BLOCK 3
IMPACTS OF CLIMATE CHANGE

BLOCK 3 INTRODUCTION

Climate change is caused due to emission of greenhouse gases into the atmosphere. The effects of global warming have been experienced by humans, animals and plants alike. In this block, we will discuss the impact of climate change on agriculture, ocean ecosystem, mountain and hill ecosystems and human health. In this block, the two-way link between climate change and agriculture is discussed. Changing climate will impact agricultural productivity and production. Climate change influences many properties of the ocean, while changes in the ocean also play a central role in regulating weather on local to global scales. The ocean has huge thermal inertia and dynamic capabilities. Being a huge reservoir of heat, the ocean plays as a moderator of climatic variations. It controls the formation of wind and rain. The ocean also traps and stores carbon dioxide (CO_2), thereby preventing an extreme greenhouse effect in the atmosphere. Increased ocean stratification, changes in ocean current regimes and an increase in depleted oxygen zones are now being observed due to climate change. Climate change also impacts the mountain ecosystem. Mountain and hill ecosystems are also characterized by their unique type of vegetation, floral and faunal diversity as well as distinct living habitats. This diversity itself varies with the altitude of mountains, with taller trees being found at lower altitudes giving way to shorter trees, grasslands etc. at higher altitudes. The highest altitudes of mountains are completely devoid of any vegetation. The consequences of climate change on the mountain ecosystem include glacier melting, cloudburst and flash floods, and Glacial Lake Outburst Floods (GLOFs). This block also discusses the impacts of climate change on human health.

Unit 9 “Agriculture” provides an overview of the effects of agriculture on the environment and the impacts of climate change on agriculture.

Unit 10 “Ocean Ecosystem” deals with the response of the ocean ecosystem to climate change; the effects of climate change on the physical, chemical and biological properties of the ocean; and thevulnerability of marine organisms to climate change.

Unit 11 “Mountain and hill ecosystems” deals with the formation of glaciers and the impacts of glacier melting on rivers and water availability.

Unit 12 “Human Health” deals with the linkages between weather and climate to human health, the direct and indirect effects of climate change on human health, and the impacts of climate change on migration and livelihoods.

Objectives

After studying this block, you should be able to:

- explain the effects of agriculture on the environment;
- discuss the effects of climate change on agriculture;
- explain the adaptation strategies to climate change;
- explain the response of the ocean ecosystem to climate change;

- explain the effects of climate change on the physical, chemical and biological properties of the ocean;
- explain thevulnerability and migration patternof marine organisms to climate change;
- discuss the impacts of glacier melting on rivers and water availability;
- describe the reasons for flash floods and their impacts;
- understand the linkages between weather and climate to human health;
- describe the direct and indirect effects of climate change on human health; and
- explain the impacts of climate change on migration and livelihoods.

We hope that after studying this block, you will acquire an understanding of the impacts of climate change.

Wishing you success in this endeavour!

UNIT 9 AGRICULTURE

Structure

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9.1 INTRODUCTION

Climate change is caused due to emission of greenhouse gases into the atmosphere. The heat trapped by the radiatively active gases causes global warming. The effects of global warming have been experienced by human, animals and plants alike. In this unit, we will deal with climate change and agriculture. There is a two-way link between climate change and agriculture. While, it is well acknowledged that change in the world climate is likely to have an impact on agriculture and food security across the globe, agricultural practices are also known to have an impact on climate change. A large portion of the world's agriculture is rainfed and changes in climate play an important role in determining productivity in these regions.This unit will give

you an overview of effects of agriculture on environment; and impacts of climate change on agriculture.

9.2 OBJECTIVES

After studying this unit, you should be able to:

- explain the effects of agriculture on environment;
- discuss the effects of climate change on agriculture; and
- explain the adaptation strategies to climate change.

9.3 IMPACTS OF AGRICULTURE ON ENVIRONMENT

Agriculture has a vast impact on environment through land degradation, salinisation, the over-extraction of water and the reduction of genetic diversity in crops and livestock. Thus, crop and livestock have a huge impact on the overall environment. Cropping practices are the main source of water pollution by nitrates, phosphates and pesticides. Similarly, livestock is the major anthropogenic source of the greenhouse gases methane and nitrous oxide, and contribute on a massive scale to other types of air and water pollution. FAO, in its summary report titled World Agriculture: Towards 2015/2030 describes about how agriculture affects environment (FAO, 2002). Some important points from the report have been summarised below:

9.3.1 Water Pollution

Pollution of water by pesticides and other plant protection chemicals is a major challenge in most of the developed and developing countries. This happens due to excessive use of plant protection chemicals. These chemical especially nitrates and phosphates get leached into groundwater or are carried off by runoffs into waterways. This nutrient overload causes what is termed as eutrophication of lakes, reservoirs and ponds, leading to excessive growth of algae which suppress other aquatic plants and animals. Up to half the nitrogen applied in China, is lost by volatilization and another 5 to 10 percent by leaching. Pesticides and herbicides also disturb the biodiversity of an area by destroying all weeds and insects which would have formed food for birds and other animals. Though the pesticides use has reduced in most of the countries over time, the use of herbicides is still on a rise in most countries. In developed countries, their rampant use is checked by imposing regulations and taxes. These days, there is also an increase in the demand for organic crops which are produced without the use of chemical inputs.

9.3.2 Air Pollution

Agriculture is the dominant anthropogenic source of ammonia which causes air pollution. Livestock account for about 40 percent of global emissions, mineral fertilizers for 16 percent and biomass burning and crop residues for

about 18 percent. Ammonia being more acidifying than sulphur dioxide and nitrogen oxides is one of the major causes of acid rain, which damages trees, acidifies soils, lakes and rivers, and damages biodiversity. Animal excreta is a predominant source of ammonia emission and is likely to continue rising in both developed and developing countries. Agriculture is also responsible for up to half of all methane emissions. Methane persists for a shorter time in the atmosphere as compared to carbon dioxide but it is twenty times more powerful in its warming effect. Current annual anthropogenic emissions of methane are around 540 million tonnes and are growing at around 5 percent per year. Livestock contributes to about a quarter of methane emissions, by way of gut fermentation and the decay of excreta. Methane emissions from livestock are likely to increase with the growing livestock numbers. Another main source of methane is irrigated rice farming, accounting for about a fifth of total anthropogenic emissions. Agriculture is also a key source of yet another important greenhouse gas i.e. nitrous oxide. Though generated naturally, it is boosted by leaching, volatilization and runoff of nitrogen fertilizers, and by the breakdown of crop residues and animal wastes. Livestock account for about half of anthropogenic emissions. Annual nitrous oxide emissions from agriculture are projected to grow by 50 percent by 2030. Biomass burning results in carbon dioxide, nitrous oxide and smoke particles which are by-products of biomass burning. Biomass burning in the form of burning forests, pastures and crop residues either to promote re-growth or to destroy pest habitats is a common activity. Projections suggest that, by 2030, emissions of ammonia and methane from the livestock sector of developing countries could be at least 60 percent higher than at present.

9.3.3 Effects on Biodiversity

One of the biggest challenges facing mankind today is to feed the ever-increasing population. In their attempt to meet this challenge, human beings are resorting to activities like deforestation, field consolidation, reduction in field margins and hedgerows, and drainage of wetlands in order to bring more and more land under cultivation. This activity is causing loss of biodiversity by destroying habitats of several plant and animal species. Many species have become extinct and still many are on the verge of extinction. Besides, removing the vegetation cover also exposes the top soil to soil erosion. Excessive grazing lowers the richness of fodder species. Intensive agriculture and excessive use of pesticides and herbicides reduces insects and plants which would otherwise have been food for higher animals.

9.4 AGRICULTURE AND GREENHOUSE GAS EMISSION

According to FAO estimates, if steps are not taken to reduce the greenhouse gas emission due to agriculture, the emissions from agriculture, forestry and fisheries which have more than doubled during the last 50 years will increase by an additional 30 percent by 2050. The emissions from agriculture and

livestock production increased from 4.7 billion tonnes of carbon dioxide equivalents in 2001 to over 5.3 billion tonnes in 2011.

9.4.1 Agriculture as a Source of Greenhouse Gases

The agriculture, forestry and other land use (AFOLU) sector is responsible for about 10–12 gigatonne of CO_2-equivalent per year. GHGs from agriculture are primarily due to land use and land use changes and forestry related activities, enteric fermentation in ruminants, biomass and biofuel burning, lowland paddy cultivation, and use of synthetic nitrogen fertilizers (Lipper et al. 2014; Smith et al. 2014; Venkatramanan and Shah 2019). Enteric fermentation is one of the largest sources of greenhouse gas emission in agriculture. During enteric fermentation, the carbohydrates are broken down by microorganisms in the digestive tract of the ruminants, producing methane as a by-product. This methane is released in the atmosphere via belches. In 2011, it accounted for 39 percent of the total GHG emission of the agricultural sector.

Soil microbes convert nitrogen rich fertilizers into nitrous oxide, a greenhouse gas which has 300 times as much heat trapping power as that of carbon dioxide. When there is an overload of nitrogenous fertilizers, the soil microbes may release high levels of nitrous oxide into the atmosphere. In 2011, emissions generated during the application of synthetic fertilizers accounted for 13 percent of agricultural emissions.

Rice farming is also one of the major contributors to greenhouse gasses. Methane is emitted in large quantities by the bacteria in the waterlogged soil from rice fields which are flooded. Nitrous oxide is another GHG that is produced by soil microbes in the rice fields. These gases generated from rice fields make upto 10 percent of the total GHG emissions from agriculture.

In 2011, 44 percent of agriculture-related GHG outputs occurred in Asia, followed by the Americas (25%), Africa (15%), Europe (12%), and Oceania (4%), according to FAO's data. This regional distribution was fairly constant over the last decade. In 1990 however, Asia's contribution to the global total (38%) was smaller than at present, while Europe's was much larger (21%) (FAO, 2014).

9.5 CHANGING CLIMATE

Climate variability has ripple effects on crop production, food prices and food security at local and global levels. Production shocks in one part of the world can have immense impact on the food prices and hence food security of various parts of the world due to the market dynamics. Sudden changes in food prices could be particularly harsh on the food security of the poor who spend a large chunk of their income on food. Understanding the nature of changing weather patterns is particularly important for this very reason.

