MODULE 3

UNIT 1 PRIMARY PRODUCTIVITY OF PLANTS

CONTENTS

1.0 INTRODUCTION

Increasingly, it is hoped that renewable energy resources will supply the power requirements of future generations. These resources depend ultimately on the power supplied by the sun.

Plants could become a highly convenient source of power, often termed biomass energy, and could yield it in many forms. In the future, crops could be grown more for their fuel energy than for their food value.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- explain the processes of energy formation by plants; and
- explain primary productivity of a community.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Biomass: mass of organism in ecosystem
Ecosystem: organisms and their environment
Ecology: study of organisms and its environment
Autotrophs: organisms, especially green plants, that are capable of making nutrients from inorganic materials

5.0 MAIN CONTENT

5.1 Photosynthesis

The bodies of living organisms within a unit area make up a standing crop of biomass. More specifically, biomass can be defined as the mass of organisms per unit area and is usually expressed in units of energy (e.g., joules m-2) or dry organic matter (e.g., tons ha -1 or grams m -2). Most of the biomass in a community is composed of plants, which are the primary producers of biomass because of their ability to fix carbon through photosynthesis. Green plants or other photosynthesising organisms use light energy from the sun to manufacture carbohydrates for their own needs. Most of this chemical energy is processed in metabolism and dissipated as heat in respiration. Plants convert the remaining energy to biomass, both above ground as woody and herbaceous tissue and below ground as roots.

This chemical reaction can be described by the following simple formula:

- $6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$

The product of photosynthesis is a carbohydrate, such as the sugar glucose, and oxygen which is released into the atmosphere (Fig. 9). All of the sugar produced in the photosynthetic cells of plants and other organisms is derived from the initial chemical combining of carbon dioxide and water with sunlight. This chemical reaction is catalysed by chlorophyll acting together with other pigment, lipid, sugar, protein, and nucleic acid molecules. Sugars created in photosynthesis can be later converted by the plant to starch for storage, or it can be combined with other sugar molecules to form specialised carbohydrates, such as cellulose. Sugars can also be combined with other nutrients such as nitrogen, phosphorus, and sulfur, to build complex molecules such as proteins and nucleic acids.

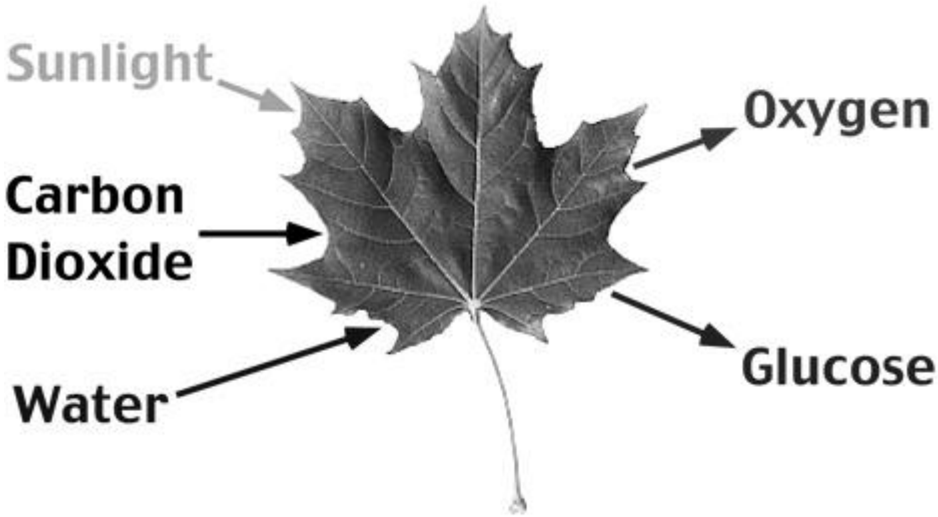

Fig. 9: Inputs and Outputs of the Photosynthetic Process

5.2 Primary Productivity of a Community

The primary productivity of a community is the amount of biomass produced through photosynthesis per unit area and time by plants, the primary producers. Primary productivity is usually expressed in units of energy (e.g., joules m -2 day -1) or in units of dry organic matter (e.g., kg m -2 year -1). Globally, primary production amounts to 243 billion metric tons of dry plant biomass per year. The total energy fixed by plants in a community through photosynthesis is referred to as gross primary productivity (GPP). Because all the energy fixed by the plant is converted into sugar, it is theoretically possible to determine a plant's energy uptake by measuring the amount of sugar produced. A proportion of the energy of gross primary productivity is used by plants in a process called respiration. Respiration provides a plant with the energy needed for various plant physiological and morphological activities. The general equation for respiration is:

- $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + released energy

Subtracting respiration from gross primary production gives us net primary productivity (NPP), which represents the rate of production of biomass that is available for consumption by heterotrophic organisms (bacteria, fungi, and animals).

Globally, patterns of primary productivity vary both spatially and temporally. The least productive ecosystems are those limited by heat energy and water like the deserts and the polar tundra. The most productive ecosystems are systems with high temperatures, plenty of water and lots of available soil nitrogen. Table 2 describes the approximate average net primary productivity for a variety of ecosystem types.

Table 2: *Average Annual Net Primary Productivity of the Earth's Major Biomes*

Ecosystem Type	**Net Primary Productivity (kilocalories/meter $^{-2}$/year)**
Tropical Rain Forest	9000
Estuary	9000
Swamps and Marshes	9000
Savanna	3000
Deciduous Temperate Forest	6000
Boreal Forest	3500
Temperate Grassland	2000
Polar Tundra	600
Desert	< 200

5.3 Biological Productivity

This is the amount and rate of production which occur in a given ecosystem over a given time period. It may apply to a single organism, a population, or entire communities and ecosystems. Productivity can be expressed in terms of dry matter produced per area per time (net production), or in terms of energy produced per area per time (gross production = respiration + heat losses + net production). In aquatic systems, productivity is often measured in volume instead of area. See also biomes.

