MODULE 2

UNIT 1 ENVIRONMENTAL POLLUTION AND BIODIVERSITY LOSS

CONTENTS

1.0 INTRODUCTION

Pollution continues to be an increasing problem for the conservation of biological diversity. River systems and near-shore environments are at particular risk. Localised impacts have occurred and their frequency is increasing. A number of river systems suffer from increasing salinity, silt loads, nutrient levels and heavy metal and chemical pollution. Pollution of groundwater has adverse effects on ecosystems in both urban and rural environments. The Environment Protection Agency is developing a National Pollutant Inventory and recommendations for standards and, once reflected in State and Territory control measures, this should help to minimise the impacts of pollution. The use of some agricultural, industrial and urban chemicals continues to cause problems for wildlife, including cumulative effects. Sewage discharge into the sea has a localised impact on biological diversity. In this unit, you will learn ways by which pollution affects biodiversity and measures for ambient air quality and ambient marine, estuarine and freshwater quality.

2.0 A: OBJECTIVES

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

- identify different types of pollution;
- explain the effects of industrial pollution of biodiversity; and
- state some controlling measures of pollution on biodiversity conservation.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or the internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

Environmental pollution is the unfavourable alteration of our surroundings, wholly or largely as a by-product of man’s actions, through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitution and abundances of organisms. These changes may affect man directly or through his supplies of water and of agricultural and other biological products, his physical objects or possessions or his opportunities for recreation and appreciation of nature.

Industrial activities generally have varying degrees of social, economic and environmental consequences. These consequences are both positive and negative, the latter being more rampant and widespread than the former. Industrial pollution and environmental degradation due to industrial activities have been a concern of the world in recent times. This is because of the levels of damage caused by the effluents generated by the industrial establishment to both natural and social environment.

Recently in Northern Europe, industrial pollutants in the form of acid rain has eroded structures, injured crops and forests and threatened the lives and habitats of the local wildlife. In 1984, it was reported that 50% of the trees in Germany's Black Forest had been destroyed by acid rain.

In China, rapid industrial growth has led to a dramatic rise in environmental damage from industrial pollution. Today, nearly 40% of China's mainland is affected by industrial pollution due to industrial emissions; a figure scientists expect will continue to rise. Industrial growth and its associated environmental problem such as soil, plant, and air contamination is fast increasing. Reports of general soil, plants, and water quality contaminations in several cities in Nigeria abound with effect.

3.1 Methods of Waste Management and Disposal

There are various methods of waste management and disposal being applied by industrial establishments. One of these methods is known as the End-of-Pipe Approach.

End-Of-Pipe (EOP) Approach

This does not encourage waste reduction, but rather seeks to introduce technology at the production line to prevent waste from becoming pollution. Some modes of EOP include: land filling, land application, containment and extraction technologies.

As the name implies, land filling involves filling the land with waste in thin layers. Pollution of surface and ground water is minimised by lining and contouring the fill, compacting and planning the cover, selecting the proper soil and placing waste in a site, not subject to flooding or high ground water levels. However, land filling still does have its problems, which include poor litter control, dust, birds, vermin and insects, also noise pollution from the heavy machinery in use.

Containment technologies are used to stop the further spread of migration of contaminants, while extraction technologies, which are also known as the removal of constituents from a site, either vapour or solids through pumping, product recovery, vapour extraction and soil washing. However, these forms of treatment are very expensive and not very reliable.

All these waste management strategies still pose serious threats to biodiversity conservation. For instance, draining or in-filling of wetlands changes hydrological regimes so that they no longer provide suitable habitats for wildlife. Untreated effluents from domestic, commercial and industrial sources have polluted coastal wetlands creating a toxicity risk for flora and fauna.

Waste Minimisation Approach

Another approach to dealing with wastes is Waste Minimisation of Pollution Prevention. In his appeal for the use of waste minimisation as against land-filling techniques, William Reilly (1990) said, "We have learned the inherent limitations of treating and burning wastes. A problem solved in one part of the environment may become a new problem in another part. We must curtail pollution closer to its point of origin so that it is not transformed from place to place".

Waste minimisation, though not a new concept, due to the fact that it has been practised in the United States, Europe and the developed world, has only begun to make rounds in the developing world. Studies have further brought to the fore sustainable waste management techniques; waste minimisation has become a key component of national waste management strategies across the world as a result of this. Obviously, if the production of waste is reduced, potential for long term environmental damage is reduced accordingly. Some methods of waste minimisation being practised include the following.

- Waste re-cycling/re-use: though not a form of waste minimisation per se, recycling is accepted as an effective form of waste reduction and is gaining ground in the developing world, such as in South America and India.
- Combustion as Fuel: combustion of waste as fuel is seen by many as a preferable alternative to landfill, where appropriate, and has received much support, but according to Wallis and Watson (1995), 2 – 5 times the amount of energy renewable by combustion of wastes is recovered by recycling.
- Composting: aerobic microbial process which depends on organic matter to produce a relatively stabilised residue, CO_2 as the main gaseous product.

Much of our native flora and fauna has evolved with fire and relies upon particular fire regimes for continued survival. With settlement, however, the timing, frequency and intensity of these fires have changed.

Although fire is a necessary part of many ecosystems, it can also be damaging. Inappropriate fire regimes - for example, fires of high or low intensity that are either too frequent or insufficiently frequent - can lead to loss of native species, communities and ecosystems. Burning can promote invasion of native vegetation by weeds, sometimes leading to increased fire hazard within a short time, and prescribed fires can escape to become wildfires.

3.2 Impacts of Industrial Pollution on Biodiversity

The issue of the impact of industrial establishments on their physical environment has been severally discussed in various academic quarters. As a result of this, scholars have deduced a number of theories and models in order to explain these impacts. Few of these theories that are related to the impacts of industrial pollution in the environment are discussed.

Industrial Pollution is not a new problem to man. It can be traced back to the industrial revolution of the early 19th Century. But even as far back as 14th Century England, the dangers of pollution were already being given centre stage treatment when King Edward II of England (1307 – 1327) tried to abate Britain's 'unbearable smoke' by prohibiting the burning of coal. This was perhaps one of the first government interventions as regards the issue of pollution.