Changing Temperatures

"*Global surface temperatures have risen by almost a degree in the last century. Sea levels have risen, while snow and ice cover has dropped significantly. Coral reefs are being destroyed and weather patterns are becoming wilder and less predictable. And the major cause of this climatic mayhem is now clear. It is the work of humans, who are burning ever increasing amounts of fossil fuel and have raised carbon dioxide levels in the atmosphere by 40% in the past 250 years*" (McKie, 2013).

The plant and animal species specific to a particular region are a reflection of the climate to which they are adapted. Once a change in their natural climate occurs, they tend to migrate to areas having more favourable environment. Species that are less mobile are the worst affected as they have to suffer a loss of their habitat combined with competition from new invading species. This results in such species becoming extinct and as a result there is loss in biodiversity.

Changing Precipitation

With increase in temperature due to global warming, the air becomes warm, resulting in more evaporation of water from the Earth's surface. Higher evaporation translates to higher precipitation. On average, the world is already getting more precipitation now than it did 100 years ago: 6 percent more in the United States and nearly 2 percent more worldwide (US EPA, 2013). Precipitation is expected to lower in areas near equator and increase in higher latitudes. The changing rainfall pattern can cause the pests and weeds to spread to newer areas.

El Nino and La Nina

El Nino phenomenon occurring in the eastern Pacific Ocean is primarily due to the build-up of warm water in the eastern Pacific Ocean. The warm ocean surface enables the moisture laden winds to form rainstorms. On the other hand, La Nina occurs due to the building up of cool Ocean waters in the eastern Pacific Ocean. The cool ocean surface leads to cooling of the atmosphere leading to lesser evaporation of water and making the air dry.

"*El Niño and La Niña reflect the two end points of an oscillation in the Pacific Ocean. The cycle is not fully understood, but the times series illustrates that the cycle swings back and forth every 3-7 years. Often, El Niño is followed immediately by La Niña, as if the warm water is sloshing back and forth across the Pacific. The development of El Niño events is linked to the trade winds. El Niño occurs when the trade winds are weaker than normal, and La Niña occurs when they are stronger than normal. Both cycles typically peak in December*" (NASA, 2009).

9.6 EFFECTS OF CIMATE CHANGE ON AGRICULTURE

Agriculture, livestock and fisheries are highly dependent on specific climatic conditions. Crops need specific conditions to thrive like right kind of soil, specific temperature, and enough water. Changes in climate could make it difficult for us to grow crops and rear livestock in the way and at places, we used to do in the past. Climate change and variability has potential to influence crop geography, crop production and productivity, and exacerbate the risks associated with crop farming activities (Scherr et al. 2012; Venkatramanan and Shah 2019). IPCC Assessment reports reiterate the gravity of climate change impacts on agricultural production and productivity in several agricultural regions of the world, and firmly expressed the vulnerability of developing countries and island and low-lying countries to negative impacts of climate change (IPCC 2014). Impacts from extreme weather events like droughts and floods, heat and cold waves, must be reckon with in the coming decades through devising appropriate climate resilient pathways (Venkatramanan and Shah 2019).

"Research has shown that crop yields reduce in response to extreme daytime temperatures particularly around 30°C. High daytime and night time temperature was reported to reduce the growth, yield and quality of rice and wheat crops which are the staple food crops of South Asia" (Venkatramanan and Singh 2009a, b; Venkatramanan and Shah 2019). "Estimated impacts of both historical and future climate change on cereal crop yields shows that yield loss can be up to 35% for rice, 20% for wheat, 50% for sorghum, 13% for barley, and 60% for maize depending on the geographic location, climate scenarios and projected year" (Porter et al. 2014; Khatri-Chhetri et al. 2017).

The negative effects of climate change on "food production, food prices and accessibility, consumption and utilization" result in marked effect on "all the dimensions of food security" (Porter et al. 2014). Further, climate change on account of its effects on "access to drinking water, income, health, sanitation, income and food supply chain" exacerbate the food insecurity. FAO (2009) reports that vulnerable, and disadvantaged group in particular the small and marginal farmers and food insecure are most likely to be the first affected from climate change (FAO 2009).

9.6.1 Monsoon Dependent Agriculture

The International Food Policy Research Institute (Gerald C. Nelson, 2009) conducted research to "*quantify the climate-change impacts on agricultural production, consumption, prices and trade*". To meet this end, the study employed a "global agricultural supply and demand projection model" and "biophysical crop model" to assess the impact of climate change on five important crops: "rice, wheat, maize, soyabean and groundnut". The results of the study on various aspects of agriculture have been summarized below:

According to the study, while the crop yields in the rainfed region are influenced both by rainfall and increases in temperature, the irrigated crop yields are influenced only by temperature factor. The study further points out that in case of developing countries, while the crop yield declines are found across most crops, the irrigated crops of rice and wheat are more vulnerable to climate change. In the regions like East Asia and Pacific region, higher temperature in fact increases crop acreage as the potential temperature increase provide congenial crop growth environment than the present environmental condition. South Asian region will be affected more by climate change, as the study found yield declines for most of the crops. Nevertheless, rainfed maize and wheat crops are more vulnerable to climate change. The results for the Latin American and Caribbean region, and Sub-Saharan Africa were mixed in terms of yields of crops grown in these regions.

9.6.2 Enhanced CO_2 on Crop Growth

"Crop species vary in their response to CO_2. Wheat, rice, and soybeans belong to a physiological class (called *C3 plants*) that respond readily to increased CO_2 levels. Corn, sorghum, sugarcane, and millet are *C4 plants* that follow a different pathway. The latter, though more efficient photosynthetically than C3 crops at present levels of CO_2, tend to be less responsive to enriched concentrations. Higher levels of atmospheric CO_2 also induce plants to close the small leaf openings known as *stomata* through which CO_2 is absorbed and water vapour is released... Thus, under CO_2 enrichment, crops may use less water even while they produce more carbohydrates. This dual effect will likely improve water-use efficiency, which is the ratio between crop biomass and the amount of water consumed. At the same time, associated climatic effects, such as higher temperatures, changes in rainfall and soil moisture, and increased frequencies of extreme meteorological events, could either enhance or negate potentially beneficial effects of enhanced atmospheric CO_2 on crop physiology". (Hillel, 1995).

9.6.3 Weeds, Pests and Diseases

Increased CO_2 leads to strong vegetative growth in both crops and weeds alike as a result of which weeds become more prolific and are expected to spread to newer places. There are also studies which prove that higher levels of CO_2 lead to herbicide resistance as a result of which more and more herbicides have to be applied. This may also have serious health implications in time to come. Besides, higher temperatures are favourable for insects and pest proliferation. Longer growing seasons will enable insects and pests to complete larger number of reproductive cycles. Changed wind patterns would lead to spread of wind-borne pests and diseases to newer areas. Warmer winter temperatures may shorten the overwintering period of pest larvae resulting in higher proliferation in the next season. Thus, an increase in weeds, pests and diseases could soon be a problem calling for immediate

action.

9.6.4 Crop Quality

Food systems can be vulnerable to climate change. Grain quality of wheat (e.g., protein content) is highly susceptible to current variations in climate and affects the type of foods that can be produced through, for example, gluten levels and related dough strength (Porter & Semenov 2005). Other examples of the effects of climate on crop quality include pests and diseases, such as dangerous levels of mycotoxin contamination of groundnuts (Julia M Slingo, 2005).

9.6.5 Livestock

Climate change is expected to impact both crops and livestock alike. Increased temperature is bound to increase stress levels among livestock. This may result in decline in the rate of reproduction, increased incidences of diseases and also loss of appetite. Increased levels of CO_2 in the atmosphere may result in production of less nutritious feed and forage which may be required to be supplemented by additives, thus adding to the cost to the grower.

9.6.6 Prices, Production and Food Consumption

The results reveal that though, even without climate change, the prices of rice, maize, soyabean and wheat are bound to rise between 2000 to 2050, however, with climate change, there will be additional price increases to the extent of a total of 32 to 37 percent for rice, 52 to 55 percent for maize, 94 to 111 percent for wheat, and 11 to 14 percent for soybeans. Though the study does not show any direct effect on livestock due to climate change, the effects of higher feed prices caused by climate change pass through to livestock, resulting in higher meat prices. For example, the prices of beef will be 33 percent higher due to no climate change by 2050 and 60 percent higher with climate change.

Importantly, the negative impacts of climate change and variability shall be markedly observed in Sub-Saharan Africa and South Asia. The results have also shown that climate change reduces the consumption of meat slightly and of cereals substantially indicating negative welfare effects due to climate change.

9.6.7 Per capita calorie consumption and child malnutrition

The results of the study showed that without climate change, the calorie availability increases throughout the world by 2050 whereas with climate change, the calorie availability showed marked reduction relative to 2000 levels.

Further, climate change and variability encompass increased frequency of extreme weather events like heat waves, droughts, etc. Heat waves, specially

occurring during some crucial stages of plant life cycle like pollination or pod set can limit yields. Heat waves can also cause wilting due to excessive transpiration, unless they are provided with irrigation. Droughts result in long term lack of water availability in plants resulting in famines. Strong winds can damage the leaves and heavy rains can cause flooding, both of which can be detrimental to the crops.

If the temperature rise occurs in cooler areas of the world, those places will become more habitable and we may witness crops moving their ranges. In areas where crops are being grown in their warmest productive temperature ranges already, heat stress or increased disease could reduce yields. When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep drop in net growth and yield. If night time temperature minima rise more than the daytime maxima--as is expected from greenhouse warming projections--heat stress during the day may be less severe than otherwise, but increased night time respiration may also reduce potential yields. Another important effect of high temperature is accelerated physiological development, resulting in hastened maturation and reduced yield.(Hillel, 1995).

Since agriculture is dependent on rainfall, any change in its pattern or total precipitation will significantly affect agriculture. Moisture stress, especially during important stages of plant growth like pollination, flowering and grain filling is harmful. Increase in temperature may lead to higher rates of transpiration causing moisture stress in plants and would call for increased need for irrigation. In coming years, the demand for water for irrigation may increase due to warmer climates and agriculture may have to compete with other industries for water. Less rainfall also results in falling water tables which would also increase the energy needed to pump underground water. Scientists and plant breeders are working towards developing new drought resistant varieties of various crops.