Ecologists distinguish between primary productivity (by autotrophs) and secondary productivity (by heterotrophs). Plants have the ability to use the energy from sunlight to convert carbon dioxide and water into glucose and oxygen, producing biomass through photosynthesis. Primary productivity of a community is the rate at which biomass is produced per unit area by plants, expressed in either units of energy [joules/(m2)(day)] or dry organic matter [kg/(m2)(year)]. The following definitions are useful in calculating production: Gross primary production (GPP) is the total energy fixed by photosynthesis per unit time. Net primary production (NPP) is the gross production minus losses due to plant respiration per unit time, and it represents the actual new biomass that is available for consumption by heterotrophic organisms. Secondary production is the rate of production of biomass by heterotrophs (animals, microorganisms), which feed on plant products or other heterotrophs. See also photosynthesis.

Productivity is not spread evenly across the planet. For instance, although oceans cover two-thirds of earth's surface, they account for only one-third of the earth's productivity. Furthermore, the factors that limit productivity in the ocean differ from those limiting productivity on land; producing differences in geographic patterns of productivity in the two systems. In terrestrial ecosystems, productivity shows a latitudinal trend, with highest productivity in the tropics and decreasing progressively toward the Poles; but in the ocean there is no latitudinal trend, and the highest values of net primary production are found along coastal regions.

6.0 ACTIVITY

i. Explain the process of energy formation in plant.
ii. Explain the following terms as they relate to energy production in plant;
   a. primary productivity of a community
   b. gross primary productivity
   c. net primary productivity.

7.0 SUMMARY

In this unit, we have learnt that:

- green plants or other photosynthesising organisms use light energy from the sun to manufacture carbohydrates for their own need
- sugars created in photosynthesis is converted to carbohydrate by plants
- the amount of biomass produced through photosynthesis per unit area and time by plants is termed primary productivity
- plants respire for their various physiological and morphological activities
- patterns of primary productivity vary both spatially and temporally across the globe.

8.0 ASSIGNMENT

1. What do you understand by the primary productivity of a community?

9.0 REFERENCES

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UNIT 2 EARTH'S TERRESTRIAL BIOMES

CONTENTS

1.0 INTRODUCTION

Many places on earth share similar climatic conditions despite being found in geographically different areas. As a result of nature selection, comparable ecosystems have developed in these separated areas. Scientists call these major ecosystem types biomes. The geographical distribution (and productivity) of the various biomes is controlled primarily by the climatic variables: precipitation and temperature.

Fig. 10: Distribution of the Earth's Eight Major Terrestrial Biomes

Tropical Rainforest	Grassland
Tropical Savanna	Temperate Deciduous Forest
Desert	Temperate Boreal Forest
Chaparral	Arctic and Alpine Tundra

Most of the classified biomes are identified by the dominant plants found in their communities. For example, grassland are dominated by a variety of annual ad perennial species of grass, while deserts are occupied by plant species that require very little water for survival or by plants that have specific adaptations to conserve or acquire water.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- draw the map of the world and locate the various biomes or climate classification;
- explain in details, the plant and animal characteristics of each biome; and
- state the soil characteristics of each biome.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Biomes: major ecological community: a division of the world's vegetation that corresponds to a defined climate and is characterized by specific types of plants and animals, e.g. tropical rain forest or desert.

Diversity: social inclusiveness: ethnic variety, as well as socioeconomic and gender variety, in a group, society, or institution.

Waterlogged: soaked with water: having absorbed so much water as to become spongy or marshy.

Boreal: describes a region that has a northern temperate climate, with cold winters and warm summers.

Deciduous: shedding leaves in fall: describes trees and bushes that shed their leaves in the fall.

5.0 MAIN CONTENT

5.1 Biomes of the World

The diversity of animal life and subdominant plants forms, characteristic of each biome are generally controlled by abiotic environmental conditions and the productivity of the dominant vegetation. In general, species diversity becomes higher with increases in net primary productivity, moisture availability, and temperature. Earth's eight major terrestrial biomes are:

1. Arctic and Alpine Tundra

Tundra means marshy plain. The geographical distribution of the tundra biome is largely pole ward of 60^0 North latitude. The tundra biome is characterised by an absence of trees, the presence of dwarf plants, and a ground surface that is wet, spongy, and hummocky. Soils of this biome are usually permanently frozen starting at a depth of a few centimeters to a meter or more. The permafrost line is a physical barrier to plant root growth. Within this biome, temperature, precipitation, and evaporation all tend to be at a minimum. Precipitation in the wettest month is normally not higher than 25 millimeters. However, despite the low levels of precipitation the ground surface of the tundra biome is often waterlogged because of low rates of evapotranspiration.

Plants communities are usually composed of a few species of dwarf shrubs, a few grass species, sedges, and mosses. The principal herbivores in this biome include caribou, musk ox, arctic hare, voles, and lemmings. Most of the bird species of the tundra have the ability to migrate and live in warmer locations during the cold winter months. The herbivore species support a small number of carnivore species like the arctic fox, snow owl, polar bear, and wolves. Reptiles and amphibians are few or completely absent because of the extremely cold temperatures. Alpine tundra is quite similar to some arctic tundra but differs in the absence of permafrost and in the presence of better drainage.