Abduli (1996) defined Industrial pollutants as all wastes arising from industrial operation or desire from the manufacturing process. Now the wastes in themselves do not constitute pollutants, but the mismanagement of these wastes is what leads to industrial pollution. From the review of the literature, most scholars agree that industrial waste in the developing countries are left untreated and are disposed of in an unsafe manner e.g. illegal dumping, open-dumping into lakes and rivers causing biodiversity loss and extinction.

This scenario has been blamed on the rapid unplanned growth of the urban and industrial centres in the developing countries, which creates stress on the natural. Pollution and other forms of degradation, and the continuing spread of urbanisation vis-à-vis industrialisation poses a threat to the sustainability of soil resources, it is generally accepted that most of the soils in the technologically advanced regions of the world are polluted at least to a slight extent. The source of this pollution is the mismanagement of waste disposal services, old industrial sites are generally characterised by being heterogeneous, both with regard to the distribution of pollutants and also to properties of the soil materials that control the behaviour of chemicals (soil pollutants), another source is through the process of land filling, a type of industrial waste management system adopted by most industrial establishments.

Land- filling creates such problems as landfill gas and land fill leachate, and this leachate is what provides the most prominent source of pollution for the soil. The leachate is made up of soluble components of waste and the soluble intermediates and products of waste degradation, which enters the water table and soil as it percolates through the waste body. The amount of leachate generated is dependent on water availability, landfill surface conditions, the state of refuse and the conditions in the surrounding strata.

Chemical pollution from industrial establishments has been estimated by a recent Global Assessment of Soil Degradation (GLASOD) to affect a total of 218 x 10^6 ha of land in Europe, Asia, Africa and Central America. Some of the major sources of pollution i.e. chemical pollutants from industries are the heavy metals e.g. Copper (Cu), Manganese (Mn), Nitrogen (N), zinc (Zn), Silver (Ag), Barium (Ba), Mercury (Hg), Lead (Pb), etc., which are hazardous to plants and animal species.
Industries involved in the following activities:

1. Metalliferous Mining e.g. Cd, Cu, N, Pb and Zn
2. Metal Smelting and Metallurgical Industries
3. The electronic industry; making of circuits, solders, batteries in gaseous or solid waste form.

Pollutants here include aerosol particles from the thermal processing of metals and solid wastes, effluents from the treatment of metals with acids.

Other forms of pollutants include hydrocarbons from petroleum comprising a range of saturated alkanes from methane (CH_4), ethane (C_2H_6) and Propane (C_3H_8) etc. As such, leakages from Industrial sites are a major industrial issue as Hydrocarbon solvents are widely used in industry for clearing and de-greasing metals and electrical components. Toxic Organic Micro-pollutants also form a major part of industrial pollutants e.g. insecticides, herbicides, fungicides, etc which pose serious threat to biodiversity.

Between 60,000 to 90,000 chemicals are being used in industry although not all are hazardous, many will cause pollution as a result of leakage during storage, from use in the environment or disposal either directly or of wastes containing them. As at 1990, the total world production of hazardous and special wastes was 338 x 10^6 tonnes according to the Organization for Economic Cooperation and Development (OECD) on the state of the environment in Paris, 1991.

Pollution Control

In advanced countries, environmental monitoring agencies are more effective and environmental laws are strictly followed. General environmental quality monitoring is compulsory and the monitoring of the quality of natural and social environment is done on a regular basis. As a result, any abnormal changes in the environment can easily be detected and appropriate action taken before the outbreak of epidemics or biodiversity loss. The case is quite the opposite in many developing countries. Environmental laws where there are any, are rarely observed.

In Europe, various protocols have been adopted to stem the tide of industrial pollution. The first Sulphur Protocol in Europe produced by the United Nations Economic Commission for Europe (UNECE) in 1985 called for the reduction of sulphur emissions to 70% of 1980 levels by 1993. Other protocols adopted include the Nitrogen Oxides Protocol, the Volatile Organic Compounds Protocol (1991) and the 2nd Sulphur Protocol (1994).

Federal, State and Local Governments should develop new pollution prevention and control measures, including market measures and national standards to minimise the impacts of pollution on biological diversity. This will require:

a. reviewing legislation and guidelines to ensure that criteria for minimising significant adverse impacts on the conservation of biological diversity are included as part of the basis for pollution prevention and control measures. Particular attention should be paid to non-point-source pollution, industrial pollution, control of the discharge of sewage, waste minimisation and accident prevention, and the need for a catchments or bioregional approach in implementation,
b. strengthening measures to deal with activities or processes that result in detrimental changes to the physical environment of organisms, such as the potentially damaging discharge of dam water,
c. strengthening the systems of control for the manufacture, importation and use of chemicals where scientific evidence shows that these chemicals adversely affect biological diversity, with a view to minimising their impacts.

SELF ASSESSEMENT

What are the methods of waste management and disposal?

4.0 CONCLUSION

The overall assessment of all impacts of industrial establishments on biodiversity loss is unprecedented. Legislation and guidelines to ensure that criteria for minimising significant adverse impacts on the conservation of biological diversity should be put in place as part of the basis for pollution prevention and control measures.

5.0 SUMMARY

In this unit, you have learnt that:

- environmental pollution is the unfavourable alteration of our surroundings, wholly or largely as a by-product of man's actions, through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitution and abundances of organisms
- industrial activities generally have varying degrees of social, economic and environmental consequences, which could be both positive and negative,
- industrial pollution are in form of waste disposal, land filling, chemical pollution in form of heavy metals, hydrocarbons from petroleum etc,
- industrial pollutants in the form of acid rain has eroded structures, injured crops and forests and threatened the lives and habitats of the local wildlife,
- industrial growth and its associated environmental problem such as soil, plant, and air contamination is fast increasing and pose serious threat to biological diversity,
- various methods of waste management and disposal being applied by industrial establishments still affect flora and fauna,
- rapid unplanned growth of the urban and industrial centres in the developing countries, creates stress on the natural environment,
- in advanced countries, environmental monitoring agencies are more effective and environmental laws are strictly followed,
- the case is quite the opposite in many developing countries and where environmental laws are in place, they are rarely observed,
- Federal, State and Local Government should develop new pollution prevention and control measures, including market measures and national standards to minimise the impacts of pollution on biological diversity.