Check Your Progress 1

Note: i) Use the space given below for your answer.

ii) Check your answers with those given at the end of the unit.

1) What are the effects of changing climate on livestock?

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2) What are the effects of changing rainfall pattern on agriculture?

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9.7 AGRICULTURE AS A SINK FOR GREENHOUSE GASES

Agriculture sector can also act as a sink to GHG. Firstly, agricultural sector can reduce its own emission. Plants use CO_2 for photosynthesis. Hence, they have the ability to offset emissions from other sectors by reducing CO_2. The biomass generated in agricultural sector can be used to produce biofuels which can be a substitute to fossil fuels which are currently used for energy. Improved management practices in agriculture can help in storage of carbon in plants and soils. Every tonne of carbon added to, and stored in, plants or soils removes 3.6 tonnes of CO_2 from the atmosphere (Paustian et. al, 2006).

Agriculture can increase soil carbon by the following:

1) Cropland Management: Several management practices can increase cropland soil carbon. Carbon inputs to soil can be increased by increasing crop productivity, growing crops that produce large amounts of residues, doing away with the practice of fallow periods between crops, efficient use of fertilizers, manures and irrigation and use of zero tillage or low tillage practices.

2) Management of Grazing Land: Soil carbon of grazing lands can be increased by improved management practices. These management practices include use of proper fertilization, irrigation, cultivation of legumes, improved grazing and use of improved grass species.

3) Changes in land use can also help to increase carbon in soil. Conversion of crop lands to forests or grasslandscan increase soil carbon. Highly degraded areas like reclaimed mines, saline soils and eroded lands have high potential of carbon sequestration if a productive plant cover with high rates of carbon inputs from residues can be achieved.

9.7.1 Mitigation of GHG emission from agriculture

Nitrous oxide and methane are two important greenhouse gasses emitted as a result of both crop and livestock operations. There is a large amount of nitrogen that is supplied to the soil in the form of nitrogenous fertilizers and also from legume crops which fix atmospheric nitrogen. The emission of nitrous oxide is largely influenced by the amount of nitrogen present in the soil. Hence the mitigation rests in efficiently using the soil nitrogen. A proper

check on the rate and time of use of nitrogenous fertilizers could help in reducing the nitrous oxide emissions from croplands.

Methane emission through agriculture is largely restricted to flooded soils specially in case of rice cultivation and cultivation of other wetland crops. Mitigation options include choosing rice varieties that have high resistance to methane transport. Also, under aerobic condition, the soil bacteria use methane and convert it into carbon dioxide. This process is known as methane oxidization. Highest methane oxidization occurs in undisturbed soils. Thus, use of zero till methods and conservation agriculture will help in creating methane sink on agricultural soils.

Mitigation of methane emitted from animal wastes can be done by capturing and burning the methane emitted from animal wastes which also helps in generation of renewable energy. Similarly, manures produced by livestock also emit nitrous oxide and methane. The nature of emissions from manure depends on the nature of storage practices. While anaerobic storage conditions will produce methane and supress nitrous oxide emissions, piled storage which is mainly aerobic will supress methane and increase nitrous oxide emissions. Proper storage preferably anaerobic which will supress nitrous oxide production and using of the methane produced as a source of energy is one of the ways of mitigating GHG emissions. The methane emission from enteric fermentation is dependent on the type of feed and digestive efficiency of the animals. Incorporating feeds like grain, silage and legume hay which are easily digestible can reduce methane emissions.

Conservation agriculture to mitigate climate change

The spread of Resource Conservation Technologies (RCTs) like conservation agriculture/ zero tillage will help to improve soil structure and reduce erosion. Integrated Pest Management which uses the information on life cycle of pests and their interaction with environment in combination with the available pest control methods to manage pests will reduce pesticide use. Use of pesticides should be subjected to more rigorous testing, and residue build up should be more closely monitored.

Farming as a sink for carbon

Soils act as sinks which can store carbon in the form of soil organic matter from crop residues and manure. Though, soils have an inherent upper limit for storage, the total amount that can be stored is crop and location-specific and the rate of sequestration declines after a few years of growth before eventually reaching this limit. Some changes like restoration of saline soils could boost the total carbon storing capacity of the soils. However, if the soil reclamation practices are discontinued, the sequestered carbon would be released over a period of a few years.

Agroforestry

Agroforestry is a practice in which woody perennials are deliberately integrated with the farming systems. This helps in improving soil structure and organic carbon content, improving land productivity, increasing infiltration and enhancing fertility and thus reducing the need for fertilizers.

9.8 ADAPTATION TO CLIMATE CHANGE

UNCCD policy brief (UNCCD, 2009) talks about adaptation approaches to climate change, especially drought. These strategies can be extended to other climate change scenarios as also.

- ✓ Early Warning Systems: If the possibility of a potential disaster is known in advance, communities can be motivated to establish safeguards particularly at household levels.
- ✓ Strengthening Coping mechanisms: New adaptive mechanisms need to be designed based on indigenous knowledge and traditional practices. This would strengthen the capacity of local people to address the issue of climate change within their own communities and social structure.
- ✓ Mitigation activities to support adaptation: Actions promoting Sustainable Land Management improve the natural resource base of a region by restoring soil fertility, improving water availability, etc.
- ✓ Joint Forest Management: Conserving and establishing forests by the communities can help in checking moisture and soil loss and improving soil quality.
- ✓ Diversification of Livelihoods: Studies assessing the diverse systems of a region supporting the local livelihoods and their resilience to climate change will help in determining viable new options that provide innovative solutions.
- ✓ Local Governance: Participation of local communities in policy formulations and project development is very essential. The ability of these communities to develop the rationale for new technologies is crucial to their ability to be flexible when there is great uncertainty.
- ✓ Climate Insurance: Financial instruments on which the communities can bank upon at times of unanticipated risks are a priority.

Check Your Progress 2

Note: i) Use the space given below for your answer.

ii) Check your answers with those given at the end of the unit.

1) Enlist 5 strategies to adapt to climate change.

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9.9 LET US SUM UP

Climate is an important factor of agricultural productivity. Climate change is likely to impact agriculture and food security across the globe. In this unit, you read about the various effects of climate change on agriculture. You have also read about how agriculture affects the environment and the remedial measures that can be under taken to combat the ill effects of agriculture on environment. Towards the end, you read about adaptation strategies that can be used to combat climate change.

9.10 KEY WORDS

Resource Conserving Technologies: Resource Conserving Technologies refer to those practices that enhance resource- or input-use efficiency. Few examples of RCTs are: new varieties that use nitrogen more efficiently; Zero or reduced tillage practices that save fuel and improve plot-level water productivity; Land levelling practices that help save water.

Conservation agriculture: Conservation agriculture practices involve the characteristics:Soil cover, particularly through the retention of crop residues on the soil surface;Sensible, profitable rotations; and a minimum level of soil movement, e.g., reduced or zero tillage.

9.11 SUGGESTED FURTHER READING/REFERENCES

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9.12 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Climate change is expected to impact both crops and livestock alike. Increased temperature is bound to increase stress levels among livestock. This may result in decline in the rate of reproduction, increased incidences of diseases and also loss of appetite. Increased levels of CO_2 in the atmosphere may result in production of less nutritious feed and forage which may be required to be supplemented by additives, thus adding to the cost to the grower.

2) Moisture stress, especially during important stages of plant growth like pollination, flowering and grain filling is harmful. Increase in temperature may lead to higher rates of transpiration causing moisture stress in plants and would call for increased need for irrigation. In coming years, the demand for water for irrigation may increase due to warmer climates and agriculture may have to compete with other industries for water. Less rainfall also results in falling water tables which would also increase the energy needed to pump underground water.

Check Your Progress 2

1) Five strategies to adapt to climate change are:

- ✓ Early Warning Systems
- ✓ Strengthening Coping mechanisms
- ✓ Mitigation activities to support adaptation:
- ✓ Joint Forest Management
- ✓ Diversification of Livelihoods

UNIT 10 OCEAN ECOSYSTEM

Structure

10.1 Introduction

10.2 Objectives

10.3 Ocean Ecosystem Responses to Climate Change

10.4 Climate Change Effect on the Physical, Chemical and Biological Properties of Ocean

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10.4.1.2 Melting of the Polar ice

10.4.1.3 Rising Sea Levels

10.4.1.4 Changes to the Ocean's Major Current Systems

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10.4.2.2 Hypoxia

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10.7 Migration Pattern

10.8 Species Emergence and Extinction

10.9 Let Us Sum Up

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10.12 Answer to Check Your Progress

10.1 INTRODUCTION

The oceans occupy about 70 percent of the Earth's surface and have an inter-relationship with daily and long-term changes in weather or climate. Climatic changes influence many properties of the ocean, while changes in the ocean also play a central role in regulating weather on local to global scales. Aquatic ecosystems (ocean and coastal ecosystems) like salt marshes, mangroves, etc., render significant services with respect to "carbon storage

and sequestration" as they deliver important ecosystem services viz. "carbon storage, oxygen generation, food, and income generation". The carbon stored in coastal and marine ecosystems is called blue carbon and it is now known to sequester and store more carbon per unit area than terrestrial forests, hence playing a role in climate change.

The ocean has huge thermal inertia and dynamic capabilities. Being a huge reservoir of heat, the ocean plays as a moderator of climatic variations. It controls the formation of wind and rain. The ocean also traps and stores carbon dioxide (CO_2), thereby preventing an extreme greenhouse effect in the atmosphere. The ability of ocean to absorb atmospheric carbon dioxide released due to fossil fuels use, is being critically examined by scientific fraternity, as they can render significant role in mitigation of climate change. According to the Fifth Assessment Report (AR5) published by the Intergovernmental Panel on Climate Change (IPCC), "the ocean has thus far absorbed 93% of the extra energy from the enhanced greenhouse effect, with warming now being noted at depths up to 1,000 m" (https://www.iucn.org/resources/issues-briefs/ocean-and-climate-change). Consequently, increased ocean stratification, changes in ocean current regimes and increase in depleted oxygen zones are now being observed. Further, shifts in geographical ranges and behaviour of marine species, changes in growing seasons, diversity and abundance of species communities are observed of late (https://www.iucn.org/resources/issues-briefs/ocean-and-climate-change). In this unit, we would endeavour to discuss the response of ocean ecosystem to climate change; effects of climate change on the physical, chemical and biological properties of ocean; and the vulnerability of marine organisms to climate change.