2. Boreal Coniferous Forest

The climate of this biome is cool to cold with more precipitation than the tundra, occurring mainly in the summer because of mid-latitude cyclones. The predominant vegetation of boreal biome are needle-leaf evergreen variety tree species. Some common species include: white spruce, red pine, and white pine. The undergrowth is relatively limited as a result of the low light penetration even during the spring and following months. Undergrowth plants in the deciduous biome take advantage of the leafless condition of trees during these seasons concentrating their growth during this time period. Common undergrowth species include orchids, shrubs like rose, blueberry, and cranberry. Mammals common to the boreal forest include moose, bear, deer, wolverine, marten, lynx, wolf, snowshoe hare etc. boreal forest soils are characterised by a deep litter layer and slow decomposition.

Soils of this biome are also acidic and mineral deficient because of the large movement of water vertically and subsequent leaching.

3. Temperate Deciduous Forest

As its name indicates, this biome is characterised by a moderate climate and deciduous trees. It once occupied much of the eastern half of the United States, central Europe, Korea, and China. This biome has been very extensively affected by human activity, and much of it has been converted into agricultural fields or urban developments. Dominant plants include trees like maple, beech, oak, hickory, basswood, cottonwood, elm, and willow. The undergrowth of shrubs and herbs in a mature deciduous forest is typically well developed and richly diversified. Many different types of herbivores and carnivores, and some reptiles and amphibians exist here. Brown forest soils characterise temperate deciduous forest ecosystems. The surface litter layer in these soils is thin due to rapid decomposition.

4. Grassland

In central North America are the grasslands, the tall grass grassland is found toward the east and the short grass grassland is found westward. In Europe and Asia, some grasslands are called Steppes. In South America, grasslands are known as Pampas. In the western end of the grassland, where precipitation is less, Buffalo Grass and other grasses only a few inches above the soil surface are common in this habitat. Flowering herbs, including many kinds of composites and legumes, are common but much less important than grass species. Trees are limited to low-lying areas and the narrow zone immediately adjacent to streams. In the tall grass grassland, organic rich and black chernozemic soils are common. Chernozems are among the richest in nutrients and consequently the most fertile in the world. In drier parts of grasslands, soils can be influenced by salinisation. As a result of their fertility, most grasslands ecosystems have been modified by humans to grow grain and other dryland crops. Grassland mammals include; grassland dogs, jack rabbits, ground squirrels, badger, coyote, ferret, wolf, and cougar. The population of many of these species has been drastically reduced because of habitat destruction. Some of these species are on the edge of extinction.

5. Desert

In its most typical form, the desert consists of shrub-covered land where the plants are spatially quite dispersed. Climatically, deserts are influenced by descending air currents which limit the formation of precipitation. Many desert areas have less than 250 millimeters of precipitation annually. Dominant plants include drought-resistant shrubs like the creosote bush and sagebrush, water-storing succulents like cactus, and many species are short-lived annuals that complete their life cycles during infrequent and short rainy periods. Deserts habitants can be devoid of vegetation if precipitation is in very short supply. Most desert mammals tend to be nocturnal to avoid the high temperatures. Desert habitants have a rich lizard and snake fauna because high temperatures promote the success of cold-blooded life forms. Because productivity is low, the litter layer is comparably limited and organic content of surface soil layers is very low. Also, evaporation tends to concentrate salts at the soil surface.

6. Chaparral

Chaparral has a very specific spatial distribution. It is found in a narrow zone between 32^0 and 40^0 latitude North and South on the west coasts of the continents. This area has a dry climate because of the dominance of the subtropical high pressure zone during the fall, summer and spring months. Precipitation falls mainly in the winter months because of the seasonal movement of the polar front and its associated mid-latitude cyclone storms. Annual averages range from about 300 to 750 millimeters and most of this rain falls in a period between 2 to 4 months long. As a result of the climate, the vegetation that inhabits this biome exhibits a number of adaptations to withstand draught and fire. Trees and shrubs tend to be small with hard evergreen leaves. Plants do not drop their leaves during the dry seasons because of the expense of replacement. The dry climate slows the rate of leaf decomposition in the soil and as a result, the plants growing in this biome do not have nutrients available for uptake to produce new leaves when the wet season begins. Instead, the plants of the chaparral develop leaves that can withstand arid conditions. Plant species include cork oak, olive, eucalyptus, arbutus, acacia, shrub and oak. Many of the plant species have thorns to protect then from herbivore damage. This biome is sometimes also called Mediterranean Scrubland or sclerophyll forest.

7. Tropical Savanna

Tropical savannas are grasslands with scattered drought-resistant trees that generally do not exceed 10 meters in height. Tree and shrub species in the savanna usually shed their leaves during the dry season and this reduces water loss from the plants. New leaves appear several weeks before the start of the rain season. Climatically, these biomes are characterised by distinct wet and dry seasons. Temperatures are hot all year long. The savanna biome constitutes extensive areas in eastern Africa, South America, and Australia. Savannas also support the richest diversity of grazing mammals in the world. The grazing animals provide food for a great variety of predators. The soils are more nutrient-rich than tropical forest soil. Some soils become extremely dry because of evaporation and form laterite layers.

8. Tropical Rainforest

Tropical rainforest occur in abroad zone outside the equator. Annual rainfall, which exceeds 2000 to 2250 millimeters, is generally evenly distributed throughout the year. Temperature and humidity are relatively high through the year. Flora is highly diverse: a square kilometer may contain as many as 100 different tree species as compared to 3 or 4 in the temperate zone. The various trees of the tropical rain forests are closely spaced together and form a thick continuous canopy some 25 to 35 meters tall. This canopy is interrupted by the presence of very tall trees that have wide buttressed bases for support. Epiphytic orchids and bromeliads, as well as vines, are very characteristic of the tropical rainforest biome. Some other common plants include ferns and palms.

