2012), Savindra Singh, Prayag Pustak Bhawan, Allahabad.
3. Evolution of Geographical Thought, (2012), Majid Husain, Rawat Publications, New Delhi.
4. Fundamentals of Human geography, L.R. Singh, Sharada Pustak Bhawan, Allahabad.

Suggested Online Readings

1. https://www.uv.mx/personal/fpanico/files/2011/04/AA.-VV.-Environmental-geography.pdf
2. http://www.dspmuranchi.ac.in/pdf/Blog/aksinghdspmuranchiacinA11.pdf
3. https://nios.ac.in/media/documents/srsec328newE/328EL23.pdf
4. http://moirabaricollegeonline.co.in/attendence/classnotes/files/1588614046.pdf

Unit 3

Determinism, Possibilism and Neo determinism

Structure

3.1 Overview

In the history of geographical concepts, there have been various approaches and schools of thought of study related to man-nature interaction. The first approach adopted by the geographers to generalize the patterns of human occupations of the earth surface was deterministic. Their major initial source for explanations was the physical environment, and that theoretical position was established around the belief that the nature of the human activity was controlled by the parameters of the physical world within which it was set. While the physical environment controls the course of human action is called Determinism. On the other hand, the philosophy of Possibilism states that man with the help of his mind will change the influence of nature on him. Slow or stop down the progress but he cannot change the direction, this is the reason why this philosophy is also called a stop and go determinism.

The relationship between man and the environment has been of increasing interest to geographers throughout its history. One can say that the idea of geography as the study of man environment relationship has a long history and has led to a long-standing debate about the position of man over nature. Determinism and possibilism are the two mutually elite philosophies in geography which are centred on a man and his place in nature. Both these doctrines try to place man within the ambit of the environment and deliberate on the issue of whether a man should be looked upon as a ‘passive’ agent or an ‘active force’ while interacting with the environment. In this process, he not only adapts to the environment but also brings changes within it.

Man-environment relationships refer to the interactions and feedbacks between the human and the natural components and, consequently, to the linkages between the social and the geophysical systems. The field of man-environment relationships operates with a series of concepts and notions. They refer to the causes of environmental change, feedback and consequences for the communities, answers of the decision-makers etc. There are various philosophies put forward by the various schools of thought to study the man-environment relationship in a better and easy way which are as follows.

Learning Objectives

After reading this unit, you will learn the following

- Determinism and Possibilism or Humanisation of Nature
- Neo-determinism or Stop and Go determinism

3.2 Historical Background

Since ancient times, determinism has been an important notion defining the man-environment relationship. The idea was that man is a product of nature or physical environment that moulds the human culture. Most of the early scholars like Aristotle, Eratosthenes, Strabo, and Hippocrates were deterministic in their approach. For Example, Aristotle believed that the world climatic zones – frigid, temperate, and torrid; determined the habitability of man. In medieval times, France scholar Montesquieu in his work The Spirit of the Laws (1748) discusses how the climatic conditions govern the degeneration and persistence of cultural traits. This philosophy even dominated the writings of Arab scholars especially Al-Masudi, IbnBattuta, and Ibn-Khaldun. In the early modern period, Kant vehemently supported determinism. Ritter, one of the founding fathers of Modern geography also had a tilt towards an anthropocentric approach and advocated geographical determinism. Ratzel (1844-1904) also propagated new determinism where he emphasized that man holds a higher position than the other organisms; still accepting that determinism is a dominant force in explaining the man-environment relationship. In the second volume of 'Anthropogeographie', he analyzed the socio-economic activities and culture of a man about the physical environment. This concept at the later stage became an inspiration for Vidal de la Blache.

Apart from determinism, scientific concepts like the deductive approach, Darwin's theory of evolution, Newtonian cause, and effect relationships in the latter half of the ninetieth century and early twentieth century influenced several geographers in France. This led to the foundation of the modern school in France the France School of Geographical Thought which had its roots in the philosophy of possibilism. Vidal de la Blache, Gallois, Brunhes, Demangeon, Emmanuel De Martonne, Blanchard, and all advocated the paradigm of possibilism. This philosophy is in direct contrast to determinism and puts a man in the first place that is a man and no longer the earth or climate influences man's habitability. Thus, presents man as an active rather than a passive agent.

3.3 Determinism

Determinism is one of the most important philosophies which persisted up to the Second World War in one shape or the other. The determinist point of view is that the environment controls the course of human action.

In other words, the belief that variation in human behaviour around the world can be explained by the differences in the natural environment.

The determinists generally consider the man a passive agent on which, the physical factors are constantly acting and thus determining his attitude and process of decision making.

In the history of geographical concepts, there have been various approaches and schools of thought of studying man-nature interaction.

The first approach adopted by the geographers to generalize the patterns of human occupations of the earth surface was deterministic. Their major initial source for explanations was the physical environment, and that theoretical position was established around the belief that the nature of the human activity was controlled by the parameters of the physical world within which it was set.

The essence of the deterministic school of thought is that the history, culture, living style and stage of development of a social group or nation are exclusively or largely governed by the physical factors of the environment.

The determinists generally consider the man a passive agent on which the physical factors are constantly acting and thus determining his attitude and process of decision making. In brief, determinists believe that most human activity can be explained as a response to the natural environment.

3.3.1 Environmental Determinism or Naturalization of Humans

Determinism is also known as environmental determinism or environmentalism. Determinism refers to the idea that everything in human life is caused inevitably by the natural environment. It is a philosophical concept that stresses the influence of the environment on man and his activities and treats man as subordinate to the environment.

The tradition of environmentalism can be traced back to the ancient classical period when Greek and Roman geographers like Hippocrates, Aristotle and Strabo evinced great conviction in the influence of the physical environment on man

The first attempt to explain the physical features and the character traits of various peoples and their cultures concerning the influence of natural conditions was made by Greek and Roman scholars.

Aristotle, for example, explained the differences between the Northern Europeans and Asians in terms of climatic causes. He argued that the colder climates of Europe produced brave but unintelligent people who were able to maintain their independence but who could not rule others.

Aristotle thought that the people inhabiting the warm climates of Asia were intelligent but lacking in spirit and therefore subject to slavery.

Strabo - the Roman geographer - attempted to explain how slope, relief, climate all were the works of God, and how these phenomena govern the lifestyles of people. Montesquieu pointed out that the people in cold climates are stronger physically, more courageous, frank, less suspicious and less cunning than those in warm climates.

Environmental determinism continued to dominate the writings of the Arab geographers. They divided the habitable world into seven terrestrial zones (climate) and highlighted the physical and cultural characteristics of races and nations of these zones. Al-Battani, Al-Masudi, Ibn-Hauqal, Al-Idrisi, and Ibn-Khaldun attempted to correlate environment with the human activities and mode of life.

Al-Masudi, for example, asserted that in a land like Sham (Syria) where water is abundant, the people are gay and humorous, while the people of dry and arid lands are short-tempered. The nomads who live in the open air are marked by strength and resolution, wisdom, and physical fitness.

Kant further stressed the point that all the inhabitants of hot lands are exceptionally lazy and timid. Timidity engenders superstition and in lands ruled by kings, it leads to slavery.

Humboldt Alexander von Humboldt was impressed by the influence of the environment on man, but he was also interested in the reaction of human beings to the environment around them. Humboldt was a determinist, but he believed in the real associations of nature and organic phenomena.

Carl Ritter viewed geography as anthropocentric but recognized the environmental influence on human character. He stressed the reciprocal influence of the earth on man and man on earth.

Friedrich Ratzel, an eminent German geographer, popularly known as the founder of human geography, stressed the influence of the physical environment on man as he reckoned man as a product of evolution. In his Political Geography, Ratzel explicitly used the Darwinian concept of ‘selection and struggle’ in his concept of ‘lebensraum’ (living space).

The American geographer, Miss Ellen Churchill Semple, considered the most influential determinist of the early twentieth century, published a famous book Influences of Geographic Environment. She considers man as the child of the earth, the dust of her dust, but that the earth has mothered him, fed him, set him tasks, directed his thoughts, confronted him with

difficulties that have strengthened his body and sharpened his wit, given him his problems and at the same time whispered hints for their solution.

Ellsworth Huntington, an American geographer, stressed the importance of climatic determinism. He was often considered an imaginative thinker and interpreter of the effects of climate on human activities and life.

3.3.2 Environmental Determinism and Early Geography

Although environmental determinism is a relatively recent approach to formal geographic study, its origins go back to ancient times. Climatic factors, for example, were used by Strabo, Plato, and Aristotle to explain why the Greeks were so much more developed in the early ages than societies in hotter and colder climates. Additionally, Aristotle came up with his climate classification system to explain why people were limited to settlement in certain areas of the globe.

Other early scholars also used environmental determinism to explain not only the culture of a society but the reasons behind the physical characteristics of a society's people. Al-Jahiz, a writer from East Africa, for instance, cited environmental factors as the origin of different skin colours. He believed that the darker skin of many Africans and various birds, mammals, and insects was a direct result of the prevalence of black basalt rocks on the Arabian Peninsula.

Ibn Khaldun, an Arab sociologist, and scholar was officially known as one of the first environmental determinists. He lived from 1332 to 1406, during which time he wrote a complete world history and explained that the hot climate of Sub-Saharan Africa caused dark human skin.

3.3.3 Environmental Determinism and Modern Geography

Environmental determinism rose to its most prominent stage in modern geography beginning in the late 19th Century when it was revived by the German geographer Friedrich Ratzel and became the central theory in the discipline. Ratzel's theory came about following Charles Darwin's *Origin of Species* in 1859 and was heavily influenced by evolutionary biology and the impact a person’s environment has on their cultural evolution.

Environmental determinism then became popular in the United States in the early 20th Century when Rätzel’s student, Ellen Churchill Semple, a professor at Clark University in Worchester, Massachusetts, introduced the theory there. Like Rätzel’s initial ideas, Semple’s theory was also influenced by evolutionary biology.

Another one of Ratzel's students, Ellsworth Huntington, also worked on expanding the theory around the same time as Semple. Huntington's work though, led to a subset of environmental determinism, called climatic determinism in the early 1900s. His theory stated that the economic development in a country could be predicted based on its distance from the equator. He said that temperate climates with short growing seasons stimulate achievement, economic growth, and efficiency. The ease of growing things in the tropics, on the other hand, hindered their advancement.

3.3.4 The Decline of Environmental Determinism

Despite its success in the early 1900s, environmental determinism's popularity began to decline in the 1920s as its claims were often found to be wrong. Also, critics claimed it was racist and perpetuated imperialism.

Carl Sauer, for instance, began his critiques in 1924 and said that environmental determinism led to premature generalizations about an area's culture and did not allow for results based on direct observation or another research. As a result of his and others' criticisms, geographers developed the theory of environmental possibilism to explain cultural development.

Environmental possibilism was set forth by the French geographer Paul Vidal de la Blanche and stated that the environment sets limitations for cultural development, but it does not wholly define culture. Culture is instead defined by the opportunities and decisions that humans make in response to dealing with such limitations.

By the 1950s, environmental determinism was almost entirely replaced in geography by environmental possibilism, effectively ending its prominence as the central theory in the discipline. Regardless of its decline, however, environmental determinism was an important component of geographic history as it initially represented an attempt by the early geographers to explain the patterns they saw developing across the globe.

3.3.5 New Determinism of Geographical Determinism

The founder of the 'new' determinism was Friedrich Ratzel. He supplemented 'classic' geographical determinism with elements of 'Social Darwinism' and developed a theory of the state as an organism that owed its life to the earth, and which was ever striving to seize more and more territory. In the opinion of Ratzel, 'similar locations lead to a similar mode of life. He cited the example of the British Isles and Japan and asserted that both these countries have insular locations, which provided a natural

defence against the invaders. Consequently, the people of these countries have been making rapid progress. Ratzel a follower of Darwin believed in the survival of the fittest and saw ‘man’ as the product of evolution and evolution in which the mainspring was the natural selection of types according to their capacity to adjust themselves to the physical environment. In his deterministic approach, he gave more weight to a location about topographic features.

The names of Friedrich Ratzel (1844-1904) and Ellen Churchill Semple (1863-1932) are associated with the most outspoken expression of the idea of this form of determinism. This approach was slightly modified by Ellsworth Huntington who tried to seek out objective evidence of the effect of the physical environment, and in particular, a climate which he regarded as an important influence on human behaviour.

Semple was the direct descendant of Ratzel. She preached the philosophy of her master and thus was a staunch supporter of determinism. Her books American History and Its Geographic Conditions (1905) and Influences of Geographic Environment (1911), established environmentalism in America in the early decades of the 20th century.

An Influence of Geographical Environment (1911) begins with the following paragraph: “Man is a product of the earth’s surface. This means not merely that he is a child of the earth, the dust of her dust, but the earth has mothered him, set him a task, directed his thought, confronted him with difficulties, that have strengthened his body and sharpened his wits, gave him his problems of navigation or irrigation and at the same time whispered hints for their solution.”

Elseworth Huntington, the American geographer who wrote the monumental book, The Principles of Human Geography in 1945 said that the supreme achievements of civilization in any region were always bound up with a particular type of climate and variation in climate led to ‘pulsations’ in history of culture. He suggested that the ‘best’ climates for work were those in which there was variety and in which the temperatures fell within a certain range.

Huntington divided the world into mild and harsh climatic zones and established that the ancient civilizations (Egyptian, Mesopotamian, Chinese, Indus) flourished in the fertile river valleys of mild climates. He also established the hypothesis of invasion and tribal warfare.

The underdevelopment of the tropics, he explains, is owing to the humid, hot, oppressive weather which makes the people lethargic, lazy, inefficient,

suspicious, and timid. Huntington thus believed that out of all the factors of the natural environment, the climate was the fundamental factor in the rise of civilization (1939).

This form of determinism is regarded by many people as overly simplistic because it neglects the scientific developments and the cultural factors that affect human behaviour. Two societies that inhabit areas having similar climates and landforms may be very dissimilar. How could two contrasting societies alike Bakarwals and Kashmiris of Jammu and Kashmir, Nepalis and Khasis of Meghalaya, Assamese and Bengalis of the Brahmaputra Valley, Tharus and Sikhs of the Tarai region of Uttar Pradesh, for example, exist in a similar environment and have different modes of life and cultural ethos.

3.3.6 Cultural or Social Determinism

Cultural or social determinism emphasizes the human element: "Our thoughts determine our acts, and our acts determine the previous nature of the world". Since human interest, desires, prejudices, and group values vary across space, there is a consequent variation in the cultural landscape and levels of socio-economic development. The modification of an environment largely depends on our perceptions, ideas, and decision-making processes.

The philosophy of cultural determinism is widespread among American geographers. Eduard Ullman, for example, wrote that "the environment is essentially neutral, its role being dependent on the stage of technology, type of culture and other characteristics of a changing society". Similar natural conditions may call forth different reactions on the part of man, and within similar sets of conditions, different cultures can take place.

George Carter singles out three fundamental factors in human geography. He has laid greater stress on cultural forces and writes that "ideas remain as the primary cause of change; it is these ideas that determine the human use of the physical world". He also emphasized the point that the human will is the decisive factor.

Social or cultural determinism thus does not adequately assess the environmental factors, i.e., the influence of natural environment upon 'cultural geographical differences. Social determinism is thus also rigid like environmental determinism and therefore cannot be accepted in its crude form.

3.3.7 Criticisms

After World War II, this philosophy was vehemently criticized in the United States, UK, Canada, and many other countries. Geographers observed that this approach exaggerated the active role of nature while interpreting human history.

The determinists only consider humans capable of being adapted but man's efforts reveal many facts which the forces of the environment cannot explain.

The does do not only become socially dysfunctional but was also subjected to an academic, theoretical critique.

Barrows (1923) initiated a meek criticism from within the environmentalist paradigm where he argues that the relations between man and environment should be seen from the standpoint of human adjustment as this was "more likely to result in the recognition and proper valuation of all the factors involved, and especially to minimize the danger of assigning to the environmental factors a determinative influence which they do not exert."

Sauer (1963) had a stronger reservation where he states that transposition of divine law into omnipotent natural law had caused the "eager adherents of the faith of causation" to sacrifice their earlier concerns in the name of a "rigorous dogma of naturalistic cosmology, most notably in American physiography and anthropogeography".

As he later added, "natural law does not apply to the social groups" (Sauer 1963); instead, what man did in an area involves the active agency of culture that shapes the landscape.

Sauer's critique played the internal role in diminishing the place of determinism as the hegemonic theory of geography and initiated the redefinition as "social science, concerned with areal differentiation.

Now the question arises did Sauer provide a valid alternative theoretical base to geographical thinking.

Peet (1985) states that the cultural geography of Blache and Sauer failed to establish a comprehensive theory within the discipline.

In the 1930s, 1940s, and 1950s geography drifted towards a regional perspective as determinism was being critiqued without being effectively replaced.

The chronological concept logically implies that relationships do not define the field.

Whatever be the goal of the geographer, he should not be limited to or prejudiced against any technique or method.

Literary description and levels of human insight are undoubtedly required, but in Hartshorne's (1939) words the geographer must analyze the relationships of earthly features, "regardless of whether these interrelations can be described in terms of 'natural laws' or 'social laws.'

Therefore, determinism has not retreated from geography; rather, several deterministic systems have been evolved to assist the interpretation of spatial patterns and have frequently been compressed into mathematical formulae.

There is sufficient room for analysis of both the physical and the cultural factors, quantitative laws, and artistic synthesis.

Determinism was redefined, refined, reviewed, and redirected, but never completely dislodged.

3.3.8 Shifting from Determinism to Possibilism

There is no doubt that the environment influence man and man, in turn, influence his environment. This interaction between man and his environment is so intricate that it becomes almost impossible to find out when one’s effect ceases and the other’s effect begins. Many landscapes that appear natural to us are in truth the work of man. Wheat, barley, olive, and vine, which dominate the Mediterranean countries, are entirely the products of human effort.

Apple and almond orchards of Kashmir, Himachal Pradesh and the Kumaon division of Uttarakhand are the creations of man. Similarly, the cultivation of basmati rice in only 50 cm rainfall areas of the Punjab and Haryana is the direct and conspicuous result of human efforts.

Wheat cultivation in West Bengal, Odisha and Dimapur of Nagaland is because of the HYVs of seeds invented by man. Countless such examples from the developed and the developing countries can be cited. Thus, man and environment are intrinsically interdependent, and it is difficult to say which becomes more influential and when. After World War II, the philosophy of environmentalism was attacked.

Many geographers in the United States, Britain, Canada, and other countries drew attention to the one-sided approach adopted by the environmentalists in their interpretation of historical reality, to their exaggeration of nature’s active role and to the fact that they only acknowledge man as capable of passive attempts at adaptation. The

actions of man reveal many facts for which environmental forces alone can give no satisfactory explanation.

Spate criticized the fanatic approach of environmental determinists. He, for example, states that “environment taken by it is a meaningless phrase; without man, the environment does not exist”. Equally important is his indication of the need to consider the psycho-physiological influence of the geographical environment via the social structure. In the final analysis, Spate concluded that the geographical environment is only one of the factors of territorial differentiation and “it acts through society; cultural tradition has a certain autonomous influence”.

Recently an Australian writer Wolfgang Hartake argued that while the role of physical factors might well be relatively unimportant in the fringe zone of Frankfurt, “it is hard to imagine the extreme climatic conditions not playing a direct role in any human activity which occurs in the Sahara”. A similar argument is put forward by Hartshorne. He rejected environmentalism purely because it separates nature from man and thus is “disruptive of the fundamental unity of the field”, i.e., contradicts the concept of geography as an integrated science.

The environmentalist movement started in the 1960s has, however, shown quite distinctly that there is an overall limit to certain kinds of human economic activity in terms of biophysical persistence and resilience of the planet’s systems. In brief, at the very largest scale, we can be determinists, whereas at the more local scales we can see the virtue of possibilism or cultural and social determinism.

3.4 Possibilism or Humanisation of Nature

As a reaction to German environmentalism (determinism), there was an emergence of possibilism in the early twentieth century in France. The concept of determinism which was conservative cannot be accepted by a society that is civilized and advanced. The reason behind this is that man with the help of technological development has modified nature, for example, he has created canals for making the water available in the extreme desert areas for making it suitable for living.

The concept of possibilism says that nature provides several opportunities and possibilities from among which man is free to select or choose. The philosophy states that man with the help of his mind will change the influence of nature on him. The philosophy of possibilism attempts to explain the man and environment relationship in different ways taking man as an active agent. The philosophy further states that nature provides

opportunities, and the number of opportunities increases as the knowledge and technology of a cultural group increases.

Possibilism is a view that, the physical environment provides the opportunities for a range of possible human responses and that people have considerable discretion to choose between them. It focuses on the role of man as a geographic agent and a modifier of the physical environment.

The hypothesis of possibilism was put forward by Lucian Febvre who thinks that man is the most powerful agent who modifies the terrestrial surface of the earth. Lucian said that 'there are no necessities but everywhere possibilities' for example man invented the iron and it was up to him how he makes use of that iron. It was up to him whether he uses the iron for making a hammer or a bicycle, a car, a ship, or a plane it depends on his technological development. So, the example proves that there are possibilities everywhere but there are no necessities. Before the invention of the iron, though there was no necessity for a plane ship or the car, possibilities were still there. Vidal de Lablache further advocated and preached the philosophy of possibilism. In his work, he has minimised the influence of the environment on man.

He tries to explain the differences between the groups living in the same environmental condition. He said that the differences are not because of the natural environmental condition but due to the variation in the attitude values and habits of man. The possibilistic school of thought tries to explain the differences in human society based on the man himself bringing the changes and influencing the environment and it is not only nature solely responsible for bringing the changes or differences in human society. After Vidal de Lablache it was Jean Brunhes who became a strong supporter of possibilism in France.

Sauer, another supporter of possibilism said that it is the work of a geographer that he should investigate and understand how a natural landscape transforms into a cultural landscape. From such work, the geographer will be able to identify the major changes in that area that has resulted because of a succession of human groups. For example, wheat does not have a high yield where it was first domesticated (south-west Asia) but in America, Europe, and some of the Asian countries. Thus, after the Second World War, the philosophy of environmentalism was attacked. Many geographers in Britain, Canada and USA said that the explanation of phenomena only based on nature and its forces is incomplete and unsatisfactory until and unless a man is included in it.

3.4.1 The Rise of Possibilism

The doctrine of possibilism tries to explain the relationship of a human being with the environment differently; it puts humans at a higher level and regards them as active agents. It is a principle that claims that the environment provides opportunities and man being an economic man chooses from those possibilities. Febvre (1932) in 'A Geographical Overview to History' stated 'there are no necessities, but everywhere possibilities; and man, as the master of these possibilities, is the judge of their use'.

The roots of possibilism can be traced back to the works of Plato, who is considered the master of deductive reasoning. Though his idea went into gloom for hundreds of years; the contrasting doctrine of determinism continued to grow and flourished. It got support in the writings of French scholar of the eighteenth century – Montesquieu, who is credited with developing a doctrine analogous to the modern paradigm of possibilism. He opined that man possesses free will and can choose from a series of opportunities. Similar thoughts were also put forward by another eighteenth-century French philosopher, Comte de Buffon. He believed that man was ordered to conquer the earth and even transform it. Their views laid the base for the crypto-possibilistic hypothesis.

In the nineteenth century, George Perkins Marsh and Kirchoff tried to put forward a non-deterministic approach to human geography; they focused on the man himself. It was only in the latter half of the nineteenth century that under the leadership of Vidal De la Blache (1845 – 1918), a possibilistic view of man-environment developed. The focus of this philosophy was that "Nature has set boundaries and has provided possibilities for human settlement, but the way a person responds to these conditions or adjusts it depends on the traditional way of life." Vidal rejected the concept of material determinism and advocated favourability. He even rejected Durkheim's opinion of human geography as social morphology rather insisted that man was a partner and not a slave of the environment (Dikshit, 2009). He was critical of Darwinian Ratzelian heritage which proposed environmental determinism and put forth the concept of possibilism. He sought a scheme for understanding the interaction of nature and culture that eschewed both environmental determinism and radical possibilism to seek answers or solutions for the dichotomy between the human and the environment.

He vehemently rejected the idea that society and nature stood out as adversaries in the human-nature confrontation. For him, the man was part of nature and therefore, his most active collaborator. To resolve this dichotomy, he generated the concept of 'genre de vie. 'Genre de vies' (way

of life) includes all activities, practices, and techniques that characterize the adaptation of a human group to the milieu – the natural surroundings of their habitat (Mercier, 2009). Vidal pointed out that the same genre de vie had different interpretations for various human groups. Thus, his works gave a sound methodological as well as a philosophical foundation for the doctrine of possibilism. This growth somewhat weakened the hold of Darwinian Determinism within geographical thinking.

In the twentieth century, possibilism got the stronghold after the publication of Blache's article in 1913 where he categorically states that geography as a discipline seeks to measure and role of man in modifying the earth surface. This was further strengthened when his book was published in 1921 (English translation in 1926), though posthumously. He observed that nature gives man materials that have their inherent needs as well as limitations thus leading them to limited uses.

Possibilism was further flourished by acclaimed historian Lucien Febvre (1878-1956). He puts forward - "Whatever the men do in their environment, they cannot completely get rid of themselves completely." Febvre emphasized human initiative and motivation against the environment, destroying the environmental deterministic reasoning and as part of the environment of any group, as well as other humans, because they belong to the next group's cultural surroundings, or the constraints of the environment are influenced by such thinking. He stated that in the view of possibilists, a homogeneous region does not necessarily result in a homogeneous society. This is because people residing in any area have the choice of possibilities from time to time and in the quantity they want.

Bruhnes followed Blache's ideas and took them to the next step, he not only transmitted Blache's philosophy in France but also disseminated it to different parts of the world. In 1910, his monumental work La Geographie de L'Histoire was published. His prime focus was on the actualities of exploitation of the earth by man. commented: "The power that is meant is limited, and it meets in it the bounds of nature that it cannot cross human activity can change within its boundaries and its environment. But it cannot be removed from its environment, it can only modify it, but it can never cross it, and it will always be conditioned by it. "He also stated, "Nature is not compulsory but the approval."

Futility is also associated with the French school of geography; French geographers saw a series of possibilities for human development in the physical environment but argued that the development in the real

development was related to the culture of related people, perhaps in the field of extremes like deserts and tundra.

3.4.2 Criticisms

Even though humans have many possibilities in some physical settings, they cannot go against the instructions set by the physical environment.

Many contemporary thinkers have criticized the possibilistic approach.

Griffith Taylor, criticizing the possibility, said that the society should elect entirely, and since only one advisory role has been assigned to geography, therefore their work is not a "plan of explanatory nature".

Taylor was right when he wrote that the work of geography is not the study of all the problems related to the natural environment and humans, humans or 'cultural landscape'.

Apart from this, the possibilities do not encourage the study of the physical environment and promote humanism in geography

3.5 Neo-determinism or Stop and Go determinism

Neo-determinism is also called scientific determinism is a revised, refined, and new form of determinism that is perhaps nearer to real-world situations than those of environmental determinism and possibilism. A geographer, Griffth Taylor, introduced the concept which reflects a middle path between the two ideas of environmental determinism and possibilism. He termed it neo-determinism or stop-go-determinism.

This concept shows that neither is there a situation of absolute necessity (environmental determinism) nor is there a state of absolute freedom (possibilism). It means that human beings can conquer nature by obeying it. They must respond to the red lights and proceed in their pursuit of developments when nature permits the modifications. It means that possibilities can be created within the limits which do not damage the environment and there is no free run without accidents.

He argued that possibilists had developed their ideas in temperate environments such as north-western Europe, which offer several viable alternative forms of human occupancy. But such environments are rare: in most of the world as in Australia the environment is much more extreme and its control over human activity is enormous.

He coined the term ‘stop-and-go determinism’ to describe his views. In the short term, people might attempt whatever they wished about their environment, but in the long term, nature’s plan would ensure that the

environment won the battle and forced a compromise out of its human occupants. He, in the 1920s, argued that the limits of agricultural settlement in Australia had been set by factors in the physical environment such as the distribution of rainfall. Taylor's view was initially most unpopular in Australia but generally accepted it since then.

In his book on Australia published in 1948, Taylor reaffirmed his basic position that the best economic programme for a country to follow has in large part been determined by nature or environment, and the geographer must interpret this programme. In his book, 'Australia' Taylor writes: "Man can accelerate, slow or stop the process of country's development. But he should not, if he is wise, depart from the direction as indicated by the natural environment. He is like the traffic controller in a large city who alters the rate and not the direction of progress."

But he should not depart from directions as indicated by the natural environment. Man is like the traffic controller in a large city who alters the rate but not the direction of progress. Neo-determinism is also known as 'stop-and-go determinism' and Griffith Taylor's philosophy can be explained by the role of a traffic controller.

Man follows nature's programme only if he is wise. But he admits the possible Structure were within the broad limits set by the environment man can choose. Taylor concedes to him the choice between what is wise and what is foolish. But wisdom and folly are human concepts. The natural environment knows nothing of them. In nature, there is only the 'possible' and 'impossible'.

The possibilists admit that the opportunities offered by any environment are not all equal. Some environments demand little adjustments while other environments make humans struggle continuously. The ratio between human effort and return can be taken as the price nature demands from human beings for their choices. In no environment are the possibilities limitless and for every choice price must be paid, proponents of possibilism admit this, but within these limits freedom to choose exists.

Man makes his choice, and the man himself judges his relative wisdom or folly by reference to goals he has established. Limits to man's freedom beyond those generally recognized by possibilists are, according to Taylor's definition, those imposed by man's conception of wisdom. There is nothing indeed that contradicts the assertion of Febvre that there are no necessities but everywhere possibilities and man as a master of these possibilities is the judge of their use.

Thus, man chooses, but only from the range which nature presents him. In brief, people might attempt whatever they wished regarding their environment, but in the long term, nature's plan would ensure that the environment won the battle and forced a compromise out of its human occupants.

Let us sum up

The human-environment relationship is the interplay between the people and their environment, including the elements and arrangements by which people use the environment and the limitations the environment puts on human behaviour. determinism and possibilism are the dominant theories. To date, they are considered as an irreconcilable paradox among them. It has been a debate for years that flourished from the ancient to the modern period. Environmental determinism natural environment influences the social, political and religious life of mankind. On the other hand, possibilism is the reaction to determinism and environmental determinism. It is based upon the assumption that the environment sets certain constraints or limitations, but culture is otherwise determined by social conditions.

Glossary

Determinism: The philosophy of Determinism is based upon the interaction between primitive human society and the strong forces of nature. This is an older philosophy that persisted till World War II. It says that the strong forces of the environment control the course of human action.

Stop and Go Determinism: A geographer, Griffith Taylor introduced another concept that reflects a middle path (Madhyam Marg) between the two ideas of environmental determinism and possibilism. He termed it as Neo determinism or stop and go determinism.

Possibilism: When man dominates nature, it is called possibilism.

Anthropogeographie: The term comes from Anthropogeographie, the title of a two-volume work published in 1882 and 1891 by the German geographer Friedrich Ratzel, who is well known for his influence in early human geography, particularly his thought in political geography.

Erdkunde: Die Erdkunde' means Earth sciences. It is often used as a translation of geography in the German language. It is a collection of 19 volumes of books with over 20000 pages by Karl Ritter

Check Your Progress

1. Define Neo determinism

   Answer: An ecosystem is a geographic area where plants, animals, and other organisms, as well as weather and landscapes, work together to form a bubble of life

2. Who gave the concept of determinism?

   Answer: Determinism was developed by the Greek philosophers during the 7th and 6th centuries BCE by the Pre-socratic philosophers Heraclitus and Leucippus, later Aristotle, and mainly by the Stoics.

3. Who is the father of possibilism?

   Answer: French historian Lucien Febvre was the first who coined the term possibilism and contrasted it with environmental determinism.

4. Mention the ideas of Griffith Taylor?

   Answer: “Stop and Go Determinism” also known as Neo-determinism is a concept that was given by Griffith Taylor.

5. Write about the contribution of Huntington?

   Answer: An American geographer Elseworth Huntington who wrote the monumental book, The Principles of Human Geography in 1945 said that the supreme achievements of civilization in any region were always bound up with a particular type of climate and variation in climate led to ‘pulsations’ in the history of culture.

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Suggested Online Readings

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UNIT 4

Marxian view on the environment

Structure

4.1 Overview

Man lives on nature means that nature is his body, with which he must remain in continuous interchange if he is not to die. That man's physical and spiritual life is linked to nature means simply that nature is linked to itself, for man is a part of nature. In these writings, Marx makes vital contributions to our understanding of the human-nature relationship. He overcomes a long philosophical tradition of viewing humans as separate from and above the rest of nature, and he asserts the necessity for both survival and spiritual well-being of a proper, active relationship with the rest of nature. At the same time, he recognises this relationship has gone wrong in the capitalist epoch.

Learning Objectives

After reading this unit, you will learn the following

- Marxism and the Environment
- Marx on nature
- Socialist ecological thought since Marx

4.2 Marxism and the Environment

Marxism is often mistakenly accused of taking the environment for granted – in the pursuit of the economic growth needed to alleviate poverty and want. Yet nothing could be further from the truth. Drawing on the works of Marx and Engels, and the experience of the first years of the Russian revolution, PER-ÅKE WESTERLUND sets the record straight. Originally published in Socialism Today, Issue 194 (December 2015 / January 2016), the political journal of the Socialist Party (sister party of Socialist Alternative in England and Wales).

There are two common accusations against Marxism regarding the environment, from right-wingers and some green activists, as well as from part of the left. The first is that Karl Marx had an overly positive view of industrialisation and saw nature as an unlimited source to be exploited. The second is that Marxism bears the responsibility for some of the worst ecological catastrophes, in the Soviet Union.

Contrary to these claims, consciousness about and struggle for the environment is nothing new for Marxists. Marx was a pioneer in analysing and criticising the destructive effect of capitalist industrialisation on nature as well as on society. Both Marx and Friedrich Engels, authors of the Communist Manifesto in 1848, closely studied and followed science in all fields.

Capitalist industrial production, and the working class (the proletariat) and its labour, had only come into existence in the preceding decades but were immediately understood by Marx as the key elements for the development of society. Stressing the importance of the working class did not mean ignoring the environment.

Interestingly, Marx viewed labour as “a process in which both man and nature participate”. This is underlined in Marx’s Critique of the Gotha Programme – the programme adopted by the initial congress of the Social Democratic Party of Germany (SPD) in 1875. Marx takes up the programme’s assertion that “labour is the source of all wealth and all culture”. “Labour is not the source of all wealth”, Marx wrote. “Nature is just as much the source of use values (and it is surely of such that material wealth consists of) as labour, which itself is only the manifestation of a force of nature, human labour-power”. The wrong idea of labour as the sole source came from Ferdinand Lassalle, not from Marx.

Marx warned of the effects of the disruption in the relationship between humanity and nature. Therefore, he saw the alienation of workers in

capitalist production as part of the same process as humanity's alienation from nature. In his time, this was particularly obvious in the industrialisation of agriculture.

The working class was and is at the forefront of the effects of capitalism on the environment. For example, energy companies – oil, coal, nuclear power – pose a direct threat to workers in those industries as well as to people and the natural environment in whole regions or countries. Workers in those industries are often the most conscious about those dangers. The struggle to improve the working environment is an important part of environmental struggles.

In addition, Marxist philosophy (dialectical materialism) offers the means to analyse and explain today's climate crisis. Marx and Engels in the mid-19th century showed how both society and nature develop through the build-up of contradictions leading to qualitative leaps. Today, climate researchers echo this method in warning of tipping points, the moment when the environment passes irreversibly from one stage to another.

Many of those blaming Marx for neglecting the environment have not studied his work, but that of his self-appointed 'followers' in social democracy or Stalinism. The societies they constructed, and described as socialism, completely contradicted Marx about workers' democracy, the role of the state, and their treatment of the environment. In contrast, Marx had predicted that "natural science… will become the basis of human science, as it has already become the basis of actual human life". (Economic and Philosophical Manuscripts, 1844)

4.3 Marx on nature

To understand Marxism and the environment there is a need to understand the method: that Marx always looked at the world and its history in its totality, as the point of departure for his analysis and programme. The fact that Marx regarded capitalism as a historically progressive system has been misunderstood and distorted by many. For example, Michael Lowy, from the United Secretariat of the Fourth International, wrote that Marx had "a fairly uncritical attitude toward industrial civilisation particularly its destructive relationship to nature". Lowy also claimed that "Marx does not possess an integrated ecological perspective". (For a Critical Marxism, Against the Current, November-December 1997)

Firstly, the progressive side of capitalism, according to Marx, was in comparison to feudalism and was, therefore, temporary. The main

achievement was that capitalism was the first society that created the basis not only to eliminate itself but class society altogether. The working-class taking power with the support of poor peasants would mean the rule of the majority and the beginning of a process towards a completely different society. Already in the Paris Commune in 1871, where workers held power for two months, Marx's perspective was proven right.

Understanding the role of capitalism does not correspond to a defence of that system. Marx, before and more than anyone else, understood capitalism as a system for producing profit out of surplus labour. Science and natural forces are adapted and exploited for this purpose. The health of workers is ignored, and so are the effects on nature. Marx saw and warned against steps to form nature according to capitalism. Some critics claim that Marx saw nature as something that was for free, and unlimited. But his point was that nature under capitalism had no value. He concluded that unexploited nature also held use value: for example, the air, forests, and fish.

Marx studied the non-mechanistic materialism of Epicurus (341-270 BCE) and the dialectics of GWF Hegel (1770-1831) and developed his philosophy, dialectical materialism. It was a brilliant view of the world, fitting perfectly into the period. The major event of the epoch, the French revolution, as a result of both the material basis – capitalist economy and society overtaking feudalism – and the conscious action of the revolutionary masses.

Marx's ideas were the most developed of all the philosophies breaking with the religious past. Instead of the Earth never changing and being at the centre of everything, with mankind the centre of the Earth, Marxism in line with classic materialism regards the world as always changing, even mortal. Life was a product of Earth (nature) and not of a god. Humanity was one with nature, not outside. Likewise, Marx did not divide history into social or natural but saw them as one. Dialectical laws apply in both nature and society, and their developments are interchanging, affecting each other. Marx used the term 'metabolism': a chain of processes linked to each other, as one body.

Marx showed that the increasing division between town and country was a breach of this metabolism, summarised in the term 'metabolic rift' by John Bellamy Foster, author of the useful book, Marx's Ecology. In the third volume of Capital, published in 1894 after Marx's death (1883), Marx describes capitalism as a break with the natural laws of life: "On the other hand, large, landed property reduces the agricultural population to a

constantly falling minimum and confronts it with a constantly growing industrial population crowded together in large cities. It thereby creates conditions which cause an irreparable break in the coherence of social interchange prescribed by the natural laws of life".

Based on a discussion about the long-term degradation of the soil following the use of chemical fertilisers in agriculture, Marx wrote that "all progress in capitalistic agriculture is a progress in the art, not only of robbing the labourer but of robbing the soil; all progress in increasing the fertility of the soil for a given time, is a progress towards ruining the lasting sources of that fertility".

He explained: "Capitalist production, by collecting the population in great centres… disturbs the circulation of matter between man and the soil, ie, prevents the return to the soil of its elements consumed by man in the form of food and clothing; it, therefore, violates the conditions necessary to lasting fertility of the soil". And further: "Capitalist production, therefore, develops technology, and the combining of various processes into a social whole, only by sapping the sources of all wealth – the soil and the labourer". (Capital, Volume I, 1867) In a farsighted prediction, Marx warned that capitalism's constant modernisation would increase "this process of destruction".

Engels summarised the dependence on, and need to learn from, nature: "Thus at every step, we are reminded that we by no means rule over nature like a conqueror over a foreign people, like someone standing outside of nature – but that we, with flesh, blood and brain, belong to nature, exist in its midst and that all our mastery of it consists in the fact that we have the advantage of all other creatures of being able to learn its laws and apply them correctly". (The Part Played by Labour in the Transition from Ape to Man, 1876)

Marx and Engels viewed humans not as something separate from the environment, as capitalist ideological orthodoxy does, but dialectically interconnected. Writes Marx on the relationship between nature and humanity:

Nature is man's inorganic body nature in so far as it is not the human body. Man lives from nature, i.e., nature is his body, and he must maintain a continuing dialogue with it if he is not to die. To say man's physical and mental life is linked to nature simply means that nature is linked to itself, for man is a part of nature.[11]

The organism interacts with its environment while simultaneously the environment acts back on the organism. In the process, both are changed. The environment is no longer a passive object to be shaped at will by whatever life-form comes along but plays a role in making the organism what it is. In this view, it is impossible to speak of any living thing, humans and their activity included, as anything but deeply enmeshed with each other, in a constant process of mutual interaction and transformation. Environmental niches don't just pre-exist so that some happy organism that just happens to wander by at the right time can slot itself in. The very idea of an environment has no meaning unless we are talking about an organism's relationship to it. For Marx and Engels, writing in *The German Ideology*, human activity had the potential to alienate all creatures from their environments:

The "essence" of the fish is its "being," water. The "essence" of the freshwater fish is the water of a river. But the latter ceases to be the essence of the fish and so is no longer a suitable medium for existence as soon as the river is made to serve the industry, as soon as it is polluted by dyes and other waste products and navigated by steamboats, or as soon as its water is diverted into canals where simple drainage can deprive fish of its medium of existence.

Climate, and the earth's ecosystem more generally, is dynamic and complex; it is best viewed as a process of many interacting factors. Every change feeds back and creates new effects on all actors. This leads to the concepts of tipping points and holism both central within Marxism. Violent shocks to the system over relatively brief timescales have dominated previous climate swings, as have the revolutionary social changes that ushered capitalism onto the world-historic stage. Rapid changes to natural and social systems can be seen to operate in analogous ways. Stresses that accumulate in climate systems and human societies often do so without much outward sign until rapid and extreme changes seem to burst forth almost out of nowhere. Under the surface, however, what seem like small, inconsequential "molecular" changes were taking place that eventually led to the radical and abrupt shifts to entirely new systems. Regarding climate change, this is the thesis of Fred Pearce's book *With Speed and Violence: Why Scientists Fear Tipping Points in Climate Change*.

In this sense, rapid climate change and revolutionary social change are analogous because they both exemplify the sudden transformation of quantity into quality. The great concern among scientists is that we are fast approaching just such a tipping point regarding global climate. In the social

realm, the great concern among many other people is that we are not approaching just such a corresponding social upheaval fast enough to prevent us from going beyond a systemic breakdown in a stable global climate.

To end the contradiction between humanity and nature requires “something more than mere knowledge. It requires a complete revolution in our hitherto existing mode of production, and simultaneously a revolution in our whole contemporary social order.” To truly end the exploitation of nature in the service of profit requires that the profit motive be excised from society in a revolutionary reconstitution by the majority on whose labour the system depends. The right to privately own the land and the means of production, which lies at the very root of capitalist economics and forces the population at large to work for a living at the behest of private capital, must be abolished. Only by holding land, along with the instruments of production, in common and producing to meet the social needs will the simultaneous exploitation of nature and humanity end. Only then can we interact with nature according to a conscious plan, utilizing the scientific knowledge and technique that we already possess to organize production and distribution on a completely new footing that thus establishes a more harmonious relationship between humanity and nature. The methodology developed and used by Marx and Engels offers insightful clues as to how to do that.