10.2 OBJECTIVES

After studying this unit, you should be able to:

- explain the response of ocean ecosystem to climate change;
- explain the effects of climate change on the physical, chemical and biological properties of ocean; and
- explain the vulnerability and migration pattern of marine organisms to climate change.

10.3 OCEAN ECOSYSTEM RESPONSES TO CLIMATE CHANGE

By means of the natural carbon cycle, many billions of tons of carbon flow through the atmosphere, ocean, terrestrial biosphere, and lithosphere in various forms. A great number of biological, chemical and physical processes, known as carbon pumps form the foundation of this continuous transport and conversion. Climatic factors strongly influence these processes and changes in the atmospheric concentrations of greenhouse gases (GHGs)

and aerosols, land cover and solar radiation alter the energy balance of the climate system and act as drivers for changes in climate. Natural drivers of climate change include changes in the Sun's energy output, Earth's orbital variations (known as Milankovitch cycles)and large volcanic eruptions. The more significant and fast drivers are the anthropogenic climate drivers including emission of greenhouse gases and alteration of land cover that make changes in the amount of sunlight reflecting back into space (the albedo).

The gases and solids released by volcanic eruptions which include carbon dioxide, water vapour, sulphur dioxide, hydrogen sulphide, hydrogen, and carbon monoxide can influence the climate over a period of a few years, causing short-term climate changes. Studies have shown that volcanic gases and particles sprayed into the stratosphere cool the oceans and temporarily slow down the rate of global sea level rise caused by the greenhouse effect, followed by acceleration over periods of a decade or more. CSIRO in 2005 reported that, subsequent to a series of major eruptions occurring since 1960 (Mt. Agung in Indonesia in 1963, El Chichon in Mexico in 1982 and Mt. Pinatubo in the Philippines in 1991), there was temporary offset in rising of global sea level, which briefly masked the acceleration of sea level rise, that would otherwise have resulted from the effects of atmospheric GHGs. In addition to GHGs, volcanic eruptions inject sulphur bearing gases into the stratosphere which get oxidized to form sulphate aerosols, with a lifetime of about 2–3 years. They spread around the globe by the atmospheric circulation, producing a cooling effect on the ocean surface temperature by approximately 0.2-0.3 °C, which usually lasts for several years. However, in the subsurface ocean, the cooling signals may linger long and may have impacts on some decadal variability, such as the Atlantic Meridional Overturning Circulation (AMOC). Lava and ash, also act as a fertilizer providing iron and phosphorus, fuelling the algae growth which has been observed in the ocean near the eruption zone.

The ocean is being also disproportionately impacted by rising carbon dioxide and other GHGs resulting from anthropogenic activities. The marine environment is *already* registering the *impacts* of increased heating in the lower atmosphere or Earth's surface resulting from the 'greenhouse' effect caused by increasing atmospheric CO_2, methane and other gasses (at a value of about 3 Wm^{-2}). The direct physical consequences include increasing wind velocity and storm frequency, changes in ocean circulation, vertical structure and nutrient loads, rise in mean global sea surface temperatures (by 0.13°C per decade since 1979), and ocean interior temperatures (by >0.1°C since 1961), as well as global sea level rise (by more than 15 cm in the last century and presently by a mean of about 3.3 mm per year). All these changes in the physical, chemical and biological properties of oceans have been discussed in detail through subsequent sections.

10.4 CLIMATE CHANGE EFFECT ON THE PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES OF OCEAN

Climate change is having enormous impacts on ocean ecosystems, but we are only beginning to understand the magnitude of these changes. Warming trend appears to be accelerating irrespective of ocean's vast capacity to absorb heat and carbon dioxide. Oceans witnessed more than 90 percent of Earth's warming since 1950. In effect, climate change has resulted in increased ocean stratification; changes in ocean current regimes; expansion of depleted oxygen zones; changes in the geographical ranges of marine species; and shifts in growing seasons, diversity and abundance of species communities. Melting of inland glaciers and ice, causing rising sea levels with significant impacts on shorelines (coastal erosion, saltwater intrusion, and habitat destruction) and coastal human settlements are happening due to atmospheric warming (https://www.iucn.org/resources/issues-briefs/ocean-and-climate-change). The IPCC has given an estimated global mean sea level rise of 0.40 (0.26–0.55) m for 2081–2100 compared with 1986–2005 in a low emission scenario, and 0.63 (0.45–0.82) m for a high emission scenario. Further, the frequency of extreme El Niño events is also predicted to increase due to rising GHG emissions.

10.4.1 Changes in Physical Properties

Changes in ocean physical properties include changes in water temperature, oceanic circulation**,** rising sea levels as well as increased storm intensity.

10.4.1.1 Changes in Water Temperature

The ocean has absorbed more than 80 percent of the heat added to the Earth's system by climate change, but it is taking a toll on the ocean. Over the course of less than a century, the frequency of oceanic heat waves has increased by more than 50 percent. Marine heat waves are defined as 'at least five days with temperatures far above average, caused by heat from blazing sunshine and by shifting warm currents. As a global average, there were over 50 percent more marine heat wave days per year in the duration 1982–2016 compared to the earlier part.

In general, heat stress and heat waves cause harm to marine environments. Heat waves result in considerable ecological and economic effects, such as coral bleaching, mass mortality of marine species due to heat stress, loss of kelp forests, species migration, and associated reshaping of community structure. Some studies suggest that fish and mobile invertebrates seem to manage the heat waves by moving out to unoccupied habitats which in turn increases diversity. Birds and corals did poorly because of changes in prey availability and susceptibility to bleaching at high temperature, respectively. Corals and sea grasses, which tend to provide both habitats and resources for many other organisms to survive, are hardly hit making the adverse effects

cascade across the ecosystem.

10.4.1.2 Melting of the Polar ice

Increasing atmospheric warming is causing polar ice to melt and Sea-ice in the Arctic has shown significant changes in coverage and thickness over the last 30 years. Studies show that, between 1980 and 2008, the extent of sea ice has declined by an average of 11%, with evidence of a recent acceleration and between 1980 and 2008 (28 years), the thickness of sea ice reduced by 50% to 1.75 m.

10.4.1.3 Rising Sea Levels

Sea level monitoring programmes and other data indicate increased sea levels currently compared to the past 2000 years. Sea expands when its water temperature increases. Likewise, melting of glaciers and polar ice leads to rising in sea level. Human activities like draining wetlands, groundwater withdrawal, dam construction, and land use change also contribute to sea level rise. Sea level rise is a serious concern as 41% of the world's population lives within 100km of the coast. The current rate of increase in sea levels (3.1mm per year), is higher than that the values predicted by the IPCC for 2100. However, these rates are not similar globally and have special variability.

10.4.1.4 Changes to the Ocean's Major Current Systems

Changes in ocean temperatures and wind patterns will affect and alter oceanic currents. As the ocean currents play a significant role in maintaining Earth's climate, changes in the ocean's major current systems will have major repercussions for the global climate. Oceanographers have observed changes in the North Atlantic Ocean currents on account of increase in sea surface temperature and increase in melting of ice. The Atlantic plays a key role in managing global ocean currents. The sinking of large amounts of cooler water in this ocean creates currents in the Southern and Pacific oceans. Hence a slowing down of the currents in this region has global impacts. The entire Northern Hemisphere cools, Indian and Asian monsoon areas dry up, North Atlantic storms get amplified and less ocean mixing results in less plankton and other life in the sea. Also, it would lead to heating up of the southern hemisphere. The IPCC concluded that the circulation may reduce up to 54% by this century if temperature increases by 4 degrees C and GHG emissions keep increasing.

10.4.2 Changes in Chemical Properties

The ocean acts as a carbon sink by absorbing large quantities of CO_2. The CO_2 absorption capacity of the ocean is ten times than that of fresh water, as CO_2 is immediately reactive in sea water. This phenomenon causes changes in the chemical properties of the ocean.

10.4.2.1 Ocean Acidification

It is reported that "the oceans absorb about 1/3rd of the anthropogenic CO_2 emitted into the atmosphere". As soon as CO_2 enters into the water from the atmosphere, it can form carbonic acid by reacting with water molecules, which causes a shift in the concentrations of the hydrogen carbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions. This has significantly slowed down global warming but made the ocean more acidic, threatening the survival of many marine species and ecosystems. The ocean acidification observed in the recent past is found to be 30 times greater than the natural variation. Further, the mean surface ocean pH has decreased by about 0.1 unit since the Industrial revolution, which accounts to 25-percent increase in acidity, which is significant. If the carbon dioxide emissions continue, it is projected that ocean acidification levels would grow 144 percent by the year 2100.

Higher acidity greatly reduces the ability of marine organisms like corals to form their shells from calcium carbonate. Studies have shown that ocean acidification is disrupting calcium carbonate formation. Further, ocean acidification exacerbates existing "physiological stresses" and greatly reduces the growth and survival rates of few marine species, particularly in their early growth stages.

10.4.2.2 Hypoxia

Increasing heat content in the ocean waters warms the water leading to lesser dissolved oxygen holding capacity. Changing global and regional climates and coastal eutrophication are observed to increase the prevalence of reduced oxygen levels (hypoxia) making marine ecosystems more vulnerable. Water where oxygen levels are less than 2ppm is known as hypoxic waters. In addition, if surface water is warmer, it doesn't mix down as much into the ocean depths any longer. Reduction in mixing of lighter, warmer surface water with denser bottom water consequently hinders the supply of dissolved oxygen to deep-dwelling aquatic organisms. This can lead to areas called "oxygen minimum zones" where plants, fish, and other organisms would struggle to survive. Well-known examples of such "dead zones" include the Gulf of Mexico, the Baltic Sea, the Adriatic Sea, the East China Sea, and the north-western shelf of the Black Sea. It is a swelling problem with severe consequences for marine life, including altering the habitat and behaviour of marine life, death, and catastrophic changes.