Most plants are evergreen with large, dark green, leathery leaves. The tropical rainforest is also home to a great variety of animals. Some scientists believe that 30 to 50 per cent of all of the earth's animal species may be found in this biome. Decomposition is rapid in the tropical rainforest because of high temperatures and an abundance of moisture. Because of the frequent and heavy rains, tropical soils are subject to extreme chemical weathering and leaching. These environmental conditions also make tropical soils acidic and nutrient-poor.

6.0 ACTIVITY

1. Distinguish between Tundra biome and Boreal Coniferous forest.
2. Tropical savanna biome and grassland biome are dissimilar. Discuss.
3. Draw the world map and locate various biomes

7.0 SUMMARY

In this unit, we have learnt that:

- biome is a division of the world's vegetation that corresponds to a defined climate and is characterised by specific types of plants and animals
- tundra biome is characterised by an absence of trees, except dwarf plants, and a ground surface that is wet, with soils that are usually permanently frozen
- boreal coniferous forest is cold with precipitation occurring mainly in the summer and needle-leaf evergreen tree

- temperate deciduous forest biome is characterised by a moderate climate and deciduous trees
- in central North America are the grasslands, with characteristics organic-rich and black chernozemic soils
- desert consists of shrub-covered land with spatially dispersed plants like the creosote bush, sagebrush and cactus
- chaparral has a very specific spatial distribution with vegetation to withstand drought and fire
- tropical savannas are grasslands with scattered drought-resistant trees that usually shed their leaves during the dry season to reduce water loss from the plants
- tropical rainforests occur in a broad zone outside the equator with annual rainfall, which exceeds 2000 to 2250 millimeters, is generally evenly distributed throughout the year and temperature and humidity are relatively high through the year.

8.0 ASSIGNMENT

i. Explain in details plants and animals character of Biomes.
ii. Chaparral has a very specific spatial distribution, explain this in relation to its general climatic characteristics.
iii. Climatically, deserts are influenced by descending air currents which limit the formation of precipitation, explain this with respect to desert climate.
iv. state the soil characteristic of each biome

9.0 REFERENCES

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UNIT 3 PLANT SUCCESSION

CONTENTS

1.0 INTRODUCTION

Succession is a directional non-seasonal cumulative change in the types of plant species that occupy a given area through time. It involves the processes of colonisation, establishment, and extinction which act on the participating plant species. It begins with the colonisation of a disturbed area (Some common mechanisms of disturbance are fires, wind storms, volcanic eruptions, logging, climate change, severe flooding, disease, and pest infestation such as an abandoned crop field or a newly exposed lava flow), by species able to reach and to tolerate the environmental conditions present. Mostly these are opportunistic species that hold on to the site for a variable length of time. Being short-lived and poor competitors, they are eventually replaced by more competitive, longer-lived species such as shrubs, and then trees.

In aquatic habitats, successional changes of this kind result largely from changes in the physical environment, such as the buildup of silt at the bottom of a pond. As the pond becomes shallower, it encourages the invasion of floating plants such as pond lilies and emergent plants such as cattails. The pace at which succession proceeds depends on the competitive abilities of the species involved; tolerance to the environmental conditions brought about by changes in vegetation; the interaction with animals, particularly the grazing herbivores; and fire. Eventually, the ecosystem arrives at a point called the climax, where further changes take place very slowly, and the site is dominated by long-lived, highly competitive species. As succession proceeds, however, the community becomes more stratified, enabling more species of animals to occupy the area. In time, animals, characteristic of later stages of succession replace those found in earlier stages. Succession stops when species composition changes no longer occur with time, and this community is said to be a climax community.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define the terms; succession and climax community;
- explain the concept of climax community; and
- explain the types of succession.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Succession: the series of changes that create a full-fledged plant and animal community, e.g. from the colonization of bare rock to the establishment of a forest.

Allogenic: describes tissues that are genetically different and therefore incompatible when transplanted.

Retrogressive: to show or develop the less complex features of simpler organisms.

5.0 MAIN CONTENT

5.1 Climax Community

The concept of a climax community assumes that the plants colonising and establishing themselves in a given region can achieve stable equilibrium. The pace at which succession proceeds depends on the competitive abilities of the species involved; tolerance to the environmental conditions brought about by changes in vegetation; the interaction with animals, particularly the grazing herbivores and fire. Eventually, the ecosystem arrives at a point called the climax, where further changes take place very slowly, and the site is dominated by long-lived, highly competitive species.

The idea that succession ends in the development of a climax community has had a long history in the fields of biogeography and ecology. One of the earliest proponents of this idea was Frederic Clements who studied succession at the beginning of the 20th century. However, beginning in the 1920s, scientists began refuting the notion of a climax state. By 1950, many scientists began viewing succession as a phenomenon that rarely attains equilibrium. The reason equilibrium is not reached is related to the nature of disturbance. Disturbance acts on communities at a variety of spatial and temporal scales. Further, the effect of disturbance is not always 100 per cent. Many disturbances remove only a part of the previous plant community. As a result of these new ideas, plant communities are now generally seen as being composed of numerous patches of various sizes at different stages of successional development.