4.4 Socialist ecological thought since Marx

Marxism is a science, not a religion. As such it is a continually evolving body of thought, adapting, and learning from new situations and knowledge. It is no surprise therefore to learn that several Marxists and socialists have made significant contributions to ecological thought.

The term “biosphere,” encompassing the entirety of an open system that supports all life and its interaction with the atmosphere and the energy coming from the sun, was coined in the 1920s by a leading scientist of the Bolshevik Soviet government, Vladimir Vernadsky. Vernadsky was one of the very first in a prophetic speech in 1922 to warn of the dangers of the misuse of atomic power. In 1926 Vernadsky published *The Biosphere*. This was before Soviet science became intensely productivist, anti-ecological and, in some important and notorious episodes, anti-scientific.

Well before James Lovelock’s rather mystical notions of Gaia and the earth as a self-regulating living organism, Vernadsky, in echoes of Marx, wrote in his book of the essential link and interconnection between all biotic and abiotic matter in shaping the earth:

Life is, thus, potently, and continuously disturbing chemical inertia on the surface of our planet. It creates colours and forms of nature, the associations of animals and plants, and the creative labour of civilized humanity, and becomes a part of the diverse chemical processes of the earth's crust. There is no substantial chemical equilibrium on the crust in which the influence of life is not evident, and in which chemistry does not display life's work. Life is, therefore, not an external or accidental phenomenon of the earth's crust. All living matter can be regarded as a single entity in the mechanism of the biosphere.

Here the biosphere, encompassing all living and nonliving matter, is the system, human society is an interacting sub-system of that, and the economy a subsystem of human society, even if the key one through which society evolves. For conventional economists it is the exact reverse: the economy is the system; human society, and, to the extent that the biosphere is even considered, are both subsystems. This reversal gives rise to the idea, essential under capitalism, that the economy can expand without limits, that capitalism is a *boundless* system. That this runs counter to the physical and biological laws of the universe goes without acknowledgement. The capitalist economy runs as a perpetual motion machine, the practical possibility of which was discredited in the nineteenth century with the enunciation of the First and Second Laws of Thermodynamics. Nevertheless, to continue, it requires a belief system that suspends knowledge of those very laws even as it utilizes them in other spheres of scientific endeavour. Hence the entirely necessary but nonsensical notion under capitalism: the economy is essentially independent of nature.

The reason I bring up these examples is to illustrate that a central preoccupation of socialists, beginning with Marx and Engels, but including scientists and leading Bolsheviks from the 1920s among others, has been our relationship to the environment. Socialists have made serious and fundamental contributions to ecological or "green" thought and practice. In addition, socialists were thinking along these lines and were able to make these contributions precisely *because* they were socialists. Marxism provides by far the best framework for understanding the concept of sustainability.

This is in contrast with much of green thought that for far too long has neglected the issue of class and the nature of the economic system. Many people truly concerned with environmental degradation and global warming view sustainability through the lens of individual responsibility working within the system to reduce one's carbon footprint, biking to work, not eating meat,

making sure to recycle, or not drinking bottled water. There is a focus on individual lifestyle changes to show in practice what an alternative, more sustainable life would look like and prefigure a sustainable world, one person at a time.

Let Us Sum Up

Nature and society cannot be seen as opposed but should co-develop with one another as natural history and human history become different aspects of the same thing. For Marx, it was necessary to heal the “metabolic rift,” to use his term, created between humanity and nature by capitalism.

Glossaries

Environment: All the physical surroundings on Earth are called the environment. The environment includes everything living and everything nonliving. ... People, animals, plants, and all other living things rely on the nonliving parts of the environment to survive.

Karl Marx: Karl Marx (1818-1883) was a philosopher, author, social theorist, and economist. He is famous for his theories about capitalism and communism.

Metabolism: Marx used the term ‘metabolism’: a chain of processes linked to each other, as one body.

Check Your Progress

1. Who is Karl Marx?

   Answer: Karl Marx (1818-1883) was a philosopher, author, social theorist, and economist. He is famous for his theories about capitalism and communism.

2. Write the importance of the environment?

   Answer: The natural environment gives us a wealth of services that are difficult to measure in dollars. Natural areas help clean our air, purify our water, produce food and medicines, reduce chemical and noise pollution, slow floodwaters, and cool our streets.

3. Who are the common accusations in Marxism?

   Answer: There are two common accusations against Marxism regarding the environment, from right-wingers and some green activists, as well as from part of the left. The first is that Karl Marx had an overly positive view of industrialisation and saw nature as an unlimited source to be exploited. The second is that Marxism bears the responsibility for some

of the worst ecological catastrophes, in the Soviet Union.

Books for Reference

1. Environmental Geography, (2007), H.M. Saxena, Rawat Publications, New Delhi.
2. Environmental Geography, (2012), Savindra Singh, Prayag Pustak Bhawan, Allahabad.
3. Evolution of Geographical Thought, (2012), Majid Husain, Rawat Publications, New Delhi.
4. Fundamentals of Human geography, L.R. Singh, Sharada Pustak Bhawan, Allahabad.

Suggested Online Readings

1. https://www.uv.mx/personal/fpanico/files/2011/04/AA.-VV.-Environmental-geography.pdf
2. https://gacbe.ac.in/pdf/ematerial/18BGE43C-U1.pdf
3. https://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_Structure/S000017GE/P001784/M027052/ET/1517479304DeterminisminGeography.pdf
4. https://rgu.ac.in/wp-Structure/uploads/2021/02/Download_593.pdf

UNIT 5

Components: Ecosystem (Geographic Classification) and Human Ecology

Structure

5.1 Overview

An Ecosystem can simply be defined as a system, comprising all living organisms existing with one another in a unit of space interacting with abiotic components. Ecosystems can be any size. A small pond in a forest is an ecosystem, and the entire forest is an ecosystem. A single farm is an ecosystem, and a rural landscape is an ecosystem. Villages, towns and large cities are ecosystems. A region of thousands of square kilometres is an ecosystem, and the planet Earth is an ecosystem.

Ecology is the science of relationships between living organisms and their environment. Human ecology is about relationships between people and their environment. In human ecology, the environment is perceived as an ecosystem. An ecosystem is everything in a specified area - the air, soil, water, living organisms and physical structures, including everything built by humans. The living parts of an ecosystem - microorganisms, plants and animals (including humans) - are its biological community

Learning Objectives

After reading this unit, you will learn the following

- Meaning, Concept, Functions, Classification and the General characterization of ecosystem functions.
- Human Ecology, The Nature, Scope, Human Ecology as a unique field of geography and Applications of Human Ecology

5.2 What is an Ecosystem?

Eco' means 'environment', and 'system' means 'functional unit'. The ecosystem is considered as an interactive system where Components of the Ecosystem interact with each other via energy exchange and flow of nutrients. The study of ecosystems is called ecology. Living things like plants interact with other nonliving things like wind, water, etc., to maintain a balance in nature. An ecosystem consists of the biological community that occurs in some locale and the physical and chemical factors that make up its non-living or abiotic environment. There are many examples of ecosystems -- a pond, a forest, an estuary, and grassland. The boundaries are not fixed in any objective way, although sometimes they seem obvious, as with the shoreline of a small pond. Usually, the boundaries of an ecosystem are chosen for practical reasons having to do with the goals of the study. The study of ecosystems mainly consists of the study of certain processes that link the living, or biotic, components to the non-living, or abiotic, components. The two main processes that ecosystem scientists' study are Energy transformations and biogeochemical cycling. As we learned earlier, ecology generally is defined as the interactions of organisms with one another and with the environment in which they occur. We can study ecology at the level of the individual, the population, the community, and the ecosystem.

In ecosystem ecology we put all of this together and, in so far as we can, we try to understand how the system operates. This means that, rather than worrying mainly about particular species, we try to focus on major functional aspects of the system. These functional aspects include such things as the

amount of energy that is produced by photosynthesis, how energy or materials flow along with the many steps in a food chain, or what controls the rate of decomposition of materials or the rate at which nutrients (required to produce new organic matter) are recycled in the system**.**

5.2.1 Functions of an Ecosystem

The ecosystem is a self-regulatory and self-sustaining structural and functional unit of landscape (biosphere) consisting of a community of living beings and the physical environment, both interacting and exchanging materials between them. A.G. Tansley (1935) coined the term ecosystem.

Ecosystems are divisible into two categories, terrestrial or land ecosystems (*e.g*., forests, grasslands, deserts, gardens) and aquatic or water ecosystems (*e.g*., ponds, lakes, streams, estuaries, sea).

The man-made ecosystem is the one that is created and maintained by human beings, *e.g*., agriculture, garden, aquarium, spacecraft. Agriculture or agroecosystem is the largest man-made ecosystem.

Structure Of Ecosystem

The interaction of biotic and abiotic components results in the physical structures that are characteristic of each type of ecosystem. These are:

- Species composition: Identification and enumeration of plant and animal species of an ecosystem give its species composition. Maximum species composition occurs in tropical rainforest and coral reefs.
- Stratification: It is the formation of vertical layers where vegetation is dense, *e.g.,* 5 – 7 strata in tropical rain forests. Stratification is absent or rare in deserts.
- Trophic structure: Trophic structure of an ecosystem is a type of producer-consumer arrangement, in which each food level is called a trophic level. Each ecosystem has specific food chains and food webs, *e.g.*, the grazing food chains in grassland.
- Standing crop: It is the amount of living biomass present in a unit area of an ecosystem.
- Standing state: It is the number of inorganic nutrients present at any time in the soil/water of the ecosystem. It tends to vary from season to season and ecosystem to ecosystem.

Functions of Ecosystem

Four important functional aspects of the ecosystem are productivity, decomposition, energy flow and nutrient cycling.

Productivity

It refers to the rate of biomass production by any trophic level per unit area in unit time. It is measured as weight (*e.g.*, g/m2/yr) or energy (*e.g.*, kcal/m2/yr). It is of the following types:

Primary productivity: It is the amount of biomass or organic matter produced per unit area over a period by plants during photosynthesis. It is further divided into gross primary productivity and net primary productivity.

The rate of production of total organic matter by green plants by photosynthesis per unit area per unit time is known as gross primary productivity (GPP). A considerable amount of GPP is utilized by plants in respiration (R). The energy left after respiration and stored as organic matter in the producers per unit time and area is called net primary productivity (NPP).

$$NPP = GPP - R$$

Secondary productivity refers to the rate of assimilation of organic matter at the level of consumers. It is the amount of energy available at the consumer level for transfer to the next trophic level.

Decomposition

It is the physical and chemical breakdown of complex organic remains (detritus) with the help of organisms called decomposers. The processes involved are fragmentation, catabolism and leaching.

Detrivores (*e.g.*, termites, earthworms) feed on large pieces, and smaller fragments are left. Pulverisations occur in the digestive tract of animals as a part of it comes out undigested. The process is called fragmentation. The decomposers (*e.g.*, bacteria, fungi) excrete digestive enzymes over the detritus.

It changes insoluble complex organic substances into simple and soluble organic compounds and inorganic substances (catabolism). Soluble substances formed during decomposition are subjected to leaching or passage to deeper layers of soil/groundwater by percolating water.

Humification leads to the formation of a dark-coloured amorphous substance called humus, rich in cellulose and lignin. It is highly resistant to microbial action and undergoes decomposition at an extremely slow rate. Humus is further degraded by some microbes and the release of inorganic nutrients occurs by the process of mineralisation.

Decomposition is dependent on oxygen availability. It also depends on the chemical composition of detritus and climatic conditions. Decomposition is faster when detritus is rich in nitrogen and sugars than when detritus is rich in lignin and chitin. A warm and moist environment favours decomposition.

Energy flow

Sun is the ultimate source of energy in all ecosystems.

Of the incident solar radiation, less than 50 per cent of it is photosynthetically active radiation (PAR). Plants and photosynthetic and chemosynthetic bacteria (autotrophs), fix the sun's radiant energy to make food from simple inorganic materials. Plants capture only 2-10 per cent of the PAR and this small amount of energy sustains the entire living world.

The flow of energy takes place from producers to different consumers in an ecosystem which constitutes different trophic levels.

Food Chain

A food chain involves a nutritive interaction between the living organisms (biotic components) of an ecosystem. Here occurs repeated eating *i.e.*, each group eats the other and is subsequently eaten by some other group of organisms. The number of steps in a food chain is limited to four or five and at each step, a large portion of the energy is lost as heat. In a food chain, there is a unidirectional flow of energy. There is a transfer of 10% energy from one trophic level to another. This is called the 10% law formulated by Lindemann in 1942.

The Food web is a network of food chains that become interconnected at various trophic levels to form several feeding connections amongst the different organisms of a biotic community.

An ecological pyramid is a graphical representation of ecological parameters like biomass, energy and the number of individuals present in the various trophic levels of a food chain with producers forming the base and top carnivores the tip. Ecological pyramids were developed by Charles Elton (1927) and are therefore also known as Estonian pyramids.

Calculations of energy Structure, biomass, or numbers must include all organisms at that trophic level. No generalizations will be true if few individuals are considered at any trophic level account.

A given species may occupy more than one trophic level in the same ecosystem at the same time; for example, the sparrow is a primary consumer when it eats seeds, fruits peas, and a secondary consumer when it eats insects worms.

There are certain limitations of ecological pyramids such as it does not consider the same species belonging to two or more trophic levels. It assumes a simple food chain, something that rarely exists in nature, it does not accommodate a food web. Moreover, saprophytes are not given any place in ecological pyramids even though they play a vital role in the ecosystem.

(iv) Nutrient cycling: Biogeochemical cycles or nutrient cycles are cyclic exchanges, transfer, and storage of biogenetic nutrients through various components of the ecosystem (biotic and abiotic) so that the nutrients can be used repeatedly again and again. The reservoir pool and cycling pool are two stores of nutrients. The reservoir pool is the reservoir of biogenetic nutrients from which the nutrients are transferred to the cycling pool.

Ecological Succession

Ecological succession is the observed process of changes in the species structure of an ecological community over time. The first group of organisms established during an ecological succession are known as the pioneers, primary community, or primary colonisers. The climax community is the stable, self-perpetuating, and final biotic community that develops at the end of biotic succession and is in perfect harmony with the physical environment. Climax community has maximum diversity and niche specialization. The various biotic communities that develop during biotic succession are termed seral or transitional communities.

Primary succession starts from the primitive substratum, on a previously sterile or primarily bare area. Secondary succession starts from the previously built-up substrate with already existing living matter. In secondary succession since the soil is already there, the rate of succession is much faster and hence, the climax is also reached more quickly.

Hydrosere (hydrarch) refers to the biotic succession in a newly formed pond or lake. The stages that occur in hydrosere are the Plankton stage, rooted submerged stage, rooted floating stage, free-floating stage, reed swamp stage, sedge or marsh meadow stage, woodland stage, climax forest stage.

Xerosere (xerarch) refers to the succession that occurs at places where moisture is present in minimal amounts such as deserts, rocks, etc. _e stages that occur in xerosere are crustose lichen stage, foliose lichen stage, moss stage, herb stage, shrub stage, forest stage.

Ecosystem Services

Healthy ecosystems are the base for a wide range of economic, environmental, and aesthetic goods and services. The products of ecosystem processes are thus named ecosystem services, for example, healthy forest ecosystems purify air and water, mitigate droughts and floods, recycle nutrients, generate fertile soils, provide habitat to wildlife, maintain biodiversity, pollinate crops, provide storage site for carbon, and also provide aesthetic, cultural and spiritual values.

5.2.2 Concept of an Ecosystem

The term 'ecosystem' was coined in 1935 by the Oxford ecologist A.G. Tansley to encompass the interactions among biotic and abiotic components of the environment at a given site. The living and non-living components of an ecosystem are known as biotic and abiotic components, respectively.

The ecosystem was defined in its presently accepted form by Eugene Odum as, "a unit that includes all the organisms, i.e., 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, i.e., exchange of materials between living and non-living, within the system".

According to thermodynamic principles, a system is an integral part of the universe, and it is separated by a boundary from the rest. For example, the human body is a system. Thermodynamically system can be of three types

Isolated system: in this system, there is neither an exchange of energy nor matter with the environment.

Closed system: Here exchange of energy took place but no matter.

Open system: Here exchange of both energy and matter took place.

5.2.3 Classification of ecosystem

Natural ecosystem: These are ecosystems that occur naturally and can survive without any intervention from human beings. Examples of natural ecosystems are forests, mountains, rivers etc. Natural ecosystems can be as small as an oasis in a desert, or as big as an ocean, spanning thousands of miles.

There are two types of ecosystems:

- Terrestrial Ecosystem
- Aquatic Ecosystem

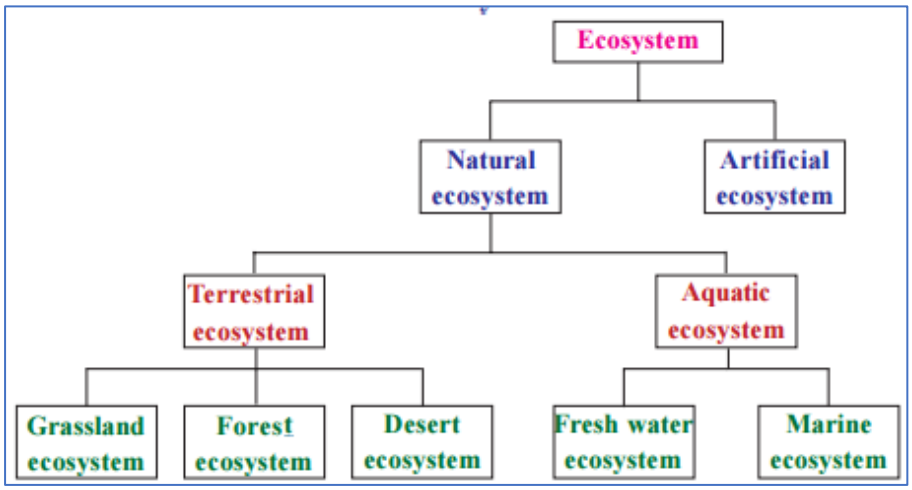

Fig. 5.9 Ecosystem Classification flow chart

Terrestrial Ecosystems

Since there are numerous different kinds of places on Earth, terrestrial ecosystems are many. Shall we explore some of the most common terrestrial ecosystems you can come across?

The Forest Ecosystems: In forest ecosystems, a massive number of organisms can live in small spaces. These are ecosystems in which you find a lot of flora. It suffices to say that the density of living organisms in forest ecosystems is high. A slight change in the forest ecosystem can affect the entire balance, effectively killing the whole ecosystem. These ecosystems also feature a wide range of fauna. They can further be divided into Tropical evergreen forest, tropical deciduous forest, temperate evergreen forest, temperate deciduous forest, and Taiga.

The Desert Ecosystem: Desert ecosystems fall within regions that receive an annual rainfall not more than 25mm. The Earth is made of about 17 per cent desert ecosystem. These ecosystems are characterized by intense sunlight, extremely high temperatures, and low availability of water. Flora and fauna are not only rare but also poorly developed. The plants feature stems and leaves that are modified in a bid to conserve as much water as possible. For instance, some common desert plants have succulent stems to store water, such as the spiny-leafed cactus. Animals in this ecosystem are also adapted to various conditions that prevail in desert environments. The animals include reptiles, camels, birds, and insects.

The Grassland Ecosystem: Grassland ecosystems can be found in both the temperate and tropical regions across the globe, but with slight variations. These ecosystems mainly comprise grasses with a few trees and shrubs. Grasses are the main vegetation here, along with legumes, which

belong to the composite family. The grassland ecosystem is also home to a variety of grazing animals, herbivores, and insectivores. This ecosystem is further divided into savanna and prairies ecosystems.

The Mountain Ecosystem: Mountain land offers a dispersed and diverse range of habitats where various plants and animals can be found. The higher altitudes are characterized by harsh environmental conditions, which can only support the lives of treeless alpine vegetation. The animals found in this habitat have thick fur coats, which protect them from cold. At the lower slopes of the mountain environment, we mostly have coniferous forests.

Tundra Ecosystem: Tundra ecosystems are devoid of trees and are found in cold climates or where rainfall is scarce. These are covered with snow for most of the year. The ecosystem in the Arctic or mountain tops is tundra type.

Aquatic Ecosystem

Aquatic ecosystems are ecosystems present in a body of water. These can be further divided into two types, namely:

Freshwater Ecosystem: The freshwater ecosystem is an aquatic ecosystem that includes lakes, ponds, rivers, streams and wetlands. These have no salt Structure in contrast with the marine ecosystem. The freshwater ecosystem is one of the essential ecosystems for humans and other organisms living on land. This is because this ecosystem is a source of drinking water. Additionally, it also helps in providing the necessary energy and water for transportation, recreation, etc. Freshwater ecosystems mainly include lentic, lotic, and wetlands.

Lentic*:* Water bodies that are moving slowly or are still in some places come under lentic. For example, ponds, lakes, pools, etc. Lakes are known as large water bodies and are surrounded by land.

Lotic: Water bodies that are moving at a fast-paced fall under a lotic. For example, streams and rivers.

Wetlands: Environments characterized by soils saturated with water for a long time fall under wetlands.

The freshwater ecosystem is the smallest type of ecosystem among the major types of ecosystems. There is usually no salt Structure in the freshwater ecosystem. Besides, it consists of many insects, small fish, amphibians, and various plant species. Plants help provide oxygen through photosynthesis and provide food for the organisms living in this ecosystem.

Marine / Oceanic Ecosystems

Covering about 71 per cent of Earth's surface and containing about 97 per cent of all the Earth's water, the ocean ecosystem is certainly the largest. Water in this ecosystem is characterized by high amounts of dissolved salts and minerals. Oceanic or marine ecosystems are divided into three main categories: deep waters, shallow waters, and deep ocean surface. Just like in freshwater ecosystems, the plankton is the basis of the oceanic ecosystem's food chain. The plankton and other plants that grow in marine ecosystems account for about 40 per cent of all photosynthesis that takes place on Earth.

5.2.4 Artificial ecosystem

An artificial ecosystem is a human-made system of plants, animals, and people living in an area together with their surroundings. Deserts, forests, and oceans are a few examples of naturally occurring ecosystems. Examples of artificial ecosystems are-Aquariums, crop fields, dams, gardens, zoos, parks, etc

Structure of the Ecosystem

The structure of an ecosystem is characterised by the organisation of both biotic and abiotic components. This includes the distribution of energy in our environment. It also includes the climatic conditions prevailing in that environment. The structure of an ecosystem can be split into two main components, namely:

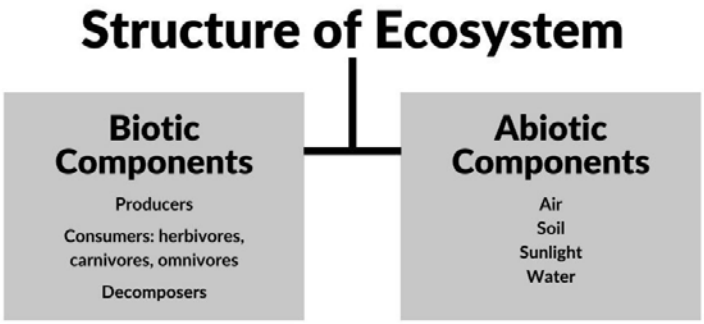

Fig. 5.9 Structure of Ecosystem

The biotic and abiotic components are interrelated in an ecosystem. It is an open system where the energy and components can flow throughout the boundaries.

Biotic (Living Components)

Biological components refer to all living organisms in the ecosystem. These components typically include organisms such as animals, plants, humans,

and other microorganisms. Based on different nutrition, biological components are classified into the following three categories:

Producers or Autotrophs: The green plants have chlorophyll with the help of which they trap solar energy and change it into chemical energy of carbohydrates using simple inorganic compounds namely water and carbon dioxide. This process is known as photosynthesis. As the green plants manufacture their food they are known as Autotrophs (i.e., auto = self, Trophos = feeder).

The chemical energy stored by the producers is utilised partly by the producers for their growth and survival and the remaining is stored in the plant parts for their future use. Autotrophs can be of two types:

Phototrophs: They derive their energy from the Sun – the primary source of energy on the planet. These are the green plants that make their food through the process of photosynthesis.

Chemotrophs: They obtain their energy from chemicals through a process called chemosynthesis and can make their food. Example: Cyanobacteria

Consumers or Heterotrophs: Consumers, also known as heterotrophs, include organisms that depend on other organisms for their food needs. Consumers are divided into primary, secondary, tertiary, and quaternary consumers. The consumers are of four types, namely:

Primary Consumers or First Order Consumers or Herbivores: These are the animals that feed on plants or the producers. They are called herbivores. Examples are rabbit, deer, goat, cattle etc.

Secondary Consumers or Second-Order Consumers or Primary Carnivores: The animals which feed on the herbivores are called the primary carnivores. Examples are cats, foxes, snakes etc.

Tertiary Consumers or Third Order Consumers: These are the large carnivores that feed on the secondary consumers. Examples are Wolves.

Quaternary Consumers or Fourth Order Consumers or Omnivores: These are the largest carnivores that feed on the tertiary consumers and are not eaten up by any other animal. Examples are lions and tigers.

Decomposers or Detritus: Decomposers are also known as detritus or saprophytes. These include microbes such as fungi and bacteria. They break down the dead organic materials of producers (plants) and consumers (animals) for their food and release to the environment the simple inorganic and organic substances produced as by-products of their metabolisms.

These simple substances are reused by the producers resulting in a cyclic exchange of materials between the biotic community and the abiotic environment of the ecosystem. The decomposers are known as Saprotrophs (i.e., approx = rotten, Trophos = feeder).

Abiotic (Non-living Components)

Abiotic components refer to all non-living elements and compounds in the ecosystem, including climates and climate components. Furthermore, the abiotic components are the primary sources of energy and nutrients and set the stage for proper ecosystem functioning.

The Sun is the primary source of energy for an ecosystem. Other examples of abiotic components are light, humidity, temperature, gas, water, air, minerals, soil, topography, and various habitats.

Temperature	Affects the kinetic of enzymes and through its basal metabolism, activity and other physiological functions of the organism. The level of thermal tolerance determines the geographical distribution of an organism. **Eurythermal** (Organism that can tolerate a wide range of temperature) **Stenothermal** (Organism that is restricted to a narrow range of temperature)
Water	The productivity and distribution of plants are heavily dependent on water. **Euryhaline**– Organism that can tolerate a wide range of salinities (Note: Salt concentration measured in parts per thousand) **Stenohaline**– Organism that is restricted to a narrow range of salinities. Many freshwater animals can't live for long in seawater and vice versa due to osmotic problems.

Light	**For Plants:** Photosynthesis **+** Photoperiodic requirement for flowering. **For Animals:** Diurnal and seasonal variation in light, intensity and duration (photoperiod) determines animals' foraging, reproductive and migratory activities. UV component of the spectrum is harmful to many organisms. Not all the colour components of the visible spectrum are available for marine plants living at different depths of the ocean. E.g., red, green, brown algae inhabit the sea at different depths.
Soil	**Vegetation in any area is determined by-** Soil composition, Percolation and Grain size, Water holding capacity. **Aggregation of soil are determined by:** PH**,** Mineral composition, Topography.

5.2.5 General characterization of ecosystem functions

Regulatory functions: this group of functions relates to the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems through biogeochemical cycles and other biospheric processes. In addition to maintaining the ecosystem (and biosphere health), these regulatory functions provide many services that have direct and indirect benefits to humans (i.e., clean air, water and soil, and biological control services).

Habitat functions: natural ecosystems provide refuge and a reproduction habitat to wild plants and animals and thereby contribute to the (in situ) conservation of biological and genetic diversity and the evolutionary process.

Production functions: Photosynthesis and nutrient uptake by autotrophs convert energy, carbon dioxide, water and nutrients into a wide variety of carbohydrate structures which are then used by secondary producers to create an even larger variety of living biomass. This broad diversity in carbohydrate structures provides many ecosystem goods for human consumption, ranging from food and raw materials to energy resources and genetic material.

Information functions: Since most of the human evolution took place within the context of an undomesticated habitat, natural ecosystems contribute to the maintenance of human health by providing opportunities for reflection, spiritual enrichment, cognitive development, recreation and aesthetic experience.

5.3 Human Ecology

Ecology (from the Greek “Oikos” meaning "house" or "dwelling", and “logos” meaning "to study") is the study of the interactions of organisms with each other and their environment. The term “Ecology” was introduced by Ernst Haeckel (German scientist) in 1869 and involves the study of interactions as well as interrelationships amongst organisms and their environment. The environment is made up of lithosphere, hydrosphere, and atmosphere. Since ecology involves the study of relations of living organisms with the environment, it is also known as environmental biology

Ecology is the science that deals with the relationships between living organisms with their physical environment and with each other. Ecology can be approached from the viewpoints of (1) the environment and the demands it places on the organisms in it or (2) organisms and how they adapt to their environmental conditions. An ecosystem consists of an assembly of mutually interacting organisms and their environment in which materials are interchanged in a largely cyclical manner. An ecosystem has physical, chemical, and biological components along with energy sources and pathways of energy and materials interchange. The environment in which a particular organism life is called its habitat. The role of an organism in a habitat is called its niche.

For the study of ecology, it is often convenient to divide the environment into four broad categories.

Terrestrial environment - The terrestrial environment is based on land and consists of biomes, such as grasslands, one of several kinds of forests, savannas, or deserts.

Freshwater environment - The freshwater environment can be further subdivided between standing-water habitats (lakes, reservoirs) and running-water habitats (streams, rivers).

Oceanic marine environment - The oceanic marine environment is characterized by saltwater and may be divided broadly into the shallow waters of the continental shelf composing the neritic zone

Oceanic region - The deeper waters of the ocean that constitute the oceanic region.

Major subdivisions of modern ecology

Ecosystem ecology - which views ecosystems as large units, and

Population ecology - which attempts to explain ecosystem behaviour from the properties of individual units.

In practice, the two approaches are usually merged. Descriptive ecology describes the types and nature of organisms and their environment, emphasizing structures of ecosystems and communities and dispersions and structures of populations. Functional ecology explains how things work in an ecosystem, including how populations respond to environmental alteration and how matter and energy move through ecosystems.

5.3.1 The Nature of Human Ecology

Human ecology is a relatively current development; the first use of the term in the literature was in 1921. The first book with the title ecology appeared in 1935 and interestingly was the work of a botanist. In this brief period, the discipline of ecology has evolved quite rapidly. When concerned with human ecology one can relate to Mackenzie's (1931) definition which states that Human ecology deals with the spatial aspects of the symbiotic relations of human beings and human institutions.

Human ecology, in so far as it is concerned with a social order that is based on competition rather than consensus, is identical, in principle at least, with plant and animal ecology. Society, as ecologists have conceived it, is a population settled and limited to its habitat. The ties that unite its units are those of a free and natural economy, based on a natural division of labour. Such a society is territorially organized and the ties which hold it together are physical and vital rather than customary and moral, Human ecology has, however, to reckon with the fact that in human society competition is limited by custom and culture.

The cultural superstructure imposes itself as an instrument of direction and control upon the biotic substructure. Reduced to its elements the human community, so conceived, may be said to consist of a population and a culture, including in the term culture (i) a body of customs and beliefs and (2) a corresponding body of artefacts and technological devices. To these three elements or factors-(i) population, (2) artefact (technological culture), (3) custom and beliefs (non-material culture) -into which the social complex resolves itself, one should, perhaps, add a fourth, namely, the natural

resources of the habitat. It is the interaction of these four factors-(i) populations, (2) artefacts (technological culture), (3) custom and beliefs (non-material culture), and (4) the natural resources that maintain at once the biotic balance and the social equilibrium, when and where they exist. The changes in which ecology is interested are the movements of population and artefacts (commodities) and changes in location and occupation-any sort of change that affects an existing division of labour or the relation of the population to the soil. Human ecology is, fundamentally, an attempt to investigate the processes by which the biotic balance and the social equilibrium (i) are maintained once they are achieved and (2) the processes by which, when the biotic balance and the social equilibrium are disturbed, the transition is made from one relatively stable order to another.

Several human geographers accept the definition of human ecology as the study of mutual relations between men and the environment, but in practice, they have limited its application to a specialized field of geographic study. Some geographers-for example, Barrows, Renner, and White make human ecology synonymous with human geography. Barrows, the first geographer to publish this point of view, has written as follows: . . .the centre of gravity within the geographic field has shifted steadily from the extreme physical side toward the human side until geographers in increasing numbers define their subject as dealing solely with the mutual relations between man and his environment. White and Renner, whose volume is entitled Geography, an Overview to Human Ecology, limit this field to a study of the direct relations between men or groups and their environments.

This specialized field of study investigates problems of man's relation to his environment, both individually and in groups, such as (i) the effects of climate upon human health and energy; (z) the influences of resources and topography upon human occupations, homes, institutions, and inventions; (3) influences of natural routes and barriers upon social isolation and contact; and (4) possible effects of natural surroundings upon customs, attitudes, and beliefs. Thus, these human geographers, who define human ecology as a specialized field of science, obviously disagree with Bews who regards it as an inclusive synthesis. Human ecology, like other specialized sciences may be defined and delimited in terms of the basic abstractions it makes. Human ecology abstracts (i) a distinctive type of ecological interaction and (ii) a distinctive aspect of community or regional structure that arises out of this interaction.

To sum up, human ecology may now be defined tentatively as a specialized field of analysis that investigates (i) those impersonal sub-social aspects of

communal structure- both spatial and functional-which arise and change as the result of interaction between men through the medium of limited supplies of the environment, and (ii) the nature and forms of the processes by which this sub-social structure arises and changes. The value of human ecology depends upon the validity and significance of its specialized abstractions and not upon its service in supplying indexes of social life.

5.3.2 Scope of Human Ecology

Human ecology has been defined as a type of analysis applied to the relations in human beings that was traditionally applied to plants and animals in ecology. Toward this aim, human ecologists (which can include sociologists) integrate diverse perspectives from a broad spectrum of disciplines covering wider points of view. Scopes of topics in human ecology are:

- The role of social, cultural, and psychological factors in the maintenance or disruption of ecosystems.
- Effects of population density on health, social organization, or environmental quality.
- New adaptive problems in urban environments.
- Interrelations of technological and environmental changes.
- The development of unifying principles in the study of biological and cultural adaptation.
- The genesis of maladaptations in human biological and cultural evolution.
- Genetic, physiological, and social adaptation to the environment and environmental change.
- The relation of food quality and quantity to physical and intellectual performance and demographic change.

The application of computers, remote sensing devices, and other new tools and techniques. While theoretical discussions continue, research published in Human Ecology Review suggests that recent discourse has shifted toward applying principles of human ecology. Some of these applications focus instead on addressing problems that cross disciplinary boundaries or transcend those boundaries altogether. Human ecology is neither anti-discipline nor anti-theory, rather it is the ongoing attempt to formulate, synthesize, and apply theory to bridge the widening schism between man and nature. This new human ecology emphasizes complexity over

reductionism, focuses on changes over stable states, and expands ecological concepts beyond plants and animals to include people.

5.3.3 Human Ecology as a unique field of geography

The modern scientific American geography that has recently emerged began with the splendid work of Davis, Gilbert, and a few others in physics or physical geography. It is a singular fact, which may be recalled in passing, that geography, though it is the mother of geology, has, in the recent period which has witnessed its revival in America, as a subject of higher study, been fostered by geology. In one university after another work in geography has been offered first in the Department of Geology. As this work increased, in some cases the official title of the department was changed to "Department-Geology and Geography". Hardly physical geography was established, an insistent demand arose for what is called "human geography". But as already stated human geography is different from human ecology.

Geography treats men and their activities in their visible aspects and so far, as they may be regarded as distributed phenomena. It does not concern, except incidentally, the interrelations among men. Human ecology, which is also interested in the relations of man to his geographic environment, fastens its attention upon the human interdependences that develop in the action and reaction of a population to its habitat. In other words, while geography views the adjustment of man from the standpoint of modifications of the earth's surface, human ecology makes a detailed analysis of the process and organization of relations involved in adjustment to the environment. This brings us to the second point of distinction between the two disciplines.

Geography will aim to make clear the relationships existing between natural environments and the distribution and activities of man. Geographers will, I think, be wise to view this problem in general from the standpoint of man's adjustment to the environment, rather than from that of environmental influence. The former approach is more likely to result in the recognition and proper valuation of all the factors involved, and especially to minimize the danger of assigning to the environmental factors a determinative influence which they do not exert." Further while defining geography as human ecology, he stated "geography is the science of human ecology.

Human ecology is, fundamentally, an attempt to investigate the processes by which the biotic balance and the social equilibrium (1) are maintained once they are achieved and (2) the processes by which, when the biotic

balance and the social equilibrium are disturbed, the transition is made from one relatively stable order to another. Several human geographers accept the definition of human ecology as the study of mutual relations between men and the environment, but in practice, they have limited its application to a specialized field of geographic study. Some geographers-for example, Barrows, Renner, and White make human ecology synonymous with human geography. Barrows, the first geographer to publish this point of view, has written as follows.

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This specialized field of study investigates problems of man's relation to his environment, both individually and in groups, such as (1) the effects of climate upon human health and energy; (2) the influences of resources and topography upon human occupations, homes, institutions, and inventions; (3) influences of natural routes and barriers upon social isolation and contact; and (4) possible effects of natural surroundings upon customs, attitudes, and beliefs. Thus, these human geographers, who define human ecology as a specialized field of science, obviously disagree with Bews who regards it as an inclusive synthesis. Human ecology, like other specialized sciences may be defined and delimited in terms of the basic abstractions it makes. Human ecology abstracts (i) a distinctive type of ecological interaction and (ii) a distinctive aspect of community or regional structure that arises out of this interaction.

Human ecology provides space to study spatial organization rather than areal differentiation which became a dominant doctrine within the discipline of geography. This is a positive outcome but at the same time has its shortcomings. According to Chorley (1973), the traditional ecological model is inadequate in answering the raised questions especially as it does not give man its a due place rather casts it in the role of a subordinate. Hagerstrand’s time-space geography gave recognition to this approach when he talks of “web-model of space-time interaction” where he suggests that this approach incorporates certain essential biotic and ecological predicates within human geography and seeks to bridge the gap between human and biological ecology

5.3.4 Applications of Human Ecology

1. Application to epidemiology and public health: The application of ecological concepts to epidemiology has similar roots to those of other disciplinary applications, with Carl Linnaeus having played a seminal role. However, the term appears to have come into common use in the medical and public health literature in the mid-twentieth century. This was strengthened in 1971 by the publication of Epidemiology as Medical Ecology, and again in 1987 by the publication of a textbook on Public Health and Human Ecology. An “ecosystem health” perspective has emerged as a thematic movement, integrating research and practice from such fields as environmental management, public health, biodiversity, and economic development. Drawing in turn from the application of concepts such as the social-ecological model of health, human ecology has converged with the mainstream of global public health literature.

2. Connection to home economics: In addition to its links to other disciplines, human ecology has a strong historical linkage to the field of home economics through the work of Ellen Swallow Richards, among others. However, as early as the 1960s, several universities began to rename home economics departments, schools, and colleges as human ecology programs. In part, this name change was a response to perceived difficulties with the term home economics in a modernizing society and reflects recognition of human ecology as one of the initial choices for the discipline which was to become home economics.

3. Ecosystem Services: The ecosystems of planet Earth are coupled to human environments. Ecosystems regulate the global geophysical cycles of energy, climate, soil nutrients, and water that in turn support and grow natural capital (including the environmental, physiological, cognitive, cultural, and spiritual dimensions of life). Ultimately, every manufactured product in human environments comes from natural systems. Ecosystems are considered common-pool resources because ecosystems do not exclude beneficiaries and they can be depleted or degraded. For example, green space within communities provides sustainable health services that reduce mortality and regulate the spread of vector-borne disease. Research shows that people who are more engaged with regular access to natural areas have lower rates of diabetes, heart disease and psychological disorders. These ecological health services are regularly depleted through urban development projects that do not factor in the common-pool value of ecosystems.

The ecological commons deliver a diverse supply of community services that sustains the well-being of human society. The Millennium Ecosystem Assessment, an international UN initiative involving more than 1,360 experts worldwide, identifies four main ecosystem service types having 30 subcategories stemming from natural capital. The ecological commons include provisioning (e.g., food, raw materials, medicine, water supplies), regulating (e.g., climate, water, soil retention, flood retention), cultural (e.g., science and education, artistic, spiritual), and supporting (e.g., soil formation, nutrient cycling, water cycling) services.

Let Us Sum Up

Ecology enriches our world and is crucial for human wellbeing and prosperity. It provides new knowledge of the interdependence between people and nature that is vital for food production, maintaining clean air and water, and sustaining biodiversity in a changing climate. Humans are an integral part of ecosystems. Ecosystems provide a variety of benefits to people, including provisioning, regulating, cultural, and supporting services. Provisioning services are the products people obtain from ecosystems, such as food, fuel, fibre, freshwater, and genetic resources. While healthy ecosystems clean our water, purify our air, maintain our soil, regulate the climate, recycle nutrients and provide us with food. They provide raw materials and resources for medicines and other purposes. They are at the foundation of all civilisations and sustain our economies.

Glossaries

Ecology: The science of relationships and interactions between living organisms and their environment.

Ecosystem: An ecosystem includes everything at a particular location: plants, animals, microorganisms, air, water, soil and human-built structures. Natural ecosystems are formed entirely by natural processes. Agricultural ecosystems are created by people to provide food or other materials. Urban ecosystems are dominated by human-built structures.

Energy flow: Movement of energy in the carbon chains of organic matter that passes through a food web as one organism consumes another.

Conservation: The management of human use of nature so that it may yield the greatest sustainable benefit to current generations while maintaining its potential to meet the needs and aspirations of future generations.

Abiotic: An abiotic factor is a non-living part of an ecosystem that shapes its environment.

Check Your Progress

1. Define Ecosystem

   Answer: An ecosystem is a geographic area where plants, animals, and other organisms, as well as weather and landscapes, work together to form a bubble of life

2. Write the Biotic Components?

   Answer: It includes plants and animals. Examples Water, light, wind, soil, humidity, minerals, gases. All living things - autotrophs and heterotrophs - plants, animals, fungi, bacteria.

3. Who introduces the term Ecology?

   Answer: The term “Ecology” was introduced by Ernst Haeckel (German scientist) in 1869 and involves the study of interactions as well as interrelationships amongst organisms and their environment.

4. Mention the types of Aquatic ecosystems?

   Answer: There are two types, Freshwater, and Oceanic/Marine ecosystem

5. Write about the natural ecosystem?

   Answer: There are two types of the natural ecosystem, Terrestrial Ecosystem and Aquatic Ecosystem.