Check Your Progress 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) What is blue carbon?

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2) What is ocean acidification?

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10.4.3 Changes in Biological properties

Biological changes include changes in the diversity and abundance of marine species. The ocean is an abode for millions of species, but our knowledge, especially for deep zones of oceans and its organisms are still only very partial making us significantly underestimate oceanic biodiversity. Climate change has a direct role in the loss of biological diversity; it alters abundance, diversity, and distribution of marine species. Their feeding, growth, development, and breeding, as well as the interactions between species, are affected. Variations in water temperature, oxygen level, acidification, the severity of extreme climatic events and ocean biogeochemical properties affect marine life either directly or indirectly causing alterations on the metabolism of individuals, life cycles of species, predator-prey relationships and on changes in habitat.

10.4.3.1 Effect of Ocean Warming on Biological Diversity

- Warmer waters cause corals to expel the algae living in their tissues resulting in coral bleaching. Coral bleaching in turn adversely impacts the entire coral ecosystem and the species dependent on these coral ecosystems for growth.
- Forced migration of many species in order to reach the temperature requirements they need for feeding and breeding.
- Warmer waters can directly impact hatching, growth, development, the age of sexual maturity, the timing of spawning and survival of marine life such as cephalopods.
- Warmer waters decreases the upwelling causing lesser nutrients to reach the surface of ocean water. It is important to note here that many marine

ecosystems available prominently in the upwelling areas of ocean. Few prominent examples of such marine ecosystems thriving in the upwelling areas are found near Galapagos Islands and along the coast of California.

10.4.3.2 Effect of Melting of Polar Ice on Biological Diversity

- Algae play a significant role in the arctic food web, and support species such as Arctic cod. On the other hand, Arctic cod is found to support Arctic species like beluga whales, seals, polar bears, and narwhals. Nevertheless, melting of sea ice affects the algal production, resulting in the cascading effect in the arctic ecosystem.
- Decreasing extent of *s*ea ice results in habitat loss for marine organisms such as minke whales, polar bears, seals, walruses, orcas, etc.
- Further, decreasing extent of *sea ice* affects the Antarctic krill, which perform a significant role in the Antarctic food chain. Antarctic krill is found to be an important food source for many seabirds and mammals (https://www.conservation.org/publications/Documents/CI_Five-Effects-of-Climate-Change-on-the-Ocean.pdf).

10.4.3.3 Effect of Sea Level Rise on Biological Diversity

- Species like coral reefs, mangroves, sea grasses, etc. depend on the shallower waters for their growth and development. Nevertheless, species that are slow growing are more vulnerable to sea level rise, as they are unlikely to keep pace with the rising sea level.
- Further, rising sea levels and change in ocean currents may affect the nesting beaches and migratory patterns of sea turtles.

10.4.3.4 Effect of Ocean Current Changes on Biological Diversity

- Ocean current changes may alter the migratory patterns of many marine animals.
- Also, species that are dependent on the ocean currents for growth and reproduction be affected. For example, many reef-building coral and reef fish species rely on dispersal of their larvae by currents (https://www.conservation.org/publications/Documents/CI_Five-Effects-of-Climate-Change-on-the-Ocean.pdf).

10.4.3.5 Effect of Increasing CO_2 on Biological Diversity

- Increase in carbon dioxide concentration in ocean and resulting ocean acidification has potential to affect marine organisms particularly those organisms which build shells of calcium carbonate. Examples are reef-building corals, molluscs, etc. Incidentally, these organisms play a significant role in maintaining the biological diversity of oceans.

- The growth of those species whose photosynthesis was limited by CO_2 will be increased in enhanced CO_2 situations. For example, a strong increase in photosynthesis rates was reported for cyanobacteria under higher CO_2 concentrations.

  Rising ocean temperatures together with ocean acidification affect marine species and ecosystems. Fishes, seabirds, and mammals living in oceans, all are at great threat from changing climate, including mass movements as species search for favourable environmental conditions, higher mortality rates and loss of breeding grounds. Physiochemical changes in characteristics of sea water also affect the metabolism of individuals, the life cycles of species, predator-prey relationships and alteration of habitats.

10.5 GEOGRAPHIC DISTRIBUTIONS

The current displacement rate of fishes towards the poles is 72.0±13.5 km/decade. Fisheries and food security in many southern countries will face a huge challenge as the geographic distribution of fish and the dynamics of ecosystems could undergo significant changes in the coming decades. The maintenance of healthy and productive marine ecosystems is a critical issue. The disturbances are now clearly established across a wide range of taxonomic groups ranging from plankton to top predators and in agreement with the theoretical approaches regarding the impact of climate change.

10.6 THE VULNERABILITY OF MARINE ORGANISMS

Coral Bleaching

Coral reefs are important group of marine organisms as they found to provide habitat to about one-third of the marine organisms. The growth and development of coral reefs are influenced by a suite of factors like temperature (optimum range lies between 22° and 29°C), nutrients, currents, turbidity, light, pH, calcium carbonate content, etc. As regards the temperature condition, coral reefs are sensitive to rise in temperature. Under the condition of warm water (temperature more than the optimum for the coral growth), corals expel the algae (zooxanthellae) living symbiotically in their tissues, resulting in the bleached appearance of the corals. This is called as coral bleaching. Eventually, the coral bleaching results in the death of the corals. (http://www.ocean-climate.org/wp-content/uploads/2017/03/coral-reefs_07-12.pdf).

In addition, acidification adversely affects coral skeletons by reducing the calcification rates of corals, by impeding the thickening process causing low skeleton density and leaving them more susceptible to breaking. However, the acidification effects differ with the species, as it may be due to a differential ability of the organisms to control the pH of its calcification site

(http://www.ocean-climate.org/wp-content/uploads/2017/03/coral-reefs_07-12.pdf).

- Rising sea levels also threaten the survival of many marine species. Species such as corals and sea grass meadows are also endangered since they require relatively shallow water for photosynthesis. Several marine species are also affected by rising sea levels. Example: Hawaiian Monk Seal. The monk seal population is reportedly declining at 4% annually.
- Declining phytoplankton population and krill may affect many marine organisms.

Check Your Progress 2

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) What is coral bleaching?

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2) What are the effects of sea level rise on biological diversity?

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10.7 MIGRATION PATTERN

The distributions of many marine species including those we rely on for food are shifting because of their dependence on specific water temperatures and nutrient availability. Many marine species are moving toward the poles disrupting fisheries around the world. A recent study noted that more than 800 species of commercially important fish, including halibut, herring, tuna, and cod have migrated north. Many marine species such as whales and salmon time their migratory and reproductive cycles around prey. Whales migrate to the Arctic to prey on krill in the summer and salmon migrate to the oceans for seasonal nutrients. When these patterns are altered due to a changing climate, it results in a change of predator-prey relationships and increases mass strandings', starvation, and poor reproductive success. For

example, warmer sea surface temperatures along the US Northeast continental shelf are forcing a specific zooplankton species to shift to cooler waters. Atlantic Cod that prey on them in the Gulf of Maine and Georges Bank are found to have lower reproductive success.

A recent study predicts that climate change will force hundreds of ocean fish northward. Northward shifts of warm water species by more than 10° latitude coinciding with a decrease in the number of cold-water species are related both to the rise in temperature in the Northern Hemisphere and to the North Atlantic Oscillation. A large number of biological events concerning maximal phytoplankton abundance as well as reproduction and migration of invertebrates, fish, and seabirds, all take place earlier in the year. Hence, in the past fifty years, the spring events have been shifting earlier for many species by an average of 4.4 ± 0.7 days per decade and the summer events by 4.4 ± 1.1 days per decade. Observations show that for all taxonomic groups, with great heterogeneity, the rate of displacement towards the poles reaches 72.0±13.5 kilometres per decade. Changes in the distribution of benthic, pelagic and demersal species can extend up to a thousand kilometres. These poleward migrations have led to an increase in the number of warm-water species in areas like the Bering Sea, the Barents Sea or the North Sea. The observed modifications in the distribution of benthic fish and shellfish with latitude and depth can be mainly explained by changes in the temperature of the sea. The migration rates recorded in the marine environment appear to be faster than observed in the terrestrial environment.

10.8 SPECIES EMERGENCE AND EXTINCTION

About 252 million years ago, the largest extinction in Earth's history marked the end of the Permian period, wherein 96% of marine species were lost. Studies reveal that this happened due to global warming. Rising temperatures led to the increased metabolic rate of marine animals. As the warm oceans were not capable of holding as much oxygen at higher temperatures, these species could not survive. Simulation and modelling studies showed that the most severe effects of oxygen deprivation are for species living near the poles. Several species are also at higher risk of extinction due to climate change effects. On the other side, some species might emerge in new areas due to range shifting caused by temperatures fluctuations. Species whose ranges might shift pole wards due to warmer water include lionfish, sea snakes, crown-of-thorns starfish and a number of different types of venomous jellies.

10.9 LET US SUM UP

Oceans play a key role in the mitigation of impacts of climate change, but this property of oceans is also slowly destroying and altering the marine ecosystem. Impact of climate change on oceans, noted in terms of rising ocean temperatures and its associated effects are modifying the distribution

of fishes and the productivity of marine species, which has direct and indirect impacts on the livelihoods of people who depend on fisheries. Apart from the havoc on the marine species, the degradation of coastal and marine ecosystems such as coral reefs also threaten the sustainability of the tourism industry and economy. Hence it is imperative that we develop a proper understanding of the vast secrets of the ocean, and act fast so that this abundant climate change mitigation system which supports numerous people globally is able to retain its functions and services. We have studied in this unit about the response of ocean ecosystem to climate change, and effects of climate change on physical, chemical, and biological properties of ocean. Further, we have discussed the vulnerability including the migration behaviour of marine organisms to climate change.

10.10 KEY WORDS

Coral Bleaching: Loss of coral pigmentation through the loss of intracellular symbiotic algae (known as zooxanthellae) and/or loss of their pigments.

Ocean Acidification: Ocean acidification refers to a reduction in the pH of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide from the atmosphere, but can also be caused by other chemical additions or subtractions from the ocean. Anthropogenic ocean acidification refers to the component of pH reduction that is caused by human activity.