5.2 Types of Succession

- **Primary succession -** is the establishment of plants on land that has not been previously vegetated.
- **Secondary succession -** is the invasion of a habitat by plants on land that was previously vegetated. Removal of past vegetation may be caused by natural or human disturbances such as fire, logging, cultivation, or hurricanes.
- **Allogenic succession -** is caused by a change in environmental conditions which in turn influences the composition of the plant community.
- **Autogenic succession -** is a succession where both the plant community and environment change, and this change is caused by the activities of the plants over time.
- **Progressive succession -** is a succession where the community becomes complex and contains more species and biomass over time.
- **Retrogressive succession -** is a succession where the community becomes simplistic and contains fewer species and less biomass over time. Some retrogressive successions are allogenic in nature. For example, the introduction of grazing animals results in degenerated rangeland.

Table 3: Comparison of Plant, Community, and Ecosystem Characteristics between Early and Late Stages of Succession

Attribute	**Early Stages of Succession**	**Late Stages of Succession**
Plant Biomass	Small	Large
Plant Longevity	Short	Long
Seed Dispersal Characteristics of Dominant Plants	Well dispersed	Poorly dispersed
Plant Morphology and Physiology	Simple	Complex
Photosynthetic Efficiency of Dominant Plants at Low Light	Low	High

Rate of Soil Nutrient Resource Consumption by Plants	Fast	Slow
Plant Recovery Rate from Resource Limitation	Fast	Slow
Plant Leaf Canopy Structure	Multilayered	Monolayer
Site of Nutrient Storage	Litter and Soil	Living Biomass and Litter
Role of Decomposers in Cycling Nutrients to Plants	Minor	Great
Biogeochemical Cycling	Open and Rapid	Closed and Slow
Rate of Net Primary Productivity	High	Low
Community Site Characteristics	Extreme	Moderate (Mesic)
Importance of Macro environment on Plant Success	Great	Moderate
Ecosystem Stability	Low	High
Plant Species Diversity	Low	High
Life-History Type	R	K
Seed Longevity	Long	Short

6.0 ACTIVITY

i. Define the term succession and explain the types that we have.
ii. Explain the concept of climax community

7.0 SUMMARY

In this unit, we have learnt that:

- succession is a directional non-seasonal cumulative change in the types of plant species that occupy a given area through time
- succession begins with the colonisation of a disturbed area
- succession ends in the development of a climax community
- disturbances that preceded succession act on communities at a variety of spatial and temporal scales.

8.0 ASSIGNMENT

1. Explain the idea that succession ends in the development of a climax community.

9.0 REFERENCES

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UNIT 4 OCEAN CURRENTS AND THEIR EFFECTS UPON WORLD CLIMATE

CONTENTS

1.0 INTRODUCTION

An ocean current can be defined as a horizontal movement of seawater at the ocean's surface. Ocean currents are driven by the circulation of wind above surface waters. Frictional stress at the interface between the ocean and the wind causes the water to move in the direction of the wind. Large ocean currents are a response of the atmosphere and ocean to the flow of energy from the tropics to Polar Regions. In some cases, currents are transient features and affect only a small area. Other ocean currents are essentially permanent and extend over large horizontal distances. It is sufficient here to consider the water movements as they exist, and to assess their total effects upon the world climates.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- give an accurate definition of an ocean current;
- state the causes and types of ocean currents;
- explain the climatic influence of ocean currents; and
- explain what is meant by ocean upwelling.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Winter: the coldest season of the year, which runs in the northern hemisphere from around November or December to February or March and in the southern hemisphere from June to August.

Summers: the warmest season of the year, falling between spring and autumn. It runs from June to August in the northern hemisphere and from December to February in the southern hemisphere.

West Coast: region comprising the coastal areas of California, Oregon, and Washington on the Pacific coast of the United States.

Oxidize: to react with oxygen, or cause a chemical to react with oxygen, e.g. in forming an oxide.

Upwelling: a process in which cold nutrient-rich water rises to the surface from the ocean depths.

5.0 MAIN CONTENT

5.1 Causes of Ocean Currents

The primary causes of ocean circulation are as follows:

- Owing to the frictional effects of the winds upon the ocean surface, the thin layer of top water is driven slowly in the general direction of the air movement.
- Contrasting densities of sea-water, due to different temperatures and salinities, are responsible for slow movements or currents within a large water mass.

Types of Ocean Currents

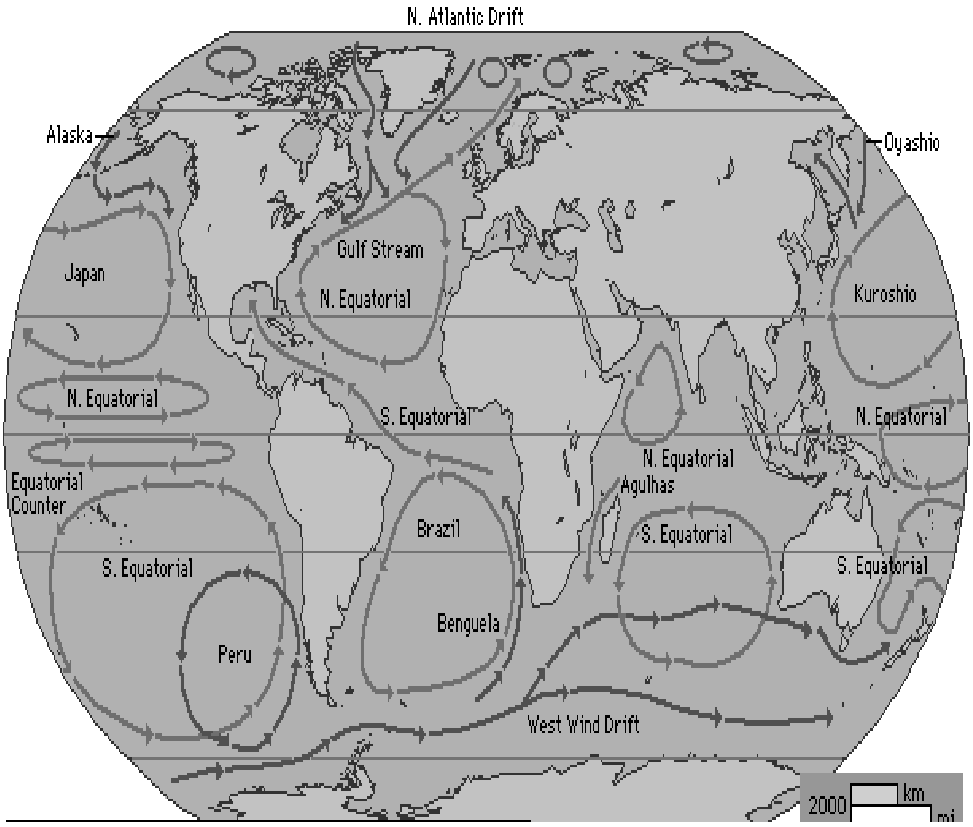
Poleward-flowing waters are inclined to be warm relative to the waters on either side, and equatorward-flowing waters are usually cooler than the sea on either side. Thus, ocean currents may be broadly classified into:

1. Warm-water currents (poleward-flowing water)
2. Cold-water currents (equator-flowing water)

The major surface currents in the world's oceans are caused by prevailing winds. The currents may be cold, as in the instance of the West Wind Drift, or warm, as the Gulf Stream. Currents circulate in paths called gyres, moving in a clockwise direction in the northern hemisphere and a counterclockwise direction in the southern hemisphere.

In figure 11 the warm and cold currents are indicated. It will be seen that, in the lower latitudes, warm ocean currents tend to flow parallel with the western sides. At 4^0S, for example, the water temperature along the S. American west coast may be only 15^0C, but at the same latitude along the New Guinea coast the surface temperature may be over 27^0C. Similarly, at about 40^0N, the surface water may be only about 10^0C along the west coast of North America, yet, at the same latitude on the east coast of Japan, the sea temperature may be 11^0C higher. In the mid and high latitudes the warm ocean currents tend to flow towards the western sides of the land masses, and the cool ones appear to affect the eastern sides.

A current of water either warms of cools the prevailing winds that pass over it and, if these winds blow on shore, indirectly affect the climate of the lands which are washed by it. A good example of this is to be found in North-west Europe, where westerly winds throughout the year carry the warmth from the North Atlantic Drift far into the continent. Similarly, along the coast of Peru, a cooling effect is produced by the cold Peru Current.



Red Arrows Warm Current
Blue Arrows Cold Currents

Fig. 11: *Warm and Cold Currents*

5.2 Climatic Influence of Ocean Current

The following summary indicates the main climatic influences of the ocean waters:

- West coasts in tropical latitudes are bordered by cool waters; thus they have low average temperatures, with small annual and diurnal ranges. The general conditions are arid and foggy.
- West coasts in mid- and high latitudes are affected by warm waters and have oceanic climates. The moderate rainfall is associated with the westerly winds. The winters are mild, and the summers are cool.
- East coasts in low latitudes are bordered by warm currents, which give warm, rainy climates as a result of the moist, on-shore trade winds.
- East coasts in mid-latitudes are bordered by warm waters, but have modified continental climates, with relatively cold winters and hot summers.
- East coast in high latitudes is bordered by cold-water currents. The shores are characterised by long, cold winters and cool summers.

5.3 Ocean Upwelling

The surface currents of the ocean are characterised by large gyres, or currents that are kept in motion by prevailing winds, but the direction of which is altered by the rotation of the earth. The best known of these currents is probably the Gulf Stream in the North Atlantic; the Kuroshio Current in the North Pacific is a similar current, and both serve to warm the climates of the eastern edges of the two oceans. In regions where the prevailing winds blow offshore, such as the west coast of Mexico and the coast of Peru and Chile, surface waters move away from the continents and they are replaced by colder, deeper water, a process known as upwelling, from as much as 300 meters down. This deep water is rich in nutrients, and these regions have high biological productivity and provide excellent fishing. Deep water is rich in nutrients because decomposition of organic matter exceeds production in deeper water; plant growth occurs only where photosynthetic organisms have access to light (see Photosynthesis). When organisms die, their remains sink and are oxidised and consumed in the deeper water; thus returning the valuable nutrients to the cycle. The regions of high productivity are generally regions of strong vertical mixing in the upper regions of the ocean. In addition to the western edges of the continents, the entire region around Antarctica is one of high productivity because the surface water there sinks after being chilled, causing deeper water to replace it. Scientists are also looking at ways to tap the energy embodied in the ocean's tides, waves, currents, and temperature differentials. Two sizeable tidal power installations are currently in place, including a facility in Nova Scotia's Annapolis Basin that has been in service since 1984. Owned by the Tidal Power Corporation, a public company, the project captures energy from the tremendous movement of water in the Bay of Fundy.

Some researchers believe the most promising of these ocean energy technologies is ocean thermal energy conversion (OTEC), a process that uses temperature differences in the ocean to create electricity. The process works by capturing the heat differential between the warm water on the ocean's surface and the colder water below to drive a generator. Proponents believe that these naturally-occurring temperature gradients have the potential to produce millions of megawatts of electricity, but the technology is still at an experimental stage.

6.0 ACTIVITY

i. What is ocean current and what are their causes?
ii. Give an account of the influence of ocean currents upon the climate of adjacent land masses.