Books for Reference

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Suggested Online Readings

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UNIT 6

Functions: Trophic Levels, Energy Flows

Structure

6.1 Overview

All organisms need the energy to perform essential functions such as maintenance, growth, repair, movement, locomotion, and reproduction; all these processes require energy expenditure. The ultimate source of energy for all ecological systems is Sun. The solar energy is captured by the green plants (primary producers or autotrophs) and transformed into chemical energy and bound in glucose as potential energy during the process of photosynthesis. In this stored form, other organisms take the energy and pass it on further to other organisms. During this process, a reasonable proportion of energy is lost out of the living system. The whole process is called the flow of energy in the ecosystem. It is the amount of energy that is received and transferred from organism to organism in an ecosystem that modulates the ecosystem structure. Without autotrophs, there would be no

energy available to all other organisms that lack the capability of fixing light energy.

A fraction i.e., about 1/50 millionth of the total solar radiation reaches the earth's atmosphere. About 34% of the sunlight reaching the earth's atmosphere is reflected into the atmosphere, 10% is held by the ozone layer, water vapours and other atmospheric gases. The remaining 56% of sunlight reaches the earth's surface. Only a fraction of this energy reaching the earth's surface (1 to 5%) is used by green plants for photosynthesis and the rest is absorbed as heat by ground vegetation or water. Only about 0.02 % of the sunlight reaching the atmosphere is used in photosynthesis. Nevertheless, it is this small fraction on which all the organisms of the ecosystem depend.

To understand the flow of energy within a food chain, let us consider a food chain:

Plant ⟶ Rabbit ⟶ Fox

When organic matter is produced by the green plants, some of it is oxidized or burnt inside their body and converted into carbon dioxide which is released during respiration (R) and is accompanied by loss of energy. Now the producers are left with a little less organic matter than what was produced by them. This is known as net primary production (NPP) and respiratory loss added to it is called gross primary production (GPP). Thus,

$$NPP = GPP - R$$

A rabbit (or a population of rabbits) ingests plant material, which is called ingestion. A part of this plant material is processed and used to make new cells or tissues in the body of rabbits, and this part is called assimilation. What cannot be assimilated, for example, some parts of the plant stems or roots, exit the rabbit's body, this is called excretion. Thus, we can calculate assimilation from the following equation:

$$Assimilation = Ingestion - Excretion$$

The efficiency of assimilation is different in organisms, ranging from 15-50% if the food is plant material, and from 60-90% if the food is animal material.

The rabbit uses a significant fraction of the assimilated energy in metabolic activities such as maintaining body temperature, protein synthesis, etc. This energy used (lost) is attributed to cellular respiration. The rest of the energy goes into making biomass of rabbits by growth and reproduction. In the food chain, a rabbit is consumed by a fox. The energy available to foxes that eat

the rabbits is known as the secondary production of rabbits. It is evident that much of the energy is used in normal metabolic activities of rabbits; the energy available to foxes is much less as compared to the energy available to rabbits. The efficiency with which an organism converts assimilated energy into primary or secondary production is called net production efficiency. This efficiency is equal to the production divided by the assimilation for animals, or the NPP divided by GPP for plants. The production here refers to growth plus reproduction.

The following points should be considered for a complete understanding of the flow of energy in an ecosystem:

- Efficiency of producers in absorption and conversion of solar energy into chemical energy
- Use of this chemical energy by the consumers
- Total input of energy in the form of food and its efficiency of assimilation
- The loss through respiration, heat, excretion etc. and
- The gross net production.

Learning Objectives

After reading this unit, you will learn about the functions of Energy flow and the Tropic level.

6.2 Ecosystem Thermodynamics

The laws of thermodynamics are elemental doctrine and theories to all the chemical processes taking place on earth. The laws state how the energy is transformed from one form to another. These apply to the flow of energy in the ecosystems.

a) The first law of thermodynamics, also known as energy-mass conservation law, states that neither energy nor matter can be created or destroyed, but it can be transformed from one form to another; rather, the amount of energy lost in a steady-state process cannot be greater than the amount of energy gained. For instance, solar energy is converted into chemical energy in the process of photosynthesis. The conversion must be balanced, as expressed in Odum's model, such that the sum of all outputs is equal to the sum of inputs.

b) The second law of thermodynamics, also known as the law of entropy, states that energy dissipates as it is used, or it is converted from a more concentrated form to a dispersed form. Any change of energy from one form to another implies an irreversible loss of useful energy in form of heat, which

increases the entropy or disorder of the universe. In some systems, entropy remains constant but never decreases; only irreversible processes produce entropy. An example of the second law of thermodynamics in ecology is metabolism, in which a set of chemical reactions in an individual transforms organic matter into a more useful component. However, the cost of this conversion includes respiration, which is the energy unavailable neither to the individuals nor to others in the food web. This shows that as the energy flows through the food chain, there occurs dissipation of energy at every trophic level. The loss of energy takes place through respiration, loss of energy in locomotion, running, hunting and other activities. At every level there is about 90% loss of energy and the energy transferred from one trophic level to the other is only about 10%.

6.3 Energy Flow Models

The energy flow models link the trophic levels with each other showing the inputs and losses of energy at each trophic level. Lindeman (1942) was the first to propose such a model assuming that plants and animals can be arranged into trophic levels and the laws of thermodynamics hold for plants and animals. He emphasized that the amount of energy at the trophic level is determined by the net primary production and the efficiency at which food energy is converted into biomass. After that, various models depicting energy flow in ecosystems are described below:

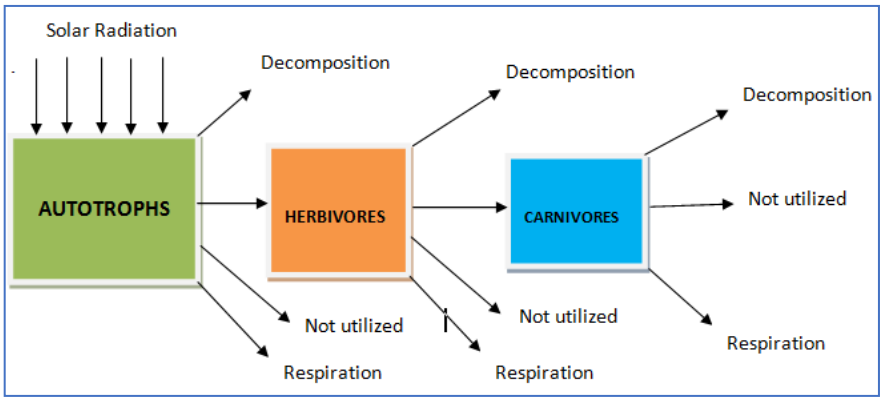
6.3.1 Single Channel Energy Flow Model

The flow of energy in an ecosystem takes place through the food chain and it is this energy flow that keeps the system going. The most common feature of this energy flow is that it is unidirectional or one-way flow or single-channel flow. Unlike the nutrients (carbon, nitrogen, phosphorus, sulphur etc.) which move cyclically and are reused by the producers after moving through the food chain, energy is not reused in the food chain. It flows from producers to herbivores to carnivores and so on. Figure 6.1 shows a simplified diagram of the Single-Channel Energy Flow Model. Two things are clear from the diagram.

Firstly, the flow of energy is unidirectional and non-cyclic. The green plants obtain energy from the sun, and it is transformed into chemical energy by the process of photosynthesis. This energy is stored in plant tissues and transformed into heat energy during metabolic activities which then passes to the next trophic level in the food chain. The solar energy captured by green plants (autotrophs) never revert to the sun, however, it passes to herbivores and that which passes to herbivores does not go back to

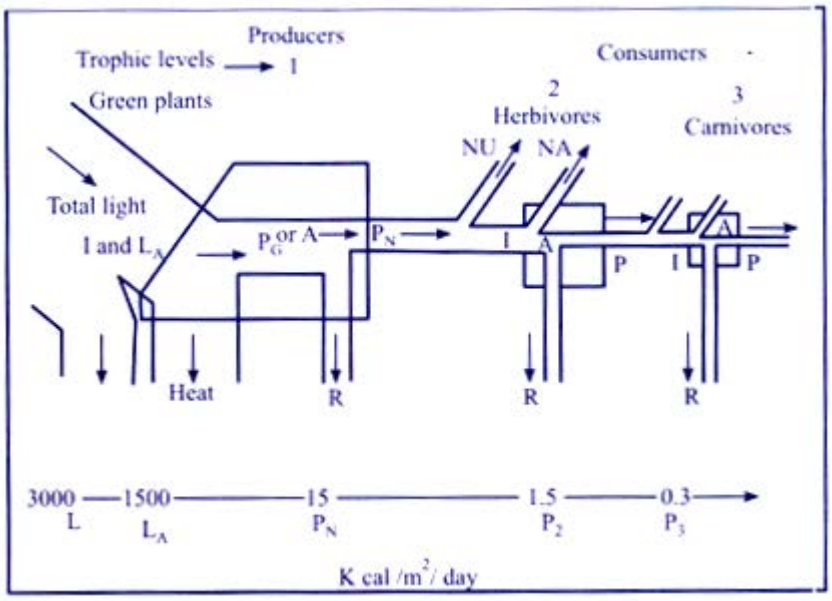
autotrophs but passes to consumers. Thus, in biological systems, the energy flows from the sun to green plants and then to all heterotrophic organisms. Due to the unidirectional flow of energy, the entire system would collapse if the primary source of energy were cut off.

Secondly, at each tropic level, there is a progressive decrease in energy as heat in the metabolic reactions and some of the energy is utilized at each tropic level.



6.1: Simplified Single Channel Energy Flow Diagram (Modified from Lindeman, 1942)

Here the boxes represent the trophic levels (producers, herbivores, and carnivores) and the pipelines depict the energy flow in and out of each trophic level. The size of the box shows energy stored in the form of biomass at that trophic level. There is a loss of energy (represented as pipes getting narrower) at every successive trophic level, there is also a corresponding decline in energy stored in standing crop or biomass (represented as decreased size of box) at the successive trophic levels. Energy inflows in the system balance the energy outflows as required by the first law of thermodynamics and each energy transfer is accompanied by loss of energy in the form of unavailable heat energy (i.e., respiration) as stated by the second law of thermodynamics. The energy flow is significantly reduced at each successive trophic level from producers to herbivores to carnivores. Thus, at each transfer of energy from one trophic level to another trophic level, a major part of the energy is lost in the form of heat or another form. There is a successive reduction in the energy flow whether we consider it in terms of total flow (I+A) or secondary productivity and respiration component.



6.2: Single Channel Energy flow model depicting three trophic levels (box 1, 2 and 3) in a linear food chain.

[I- total energy input, LA – light absorbed by plant cover, PG – gross primary production, A – total assimilation, PN – net primary production, P – Secondary production, NU – Energy not used (stored), NA – Energy not assimilated by consumers (egested), R – respiration. The bottom line in the diagram shows the order of the magnitude of energy losses expected at major transfer points, starting with a solar input of 3,000 Kcal per square meter per day. Thus, of the 3000 Kcal of total light falling upon green plants, approximately 50% is absorbed (1500 Kcal), 1% is converted at the first trophic level (15 Kcal). Thus, net primary production (PN) is 15 Kcal only. Secondary productivity (P2 and P3) tends to be about 10% at successive consumer levels, i.e., herbivores and carnivores, although efficiency maybe sometimes up to 20% at the carnivores' level (as shown in diagram P3 = 0.3 Kcal). There is a successive reduction in energy flow at successive trophic levels. Thus, the shorter the food chain, the greater would be the energy available at higher trophic levels.

6.3.2 Double Channel or Y-Shaped Energy Flow Model

The double channel or Y-Shaped energy flow model depicts the simultaneous working of grazing and detritus food chains in an ecosystem. In nature, both grazing and detritus food chains are interconnected in the same ecosystem. For example, dead bodies of small animals that were once part of the grazing food chain become incorporated in the detritus food chain as do the faeces of grazing food animals. Functionally, the distinction between the two is of the time lag between the direct consumption of living

plants and the ultimate utilization of dead organic matter. The importance of two food chains may differ in different ecosystems, in some cases, grazing is more important and in others, detritus is more important. It happens in marine ecosystems where primary production at open sea is limited and a major portion of it is eaten by herbivores marine animals. Therefore, very little primary production is left to be passed onto the detritus pathways. On the other hand, in a forest ecosystem, the huge quantity of biomass produced cannot be all consumed by herbivores and a large part of it enters the detritus compartment in the form of litter. Hence the detritus food chain is more important there. In an example given by Singh et al (2015), in a lake open water zone, the grazing food chain predominates as phytoplanktons are eaten upon by zooplankton and other organisms. On the other hand, in the lake bottom, dead organisms are deposited, and they are acted upon by detritus feeders and decomposers.

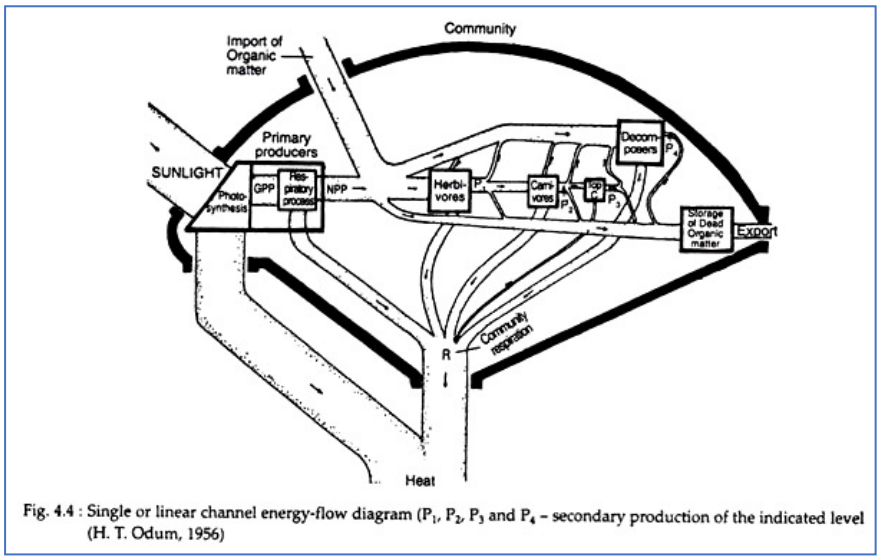


Fig. 4.4 : Single or linear channel energy-flow diagram (P_1, P_2, P_3 and P_4 – secondary production of the indicated level (H. T. Odum, 1956)

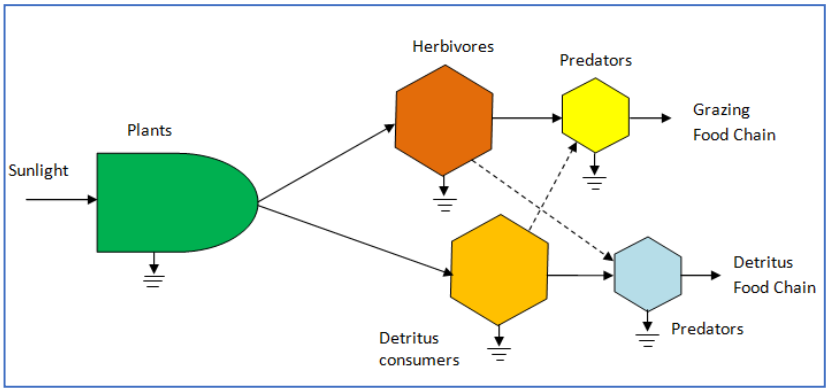
6.3: The relationship between the flow of energy through grazing and detritus pathways

Figure 6.3 represents one of the first published energy flow models pioneered by H.T. Odum in 1956. A common boundary is also shown, sunlight and heat flows, import, export, and storage of organic matter are also included in the diagram. Decomposers are placed in a separate box to separate grazing and detritus food chains.

E.P. Odum (1983) gave a generalized model of Y-shaped or double channel energy flow (Fig. 6.4), which applies to both terrestrial and aquatic ecosystems. In the energy flow diagram, one arm represents the grazing food chain, and another represents the detritus food chain. The important

point in this model is that both the chains are not separated from each other. Odum regarded this model as more realistic than the single-channel energy flow model for the following reasons:

- It confirms the basic stratified structure of the ecosystem by including both grazing and detritus pathways.
- It separates the grazing food chain from the detritus food chain in both time and space as shown by direct consumption of living plants and utilization of dead organic matter respectively.
- Macroconsumer (animals) and micro consumer (bacteria and fungi) differ greatly in size metabolism relations.



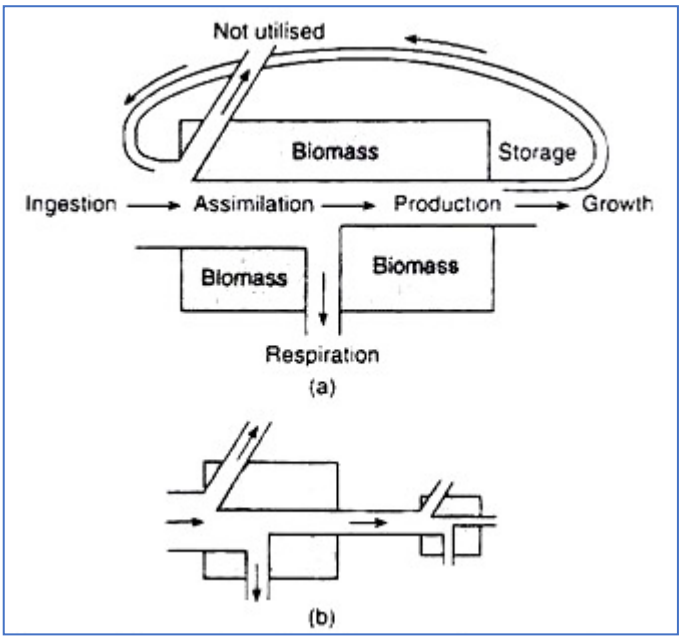
6.4: Double Channel or Y-shaped Energy Flow Model (based on Odum, 1983)

The two arms differ fundamentally in the way they can influence primary producers. In the grazing food chain, herbivores feed on living plants, therefore they directly affect the plant population. Whatever they do not eat is available to the decomposers after death. As a result, decomposers are not able to directly influence the rate of supply of their food. Further, the amount of net production energy that flows down the two pathways varies in different kinds of ecosystems and often in the same ecosystem; it may vary seasonally or annually. In heavily grazed grassland, 50% or more of the net production may pass down the grazing pathway. But aquatic systems like marshes or forests operate as detritus systems, for, over 90% of primary production is not consumed by heterotrophs until plant parts die and reach water, sediments, and soils. This delay in the consumption of primary production increases the structural complexity of the ecosystem. Since all the food is not assimilated by the grazers, some are diverted to the detritus route. So, the impact of grazers on the community depends on the rate of removal of living plants and the amount of energy in the food that is assimilated. Marine zooplanktons commonly graze more phytoplanktons than they can assimilate, the excess being egested to the detritus food

chain. Thus, energy flow along the different paths is dependent on the rate of removal of living plant material by herbivores as well as on the rate of assimilation in their bodies.

6.3.3 Universal Energy Flow Model

E.P. Odum (1968) gave the Universal Energy Flow Model which represents the basis for a general explanation of ecosystem trophic flows. The model can be applied to any living component, whether it is a plant, animal, microorganism, individual, population or trophic group. Such a model may depict the food chain as already shown in previous models or the bioenergetics of an entire ecosystem. In the figure, the living structure or biomass of the component is represented as the shaded box. Further, I - is the ingested energy which is solar radiation in the case of autotrophs and ingested food in the case of heterotrophs. Since not all the energy supplied is utilized, the lost part is called energy not utilized (NU). The assimilated energy (A) is known as gross production.



6.5: Universal Energy Flow Model

[I- Input solar radiations or ingestion of food; A- Assimilated energy; P-net production; G – Growth and Reproduction; B- Standing crop Biomass; R-Respiration; S-Stored energy; E Excreted energy; NU-energy not utilized] Part of A is used for system structural maintenance, that is the respiration (R), and the other part is transformed into organic matter (P), known as net production. P is the energy available for other individuals or trophic levels. Individuals use part of the net production for growth (G) or, in the case of populations or trophic levels, for biomass accumulation (B). A part of net

production can be stored (S) at an individual level in the form of organic compounds of higher energetic Structure (lipids) or, at the ecosystem level, as a nutrients deposit or detritus. Some products can be excreted by individuals or, analogously, exported from the ecosystem (E).

The universal energy flow can be used in two ways: i) The model can represent a species population in which case the appropriate energy inputs and links with other species would be shown as a conventional species-oriented food web diagram or ii) the model can represent a discrete energy level in which case the biomass and energy channels represent all or parts of many populations supported by the same energy source. Foxes, for example, usually obtain part of their food by eating plants (fruits etc) and part by eating herbivores (rabbit, field mice model etc). A single box diagram could be used to represent the whole population of foxes if to express intrapopulation energy. On the other hand, two or more boxes may be used if we wish to represent two or more trophic levels. Energy partitioning between P and R is of vital importance to the individual and species. Different organisms have different patterns of energy consumption. Large organisms require more maintenance energy as they have more biomass to maintain. The warm-blooded animals (birds and mammals) require more energy than cold-blooded animals. Predators use a large part of assimilated energy in respiration than herbivores, to find and overcome prey. The species adapted to unstable, recently derivunderpopulated areas, generally allocate a large portion of their energy to reproduction. The species adapted to stable and more favourable habitats allocate little energy to reproduction.

6.4 Trophic Levels

The feeding positions in a food chain or web are called **trophic levels**. Trophic levels provide a structure for understanding food chains and how energy flows through an ecosystem. At the base of the pyramid are the producers, who use photosynthesis or chemosynthesis to make their food. Herbivores or primary consumers, make up the second level. Secondary and tertiary consumers, omnivores, and carnivores follow in the subsequent sections of the pyramid. At each step up the food chain, only 10 per cent of the energy is passed on to the next level, while approximately 90 per cent of the energy is lost as heat. The first trophic level, or base, of an ecosystem, has the highest energy concentration. This energy is dispersed among animals in the subsequent three or four levels. Certain organisms, because of their size, function or eating behaviour, belong in a particular trophic level, though sometimes it's difficult to place animals with more complex behaviours.

The different trophic levels are defined in the **table** below. Examples are also given in the table. All food chains and webs have at least two or three trophic levels. Generally, there are a maximum of four trophic levels.

Trophic Level	Where It Gets Food	Example
1st Trophic Level: Producer	Makes its food	Plants make food
2nd Trophic Level: Primary Consumer	Consumes producers	Mice eat plant seeds
3rd Trophic Level: Secondary Consumer	Consumes primary consumers	Snakes eat mice
4th Trophic Level: Tertiary Consumer	Consumes secondary consumers	Hawks eat snakes

Many consumers feed at more than one trophic level. Humans, for example, are primary consumers when they eat plants such as vegetables. They are secondary consumers when they eat cows. They are tertiary consumers when they eat salmon.

6.4.1 Trophic Level interaction

The Trophic Level interaction starts with the Members of the Ecosystem-based on the Nutritional Needs as Follows:

- Autotrophs (Producers)
- Heterotrophs (Primary Consumers)
- Heterotrophs (Secondary Consumers)
- Heterotrophs (Tertiary Consumers)
- Heterotrophs (Quaternary Consumers)

While the Energy Flows from Producers to the Subsequent Trophic Level Which Means Always from Producers to the Carnivores.

6.4.2 Trophic Levels and Energy

Energy is passed up a food chain or web from lower to higher trophic levels. However, generally, only about 10 per cent of the energy at one level is available to the next level. This is represented by the ecological pyramid in the Figure below. What happens to the other 90 per cent of energy? It is used for metabolic processes or given off to the environment as heat. This loss of energy explains why there are rarely more

than four trophic levels in a food chain or web. Sometimes there may be a fifth trophic level, but usually, there's not enough energy left to support any additional levels.

The solar radiation from the Sun provides the input of energy, which is used by primary producers, also known as autotrophs. Primary producers are usually plants and algae, which perform photosynthesis to manufacture their food source.

Primary producers make up the first trophic level. The rest of the trophic levels are made up of consumers, also known as heterotrophs; heterotrophs cannot produce their food, so must consume other organisms to acquire nutrition. The second trophic level consists of herbivores, these organisms gain energy by eating primary producers and are called primary consumers.

Trophic levels three, four and five consists of carnivores and omnivores. Carnivores are animals that survive only by eating other animals, whereas omnivores eat animals and plant material.

Fig. 6.6 Tropic level

Trophic level three consists of carnivores and omnivores which eat

herbivores: these are the secondary consumers. Trophic level four contains carnivores and omnivores which eat secondary consumers and are known as tertiary consumers. Trophic level five consists of apex predators; these animals have no natural predators and are therefore at the top of the food chain.

Decomposers or detritivores are organisms that consume dead plant and animal material, converting it into energy and nutrients that plants can use for effective growth. Although they do not fill an independent trophic level,

decomposers, and detritivores, such as fungi, bacteria, earthworms, and flies, recycle waste material from all other trophic levels and are an important part of a functioning ecosystem.

Due to the way that energy is utilized as it is transferred between levels, the total biomass of organisms on each trophic level decreases from the bottom-up. Only around 10% of the energy consumed is converted into biomass, whereas the rest is lost as heat, as well as to movement and other biological functions. Because of this gradual loss of energy, the biomass of each trophic level is often viewed as a pyramid, called a trophic pyramid.

6.4.3 Examples of Trophic Level

Primary Producers: Primary producers, or “autotrophs”, are organisms that produce biomass from inorganic compounds. In general, these are photosynthesizing organisms such as plants or algae, which convert energy from the sun, using carbon dioxide and water, into glucose. This glucose is then stored within the plant as energy, and oxygen, which is released into the atmosphere. In terrestrial ecosystems, almost all of the primary production comes from vascular plants such as trees, ferns, and flowering plants. In marine ecosystems, algae and seaweed fill the role of primary production. Some deep-sea primary producers perform oxidization of chemical inorganic compounds instead of using photosynthesis; these organisms are called” chemoautotrophs”.

Primary Consumers: Primary consumers are herbivores, that is, animals that are adapted to consuming and digesting plants and algae (autotrophs). Herbivores are generally split into two categories: grazers, such as cows, sheep and rabbits, whose diets consist at least 90% of grass, and browsers, such as deer and goats, whose diets consist of at least 90% of tree leaves or twigs. Primary consumers may also consume other forms of plant material. Many bats, birds and monkeys eat fruit (frugivores); birds, insects, bats and arachnids (spiders) eat nectar (nectarivores); and termites and beetles eat wood (xylophages). In marine ecosystems, primary consumers are zooplankton, tiny crustaceans which feed off photosynthesizing algae known as phytoplankton.

Secondary Consumers: Secondary consumers, at trophic level three, are carnivores and omnivores, which obtain at least part of their nutrients from the tissue of herbivores. This includes animals and carnivorous plants that feed on herbivorous insects (insectivores). Secondary consumers are usually small animals, fish and birds such as frogs, weasels, and snakes, although larger apex predators, such as lions and eagles, may consume herbivores, and can also exist within the second trophic level of an

ecosystem. In marine ecosystems, all species that consume zooplankton are secondary consumers; this ranges from jellyfish to small fish such as sardines and larger crustaceans such as crabs and lobsters, as well as whales, which filter feed, and basking sharks.

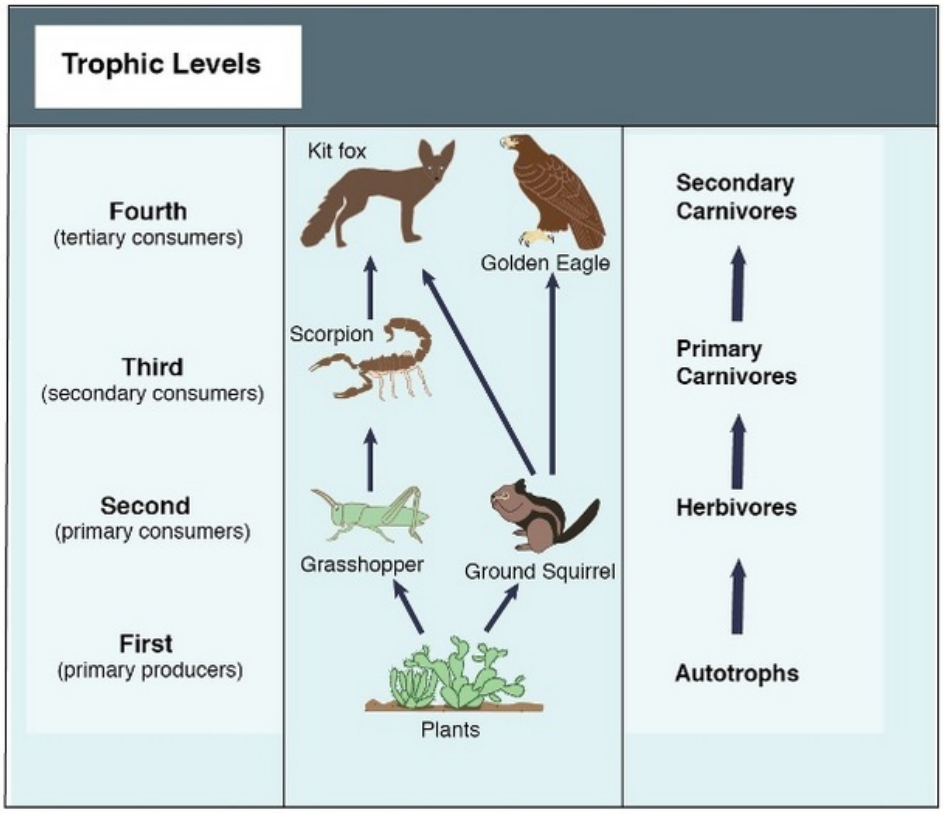


Fig. 6.7 Diagrammatic representation of the Tropic level

Tertiary Consumers: Tertiary consumers acquire energy by eating other carnivores but may be preyed upon. Owls are an example of tertiary consumers; although they feed off mice and other herbivores, they also eat secondary consumers such as stoats. In turn, owls may be hunted by eagles and hawks, and are therefore not apex predators.

Apex Predators: Apex predators are organisms at the top of the food chain, and which do not have any natural predators. Eagles, wolves, large cats such as lions, jaguars and cheetahs, and marine animals such as sharks, tuna, killer whales and dolphins are all examples of apex predators, although there are many more. Apex predators often have specific adaptions, which make them highly efficient hunters, such as sharp teeth and claws, speed and agility and stealth; sometimes they work within groups, enhancing the success of their hunting abilities. However, not all apex predators are vicious hunters. Whale sharks are large filter feeders,

consuming only small fish and plankton, although because they have no natural predators, they are apex predators in their environment.

Apex predators play an extremely important role in an ecosystem; through predation, they control populations of the lower trophic levels. If apex predators are removed from an ecosystem, organisms such as grazing herbivores can over-populate, therefore placing intense grazing and browsing pressure on the plants within a habitat. If there are fewer available plant resources, other organisms that depend on the plants (although are not hunted by the apex predator), such as insects and small mammals, will suffer population declines, and in turn, can affect all trophic levels within an ecosystem. This disturbance is called a top-down trophic cascade and can lead to ecosystem collapse.

Decomposers or detritivores or transformers: Decomposers are organisms that feed on dead and decaying plants and animals, converting organic matter into energy and nutrients. The energy and nutrients can then be taken up by plants for their effective growth. Decomposers include organisms like bacteria, fungi, and some arthropods that do not form an independent trophic level but are involved in the recycling of waste material from all trophic levels. These are essential in a functioning ecosystem as they prevent the loss and nutrients from the ecosystem after the death of various living beings.

6.4.4 Trophic Level pyramid

The trophic level pyramid or ecological pyramid is the graphical structure representing the interactions in biological communities in the form of the transfer of food and energy from one trophic level to the next in a food chain. The trophic pyramid is one of the three types, each of which represents the different relationships between different parameters.

An energy pyramid represents the flow of energy from one trophic level to another. A biomass pyramid indicates the amount of living or organic matter (biomass) present at a particular trophic level. A number pyramid represents the number of individual organisms present in different trophic levels. The concept of pyramids was derived from the works of G. Evelyn Hutchinson, and Raymond Lindeman and the pyramid of numbers was the first pyramid to be developed. All these pyramids begin with the producers at the bottom, followed by other living beings at different trophic levels. The highest trophic level in the pyramid represents the top of the food chain.

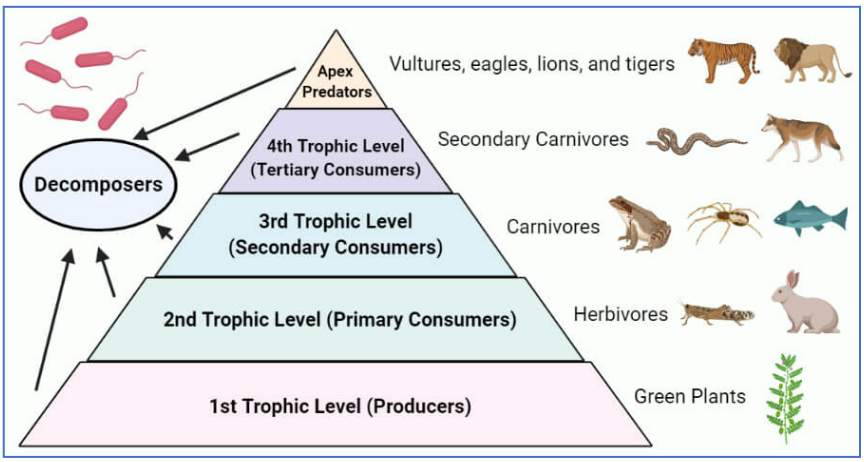


Fig. 6.8 Trophic level pyramid

The organisms that occupy the base of the pyramid differ in different ecosystems as in terrestrial ecosystems, green plants are present at the bottom, whereas, in aquatic ecosystems, multicellular plants and green algae occupy the level. The ecological pyramid of energy is always upright as the flow of energy in an ecosystem is unidirectional, but inverted pyramids can be observed in the pyramid of biomass. In ocean or pond ecosystems, the biomass of producers or phytoplanktons is lower than the biomass of zooplanktons as phytoplanktons have shorter individual lives. Even though trophic level pyramids are essential to determine the efficiency of energy transfer and monitor the condition of the ecosystem, there are some limitations to these pyramids. The pyramids do not represent the relationship between the ecosystem and seasons. Some species might exist at different levels that cannot be defined through the pyramids.

Let Us Sum Up

Ecology enriches our world and is crucial for human wellbeing and prosperity. It provides new knowledge of the interdependence between people and nature that is vital for food production, maintaining clean air and water, and sustaining biodiversity in a changing climate. Humans are an integral part of ecosystems. Ecosystems provide a variety of benefits to people, including provisioning, regulating, cultural, and supporting services. Provisioning services are the products people obtain from ecosystems, such as food, fuel, fibre, freshwater, and genetic resources. While healthy ecosystems clean our water, purify our air, maintain our soil, regulate the climate, recycle nutrients and provide us with food. They provide raw materials and resources for medicines and other purposes. They are at the foundation of all civilisations and sustain our economies.

Glossaries

Ecology: The science of relationships and interactions between living organisms and their environment.

Ecosystem: An ecosystem includes everything at a particular location: plants, animals, microorganisms, air, water, soil, and human-built structures. Natural ecosystems are formed entirely by natural processes. Agricultural ecosystems are created by people to provide food or other materials. Urban ecosystems are dominated by human-built structures.

Energy flow: Movement of energy in the carbon chains of organic matter that passes through a food web as one organism consumes another.

Conservation: The management of human use of nature so that it may yield the greatest sustainable benefit to current generations while maintaining its potential to meet the needs and aspirations of future generations.

Abiotic: An abiotic factor is a non-living part of an ecosystem that shapes its environment.

Check Your Progress

1. Define Ecosystem
   Answer: An ecosystem is a geographic area where plants, animals, and other organisms, as well as weather and landscapes, work together to form a bubble of life
2. Write the Biotic Components?
   Answer: It includes plants and animals. Examples Water, light, wind, soil, humidity, minerals, gases. All living things - autotrophs and heterotrophs - plants, animals, fungi, bacteria.
3. Who introduces the term Ecology?
   Answer: The term “Ecology” was introduced by Ernst Haeckel (German scientist) in 1869 and involves the study of interactions as well as interrelationships amongst organisms and their environment.
4. Mention the types of Aquatic ecosystems?
   Answer: There are two types, Freshwater, and Oceanic/Marine ecosystem
5. Write about the natural ecosystem?
   Answer: There are two types of the natural ecosystem, Terrestrial Ecosystem and Aquatic Ecosystem.

Books for Reference

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Suggested Online Readings

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3. https://drive.google.com/file/d/1_z3rRVihN_wWThNRZ-dSvvODxvqvqQxp/view
4. https://www.hzu.edu.in/bed/E%20V%20S.pdf
5. https://www.ugc.ac.in/oldpdf/modelcurriculum/env.pdf
6. https://drive.google.com/file/d/1eIxTTKQYV5rL3019D0MJ_tM7TvZPLaZy/view
7. http://magadhmahilacollege.org/wp-Structure/uploads/2020/05/Energy-Flow-through-the-Ecosystem-converted.pdf

UNIT 7

Cycles (geo-chemical, carbon, nitrogen, and oxygen)

Structure

7.1 Overview

The energy, water and many other chemical elements are cycled in the ecosystem which influences the growth and reproduction system of the organism. The Water, Nitrogen and Phosphorous cycles are the most biochemical cycles that affect the health of the ecosystem. While ecosystems flow of energy is linear that of nutrients is cyclical. This is because energy flows downhill i.e., it is utilized or lost as heat as it flows

forward the nutrients on the other handcycle from dead remains of organisms released back into the soil by detrivores which are absorbed again i.e., nutrients absorbed from soil by the root of green plants are passed on to herbivores and then carnivores. The nutrients are locked in the dead remains of organisms and released back into the soil by detrivores and decomposers. This recycling of the nutrients is called biogeochemical or nutrient cycle (Bio = living, geo = rock chemical = element). There are more than 40 elements required for the various life processes by plants and animals. The entire earth or biosphere is a closed system i.e., nutrients are neither imported nor exported from the biosphere.

Learning Objectives

After studying this unit, you will learn about the

Biogeochemical Cycles and types such as Carbon Cycle, Nitrogen Cycle, Water Cycle, Oxygen Cycle, Phosphorus Cycle and Sulphur Cycle.

7.2 What are Biogeochemical Cycles?

The Biogeochemical Cycles can be defined as the cyclic movement of chemical elements of the biosphere between the organism and the environment. The term 'Biogeochemical' is a combination of two words- Bio which refers to living organisms; geo refers to the rocks, soil, air and water on the earth and the earth and chemical means elements such as carbon, phosphorous, nitrogen etc. Besides these elements, several other elements play important role in the growth of organisms. The growth nutrients are cycled or recycled repeatedly between the living and non-living components of the ecosystem. There are some distinguishing factors of the nutrient cycles as opposed to the energy flow such as:

1. Energy flow in an ecosystem involves living components only whereas both living and non-living organisms are involved in the nutrient cycle.

2. the Net amount of nutrient cycling through the biosphere remains constant.

7.3 Biogeochemical Cycles

All elements in the earth are recycled time and again. The major elements such as oxygen, carbon, nitrogen, phosphorous, and sulphur are essential ingredients that makeup organisms. Biogeochemical cycles refer to the flow of such chemical elements and compounds between organisms and the physical environment. Chemicals taken in by organisms are passed through the food chain and come back to the soil, air, and water through mechanisms such as respiration, excretion, and decomposition. As an

element moves through this cycle, it often forms compounds with other elements because of metabolic processes in living tissues and of natural reactions in the atmosphere, hydrosphere, or lithosphere. Such cyclic exchange of material between the living organisms and their non-living environment is called Biogeochemical Cycle.

There are two important components of a biogeochemical cycle

- Reservoir pool – atmosphere or rock, which stores large amounts of nutrients.
- Cycling pool or compartments of cycle-They are relatively short storages of carbon in the form of plants and animals.

7.4 Types of Biogeochemical/Nutrient Cycles

Biogeochemical cycles are divided into two types: (a) gaseous and (b) sedimentary. The reservoir for the gaseous type of nutrient cycle (e.g., nitrogen, oxygen, water carbon cycle) exists in the atmosphere and for the sedimentary cycle (e.g., sulphur, rock, and phosphorus cycle), the reservoir is in Earth's crust. Environmental factors, e.g., soil, moisture, pH, temperature, etc., regulate the rate of release of nutrients into the atmosphere. The function of the reservoir is to meet the deficit which occurs due to an imbalance in the rate of influx and efflux.

The following are some important biogeochemical cycles: Carbon Cycle, Nitrogen Cycle, Water Cycle, Oxygen Cycle, Phosphorus Cycle and Sulphur Cycle

7.4.1 Carbon Cycle

Carbon is the second most abundant element in organisms, by mass. Carbon is present in all organic molecules (and some not organic molecules such as CO2), and its role in the structure of biomolecules is of primary importance. Carbon compounds contain energy, and many of these compounds from dead plants and algae have been fossilized over millions of years and are known as fossil fuels.

Carbon enters the living world in the form of carbon dioxide through the process of photosynthesis as carbohydrates. These organic compounds (food) are then passed from the producers to the consumers (herbivores & carnivores). This carbon is finally returned to the surrounding medium by the process of respiration or decomposition of plants and animals by the decomposers. Carbon is also recycled during the burning of fossil fuels.

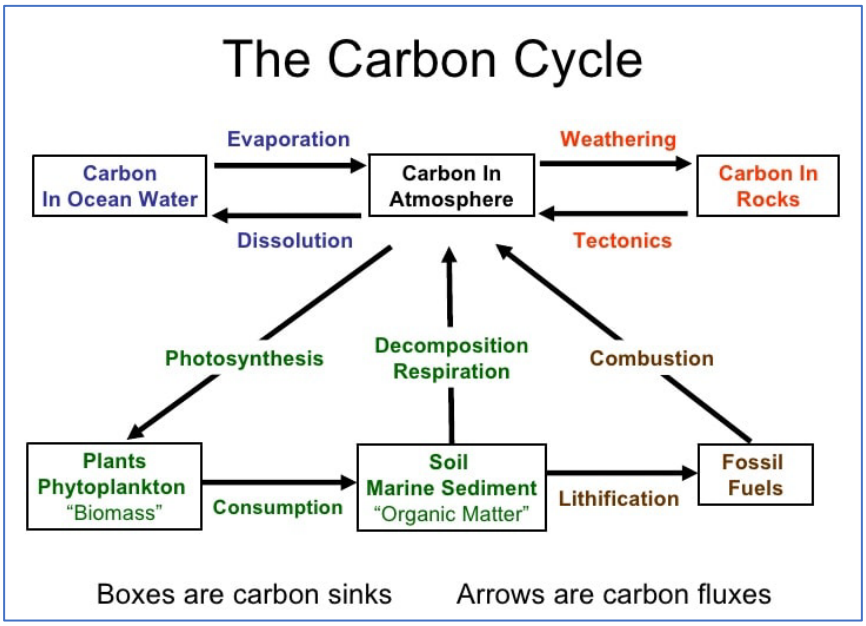


Fig.7.1 Carbon Cycle

The carbon cycle is most easily studied as two interconnected sub-cycles:

- One dealing with rapid carbon exchange among living organisms
- One dealing with long-term cycling of carbon through geologic processes

Although we will look at them separately, it's important to realize these cycles are linked. For instance, the same pools of atmospheric and oceanic CO2 that are utilized by organisms are also fed and depleted by geological processes.