6.0 TUTOR-MARKED ASSIGNMENT

Discuss why biological diversities are still being threatened by environmental pollution in a named developing country in spite of different environmental laws and environmental protection agencies in place.

7.0 REFERENCES/FURTHER READING

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UNIT 2 CLIMATE CHANGE AND BIODIVERSITY

CONTENTS

1.0 INTRODUCTION

Weather is the day-to-day state of the atmosphere, and is a chaotic non-linear dynamical system. On the other hand, *climate* is the average state of weather which is fairly stable and predictable. Climate includes the average temperature, amount of precipitation, days of sunlight, and other variables that might be measured at any given site. However, there are also changes within the Earth's environment that can affect the climate. Climate changes reflect variations within the Earth's atmosphere, processes in other parts of the Earth such as oceans and ice caps, and the effects of human activity. The external factors that can shape climate are often called climate forcing and this includes such processes as variations in solar radiation, the Earth's orbit, and greenhouse gas concentrations. In this unit, the drivers of climate change are considered.

2.0 A: OBJECTIVES

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

- define climate change;
- differentiate between climate change and global warming and
- identify and explain the drivers of climate change.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully; through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

3.1 Definition of Climate Change

The term, Climate Change is used to refer to changes in the Earth's climate. Generally, this is taken to regard changes in temperature, by monitoring averages, extremes, durations, and geographic coverages. Climate change is the variation in the Earth's global climate or in regional climates over time. It involves changes in the variability or average state of the atmosphere over durations; ranging from decades to millions of years. These changes can be caused by dynamic process on Earth, external forces including variations in sunlight intensity, and more recently, by human activities. 'Climate change' is caused by natural forces including, but not limited to, human activities.

3.2 Difference between Climate Change and Global Warming

When scientists talk about the issue of climate change, their concern is about *global warming* caused by human activities. The terms, global warming and climate change are often used interchangeably, but the two phenomena are different. Global warming is the rise in global temperatures due to an increase of heat-trapping carbon emissions in the atmosphere. Climate change, on the other hand, is a more general term that refers to changes in many climatic factors (such as temperature and precipitation) around the world.

These changes are happening at different rates and in different ways. For example, the United States has become wetter over the 20th century, while the Sahel region of central Africa has become drier.

3.3 Factors Driving Climate change

The factors include change within the earth environment, non climatic factors and human influence on climatic change.

Changes within the Earth's Environment

There are changes within the Earth's environment that can affect the climate; among them are:

1. Glaciation

Glaciers are recognised as being among the most sensitive indicators of climate change, advancing substantially during climate cooling (e.g., the Little Ice Age) and retreating during climate warming on moderate time scales. Glaciers grow and collapse, both contributing to natural variability and greatly amplifying externally forced changes. For the last century, however, glaciers have been unable to regenerate enough ice during the winters to make up for the ice lost during the summer months.

The most significant climate processes of the last several million years are the glacial and *interglacial* cycles of the present ice age. Though shaped by *orbital variations,* the internal responses involving *continental* ice sheets and 130 m sea-level change certainly played a key role in deciding what climate response would be observed in most regions. Other changes, including Heinrich events, Dansgaard–Oeschger events and the Younger Dryas show the potential for glacial variations to influence climate even in the absence of specific orbital changes.

b. Ocean Variability

On the scale of decades, climate changes can also result from interaction of the atmosphere and oceans. Many climate fluctuations — including not only the El Niño Southern oscillation (the best known) but also the Pacific decadal oscillation, the North Atlantic oscillation, and the Arctic oscillation — owe their existence at least in part to different ways that heat can be stored in the oceans and move between different reservoirs. On longer time scales ocean processes such as thermohaline circulation play a key role in redistributing heat, and can dramatically affect climate.

2. The Memory of Climate

More generally, most forms of internal variability in the climate system can be recognised as a form of hysteresis, meaning that the current state of climate reflects not only the inputs, but also the history of how it got there. For example, a decade of dry conditions may cause lakes to shrink, plains to dry up and deserts to expand. In turn, these conditions may lead to less rainfall in the following years. In short, climate change can be a self-perpetuating process because different aspects of the environment respond at different rates and in different ways to the fluctuations that inevitably occur.

Non-Climate Factors Driving Climate Change

3. Greenhouse Gases

Current studies indicate that radioactive forcing by greenhouse gases is the primary cause of global warming. Greenhouse gases are also important in understanding Earth's climate history. According to these studies, the greenhouse effect, which is the warming produced as greenhouse gases trap heat, plays a key role in regulating Earth's temperature.

Over the last 600 million years, carbon dioxide concentrations have varied from perhaps great than 5000 ppm^3 to less than 200 ppm^3, due primarily to the effect of geological processes and biological innovations. It has been argued that variation in greenhouse gas concentrations over tens of millions of years have not been well correlated to climate change, with plate tectonics; perhaps playing a more dominant role. More recently, CO_2-climate has been correlation to derive a value for the climate sensitivity. There are several examples of rapid changes in the concentrations of greenhouse gases in the Earth's atmosphere that do appear to correlate to strong warming, including the Paleocene–Eocene thermal maximum, the Permian–Triassic extinction event, and the end of the Varangian snowball earth event.

During the modern era, the naturally rising carbon dioxide levels are implicated as the primary cause of global warming since 1950. According to the Intergovernmental Panel on Climate Change (IPCC), (2007), the atmospheric concentration of CO_2 in 2005 was 379 ppm^3 compared to the pre-industrial levels of 280 ppm^3. Thermodynamics and Le Chatelier's principle explain the characteristics of the dynamic equilibrium of a gas in solution such as the vast amount of CO_2 held in solution in the world's oceans moving into and returning from the atmosphere. These principles can be observed as bubbles which rise in a pot of water heated on a stove, or in a glass of cold beer allowed to sit at room temperature; gases dissolved in liquids are released under certain circumstances.