7.0 SUMMARY

In this unit, we have learnt that:

- ocean current is the horizontal movement of seawater at the ocean's surface, and is driven by the circulation of wind above surface waters
- ocean current is caused by frictional effects of the winds upon the ocean surface and contrasting densities of sea-water, due to different temperatures and salinities
- ocean currents are of two types; warm-water and cold-water currents
- ocean current affects climate of adjacent areas where they are found
- when surface waters move away from the continents and they are replaced by colder, deeper water, this process is known as upwelling
- the regions of high productivity of nutrients in the ocean are generally regions of strong vertical mixing in the upper regions of the ocean.

8.0 ASSIGNMENT

i. Explain the climatic influence of ocean current.
ii. What is ocean upwelling?

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UNIT 5 ENVIRONMENT AND CLIMATE CHANGE

CONTENTS

1.0 INTRODUCTION

Organisms and their environment constantly interact, and both are changed by this interaction. Like all other living creatures, humans have clearly changed their environment, but they have done so generally on a grander scale than all other species. Some of these human-induced changes—such as the destruction of the world's tropical rain forests to create farms or grazing land for cattle—have led to altered climate patterns (see Global Warming). In turn, altered climate patterns have changed the way animals and plants are distributed in different ecosystems.

Scientists study the long-term consequences of human actions on the environment, while environmentalists—professionals in various fields, as well as concerned citizens—advocate ways to lessen the impact of human activity on the natural world.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- explain the term "carrying population capacity" of an environment;
- give an account of factors affecting the environment; and
- account for the global steps being taken to protect the environment.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Population: all of the people of a particular nationality, ethnic group, religion, or class who live in an area.
Growth: the process of becoming larger and more mature through natural development:
Depletion: to use up or reduce something such as supplies, resources, or energy.
Acid rain: rain that contains dilute acid derived from burning fossil fuels and that is potentially harmful to the environment.

5.0 MAIN CONTENT

5.1 Understanding the Environment

The science of ecology attempts to explain why plants and animals live where they do and why their populations are the sizes they are. Understanding the distribution and population size of organisms helps scientists evaluate the health of the environment.

In 1840, German chemist Justus von Liebig first proposed that populations cannot grow indefinitely, a basic principle now known as the Law of the Minimum. Biotic and abiotic factors, singly or in combination, ultimately limit the size that any population may attain. This size limit, known as a population's carrying capacity, occurs when needed resources, such as food, breeding sites, and water, are in short supply. For example, the amount of nutrients in soil influences the amount of wheat that grows on a farm. Population size and distribution may also be affected, either directly or indirectly, by the way species in an ecosystem interact with one another. Typically, the species that coexist in ecosystems have evolved together for many generations. These populations have established balanced interactions with each other that enable all populations in the area to remain relatively stable. Occasionally, however, natural or human-made disruptions occur that have unforeseen consequences on populations in an ecosystem.

5.2 Factors Threatening the Environment

The problems facing the environment are vast and diverse. Global warming, the depletion of the ozone layer in the atmosphere, and destruction of the world's rain forests are just some of the problems that many scientists believe will reach critical proportions in the coming decades. All of these problems will be directly affected by the size of the human population. Some of the factors threatening the environment include:

1. Population Growth

Human population growth is at the root of virtually all of the world's environmental problems. Although the growth rate of the world's population has slowed slightly since the 1990s, the world's population increases by about 77 million human beings each year. As the number of people increases, crowding generates pollution, destroys more habitats, and uses up additional natural resources. Although rates of population increase are now much slower in the developed world than in the developing world, it would be a mistake to assume that population growth is primarily a problem of developing countries. In fact, because larger amounts of resources per person are used in developed nations, each individual from the developed world has a much greater environmental impact than does a person from a developing country. Conservation strategies that would not significantly alter lifestyles but that would greatly lessen environmental impact are essential in the developed world.

2. Global Warming

Like the glass panes in a greenhouse, certain gases in the earth's atmosphere permit the sun's radiation to heat earth. At the same time, these gases retard the escape into space of the infrared energy radiated back out by earth. This process is referred to as the greenhouse effect. These gases, primarily carbon dioxide, methane, nitrous oxide, and water vapour, insulate earth's surface, helping to maintain warm temperatures. If the concentration of these gases rises, they trap more heat within the atmosphere, causing worldwide temperatures to rise. Within the last century, the amount of carbon dioxide in the atmosphere has increased dramatically, largely because people burn vast amounts of fossil fuels—coal and petroleum and its derivatives. Average global temperature also has increased—by about 0.6^0 C (1 Fahrenheit degree) within the past century.

Atmospheric scientists have found that at least half of that temperature increase can be attributed to human activities. The consequences of such a modest increase in temperature may be devastating. Already, scientists have detected a 40 per cent reduction in the average thickness of Arctic ice. Other problems that may develop include a rise in sea levels that will completely inundate a number of low-lying island nations and flood many coastal cities, such as New York and Miami. Many plant and animal species will probably be driven into extinction; agriculture will be severely disrupted in many regions, and the frequency of severe hurricanes and droughts will likely increase.