7.4.1.1 The biological carbon cycle

Carbon enters all food webs, both terrestrial and aquatic, through autotrophs, or self-feeders. Almost all these autotrophs are photosynthesizers, such as plants or algae. Autotrophs capture carbon dioxide from the air or bicarbonate ions from the water and use them to make organic compounds such as glucose. Heterotrophs, or other feeders, such as humans, consume the organic molecules, and the organic carbon is passed through food chains and webs. To release the energy stored in carbon-containing molecules, such as sugars, autotrophs and heterotrophs break these molecules down in a process called cellular respiration. In this process, the carbons of the molecule are released as carbon dioxide. Decomposers also release organic compounds and carbon dioxide when they break down dead organisms and waste products.

7.4.1.2 The geological carbon cycle

The geological pathway of the carbon cycle takes much longer than the biological pathway described above. It usually takes millions of years for carbon to cycle through the geological pathway. Carbon may be stored for long periods in the atmosphere, bodies of liquid water—mostly oceans—ocean sediment, soil, rocks, fossil fuels, and Earth's interior.

The level of carbon dioxide in the atmosphere is influenced by the reservoir of carbon in the oceans and vice versa. On land, carbon is stored in the soil as organic carbon from the decomposition of living organisms or as inorganic carbon from weathering of terrestrial rock and minerals. Deeper under the ground are fossil fuels such as oil, coal, and natural gas, which are the remains of plants decomposed under anaerobic—oxygen-free—conditions. Fossil fuels take millions of years to form. When humans burn them, carbon is released into the atmosphere as carbon dioxide.

Another way for carbon to enter the atmosphere is by the eruption of volcanoes. Carbon-containing sediments in the ocean floor are taken deep within the Earth in a process called subduction, in which one tectonic plate moves under another. This process forms carbon dioxide, which can be released into the atmosphere by volcanic eruptions or hydrothermal vents.

7.4.2 Nitrogen Cycle

The nitrogen cycle refers to the circulation of nitrogen in various chemical forms through the atmospheric, terrestrial, and marine ecosystems. Nitrogen is an essential component of protein and is required by all living organisms including human beings. Nitrogen is a constituent of amino acids, proteins, hormones, chlorophylls, and many vitamins. Plants compete with microbes for the limited nitrogen that is available in the soil. Thus, nitrogen is a limiting nutrient for both natural and agricultural ecosystems.

Nitrogen exists as two nitrogen atoms (N_2) joined by a very strong triple covalent bond (N ≡ N). In nature, lightning and ultraviolet radiation provide enough energy to convert nitrogen to nitrogen oxides (NO, NO_2, N_2O). Industrial combustions, forest fires, automobile exhausts and power-generating stations are also sources of atmospheric nitrogen oxides.

Our atmosphere contains nearly 79% of nitrogen but it cannot be used directly by most living organisms. Broadly like carbon dioxide, nitrogen also cycles from the gaseous phase to the solid phase then back to the gaseous phase through the activity of a wide variety of organisms. Cycling nitrogen is vitally important for all living organisms. There are five main processes which essential for the nitrogen cycle are elaborated on below.

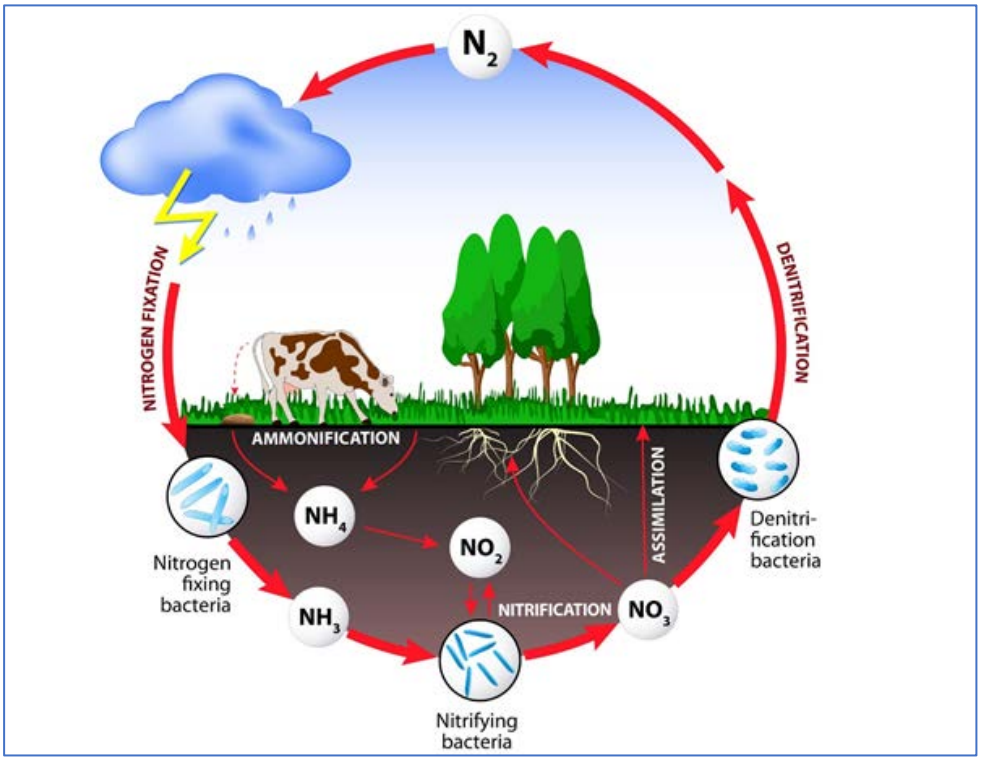


Fig.7.2 Nitrogen Cycle

(a) Nitrogen fixation: This process involves the conversion of gaseous nitrogen into Ammonia, a form in which it can be used by plants. Atmospheric nitrogen can be fixed by the following three methods: –

Atmospheric fixation: Lightening, combustion, and volcanic activity help in the fixation of nitrogen.

Industrial fixation: At high temperature and high pressure, molecular nitrogen is broken into atomic nitrogen which then combines with hydrogen to form ammonia.

Bacterial fixation: There are two types of bacteria

Symbiotic bacteria e.g., Rhizobium in the root nodules of leguminous plants.

Free-living or symbiotic e.g., 1. Nostoc 2. Azobacter 3. Cyanobacteria can combine atmospheric or dissolved nitrogen with hydrogen to form ammonia.

(b) Nitrification: In nitrification, a host of soil bacteria participate in turning ammonia into nitrate – the form of nitrogen that can be used by plants and animals. This requires two steps, performed by two different types of bacteria.

First, soil bacteria such as Nitrosomonas or Nitro coccus convert ammonia into nitrogen dioxide. Then another type of soil bacterium, called Nitrobacter, adds a third oxygen atom to create nitrate.

These bacteria don't convert ammonia for plants and animals out of the goodness of their hearts. Rather, they are "chemotrophs" who obtain their energy from volatile chemicals. By metabolizing nitrogen along with oxygen, they obtain energy to power their life processes.

The process can be thought of as a rough (and much less efficient) analogue to the cellular respiration performed by animals, which extract energy from carbon-hydrogen bonds and use oxygen as the electron acceptor, yielding carbon dioxide at the end of the process.

Nitrates, the product of this vital string of bacterial reactions – can be made artificially and are the main ingredient in many soil fertilizers. You may hear such fertilizer referred to as "nitrate fertilizer." By pumping the soil full of nitrates, such fertilizers allow plants to grow large quickly, without being dependent on the rate at which nitrogen-fixing bacteria do their jobs.

Interestingly, high-energy environments such as lightning strikes and volcanic eruptions can convert nitrogen gas directly into nitrates but this doesn't happen nearly enough to keep modern ecosystems healthy on their own.

(c) Assimilation: In assimilation, plants finally consume the nitrates made by soil bacteria and use them to make nucleotides, amino acids, and other vital chemicals for life.

Plants take up nitrates through their roots and use them to make amino acids and nucleic acids from scratch. Animals that eat the plants are then able to use these amino acids and nucleic acids in their cells.

(d) Ammonification: Because there is so much nitrogen in the atmosphere, it may seem that the process could stop there but the atmosphere's supply is not infinite and keeping nitrogen inside the plant and animal cells would eventually result in big changes to our soil, our atmosphere, and our ecosystems.

Fortunately, that's not what happens. In a robust ecosystem like ours, anywhere that energy has been put into creating an organic chemical, there is another form of life that is waiting to extract that energy by breaking those chemical bonds.

In this case, a process called "ammonification" is performed by soil bacteria that decompose dead plants and animals. In the process, these

decomposers break down amino acids and nucleic acids into nitrates and ammonia and release those compounds back into the soil.

(e) Denitrification: In the final step of the nitrogen cycle, anaerobic bacteria can turn nitrates back into nitrogen gas.

This process, like the process of turning nitrogen gas into ammonia, must happen in the absence of oxygen. As such it often occurs deep in the soil, or in wet environments where mud and muck keep oxygen at bay.

In some ecosystems, this denitrification is a valuable process to prevent nitrogen compounds in the soil from building up to dangerous levels. Denitrification is the reverse of nitrogen fixation.

7.4.3 Oxygen Cycle

According to the earth's history, oxygen gas was first introduced by cyanobacteria through the process of photosynthesis. Earlier, around 4.6 billion years ago, there was no life on planet earth because the atmosphere was devoid of oxygen. Later, there was a gradual increase in the oxygen levels and by the Carboniferous Period- 299 million years ago, oxygen reached the levels that were like today's estimates.

Today, oxygen is freely available in the air and dissolved in water. It is the second most abundant gas present in the atmosphere and the most common element of the human body. It plays an essential role in most life forms on earth and serves as an essential element in biomolecules like proteins and nucleic acids.

7.4.3.1 What is Oxygen Cycle?

The oxygen cycle, along with the carbon cycle and nitrogen cycle plays an essential role in the existence of life on the earth. The oxygen cycle is a biological process that helps in maintaining the oxygen level by moving through three main spheres of the earth which are: Atmosphere, Lithosphere and Biosphere. This biogeochemical cycle explains the movement of oxygen gas within the atmosphere, the ecosystem, biosphere and lithosphere. The oxygen cycle is interconnected with the carbon cycle.

The atmosphere is the layer of gases presented above the earth's surface. The sum of Earth's ecosystems makes a biosphere. The lithosphere is the solid outer section along with the earth's crust and it is the largest reservoir of oxygen.

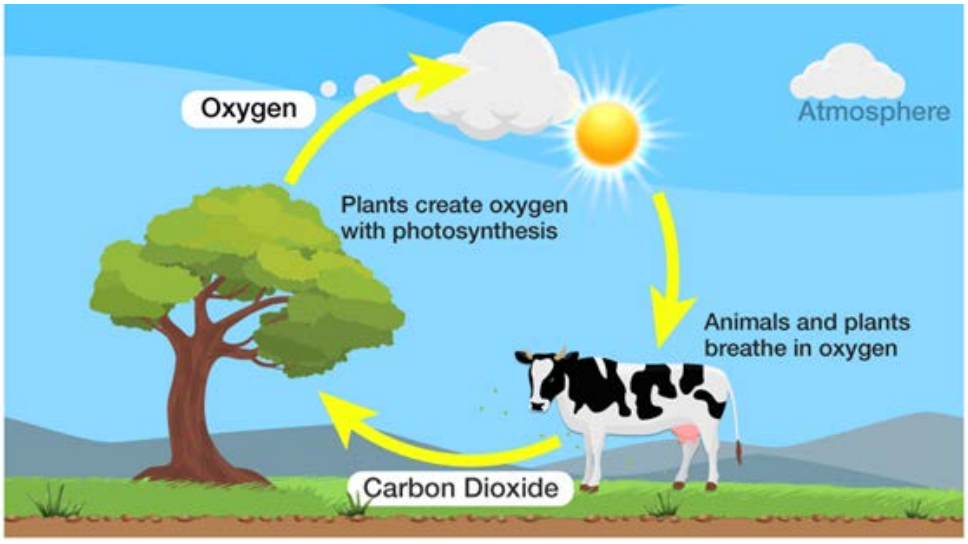


Fig.7.3 Oxygen Cycle

7.4.3.2 Stages of the Oxygen Cycle

The steps involved in the oxygen cycle are:

Stage-1: All green plants during the process of photosynthesis, release oxygen back into the atmosphere as a by-product.

Stage-2: All aerobic organisms use free oxygen for respiration.

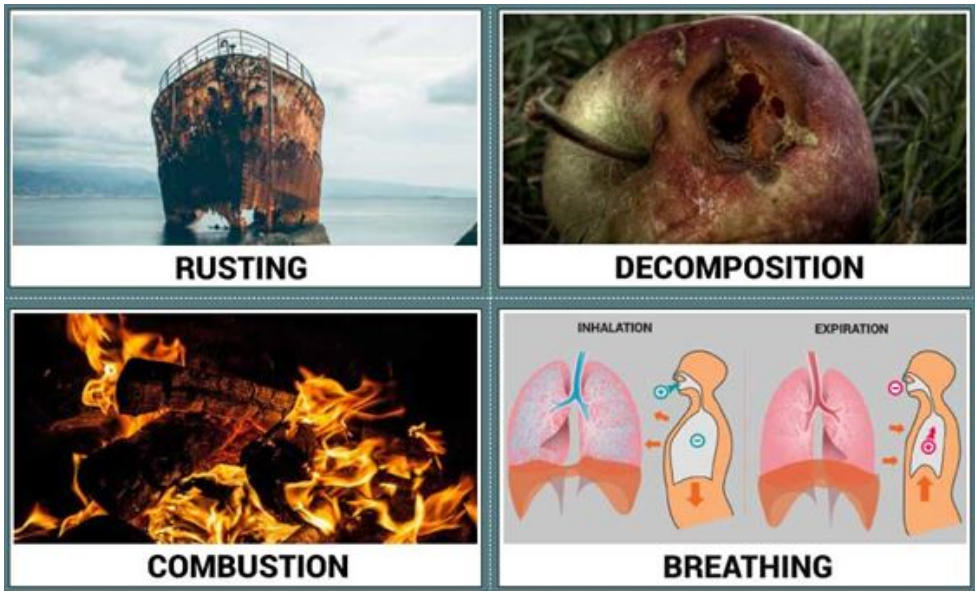
Stage-3: Animals exhale Carbon dioxide back into the atmosphere which is again used by the plants during photosynthesis. Now oxygen is balanced within the atmosphere.

7.4.3.3 Uses of Oxygen

The four main processes that use atmospheric oxygen are:

Breathing – It is the physical process, through which all living organisms, including plants, animals, and humans inhale oxygen from the outside environment into the cells of an organism and exhale carbon dioxide back into the atmosphere.

Decomposition: It is one of the natural and most important processes in the oxygen cycle and occurs when an organism dies. The dead animal or plants decay into the ground, and the organic matter along with the carbon, oxygen, water and other components are returned into the soil and air. This process is carried out by the invertebrates, including fungi, bacteria and some insects which are collectively called decomposers. The entire process requires oxygen and releases carbon dioxide



. Fig. 7.4 Major uses of Oxygen

Combustion: It is also one of the most important processes which occur when any of the organic materials, including fossil fuels, plastics, and wood, are burned in the presence of oxygen and releases carbon dioxide into the atmosphere.

Rusting: This process also requires oxygen. It is the formation of oxides which is also called oxidation. In this process, metals like iron or alloy rust when they are exposed to moisture and oxygen for an extended period and new compounds of oxides are formed by the combination of oxygen with the metal.

7.4.3.4 Production of Oxygen

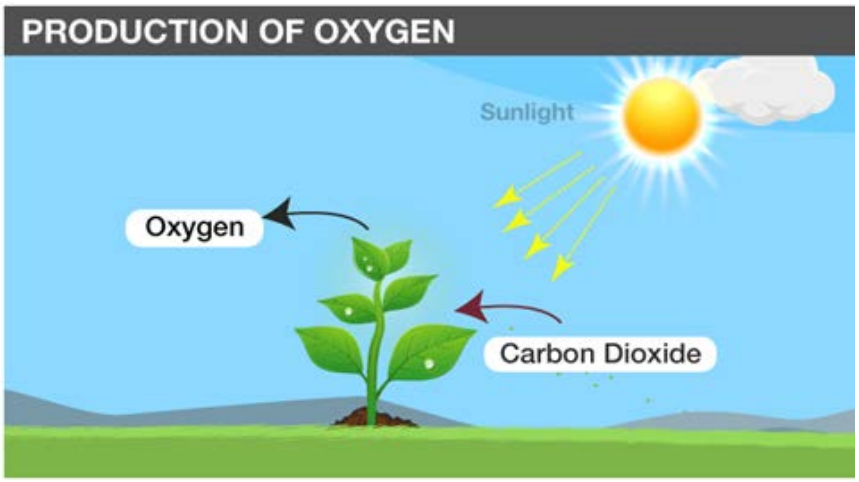
Plants: The leading creators of oxygen are plants by the process of photosynthesis. Photosynthesis is a biological process by which all green plants synthesize their food in the presence of sunlight. During photosynthesis, plants use sunlight, water, carbon dioxide to create energy and oxygen gas is liberated as a by-product of this process.

Sunlight: Sunlight also produces oxygen. Some oxygen gas is produced when the sunlight reacts with water vapour in the atmosphere.

7.4.3.5 Some Interesting Facts about Oxygen

- Phytoplankton is one of the most significant producers of oxygen, followed by terrestrial plants and trees.
- Oxygen is also produced when the sunlight reacts with water vapour

present in the atmosphere.



- Fig.7.5 Production of Oxygen

- A large amount of oxygen is stored in the earth's crust in the form of oxides, which cannot be used for the respiration process as it is available in the combined state.
- Importance of Oxygen Cycle
- As we all know, oxygen is one of the most essential components of the earth's atmosphere. It is mainly required for: Breathing, Combustion, Supporting aquatic life and Decomposition of organic waste.

Let Us Sum Up

The chemical elements and water that are needed by organisms continuously recycle in ecosystems. They pass through biotic and abiotic components of the biosphere. That's why their cycles are called biogeochemical cycles. For example, a chemical might move from organisms (bio) to the atmosphere or ocean (geo) and back to organisms again. Elements of water may be held for various periods in different parts of a cycle. The three main cycles of an ecosystem are the oxygen cycle, the carbon cycle, and the nitrogen cycle. These three cycles working in balance are responsible for carrying away waste materials and replenishing the ecosystem with the nutrients necessary to sustain life.

Glossaries

Carbon Cycle: Carbon is the second most abundant element in organisms, by mass. Carbon is present in all organic molecules (and some not organic molecules such as CO2), and its role in the structure of biomolecules is of primary importance.

Ammonification: Because there is so much nitrogen in the atmosphere, it may seem that the process could stop there but the atmosphere's supply is not infinite and keeping nitrogen inside the plant and animal cells would eventually result in big changes to our soil, our atmosphere, and our ecosystems.

Sunlight: Sunlight also produces oxygen. Some oxygen gas is produced when the sunlight reacts with water vapour in the atmosphere

Combustion: It is also one of the most important processes which occur when any of the organic materials, including fossil fuels, plastics, and wood, are burned in the presence of oxygen and releases carbon dioxide into the atmosphere.

Assimilation: In assimilation, plants finally consume the nitrates made by soil bacteria and use them to make nucleotides, amino acids, and other vital chemicals for life.

Check Your Progress

1. Write the type of Biogeochemical cycles?

   Answer: Biogeochemical cycles are divided into two types: (a) gaseous and (b) sedimentary.

2. Mention the uses of Oxygen?

   Answer: There are four main uses in oxygen Breathing, Combustion, Decomposition and Rusting.

3. Define Nitrogen cycle?

   Answer: The nitrogen cycle refers to the circulation of nitrogen in various chemical forms through the atmospheric, terrestrial, and marine ecosystems.

4. Mention the types of Aquatic ecosystems?

   Answer: There are two types, Freshwater, and Oceanic/Marine ecosystem

5. Write about the Industrial fixation?

   Answer: At high temperature and high pressure, molecular nitrogen is broken into atomic nitrogen which then combines with hydrogen to form ammonia.

Books for Reference

1. Environmental Geography, (2007), H.M. Saxena, Rawat Publications,

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2. Environmental Geography, (2012), Savindra Singh, Prayag Pustak Bhawan, Allahabad.
3. Concepts of Ecology, (2019), N. Arumugam, Saras Publications, Nagarcoil.
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Suggested Online Readings

1. https://www.uv.mx/personal/fpanico/files/2011/04/AA.-VV.-Environmental-geography.pdf
2. https://drive.google.com/file/d/179FJ0X3tMxk76IpQz1E8EEbDqxmnJr_1/view
3. https://drive.google.com/file/d/1_z3rRVihN_wWThNRZ-dSvvODxvqvqQxp/view
4. https://www.hzu.edu.in/bed/E%20V%20S.pdf
5. https://www.ugc.ac.in/oldpdf/modelcurriculum/env.pdf
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UNIT 8

Food Chain, Food Web and Ecological Pyramid

Structure

8.1 Overview

In an ecosystem, plants capture the sun's energy and use it to convert inorganic compounds into energy-rich organic compounds. This process of using the sun's energy to convert minerals (such as magnesium or nitrogen) in the soil into green leaves, carrots, or strawberries, is called photosynthesis. Photosynthesis is only the beginning of a chain of energy conversions. There are many types of animals that will eat the products of the photosynthesis process. Examples are deer eating shrub leaves, rabbits eating carrots, or worms eating grass. When these animals eat these plant products, food energy and organic compounds are transferred from the plants to the animals. These animals are in turn eaten by other animals, again transferring energy and organic compounds from one animal to another. Examples would be lions eating zebras, foxes eating rabbits, or birds eating worms.

This chain of energy transferring from one species to another can continue several more times, but it eventually ends. It ends with the dead animals that are broken down and used as food or nutrition by bacteria and fungi. As these organisms, referred to as decomposers, feed on the dead animals, they break down the complex organic compounds into simple nutrients. Decomposers play a very important role in this world because they take care of breaking down (cleaning) many dead materials. There are more than 100,000 different types of decomposer organisms! These simpler nutrients are returned to the soil and can be used again by plants. The energy transformation chain starts all over again in various trophic levels.

Learning Objectives

After reading this unit, you will learn about the characteristics and the types of Food Chain, Food Web and Ecological Pyramid.

8.2 Food Chain

A food chain explains which organism eats another organism in the environment. The food chain is a linear sequence of organisms where nutrients and energy are transferred from one organism to the other. This occurs when one organism consumes another organism. It begins with the producer organism, follows the chain, and ends with a decomposer organism. After understanding the food chain, we realise how one organism is dependent upon another species for survival.

A food chain refers to the order of events in an ecosystem, where one living organism eats another organism, and later that organism is consumed by

another larger organism. The flow of nutrients and energy from one organism to another at different trophic levels forms a food chain.

The order of living organisms in a community in which one organism consumes another and is itself consumed by another organism to transfer energy is called a food chain. The food chain is also defined as “a chain of organisms, existing in any natural community, through which energy is transferred”. Every living being irrespective of their size and habitat, from the tiniest algae to giant blue whales, need food to survive. The food chain is structured differently for different species in different ecosystems. Each food chain is the vital pathway for energy and nutrients to follow through the ecosystem.

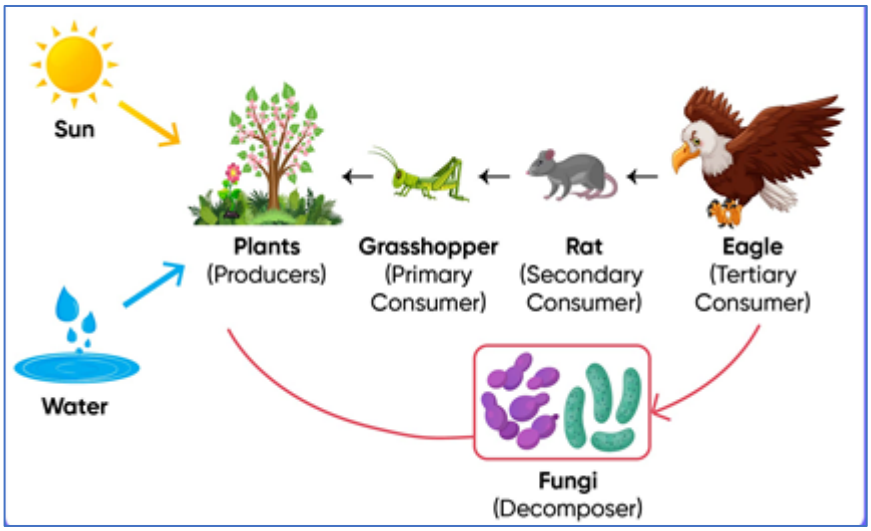

Fig. 8.1 Food Chain

Food chains were first introduced by the African-Arab scientist and philosopher Al-Jahiz in the 9th century and later popularized in a book published in 1927 by Charles Elton. A food chain starts with a producer such as plants. Producers form the basis of the food chains. Then there are consumers of many orders. Consumers are organisms that eat other organisms. All organisms in a food chain, except the first organism, are consumers.

Plants are called producers because they produce their food through photosynthesis. Animals are called consumers because they depend on plants or other animals for food to get the energy they need. In a certain food chain, each organism gets energy from the one at the level below. In a food chain, there is reliable energy transfer through each stage. All the energy at one stage of the chain is not absorbed by the organism at the next stage.

The food chain also explains the feeding pattern or relationship between living organisms. A trophic level refers to the sequential stages in a food chain, starting with producers at the bottom, followed by primary, secondary and tertiary consumers. Every level in a food chain is known as a trophic level.

8.3 Trophic Levels in a Food Chain

Trophic levels are different stages of feeding position in a food chain such as primary producers and consumers of different types. Organisms in a food chain are categorized under different groups called trophic levels. They are as follows.

The Sun: The sun is the initial source of energy, which provides energy for everything on the planet.

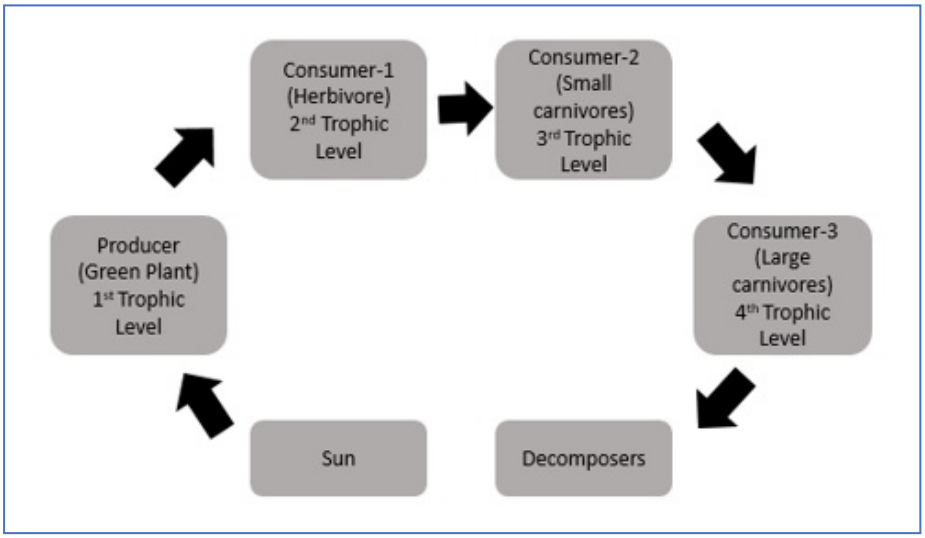

Fig 8.2 Tropic level Cycle

Producers (First Trophic Level) − Producers otherwise called autotrophs prepare their food by themselves. They form the first level of every food chain. Plants and one-celled organisms, some types of bacteria, algae, etc. come under the category of Autotrophs. Virtually, almost all autotrophs use a process called photosynthesis to prepare food.

Consumers − At the second trophic level, some consumers depend upon others for food.

Primary Consumers (Second Trophic Level) − Primary consumers eat the producers. They are called herbivores. Deer, turtles, and many types of birds are herbivores.

Secondary Consumers (Third Trophic Level) − Secondary consumers based at the third trophic level eat plants and herbivores. They are both carnivores (meat-eaters) and omnivores (animals that eat both animals and plants). In a desert ecosystem, a secondary consumer may be a snake that eats a mouse. Secondary consumers may eat animals bigger than they are. Some lions, for example, kill and eat buffalo. The buffalo weighs twice as much as the lions do.

Tertiary Consumers (Fourth Trophic Level) − Tertiary consumers are animals eating other carnivores. The secretary bird in Africa and the King Cobra specializes in killing and eating snakes but all snakes are carnivores. The leopard seal eats mostly other carnivores - mainly other seals, squids, and penguins, all of which are carnivores.

Decomposers − Decomposers that don't always appear in the pictorial presentation of the food chain, play an important part in completing the food chain. These organisms break down dead organic material and wastes. Fungi and bacteria are the key decomposers in many ecosystems; they use the chemical energy in dead matter and wastes to fuel their metabolic processes. Other decomposers are detritivores - detritus eaters or debris eaters. Understanding the food chain helps us know the feeding interrelationship and interaction between an organism and the ecosystem. It also enables us to know the mechanism of energy flow in an ecosystem. Decomposers complete a life cycle. They help in recycling the nutrients as they provide nutrients to soil or oceans, that can be utilised by autotrophs or producers. Thus, starting a whole new food chain.

8.4 Types of Food Chain

There are three types of food chains, namely detritus food chain, grazing food chain p and parasitic food chain. Let's look at them more closely:

Detritus food chain: The detritus food chain includes different species of organisms and plants like algae, bacteria, fungi, protozoa, mites, insects, worms and so on. The detritus food chain begins with dead organic material. The food energy passes into decomposers and detritivores, which are further eaten by smaller organisms like carnivores. Carnivores, like maggots, become a meal for bigger carnivores like frogs, snakes and so on. Primary consumers like fungi, bacteria, protozoans, and so on are detritivores that feed on detritus.

Grazing food chain: The grazing food chain is a type of food chain that starts with green plants, passes through herbivores and then to carnivores. In a

grazing food chain, energy in the lowest trophic level is acquired from photosynthesis.

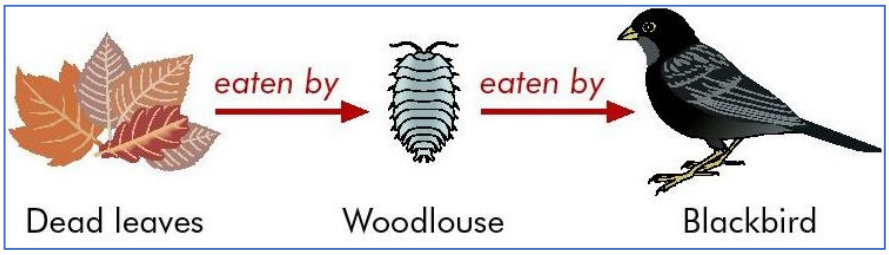

Fig. 8.3 Detritus Food Chain

In this type of food chain, the first energy transfer is from plants to herbivores. This type of food chain depends on the flow of energy from autotrophs to herbivores. As autotrophs are the base for all ecosystems on Earth, most ecosystems in the environment follow this kind of food chain.

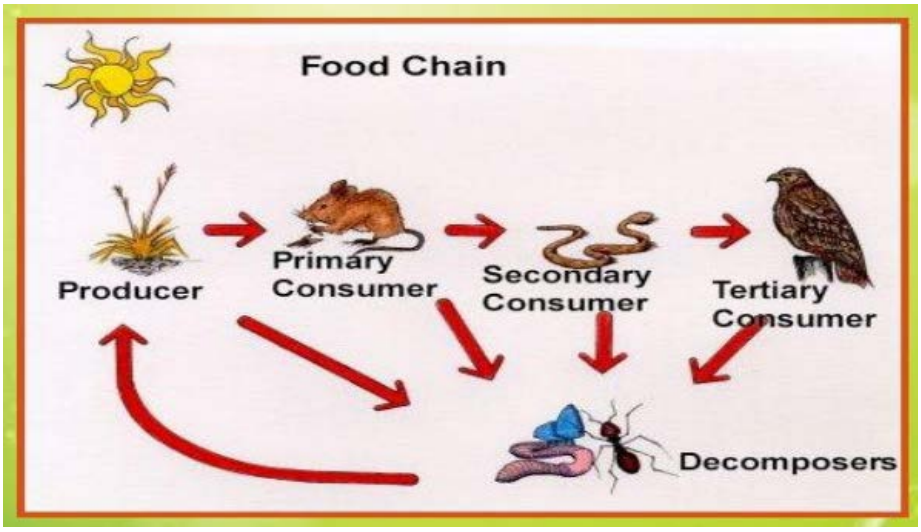

Fig. 8.4 Grazing Food Chain

Parasitic food chain: Parasitic food chain is a type of food chain that starts from herbivores, but the food energy transfers from larger organisms to smaller organisms, without killing in case of a predator. Thus, the larger animals are known to be the hosts and the smaller living organisms which acquire nutrition from the hosts are known to be the parasites. In this type of food chain, either the producer or the consumer is parasitized. Therefore, the food passes on to smaller living organisms.

Implications of Parasite in a food chain: A parasite is an organism that lives inside or on another living organism to survive. A parasite in a food chain can change the flow of energy in the food chain. All parasites are consumers. Therefore, parasites in a food chain are related to organisms that the parasite can consume. Parasites in a food chain are overlooked

mostly but affect the flow of energy in a food chain. The pyramid of numbers shows the total number of organisms at a trophic level. In a parasitic food chain, the shape of the pyramid is inverted. This is because the number of producers is low and primary consumers (herbivores) have a greater number of organisms. After this, we see secondary consumers like carnivores.

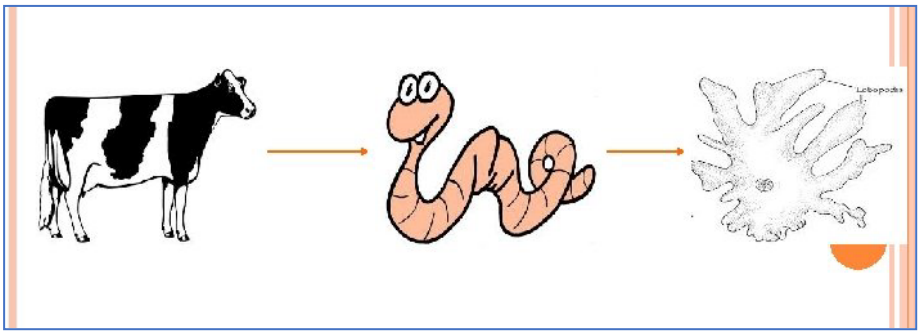

Fig. 8.5 Parasite in a food chain

8.5 Food Web

The word ‘web’ means to network. The Food web can be defined as a network of interconnected food chains to form several feeding relationships amongst different organisms of a biotic community. A food chain cannot stand isolated in an ecosystem. The same food resource may be a part of more than one chain. This is possible when the resource is at the lower tropic level.

A food web comprises all the food chains in a single ecosystem. It is essential to know that each living thing in an ecosystem is a part of multiple food chains. On the other hand, it comprises several interconnected food chains that form a food web. This is usually like a food chain, but it is larger than a food chain. In this, a single organism is consumed by several organisms. A single food chain is the single possible path that energy and nutrients may make while passing through the ecosystem. All the interconnected and overlapping food chains in an ecosystem make up a food web.

Food webs are significant tools in understanding that plants are the foundation of all ecosystems and food chains, sustaining life by providing nourishment and oxygen needed for survival and reproduction. The food web provides stability to the ecosystem. The tertiary consumers are eaten by quaternary consumers. For example, a hawk eats owls. Each food chain ends with a top predator and animal with no natural enemies (such as an alligator, hawk, or polar bear).

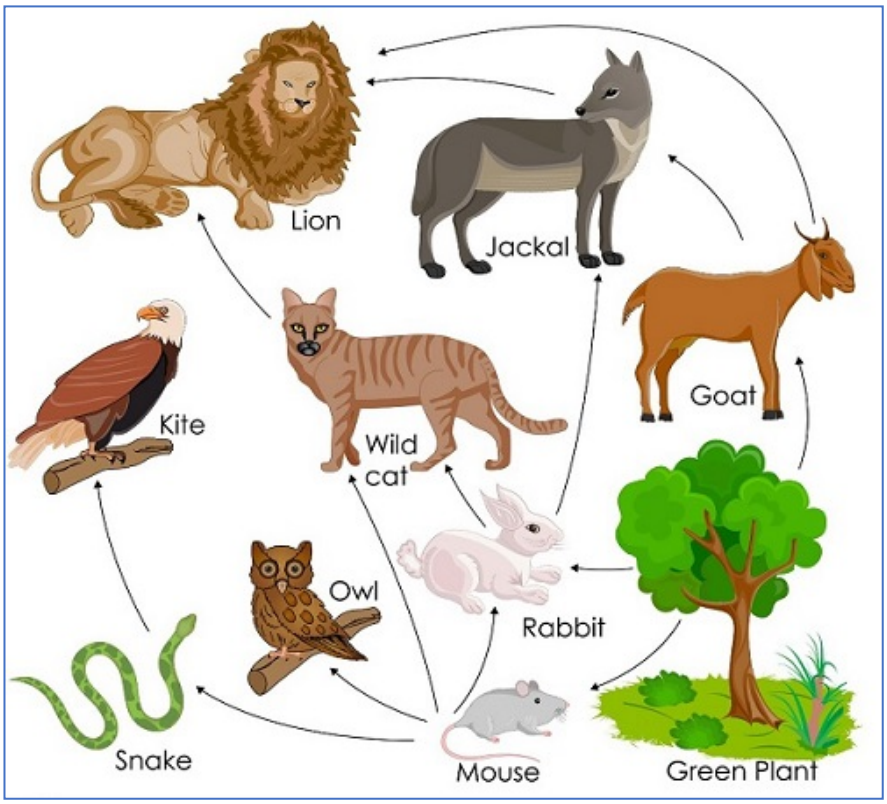

Fig. 8.6 Food web

Charles Elton presented the food web concept in the year 1927, which he termed the food cycle. Charles Elton described the concept of the food web as The carnivore animals' prey on the herbivores. These herbivores obtain energy from sunlight. The later carnivores may also be preyed upon by other carnivores. Until a reach where an animal has no enemies, it forms a terminus on this food cycle. There are chains of animals that are related together by food, and all are dependent on plants in the long run. This is termed a food chain and all the food chains in a community are known as the food web. A food web is a graphical depiction of feeding connections among species of an ecological community.

8.6 Types of Food Webs

There are two main categories of the food web: 1) Terrestrial food web or Biomes and 2) Aquatic food web

Terrestrial food web

The terrestrial food web links creatures on land, from the tiniest microbes in the soil to the large mammals of the forests. Ecologists at SERC study the connections between herbivores (plant-eaters), scavengers (eaters of dead

plants or animals), and decomposers. These links can reveal secrets about climate change, biodiversity, and the ongoing battle between native and invasive species.

Producers include grasses, berries and flowers, and seeds. These producers are eaten by insects such as butterflies, as well as birds, chipmunks, and deer, as well as by omnivores such as bears. Birds also eat insects and small mammals, and bears eat small mammals that consume the producers as well. When these animals die, they are decomposed by fungi and insects, and then used as fertilizer for the producers.

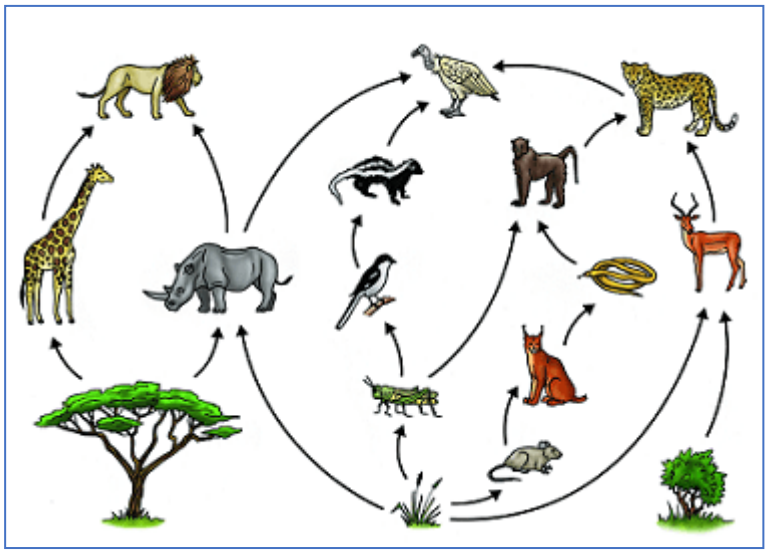

Fig. 8.7 Terrestrial Food web

Aquatic food web

Phytoplankton and algae form the bases of aquatic food webs. They are eaten by primary consumers like zooplankton, small fish, and crustaceans. Primary consumers are in turn eaten by fish, small sharks, corals, and baleen whales. Top ocean predators include large sharks, billfish, dolphins, toothed whales, and large seals. Humans consume aquatic life from every section of this food web.

Aquatic ecosystems are made up of both freshwater and saltwater. In freshwater, there are shredders like the stonefly, which feed on organic matter. Phytoplankton is the main producer of the aquatic web. Some phytoplankton and terrestrial organic matter fall to the bottom of an aquatic ecosystem where they are eaten by bottom grazers. Other phytoplankton is eaten by zooplankton. The primary consumers of zooplankton are small fish and whales. Secondary consumers are larger fish who eat the smaller fish, which can then also be eaten by larger fish or tertiary consumers.