4. Plate Tectonics

On the longest time scales, plate tectonics will reposition continents, shape oceans, build and tear down mountains and generally serve to define the stage upon which climate exists. More recently, plate motions have been implicated in the intensification of the present ice age when, approximately 3 million years ago, the North and South American plates collided to form the Isthmus of Panama and shut off direct mixing between the Atlantic and Pacific Oceans.

f. Solar Variation

The sun is the ultimate source of essentially all heat in the climate system. The energy output of the sun, which is converted to heat at the Earth's surface, is an integral part of shaping the Earth's climate. On the longest time scales, the sun itself is getting brighter with higher energy output, as it continues its main sequence, this slow change or evolution affects the Earth's atmosphere. It is thought that, early in Earth's history, the sun was too cold to support liquid water at the Earth's surface, leading to what is known as the Faint young sun paradox.

On more modern time scales, there are also a variety of forms of solar variation, including the 11-year solar cycle and longer-term modulations. However, the 11-year sunspot cycle does not manifest itself clearly in the climatological data. Solar intensity variations are considered to have been influential in triggering the Little Ice Age, and for some of the warming observed from 1900 to 1950. The cyclical nature of the sun's energy output is not yet fully understood; it differs from the very slow change that is happening within the sun as it ages and evolves.

g. Orbital Variations

In their effect on climate, orbital variations are in some sense an extension of solar variability, because slight variations in the Earth's orbit lead to changes in the distribution and abundance of sunlight reaching the Earth's surface. Such orbital variations, known as Milankovitch cycles, are a highly predictable consequence of basic physics due to the mutual interactions of the Earth, its moon, and the other planets. These variations are considered the driving factors underlying the glacial and interglacial cycles of the present ice age. Subtler variations are also present, such as the repeated advance and retreat of the Sahara desert in response to orbital precession.

h. Volcanism

A single eruption of the kind that occurs several times per century can affect climate, causing cooling for a period of a few years. For example, the eruption of Mount Pinatubo in 1991 affected climate substantially. Huge eruptions, known as large igneous provinces, occur only a few times every hundred million years, but can reshape climate for millions of years and cause mass extinctions. Initially, scientists thought that the dust emitted into the atmosphere from large volcanic eruptions was responsible for the cooling by partially blocking the transmission of solar radiation to the Earth's surface. However, measurements indicate that most of the dust thrown in the atmosphere returns to the Earth's surface within six months.

Volcanoes are also part of the extended carbon cycle. Over very long (geological) time periods, they release carbon dioxide from the earth's interior, counteracting the uptake by sedimentary rocks and other geological carbon dioxide sinks. However, this contribution is insignificant compared to the current anthropogenic emissions. The US Geological Survey estimates that human activities generate more than 130 times the amount of carbon dioxide emitted by volcanoes.

Human Influences on Climate Change

Anthropogenic factors are human activities that change the environment and influence climate. In some cases the chain of causality is direct and unambiguous (e.g., by the effects of irrigation on temperature and humidity), while in others it is less clear. Various hypotheses for human-induced climate change have been debated for many years. In the late 1800s, the "rain follows the plow" idea had many adherents in the western United States.

The biggest factor of present concern is the increase in CO_2 levels due to emissions from fossil fuel combustion, followed by aerosols (particulate matter in the atmosphere), which exert a cooling effect, and cement manufacturing. Other factors, including land use, ozone depletion, animal agriculture and deforestation, also affect climate.

5. Fossil Fuels

Carbon dioxide variations over the last 400,000 years show a rise since the industrial revolution. Beginning with the industrial revolution in the 1850s and accelerating ever since, the human consumption of fossil fuels has elevated CO_2 levels from a concentration of ~280 ppm to more than 380 ppm today. These increases are projected to reach more than 560 ppm before the end of the 21st century. It is known that carbon dioxide levels are substantially higher now than at any time in the last 750,000 years. Along with rising methane levels, these changes are anticipated to cause an increase of 1.4–5.6 °C between 1990 and 2100. (see global warming).

j. Aerosols

Anthropogenic aerosols, particularly sulphate aerosols from fossil fuel combustion, exert a cooling influence. This, together with natural variability, is believed to account for the relative "plateau" in the graph of 20^{th}-century temperatures in the middle of the century.

k. Cement Manufacturing

Cement manufacturing is the third largest cause of man-made carbon dioxide emissions. Carbon dioxide is produced when calcium carbonate ($CaCO_3$) is heated to produce the cement ingredient calcium oxide (CaO, also called *quicklime*). While fossil fuel combustion and deforestation each produce significantly more carbon dioxide (CO_2), cement-making is responsible for approximately 2.5% of total worldwide emissions from industrial sources (energy plus manufacturing sectors).

l. Land Use

Prior to widespread fossil fuel use, humanity's largest effect on local climate is likely to have resulted from land use. Irrigation, deforestation, and agriculture fundamentally change the environment. For example, they change the amount of water going into and out of a given location. They also may change the local albedo by influencing the ground cover and altering the amount of sunlight that is absorbed. For example, there is evidence to suggest that the climate of Greece and other Mediterranean countries was permanently changed by widespread deforestation between 700 BC and 1 AD (the wood being used for shipbuilding, construction and fuel), with the result that the modern climate in the region is significantly hotter and drier, and the species of trees that were used for shipbuilding in the ancient world can no longer be found in the area.

A controversial hypothesis by William Ruddiman called the early anthropocene hypothesis suggests that the rise of agriculture and the accompanying deforestation led to the increases in carbon dioxide and methane during the period 5000–8000 years ago. These increases, which reversed previous declines, may have been responsible for delaying the onset of the next glacial period, according to Ruddimann's overdue-glaciation hypothesis.