3. Depletion of the Ozone Layer

As we discussed in module one unit three, the ozone layer as a thin band in the stratosphere (layer of the upper atmosphere), serves to shield earth from the sun's harmful ultraviolet rays. In the 1970s, scientists discovered that chlorofluorocarbons (CFCs)—chemicals used in refrigeration, air-conditioning systems, cleaning solvents, and aerosol sprays—destroy the ozone layer. CFCs release chlorine into the atmosphere; chlorine, in turn, breaks down ozone molecules. Because chlorine is not affected by its interaction with ozone, each chlorine molecule has the ability to destroy a large amount of ozone for an extended period of time. The consequences of continued depletion of the ozone layer would be dramatic. Increased ultraviolet radiation would lead to a growing number of skin cancers and cataracts and also reduce the ability of immune systems to respond to infection. Additionally, the growth of the world's oceanic plankton, the base of most marine food chains, would decline.

4. Habitat Destruction and Species Extinction

Plant and animal species are dying out at an unprecedented rate. It was estimated that between 4,000 to as many as 50,000 species per year become extinct. The leading cause of extinction is habitat destruction, particularly of the world's richest ecosystems—tropical rain forests and coral reefs. If the world's rain forests continue to be cut down at the current rate, they may completely disappear by the year 2030. In addition, if the world's population continues to grow at its present rate and puts even more pressure on these habitats, they might well be destroyed sooner.

5. Air Pollution

A significant portion of industry and transportation burns fossil fuels, such as gasoline. When these fuels burn, chemicals and particulate matter are released into the atmosphere. Although a vast number of substances contribute to air pollution, the most common air pollutants contain carbon, sulfur, and nitrogen. These chemicals interact with one another and with ultraviolet radiation in sunlight in dangerous ways. Smog, is usually found in urban areas with large numbers of automobiles, forms when nitrogen oxides react with hydrocarbons in the air to produce aldehydes and ketones. Smog can cause serious health problems.

Acid rain forms when sulfur dioxide and nitrous oxide transform into sulfuric acid and nitric acid in the atmosphere and come back to earth in precipitation .Acid rain has made numerous lakes so acidic that they no longer support fish populations. Acid rain is also responsible for the decline of many forest ecosystems worldwide, including Germany's Black Forest.

6. Water Pollution

Estimates suggest that nearly 1.5 billion people worldwide lack safe drinking water and that at least 5 million deaths per year can be attributed to waterborne diseases. Water pollution may come from point sources or nonpoint sources. Point sources occur when discharge pollutants are from specific locations, such as factories, sewage treatment plants, and oil tankers. Pollution from nonpoint sources occurs when rainfall or snowmelt moves over and through the ground. As the run-off moves, it picks up and carries away pollutants, such as pesticides and fertilisers, depositing the pollutants into lakes, rivers, wetlands, coastal waters, and even underground sources of drinking water. Pollution arising from nonpoint sources accounts for a majority of the contaminants in streams and lakes. However, raw sewage, garbage, and oil spills have begun to overwhelm the diluting capabilities of the oceans, and most coastal waters are now polluted; threatening marine wildlife.

7. Groundwater Depletion and Contamination

Water that collects beneath the ground is called groundwater. Worldwide, groundwater is 40 times more abundant than fresh water in streams and lakes. Although groundwater is a renewable resource, reserves replenish relatively slowly. Agricultural practices depending on this source of water need to change within a generation in order to save this groundwater source. In addition to groundwater depletion, scientists worry about groundwater contamination, which arises from leaking underground storage tanks, poorly designed industrial waste ponds, and seepage from the deep-well injection of hazardous wastes into underground geologic formations. In addition to groundwater depletion, scientists worry about groundwater contamination, which arises from leaking underground storage tanks, poorly designed industrial waste ponds, and seepage from the deep-well injection of hazardous wastes into underground geologic formations.

5.3 Global Efforts to Protect the Environment

Most scientists agree that if pollution and other environmental deterrents continue at their present rates, the result will be irreversible damage to the ecological cycles and balances in nature upon which all life depends. Scientists warn that fundamental, and perhaps drastic, changes in human behaviour will be required to avert an ecological crisis.

To safeguard the healthful environment that is essential to life, humans must learn that earth does not have infinite resources. Earth's limited resources must be conserved and, where possible, reused. Furthermore, humans must devise new strategies that mesh environmental progress with economic growth. The future growth of developing nations depends upon the development of sustainable conservation methods that protect the environment while also meeting the basic needs of citizens.

Many nations have acted to control or reduce environmental problems. For example, Great Britain has largely succeeded in cleaning up the waters of the Thames and other rivers, and London no longer suffers the heavy smogs caused by industrial pollutants. Japan has some of the world's strictest standards for the control of water and air pollution. In Canada, the Department of Commerce has developed comprehensive programmes covering environmental contaminants. In the United States, the Environmental Protection Agency (EPA) was established in 1970 to protect the nation's natural resources. In addition, the U.S. Congress has provided governmental agencies with legislation designed to protect the environment. Many U.S. states have also established environmental protection agencies. Citizen groups, such as the Sierra Club and the National Audubon Society, educate the public, support environment-friendly legislation, and help assure that federal and state laws are enforced by pointing out violations. Much still needs to be done in the area of environmental protection in Africa with proper legislation to curb indiscriminate dumping of refuse and industrial waste discharge.

6.0 ACTIVITY

i. What is "carrying population capacity" of an environment?
ii. What are the factors militating against the environment.
iii. Global warming and population growth are the major factors threatening the environment. Discuss.

7.0 SUMMARY

In this unit, we have learnt that:

- organisms interact with their environment
- there is a limit to which the size of any population may attain
- most of the factors threatening the environment are man-made
- in order to safeguard a healthful environment, humans must understand that earth does not have infinite resources
- many nations have acted to control or reduce environmental problems.

8.0 ASSIGNMENT

i. Altered climate patterns have changed the way animals and plants are distributed in different ecosystems. Discuss.
ii. State the global steps taken to protect the environment.

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