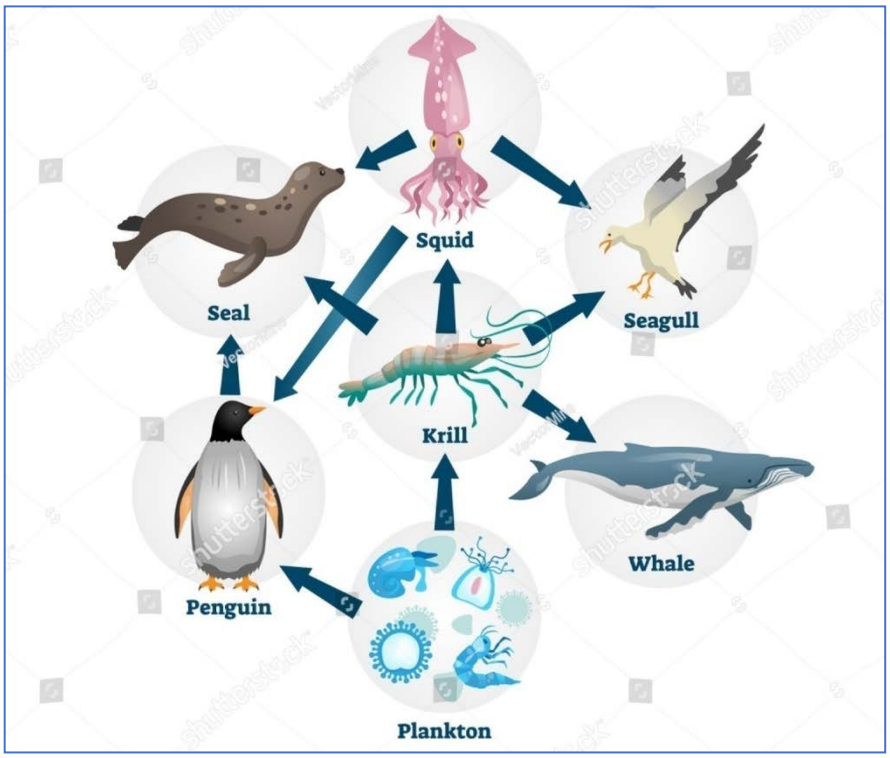

Fig. 8.8 Aquatic Food web

8.7 Some other types of Food Web

There are several different types of food webs, which differ in how they are constructed and what they show or emphasize about the organisms within the ecosystem depicted. Scientists can use connectance and interaction food webs along with energy flow, fossil, and functional food webs to depict different aspects of the relationships within an ecosystem. Scientists can also further classify the types of food webs based on what ecosystem is being depicted on the web.

connectance Food Webs: In a connectance food web, scientists use arrows to show one species being consumed by another species. All the arrows are equally weighted. The degree of strength of the consumption of one species by another is not depicted.

Interaction Food Webs: Like connectance food webs, scientists also use arrows in interaction food webs to show one species being consumed by another species. However, the arrows used are weighted to show the degree or strength of consumption of one species by another. The arrows depicted in such arrangements can be wider, bolder, or darker to denote the strength of consumption if one species typically consumes another. If the interaction between species is very weak, the arrow can be very narrow or not present.

Energy Flow Food Webs: Energy flow food webs depict the relationships between organisms in an ecosystem by quantifying and showing the energy flux between organisms.

Fossil Food Webs: Food webs can be dynamic and the food relationships within an ecosystem change over time. In a fossil food web, scientists attempt to reconstruct the relationships between species based on available evidence from the fossil record.

Functional Food Webs: Functional food webs depict the relationships between organisms in an ecosystem by depicting how different populations influence the growth rate of other populations within the environment.

8.8 Characteristics of Food webs

- Food webs describe direct and indirect species interactions in a community
- Food webs can also be used to illustrate indirect interactions among species.
- There are two approaches by which food webs can be used to study the control of community structure – the bottom-up or top-down approach.

8.9 Significance of Food chains and Food webs

1. The food chains and food webs help understand the feeding relationships and the interactions between organisms in any ecosystem.

2. Nutrient cycling and energy flow in an ecosystem takes place through food chains and food webs.

3. Food chains keep a check on the population size of different organisms. For example, in a food chain in grassland, if the deer population increases, there will be more food for the carnivores, their population will increase, which in turn will reduce the deer population. If there are fewer deer, some of the carnivores will starve and die, letting the deer population grow.

4. Food webs are very important in maintaining the stability of an ecosystem in nature. In a linear food chain, if one species become extinct or one species suffers then the species in the subsequent trophic levels are also affected. In a food web, on the other hand, there are several options available at each trophic level. So, if one species is affected, it does not affect other trophic levels so seriously.

5. Each species of any ecosystem is kept under a natural check so that the system remains balanced. For instance, if the primary consumers (herbivores) had not been in nature, the producers would have been

perished due to overcrowding and competition. Similarly, the survival of primary consumers is linked with the secondary consumers (carnivores) and so on.

6. The study of the food chain helps us to understand the problems of biomagnifications. Sometimes certain toxic substances, instead of dispersing, get concentrated at each level in the food chain and are referred to as biological magnification or bioaccumulation.

8.10 Difference Between Food Chain and Food Web

Food chain	Food web
It is a pathway in which organisms in an ecosystem are grouped into trophic levels and are shown in a succession to represent a linear flow of food energy and the feeding relationships between them.	It is a graphical model showing the interconnecting food chains in an ecological community.
It is a single linear pathway of energy flow.	It has several interconnected pathways through which the energy flows within an ecosystem.
It is a single unit.	It is a connection of several interconnected food chains.
It may consist of 4 - 6 trophic levels.	It consists of many numbers trophic levels
It increases the instability of an ecosystem.	It increases the stability of an ecosystem
It does not improve the adaptability and competition amongst the organisms.	It improves the adaptability and competitiveness of organisms
The whole food chain can be disturbed if a disturbance occurs at a single trophic level.	The whole food web won't be disturbed if a disturbance occurs at a single trophic level.

Higher trophic level members can only feed upon a single type of organism in its lower trophic level	Higher trophic level members can feed upon several types of organisms in their lower trophic levels.
It can be a grazing food chain and a detritus food chain	No such type is considered for the food web.
It is a simple and easy process.	It is a much more complex process in the ecosystem
Example - Food chain in the grassland ecosystem	Example - Food web of a grassland ecosystem

8.11 Ecological Pyramid

An ecological pyramid (also trophic pyramid, Estonian pyramid, energy pyramid, or sometimes food pyramid) is a graphical representation designed to show the biomass or bio productivity at each trophic level in a given ecosystem. An ecological pyramid is a graphical representation of the relationship between the different living organisms at different trophic levels.

The concept of the pyramid of numbers ("Estonian pyramid") was developed by Charles Elton (1927). Later, it would also be expressed in terms of biomass by Bodenheimer (1938). The idea of the pyramid of productivity or energy relies on the works of G. Evelyn Hutchinson and Raymond Lindeman (1942). It can be observed that these pyramids are in the shape of actual pyramids with the base being the broadest, which is covered by the lowest trophic level, i.e., producers. The next level is occupied by the next trophic level, i.e., the primary consumers and so on. All the calculations for the construction of these types of ecological pyramids must consider all the organisms in a particular trophic level because a sample space of a few numbers or a few species will end up giving a huge level of errors.

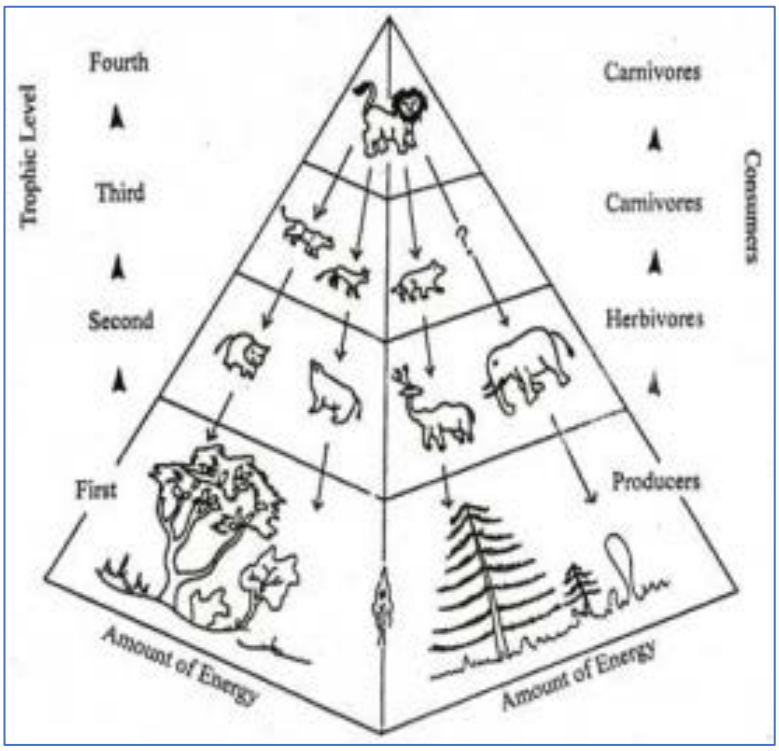

Fig. 8.9 Ecological Pyramid

The ecological pyramid includes trophic pyramid, energy pyramid, or sometimes food pyramid. Biomass is the quantity of living or organic matter present in an organism. Biomass pyramids represent the amount of biomass, and how much of it is present in the organisms at each trophic level. The productivity pyramids show the production or turnover in biomass. Ecological pyramids initiate with producers on the bottom such as green plants and proceed through the various trophic levels such as herbivores that feed on plants, then carnivores that feed on herbivores, then carnivores that feed those carnivores, and so on. The highest level is shown at the top of the chain. An ecological pyramid of biomass represents the relationship between biomass and trophic level by quantifying the biomass present at each trophic level of an ecological community at a particular time. It is a graphical representation of biomass present per unit area in different trophic levels. The flow of energy through the food chain will be in a predictable way, entering at the base of the food chain, by photosynthesis in primary producers, and then moving up the food chain to higher trophic levels. The transfer of energy from one trophic level to the next is not efficient. It may also be useful and productive to analyse how the number and biomass of organisms differ across trophic levels. Both the number and biomass of organisms at each trophic level should be affected by the amount of energy

joining that trophic level. When there is a direct correlation between energy, numbers, and biomass then biomass pyramids and numbers of pyramids will be formed.

However, the relationship between energy, biomass, and number can be complex by the growth form and size of organisms and ecological relationships occurring among trophic levels.

8.12 Types of pyramids

Three types of ecological pyramids exist. They are as follows:

Pyramid of Numbers: In this type of ecological pyramid, the number of organisms in each trophic level is considered as a level in the pyramid. The pyramid of numbers is usually upright except for some situations like that of the detritus food chain, where many organisms feed on one dead plant or animal.

1. Pyramid of numbers:

The pyramid of numbers represents the population of trophic level as the total number of individuals of different species present at each trophic level. The pyramid of numbers may be upright and or completely inverted depending upon the count of individuals present and so. The pyramid of numbers does not completely define the trophic structure for an ecosystem as it is very tough to count all the organisms present there. Pyramid of number - upright: grassland ecosystem. In this pyramid, the number of individuals is decreased from lower level to higher trophic level.

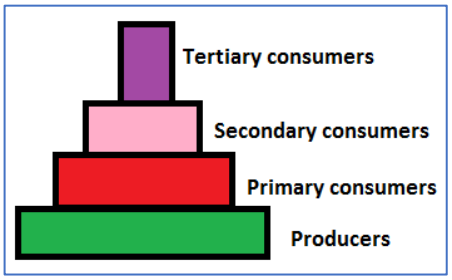

Fig. 8.10 Pyramid Numbers

Examples of the pyramid numbers are the Grassland ecosystem and pond ecosystem. In the grass ecosystem, at the base (lowest trophic level) grass is present in plentiful amounts. The next higher trophic level is primary consumer i.e., herbivore (example – grasshopper). The number count of grasshoppers is less than that of grass.

The next energy level is a primary carnivore (example: rat). The number of rats is less than grasshoppers because they feed on grasshoppers. The

next higher trophic level is a secondary carnivore (example: snakes). They feed on rats. The next higher trophic level is the top carnivore. (Example – Hawk).

As we reach each higher trophic level, the number of individuals decreases from lower to higher trophic levels.

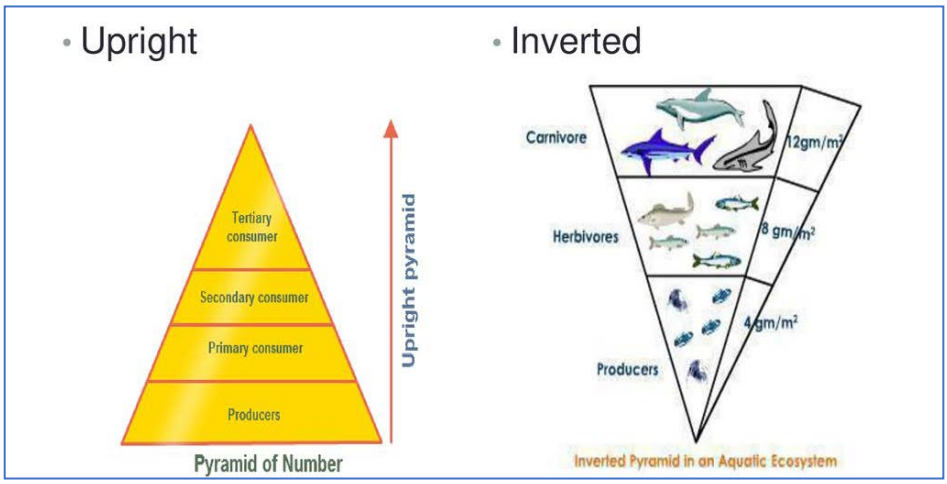

Fig. 8.11 Pyramid of numbers – inverted: tree ecosystem

In this type of pyramid, the number of individuals is increased from lower level to higher trophic level. For example, the tree ecosystem.

Pyramid of Biomass: In this ecological pyramid, each level takes into account the amount of biomass produced by each trophic level. The pyramid of biomass is also upright except for that observed in oceans where large numbers of zooplanktons depend on a relatively smaller number of phytoplanktons.

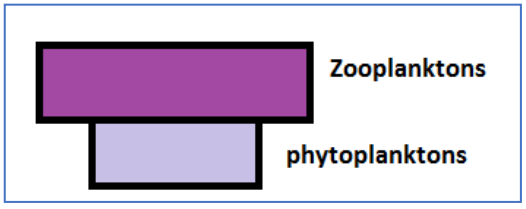

Fig. 8.12 Pyramid of Biomass in Ocean

2. Pyramid of biomass:

The pyramid of biomass represents the total dry weight of organisms.

It is usually determined by collecting all organisms invading each trophic level separately and measuring their dry weight. This will serve to solve the size difference problem because all kinds of organisms at a trophic level are weighed. The unit for the measurement of biomass is g/m2. The biomass of a species is expressed in terms of fresh or dry weight. Measurement of

biomass in terms of dry weight is considered more accurate. A certain mass of living material of each trophic level at a particular time is called a standing crop. The standing crop is measured as the mass of living organisms (biomass) or the number in a unit area.

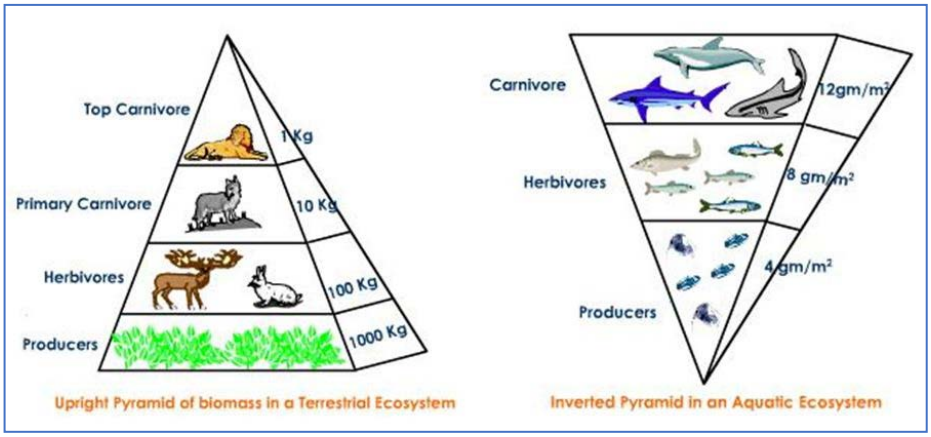

Fig. 8.13 Pyramid Upright and Inverted.

Pyramid of biomass: upright

The pyramid of biomass on land contains a large base of primary producers with a lesser trophic level present on top. The biomass of producers termed autotrophs are at the maximum trophic level.

The biomass of the next trophic level from the base, i.e., primary consumers is less than the producers. The biomass of the next higher trophic level, i.e., secondary consumers is less than the primary consumers (Fig.8.13).

The top, high trophic level consists very less amount of biomass.

On another hand, in many aquatic ecosystems, the pyramid of biomass may be present in an inverted form whereas the pyramid of numbers for the aquatic ecosystem is upright. It is because the producers are small phytoplankton that grows and reproduces very rapidly.

Here, the pyramid of biomass has a small base as compared to the consumer biomass at any instant exceeding the producer biomass and the pyramid is represented in an inverted shape.

Pyramid of Energy: The pyramid of energy is the only type of ecological pyramid, which is always upright as the energy flow in a food chain is always unidirectional. Also, with every increasing trophic level, some energy is lost in the environment.

3. Pyramid of energy

The pyramid of energy represents the flow of energy from lower trophic levels to higher trophic levels. During the flow of energy from one organism

to another, there is a remarkable loss of energy. This loss of energy is in the form of heat. The primary producers like the autotrophs contain more amount of energy available. The least energy is available in the tertiary consumers. Thus, a shorter food chain has more amount of energy available even at the highest trophic level.

An energy pyramid is regarded as most suitable to compare the functional roles of the trophic levels in an ecosystem. An energy pyramid represents the amount of energy at each trophic level and the loss of energy taking place during transfer to another trophic level. Hence the pyramid is always upward, with a large energy base at the bottom. Suppose an ecosystem receives 1000 calories of light energy each day. Most of the energy is not absorbed by plants; some amount of energy is reflected in space.

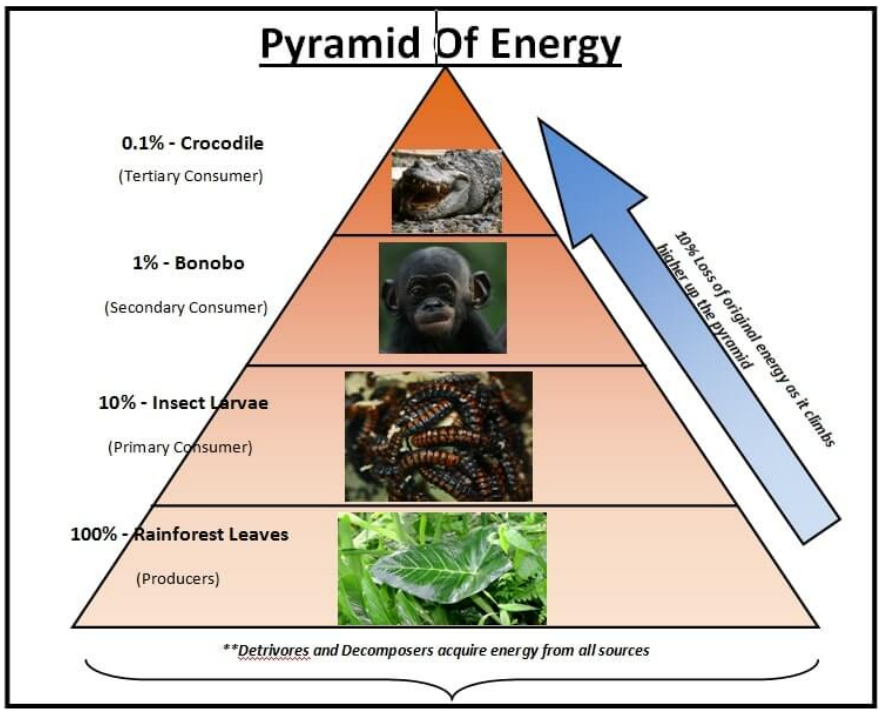

Fig. 8.14 Energy Pyramid

Green plants utilise only a small portion of that absorbed energy, out of which the plant uses up some for respiration and of the 1000 calories, only 100 calories (10%) are stored as energy-rich materials. Now, suppose an animal eats the plant containing 100 calories of food energy, that animal uses some of it for its metabolism and stores only 10 calories as food energy. A lion that eats that animal gets an even smaller amount of energy.

Thus, usable energy decreases while passing from sunlight to producer to herbivore to carnivore. Therefore, the energy pyramid will always be upright.

8.13 Function of Ecological Pyramid:

1. An ecological pyramid not only shows us the feeding patterns of organisms in different ecosystems but can also give us an insight into how inefficient energy transfer is and show the influence that a change in numbers at one trophic level can have on the trophic levels above and below it.

2. Also, when data are collected over the years, the effects of the changes that take place in the environment on the organisms can be studied by comparing the data.

3. If an ecosystem's conditions are found to be worsening over the years because of pollution or overhunting by humans, action can be taken to prevent further damage and possibly reverse some of the present damage.

8.14 Importance of Ecological Pyramid

The importance of the ecological pyramid can be explained in the following points: They show the feeding of different organisms in different ecosystems. It shows the efficiency of energy transfer. The condition of the ecosystem can be monitored, and any further damage can be prevented.

8.15 Limitations of the Ecological Pyramid

- More than one species may occupy multiple trophic levels as in the case of the food web. Thus, this system does not consider food webs.
- The saprophytes are not considered in any of the pyramids even though they form an important part of the various ecosystem.
- These pyramids apply only to simple food chains, which usually do not occur naturally.
- These pyramids do not deliver any concept about variations in season and climate.
- They do not consider the possibility of the existence of the same species at different levels.

Let Us Sum Up

The trophic level interaction among the organisms leads to the formation of the Food Web, Food Chain and Ecological Pyramid. Understanding food chains is vital, as they explain the intimate relationships in an ecosystem. A food chain shows us how every living organism is dependent on other organisms for survival. The food chain explains the path of energy flow inside an ecosystem. The Food web provides multiple alternatives for the

food to organisms and if any of the intermediate food chains is removed the other succeeding links of the food chain will also get affected to a larger extent. An Ecological Pyramid is the graphical representation of trophic levels in terms of Biomass, Energy concentrated at a particular trophic level, Number of Organisms etc. When the organisms are plotted in terms of energy, Biomass, Number associated at trophic levels, they assume the shape of the Pyramid known as the Ecological Pyramid.

Glossaries

Food chain: A food chain describes the feeding relationships of different organisms in a linear fashion. This is the simplest way of showing feeding relationships.

Food web: A food web shows multiple food chains, multiple relationships and connections. This is a more complicated but more realistic way of showing feeding relationships, as most organisms consume more than one species and are consumed by more than one species

Ecological Pyramid: An ecological pyramid is a graphical representation of the relationship between different organisms in an ecosystem. Each of the bars that make up the pyramid represents a different trophic level, and their order, which is based on who eats whom, represents the flow of energy.

Producers: Producers otherwise called autotrophs prepare their food by themselves. They form the first level of every food chain.

Pyramid of Biomass: In this ecological pyramid, each level considers the amount of biomass produced by each trophic level.

Check Your Progress

1. What is mean by herbivores

   Answer: Primary consumers eat the producers. They are called herbivores. Deer, turtles, and many types of birds are herbivores.

2. Write the type of food chain?

   Answer: There are three types of food chains, namely the detritus food chain, grazing food chain p and parasitic food chain.

3. Mention the importance of the Aquatic food web?

   Answer: Phytoplankton and algae form the bases of aquatic food webs. They are eaten by primary consumers like zooplankton, small fish, and crustaceans. Primary consumers are in turn eaten by fish, small sharks, corals, and baleen whales. Top ocean predators include large sharks,

billfish, dolphins, toothed whales, and large seals.

4. Briefly mention the Pyramid of Energy?

   Answer: Pyramid of energy is the only type of ecological pyramid, which is always upright as the energy flow in a food chain is always unidirectional

5. Give the types of energy pyramid?

   Answer: There are three types of energy pyramid, Pyramid in Number, Pyramid in Biomass and Pyramid in Energy

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Suggested Online Readings

1. https://www.uv.mx/personal/fpanico/files/2011/04/AA.-VV.-Environmental-geography.pdf
2. https://drive.google.com/file/d/179FJ0X3tMxk76IpQz1E8EEbDqxmnJr_1/view
3. https://drive.google.com/file/d/1_z3rRVihN_wWThNRZ-dSvvODxvqvqQxp/view
4. https://www.hzu.edu.in/bed/E%20V%20S.pdf
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6. https://drive.google.com/file/d/1eIxTTKQYV5rL3019D0MJ_tM7TvZPLaZy/view
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UNIT 9

Environmental Ethics and Deep Ecology

Structure

9.1 Overview

Environmental ethics is a branch of applied philosophy that studies the conceptual foundations of environmental values as well as more concrete issues surrounding societal attitudes, actions, and policies to protect and sustain biodiversity and ecological systems. As we will see, there are many different environmental ethics one could hold, running the gamut from human-centred (or "anthropocentric") views to more nature-centred (or "non-anthropocentric") perspectives. Non-anthropocentric argues for the promotion of nature's intrinsic, rather than instrumental or use value to humans. For some ethicists and scientists, this attitude of respecting species and ecosystems for their sakes is a consequence of embracing an ecological worldview; it flows out of an understanding of the structure and function of ecological and evolutionary systems and processes. We will consider how newer scientific fields devoted to environmental protection such as conservation biology and sustainability science are thus often described as "normative" sciences that carry a commitment to the protection

of species and ecosystems; again, either because of their intrinsic value or for their contribution to human wellbeing over the long run.

The relationship between environmental ethics and the environmental sciences, however, is a complex and often contested one. For example, debates over whether ecologists and conservation biologists should also be advocates for environmental protection — a role that goes beyond the traditional profile of the "objective" scientist — have received much attention in these fields. Likewise, we will see those issues such as the place of animal welfare concerns in wildlife management, the valuation and control of non-native species, and the adoption of a more interventionist approach to conservation and ecological protection (including proposals to relocate wild species and to geoengineer earth systems to avoid the worst effects of global climate change) frequently divide environmental scientists and conservationists. This split often has as much to do with different ethical convictions and values regarding our responsibility to species and ecosystems as it does with scientific disagreements over the interpretation of data or the predicted outcomes of societal actions and policies.

Learning Objectives

After studying this unit, you will learn the following,

- Environmental Ethics, types, Approaches, Issues involved in environmental ethics and Measures to maintain environmental ethics
- Deep Ecology and Principles of Deep Ecology

9.3 Environmental Ethics

Sustainability and environmental issues make up a significant aspect of human life, so understanding the importance of environmental ethics can benefit both humans and the environment. At its core, Environmental ethics is the discipline in philosophy that studies the moral relationship of human beings to, and the value and moral status of, the environment and its non-human Structure.

Environmental ethics is a branch of ethics that studies the relation of human beings and the environment and how ethics play a role in this. Environmental ethics believe that humans are a part of society as well as other living creatures, which includes plants and animals. These items are a very important part of the world and are a functional part of human life. Therefore, it is essential that every human being respected and honour this and use morals and ethics when dealing with these creatures.

The Earth Day celebration of 1970 was also one of the factors which led to the development of environmental ethics as a separate field of study. This field received impetus when it was first discussed in academic journals in North America and Canada. Around the same time, this field emerged in Australia and Norway. Scientists like Rachel Carson and environmentalists who led philosophers to consider the philosophical aspect of environmental problems, pioneered in the development of environmental ethics as a branch of environmental philosophy. Today, environmental ethics is a widely discussed topic. It covers aspects such as ethical principles that guide our use of natural resources, our duty to take efforts towards environmental protection, and our moral responsibility towards animals.

The study of environmental ethics became an official discipline in the 1970s. During this time, experts sought to understand how technology, commercial industries, and the growing global population had and would continue to have an impact on the environment. Individuals have continued to work toward understanding how these human-related factors will have a long-term impact on the environment, nonrenewable resources, climate change, rising sea levels, loss of biodiversity, and other issues. It aims to provide ethical justification and moral motivation for the cause of global environmental protection. Several distinctive features of environmental ethics deserve our attention.

First, environmental ethics is extended.

Traditional ethics mainly concerns intra-human duties, especially duties among contemporaries. Environmental ethics extends the scope of ethical concerns beyond one's community and nation to include not only all people everywhere but also animals and the whole of nature – the biosphere – both now and beyond the imminent future to include future generations.

Second, environmental ethics is interdisciplinary.

There are many overlapping concerns and areas of consensus among environmental ethics, environmental politics, environmental economics, environmental sciences and environmental literature, for example. The distinctive perspectives and methodologies of these disciplines provide important inspiration for environmental ethics, and environmental ethics offers value foundations for these disciplines. They reinforce, influence and support each other.

Third, environmental ethics is plural.

From the moment it was born, environmental ethics has been an area in which different ideas and perspectives compete with each other.

Anthropocentrism, animal liberation/rights theory, biocentrism and ecocentrism all provide unique and, in some sense, reasonable ethical justifications for environmental protection. Their approaches are different, but their goals are by and large the same, and they have reached this consensus: it is everyone's duty to protect the environment. The basic ideas of environmental ethics also find support from and are embodied in, various well-established cultural traditions. The pluralism of theories and multicultural perspectives is critical for environmental ethics to retain its vitality.

Fourth, environmental ethics is global.

The ecological crisis is a global issue. Environmental pollution does not respect national boundaries. No country can deal with this issue alone. To cope with the global environmental crisis, human beings must reach some value consensus and cooperate at the personal, national, regional, multinational, and global levels. Global environmental protection depends on global governance. An environmental ethic is, therefore, typically a global ethic with a global perspective.

Fifth, environmental ethics is revolutionary.

At the level of ideas, environmental ethics challenges the dominant and deep-rooted anthropocentrism of modern mainstream ethics and extends the object of our duty to future generations and non-human beings. At the practical level, environmental ethics forcefully critiques the materialism, hedonism and consumerism accompanying modern capitalism, and calls instead for a 'green lifestyle' that is harmonious with nature. It searches for an economic arrangement that is sensitive to Earth's limits and concerns for the quality of life. In the political arena, it advocates a more equitable international economic and political order that is based on the principles of democracy, global justice and universal human rights. It argues for pacifism and against an arms race. In short, as the theoretical representation of a newly emerging moral idea and value orientation, environmental ethics is the fullest extension of human ethics. It calls on us to think and act locally as well as globally. It calls for a new, deeper moral consciousness.

9.4 Main types of environmental ethics

A wide variety of options exist when it comes to taking environmental considerations into account in an ethical framework. Taking environmental matters into account does not necessarily mean favouring the environment. A frequently encountered attitude is the traditional minimization of environmental considerations in socio-economic discussions. However, on

the other side of the spectrum, one finds genuinely concerned with environmental thinking. When it comes to dealing with environmental issues in ethics, the range covers pro-, through neutral, to anti-environmental thinking. According to this background, Sylvan and Bennett (1994) describe three main types of environmental ethics:

The green "application" of standard ethics: many applications in this context may yield outcomes that are far from beneficial to the environment.

Adaptation or extension of standard ethics to accommodate environmental causes: an example of this is the adaptation of utilitarianism to animal liberation purposes.

New, non-standard ethics, which supersede established ethics. An example of this type of ethics is "deep ecology" which is discussed in section 3.5.

There are many other systems for classifying the variety of approaches in environmental ethics. To this text, the above system is used because it usefully classifies the wide array of approaches according to their level of commitment to environmental values.

9.5 Approaches in Environmental Ethics

Anthropocentric Approach: According to one belief, humans are dominating species on the planet Earth. Human beings have used nature for their benefit. It is a human-centred thought, so it is called anthropocentric.

Bio-centred approach: As per this approach Human beings have a moral responsibility to be responsible to future generations of humans. This approach is the basis of sustainable development.

Eco Centric approach: People who want goodwill towards all living beings and demand their reverence and respect towards the entire environment. These types of work speak of moral responsibilities towards other beings. Is indicative of an ecological approach

9.6 Issues involved in environmental ethics

Consumption of natural resources: Since humans are part of nature, sustainable use of resources can be achieved through cooperation with nature.

Destruction of forests: big industries and multinational companies form the major section which exploits forests unsustainably. However, the brunt of the destruction is faced by the poor and tribals who are the inhabitants of the forests. It leads to the loss of biodiversity, habitats and extinction of plants and animals.

Environmental pollution: Consequences of environmental pollution do not respect national boundaries. Moreover, the poor and weaker sections of society are disproportionately affected by the negative effects of climate change.

Anthropocentrism: It refers to an ethical framework that grants "moral standing" solely to human beings. Thus, an anthropocentric ethic claims that only human beings are morally considerable, meaning that all the direct moral obligations we possess, including those we have about the environment, are owed to our fellow human beings.

Equity: People living in the economically advanced sections/ parts use a greater number of resources and energy per individual and waste more resources. This is at the cost of poor people who are resource-deprived.

Animal rights: The plants and animals that share the Earth with us have a right to live and share the Earth's resources and living space. Animal welfare is relevant to environmental ethics because animals exist within the natural environment and thus form part of environmentalists' concerns.

9.7 Measures to maintain environmental ethics

The "land ethic" of Aldo Leopold: Demands that we stop treating the land as a mere object or resource. The land is not merely soil, instead, it is a fountain of energy, flowing through a circuit of soils, plants, and animals.

To preserve the relations within the land, Leopold claims that we must move towards a "land ethic", thereby granting moral standing to the land community itself, not just its members.

9.8 Deep Ecology

The concept of "Deep ecology" was born in Scandinavia, the result of discussions between Arne Naess and his colleagues Sigmund Kvaloy and Nils Faarlund. All three shared a passion for the great mountains. On a visit to the Himalayas, they became impressed with aspects of "Sherpa culture" particularly when they found that their Sherpa guides regarded certain mountains as sacred and accordingly would not venture onto them.

Deep ecology is just one of several perspectives to arise in environmental ethics. Environmental ethics is a philosophical domain concerned with human interaction with nature and the morally right ways of behaving toward and thinking about nature. Deep ecology was so named by Naess because it specifically required people to question their most basic values and purposes when interacting with other species and entities in nature. With

entities, Naess was referring to non-biological entities like mountains, rivers, and the atmosphere.

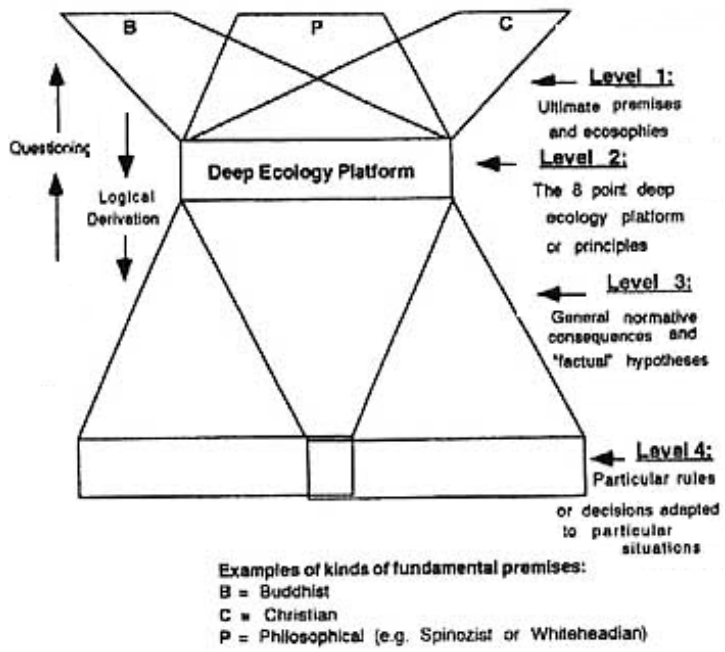

Fig.9.1 Deep Ecology Platform

This diagram shows how deep ecology moves from basic actions to deeper questions. Naess saw deep ecology as separate from, but not incompatible with, other ecological movements, which he deemed shallow ecology. "Shallow" and "deep" provided descriptive terms for the level of introspection and the societal transformation required to fulfil what Naess thought of as humankind's obligation to nature. Shallow ecology movements, according to Naess, aimed to develop solutions to ecological problems and ecological ethics through the systems and institutions already established in society. These were predominantly based on science and involved modifying consumer culture.

9.9 Principles of Deep Ecology

Naess together with the American philosopher Sessions developed eight essential principles for deep ecology in the mid-1980s that, 40 years later, continue to be true:

- Inherent value: There is intrinsic value to the well-being of all life on earth, human and non-human alike.
- Diversity: This intrinsic value is realized in and supported by the rich diversity of life forms on the planet.

- Vital Needs: Except when satisfying their basic survival needs, humans have no right to reduce this rich diversity.
- Population: The current human impact on other life forms is detrimental, excessive, and accelerating.
- Human Interference: For non-human life to thrive, the human population must substantially decrease. However, this does not mean humans cannot flourish nor does it mean reducing the rich diversity of human cultures.
- Policy Change: To remedy society's impact on nature, there must be a deep and fundamental change in policies, economics, technology, and even ideologies, resulting in a vastly different society.
- Quality of Life: Required ideological changes include abandoning the quest for ever-increasing standards of living, mainly the relentless pursuit of excessive wealth.
- Obligation of Action: Those who believe in these principles are morally obligated to help bring about the needed changes.

The first principle of deep ecology has a couple of basic points that it aims to get across. The most important part, however, is that every living being, human and nonhuman, has its inherent value, and thus has its right to live and flourish. Essentially, everything has an “own” to it, and therefore has its irreducible right to live, to blossom, to reach its fullness in existing and reproducing. Each living thing is independent and separate from its “usefulness” to any other thing, specifically of humans. Lastly, these all mean that deep ecology is really about ecocentrism, and not anthropocentrism, in that it is against seeing everything in terms of its beneficial usefulness (or lack thereof) to humans. It is important to note that not just the actual living and breathing beings are the ones that should be considered. The “non-living”, as Naess put it, which include watersheds, landscapes, and ecosystems as their wholes, should never be overlooked, in that they too have an unbelievable amount of importance.

The second principle addresses the issue of why everything should be seen as having its value, through the explanation of interconnectedness. This point reinforces the importance of biodiversity in the world--that everything is connected to everything else. No hierarchy exists of living things, simply because without everything, everything else would not exist. Everything is reliant upon everything, and therefore nothing can be less or more than anything else in the web of life. Deep ecology calls for humans to view everything as in the relationship Naess describes between object A and

object B: “An intrinsic relation between two things A and B is such that the relation belongs to the definitions or basic constitutions of A and B so that without the relation, A and B are no longer the same things (Sessions, 151).” In their infinite relationships, all things help to contribute to the richness and diversity in life, and the web is moreover not about the complication with the inclusion of all things, but the beautiful complexity that is brought about by all things. We need to value the richness and diversity of life forms in and of themselves because we as humans also rely on them. It furthermore explains that ecosystems are self-regulating and self-maintaining because of this biodiversity and interdependence. Ecosystems require every member to function, but if they have that, there is no other need for human interference.

It is next explained in the third principle to what extent a living being’s inherent value can be ignored. Essentially, this inherent value, or intrinsic worth, is only reducible by the vital needs of the individual. This is somewhat of a vague area, and it was meant to be left this way for the individual’s interpretation of what they define as vital needs. Vital needs are the opposite of “other” needs, meaning that while it is the individual’s job to determine the difference between the two, all of these should be categorized as such. While some would say that vital needs are just food, clothing, and shelter, many others may say that all the daily activities and ways of life are vital needs. It is also important to look into the intention of reducing a living thing inherent worth. While some individuals go hunting for food to eat, others go for sport. While some accidentally step on a bug, others do it on purpose. It is being stressed that no human has the right to reduce any other living things right to live and flourish, except in the case of its own vital needs, and every living thing needs to be taken into consideration. If an individual does so happen to violate another beings’ right when it is not a vital need, it should never be done with intention or awareness of doing so.

The fourth principle is perhaps one of the most controversial parts of deep ecology and this is where much of the criticism of deep ecology is rooted as well. Because of excessive human interference in the environment, deep ecology calls for a decrease in the human population, and this will then lead to a higher quality of life. Increasing population is simply not the best for quality of life, nor is it good for the environment, and therefore needs to be significantly cut back. Doing so will bring about the stabilization of the ecosystems. If this is not done, Naess says that “substantial decreases in richness and diversity are liable to occur (Sessions, 69).” While this is ideally supposed to be recognized and started upon as quickly as possible, it is also important to realize that this will take many years to become a reality.

The fifth principle identifies where environmental problems are stemming from, and that is human interference. This goes back to the second principle, in humans being able to identify that ecosystems are self-regulating, and there is no need for human involvement. Essentially, humans are a part of nature and are expected to interfere in their environment to a certain extent. Naess explains that every animal interferes with its surroundings, such as a beaver building its dam, or a bird building her nest. However, human interference has been going on excessively and must be put to a stop. Without exception, it seems, human interference has continually done more harm than good because ecosystems are developed to maintain themselves.

In the sixth principle, there is a call for new policies and radical social changes to be made. To make changes, new ideas and mindsets need to come about, and thus, new policies will emerge on how humans treat the environment. This is nothing that can be done overnight but needs to be done over decades. It is not something that can suddenly be made into a law, and it is essentially thought to have a purpose of completely transforming every single part of human life.

The seventh principle supports a simplified lifestyle. It addresses the fact that quality of life should take precedent over the number of things, to reach a higher level of happiness instead of a higher standard of living. It calls for voluntary simplicity, meaning that not only is it that the human reduction of needs must happen, but that it must be wanted to happen, and through this, greater happiness will emerge.

Lastly, the seven principles, after being read and understood, call for an “obligation” of direct or indirect action. It is not necessarily about obligation, however, but what the understanding of these principles should bring about in its awareness and intention of a better living, and in theory, a better environment. Deep ecology does not call for just the Earth to be fought for, but for these values to be fought for, and for a new change in the world to develop and take over. In the environment, many things are overlooked, and essentially, what this philosophy is trying to get across is a coming about of a better world, spawned by the better individual. It is something that can and should be adopted by all humans, and through living these principles, it is theorized that not just the environmental problems will disappear, but social, political, economic, and human relational problems will dissolve as well. Basing thought on the environment is a start, but it is not solely about that and in its hopes, a better place will be attained.

Let Us Sum Up

Environmental ethics is theory and practice about appropriate concern for, values in, and duties regarding the natural world. By classical accounts, ethics are people relating to people in justice and love. Environmental ethics starts with human concerns for a quality environment, and some think this shapes the ethic from start to finish. Others hold that, beyond inter-human concerns, values are at stake when humans relate to animals, plants, species, and ecosystems. Deep ecology proposes an embracing of ecological ideas and environmental ethics (that is, proposals about how humans should relate to nature). ... Deep ecology claims that ecosystems can absorb damage only within certain parameters, and contends that civilization endangers the biodiversity of the earth

Glossaries

Environmental Ethics: a new sub-discipline of philosophy that deals with the ethical problems surrounding environmental protection. It aims to provide ethical justification and moral motivation for the cause of global environmental protection.

Deep Ecology: it is an environmental movement and philosophy which regards human life as just one of many equal components of a global ecosystem.

Hazard: Hazard is a condition/event that has the potential for causing injury/ loss of life or damage to property/environment.

Disaster: Disaster is an event that occurs suddenly/unexpectedly in most cases and disrupts the normal course of life in the affected area; results in loss or damage to life property or environment and is beyond the coping capacity of the local affected population/society and therefore requires external help.