In modern times, Jet Propulsion Laboratory study found that the average temperature of California has risen about 2 degrees over the past 50 years, with a much higher increase in urban areas. The change was attributed mostly to extensive human development of the landscape.

m. Livestock

According to a 2006 United Nations report, Livestock's Long Shadow, livestock is responsible for 18% of the world's greenhouse gas emissions as measured in CO_2 equivalents. This, however, includes land usage change, meaning deforestation in order to create grazing land. In the Amazon Rainforest, 70% of deforestation is to make way for grazing land, so this is the major factor in the 2006 UN FAO report, which was the first agricultural report to include land usage change into the radiative forcing of livestock. In addition to CO_2 emissions, livestock produces 65% of human-induced nitrous oxide (which has 296 times the global warming potential of CO_2) and 37% of human-induced methane (which has 23 times the global warming potential of CO_2).

SELF ASSESSEMENT

Differentiate between climate change and global warming

4.0 CONCLUSION

Ecosystems could be affected by a change in temperature. It has been predicted that an increase in temperature would affect species composition. Scientists also believe that up to two thirds of the world's forests would undergo major changes. Scientists believe that deserts would become hotter, and desertification would extend and become harder to reverse.

5.0 SUMMARY

In this unit, you have learnt that:

- climate change is the variation in the Earth's global climate or in regional climates over time
- global warming is the rise in global temperatures due to an increase of heat-trapping carbon emissions in the atmosphere
- drivers of climate change are in categories which include:

    a. Changes within the Earth's environment (Glaciation, Ocean variability, memory of climate)

b. Non-climate factors driving climate change (Greenhouse gases, Plate tectonics, solar variation, Orbital variations, Volcanism)

c. Human influences on climate change (Fossil fuels, Cement manufacture, Land use, Livestock).

6.0 TUTOR-MARKED ASSIGNMENT

Discuss physical and human factors driving climate change.

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UNIT 3 IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

CONTENTS

1.0 INTRODUCTION

Climate change is one of the most critical global challenges of our time. Recent events have emphatically demonstrated our growing vulnerability to climate change. Climate change impacts range from affecting agriculture to further endangering food security, sea-level rise and the accelerated erosion of coastal zones, increasing intensity of natural and biological resources. In this unit, the impact of climate change on the performance or the life cycle of the species is considered.

2.0 A: OBJECTIVES

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

- explain the influence of climate change on biodiversity.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
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4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

Due to past and present emissions, climate change is unavoidable. According to the UNFCC, the climate does not respond immediately to external changes, but after 150 years of industrialisation, global warming has momentum, and it will continue to affect the earth's natural systems for hundreds of years even if greenhouse gas emissions are reduced and atmospheric levels stop rising. Even the minimum predicted shifts in climate for the 21st century are likely to be significant and disruptive. Scientific understanding and computer models have improved recently and many projections can now be made with greater certainty. Predictions of future climate impacts show that the consequences could vary from disruptive to catastrophic. Current climate models predict a global temperature increase of 1.4-5.8°C by 2100 if nothing is done to reduce emissions. The minimum warming forecast for the next 100 years is more than twice the 0.6°C increase that has occurred since 1900 and that earlier increase is already having marked consequences.

3.1 Climate Change and Biodiversity

The life cycles of many wild plants and animals are closely linked to the passing of the seasons, climatic changes can lead to *interdependent* pairs of species (e.g. a wild flower and its pollinating insect) losing synchronization, if, for example, one has a cycle dependent on *day length* and the other on temperature or precipitation. In principle, at least, this could lead to extinctions or changes in the distribution and abundance of species.

One phenomenon is the movement of species northwards in Europe. A recent study by *Butterfly Conservation* in the UK has shown that relatively common species with a southerly distribution have moved north, whilst scarce upland species have become rarer and lost territory towards the south. This picture has been mirrored across several invertebrate groups.

Drier summers could lead to more periods of drought, potentially affecting many species of animal and plant. For example, in the UK during the drought year of 2006 significant numbers of trees died or showed dieback on light sandy soils. In Australia, since the early 90s, tens of thousands of flying foxes (Pteropus) have died as a direct result of extreme heat. Wetter, milder winters might affect temperate mammals or insects by preventing them *hibernating* or entering *torpor* during periods when food is scarce.

One predicted change is the ascendancy of ‘weedy’ or opportunistic species at the expense of scarcer species with narrower or more specialized ecological requirements. One example could be the expanses of *bluebell* seen in many types of woodland in the UK. These have an early growing and flowering season before competing weeds can develop and the tree canopy closes. Milder winters can allow weeds to overwinter as adult plants or germinate sooner, whilst trees leaf earlier, reducing the length of the window for bluebells to complete their life cycle.

Organisations such as *Wildlife Trust, World Wide Fund for Nature, Birdlife International* and the *Audubon Society* are actively monitoring and research the effects of climate change on biodiversity and advance policies in areas such as *landscape scale conservation* to promote *adaptation* to climate change.

Changes in climate over the last few decades of the 20th century have already affected biodiversity. The observed changes in the climate system (e.g., increased atmospheric concentrations of carbon dioxide, increased land and ocean temperatures, changes in precipitation and sea level rise), particularly the warmer regional temperatures, have affected the timing of reproduction of animals and plants and/or migration of animals, the length of the growing season, species distributions and population sizes, and the frequency of pest and disease outbreaks. Projected changes in climate during the 21st century occur faster than in at least the past 10,000 years and combined with land use change and exotic/ alien species spread, are likely to limit both the capability of species to migrate and the ability of species to persist in fragmented habitats.

There is a growing body of evidence showing that increases in atmospheric concentrations of ‘greenhouse’ gases will enhance the greenhouse effect, resulting on average in additional warming of the earth’s surface. This is likely to lead to climatic changes, including increased temperatures, sea level rises and altered rainfall regimes. The extent, pattern and timing of such changes remain uncertain. However, sea level rises would have a direct effect on coastal and estuarine ecosystems and freshwater lagoons near the coast, many of which are important breeding grounds for birds. In alpine ecosystems relatively small temperature changes may result in extensive loss of habitat and consequently extinction of some alpine species. Scientists have observed climate-induced changes in at least 420 physical processes and biological species or communities. In the Alps, some plant species have been migrating upward by one to four metres per decade, and some plants previously found only on mountaintops have disappeared. The ability of species and ecosystems to adapt to climate changes is affected by the rate of change and possible increases in the frequency of extreme climatic events. Pollution and the fragmentation of many natural habitats place further stresses on biological diversity and ecosystem function. Integrated conservation and sympathetic management of large areas of the environment, within a bioregional context, have the greatest potential to mitigate the possible effects of climate change on biological diversity.