Upwelling Region: A region of an ocean where cold, typically nutrient-rich waters well up from the deep ocean.

Sea Level Change: Sea level can change, both globally and locally due to (1) changes in the shape of the ocean basins, (2) a change in ocean volume as a result of a change in the mass of water in the ocean, and (3) changes in ocean volume as a result of changes in ocean water density.

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10.12 ANSWER TO CHECK YOUR PROGRESS

Check Your Progress 1

1) The carbon stored in coastal and marine ecosystems is called blue carbon. The carbon captured by the living organisms (ocean's vegetated habitats) in the marine and coastal ecosystems, is stored in the form of biomass and sediments. The ocean's vegetated habitats include but not limited to mangroves, salt marshes, and sea grasses.

2) Ocean acidification occurs due to the uptake of $CO_2$by the ocean mainly from the atmosphere. As CO_2 enters into the water, it forms carbonic acid by reacting with water molecules, which causes a shift in the concentrations of the hydrogen carbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions. Since the Industrial revolution, the mean surface ocean pH has decreased by about 0.1 unit.

Check Your Progress 2

1) Coral reefs are important group of marine organisms as they found to provide habitat to about one-third of the marine organisms. The growth and development of coral reefs are influenced by factors like temperature

(optimum range lies between 22° and 29°C), nutrients, currents, turbidity, light, pH, calcium carbonate content, etc. As regards the temperature condition, coral reefs are sensitive to rise in temperature. Warmer waters cause corals to expel the algae(zooxanthellae) living symbioticallyin their tissues resulting in coral bleaching. Coral bleaching in turn adversely impacts the entire coral ecosystem and the species dependent on these coral ecosystems for growth.

2) Marine species like coral reefs, mangroves, sea grasses, etc. depend on the shallower waters for their growth and development. Further, species that are slow growing are more vulnerable to sea level rise, as they are unlikely to keep pace with the rising sea level. In the case of sea turtles, rising sea levelsmay affect the nesting beaches and migratory behaviour of sea turtles.

UNIT11 MOUNTAIN AND HILL ECOSYSTEMS

Structure

11.1 Introduction

11.2 Objectives

11.3 Glaciers and their Formation

- 11.3.1 Components of a Glacier
- 11.3.2 Types of Glaciers
- 11.3.3 Glaciers in Himalayas
- 11.3.4 Ice Ages

11.4 Glacier Melting

- 11.4.1 Glacier Retreat
- 11.4.2 Climate change and Glacier Melting
- 11.4.3 Melting of Himalayan Glaciers
- 11.4.4 Melting Glaciers and Impact on River System
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11.5 Cloudburst and Flash Floods

- 11.5.1 Glacial Lake Outburst Floods (GLOFs)
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11.6 Biodiversity and Ecosystem services

- 11.6.1 Impacts of Climate Change on Biodiversity and Ecosystem Services
- 11.6.2 Barriers in Migration
- 11.6.3 Extinction of Species

11.7 Timberline and Snow line

11.8 Let Us Sum Up

11.9 Key Words

11.10 Suggested Further Readings/References

11.11 Answers to Check Your Progress

11.1 INTRODUCTION

Mountains generally are larger and higher than hills. Together, mountains and hills represent a unique type of Earth's ecosystem characterized by a generally cooler climate than the surrounding plain areas. Atmospheric temperature in mountains drops by 0.5 to 0.6^0C for every 100 m increase in altitude. Thus, higher the mountains, cooler will be the temperature. Mountains also act as barriers for moisture laden winds, and mountains receive generally higher rainfall than the surrounding plain areas.

Mountain and hill ecosystems are also characterized with their unique type of vegetation, floral and faunal diversity as well as distinct living habitats. This diversity itself varies with altitude of mountains, with taller tress being found at lower altitudes giving way to shorter trees, grasslands etc. at higher altitudes. Highest altitudes of mountains are completely devoid of any vegetation.

Mountains and hills found at different places also differ from each other in terms of type of vegetation, floral and faunal diversity as well as living habitats. Himalayas are the highest mountains in India and Western Ghats in south west India are the wettest. Aravalli mountains in northwest India are driest while Satpura and Vindhyan mountains in central India are characterized by dominance of deciduous forests. Mount Everest (8848 m) is the highest peak in Himalayas while Kalumar Peak with a height of only 752m is the highest peak in Vindhyan Mountains. In this unit, we would be discussing the formation of glaciers and the impacts of glacier melting on rivers and water availability. Further, we will be discussing the reasons for flash floods and their impacts.

11.2 OBJECTIVES

After studying this unit, you should be able to:

- differentiate between glaciers, ice sheets and icebergs;
- explain the formation of glaciers;
- discuss the impacts of glacier melting on rivers and water availability;
- describe the reasons for flash floods and their impacts; and
- explain the types of services provided by an ecosystem.

11.3 GLACIERS AND THEIR FORMATION

A Glacier is a frozen mass of ice moving slowly over land. Glaciers form when snow remains in one location long enough to transform into ice. Thus, glaciers are formed due to continuous accumulation of snow and its compaction under its own weight. Thus, annual snowfall in hill stations like Shimla, Manali etc., does not lead to the formation of glaciers, as snow melts away within a few days. Present day glaciers were formed at least 12000 years ago, during the last little ice age/ glacial phase.

Health of a glacier is assessed through its mass balance. The mass balance of a glacier is the net change in its mass over a reference period, generally in a year. A glacier gains mass through snow from snowfall and loses mass by melting of snow or ice. When a glacier loses more mass than it receives, its mass balance is negative. When a glacier gains more mass than it loses, its mass balance is positive. Glaciers gaining and losing approximately the same amount of snow and ice are in equilibrium.

11.3.1 Components of a glacier

The point of origin of the glacier is known as its 'head' and the point of termination of a glacier is known as 'snout'.

- Upper part of a glacier where there is net gain of snow is known as accumulation zone
- Lower part of a glacier where there is net loss of glacier mass is known as ablation zone
- That part of the glacier which separates accumulation and ablation zones, and the amount of new snow gained by accumulation is equal to the amount of snow/ ice lost through ablation, is known as Equilibrium Line Altitude (ELA).

11.3.2 Types of glaciers

Based on the form and shape, glaciers can be grouped into two major classes:

1) Ice sheets and ice caps

These are huge ice masses found near north and south poles on Earth. Ice sheets are larger than 50000 km^2 and their maximum ice thickness is about 3000 m. For example, Greenland and Antarctica ice sheets.

Ice caps are dome shaped ice masses, smaller than 50000 km^2 and maximum thickness being limited to less than 1000 m. Ice caps are miniature ice sheets, which form primarily in polar and sub-polar regions that are relatively flat and high in elevation. For example, Vatnajökull Ice Cap in Iceland.

2) Mountain glaciers

These are the glaciers which develop in mountains. They take the shape of the space which they occupy in mountains. Glaciers occupying the valleys between mountains are typical types of mountain glacier, also known as Valley glaciers. Glaciers like Siachen, Gangotri, Zemu are the common examples of valley glaciers. Valley glaciers are generally longer than they are wide. These glaciers may range in length from a few hundred kilometres to even less than a kilometre. Other important mountain glaciers are Cirque glaciers and Piedmont glaciers.

Icebergs

Icebergs are huge pieces of ice which get detached from a glacier and float in an ocean or lake. Icebergs are not a glacier but the part of a mountain glacier or an ice sheet. An iceberg is generally larger than 5 metres across and could be as large as a few kilometres. The largest iceberg recorded till now was almost 335 kilometre in length with a total area of 31000 square kilometres. Icebergs pose a danger to ships traversing the North Atlantic and the waters around Antarctica. *Titanic,* a British passenger ship sank in North Atlantic Ocean near Newfoundland in 1912, after striking an iceberg.

11.3.3 Glaciers in Himalayas

According to Geological Survey of India, there are 9575 glaciers in Indian Himalaya distributed among the three river basins – Indus, Ganga and Brahmaputra. However, more than 90% of Indian glaciers are small to very small in size – being smaller than 5 km in length and smaller than 5 sq km in area. Most of them are even smaller than 1 sq km in area. Only a few glaciers like Siachen, Gangotri and Zemu are bigger than 10 sq km in area.

Glaciers in eastern Himalaya receive maximum amount of their annual snowfall during monsoon season, and the glaciers in western Himalaya receive maximum amount of snowfall during winter season through "Western Disturbances". Accordingly, the glaciers in eastern and western Himalaya are known as summer and winter accumulation type glaciers, respectively.

11.3.4 Ice Ages

An ice age is considered to be that time period when there is significant reduction in the temperature of the Earth's surface and atmosphere, which results in the formation of new or expansion of existing continental and polar ice sheets and alpine glaciers.

Causes of an Ice Age

Scientists have propounded a number of theories of the causes leading to setting up of an ice age on Earth and the formation of glaciers. Some of the important theories are listed below:

1) **Continental Drift Theory** As you know, continents are not stationary but drift from one place to other, over geological time period. Due this drifting, continents which reach to the Earth's polar latitude, experience very low temperature. Sub-zero temperature at high latitudes leads to the compaction of snow and hence, the formation of glaciers/ ice sheets.

2) **Carbon dioxide Hypothesis** Carbon dioxide in the atmosphere is considered to be responsible for greenhouse effect leading to entrapment of outgoing longwave radiations, thus maintaining the Earth's average

temperature to the constant level. An increase in concentration of carbon dioxide in the Earth's atmosphere leads to increase in its temperature and vice versa. It has been proposed by some scientists that during certain periods of geological era, concentration of carbon dioxide in the Earth's atmosphere reduced significantly, thus bringing on a colder climate leading to formation of glaciers.

3) **Volcanic Dust Hypothesis** This hypothesis states that intensive volcanic activity during certain geological periods led to release of excessive amount of dust, which covered the Earth's atmosphere and obstructed the incoming solar radiation. This led to the onset of colder climate and so to the formation of glaciers.

4) **Simpson's Hypothesis:** This hypothesis correlates the formation of glaciers on Earth with the solar cycles i.e., variations in the amount of radiation given off by the Sun. During the time of maximum solar radiation, heating of Earth takes place and during the time of minimum solar radiation, glaciers are formed.