Anthropocentrism: It refers to an ethical framework that grants “moral standing” solely to human beings.

Check Your Progress

1. Mention the types of hazards?

   Answer: Biological, Environmental, Geological, or geophysical, Hydrometeorological and Technological hazards

2. When did the study of environmental ethics start?

   Answer: The study of environmental ethics became an official discipline in the 1970s.

3. What are the environmental ethics approaches?

   Answer: Anthropocentric Approach, Bio-centered approach, and Eco Centric approach

4. Who coined the concept of Deep Ecology?

   Answer: Arne Naess.

5. How many principles are there in deep ecology?

   Answer: Eight Principles.

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UNIT 10

Global Warming and Urban Heat Island

Structure

10.1 Overview

“Global warming is a gradual increase in the earth's temperature generally due to the greenhouse effect caused by increased levels of carbon dioxide, CFCs, and other pollutants. The United Nations Framework Convention on Climate Change (UNFCCC) defines ‘climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods. The major characteristics of climate change include a rise in average global

temperature, ice cap melting, changes in precipitation, and an increase in ocean temperature leading to sea-level rise. Climate change leads to Global Warming.

Learning Objectives

After learning this unit, you will learn the following

- Meaning of Global Warming, Greenhouse Gases, Impacts of Global Warming and Global Warming Potential (GWP)
- Urban Heat Island, types, causes, effect and control methods

10.2 Global Warming

Global warming is one of the most serious threats in the 21st century. It is the long-term heating of Earth's climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere. The term is frequently used interchangeably with the term climate change, though the latter refers to both human and naturally produced warming and the effects it has on our planet. It is mostly measured as the average increase in Earth's global surface temperature, which can contribute to changes in global climate patterns.

Global warming can occur from a variety of causes, both natural and human-induced. In common usage, "global warming" often refers to the warming that can occur because of increased emissions of greenhouse gases from human activities. Global Warming is important since it helps determine future climate expectations.

10.3 Greenhouse Gases

The greenhouse gases absorb heat radiation from the sun. Following the initiation of the Industrial Revolution, the emission of greenhouse gases into the atmosphere has increased exponentially. This has led to more absorption and retaining the heat in the atmosphere. This increased Global Temperature. The greenhouse gases mostly do not absorb the solar radiation but absorb most of the infrared emitted by the Earth's surface. The main greenhouse gases include

Water vapour: It is the most abundant greenhouse gas (GHG); however it spends just a short time in the atmosphere. The amount of water vapour varies drastically with time, region and altitude. It is not considered the most important GHG

Carbon dioxide (CO2): Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.

Methane (CH4): Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.

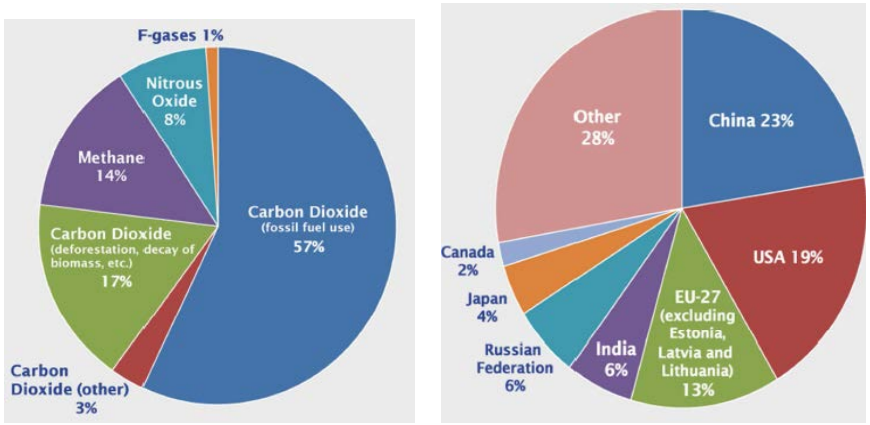

Fig. 10.1 Percentage Share of Greenhouse Gases and Country - wise share

Nitrous oxide (N2O): Nitrous oxide is emitted during agricultural and industrial activities, combustion of fossil fuels and solid waste, as well as during treatment of wastewater.

Fluorinated gases: Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases").

Hence these gases are known as greenhouse gases and the heating effect is known as the greenhouse effect.

10.4 Man-made Causes of Global Warming

Deforestation: Plants are the main source of oxygen. They take in carbon dioxide and release oxygen thereby maintaining environmental balance. Forests are being depleted for many domestic and commercial purposes. This has led to an environmental imbalance, thereby giving rise to global warming.

Use of Vehicles: The use of vehicles, even for a very short distance results in various gaseous emissions. Vehicles burn fossil fuels which emit a large amount of carbon dioxide and other toxins into the atmosphere resulting in a temperature increase.

Chlorofluorocarbon: With the excessive use of air conditioners and refrigerators, humans have been adding CFCs into the environment which affects the atmospheric ozone layer. The ozone layer protects the earth surface from the harmful ultraviolet rays emitted by the sun. The CFCs has led to ozone layer depletion making way for the ultraviolet rays, thereby increasing the temperature of the earth.

Industrial Development: With the advent of industrialization, the temperature of the earth has been increasing rapidly. The harmful emissions from the factories add to the increasing temperature of the earth. In 2013, the Intergovernmental Panel for Climate Change reported that the increase in the global temperature between 1880 and 2012 has been 0.9 degrees Celsius. The increase is 1.1 degrees Celsius when compared to the pre-industrial mean temperature.

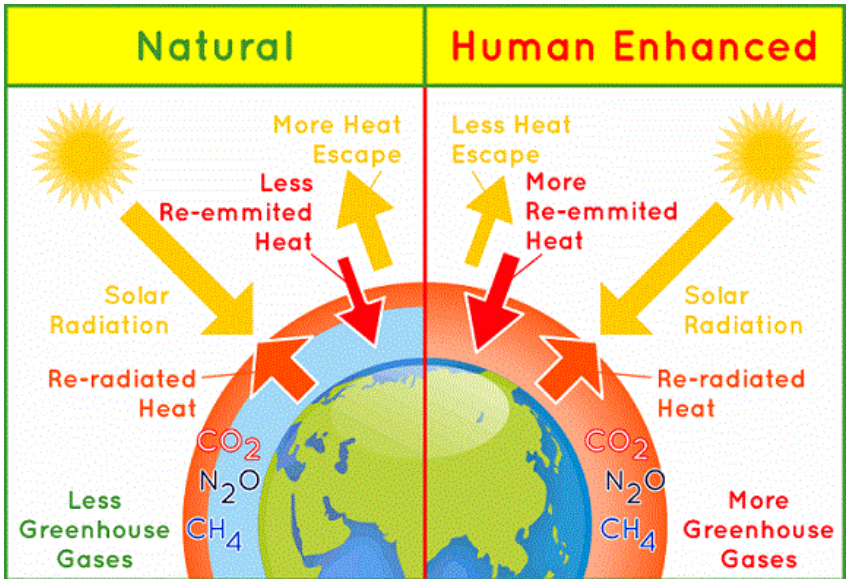

Fig. 10.2 Greenhouse Effect

Agriculture: Various farming activities produce carbon dioxide and methane gas. These add to the greenhouse gases in the atmosphere and increase the temperature of the earth.

Overpopulation: Increase in population means more people breathing. This leads to an increase in the level of carbon dioxide, the primary gas causing global warming, in the atmosphere.

10.5 Natural Causes of Global Warming

Volcanoes: Volcanoes are one of the largest natural contributors to global warming. The ash and smoke emitted during volcanic eruptions goes out into the atmosphere and affects the climate.

Water Vapour: Water vapour is a kind of greenhouse gas. Due to the increase in the earth's temperature more water gets evaporated from the water bodies and stays in the atmosphere adding to global warming.

Melting Permafrost: Permafrost is there where glaciers are present. It is frozen soil that has environmental gases trapped in it for several years. As the permafrost melts, it releases the gases back into the atmosphere increasing the earth's temperature.

Forest Blazes: Forest blazes or forest fires emit a large amount of carbon-containing smoke. These gases are released into the atmosphere and increase the earth's temperature resulting in global warming.

10.6 Impacts of Global Warming

Rising Sea level: Flooding of freshwater marshlands, low-lying cities, and islands with marine water is one of the major effects of global warming.

Changes in rainfall patterns: In some areas, droughts and fires happen, whereas in other areas, flooding takes place. This all is due to changes in rainfall patterns.

Melting of the ice peaks: Due to the melting of the ice peaks, there is a loss of habitat near the poles. Now the polar bears are greatly endangered by the shortening of their feeding season because of declining ice packs.

Melting glaciers: There is a significant melting of old glaciers.

Spread of disease: There is a spread of diseases like malaria due to migration to newer and currently warmer regions.

Thinning of Coral Reefs due to warming seas as well as acidification because of carbonic acid formation: Almost one-third of coral reefs are now severely damaged by warming seas.

Loss of Plankton owing to warming seas: The large (900 miles long) Aleutian Island ecosystems consisting of whales, sea lions, sea urchins, kelp beds, fish, and other aquatic animals, has now been reduced due to loss of plankton.

10.7 Global Warming Potential (GWP)

Global warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. A GWP is calculated over a specific time interval, commonly 20, 100, or 500 years. GWP is expressed as a factor of carbon dioxide (whose GWP is standardized to 1). The GWP depends on the following factors:

- The absorption of infrared radiation by a given species
- The spectral location of its absorbing wavelengths
- The atmospheric lifetime of the species

Thus, a high GWP correlates with a large infrared absorption and a long atmospheric lifetime. The dependence of GWP on the wavelength of absorption is more complicated. Even if a gas absorbs radiation efficiently at a certain wavelength, this may not affect its GWP much if the atmosphere already absorbs most radiation at that wavelength. Gas has the most effective if it absorbs in a “window” of wavelengths where the atmosphere is transparent.

10.8 Urban Heat Island

Heat islands form as vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. These surfaces absorb - rather than reflect - the sun's heat, causing surface temperatures and overall ambient temperatures to rise. An Urban Heat Island (UHI) is a part of an urban or a metropolitan area that is marked by remarkably high temperatures as compared to its rural counterpart due to excessive human activity. The temperature difference is noticed usually during the night and when winds are weak. The UHI is noticed when both the summer and winter seasons are at their peak. The term heat island is also used. Generally, such terms are used to denote any area that has high temperatures compared to the surrounding area, but it usually refers to those areas which have a high level of human activity.

The term “urban heat island” refers to the fact that cities tend to get much warmer than their surrounding rural landscapes, particularly during the

summer. This temperature difference occurs when cities' unshaded roads and buildings gain heat during the day and radiate that heat into the surrounding air. As a result, highly developed urban areas can experience mid-afternoon temperatures that are 15°F to 20°F warmer than surrounding, vegetated areas. The phenomenon, 'Urban Heat Island' was first investigated and described by Luke Howard in the 1810s. The temperature difference usually is larger at night than during the day and is most apparent when winds are weak. The typical temperature difference is several degrees between the centre of the city and surrounding fields. It can be as high as 10 °C.

Urban Heat Island Profile

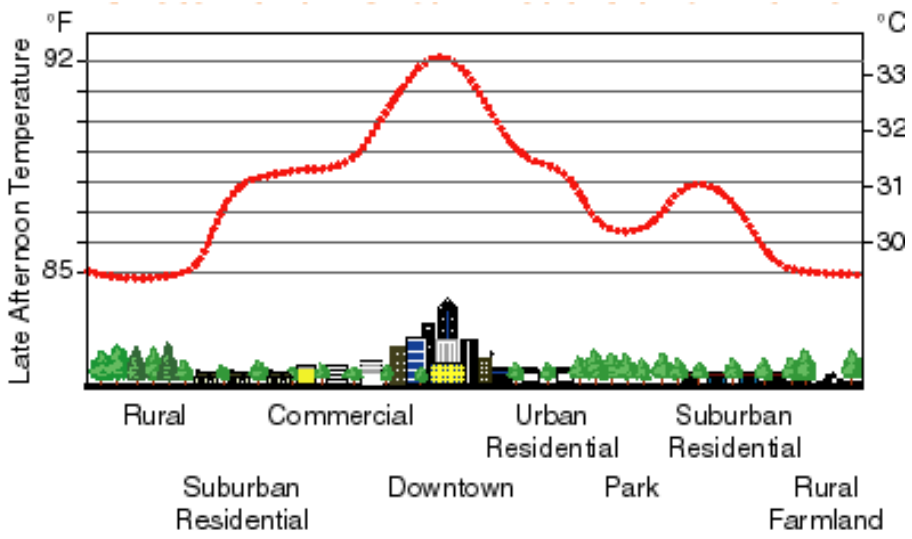

Fig. 10.3 Urban Heat Island Profile

There are three main factors responsible for this:

- The direct production of heat in the city from fires, industry, home
- Heat conserving properties of the bricks and fabric of the city
- Blanketing effect by atmospheric pollution on outgoing radiation

Urban Heat Island is generally classified as surface and atmospheric urban heat islands. These two heat island types differ in the ways they are formed, the techniques used to identify and measure them, their impacts, and to some degree, the methods available to mitigate them.

10.9 Surface Urban Heat Islands

On a hot, sunny summer day, the sun can heat dry, exposed urban surfaces, like roofs and pavement, to temperatures 50 to 90°F (27 to 50°C) hotter than

the air,5 while shaded or moist surfaces—often in more rural surroundings—remain close to air temperatures. Surface urban heat islands are typically present day and night but tend to be strongest during the day when the sun is shining.

On average, the difference in daytime surface temperatures between developed and rural areas is 18 to 27°F (10 to 15°C); the difference in nighttime surface temperatures is typically smaller, at 9 to 18°F (5 to 10°C).6 The magnitude of surface urban heat islands varies with seasons, due to changes in the sun's intensity as well as ground cover and weather.

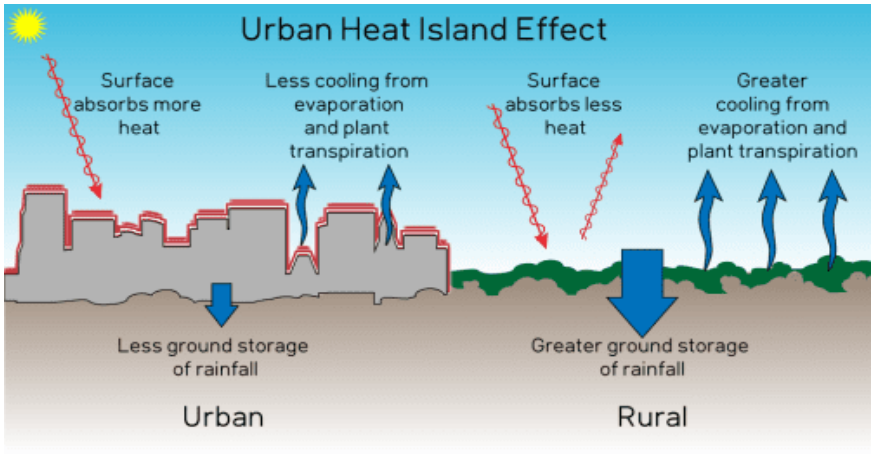

Fig. 10.4 Basic Characteristics of Surface and Atmospheric

Urban Heat Islands (UHIs)

Feature	Surface UHI	Atmospheric UHI
Temporal Development	• Present at all times of the day and night • Most intense during the day and in the summer	• May be small or non-existent during the day • Most intense at night or predawn and in the winter
Peak Intensity (Most intense UHI conditions)	• More spatial and temporal variation: ▪ Day: 18 to 27°F (10 to 15°C) ▪ Night: 9 to 18°F (5 to 10°C)	• Less variation: ▪ Day: -1.8 to 5.4°F (-1 to 3°C) ▪ Night: 12.6 to 21.6°F (7 to 12°C)
Typical Identification Method	• Indirect measurement: ▪ Remote sensing	• Direct measurement: ▪ Fixed weather stations ▪ Mobile traverses
Typical Depiction	• Thermal image	• Isotherm map • Temperature graph

10.10 Atmospheric Urban Heat Islands

Warmer air in urban areas compared to the cooler air in nearby rural surroundings defines atmospheric urban heat islands. Experts often divide these heat islands into two different types:

Canopy layer urban heat islands: exist in the layer of air where people live, from the ground to below the tops of trees and roofs.

Boundary layer urban heat islands: start from the rooftop and treetop level and extend up to the point where urban landscapes no longer influence the atmosphere. This region typically extends no more than one mile (1.5 km) from the surface.

Canopy layer urban heat islands are the most observed of the two types and are often the ones referred to in discussions of urban heat islands. For this reason, this chapter and compendium use the more general term atmospheric urban heat islands to refer to canopy layer urban heat islands.

Atmospheric urban heat islands are often weak during the late morning and throughout the day and become more pronounced after sunset due to the slow release of heat from urban infrastructure. The timing of this peak, however, depends on the properties of urban and rural surfaces, the season, and prevailing weather conditions.

10.11 Causes of Urban Heat Island effect

Use of construction materials like Asphalt and Concrete: Asphalt and concrete, needed for the expansion of cities, absorb huge amounts of heat, increasing the mean surface temperatures of urban areas.

Dark surfaces: Many buildings found in urban areas have dark surfaces, thereby decreasing albedo and increasing the absorption of heat.

Air conditioning: Buildings with dark surfaces heat up more rapidly and require more cooling from air conditioning, which requires more energy from power plants, which causes more pollution. Also, air conditioners exchange heat with atmospheric air, causing further local heating. Thus, there is a cascade effect that contributes to the expansion of urban heat islands.

Urban Architecture: Tall buildings, and often, accompanying narrow streets, hinder the circulation of air, reduce the wind speed, and thus reduce any natural cooling effects. This is called the Urban Canyon Effect.

Need for mass transportation system: Transportation systems and the unimpeded use of fossil fuels also add warmth to urban areas.

Lack of Trees and green areas: which impedes evapotranspiration, shade and removal of carbon dioxide, all the processes that help to cool the surrounding air.

10.12 Effects of Urban Heat Island

Increased Energy Consumption: Increased temperatures during summer in cities amplify energy demand for air conditioning. Studies reveal that electricity demand for air conditioning or cooling increases in the ranges of 1.5 to 2 per cent for every 1°F (0.6°C) increase in air temperatures (ranges of 68 to 77°F (20 to 25°C), implying that the community requires about 5 to 10 per cent more electricity demand to cater for the urban heat effect. This means the increased demands for cooling or air-conditioning during summer contribute to higher energy bills. Also, during exacerbated periods of urban heat islands, the resulting demand for air conditioning can overload systems, which can lead to power outages and blackouts.

Elevated Greenhouse Gas Emissions and Air Pollution: As explained earlier, urban heat island (UHI) raises electricity demand during summer. As a result, power plants must supply the needed extra energy, and since they rely on fossil fuels for energy production, there is an increase in greenhouse gas emissions and air pollutants. The main greenhouse gases and pollutants include carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter and mercury (Hg). Increased greenhouse gases cause global warming and climate change, while the pollutants negatively impact human health as well as the decline of air quality. Sometimes the UHI can also lead to the formation of ground-level ozone and acid rain. Research shows that high UHI correlates with increased levels and accumulation of air pollutants at night, affecting the next day's air quality.

Poses Danger to Aquatic Systems: High temperatures within the urban areas mean elevated temperatures for pavements and rooftops. Accordingly, these surface temperatures can heat stormwater runoff. Trials have demonstrated that pavements with temperatures of 100°F (38°C) can increase initial rainwater temperately from about 70°F (21°C) to over 95°F (35°C). This heated stormwater is the runoff that flows into storm drainage systems and raises water temperatures as it is discharged into ponds, streams, rivers, lakes, and oceans, resulting in thermal pollution. As a result, the increased water temperature affects the aquatic system, especially the reproduction and metabolism of aquatic species and can be even fatal to aquatic life.

Discomfort and Danger to Human Health: Higher air pollution reduced nighttime cooling, and increased temperatures as outcomes of urban heat islands can adversely affect human health. Human health is negatively impacted because of increased general discomfort, exhaustion, heat-

related mortality, respiratory problems, headaches, heat stroke and heat cramps. Because urban heat islands can also worsen the impacts of heatwaves, abnormal weather periods can arise, which can seriously affect the health of sensitive and vulnerable populations such as older adults, children, and those with weather-responsive health conditions. Exacerbated heat events or sudden temperature increases can result in higher mortality rates. Research by the Center for Disease Control and Prevention indicates that between 1997 and 2003, more than 8,000 premature deaths were registered in the United States owing to excessive exposure to heat.

Secondary Impacts on Weather and Climate: Besides the high-temperature increases, urban heat islands (UHIs) can bring forth secondary effects on the local weather and climate. This includes changes in local wind patterns, the formation of fog and clouds, precipitation rates and humidity. The unusual heat caused by UHI contributes to a more intense upward wind movement that can stimulate thunderstorms and precipitation activity. Furthermore, an urban heat island (UHI) creates a local low-pressure area where cool air from its adjacent areas converges inducing the formation of clouds and rain. This increases the total rainfall rates within cities. These changes may impact growing seasons within cities, especially by prolonging the growth of plants and crops.

Impacts on Animals: Most species need optimum temperatures to colonize, utilize and thrive in their ecosystems. When there is the existence of high temperatures due to urban heat island (UHI), harsh and cruel ecological surrounding is created which limits the essential activities of the organisms such as metabolism, breeding and reproduction. The temperature changes may also make the cities more suitable for survival compared to the wilderness, which may attract wild animals into the cities. An example is the Grey-headed flying foxes in Melbourne Australia, which colonized urban habitats following an increase in temperatures there. Besides, the urban heat island (UHI) can equally alter the natural selection process, causing a counterbalance of a new set of selective forces. For instance, the number of insects may be more in urban areas than the rural areas since most of them depend on environmental temperatures to control their body temperatures. Hence, moving to the city is just right for their survival.

10.13 Control of UHIs and mitigation

Industrialization and economic development are vital to the country, but the control of UHIs and their fallouts are equally vital. Towards this, several methods are being and can be, tried.

One of them is to use greener rooftops, using light-coloured concrete (using limestone aggregates along with asphalt (or tar) making the road surface greyish or even pinkish (like some places in the US have done); these are 50% better than black since they absorb less heat and reflect more sunlight.

Likewise, we should paint rooftops green, and install solar panels there amidst a green background. The other is to plant as many trees and plants as possible

Let Us Sum Up

Global warming is the unusually rapid increase in Earth's average surface temperature over the past century primarily due to the greenhouse gases released as people burn fossil fuels. Temperatures are certain to go up further. Despite ups and downs from year to year, the global average surface temperature is rising. Humans are facing the problem of climate change today, and the ones who are causing these conflicts are humans. It is impossible to stop global warming, but people still can reduce and slow down this problem.

The phenomenon of urban heat islands, in which concrete and built areas in cities experience higher temperatures than surrounding rural areas, may get accentuated with rapid urbanisation. Trees, green roofs, and vegetation can help reduce urban heat island effects by shading building surfaces, deflecting the radiation from the sun, and releasing moisture into the atmosphere.

Glossaries

Global Warming: A gradual increase in the overall temperature of the earth's atmosphere is generally attributed to the greenhouse effect caused by increased levels of carbon dioxide, CFCs, and other pollutants.

CFCs: Chlorofluorocarbons

Green House Gases: Greenhouse gases are gases in Earth's atmosphere that trap heat. They let sunlight pass through the atmosphere, but they prevent the heat that the sunlight brings from leaving the atmosphere.

Urban Heat Island: An urban heat island is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. The temperature difference is usually larger at night than during the day and is most apparent when winds are weak.

GWP: Global warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere.

Check Your Progress

1. Give the types of global warming?

   Answer: natural and man-made are the two types of global warming.

2. What are greenhouse gases?

   Answer: Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, ozone and some artificial chemicals such as chlorofluorocarbons (CFCs).

3. Which gas is the highest percentage share in the greenhouse effect?

   Answer: Carbon Dioxide gas has a share of 57%.

4. Mention the types of UHI?

   Answer: Surface and Atmospheric urban heat islands are the two types.

5. What are the main factors to contribute UHI?

   Answer: Paved and impermeable surfaces, Dark surfaces, Thermal mass, Lack of vegetation, Waste heat and changing climate.

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UNIT 11

Atmospheric Pollution

Structure

11.1 Overview

Pollution is defined as the addition of excessive addition of certain materials to the physical environment thereby making it less fit or unfit for living. These materials are called pollutants and can be classified into various categories. The term "pollution" refers to any substance that negatively impacts the environment or organisms that live within the affected environment. The five major types of pollution include air pollution, water pollution, soil pollution, light pollution, and noise pollution.

Learning Objectives

After studying this unit, you will learn the following,

- Sources, causes and consequences of Atmospheric pollution
- Control measures and National air quality index.

11.2 Atmospheric Pollution

Atmospheric pollution is the presence of undesirable material in the air in quantities large enough to produce harmful effects. Air pollution is the presence of substances in the atmosphere that are harmful to the health of humans and other living beings, or cause damage to the climate or materials. ... Both human activity and natural processes can generate air pollution. The ever-increasing use of fossil fuels in power plants, industries, transportation, mining, construction of buildings, stone quarries had led to air pollution.

Pollution can be man-made or natural. Man-made pollution can be described at 3 levels:

Personal Pollution: It is caused by an individual and is restricted to a small area. Example: tobacco smoke, kitchen smoke.

Occupational Pollution: It is due to an occupation which affects all the workers and some areas around them. Example: gem cutting, stone crushing; textile mill. These generally lead to occupational diseases or hazards.

Community Pollution: It affects the whole community or area around the source of pollution. Example: Thermal power plant, automobiles.

The Air (Prevention and Control of Pollution) Act, 1981: Section 2 (1): Definition of pollutant: Any solid, liquid, or gaseous substance (including noise) present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment.

11.3 Types of Air Pollutants

Air pollutants can be classified into the following three types:

Natural Pollutants: The pollutants which come out from natural sources such as forest fires started by lightning, dispersal of pollen, soil erosion, volcanic eruptions, volatile organic compounds from leaves and trees, decomposition of organic matter and natural radioactivity, etc. are natural.

Primary Pollutants: A primary pollutant is a harmful substance that directly enters the air because of human activities. For example, when coal, oil, natural gas, or wood is burnt, carbon dioxide and carbon monoxide are formed, automobiles contribute a large share of carbon monoxide. All these gases enter the atmosphere. Another important pollutant is sulphur dioxide (SO2) which is added to the atmosphere by burning coal and oil containing sulphur as an impurity in electric power plants. Other primary pollutants are oxides of nitrogen, hydrocarbons and suspended particulate matter.

Secondary Pollutants: Secondary pollutants result from the harmful chemical reactions between two or more air components. For example, sulphur dioxide, the primary pollutant reacts with oxygen in the atmosphere to form the secondary pollutant, sulphur trioxide (SO3) (2SO2 + O2 = 2S03). The sulphur trioxide can then react with water vapour in the air to form droplets of sulphuric acid (H2SO4), another secondary pollutant. Troposphere Ozone (O3) is another secondary pollutant. According to their existence in nature, it's divided into Quantitative Pollutants and Qualitative Pollutants

Quantitative Pollutants: These occur in nature and become pollutants when their concentration reaches beyond a threshold level. E.g., carbon dioxide, nitrogen oxide.

Qualitative Pollutants: These do not occur in nature and are human made. E.g., fungicides, herbicides, DDT etc.

11.4 Source of Air Pollution

There is not any society that does not discharge pollutants into the atmosphere. The question, however, is how much and what type? Both developed and developing countries are major contributors to air pollution, but not equally so. The main sources of air pollution in developed countries include motor vehicles, power plants, and industrial plants. Most pollution results from the combustion of fossil fuels, which emits CO, NOx, SO2, particulates and hydrocarbons. While developing countries emit large amounts of traditional pollutants such as CO2 and NOx. Developing countries are becoming major centres of urban pollution and source of technological pollutants such as insecticides residues used in agriculture and disease control. There are four main types of air pollution sources in both wealthy and poor countries:

Mobile Sources: A mobile source of air pollution refers to a source that can move under its power, such as cars, buses, planes, trucks, trains etc. Mobile

sources account for more than half of all the air pollution in the United States.

Stationary sources: Stationary sources emit large amounts of pollution from a single location, these are also known as point sources of pollution. It includes factories, power plants, dry cleaners and degreasing operations.

Area sources: Area sources are made up of lots of smaller pollution sources that aren't a big deal by themselves but when considered as a group can be. Such as agricultural areas, cities, and wood-burning fireplaces.

Natural sources: Natural sources can sometimes be significant but do not usually create ongoing air pollution problems as the other source types can. Wildland fires, dust storms, and volcanic activity also contribute gases and particulates to our atmosphere.

11.5 Major Air Pollutants and Their Source

Carbon Monoxide: Carbon Monoxide is a poisonous gas as it can cause death if present beyond a certain limit. It is produced by an incomplete combustion process in various industrial activities and the engines of automobiles.

If Carbon monoxide is present in our blood, it will combine with the oxygen in the blood thereby decreasing the amount of oxygen in the blood which is required for various metabolic activities in the body.

Carbon Dioxide: It is the principal greenhouse gas emitted due to human activities such as the burning of coal, oil, and natural gas.

Chlorofluorocarbons: Also known as CFCs or freons, these are the gases released mainly from air-conditioning systems and refrigeration. When released into the air, CFCs rise to the stratosphere where they meet a few other gases which lead to the depletion of the ozone layer that protects the earth from the harmful ultraviolet (UV) rays in the incoming solar radiation.

Lead: It is present in petrol, diesel, lead batteries, paints, hair dye products etc. Lead affects children. It can cause damage to the nervous system, digestive problems, and in some cases, even cancer.

Ozone: It is a naturally occurring gas, usually found in the upper layers of the atmosphere, shielding the earth from the sun's harmful UV rays. However, Ozone can be harmful if present at ground level. Vehicles and industries are the major sources of ground-level ozone. Ozone causes itching and burning sensation in the eyes, which turns them watery. It lowers our resistance to cold and pneumonia.

Nitrogen oxides (Nox): They are responsible for smog and acid rain. They are produced by burning fossil fuels such as coal, petrol, and diesel. They make children vulnerable to respiratory diseases, especially in winters.

Particulate Matter Suspended in Air (SPM): The dust particle, water vapour and smoke present in the air are called SPM. SPM crates haze and reduces visibility. SPM may also cause damage to the respiratory system of humans as these fine particles when inhaled during breathing can deposit in the alveoli.

Sulphur Dioxide: It is produced mainly by the combustion of coal, such as in thermal power plants. Some industrial processes such as the production of paper, smelting of metals etc., also produce sulphur dioxide. It is a major contributor to smog and acid rain. It can also cause lung diseases.

Smog: Smog is a combination of the words fog and smoke. It is a condition in which fog gets mixed with soot or smoke. Photochemical smog is a condition where smog is formed at the ground level due to the interaction of certain air pollutants with sunlight. One of the primary components of photochemical smog is ozone. Ground-level ozone is formed when nitrogen oxides contained in the vehicular emissions interact with volatile organic compounds (VOCs such as those found in paints, solvents, printing inks, petroleum products etc.) in the presence of sunlight. Smog refers to hazy air that causes difficulty in breathing. It is a combination of various gases mixed with water vapour and dust. Its occurrence is linked to heavy traffic, high temperatures, and calm winds. During winter, wind speeds are low and cause the smoke and fog to stagnate near the ground; hence the pollution levels can increase near ground levels.

Smoke particles trapped in fog give it a yellow/black colour and this smog often settles over cities for many days. Effects of smog include Hampering visibility and harm to the environment, Respiratory problems, Deaths related to bronchial diseases, Heavy smog reduced UV radiation and Reduction in the production of vitamin D leading to a rise in the occurrence of rickets (deficiency disease of vitamin D)

Indoor Air Pollution: Indoor Air refers to the physical, chemical, and biological makeup of the air inside our home, office etc. It is a cause for concern when energy efficiency improvements sometimes make houses relatively air-tight, reducing ventilation and raising pollutant levels. Indoor air problems can be subtle and do not always produce easily recognizable impacts on health.

11.6 Other Pollutants

Volatile Organic Compounds: The source of VOC's are perfumes, hair sprays, furniture polish, glues, air fresheners, moth repellents, wood preservatives, and other products. Health effects include irritation of the eye, nose and throat, headaches, nausea and loss of coordination. Long-term effects can include damage to the liver and other parts of the body.

Tobacco: Its smoke generates a wide range of harmful chemicals that can be carcinogenic. Health effects include burning sensations in the eyes, nose, throat irritation, cancer, bronchitis, severe asthma, and a decrease in lung function.

Biological pollutants: They include pollen from plants, mites, hair from pets, fungi, parasites, and some bacteria. Most of them are allergens and can cause asthma, hay fever, and other allergic diseases.

Formaldehyde: Mainly from carpets, particle boards, and insulation foam. It irritates the eyes, nose, and allergies

Radon: It is a gas that is emitted naturally by the soil. Since many modern houses have poor ventilation, it is confined inside the house and causes lung cancers.

Fly Ash: It is a residue of coal combustion which tends to rise with other gases produced by the burning of coal. It is a very fine powder and tends to travel far in the air. Fly ash is collected by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants.

11.7 Control of Air Pollution

Worldwide air pollution control remains a great uphill task and is certain to remain so for many decades. Air pollution control is pursued at all scales from global to local including the home and at the workplace. However, the effort is very spotty geographically with programs limited mostly to developed nations. Some of the effective methods to control air pollution are as follows: Source Correction Methods, Pollution Control equipment, Diffusion of Pollutant in Air, Vegetation and Zoning.

11.7.1 Source Correction Methods

Industries make a major contribution towards causing air pollution. The formation of pollutants can be prevented, and their emission can be minimised at the source itself. By carefully investigating the early stages of design and development in industrial processes e.g., those methods which

have minimum air pollution potential can be selected to accomplish air-pollution control at the source itself. The source correction methods are:

(i) Substitution of raw materials: If the use of a particular raw material results in air pollution, then it should be substituted by another purer grade raw material which reduces the formation of pollutants. For example, low sulphur fuel can be used as an alternative to high sulphur fuels, and comparatively more refined liquid petroleum gas (LPG) or liquefied natural gas (LNG) can be used instead of traditional high contaminant fuels such as coal.

(ii) Process Modification: The existing process may be changed by using modified techniques to control emission at the source. For example, smoke, carbon monoxide, and fumes can be reduced if open-hearth furnaces are replaced with controlled basic oxygen furnaces or electric furnaces. In petroleum refineries, loss of hydrocarbon vapours from storage tanks due to evaporation, temperature changes or displacement during filling etc. can be reduced by designing the storage tanks with floating roof covers. An appreciable amount of pollution is caused due to poor maintenance of the equipment which includes the leakage around ducts, pipes, valves, pumps etc. Emission of pollutants due to negligence can be minimised by a routine checkup of the seals and gaskets.

11.7.2 Pollution Control Equipment

Sometimes pollution control at the source is not possible by preventing the emission of pollutants. Then it becomes necessary to install pollution control equipment to remove the gaseous pollutants from the main gas stream. Pollution control equipment include,

(i) Gravitational Settling Chamber: For the removal of particles exceeding 50 μm in size from polluted gas streams, gravitational settling chambers are used.

(ii) Cyclone Separators (Reverse flow Cyclone): Instead of gravitational force, centrifugal force is utilized by cyclone separators, to separate the particulate matter from the polluted gas.

(iii) Fabric Filters (Baghouse Filters): In a fabric filter system, a stream of the polluted gas is made to pass through a fabric that filters out the particulate pollutant and allow the clear gas to pass through. The particulate matter is left in the form of a thin dust mat on the insides of the bag. This dust mat acts as a filtering medium for further removal of particulates increasing the efficiency of the filter bag to sieve more sub-micron particles.

(iv) Electrostatic Precipitators: The electrostatic precipitator works on the principle of electrostatic precipitation i.e., electrically charged particulates present in the polluted gas are separated from the gas stream under the influence of the electrical field.

(v) Wet Collectors (Scrubbers): In wet collectors or scrubbers, the particulate contaminants are removed from the polluted gas stream by incorporating the particulates into liquid droplets. Common wet scrubbers include Spray Tower, Venturi Scrubber and Cyclone Scrubber.

11.7.3 Diffusion of Pollutants in Air

Dilution of the contaminants in the atmosphere is another approach to control air pollution. If the pollution source releases only a small quantity of the contaminants, then pollution is not noticeable as these pollutants easily diffuse into the atmosphere but if the quantity of air contaminants is beyond the limited capacity of the environment to absorb the contaminants, then pollution is caused. However, dilution of the contaminants in the atmosphere can be accomplished using tall stacks which penetrate the upper atmospheric layers and disperse the contaminants so that the ground level pollution is greatly reduced.

11.7.4 Vegetation

Plants contribute towards controlling air pollution by utilizing CO2 and releasing oxygen in the process of photosynthesis. Gaseous pollutants like CO are fixed by some plants, namely, Ficus variegata, Phaseolus Vulgaris etc. Species of Pinus, Pyrus, Juniperus and Vitis depollute the air by metabolising nitrogen oxides. Plenty of trees should be planted especially around those areas which are declared as high-risk areas of pollution.

11.7.5 Zoning

This method of controlling air pollution can be adopted at the planning stages of the city. Zoning advocates set aside separate areas for industries so that they are far removed from the residential areas. The heavy industries should not be located too close to each other. New industries, as far as possible, should be established away from larger cities and the locational decisions of large industries should be guided by regional planning.

11.8 National Air Quality Index

It was launched in 2015 starting with 14 cities to disseminate air quality information. The AQI has six categories of air quality viz., good, satisfactory, moderately polluted, poor, very poor, and severe with a distinct colour scheme. Each of these categories is associated with likely health impacts.

AQI considers eight pollutants - PM10, PM2.5, nitrogen dioxide, sulphur dioxide, carbon monoxide, ozone, ammonia, and lead - up to 24 hourly average periods for which National Ambient Air Quality Standards are prescribed.

The AQI values and corresponding ambient concentrations (health breakpoints), as well as associated likely health impacts for the identified eight pollutants, are as follows:

AQI Category, Pollutants and Health Breakpoints								
AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24-hr	NO_2 24-hr	O_3 8-hr	CO 8-hr (mg/m^3)	SO_2 24-hr	NH_3 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.5 – 1.0
Moderately polluted (101-200)	101-250	61-90	81-180	101-168	2.1- 10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17-34	801-1600	1200-1800	3.1-3.5
Severe (401-500)	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

**One hourly monitoring (for mathematical calculations only)*

(Source: https://app.cpcbccr.com/AQI_India/)

AQI	Remark	Colour Code	Possible Health Impacts
0-50	Good		Minimal impact
51-100	Satisfactory		Minor breathing discomfort to sensitive people

AQI	Remark	Colour Code	Possible Health Impacts
101-200	Moderate		Breathing discomfort to the people with lungs, asthma and heart diseases
201-300	Poor		Breathing discomfort to most people on prolonged exposure
301-400	Very Poor		Respiratory illness on prolonged exposure
401-500	Severe		Affects healthy people and seriously impacts those with existing diseases

11.9 Consequences of Air Pollution

A large number of deaths (around 2000) is attributed due to pollution which is very frightening. The figures may not be correct because they are only estimates. To find out precise data requires a serious investigation for which neither the manpower is available nor are the time and resources available. Therefore, we need to take a precautionary approach towards tackling pollution.

India has recorded a 50% increase in premature deaths linked to PM 2.5 and this is between 1990 and 2015 almost coinciding with the economic liberalisation.

Air quality has become a serious health issue because the pollutants enter deep inside the lungs and the lungs capacity to purify blood gets reduced which affects the person's growth, mental ability, and working capacity especially for children, pregnant women, and elderly people.

Poor people are more vulnerable to air pollution because they are the ones who spend more time on roads.

Let Us Sum Up

Atmospheric pollution is the presence of undesirable material in the air in quantities large enough to produce harmful effects. Air pollution is caused by solid and liquid particles and certain gases that are suspended in the air. These particles and gases can come from car and truck exhaust, factories, dust, pollen, mould spores, volcanoes, and wildfires. Reduce the number of trips you take in your car. Reduce or eliminate fireplace and wood stove use. Avoid burning leaves, trash, and other materials. Avoid using gas-powered lawn and garden equipment. air pollution challenges have been felt globally because life processes have been interfered with. The government and citizens have a collective responsibility in the prevention and control of air pollution.

Glossaries

Pollution: The contamination of air, water, or soil by substances that are harmful to live organisms is called pollution.

Fly Ash: It is a residue of coal combustion which tends to rise with other gases produced by the burning of coal. It is a very fine powder and tends to travel far in the air.

Chlorofluorocarbons: Also known as CFCs or freons, these are the gases released mainly from air-conditioning systems and refrigeration.

SPM: The dust particle, water vapour and smoke present in the air are called Suspended Particulate Matter.

Smog: Smog is a combination of the words fog and smoke. It is a condition in which fog gets mixed with soot or smoke

Check Your Progress

1. Write the major types of pollution?

   Answer: The five major types of pollution include: air pollution, water pollution, soil pollution, light pollution, and noise pollution

2. What are the types of Air Pollutants?

   Answer: Air pollutants can be classified into the following three types, 1. Natural Pollutants. 2. Secondary Pollutants and 3. Secondary Pollutants

3. List out the man-made pollution?

   Answer: Man-made pollution is generally a byproduct of human actions such as consumption, waste disposal, industrial production, transportation, and energy generation.

4. Give the importance of AQI?

   Answer: Air Quality Index was launched in 2015 starting with 14 cities to disseminate air quality information. It has six categories of air quality viz., good, satisfactory, moderately polluted, poor, very poor, and severe with a distinct colour scheme.

5. Define Indoor Air Pollution?

   Answer: Indoor Air refers to the physical, chemical, and biological makeup of the air inside our home, office etc.

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UNIT 12

Water Pollution

Structure

12.1 Overview

Water is one of the most vital natural resources on earth and has been around for a long time. The same water which we drink has been around in one form or the other. Water is a substance composed of the chemical elements hydrogen and oxygen and exists in gaseous, liquid, and solid states. It is one of the most plentiful and essential compounds. A tasteless and odourless liquid at room temperature, it has the important ability to dissolve many other substances. Around the world, human activity and natural forces are reducing available water resources. Although public awareness of the need to better manage and protect water has grown over the last decade, economic criteria and political considerations still tend to drive water policy at all levels.

Learning Objectives

After studying this unit, you will learn the following,

- Sources, causes and consequences of Water pollution
- Control measures for water pollution.

12.2 Water Pollution

Water is essential for the existence of all life forms. In addition to household uses, water is vital for agriculture, industry, fishery, tourism etc. Increasing population, urbanisation and industrialisation has led to the decreased availability of water. The quality of water used is also being deteriorated as it is getting more and more polluted. Water pollution is the contamination of water bodies (like oceans, seas, lakes, rivers, aquifers, and groundwater) usually caused due to human activities. Water pollution is any change in the physical, chemical, or biological properties of water that will have a detrimental consequence on any living organism. Water pollution is one of the main environmental issues that we are facing, as more than 70% of the Earth's surface is water-covered.