In the National Greenhouse Response Strategy, governments have emphasized the need to adopt land uses and management measures designed to conserve carbon sinks and increase the amount of vegetation in forests and elsewhere. They have also stated in the Strategy that they will seek to provide corridor systems that link reserves and refuges with a relatively large range of altitudinal and other geographical variation, to take into account possible impacts of climate change.

SELF ASSESSEMENT
Explain 5 influences of climate change on biodiversity.

4.0 CONCLUSION

Human activities that contribute to climate change include in particular, the burning of fossil fuels, agriculture and land-use changes like deforestation. These cause emissions of carbon dioxide (CO_2), the main gas responsible for climate change, as well as of other 'greenhouse' gases. To bring climate change to a halt, global greenhouse gas emissions must be reduced significantly.

5.0 SUMMARY

In this unit, you have learnt that:

- due to past and present emissions, climate change is unavoidable
- the observed changes in the climate system particularly the warmer regional temperatures, have affected the timing of reproduction of animals and plants
- the observed changes in the climate system have affected migration of animals
- the observed changes in the climate system have affected the length of the growing season, species distributions and population sizes, and the frequency of pest and disease outbreaks
- the ability of species and ecosystems to adapt to climate changes is affected by the rate of change and possible increases in the frequency of extreme climatic events
- pollution and the fragmentation of many natural habitats place further stresses on biological diversity and ecosystem function.

6.0 TUTOR-MARKED ASSIGNMENT

Changes in climate over the last few decades of the 20^{th} century have affected biodiversity – Discuss.

7.0 REFERENCES/FURTHER READING

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Miller, C. & Edwards, P. N. (ed.) (2001). *Changing the Atmosphere: Expert Knowledge and Environmental Governance*, MIT Press.

UNIT 4 CLIMATE CHANGE MITIGATION AND BIODIVERSITY CONSERVATION

CONTENTS

1.0 INTRODUCTION

There are significant opportunities for mitigating climate change, and for adapting to climate change, while enhancing the conservation of biodiversity. Carbon mitigation and adaptation options that take into account environmental (including biodiversity), social and economic considerations, offer the greatest potential for positive synergistic impacts.

2.0 A: OBJECTIVES

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

- define mitigation and adaptation;
- identify different mitigation methods of climate change on biodiversity;
- explain the methods of mitigation;
- assess the effects of the methods on biodiversity conservation and
- explain the significance of climate change mitigation for biodiversity conservation.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.

2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

3.1 Definition of Mitigation and Adaptation

Mitigation involves reducing the greenhouse gas emissions from energy and biological sources or enhancing the sinks of greenhouse gases. **Adaptation** is comprised of activities that reduce a system's (human and natural) vulnerability to climate change.

3.2 Methods of Climate Change Mitigation for Biodiversity

Land-use change and forestry activities can play an important role in reducing net greenhouse gas emissions to the atmosphere. Biological mitigation of greenhouse gases through land use change and forestry (LUCF) activities can occur by three strategies:

1. conservation of existing carbon pools, i.e., avoiding deforestation
2. sequestration by increasing the size of carbon pools, e.g., through afforestation and reforestation, and
3. substitution of fossil fuel energy by use of modern biomass.

The estimated upper limit of the global potential of biological mitigation options (a and b) through afforestation, reforestation, avoided deforestation, and agriculture, grazing land, and forest management is on the order of 100 Gt C (cumulative) by the year 2050, equivalent to about 10– 20% of projected fossil-fuel emissions during that period, although there are substantial uncertainties associated with this estimate.

3.3 Effects of Climate Change Mitigation Strategies on Biodiversity

Afforestation and reforestation can have positive, neutral or negative impacts on biodiversity depending on the ecosystem being replaced, management options applied, and the spatial and temporal scales. The value of a planted forest to biodiversity will depend to a large degree, on what was previously on the site and also, on the landscape context in which it occurs. The reforestation of degraded lands will often produce the greatest benefits to biodiversity but can also provide the greatest challenges to forest management. Afforestation and reforestation activities that pay attention to species selection and site location, can promote the return, survival and expansion of native plant and animal populations. In contrast, clearing native forests and replacing them with a monoculture forest of exotics would clearly have a negative effect on biodiversity. Afforestation of other natural grasslands and other native habitat types would also entail significant loss of biodiversity.

Short rotation plantations will not sequester and maintain carbon as much as long rotation plantations in which vegetation and soil carbon is allowed to accumulate. Loss of soil carbon occurs for several years following harvesting and replanting due to the exposure of soil, increased leaching and runoff and reduced inputs from litter. Short rotation forests, with their simpler structure, foster lower species richness than longer-lived forests. However, products from short rotation plantations may alleviate the pressure to harvest or deforest longer-lived or primary forests.

Plantations of native tree species will support more biodiversity than exotic species and plantations of mixed tree species will usually support more biodiversity than monocultures. Plantations of exotic species support only some of the local biodiversity but may contribute to biodiversity conservation if appropriately situated in the landscape. Planting of invasive exotic species, however, could have major and widespread negative consequences for biodiversity. Tree plantations may be designed to allow for the colonization and establishment of diverse under storey plant communities by providing shade and by ameliorating microclimates. Involvement of local and indigenous communities in the design and the benefits to be achieved from a plantation may contribute to local support for a project and hence contribute to its longevity. Plantations may contribute to the dispersal capability of some species among habitat patches on a formerly fragmented landscape. Even plantations of a single species can confer some benefits to local biodiversity, especially if they incorporate features such as allowing canopy gaps, retaining some dead wood components, and providing landscape connectivity.