Chronology of Ice Ages

With the help of fossils and other geomorphological features, scientists have established five significant ice ages throughout the Earth's history: the Huronian (2.4-2.1 billion years ago), Cryogenian (850-635 million years ago), Andean-Saharan (460-430 million years ago), Karoo (360-260 million years ago) and Quaternary (2.6 million years ago - present). Within the Quaternary ice age, a number of glacial phases have been reported, each separated by an interglacial phase. Within the Earth's recent geological history of 6,50,000 years, four glacial phases have been established by the scientists. These glacial phases have been named as Gunz, Mindal, Riss and Wurm with Gunz being the oldest and Wurm, the latest. Each of these glacial phases was separated by the interglacial phases. Both the glacial as well as interglacial phases varied in their duration also.

11.4 GLACIER MELTING

Glaciers are considered as *climatic thermometers***,** due to their high sensitivity to atmospheric temperature. Melting of glaciers is a natural phenomenon. Glaciers being the mass of ice, melt as soon as the temperature reaches above 0 ^{0}C. Every year glaciers receive snow from snowfall especially during winter season, and melt when the temperature gets higher especially during the summer season. This may show 3 types of glacier responses:

Advancing Glaciers: When the snow received from snow fall during a year is more than the snow lost due to melting during the year, glacier gains mass which results in increase in the size of the glacier. Such type of glaciers are known as advancing glaciers. Many glaciers across the world have been reported to be advancing or growing in size, especially in Greenland,

Norway, Canada and New Zealand. At least 58 New Zealand glaciers are reported to have advanced between 1983 and 2008, with Franz Josef Glacier advancing nearly continuously during this time.

Stationary Glaciers: When the snow received from snow fall during a year balance with the snow lost due to melting during the year, glacier mass doesn't change. Such a glacier is considered to be stationary and in equilibrium with the atmosphere. Perito Moreno Glacier in Patagonia has been reported to be in equilibrium since 1950s.

Retreating Glaciers: When the snow received from snow fall during a year is less than the snow lost due to melting during the year, glacier loses mass which results in decrease in the size of the glacier. Such types of glaciers are known as retreating glaciers. Majority of world glaciers are retreating. Some notable examples of retreating glaciers include Muir glacier in Alaska, Easton and Grinnell glacier in USA, Mer de Glace in France, Morteratsch Glacier in Switzerland, Chacaltaya Glacier in Bolivia and Furtwängler Glacier in Kilimanjaro mountains of Africa. In Himalayas, some notable examples include Rongbuk and Khumbu glaciers in Mt. Everest region, Kolahoi glacier in Kashmir, Chota Shigri glacier in Himachal Pradesh, Pindari glacier in Uttarakhand and East Rathong glacier in Sikkim.

A single glacier can also be advancing, stationary or retreating glacier in different years, depending on the amount of snowfall and rate of melting during a year.

11.4.1 Glacier Retreat

Glaciers retreat when their ice melts or ablates more quickly than snowfall can accumulate and form new glacial ice. Generally, glacier retreat is the backward shifting of its terminus point, known as snout, leading to reduction in length of the glacier. Due to retreat, glaciers do not extend as far down the valley as they used to several decades or centuries back. However, melting of a glacier is the three-dimensional phenomenon. Along with length, its area and thickness also decrease due to melting.

Gangotri Glacier

Gangotri glacier is located in Uttarakhand and is considered to be the source of river Ganga. Snout of Gangotri glacier is known as 'Gaumukh', due to its resemblance with the cow's mouth, which is the starting point of river Ganga. Gangotri glacier is almost 25 km in length and has several tributary glaciers attached to it and draining their ice into the main trunk of the glacier. Previously, snout of Gangotri glacier extended up to the Gangotri town, which is almost 18 km down from its current location. According to NASA, Gangotri glacier has retreated by almost 1000 m during the 20th century itself.

11.4.2 Climate Change and Glacier Melting

Increase in average temperature of Earth is leading to global warming. This is affecting the normal atmospheric circulation of air along the globe and influencing the normal temperature as well as precipitation pattern on Earth. According to IPCC, release of greenhouses gases by human activities has increased the Earth's average temperature by 0.8°C to 1.2°C since industrial revolution. Also, it is estimated that global temperature will increase by 1.5°C between 2030 and 2052, if warming continues at the same rate.

Indian Meteorological Department based on temperature and precipitation data from 1951-2010, has reported a decrease in mean maximum, mean minimum and mean annual temperature for westernmost state of Jammu and Kashmir in Himalayas, while the same parameters have been reported to be showing positive trends for eastern most states of Sikkim and Arunachal Pradesh. Simultaneously, an increase of 2.13 mm/year in rainfall has been reported for western state and a decrease of about 3 mm/year for the eastern states, over the same time period. This increase or decrease in rainfall has been attributed mainly to increase in winter rainfall over western state and decrease in monsoon rainfall in eastern states. However, the trend for decrease in temperature is not consistent throughout western Himalaya. The decadal temperature rise in the Himalayan region is higher than the global rate of rising temperatures.

Almost 75% of glacial mass of Glacier National Park in USA has disappeared. In the Alps, home to the world-famous Matterhorn, nearly half the glaciers have disappeared since record keeping began.

11.4.3 Melting of Himalayan Glaciers

According to Intergovernmental Panel on Climate Change (IPCC), smaller glaciers are more vulnerable to global warming as compared to larger glaciers, due to their faster response time to climatic change. Glaciers in Himalaya being small to very small in size are especially vulnerable. It is reported by Space Application Centre (SAC), Ahmedabad that Equilibrium Line Altitude in western Himalaya has shifted upward by 300 m in the last 40 years. A region wide study by SAC indicates retreating pattern for almost 77% of the Himalayan glaciers. Similarly, regional study based on satellite images of glaciers in different sub-basins of Himalayas indicate an area loss ranging between 1-14%, over a period of 15 years from 1990. With reference to mass balance, over the past 4 decades, Himalayan glaciers are suggested to have lost almost 10% of their glacial mass.

11.4.4 Melting Glaciers and Impact on River System

Almost 800 million people living in Indus, Ganges and Brahmaputra River basins are dependent on Himalayan glaciers. They provide water during the non-rainfall summer season when demand is high and precipitation is less. Meltwater from Himalayan glaciers during the lean period, makes these

rivers and thousands of their tributaries, perennial in nature, with water availability throughout the year. This is in contrast to the rivers in South India which are seasonal in nature with water availability mainly during the rainfall season.

Among the three major Himalayan rivers, annual as well as seasonal contribution of meltwater is maximum in Indus River followed by Ganges and Brahmaputra. This is mainly due to dominance of monsoon rainfall in central and eastern areas, whereas meltwater remains a significant contributor to downstream flow of westerly river basin, as it receives maximum precipitation during winter.

Hydrology of glacierised regions is thermally controlled and the increasing temperature is affecting both the quantum as well as timing of runoff. Increase in temperature lead to earlier onset of melting season and higher runoff. Also, increase in rate of melting of glaciers is leading to increase in discharge in Himalayan rivers. It is estimated that by middle of this century, glaciers will recede to such an extent that their contribution to river runoff of Himalayan rivers will start declining, influencing the water availability in these rivers during the summer season. It has been reported that glacier melting during the last decade contributed almost 400 $m^3s^{-1}$to the river discharge in Indus, Ganges and Brahmaputra, respectively.

Similar to spatial variation in increase in temperature and rate of melting across Himalayas, impact on water and river systems associated with glaciers is also variable. Some basins like Satluj in Himalayas are reported to show not much change in total streamflow but there is change in distribution of streamflow with more snowmelt runoff happening earlier.

Eastern Himalaya's, mighty basin Brahmaputra also reflects increase in annual flow. Scientists have reported that the total runoff will increase in the basin up to middle of this century because of increase in precipitation and melt.

11.4.5 Impact due to change in snowfall pattern on agriculture

Variability in meltwater from glaciers will have many effects. For example, the melting of glaciers will affect drinking water supplies to the millions who rely on these rivers, especially during the summer season.

In Himalayas, apple is one of the major horticulture and commercial crop, and it is vulnerable to impacts of changing climate. Apple cultivators have been witnessing rise in temperatures and declining snowfall which is affecting the quality of fruit size. With apple production being greatly affected, farmers are steadily moving towards other crop options. Farmers have shifted to cultivation of pomegranate, kiwi and other vegetable crops.

Similarly, cardamom is an important horticultural crop in eastern Himalaya. Large cardamom production has been affected due to changing climate

impacts like variability in rainfall, rising temperature, early flowering, less snow in the mountains and rapid melting of snow, early onset of summer and monsoon, and the drying up of water sources.

In addition to that melting of glaciers is leading to higher river flows in the sea, which is causing rise in sea level, which in turn will cause flooding of the coastal areas.

11.5 CLOUDBURST AND FLASH FLOODS

Cloudburst is an extreme amount of precipitation in a short period of time occurring in a small geographical area. According to India Meteorological Department (IMD), rainfall over 100 mm per hour occurring in a small geographical area is referred as cloudburst. High temperature leads to excessive built up of moisture levels in the atmosphere and extreme condensation. This moisture content then falls in the form of either thunderstorms/ intense rainfall in the plains or cloudbursts or hailstorms in mountainous regions.

Long term records indicate that the frequency of cloudburst events has increased, and their timing has also changed. Earlier, cloudbursts were common during monsoon or post-monsoon period, which is September-October in India. However, now the cloudburst events are commonly being recorded during pre-monsoon and early monsoon season.

In India, cloudbursts mostly occur in mountain areas, where low monsoon clouds are stopped by mountains. Most of the cloudburst events are seen occurring in the elevation range between 1000m and 2500m. A number of a cloudburst events have been recorded in western Himalayan states, some of which become major due to their widespread impacts.