According to the Water (Prevention and Control of Pollution) Act, 1974, water pollution may be defined as Water pollution as the addition of some substance (organic, inorganic, biological or radiological) or factor (heat) which degrades the quality of water so that it either becomes a health hazard for man, animals, or plants or unfit for use.

Water may be called polluted when the following parameters stated below reach beyond a specified concentration in water.

i) Physical parameters: Colour, odour, turbidity, taste, temperature, and electrical conductivity constitute the physical parameters and are good indicators of contamination. For instance, colour and turbidity are visible evidence of polluted water while an offensive odour or a bitter and different than normal taste also makes water unfit for drinking.

ii) Chemical parameters: These include the number of carbonates, sulphates, chlorides, fluorides, nitrates, and metal ions. These chemicals form the total dissolved solids, present in water.

iii) Biological parameters: The biological parameters include matter like algae, fungi, viruses, protozoa and bacteria. The life forms present in water are affected to a good extent by the presence of pollutants. The pollutants in water may cause a reduction in the population of both lower and higher plant and animal lives. Thus, the biological parameters give an indirect indication of the amount of pollution in water.

12.3 Sources of surface water pollution

Water pollution occurs in many forms, from a wide range of sources. Agriculture may contribute to water pollution from feedlots, pastures, and croplands. Mining, petroleum drilling, and landfills may also be major sources of water pollution. Surface water pollution has several sources, and these can be categorised as Point sources, Non-point Sources, Natural and Anthropogenic Sources

1. Point and Non-point source: Point sources of pollution are those which have a direct idea. An example includes pipe attached to a factory, oil spill from a tanker, effluents coming out from industries. Point sources of pollution include wastewater effluent (both municipal and industrial) and storm sewer discharge and affect mostly the area near it. Non-point sources of pollution are those which arrive from different sources of origin and a number ofntifiseveral ways by which contaminants enter into groundwater or surface water and arrive in the environment from different non-identifiable sources. Examples are runoff from agricultural fields, urban waste etc.

2. Natural and Anthropogenic Sources: As mentioned earlier, an increase in the concentration of naturally occurring substances is also termed pollution. The sources of such an increase are called natural sources. Siltation (which includes soil, sand, and mineral particles) is one such natural source. It is a common natural phenomenon, which occurs in most water bodies. Indiscriminate deforestation makes the soil loose and floodwaters bring silt from mountains into streams, rivers, and lakes.

12.4 Sources of Ground Water Pollution

When the polluted water seeps into the ground and enters an aquifer it results in groundwater pollution. The most of our villages and many townships, groundwater is the only source of drinking water. Therefore, the pollution of groundwater is a matter of serious concern. Groundwater gets polluted in several ways.

- Sewage and industrial effluents spilt over the ground
- Fertilizers and pesticides used in the field percolate.
- Refuse dumps, septic tanks, seepage pits, mining activities etc.

12.5 Causes of Water Pollution

Sewage Water: Sewage water includes discharges from houses and other establishments. The sewage contains human and animal excreta, food

residues, cleaning agents, detergents, etc. Domestic and hospital sewage contain many undesirable pathogenic microorganisms.

Dissolved Oxygen (DO): The presence of organic and inorganic wastes in water decreases the dissolved oxygen Structure of the water. Water having DO Structure below 8.0 mg/L may be considered contaminated. Water having DO Structure below. 4.0 mg/L is highly polluted. DO Structure of water is important for the survival of aquatic organisms.

Biological Oxygen Demand (BOD): Water pollution by organic wastes is measured in terms of Biochemical Oxygen Demand (BOD). BOD is the amount of dissolved oxygen needed by bacteria in decomposing the organic wastes present in water. It is expressed in milligrams of oxygen per litre of water. The higher value of BOD indicates a low DO Structure of water.

Chemical oxygen demand (COD): Chemical oxygen demand (COD) is a slightly better mode used to measure pollution load in the water. COD measures the amount of oxygen in parts per million required to oxidise organic (biodegradable and non-biodegradable) and oxidizable inorganic compounds in the water sample.

Industrial Wastes: Discharge of wastewater from industries like petroleum, paper manufacturing, metal extraction and processing, chemical manufacturing, etc., that often contain toxic substances, notably, heavy metals (defined as elements with density > 5 g/cm3 such as mercury, cadmium, copper, lead, arsenic) and a variety of organic compounds.

Agricultural sources: Agricultural runoff contains dissolved salts such as nitrates, phosphates, ammonia and other nutrients, and toxic metal ions and organic compounds. Fertilizers contain major plant nutrients such as nitrogen, phosphorus, and potassium. Excess fertilisers may reach the groundwater by leaching or may be mixed with surface water. Many of the pesticides are non-degradable, and their residues have a long life. Wastes from poultry farms, piggeries slaughterhouses etc. reach the water through runoff.

Thermal and Radiation Pollution: Power plants – thermal and nuclear, chemical, and other industries use a lot of water for cooling purposes, and then used hot water is discharged into rivers, streams, or oceans. Discharge of hot water may increase the temperature of the receiving water by 10 to 15 °C above the ambient water temperature. This is thermal pollution. An increase in water temperature decreases dissolved oxygen in the water.

Marine pollution: Oceans are the ultimate sink of all-natural and manmade pollutants. The sewerage and garbage of coastal cities are also dumped

into the sea. The other sources of oceanic pollution are navigational discharge of oil, grease, detergents, sewage, garbage and radioactive wastes, offshore oil mining, oil spills.

Oil Spills: The most common cause of oil spills is leakage during marine transport and leakage from underground storage tanks. An oil spill could occur during offshore oil production as well.

12.6 Effects of Water Pollution

The effect of water pollution depends upon the type of pollutants and their concentration. Also, the location of water bodies is an important factor to determine the levels of pollution.

Water bodies in the vicinity of urban areas are extremely polluted. This is the result of dumping garbage and toxic chemicals by industrial and commercial establishments.

Water pollution drastically affects aquatic life. It affects their metabolism, behaviour, causes illness and eventual death. Dioxin is a chemical that causes a lot of problems from reproduction to uncontrolled cell growth or cancer. This chemical is bioaccumulated in fish, chicken and meat. Chemicals such as this travel up the food chain before entering the human body.

The effect of water pollution can have a huge impact on the food chain. It disrupts the food chain. Cadmium and lead are some toxic substances, these pollutants upon entering the food chain through animals (fish when consumed by animals, humans) can continue to disrupt at higher levels.

Humans are affected by pollution and can contract diseases such as hepatitis through faecal matter in water sources. Poor drinking water treatment and unfit water can always cause an outbreak of infectious diseases such as cholera, etc.

The ecosystem can be critically affected, modified and structured because of water pollution.

12.7 Control Measures of Water Pollution

Realising the importance of maintaining the cleanliness of the water bodies, the Government of India has passed the Water (Prevention and Control of Pollution) Act, 1974 to safeguard our water resources. An ambitious plan to save the river called the Ganga Action Plan was launched in 1985.

In India, the Central Pollution Control Board (CPCB), an apex body in the field of water quality management, has developed a concept of “designated

best use". Water pollution, to a larger extent, can be controlled by a variety of methods. The treatment of this wastewater is carried out in the following three stages:

(i) Primary treatment

(ii) Secondary treatment, and

(iii) Tertiary treatment

Primary Treatment: When the wastewater is to be dumped off into a river or flowing stream, the treatment is carried out by sedimentation, coagulation, and filtration. This is known as primary treatment. If the water is required for drinking purposes, it must undergo a further treatment called secondary and tertiary treatments. The following steps are performed to do primary treatment of water:

(i) Sedimentation

(ii) Coagulation and

(iii) Filtration

Secondary or Biological Treatment: The water after primary treatment is not fit for drinking purposes and must undergo further treatment. This is done through secondary or biological treatment. A commonly used method is to allow polluted water to spread over a large bed of stones and gravel so that the growth of different microorganisms needing nutrients and oxygen is encouraged. Over a period, a fast-moving food chain is set up. This is called the secondary treatment of water. It involves the following processes

(i) Softening

(ii) Aeration

Tertiary Treatment: The tertiary treatment is disinfecting water. Chlorine is the most used disinfectant used for killing bacteria. However, chlorine also reacts with traces of organic matter present in water and forms undesirable chlorinated hydrocarbons (toxic and potentially carcinogenic). It is therefore desirable to reduce the organic matter in water before passing chlorine gas. Other methods of disinfection such as ultraviolet radiation, ozone gas treatment or reverse osmosis are preferred over chlorine treatment. But these methods are more expensive. Tertiary treatment is done when water is to be reused. Here 99% of solids are removed and various chemical processes are used to ensure that water is free from infected materials.

12.8 steps were taken to reduce water pollution

- Preparation of action plan for sewage management and restoration of water quality in aquatic resources by State Governments.
- Installation of Online Effluent Monitoring System to check the discharge of effluent directly into the rivers and water bodies.
- Setting up of monitoring network for assessment of water quality.
- Action to comply with effluent standards is taken by SPCBs / PCCs to improve the water quality of the rivers.
- Financial assistance for installation of Common Effluent Treatment Plants for a cluster of Small-Scale Industrial units.
- Issuance of directions for implementation of Zero Liquid Discharge.
- Issuance of directions under Section 5 of Environment (Protection) Act, 1986 to industries and under Section 18(1)(b) of Water (Prevention and Control of Pollution) Act, 1974.

Implementation of National Lake Conservation Plan (NLCP) and National Wetland Conservation Programme (NWCP) for conservation and management of identified lakes and wetlands in the country which have been merged in February 2013 into an integrated scheme of National Plan for Conservation of Aquatic Eco-systems (NPCA) to undertake various conservation activities including interception, diversion and treatment of wastewater, pollution abatement, lake beautification, biodiversity conservation, education and awareness creation, community participation etc.

12.9 Key findings of World Bank report on water pollution

Clean water is a key factor for economic growth. Deteriorating water quality is stalling economic growth, worsening health conditions, reducing food production, and exacerbating poverty in many countries. Heavily polluted water is reducing economic growth by up to a third in some countries.

When Biological Oxygen Demand — an index of the degree of organic pollution and a proxy for overall water pollution — crosses a threshold of 8 milligrams per litre, GDP growth in downstream regions drops by 0.83 percentage points, about a third of the mean growth rate of 2.33 per cent used in the study.

A key contributor to poor water quality is nitrogen, essential for agricultural production but which leaches into rivers and oceans where it creates

hypoxia and dead zones, and in the air where it forms a nitrous oxide, a greenhouse gas.

Early exposure of children to nitrates affects their growth and brain development, reducing their health and earning potential.

For every additional kilogram of nitrogen fertilizer per hectare, yields may rise to five per cent, but childhood stunting increases as much as 19 per cent and future adult earnings fall by up to two per cent compared to those not affected.

And increased salinity because of manmade pressures such as irrigation, stormwater runoff, leaching of fertilizer, and urban wastewater discharge is pushing down agricultural yields.

The report estimated enough food is lost to saline water each year to feed 170 million people, about the population of Bangladesh.

Let Us Sum Up

Pollution may be caused by natural sources or human activities, but regardless of the cause, the result is the same. It can have detrimental effects on aquatic ecosystems as well as the health of those who depend on those sources of water. Pollution can be difficult to determine because it is not always visible, so scientists use a variety of techniques and tests to measure water quality and the level of contaminants Water pollution is not only confined to the surface, but it has also spread to groundwater, as well as seas and oceans. Most of the major water bodies in cities are facing the brunt of water pollution. Disposal of wastewater from industries, untreated waste from municipalities and solid waste dumping close to water sources has remained the major cause of water pollution.

Glossaries

Sewage Water: Sewage water is wastewater from people living in a community. It is the water released from households after use for various purposes like washing dishes, laundry, and flushing the toilet, thus the name wastewater.

COD: Chemical oxygen demand is one of the causes of water

NLCP: National Lake Conservation Plan

Oil Spills: The most common cause of oil spill is leakage during marine transport and leakage from underground storage tanks

Aeration: It is one of the secondary or biological water treatment methods

Check Your Progress

1. Define the Non-point source of water pollution?

   Answer: Non-point sources of pollution are those which arrive from different sources of origin and several ways by which contaminants enter groundwater or surface water and arrive in the environment from different non-identifiable sources.

2. What are the parameters are responsible for water pollution?

   Answer: Physical, Chemical and Biological parameters.

3. Describe the Water Act in India?

   Answer: Water (Prevention & Control of Pollution) Act, 1974 is comprehensive legislation that regulates agencies responsible for checking on water pollution and ambit of pollution control boards both at the centre and states.

4. What are water treatment methods?

   Answer: Primary, Secondary and Tertiary are the three methods are there.

5. Write about the chemical parameters of water?

   Answer: These include the number of carbonates, sulphates, chlorides, fluorides, nitrates, and metal ions. These chemicals form the total dissolved solids, present in water.

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UNIT 13

Land Degradation

Structure

13.1 Overview

The land is a complex mixture of soil, water, and biodiversity. Working together, these three elements create goods and services that provide a foundation for sustainable livelihoods and peaceful co-existence between peoples. Yet land degradation is putting the health, livelihoods, and security of an estimated 3.2 billion people at risk.

Land degradation is a process in which the value of the biophysical environment is affected by a combination of human-induced processes acting upon the land. It causes Loss of natural fertility of soil because of loss of nutrients, less vegetation cover, Changes in the characteristic of soil, Pollution of water resources and Changes in climatic conditions. Degraded land is land that has lost some degree of its natural productivity due to human-caused processes.

Learning Objectives

After studying this unit, you will learn the following,

- Sources, causes and consequences of Land Degradation
- Control measures, Schemes and steps taken by India to prevent Land Degradation.

13.2 Land Degradation

According to the United Nations Convention to Combat Desertification (UNCCD), land degradation is the reduction or loss of biological or economic productivity resulting from land users or a process or combination of processes, including human activities. When land degradation occurs in dryland areas, more specifically arid sub-humid areas, it is referred to as desertification.

Land degradation (LD) can be broadly divided into physical, chemical & biological degradation

- Physical degradation is erosion, soil organic carbon loss, change in soil's physical structure-e.g., compaction, waterlogging. Globally soil erosion is the most important LD process resulting in the removal of topsoil. Soil productivity is depleted through reduced rooting depth, loss of plant nutrients and physical loss of topsoil
- Chemical degradation refers to leaching, salinisation, fertility depletion, acidification, nutrient imbalances
- Biological degradation implies the loss of vegetation, rangeland degradation and loss in biodiversity including soil organic matter

13.3 United Nations Convention to Combat Desertification (UNCCD)

It was established in 1994.

The United Nations Convention to Combat Desertification (UNCCD) is the sole legally binding international agreement linking environment and development to sustainable land management.

The Convention addresses specifically the arid, semi-arid and dry sub-humid areas, known as the drylands, where some of the most vulnerable ecosystems and peoples can be found.

The new UNCCD 2018-2030 Strategic Framework is the most comprehensive global commitment to achieve Land Degradation Neutrality (LDN) to restore the productivity of vast expanses of degraded land, improve the livelihoods of more than 1.3 billion people, and reduce the impacts of drought on vulnerable populations to build

The UNCCD is particularly committed to a bottom-up approach, encouraging the participation of local people in combating desertification and land degradation.

The UNCCD secretariat facilitates cooperation between developed and developing countries, particularly around knowledge and technology transfer for sustainable land management.

13.4 Land Degradation Neutrality

Land degradation neutrality (LDN) is a condition where further land degradation (loss of productivity caused by environmental or human factors) is prevented and already degraded land can be restored.

LDN has been defined by the Parties to the Convention as A state whereby the amount and quality of land resources, necessary to support ecosystem functions and services and enhance food security, remains stable or increases within specified temporal and spatial scales and ecosystems.

13.4.1 Benefits of LDN

As land is fixed in quantity, there is an ever-increasing competition to control land resources and capitalize on the flows of goods and services from the land. LDN represents a paradigm shift in land management policies and practices. It is a unique approach that counterbalances the expected loss of productive land with the recovery of degraded areas. This has the potential to cause social and political instability, fueling poverty, conflict and migration.

13.4.2 Implementation of LDN

The implementation of LDN requires multi-stakeholder engagement and planning across scales and sectors, supported by national-scale coordination that utilizes existing local and regional governance structures. UNCCD and the UN Environment Programme (UN Environment) came together to mark the United Nations General Assembly adoption of the "2030 Agenda for Sustainable Development". To date, over 120 countries have engaged with the LDN Target Setting Programme and considerable progress has been made since the 2030 Agenda was adopted in 2015.

13.5 Bonn Challenge

It is a global effort to bring 150 million hectares of degraded and deforested land into restoration by 2020 and 350 million by 2030.

It was launched in 2011 by the government of Germany and IUCN and later endorsed and extended by New York.

The Bonn Challenge is the forest landscape restoration (FLR) approach, which aims to restore ecological integrity at the same time as improving human well-being through multifunctional landscapes.

The Bonn Challenge is an implementation vehicle for national priorities such as water and food security and rural development while simultaneously helping countries contribute to the achievement of international climate change, biodiversity and land degradation commitments.

The 2020 target was launched at a high-level event in Bonn in 2011 organised by the Government of Germany and IUCN and was later endorsed and extended to 2030 by the New York Declaration on Forests of the 2014 UN Climate Summit.

13.6 Forest Landscape Restoration (FLR)

It is the ongoing process of regaining ecological functionality and enhancing human well-being across deforested degraded forest landscapes.

FLR is more than just planting trees – it is restoring a whole landscape to meet present and future needs.

It is long-term because it requires a multi-year vision of the ecological functions.

The majority of restoration opportunities are found on or adjacent to agricultural or pastoral land, in these situations, restoration must complement and not displace existing land users.

This result in a mosaic of different land uses including agriculture, agroforestry systems and improved ecological corridors.

It integrates several guiding principles, including focusing on landscapes, restoring functionality, involving stakeholders, Tailor to local conditions and avoiding further reduction of natural forest cover.

13.7 Great Green Wall

The Great Green Wall is a symbol of hope in the face of one of the biggest challenges of our time – desertification. Launched in 2007 by the African Union, this game-changing African-led initiative aims to restore Africa's degraded landscapes and transform millions of lives in one of the world's poorest regions, the Sahel. Once complete, the Wall will be the largest living structure on the planet – an 8,000 km natural wonder of the world stretching across the entire width of the continent.

The Great Green Wall is the first flagship of the UN Decade on Ecosystem Restoration 2021–2030, and the United Nations Environment Programme (UNEP), through the Global Environment Facility and other donors, operates many restoration projects along with it.

13.7.1 Key points of GGW

The Great Green Wall snakes the Sahel region from Senegal in the West to Djibouti in the East of Africa.

It was launched in 2007 by the African Union to restore Africa's degraded landscapes and transform millions of lives in one of the world's poorest regions (the Sahel).

The project aims to restore 100 million hectares of degraded land by 2030.

100 million hectares of land area to be restored, 10 million jobs created and 250 megatonnes of carbon sequestered.

Now, It is being implemented in more than 20 countries across Africa and more than eight billion dollars have been mobilized and pledged for its support.

The Great Green Wall is a symbol of hope in the face of one of the biggest challenges of our time which is called desertification.

The African initiative is still only 15% complete.

Once fully completed, the Wall will be the largest living structure on the planet – an 8,000 km natural wonder of the world stretching across the entire width of the continent.

13.7.2 Green Wall of India

The Centre is mulling an ambitious plan to create a 1,400km long and 5km wide green belt from Gujarat to the Delhi-Haryana border. The plan is inspired by Africa's 'Great Green Wall' project, running from Senegal (West) to Djibouti (East), which came into effect in 2007.

The overarching objective of India's Green Wall will be to address the rising rates of land degradation and the eastward expansion of the Thar desert.

The green belt being planned from Porbandar to Panipat will help in restoring degraded land through afforestation along with the Aravali hill range. It will also act as a barrier for dust coming from the deserts in western India and Pakistan.

The Aravali has been identified as one of the key degraded zones to be taken up for greening under India's target to restore 26 million hectares (mha) of its land. A 2016 report from the Indian Space Research Organisation (ISRO) had also indicated that Delhi, Gujarat, and Rajasthan had already degraded over 50% of their land.

13.8 Land degradation in India

India is facing a severe problem of land degradation ie. soil becoming unfit for cultivation. About 29% or about 96.4 million hectares are considered degraded. To fight this menace, India will convert degraded land of nearly 50 lakh (5 million) hectares to fertile land in the next 10 years (between 2021 and 2030). 5 million hectares are part of the Bonn Challenge commitment. "Bonn Challenge" is a global effort to bring 150 million hectares of the world's deforested and degraded land into restoration by 2020, and 350 million hectares by 2030. At the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) 2015 in Paris, India joined the voluntary Bonn Challenge and pledged to bring into restoration 13 million hectares of degraded and deforested land by 2020, and an additional 8 million hectares by 2030. India's pledge is one of the largest in Asia. India became a signatory to the UNCCD on 14th October 1994 and ratified it on 17th December 1996. The main objective of the convention is to combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification.

13.8.1 Action Plans for Land Degradation in India

India is focusing on sustainable land and resource management for livelihood generation at the community level for making the local lands healthier and productive for providing a better homeland and a better future

for its inhabitants. Some of the major programmes which address issues related to land degradation and desertification, being implemented currently are as follows:

- Adoption of watershed approach- planning based on micro-watersheds, use of remote sensing data and spatial data in planning at the micro-watershed level. E.g., Integrated Watershed Management Programme (IWMP)
- Integrated treatment incorporating contouring, gully plugging, vegetative as well as engineering-based solutions for soil moisture conservation, covering agricultural as well as non-agricultural lands. E.g., Fodder and Feed Development Scheme-its component of Grassland Development including Grass Reserves.
- Integrated farming-based approach- e.g., National Afforestation Programme (NAP), National Mission for Green India (GIM), incorporating fodder and fuelwood supply, farm-forestry and agroforestry and Silvi pastures (combination of trees, forage plants and livestock together as an integrated, intensively managed system), stall feeding, improved challahs etc.
- Focus on water management- aquifer recharge and water budgeting as well as crop planning. E.g., Command Area Development and Water Management (CADWM) programme, Soil Conservation in the Catchment of River Valley Project National Watershed Development Project for Rainfed Areas (NWDPRA).
- Focus on social aspects- e.g., Constitution of Watershed Committee under the Gram Sabha, Water User Association development, Social Audit under MGNREGA, Joint Forest Management (JFM) and Social Fencing by involving local communities.
- Incorporation of livelihood related activities- Development of micro-enterprises, involvement of Self-Help Groups (SHGs), programmes such as Mahila Kisan Sashaktikaran Pariyojana (MKSP) focusing on increasing capabilities of women farmers to increase sustainability.
- Adoption of climate-adaptation related solutions- both about floods and intense precipitation as well as temperature and moisture stress.
- Increasing the role of Panchayati Raj Institutions (PRIs)- and ensuring "convergence" between Government programmes and programmes executed by PRIs.

13.9 Responsible Factors for land degradation

1. **Deforestation:** Forests play an important role in maintaining the fertility of the soil by shedding their leaves which contain many nutrients. Therefore, cutting forests will affect the soil adversely.
2. **Excessive use of pesticides and fertilizers** causes an imbalance in the number of certain nutrients in the soil. This imbalance adversely affects the vegetation.
3. **Overgrazing:** with loss of grass and other vegetation causes soil erosion.
4. **Salination:** due to the low Quality of Irrigation Water, excessive fertilizer use, poor drainage of soil etc.,
5. **Water logging:** Excessive irrigation and improper drainage facility in the fields cause a rise in the groundwater level which has salt Structure result in soil salinity.
6. **Desertification:** due to Degradation of vegetative cover, water erosion, wind erosion, salinization, excess of toxic substances etc.,
7. **Soil erosion:** where the topmost nutritious layer is eroded making the soil infertile.
8. **Wind Erosion:** depletion of forests leads to loosening of soil particles due to lack of roots and moisture in the soil.
9. **Water Erosion:** which includes sheet erosion, rill erosion and so on leading to huge loss of top fertile soil along with plant nutrients through runoff water.
10. **Wasteland:** include ravenous land, waterlogged land, marsh and saline lands, forest land, degraded land, strip land, mining, and industrial wastelands.
11. Natural disasters like Landslides, earthquakes, forest fires etc., cause sudden movements and cause vegetation loss, soil erosion etc., resulting in soil degradation.
12. Improper agricultural practices like lack of crop rotation, excessive and unscientific irrigation and so on.

13.10 Reasons for increasing land degradation

Growing Demand: Growing demand for food, fodder, fuel, and raw materials is increasing the pressure on land and the competition for natural resources. This has led to stress on land usage and has led to over-

exploitation of land resources like overgrazing, and conversion to other land uses.

Unsustainable agricultural practices: About 141 million hectares of land is used by agriculture in India. Faulty land and water management practices in agriculture have significantly contributed to land degradation. Intensive irrigation and high chemical use (fertilisers, pesticides, etc.) add to degradation.

Increasing population: With the rise in population, stress on natural resources is increasing. People are looking to move into new areas and are invading new land to make houses. This is contributing to the rise in desertification and land degradation.

Unplanned urbanisation: Economic development has led to the expansion of urban and industrial land. Much of the present urban and industrial development has taken place on agricultural land. The expansion of cities has resulted in the encroachment of forest areas and wetlands. For example, rapid urbanisation triggered by a population increase in coastal areas has caused coastal land degradation.

Climate Change: Climate change plays a huge role in desertification. As the days get warmer and periods of drought become more frequent, desertification becomes more and more eminent. Further rise in incidents like forest fires are destroying forests and leading to rising in desertification

13.11 Prevention and Control Measures for Land Degradation

Strip farming: It is & pa practices in which cultivated crops are sown in alternative strips to prevent water movement.

Crop Rotation: It is one of the agricultural practices in which different crops are grown in the same area following a rotation system which helps in the replenishment of the soil.

Ridge and Furrow Formation: Soil erosion is one of the factors responsible for land degradation. It can be prevented by the formation of ridges and furrows during irrigation which lessens runoff.

Construction of Dams: This usually checks or reduces the velocity of runoff so that soil support vegetation.

Contour Farming: This type of farming is usually practised across the hillside and is useful in collecting and diverting the runoff to avoid erosion.

Let Us Sum Up

Land degradation is a concept in which the value of the biophysical environment is affected by one or more combinations of human-induced processes acting upon the land. Land degradation is caused by multiple forces, including extreme weather conditions, particularly drought. It is also caused by human activities that pollute or degrade the quality of soils and land utility. Desertification is a form of land degradation by which fertile land becomes desert. Land degradation and desertification, largely due to deforestation and unsustainable land use, are amongst the most pressing problems facing the world today. Without a long-term solution to this issue, the world risks increasing food shortages, rising poverty, and increased migration; all of which threaten the stability of societies and our sustainable development ambitions.

Glossaries

LDN: Land degradation neutrality.

Salination: due to the low Quality of Irrigation Water, excessive fertilizer use, poor drainage of soil etc.,

UNCCD: United Nations Convention to Combat Desertification

Strip farming: It is & a practice in which cultivated crops are sown in alternative strips to prevent water movement

Water Erosion: It sheet erosion, rill erosion and so on leading to huge loss of top fertile soil along with plant nutrients through runoff water.

Check Your Progress

1. Define land Degradation?

   Answer: Land degradation is defined as the temporary or permanent decline in the productive capacity of the land, and the diminution of the productive potential, including its major land, use.

2. What are the types of land degradation?

   Answer: Land degradation (LD) can be broadly divided into physical, chemical & biological degradation

3. Write the importance of the Bonn Challenge?

   Answer: The Bonn Challenge is the forest landscape restoration (FLR) approach, which aims to restore ecological integrity at the same time as improving human well-being through multifunctional landscapes.

4. What is meant by GGW?

   Answer: Great green Wall was launched in 2007 by the African Union to restore Africa's degraded landscapes and transform millions of lives in one of the world's poorest regions (the Sahel).

5. What are the factors responsible for land degradation?

   Answer: Deforestation, Overgrazing, Water Logging, Soil erosion, natural disasters etc...

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UNIT 14

National Programmes and Policies: Legal Framework, Environmental Policy, and International Treaties

Structure

14.1 Overview

Science and Technological developments help to boom the various advancements in all types of industries. These developments have merits as well as demerits of all the requirements of humans in the world. However, this development disturbing the surrounding environment in many ways. There is a need for knowing the legal and constitutional provisions for protecting and nurturing nature. Keeping this in mind a policy was framed and implemented to reduce the demerits of technological development. The environmental policy is one such kind of policy. Policy refers to a set of principles or plans agreed upon by a government or an organization to be carried out in a particular situation. Environmental policy is defined as “any action deliberately taken to manage human activities to prevent, reduce, or mitigate harmful effects on nature and natural resources, and to ensure that man-made changes to the environment do not have harmful effects on human or the environment”. The environmental policy provides a framework for action and the setting of environmental objectives and environmental targets”

Environmental policies must include a pledge to continually measure and improve environmental performance, and many include a promise to seek ways to reduce energy, limit fuel consumption, lessen emissions, prevent pollution, reduce greenhouse gases, and reduce potable water consumption, or an infinite number of other appropriate metrics, that when measured can show improvement in environmental sustainability in the world.

The environmental policy usually covers air and water pollution, waste management, ecosystem management, biodiversity protection, and the protection of natural resources, wildlife, and endangered species. Proper policies and legislation at the national and international levels can reduce venomous pollution and help protect biodiversity and natural resources.

Learning Objectives

After reading this unit, you will learn about the following,

- Environmental Protection Acts in India and World
- Environmental Policy and Major environmental challenges
- International Treaties and Conventions

14.2 Environmental Protection Act

Most of the countries in the world have enacted Environmental Protection Acts considering the need for the protection of our environment. In the US, the National Environmental Policy Act (NEPA) of 1970 promotes the enhancement of the environment and established the President's Council on Environmental Quality (CEQ). It is referred to as the 'environmental Magna Carta' in the USA because it was an early step towards the development of the US environmental policy. Other environmental acts in the USA are as follows.

- Clean Air Act of 1970 and 1990
- Clean Water Act of 1972
- Endangered Species Act of 1973
- Resource Conservation and Recovery Act of 1976
- National Forest Management Act of 1976
- Surface Mining Control and Reclamation Act of 1977
- Comprehensive Environmental Response, Compensation and Liability Act of 1980

14.3 Environmental Protection Acts in India

In the Constitution of India, it is clearly stated that the state must 'protect and improve the environment and to safeguard the forests and wildlife of the country'. It imposes a duty on every citizen 'to protect and improve the natural environment including forests, lakes, rivers, and wildlife. There are several environmental acts enacted in India. Some of the important legislations in this respect are −

1. Wildlife Protection Act, 1972

In 1972, Parliament enacted the Wildlife Act (Protection) Act.

Objective

The Wildlife Act provides for state wildlife advisory boards, regulations for hunting wild animals and birds, the establishment of sanctuaries and national parks, tiger reserves regulations for trade in wild animals, animal products and trophies, and judicially imposed penalties for violating the Act.

Key Features

- Harming endangered species listed in Schedule 1 of the Act is prohibited throughout India.
- Hunting species, like those requiring special protection (Schedule II), big game (Schedule III), and small game (Schedule IV), is regulated through licensing.
- A few species classified as vermin (Schedule V), may be hunted without restrictions.
- Wildlife wardens and their staff administer the act.
- An amendment to the Act in 1982, introduced a provision permitting the capture and transportation of wild animals for the scientific management of the animal population.

2. Forest (Conservation) Act, 1980

First Forest Act was enacted in 1927. Alarmed at India's rapid deforestation and resulting environmental degradation, the Centre Government enacted the Forest (Conservation) Act in1980.

Objective

It was enacted to consolidate the law related to forest, the transit of forest produces and the duty liveable on timber and other forests produced.

Key Features

- Under the provisions of this Act, prior approval of the Central Government is required for the diversion of forestlands for non-forest

purposes.

- Forest officers and their staff administer the Forest Act.
- An Advisory Committee constituted under the Act advises the Centre on these approvals.
- The Act deals with the four categories of forests, namely reserved forests, village forests, protected forests, and private forests.

3. Water (Prevention and Control of Pollution) Act, 1974

Water (Prevention and Control of Pollution) Act was enacted in 1974 to provide for the prevention and control of water pollution, and for the maintaining or restoring of wholesomeness of water in the country.

Key Features

- The Act provides for maintenance and restoration of quality of all types of surfaces and groundwater.
- Controlling bodies: It provides for the establishment of Central and State Boards for pollution control.
- Functions: The Act assigns powers and functions to these Boards to control pollution.
- Authority to board: The Central and State Pollution Control Boards are given comprehensive powers to advise, coordinate, and provide technical assistance for the prevention and control of water pollution.
- Audit: The Act has provisions for funds, budgets, accounts, and audits of the Central and State Pollution Control Boards.
- Prohibition: The Act prohibits disposal of any poisonous, noxious, or polluting matter to the flow of water in a stream. However, dumping any material into a stream for reclamation of land is not considered an offence.
- Penalties: The Act provides for severe and deterrent punishments for violation of the Act which includes fines and imprisonment.

4. The Air (Prevention and Control of Pollution) Act, 1981

The Air (Prevention and Control of Pollution) Act, 1981 an Act of the Parliament of India to control and prevent air pollution in India. It was amended in 1987. The Government passed this Act in 1981 to clean up our air by controlling pollution. It states that sources of air pollution such as industry, vehicles, power plants, etc., are not permitted to release particulate matter, lead, carbon monoxide, sulfur dioxide, nitrogen oxide, volatile organic compounds (VOCs) or other toxic substances beyond a prescribed level

Objectives

- To provide for the prevention, control, and abatement of air pollution
- To provide for the establishment of central and State Boards to implement the Act (Central Pollution Control Board and State Pollution Control Board)
- To confer on the Boards the powers to implement the provisions of the Act and assign to the Boards functions relating to pollution

Key Features

- The Act specifically empowers State Government to designate air pollution areas and to prescribe the type of fuel to be used in these designated areas.
- According to this Act, no person can operate certain types of industries including the asbestos, cement, fertilizer, and petroleum industries without the consent of the State Board.

5. Environmental Protection Act, 1986

Environment Protection Act, 1986 is an Act of the Parliament of India. In the wake of the Bhopal Tragedy, the Government of India enacted the Environment Protection Act of 1986 under Article 253 of the Constitution. Passed in March 1986, it came into force on 19 November 1986. The Act is an “umbrella” for legislations designed to provide a framework for Central Government, coordination of the activities of various central and state authorities established under previous Acts, such as the Water Act and the Air Act. In this Act, the main emphasis is given to “Environment”, defined to include water, air and land and the inter-relationships which exist among water, air and land and human beings and other

Objective

The purpose of the Act is to implement the decisions of the United Nations Conference on the Human Environment of 1972, in so far as they relate to the protection and improvement of the human environment and the prevention of hazards to human beings, other living creatures, plants and property.

6. Handling and Management of Hazardous Waste Rules, 1989

The Ministry of Environment & Forests, Govt. of India has notified rules, vide Gazette notification no. S.O. 694 (E) DT. 28th July '89, under title Hazardous Wastes (Management & Handling) Rules, 1989 to deal with various environmental aspects related to hazardous wastes.

Key features

- The occupier generating hazardous wastes shall take all practical steps to ensure proper handling and disposal of hazardous wastes in an environment-friendly manner.
- The occupier generating hazardous wastes, subject to the quantity specified in the schedule, shall apply to the State Pollution Control Board, in Form–1 for the necessary authorisation.
- The State Pollution Control Board shall grant authorisation having satisfied that the operator of a facility or an occupier possesses appropriate facility, technical capabilities and equipment to handle hazardous wastes.
- The Authorisation, unless suspended or cancelled, shall remain in force for two years from the date of issue or the date of renewal.
- The occupier shall apply for the renewal of authorisation before its expiry.
- The authorisation shall continue to be in force until it is renewed or revoked.

7. The National Environmental Tribunal Act, 1995

The National Environment Tribunal Act, 1995 and National Environment Appellate Authority Act, 1997 were found to be inadequate giving rise to the demand for an institution to deal with environmental cases more efficiently and effectively.

Key Features

- National Environment Tribunal Act, 1995 consists of 31 Sections to fulfil the broad objectives laid under the Act.
- As the Act enacted with a broad objective to provide compensation to the person who got injured, the owner must pay compensation under Section 3, where there has been damage caused to the environment and the death or injury has been resulted due to the accident.
- The person can make an application concerning a claim for compensation to the Tribunal under the provision as specified under Section 4(1), Tribunal while dealing with the application of compensation as specified in the provisions of Act shall exercise the same jurisdiction and authority as that of matters as specified in Public Liability Insurance Act, 1991.
- Owner who is responsible for the environmental accident is liable to pay compensation not only under National Environment Tribunal Act, 1995, but also liable to pay relief specified under the provisions of Public Liability Insurance Act, 1991and the relief paid to be substantiated by

the compensation paid.

8. The Biological Diversity Act, 2002

The Biological Diversity Bill was introduced in the Parliament in 2000 and was passed in 2002.

Objective

India's richness in biological resources and indigenous knowledge relating to them is well recognized. The legislation aims at regulating access to biological resources to ensure equitable sharing of benefits arising from their use

Key Features

- The main intent of this legislation is to protect India's rich biodiversity and associated knowledge against their use by foreign individuals and organizations without sharing the benefits arising out of such use and to check biopiracy.
- This bill seeks to check biopiracy, protect biological diversity and local growers through a three-tier structure of central and state boards and local committees.
- The Act provides for the setting up of a National Biodiversity Authority (NBA), State Biodiversity Boards (SBBs) and Biodiversity Management Committees (BMCs) in local bodies. The NBA will enjoy the power of a civil court.
- BMCs promote conservation, sustainable use and documentation of biodiversity.
- NBA and SBB are required to consult BMCs in decisions relating to the use of biological resources.
- All foreign nationals or organizations require prior approval of the NBA for obtaining biological resources and associated knowledge for any use.
- Indian individuals/entities require the approval of the NBA for transferring results of research concerning any biological resources to foreign nationals/organizations.

14.4 Environmental Policy of India

Environment policies of the Government of India include legislation related to the environment. In the Directive Principles of State Policy, Article 48 says "the state shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country"; Article 51-A states that "it shall be the duty of every citizen of India to protect and improve the natural

environment including forests, lakes, rivers and wildlife and to have compassion for living creatures."

India is one of the parties to the Convention on Biological Diversity (CBD) treaty. Before the CBD, India had different laws to govern the environment. The Indian Wildlife Protection Act 1972 protected biodiversity. It was amended later multiple times. The 1988 National Forest Policy had conservation as its fundamental principle. In addition to these acts, the government passed the Environment (Protection) Act 1986 and Foreign Trade (Development and Regulation) Act 1992 for control of biodiversity.

An overview of National Environment Policy, 2006

A rapidly expanding society like ours faces numerous political, social, economic, cultural, and environmental challenges. Every such challenge or complication is in some way or the other related to our habits, customs, and patterns of habitation. Such routine styles have a direct or indirect impact on the environment. Therefore, it becomes mandatory to have thorough periodical checks on this blanket of protection that has helped mankind to thrive since time immemorial. For this purpose, many national policies to manage the environment have been devised which includes:

- National Forest Policy of 1988
- National Conservation Strategy and Policy Statement on Environment and Development, 1992
- Policy Statement on Abatement of Pollution, 1992
- National Agriculture Policy, 2000
- National Population Policy, 2000
- National Water Policy, 2000

All these policies have worked out strategies and plan to resolve the specific issue in which context they were formulated. However, certain underlying factors and gaps still needed to be filled to achieve a comprehensive plan for environmental management.

The National Environment Policy of 2006 was framed in this regard to extend the coverage of such already existing policies. It does not displace, but rather builds on the earlier policies. It is an acknowledgement of India's commitment to a clean and safe environment mandated in Articles 48A and 51A(g) of the Indian Constitution substantiated by judicial interpretation of Article 21. It calls for cooperation between states and their citizens towards maintaining and upgrading the quality of the environment.

Objectives of this Policy

The fundamental objectives of the National Environment Policy are listed below. These objectives outline the contemporaneous perception of the environmental challenges of the time.

- **Conservation of Critical Environmental Resources:** It involves protecting and conserving crucial ecological systems and resources along with vital natural and human-made heritage. These are essential for livelihoods, economic growth, and the wellbeing of man.
- **Intra-generational Equity:** It includes securing equitable access to environmental resources to different sections of society with a specific focus on low-income groups which are mostly reliant on environmental resources for livelihoods.
- **Inter-generational Equity:** It aims at wise and judicious use of environmental resources to meet the demands and needs of the current generation without compromising with the aspirations and needs of the future generations.
- **Integration of Economic and Social development Environmental concerns:** It focuses on integrating environmental concerns into effective plans, programs, projects, and policies for socio-economic progress.
- **Efficient use of Environmental Resource:** It involves ensuring efficient use of environmental resources to reduce their use per unit of economic output, to reduce negative ecological impacts.
- **Environmental Governance:** It means applying the fundamental principles of good governance to manage and regulate the use of environmental resources.
- **Enhancement of Resources for Environmental Conservation:** It aims at partnering with various local communities, public agencies, investors, researchers, and academic groups to ensure higher resource flows, including finance, technology, management skills, traditional knowledge for environmental protection.

Principles of National Environment Policy 2006

The Policy evolved from the recognition that only such development is sustainable, which respects ecological constraints, and the imperatives of justice. The Objectives stated above are to be realized through various strategic interventions by different public authorities at Central, State, and Local Government levels. They would also be the basis of diverse partnerships. The principles followed in the policy are:

1. Human Beings are at the Centre of Sustainable Development Concerns

2. Right to development must be filled to equitably meet the developmental and environmental needs of present and future generations.
3. To achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.
4. Where there are credible threats of serious or irreversible damage to key environmental resources, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.
5. In various public actions for environmental conservation, economic efficiency would be sought to be realized

14.5 Major environmental challenges

The main environmental challenges that India faces is due to the interconnection between environmental deterioration with poverty. The state of natural resources like flora, fauna, land, water, air form an essential part of these challenges posed.

It could be said, undeniably, that environmental degradation is a prime factor of perpetual poverty and the worst affected are often the rural poor as such degradations have a direct impact on soil fertility, water, air quality, wildlife, and fisheries. The loss of resilience in the ecosystem pushes the poor more to vulnerability.

In the urban sector, environmental degradation is often caused due to inappropriate waste treatment, lack of sanitation, industrial pollution which directly affects the quality of air, water, and soil which, in turn, causes serious health implications amongst the urban population. Consequently, it reduces their capacity to seek and retain employment, teach or attend schools, and foster gender inequalities, all of which perpetuate poverty. Moreover, it is estimated that 20 per cent of diseases caused in India are due to ecological factors.