Slowing deforestation and forest degradation can provide substantial biodiversity benefits in addition to mitigating greenhouse gas emissions and preserving ecological services. In temperate regions, deforestation mainly occurred, when it did, several decades to centuries ago. In recent decades, deforestation has been most prevalent in the tropics. Since the remaining primary tropical forests are estimated to contain 50–70 percent of all terrestrial plant and animal species, they are of great importance in the conservation of biodiversity. Tropical deforestation and degradation of all types of forests remain major causes of global biodiversity loss. Any project that slows deforestation or forest degradation will help to conserve biodiversity. Projects in threatened/vulnerable forests that are unusually species-rich, globally rare, or unique to that region can provide the greatest immediate biodiversity benefits. Projects that protect forests from land conversion or degradation in key watersheds have potential to substantially slow soil erosion, protect water resources, and conserve biodiversity.

Most of the world's forests are managed, hence improved management can enhance carbon uptake or minimize carbon losses and conserve biodiversity. Humans manage most forests for conservation purposes and to produce goods and services. Forest ecosystems are extremely varied and the positive or negative impact of any forest management operation will differ according to soil, climate and site history, including disturbance regimes (such as fire). Because forests are enormous repositories of terrestrial biodiversity at all levels of organization (genetic, species, population, and ecosystem), improved management activities have the potential to positively affect biodiversity. Forestry practices that enhance biodiversity in managed stands and have a positive influence on carbon retention within forests include: increasing rotation length, low intensity harvesting, leaving woody debris, post-harvest silviculture to restore the local forest types, paying attention to landscape structure and harvesting that emulates natural disturbance regimes. Management that maintains natural fire regime will usually maintain biodiversity and carbon storage.

Revegetation activities that increase plant cover on eroded, severely degraded, or otherwise disturbed lands have a high potential to increase sequestration and enhance biodiversity. Sequestration rates will depend on various factors. Soils of eroded or degraded sites generally have low carbon levels and therefore a high potential to accumulate carbon, however, revegetation of these types of such sites will pose technical challenges. An important consideration is to match the plant species to the site conditions and to consider which key ecological functions need to be restored. Biodiversity can be improved if revegetation aids recruitment of native species over time or if it prevents further degradation and protects neighboring ecosystems. In certain instances, where native species may now be impossible to grow on some degraded sites, the use of exotic species and fertilizers may provide the best (and only) opportunity for re-establishing vegetation. However, care should be exercised to avoid situations where exotics that have invasive characteristics end up colonizing neighboring native habitats.

Bio-energy plantations provide the potential to substitute fossil fuel energy with biomass fuels but may have adverse impacts on biodiversity if they replace ecosystems with higher biodiversity. However, bio-energy plantations on degraded lands or abandoned agricultural sites could benefit biodiversity.

SELF ASSESSEMENT

1. What is mitigation and adaptation?
2. Explain the methods of mitigation

4.0 CONCLUSION

Since the remaining primary tropical forests are estimated to contain 50–70 percent of all terrestrial plant and animal species, they are of great importance in the conservation of biodiversity. Tropical deforestation and degradation of all types of forests remain major causes of global biodiversity loss. Any project that slows deforestation or forest degradation will help to conserve biodiversity.

5.0 SUMMARY

In this unit, you have learnt that:

- Mitigation involves reducing the greenhouse gas emissions from energy and biological sources or enhancing the sinks of greenhouse gases
- Biological mitigation of greenhouse gases through land use change and forestry activities can occur in three ways
- Afforestation and reforestation can have positive, neutral or negative impacts on biodiversity depending on the ecosystem being replaced, management options applied, and the spatial and temporal scales
- Afforestation and reforestation activities that pay attention to species selection and site location, can promote the return, survival and expansion of native plant and animal populations
- The reforestation of degraded lands will often produce the greatest benefits to biodiversity but can also provide the greatest challenges to forest management
- Clearing native forests and replacing them with a monoculture forest of exotics would have a negative effect on biodiversity
- Plantations of native tree species will support more biodiversity than exotic species
- Plantations of mixed tree species will usually support more biodiversity than monocultures
- Slowing deforestation and forest degradation can provide substantial biodiversity benefits in addition to mitigating greenhouse gas emissions and preserving ecological services

- Managed forests can enhance carbon uptake or minimize carbon losses and conserve biodiversity
- Revegetation activities that increase plant cover on eroded, severely degraded, or otherwise disturbed lands have a high potential to increase sequestration and enhance biodiversity
- Bio-energy plantations provide the potential to substitute fossil fuel energy with biomass fuels but may have adverse impacts on biodiversity if they replace ecosystems with higher biodiversity.

6.0 TUTOR-MARKED ASSIGNMENT

Critically examine the impacts of climate change mitigation on biodiversity conservation.

7.0 REFERENCES/FURTHER READING

IPCC. (2007) *Climate Change 2007: the Physical Science Basis (Summary for Policy Makers)*, IPCC.

Miller, C. & Edwards, P. N. (ed.) (2001). *Changing the Atmosphere: Expert Knowledge and Environmental Governance*, MIT Press.

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UNIT 5 BIODIVERSITY IN WEST AFRICA (W/A) (A CASE STUDY)

CONTENTS

1.0 INTRODUCTION

Habitat diversity in Western Africa ranges from semi-desert and savanna to tropical forests, mangroves, freshwater, lakes and rivers, and inland and coastal wetlands. The upper Guinea forest, which extends from western Ghana through Cote d'Ivoire, Liberia and Guinea to Southern Sierra Leone, is a biologically unique system that is considered one of the world's priority conservation areas because of its high endemism. Nearly 2,000 plants and more than 41 mammals are endemic to the ecosystem. Species diversity is also high, with more than 20,000 butterfly and moth species, 15 species of even toed ungulates and 11 species of primates. In this unit, the biologically diverse communities of Western Africa are considered.

2.0 A: OBJECTIVES

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

- explain different types of habitat diversity in West Africa;
- state three biological resources in W/A;
- discuss threat to W/A biodiversity; and
- list measures towards the sustainable management and conservation of biodiversity in W/A.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENT

The richness of Western Africa's biological resources has constituted the basis of survival of the sub-region's indigenous societies. The local human populations have developed knowledge systems and practised traditions which have protected and conserved plants, animals, water resources and other components of their life support systems. In Ghana, sacred groves protect biodiversity in three different ways:

1. by protecting particular ecosystems or habitats,
2. by protecting particular animal or plant species and
3. by regulating the exploitation of natural resources.

Many plants species are also used in Ghana in traditional herbal medicines and the Kakum National Park in Ghana, with its canopy walkway, attracts thousands of visitors a year, helping to boost the economy as well as awareness of environmental issues.

3.1 Threat to Biodiversity in Western Africa

Since the beginning of the last century, biological resources in Western Africa have been rapidly degraded and lost through practices such as large scale clearing and burning of forest, overharvesting of plants and animals, indiscriminate use of persistent chemical pesticides, draining and filling of wetlands, destructive fishing practices, air pollution, and the conversion of protected lands to agricultural and urban development. These activities are the results of uncontrolled population growth and increasing poverty, as well as of economic policies and priorities.

For example, economic pressures led to concessions being granted to foreign logging companies to exploit Western **tropical forests** and prices of cash crops especially in the 1980s, resulted in clearing of large areas of natural habitat for agriculture. Benin, Cote d'Ivoire, Liberia, Mauritania, Niger, Nigeria, Sierra Leone and Togo all have rates of deforestation of more than 2 percent per year. Remnants of forest vegetation are presently found in protected areas in coastal countries. The Upper Guinea forest extends over approximately 420,000 sq km, but estimates of existing forests suggest a loss of nearly 80 percent of the original extent. The remaining forest is highly fragmented and spread across national borders. The forest fragments that remain are under severe threat, mainly arising from slash and burn agriculture, which accounts for much of the sub-region’s subsistence food production.

Savannas are the dominant ecosystems in Western Africa, after tropical forests. Like the forests, they also support extremely biologically diverse communities of animals and plants but persistent exploitation for food, fuelwood and other resources from the savanna has resulted in their widespread degradation. For instance, the rich and extensive savanna vegetation found in the northern portions of the sub-region has been severely degraded, with resultant loss of vegetation cover, fertile top soil and wild fauna species.

Another major biodiversity issue in Western Africa is the loss and degradation of **wetlands**. Coastal and inland wetlands in W/A have been regarded as wastelands constituting habitats for pests and thus, representing a threat to public health. As a result of this perception, wetlands in W/A have been under constant threat from development activities, especially agriculture and construction of harbours. Draining or in-filling of wetlands changes hydrological regimes so that they no longer provide suitable habitats for wildlife. Untreated effluents from domestic, commercial and industrial sources in nearby settlements have polluted coastal wetlands creating a toxicity risk for flora and fauna.

Habitat loss is not the only threat to wildlife in W/A. The demand for bush meat is driving high rates of poaching and an international trade in endangered species and wildlife products is also flourishing. A series of surveys of endangered primates in the forest reserves of Eastern Cote D’Ivoire and southern Ghana from 1993 to 1999 document the first recorded extinction of a widely recognized primate taxon.

Rural people in W/A depend heavily on medicinal plants for their health needs. However, as a result of extensive agricultural practices and annual bush fires, many medicinal plants have been lost at a time when conscious efforts are being made in many countries to promote herbal and traditional medicine. Other species are threatened by a few invasive species of animals and plants.

3.2 Sustainable Management and Conservation of Biodiversity in W/A

The countries of W/A have responded to the problems of habitat loss by placing natural areas under protection. However, the number and size of protected areas varies from one country to another. Burkina Faso and Senegal have over 10 % of their lands area under national protection, whereas in Guinea and Guinea Bissau this was less than 1%, although they do have marine protected areas.

International efforts to conserve natural habitats have been very successful as a result of ratification of the Rasmsar convention, and the convention on Biological Diversity. There are 15 Biosphere reserves in the sub-region, 10 World Heritage Sites and 37 Ramsar sites.

Nearly all countries within the sub-region are signatories to the Convention and Biological Diversity and the Ramsar Convention, and many have drawn up programmes and projects under these agreements. Capacity development activities are also underway, under the aegis of new institutions created to coordinate and implement them. Most notable in the area has been GEF support for biological programmes and projects in the recipient of GEF biodiversity funding by mid 1998, with emphasis on coastal, marine and freshwater ecosystems.

SELF ASSESSEMENT
What are the threats to biodiversity in Nigeria?

4.0 CONCLUSION

The range of climatic conditions and geomorphology found in Africa has created a wide diversity of habitats, which various species of flora and fauna have evolved to exploit. As a result, the region is exceedingly well endowed with diverse biological resources. African countries and sub-regional grouping must cooperate in devising policies, programmes and projects that harmonise biodiversity management and conservation throughout ecologically determined regions.

5.0 SUMMARY

In this unit, you have learnt that:

- The range of climatic conditions and geomorphology found in Africa has created a wide diversity of habitats
- Habitat diversity in Western Africa ranges from semi-desert and savanna to tropical forests, mangroves, freshwater, lakes and rivers, inland and coastal wetlands

- The local human populations have developed knowledge systems and practiced traditions which have protected and conserved plants, animals, water resources and other components of their life support systems
- Biological resources in Western Africa have been rapidly degraded and lost through practices such as, large scale clearing and burning of forest, overharvesting of plants and animals, indiscriminate use of persistent chemical pesticides, draining and filling of wetlands, destructive fishing practices, air pollution, and the conversion of protected lands to agricultural and urban development
- These activities are the results of uncontrolled population growth and increasing poverty, as well as of economic policies and priorities
- The countries of W/A have responded to the problems of habitat loss by placing natural areas under protection.

6.0 TUTOR-MARKED ASSIGNMENT

i. Discuss West African biodiversity under the following headings:

   a. Ecological, Economic and Social values of biological resources in Western Africa.
   b. Threat to biodiversity in Western Africa.
   c. Sustainable management and conservation of biodiversity in Western Africa.

7.0 REFERENCES/FURTHER READING

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