The increasing focus of developing and developed nations on economic growth has accelerated environmental degradation due to the unchecked use of natural resources to meet their aim and the growing demands of the population. Unsustainable consumption patterns add to the aggravated condition of both- local and global life.

Government policy failures which provide incentives for indiscriminate and excessive use of natural resources coupled with institutional failures regarding insufficient enforced rights of access to, and use of, natural resources have depleted the environment further.

Another challenge is the emerging global environmental issues such as Climate change, ozone depletion, loss of biodiversity, etc. Multilateral programs and plans devised to meet such global challenges might negatively impact the development opportunities of developing nations.

14.6 International Treaties and Conventions

International conventions are treaties or agreements between countries. "International convention" is often used interchangeably with terms like "international treaty," "international agreement," "compact," or "contract between states." Conventions may be of a general or specific nature and between two or multiple states. Conventions between two states are called bilateral treaties; conventions between a small number of states (but more than two) are called plurilateral treaties; conventions between many states are called multilateral treaties. The important treaties and conventions are as follows,

1. Ramsar Convention

It is called the Convention on Wetlands. It was adopted in the city of Iran, Ramsar in 1971. It came into force in 1975.

2. Stockholm Convention

It is a convention on Persistent Organic Pollutants (POPs). It was adopted in 2001 in Geneva, Switzerland. It came into force in 2004.

3. CITES *(Convention on International Trade in Endangered Species of Wild Flora and Fauna)*

It is a convention on International Trade in Endangered Species of Wild Fauna and Flora. It was adopted in 1963. It came into force in 1975.

4. Convention on Biological Diversity (CBD)

It is a convention for the conservation of biological diversity. It was adopted in 1992

It came into force in 1993.

5. Bonn Convention

It is a Convention on the Conservation of Migratory Species of Wild Animals. It was adopted in 1979. It came into force in 1983.

6. Vienna Convention

It is a convention for the Protection of Ozone Layer. It was adopted in 1985. It came into force in 1988.

7. Montreal Protocol

It is an international environment protocol on substances that deplete the Ozone Layer. It was adopted in 1987. It came into force in 1989.

8. Kyoto Protocol

It is an international protocol to reduce greenhouse gas emissions. It was adopted in 1997. It came into force in 2005.

9. United Nations Framework Convention on Climate Change

It is an international environmental treaty governing actions to combat climate change through adaptation and mitigation efforts directed at control of emission of Green House Gases (GHGs) that cause global warming. It was adopted in 1992. It came into force in 1994.

10. Rio Summit

It is a United Nations Conference on Environment and Development. It was held in 1992 in Rio de Janeiro, Brazil.

11. UNCCD

It is a United Nations Convention to Combat Desertification. It was adopted in 1994. It came into force in 1996.

12. Basel Convention

It is a convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. It was adopted in 1989. It came into force in 1992.

13. Cartagena Protocol

It is an international environmental protocol on Biosafety to the Convention on Biological Diversity. It was adopted in 2000. It came into force in 2003.

14. UN-REDD

It is a United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation. It was created in 2008.

15. Nagoya Protocol

It is an international environment protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) to the Convention on Biological Diversity (CBD). It was adopted in 2010. It came into force in 2014.

16. COP24

It is the 24th meeting of the conference of parties (COP) to the United Nations Framework Convention on Climate Change. It took place in 2018.

17. COP21

It is the 21st meeting of the conference of parties (COP) to the United Nations Framework Convention on Climate Change. It took place in 2018.

18. Kigali Agreement

It is an amendment to the Montreal Protocol. It was adopted in 2016. It came into force in 2019.

19. Minamata Convention

It is an international environmental treaty intended to protect health and the environment from the adverse effects of mercury. It was adopted in 2013. It came into force in 2017.

20. Rotterdam Convention

It is an international environmental convention on Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. It was adopted in 1998. It came into force in 2004.

Let Us Sum Up

Environmental policy is a set of principles or plans agreed upon by a government or an organization to be carried out in a particular situation. It means to prevent, reduce, or mitigate harmful effects on nature and natural resources, and to ensure that man-made changes to the environment do not have harmful effects on humans or the environment. The environmental policies are national and international levels to protect our nature. Environmental conventions or treaties are discussed above the topic in detail.

Glossaries

Policy: It is a written statement, usually signed by senior management, which outlines a business' aims and principles about managing the environmental effects and aspects of its operations.

Treaties: it is "an intergovernmental document intended as legally binding with a primary stated purpose of preventing or managing human impacts on natural resources

Bilateral treaties: Conventions between two states are called bilateral treaties

NEPA: National Environmental Policy Act

Tribunal: A type of court with the authority to decide who is right types of disputes or disagreement

Check Your Progress

1. What are the two types of environmental policies?
   Answer: National level and international level policies.
2. Give the importance of the Kyoto protocol?
   Answer: Kyoto Protocol main aim is to limit and reduce greenhouse gas (GHG) emissions by agreed individual targets.
3. Give a short note on Environmental Degradation?
   Answer: It is the deterioration of the environment through depletion of resources such as quality of air, water and soil; the destruction of ecosystems; habitat destruction; the extinction of wildlife; and pollution.
4. What was the aim of the Rio summit?
   Answer: The Rio 'Earth Summit' was to produce a broad agenda and a new blueprint for international action on environmental and development issues that would help guide international cooperation and development policy in the twenty-first century.
5. What is meant by Environmental Governance?
   Answer: It means applying the fundamental principles of good governance to manage and regulate the use of environmental resources.

Suggested Readings

1. https://www.un.org/esa/dsd/agenda21/Agenda%2021.pdf
2. https://www.gktoday.in/topic/national-environment-policy-2006/
3. https://byjus.com/free-ias-prep/environment-conventions-protocols/
4. https://gradeup.co/environmental-conventions-and-protocols-notes-i
5. https://upscnav.com/international-conventions-on-environment
6. https://www.civilsdaily.com/conventions-protocols-declarations-related-to-environment-conservation/

UNIT 15

International Programmes and Policies - Brundtland Commission, Kyoto Protocol and Agenda 21

Structure

15.1 Overview

International environmental policy is particularly important in times of increasing globalisation, for many environmental problems extend beyond national borders and can only be solved through international cooperation. The international environmental policy covers several issues: climate protection, sustainable energy policy, preservation of biological diversity and the conservation of forests, seas and soils. Further related topics are pollution, desertification, sustainable waste management and protection against hazardous substances. Nearly all these issues need overarching strategies to ensure that environmental protection is considered in other policy areas, such as cooperation with developing countries, as well.

Learning Objectives

After reading this unit, you will learn about the following,

- International Environmental Policies
- Brundtland Commission

- Earth Charter
- Kyoto Protocol and Agenda 21

15.2 International Environmental Policies

International environmental policy is particularly important in times of increasing globalisation, for many environmental problems extend beyond national borders and can only be solved through international cooperation. The international environmental policy covers several issues: climate protection, sustainable energy policy, preservation of biological diversity and the conservation of forests, seas, and soils. Further related topics are desertification, sustainable waste management and protection against hazardous substances. Nearly all these issues need overarching strategies to ensure that environmental protection is considered in other policy areas, such as cooperation with developing countries, as well. Some of the international level environmental policies are,

1. International Whaling Commission (1947):

To preserve whales in the high seas, and to protect them from extinction, the IWC was set up in 1947, though the League of Nations in 1927 itself recognised the need for such an action. The International Commission on Whales has prohibited altogether the killing of blue whales, and commercial whaling has been banned in most of the Indian Ocean.

Several 'Whale Sanctuaries' have been established in many parts of the world, Similarly, efforts have been taken to reduce the killing of 'Dolphins' in the Eastern Pacific. Despite all efforts through international agreements, prohibiting commercial Whaling and other rare varieties of marine animals, under the guise of scientific research, many whales and dolphins are killed every year.

2. Inter-Governmental Maritime Consultative Organisation (IMCO):

For purpose of effectively controlling discharges of oil from the tankers, the Inter-Governmental Maritime Consultative Organisation (IMCO) signed an agreement in the year 1954. At that time, only 30 nations joined this Organisation, while several nations did not opt to join.

According to the agreement, the signatory nations agreed not to spill oil in the oceans through ballasting operations. However, by 1969, many nations joined this organisation and signed the agreement, when specific amendments were brought into operation.

After the 'Torrey Canyon' disaster in 1967, the members of IMCO agreed to follow stringent steps to stop pollution of the seas when it threatens their

coast. The agreement insisted on several safety measures in the navigational system, such as ‘Sea Lanes:’ ‘Speed restrictions’, ‘Testing of navigational equipment, ‘Better training of Officers and Crew’ and also ‘Better methods in the construction of tankers.

The Stockholm Conference on Human Environment is unique in many respects. This was the first to be held in the seventies in a series of major UN conferences which made an in-depth study of the environmental problems and the dangers connected therewith and the need for doing something substantial with the cooperation of the nations of the world. Later, it covered problems of pollution, food, women’s rights, desertification, human settlements, Science & Technology, and other similar topics.

3. OECD Environmental Committee (1974):

The OECD Environmental Committee proposed the following:

1. There should be a policy on non-discrimination between countries in the matters of pollution and every country should have equal rights of access to knowledge and justice.

2. Polluting countries causing damage or likely to cause damage in other countries should be subject to stringent controls like those controlling policies adopted by these countries within national boundaries. This is to say that polluting countries in the international field should subject themselves to the same type of control, as they would control their polluters within their countries.

3. Victims of pollution should have access to administrative bodies and also to the courts in polluting countries, to ensure legal protection of the interest.

4. In the event of receiving compensation by the victims of pollution they should not accept less compensation if their national standards are less stringent than those of polluters.

The OECD Environmental Committee extended the principle of the equal right of access in the courts of the polluting country as they would do in their own country. The victim could also seek justice from International Joint Commission. Though the Principles advocated by OECD are very laudable, in practice they are very difficult procedures.

4. Helsinki Convention 1974:

Baltic Sea is surrounded by several countries and this Sea has become a sink for hazardous wastes, dumped by almost all countries surrounding it. Hence, in 1974 all the seven Baltic States signed the Helsinki Convention to control, if not altogether prohibit, the discharge of hazardous substances

into the Baltic Sea. But this could not prove effective or satisfactory, even, due to the attitude of Soviet States which differed from other States.

5. OECD Meet on Environment – 2001:

It was held parries on May 16, 2001. Enviro-ministers or their representatives from 30 countries participated. As per this conference, the strategy commits the members to specific national action over the next Ten Years to tackle the Enviro-problem including climate change.

6. Basel Convention on Hazardous Waste (1989):

The European Economic Community and Thirty-Five nations of the world met at BASEL in Switzerland in March 1989 to limit and control international transport and also disposal of hazardous waste. The report of the Basel Convention contains 29 Articles.

The main points contemplated in it are:

(a) Signatory States are prohibited from transporting hazardous waste to another State which had banned the import of it.

(b) Every country has the right to refuse acceptance of a shipment of hazardous waste.

(c) No signatory country can ship hazardous waste to another signatory country if the latter does not have facilities to dispose of the waste without detriment to the environment.

(d) In the event of shipment of hazardous wastes, on agreement of acceptance, the wastes must be well packaged, labelled and transported in conformity with the generally accepted and recognised international rules and standards.

This treaty declared that traffic in hazardous wastes is criminal.

7. Montreal Protocol (1989):

The role played by Chlorofluorocarbons (CFCs) and other halogens responsible for global ozone depletion. We had also studied the emission of sulphur and nitrogen oxides which are responsible for ‘Acid Rain’. We also studied about the hole in ‘Ozone Layer’ which created much concern to the scientists, as well as administrators, of different countries of the world.

Though in the early 1980s the USA did not recognise the importance of controlling CFCs and refused to participate in any international agreements, by 1989, it realised the impending danger to the global environment and changed its policy. The result was Montreal Protocol.

8. Indian Ocean Rimi Organisation for Regional Corporation:

The importance of IORORC is in the importance and significance of the Indian Ocean particularly, in terms of trade for its five sub-regions Persian Gulf, South Asia, East Asia. The Horn of Africa and Eastern and Southern Africa.

End of the II World War, new powerful eco-forces aimed at Global competition and expansion trade have been unleashed. Regional blocks of free trading nations are being formed in different I the world. Asian, Asia Pacific Forum, North American free-trade Area and European community are some of the examples.

The Indian Ocean's water provides essential transport connections vital for the trade and economy of the world. Suez Canal, Cape of Good Hope, Harmillz Straits, Mataica Straits and Sundays are some of the important strategic waterways.

9. United Nations Conference on Environment and Development at Rio De Janeiro, (June 1992) (Agenda 21):

In June 1992,178 nations of the World participated in the historic 'Earth Summit, the United Nations Conference on Environment and Development held in Rio De Janeiro. This conference adopted the Rio Declaration which has come to be known as Agenda 21.

Agenda 21 is a comprehensive document that will set the planet 'Earth' on a new course of Sustainable development and save this fragile earth from environmental degradation. This Agenda 21 is intended to provide a blueprint of action in all areas relating to the sustainable development of the 'Earth' from now until the 21st Century.

Rio Declaration: The declaration stated that human beings were at the centre of concerns for sustainable development and set the goal of establishing "a new and equitable global partnership through the creation of new levels of cooperation among States, key sectors of societies and people".

10. Agenda 21

The agenda covers in great length and details the issues of 'sustainable development' on the planet. Poverty, in all its complex multidimensional aspects, forms an important part of the agenda.

Its proposals cover population policies, health care, education, women, you, and indigenous people, including local communities, and their rights to

achieve sustainable livelihoods. Food, security, clean water, and sanitation are also dealt with in length.

11. The Hague Conference

The Sixth Edition of the conference of parties (COP6) of the UN Framework Convention on ultimate Change (UNFCL) was held at the Hague in Nov. 2000. The conference was commenced to shape the modalities of a plan that would ensure that countries reach the qualified targets that they committed to at COP3 at Kyoto, Japan, in 1997 to reduce consumption of Greenhouse Gases responsible for Global warming.

The COP3 at Kyoto Protocol had identified six greenhouse gases (GHG5) mainly responsible for global warms. Carbon dioxide, methane, nitisinone oxide, Hydrofluorocarbon's perfluorocarbons and sulfur, Hexafluoride.

12. DOHA Conference

The Fourth WTO Ministerial Conference was held at DOHA during Nov 9-14-2001 to decide upon the future work programme of the WTO. WTO was set up in 1994, has in its constitution a provision for a ministerial conference after every two years.

The first ministerial conference was held in Singapore. The Second in Geneva and the Third in Seattle. The fourth was held in DOHA in November 2001, given the failure of the III ministerial conference.

15.3 Brundtland Commission

The UN's World Commission for Environment and Development, chaired by former Norwegian Prime Minister Gro Harlem Brundtland and thus referred to as the Brundtland Commission, published the report "Our Common Future," also known as the "Brundtland Report," in 1987.

The Brundtland Commission aimed to help direct the nations of the world towards the goal of sustainable development. The commission is also known as the World Commission on Environment and Development (WCED). Simultaneously, it promoted decoupling environmental degradation and economic prosperity

The Brundtland Commission officially dissolved in 1987 after releasing Our Common Future, also known as the Brundtland Report. The document popularized the term "sustainable development" and won the University of Louisville Grawemeyer Award in 1991. In 1988, the Center for Our Common Future was started to take the place of the Commission

The Brundtland Commission gave a new definition of sustainable development as a concept that integrates the importance of development with the cause of environmental protection. Since the Commission's report, the importance of sustainable development has been realized all over the world. The three main pillars of sustainable development include economic growth, environmental protection, and social equality.

Brundtland Report, also called Our Common Future, the publication released in 1987 by the World Commission on Environment and Development (WCED) that introduced the concept of sustainable development and described how it could be achieved. Sponsored by the United Nations (UN) and chaired by Norwegian Prime Minister Gro Harlem Brundtland, the WCED explored the causes of environmental degradation, attempted to understand the interconnections between social equity, economic growth, and environmental problems, and develop policy solutions that integrated all three areas, and highlighted several major proposals for sustainable development:

1. **Environment:** We should conserve and enhance our resource base, by gradually changing how we develop and use technologies.
2. **Social Equity:** Developing nations must be allowed to meet their basic needs of employment, food, energy, water, and sanitation. If this is to be done sustainably, then there is a definite need for a sustainable level of population.
3. **Economic Growth:** Economic growth should be revived and developing nations should be allowed the growth of equal quality to the developed nations.

15.4 Earth Charter

“Our Common Future” the report of the “Brundtland Commission” came out with a new guide to sustainable development. The “Brundtland Commission”, called for “a universal declaration” and a “new charter” to set “new norms” to guide the transition to sustainable development. Maurice Strong was a distinguished member of the Commission. The Earth Charter was proposed during the preparatory process to the UN Conference on Environment and Development — best known as the Earth Summit — held in Rio de Janeiro, Brazil, in 1992.

The Report is divided into four main parts (WCED 1987).

The first examines the various successes and failures surrounding sustainable development, the interconnected nature of the crisis, a definition

of sustainable development, and the holes currently limiting the ability of institutions to target the problems

The second examines policy, including population and human resources, food security, species and ecosystems, sustainable energy, industrial productivity, and the urban environment

The third targets international reform, including the international economy's role, the management of the commons, how peace, security, development, and the environment interrelate, and the institutional and legal changes needed to accomplish the Report's goals.

Part three also highlights the cooperation needed between various stakeholders (government, civil society, individuals, et al), how global risks need to be assessed, and making informed choices on those assessments Finally, the report concludes with "A Call for Action", urging the changes outlined to be implemented

15.5 Kyoto Protocol

The Kyoto Protocol is an international agreement that aimed to reduce carbon dioxide (CO2) emissions and the presence of greenhouse gases (GHG) in the atmosphere. The essential tenet of the Kyoto Protocol was that industrialized nations needed to lessen the amount of their CO2 emissions.

The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. There were 192 parties (Canada withdrew from the protocol, effective December 2012) to the Protocol in 2020. The main goal of this protocol is to fight global warming by reducing greenhouse gas concentrations in the atmosphere to "a level that would prevent dangerous anthropogenic interference with the climate system

The Kyoto Protocol came into effect on 16 February 2005. This international treaty seeks to implement the objectives of the United Nations Framework Convention on Climate Change (UNFCCC) to combat global warming by decreasing greenhouse gas concentrations in the atmosphere.

The major greenhouse gases that are addressed are:

- Carbon dioxide (CO2)
- Methane (CH4)
- Nitrous oxide (N2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)

- Sulphur hexafluoride (SF6)

In December 2012, after the first commitment period of the Protocol ended, participating countries in the Kyoto Protocol met in Doha, Qatar to adopt an amendment to the original Kyoto agreement. This was called the Doha Amendment which added new emission-reduction targets for the second commitment period, 2012–2020, for these countries. In 2015, at the sustainable development summit held in Paris, all UNFCCC participants signed yet another pact, the Paris Climate Agreement, which effectively replaced the Kyoto Protocol.

Kyoto Protocol – Salient Features

- The UNFCCC was an international agreement held in 1992 in which member countries agreed to reduce greenhouse gas concentrations in the earth's atmosphere to prevent devastating climate change. This was, however, not binding on the members, and no specific targets were set.
- By 1995, the countries, understanding the need for a stricter demand on greenhouse reduction, began negotiating on a protocol that was based on the UNFCCC but would be a standing agreement on its own.
- The Kyoto Protocol extends the UNFCCC and makes members commit to a specific reduction target. The text of the protocol was unanimously adopted on 11 December 1997. It entered into force in February 2005. Currently, there are 192 parties to the protocol.
- The protocol gives specific target cuts in the emission levels of greenhouse gases of member countries and makes it binding. However, only developed countries have binding targets based on the (accurate) premise that they have had a historically larger share in the emission of pollutants due to the antecedence of industrialisation in those countries compared to developing economies. This is based on common but differentiated responsibility.
- These targets are between -8% and +10% of the countries' 1990 emission levels.
- To make the 'binding targets' more acceptable, the protocol provides flexibility in how countries meet the targets. Countries are allowed to partially compensate for the emissions by increasing what is called 'sinks', i.e., forests. This is because forests reduce carbon dioxide from the atmosphere.
- Most nations have ratified the treaty. The USA is a notable exception to this. It takes the stand that having binding targets only for developed countries and not polluting countries like China and India is potentially

harmful to its economy. Canada withdrew from the Kyoto Protocol in 2012.

- The targets are for the following greenhouse gases/gas groups: carbon dioxide, nitrous oxide, methane, sulphur hexafluoride, hydrofluorocarbons, and perfluorocarbons.

The first commitment period for the agreement was from 2008 to 2012. Apart from national measures, the agreement has three mechanisms that are meant to achieve the Kyoto targets:

- International Emissions Trading
- Clean Development Mechanism
- Joint Implementation

India is a non-Annex I country. India is exempt from the treaty's framework. The Indian government ratified the treaty in August 2002. Since the per capita emission rates are much smaller for developing countries compared to the developed countries, India takes the stand that the major responsibility of reducing emissions lies with the latter.

Kyoto Protocol – Monitoring Emission

The emission monitoring process must be carried out by various countries and a proper track record has to be maintained.

The emission monitoring is managed by the following process:

1. Registry systems – These are meant to track the transactions carried out by the parties as per the Kyoto mechanisms.
2. Reporting- This is an important part of the process as the respective parties must submit their information related to annual emission inventories as per the guidelines in the protocol.
3. Compliance system – This ensures that the commitments are met by the parties and in case of issues relating to this.
4. Adaptation- This part of the process facilitates the development and deployment of technologies that can help increase resilience to the impacts of climate change. There is an adaptation fund to provide financial assistance to parties that take up adaptation projects and programmes.

15.6 Agenda 21

Agenda 21 is the plan of action to achieve sustainable development that was adopted by the world leaders at the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, in June 1992. Agenda 21, an action plan of the United Nations (UN) related to sustainable

development, clearly identified information, integration, and participation as key building blocks to help countries achieve development that recognizes these interdependent pillars - economic development, environmental development, social development and cultural development.

Rio Summit 1992

The Rio Summit 1992 is also called the Earth Summit. This summit led to the development of the following documents:

1. Rio Declaration on Environment and Development
2. Agenda 21
3. Forest Principles

The first document called the Rio Declaration, in short, contained 27 principles that were supposed to guide countries in future sustainable development. Agenda 21 is an action plan concerning sustainable development, but it is non-binding. The Forest Principles is formally called 'Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests'. It makes many recommendations for conservation and sustainable development forestry and is non-binding.

Agenda 21 emphasizes that broad public participation in decision-making is a fundamental prerequisite for achieving sustainable development.

Agenda 21 is the outcome of the 1992 Earth Summit. It is the "Voluntary" action plan of the United Nations (UN) related to sustainable development. This 40-point document was a comprehensive blueprint of 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. For the implementation of these points, a Commission on Sustainable Development was established as a high-level forum on sustainable development. Agenda 21 was adopted by the UNCED (United Nations Conference on Sustainable Development) in June 1992. It recognised that humanity was at a defining moment? it could either continue with the present policies which deepen economic divisions within and among countries, which increase poverty, hunger, sickness and illiteracy worldwide sad which continue to deteriorate the ecosystems on which the Earth depends: OR we could change course and bring about a better and sustainable future for all through better management of the ecosystem.

Agenda 21 supported the liberalisation of trade and the removal of distortions in international trade. It calls for increased investment in developing countries and better management of financial resources. It calls

for combating poverty through policies in respect of population, health care and education, the rights of women and disadvantaged people. It emphasises the need to provide improved shelter, energy-efficient technology, human resource development, protecting the atmosphere, combating deforestation and advocates sustainable agriculture and use of biotechnology.

Let Us Sum Up

International agreements that become policies allow countries to work together in trade and investment and in addressing global concerns such as air pollution, water pollution, managing hazardous wastes, and climate change. The International Environmental policy is the commitment of an organization or government to the laws, regulations, and other policy mechanisms concerning environmental issues in the world. However, international environmental policies are used to reduce pollution and protect nature. Many protocols, Agendas and summits are implemented to save our environment.

Glossaries

Protocols: It is the first or original version of a written agreement, especially one between countries; an extra part added to a written agreement.

Agenda 21: Action plans to achieve sustainable development that was adopted by the world leaders at the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, in June 1992

UNFCCC: United Nations Framework Convention on Climate Change

Earth Summit: United Nations Conference on Environment and Development (UNCED), also known as the 'Earth Summit, was held in Rio de Janeiro, Brazil, from 3-14 June 1992.

Conference: It is a large official meeting, often lasting several days, at which members of an organization, profession, etc. meet to discuss important matters

Check Your Progress

1. Which report is called Our Common Feature??
   Answer: Brundtland Commission report is also known as Our Common Future,
2. Give the importance of Montreal protocol?
   Answer: Montreal Protocol is related to reducing global ozone depletion.
3. Mention the importance of the Rio Summit?

Answer: One of the major objectives of agenda 21 is that every local government should have its own local Agenda 21 to combat environmental degradation.

4. What are the types of emission monitoring in the Kyoto Protocol?
   Answer: They are four types. Registry systems, Reporting, Compliance system and Adaptation

5. What is meant by IORORC?
   Answer: Indian Ocean Rimi Organisation for Regional Corporation for trade.

Suggested Readings

1. https://www.environmentalpollution.in/environmental-policies/list-of-top-12-international-environmental-policies/1267
2. https://byjus.com/free-ias-prep/environment-conventions-protocols/
3. https://www.pmfias.com/unep-un-environment/
4. https://upscnav.com/international-conventions-on-environment
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UNIT 16

Sustainable Development Goals and Paris Agreement

Structure

16.1 Overview

Sustainable development aims at meeting the basic needs of all people in general and the poor majority in particular- their employment, food, energy, water, housing, etc., by ensuring the growth of agriculture, manufactures, power and services with due consideration for environmental concerns.

Over the past two decades, economic growth has lifted more than 660 million people out of poverty and has raised the income levels of millions more, but too often it has come at the expense of the environment and poor communities.

Through a variety of market, policy, and institutional failures. Earth's natural capital has been used in ways that are economically inefficient and wasteful, without sufficient reckoning of the true costs of resource depletion. The burning of fossil fuels supported rapid growth for decades but set up dangerous consequences, with climate change today threatening to roll back decades of development progress. At the same time, growth patterns have left hundreds of millions of people behind: 1.2 billion still lack access to electricity, 870 million are malnourished, and 780 million are still without access to clean, safe drinking water.

Sustainable development recognizes that growth must be both inclusive and environmentally sound to reduce poverty build shared prosperity for today's population and to continue 10 meet the needs of future generations. It is efficient with resources and carefully planned to deliver both immediate and long-term benefits for people, the planet, and prosperity.

Learning Objectives

After reading this unit, you will learn about the following,

- History, concept, and Sustainable Development Goals and
- Aim, goal, framework, key aspects and criticism of Paris Agreement

16.2 A Brief History of Sustainable Development

- 1980: United Nations set up Brundtland Commission on Environment and Development, which came up with a report titled, “Our Common Future” that defined “Sustainable development as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs”
- 2000: UN General Assembly approved 8 Millennium Development Goals (MDGs) with 18 associated targets, to be achieved by 2015
- 2012: Earth Summit in Rio, Brazil in 2012, also called Rio+20 summit
- Leaders announced to prepare “Sustainable Development Goals” (SDGs) for the post-2015 era when MDGs would expire
- 2015: United Nations General Assembly approved 17 goals with 169 associated targets. They became effective from 1/1/2016 and were to be achieved by 2030

16.2.1Concept of Sustainable Development

The term was used by the Brundtland Commission which coined what has become the most often-quoted definition of sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development implies economic growth together with the protection of environmental quality, each reinforcing the other. It is maintaining a delicate balance between the human need to improve lifestyles and preserve natural and cultural ecosystems. The field of sustainable development can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and socio-political sustainability. The essence of this form of development is a stable relationship between human activities and the natural world, which does not diminish the prospects for future generations to enjoy a quality of life at least as good as our own.

The linkage between environment and development was globally recognized in 1980 when the International Union for the Conservation of Nature published the World Conservation Strategy and used the term "sustainable development". This term has been used as a unifying theme in presenting environmental and social concerns about worrisome trends towards accelerated environmental degradation and social polarization in the 1970s and 1980s.

The concept came into general usage after the Brundtland Commission Report (1987), formally called the Report of the World Commission on Environment and Development (WCED). WCED was set up by the United Nations General Assembly. Thus, the term 'sustainable development' was widely adopted by mainstream development agencies following the publication in 1987 of "Our Common Future" by the World Commission on Environment and Development (WCED), chaired by the then prime minister of Norway, Gro Harlem Brundtland.

The Brundtland Report coined the most often cited phrase to describe the principle of sustainable development as... development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

16.2.2 The three pillars of sustainable development

Economic growth, environmental stewardship, and social inclusion - carry across all sectors of development, from cities facing rapid urbanization to agriculture, infrastructure, energy development and use, water availability, and transportation. Cities are embracing low-carbon growth and public

transportation. Farmers are picking up the practices of climate-smart agriculture. Countries are recognizing the value of their natural resources, and industries are realizing how much they can save through energy and supply chain efficiency.

16.2.3 Sustainable Development Goals (SDGs)

The Sustainable Development Goals (SDGs) are a collection of 17 global goals designed to be a “blueprint to achieve a better and more sustainable future for all” The SDGs, set in 2015 by the United Nations General Assembly and intended to be achieved by the year 2030, is a part of UN Resolution 70/1, the 2030 Agenda. They are officially referred to as “Transforming our world: the 2030 Agenda for Sustainable Development”. The following are the list of sustainable development goals.

1. No Poverty
2. Zero Hunger
3. Good Health and Well-being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation and Infrastructure
10. Reduced Inequality
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace and Justice Strong Institutions and
17. Partnerships to achieve the Goal

16.3 Paris Agreement

The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016. Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate-neutral world by mid-century. The Paris

Agreement is a landmark in the multilateral climate change process because, for the first time, a binding agreement brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects. The Paris Agreement was said to work on a 5- year cycle of increasingly ambitious climate action that was carried out by 196 countries. Now that it is 2020, countries had to submit their plans for climate action known as nationally determined contributions (NDCs).

16.3.1 Three Pillars of the agreement

- Capacity Building for climate change
- Technological Development and transfer for climate change issues
- Finance provision to poor countries for mitigation and adaptation for climate change

16.3.2 Aims of the Agreement

As countries around the world recognized that climate change is a reality, they came together to sign a historic deal to combat climate change – Paris Agreement. The aims of the Paris Agreement are as below:

- Keep the global temperature rise this century well below 2 degrees Celsius above the pre-industrial level.
- Pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.
- Strengthen the ability of countries to deal with the impacts of climate change.

16.3.3 Goals of the Agreement

- To curtail the rise of global temperature this century below 2-degree Celsius, above pre-industrial levels; and also pursue efforts to limit the increase to 1.5 degrees Celsius.
- Develop mechanisms to help and support countries that are very vulnerable to the adverse impacts of climate change. An example would be countries like the Maldives facing threats due to sea-level rise.
- Confirms the obligation that developed countries have towards developing countries, by providing them financial and technological support.

16.3.4 Nationally Determined Contributions (NDC)

- The national pledges by countries to cut emissions are voluntary.
- The Paris Agreement requires all Parties to put forward their best efforts through “nationally determined contributions” (NDCs) and to strengthen these efforts in the years ahead.

- This includes requirements that all Parties report regularly on their emissions and their implementation efforts.
- In 2018, Parties will take stock of the collective efforts about progress towards the goal set in the Paris Agreement.
- There will also be a global stocktake every 5 years to assess the collective progress towards achieving the purpose of the Agreement and to inform further individual actions by Parties.

16.3.5 India's intended Nationally Determined Contribution (INDC)

- India's INDC include a reduction in the emissions intensity of its GDP by 33 to 35 per cent by 2030 from the 2005 level.
- India has also pledged to create an additional carbon sink of 2.5 to 3 billion tons of CO2 equivalent through additional forest and tree cover by 2030.
- India will anchor a global solar alliance, INSPA (International Agency for Solar Policy & Application), of all countries located in between Tropic of Cancer and Tropic of Capricorn.

16.3.6 How are countries supporting one another?

The Paris Agreement provides a framework for financial, technical, and capacity-building support to those countries who need it.

- **Finance:** The Paris Agreement reaffirms that developed countries should take the lead in providing financial assistance to countries that are less endowed and more vulnerable, while for the first time also encouraging voluntary contributions by other Parties. Climate finance is needed for mitigation because large-scale investments are required to significantly reduce emissions. Climate finance is equally important for adaptation, as significant financial resources are needed to adapt to the adverse effects and reduce the impacts of a changing climate.
- **Technology:** The Paris Agreement speaks of the vision of fully realizing technology development and transfer for both improving resilience to climate change and reducing GHG emissions. It establishes a technology framework to provide overarching guidance to the well-functioning Technology Mechanism. The mechanism is accelerating technology development and transfer through its policy and implementation arms.
- **Capacity-Building:** Not all developing countries have sufficient capacities to deal with many of the challenges brought by climate change. As a result, the Paris Agreement places great emphasis on climate-related capacity-building for developing countries and requests

all developed countries to enhance support for capacity-building actions in developing countries.

16.3.7 Steps towards Climate Change Control

- The countries of the world agreed to counter climate change and rising temperatures. But countries like the United States, which had been long-term historical contributors, did not want this deal. The US stated that it put too much pressure on it to make reductions.
- Such countries wanted to erase the very idea of the past and to focus on the need for all to act and for all to take actions based on what they believed they could do.
- Although climate change action needs to be massively increased to achieve the goals of the Paris Agreement, the years since its entry into force have already sparked low-carbon solutions and new markets.
- More and more countries, regions, cities and companies are establishing carbon neutrality targets.
- Zero-carbon solutions are becoming competitive across economic sectors representing 25% of emissions. This trend is most noticeable in the power and transport sectors and has created many new business opportunities for early movers.
- By 2030, zero-carbon solutions could be competitive in sectors representing over 70% of global emissions.

16.3.8 Some of the key aspects of the Agreement are set out below

- **Long-term temperature goal (Art. 2)** – The Paris Agreement, in seeking to strengthen the global response to climate change, reaffirms the goal of limiting global temperature increase to well below 2 degrees Celsius while pursuing efforts to limit the increase to 1.5 degrees.
- **Global peaking and 'climate neutrality' (Art. 4)** – To achieve this temperature goal, Parties aim to reach global peaking of greenhouse gas emissions (GHGs) as soon as possible, recognizing peaking will take longer for developing country Parties, to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of the century.
- **Mitigation (Art. 4)** – The Paris Agreement establishes binding commitments by all Parties to prepare, communicate and maintain a nationally determined contribution (NDC) and to pursue domestic measures to achieve them. It also prescribes that Parties shall communicate their NDCs every 5 years and provide information necessary for clarity and transparency. To set a firm foundation for

higher ambition, each successive NDC will represent a progression beyond the previous one and reflect the highest possible ambition. Developed countries should continue to take the lead by undertaking absolute economy-wide reduction targets, while developing countries should continue enhancing their mitigation efforts, and are encouraged to move toward economy-wide targets over time in the light of different national circumstances.

- **Sinks and reservoirs (Art.5)** – The Paris Agreement also encourages Parties to conserve and enhance, as appropriate, sinks and reservoirs of GHGs as referred to in Article 4, paragraph 1(d) of the Convention, including forests.
- **Voluntary cooperation/Market and non-market-based approaches (Art. 6)** – The Paris Agreement recognizes the possibility of voluntary cooperation among Parties to allow for higher ambition and sets out principles – including environmental integrity, transparency and robust accounting – for any cooperation that involves internationally transferal of mitigation outcomes. It establishes a mechanism to contribute to the mitigation of GHG emissions and support sustainable development and defines a framework for non-market approaches to sustainable development.
- **Adaptation (Art. 7)** – The Paris Agreement establishes a global goal on adaptation – of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change in the context of the temperature goal of the Agreement. It aims to significantly strengthen national adaptation efforts, including through support and international cooperation. It recognizes that adaptation is a global challenge faced by all. All Parties should engage in adaptation, including by formulating and implementing National Adaptation Plans, and should submit and periodically update an adaptation communication describing their priorities, needs, plans and actions. The adaptation efforts of developing countries should be recognized
- **Loss and damage (Art. 8)** – The Paris Agreement recognizes the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage. Parties are to enhance understanding, action and support, including through the Warsaw International Mechanism, on a cooperative and facilitative basis concerning loss and damage associated with the adverse effects of climate change.

- **Finance, technology and capacity-building support (Art. 9, 10 and 11)** – The Paris Agreement reaffirms the obligations of developed countries to support the efforts of developing country Parties to build clean, climate-resilient futures, while for the first time encouraging voluntary contributions by other Parties. The provision of resources should also aim to achieve a balance between adaptation and mitigation. In addition to reporting on finance already provided, developed country Parties commit to submit indicative information on future support every two years, including projected levels of public finance. The agreement also provides that the Financial Mechanism of the Convention, including the Green Climate Fund (GCF), shall serve the Agreement. International cooperation on climate-safe technology development and transfer and building capacity in the developing world are also strengthened: a technology framework is established under the Agreement and capacity-building activities will be strengthened through, inter alia, enhanced support for capacity building actions in developing country Parties and appropriate institutional arrangements. Climate change education, training as well public awareness, participation and access to information (Art 12) are also to be enhanced under the Agreement.
- **Climate change education, training, public awareness, public participation and public access to information (Art 12)** is also to be enhanced under the Agreement.
- **Transparency (Art. 13), implementation and compliance (Art. 15) –** The Paris Agreement relies on a robust transparency and accounting system to provide clarity on action and support by Parties, with flexibility for their differing capabilities of Parties. In addition to reporting information on mitigation, adaptation and support, the Agreement requires that the information submitted by each Party undergoes international technical expert review. The Agreement also includes a mechanism that will facilitate implementation and promote compliance in a non-adversarial and non-punitive manner and will report annually to the CMA.
- **Global Stocktake (Art. 14)** – A “global stocktake”, to take place in 2023 and every 5 years thereafter, will assess collective progress toward achieving the purpose of the Agreement in a comprehensive and facilitative manner. It will be based on the best available science and its long-term global goal. Its outcome will inform Parties in updating and enhancing their actions and support and enhancing international cooperation on climate action.

- **Decision 1/CP.21** also sets out several measures to enhance action before 2020, including strengthening the technical examination process, enhancement of provision of urgent finance, technology and support and measures to strengthen high-level engagement. For 2018 a facilitative dialogue is envisaged to take stock of collective progress towards the long-term emission reduction goal of Art 4. The decision also welcomes the efforts of all non-Party stakeholders to address and respond to climate change, including those of civil society, the private sector, financial institutions, cities and other subnational authorities. These stakeholders are invited to scale up their efforts and showcase them via the Non-State Actor Zone for Climate Action platform (http://climateaction.unfccc.int). Parties also recognized the need to strengthen the knowledge, technologies, practices and efforts of local communities and indigenous peoples, as well as the important role of providing incentives through tools such as domestic policies and carbon pricing.

16.3.9 Criticisms of the Agreement

- According to a study published in Nature in June 2016, current country pledges are too low to lead to a temperature rise below the Paris Agreement temperature limit of “well below 2 °C”.
- Even a UNFCCC report had observed that even if all the pledges made by 197 countries that are signatory to the Paris pact were fulfilled, it would be insufficient to meet the conservative goal of keeping global temperature rise within the 2-degree Celsius threshold.
- Most of the agreement consists of “promises” or aims and not firm commitments. The starting point of $100bn per year remains under 8% of worldwide declared military spending each year.
- Since the only mechanism remains voluntary national caps on emissions, without even any guidance on how stringent those caps would need to be, it is hard to be optimistic that these goals are likely to be achieved.
- There is only a “name and shame” system or a “name and encourage” plan and the ‘contributions’ themselves are not binding as a matter of international law.

Let Us Sum Up

Sustainable development recognizes that growth must be both inclusive and environmentally sound to reduce poverty build shared prosperity for today's population and to continue 10 meet the needs of future generations. On the other hand, the Paris Agreement is an agreement within the United Nations

Framework Convention on Climate Change (UNFCCC). Countries will aim to keep global temperatures from rising more than 2°C (3.6°F) by 2100 with an ideal target of keeping temperature rise below 1.5°C (2.7°F). Paris is only the beginning of a shift towards a low-carbon world, and there is much more to do.

Glossaries

SDG: Sustainable Development Goals.

Paris Agreement: The Paris Agreement is a legally binding international treaty on climate change.

INDC Intended Nationally Determined Contribution (INDC) to the secretariat of the United Nations Framework Convention on Climate Change

UNFCCC: United Nations Framework Convention on Climate Change (UNFCCC) established an international environmental treaty to combat "dangerous human interference with the climate system".

Zero Hunger: SDGs second is Zero Hunger – pledges to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture, and is the priority of the World Food Programme.

Check Your Progress

1. What is the agenda for 2030?

Answer: “Transforming our world: the 2030 Agenda for Sustainable Development.

2. Write another name of WCED?

Answer: Brundtland Commission Report is another name of World Commission on Environment and Development

3. Give the importance of the Paris Agreement?

Answer: The Paris Agreement is a landmark international accord that was adopted by nearly every nation in 2015 to address climate change and its negative impacts.

4. What is meant by Nationally Determined Contributions?

Answer: It is a non-binding national plan highlighting climate actions, including climate-related targets for greenhouse gas emission reductions, policies and measures governments aim to implement in response to climate change

5. How many Sustainable Development Goals are there?

Answer: At present, there are 17 SDGs is there.

Suggested Readings

1. https://www.unep.org/about-un-environment/evaluation-office/our-evaluation-approach/sustainable-development-goals
2. https://sdgs.un.org/goals
3. https://www.un.org/sustainabledevelopment/sustainable-development-goals/
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SA	**Environmental science foundation final 7 new.pdf** Document Environmental science foundation final 7 new.pdf (D20505635)	5
W	URL: https://aits-tpt.edu.in/wp-content/uploads/2018/08/Environmental-Studies-Lecture-notes.doc-I_Betech_-ECE-CSE-EEE-CEME_III-Sem_BR.pdf Fetched: 2021-12-27T10:12:00.0000000	2
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W	URL: https://globalchange.umich.edu/globalchange1/current/lectures/kling/ecosystem/ecosystem.html Fetched: 2019-09-24T22:58:33.7130000	4
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About Tamil Nadu Open University

Tamil Nadu Open University (TNOU), with its Headquarters at Chennai was established in 2000 by an Act of Tamil Nadu Legislature at the State level for the introduction and promotion of Open University and Distance Education in the educational and for the co-ordination and determination of standards in such system. The salient features of TNOU are , relaxed entry rules, maintenance of standards, individualized study, flexible in term of place, duration of the study, use of latest information and communication technology, well-knit student support services network, cost effective programmes, collaboration and resource sharing with other Universities.

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For details contact:

Ph :044-24306641

E-Mail :geotnou@gmail.com/sostnou@gmail.com

Tamil Nadu Open University

Chennai - 600 015

www.tnou.ac.in