Recent major cloudburst events in Himalayas:

- July 1970 - Badrinath town, Alaknanda River, Uttarakhand
- August 1997 - Shimla district, Himachal Pradesh
- August 1998 - Malpa village, Kumaon division, Uttarakhand
- July 2003 - Kullu, Himachal Pradesh
- July 2004 - Chamoli district, Uttarakhand
- July 2005 - Mumbai, Maharashtra
- August 2009 - Pithoragarh district, Uttarakhand
- August 2010 - Leh, Jammu and Kashmir
- June 2011 - Jammu division, Jammu and Kashmir
- June 2013 - Almost entire Uttarakhand
- September 2014 - Kashmir valley, Jammu and Kashmir

Rapid flooding of a low-lying area is known as flash flood. A flash flood is characterized by a fast rise in volume of water. It occurs within minutes or hours of heavy rainfall. Flash floods cause heavy damage due to their

suddenness. Cloudburst often leads to the occurrence of flash floods. Flash flooding can also be caused by excessive rainfall released by cyclones or hurricanes and other tropical storms, as well as the sudden release of meltwater from glaciers. Dam breaks can also cause flash floods to occur. Landslide or mudflows in mountain areas leading to blockage in normal course of a river, also lead to flooding in the adjoining areas.

As climate change is considered to have caused increase in heavy precipitation, occurrence of flash floods is also on the rise. Human activities like unscientific development and land use pattern, deforestation, unmanaged waste disposal exacerbate the impacts of flash floods.

11.5.1 Glacial Lake Outburst Floods (GLOFs)

Flash floods caused by the outburst of glacial lakes are called as Glacial Lake Outburst Floods (GLOFs). Glacial lakes are formed due to impoundment of water at the glacier terminus due to landslide or huge ice blocks detached from the main glacier or debris deposited by the retreating glacier. These lakes normally drain their water through seepage from the material damming their water. However, cloudburst, earthquake or other intense events may lead to failure of dam impounding glacial lake, causing flash floods in the downstream region.

Glacial Lakes in Himalayas

Indian Space Research Organisation monitored a total of 459 glacial lakes and water bodies, each with an area more than 50 ha, during June to October 2015. Out of these monitored glacial lakes and water bodies, 144 have shown decrease in water spread area, 119 have shown increase, 195 have not shown any significant change (± 5%), while one glacial lake has dried up. Thus, glacial lakes are dynamic in nature which expand or shrink depending upon the rate of melting, precipitation in the region as well as rate of seepage from the lake.

11.5.2 Impacts of Cloudburst and Flash Floods

Flash floods with huge sediment loads washed away large sections of roads, bridges, vehicles, houses and hotels along the river banks.

Cloudburst and flash floods are intense events which are often associated with the loss of life – both human and animals. Heavy rain causes landslides and tree fall which results in blockage of roads and river streams. Damage to roads and bridges get the residents as well as tourists trapped in the area. Destruction of houses and public property like telephone towers and electricity poles obstructs the communication as well as electricity supply. Often vehicles get washed away due to flash floods and standing crops get damaged. The average annual flood damage has been estimated by National Disaster Management Authority to be more than Rs. 5000 crores per year in

the country.

Cloudburst and Flash Floods in Uttarakhand – June 2013

In June 2013, Uttarakhand experienced multiple cloud burst events spread across many districts in the state. It caused devastating floods and landslides in the state. It stranded several thousand local residents as well as tourists due to destruction of roads, bridges and other communication infrastructure. According to some estimates, cloudburst and associated flash floods led to death of almost 5000 people.

Check Your Progress 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) Differentiate between accumulation and ablation zone.

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2) Differentiate between summer accumulation and winter accumulation type glaciers.

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3) Differentiate between advancing and retreating glaciers.

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4) What is Equilibrium Line Altitude?

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5) What are icebergs and how are they different from a glacier?

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6) What is an ice age? Name different glacial phases of recent time period.

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7) What is the influence of glacier melting on rivers?

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8) What is GLOF? How does it affect the communities?

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11.6 BIODIVERSITY AND ECOSYSTEM SERVICES

All around us, we see a number of life forms. Plants, trees, flowers, animals, aquatic organisms etc. together constitute the life forms on Earth. This diversity of life present on Earth is referred as biodiversity.

Biodiversity is defined as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

India accounts for 7-8% of all recorded species, including over 45,000 species of plants and 91,000 species of animals. The country's diverse physical features and climatic conditions have resulted in a variety of ecosystems such as forests, wetlands, grasslands, desert, coastal and marine ecosystems which harbour and sustain high biodiversity and contribute to human well-being. Four of 34 globally identified biodiversity hotspots: The Himalayas, the Western Ghats, the North-East, and the Nicobar Islands, are found in India.

Ecosystem services refer to the services provided by an ecosystem – directly or indirectly, to the human beings. These services are the result of many conditions and processes associated with natural ecosystems that benefit humanity. For example, trees provide fruits/ flowers/shade/ foliage, but also help in air pollutant removal, carbon storage and sequestration, soil enrichment, flood protection etc. besides providing timber when cut. Thus, ecosystem services refer to all the benefits that nature provides to human beings.

Different types of services provided by an ecosystem are grouped into 4 categories:

1) **Provisioning services** are the products obtained from ecosystems such as food, fresh water, wood, fiber, genetic resources and medicines.

2) **Regulating services** are defined as the benefits obtained from the regulation of ecosystem processes such as climate regulation, natural hazard regulation, water purification and waste management, pollination or pest control.

3) **Habitat services** highlight the importance of ecosystems to provide habitat for migratory species and to maintain the viability of gene-pools.

4) **Cultural services** include non-material benefits that people obtain from ecosystems such as spiritual enrichment, intellectual development, recreation and aesthetic values.

11.6.1 Impacts of Climate Change on Biodiversity and Ecosystem Services

Climatic envelope refers to the range of temperatures, rainfall and other climate-related parameters in which a particular species currently exists. With increase in temperature and changes in other related climatic parameters, climatic envelope of a place changes and original set of climatic parameters may be found at other places, nearby or far away. This is known as shifting of climatic envelope. Species are capable to adapt to minor changes in climatic envelope. However, significant changes in climatic envelope, makes it difficult for the species to survive in their current locations. Due to changed envelope of their original habitat, species need to follow their climatic envelopes to survive and shift along with their climatic envelopes to new place. Generally, species on land migrate to cooler and moister environments. In an aquatic/ marine environment, species migrate to deeper and cooler depths. In a mountain environment, species shift uphill.

11.6.2 Barriers in Migration

In many cases, migration of species in response to shifting of climatic envelope might not be possible due to factors – natural and/ or human-made. Natural barriers are physical features that obstruct movement through them. Examples of natural barriers are deserts, oceans, mountains etc. Also, harsh climatic conditions of places in between original and new habitat, limits the migration through them. Artificial barriers are the structures created by human being, which limits the movement through or over them. For example, dams built on rivers obstruct the migration of fishes within the river. Similarly, powerlines, pipelines and roads obstruct the migration. Other obstructions in migration are competition from species already existing or lack of food, in the new area.

11.6.3 Extinction of Species

Human activities like hunting and overharvesting, cutting down of trees, conversion of forests and other natural habitats to croplands and urban areas, pollution, the introduction of invasive species etc. create difficulty in normal life of other life forms on Earth. In addition, climate change is altering the environment in different species habitats which is forcing them to migrate toward the poles or up mountain slopes in search of suitable climatic conditions for survival. However, barriers in migration and the rate of change in climatic envelope being higher than the rate of species migration are leading to extinction of species i.e., disappearance of a type of organisms or a group of similar organisms from Earth.

It has been estimated that almost 5.2 percent of species would be lost as a result of global warming alone with a rise in average temperatures of 2 °C. It is estimated that species are becoming extinct 100 times faster than they would without human impacts, and the populations of wild animals have

more than halved since 1970, while the human population has doubled. Some of the common species reported to have extinct from India in recent past are Asiatic Cheetah, Sumatran rhinoceros, pink-headed duck and Himalayan quail. According to Botanical Survey of India, 18 species of plants — four non-flowering and 14 flowering — have also gone extinct from the country.

Species Recovery Programme

Government of India is executing a scheme known as 'Integrated Development of Wildlife Habitats (IDWH)' in consultation with Wildlife Institute of India and other scientific institutions/ organizations. Under the scheme 16 terrestrial and 7 aquatic species have been identified with the objective of saving critically endangered species/ecosystems and to ensure their protection outside Protected Areas, across the widerlandscape/seascape.

Species Recovery Plans, specific to each species were prepared which have started showing positive results and the population of animal species like Lion (*Panthera leo persica*) and Rhinoceros (*Rhinoceros unicornis*) are showing an increasing trend. Some of the important species under IDWH are Asian Wild Buffalo, Asiatic Lion, Gangetic River Dolphin, Great Indian Bustard, Hangul, Indian Rhino or Great One-horned Rhinoceros, Marine Turtles, Snow Leopard, Swamp Deer and Vultures

11.7 TIMBERLINE AND SNOW LINE

Timberline refers to the highest altitude in a mountain or hill up to which the trees can survive. Beyond this altitude, climatic conditions – mainly low temperature and lack of moisture, become too severe for plants to survive. It is also called as tree line. Timberline boundary is never abrupt but transit gradually from closed forest system to open forest system followed by shrubs and grasslands below and treeless alpine tundra above.

Snowline refers to the lowest altitude above which snow is present throughout the year. Snowfall during winter months shifts the snowline but major parts of lower altitude become snow free with the onset of summer and melting of snow. However, in higher altitudes temperature remains low maintaining snow cover throughout the year. For example, snow fall in hill stations like Shimla and Srinagar during winters melts away with the start of summer season and doesn't make the part of permanent snowline.

The zone between tree line and snowline in mountains is covered with shrubs and grasslands. With increase in temperature in mountains, both tree line as well as snow line is moving upward. Rising tree line means that elevations which were once too cold for plants to survive are becoming hospitable to them. On the contrary, rising snowline means that the area under permanent snow cover is reducing due to increase in temperature.

Check Your Progress 2

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) Define biodiversity.

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2) What are provisioning services?

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3) What are the barriers to migration of species?

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11.8 LET US SUM UP

- A glacier is a frozen mass of ice moving slowly over land. Glaciers are formed due to continuous accumulation of snow and its compaction under its own weight.
- Health of a glacier is assessed through its mass balance. The mass balance of a glacier is the net change in its mass over a reference period, generally in a year. A glacier gains mass through snow from snowfall and loses mass by melting of snow or ice.
- Greenland and Antarctica are the example of ice sheets on Earth and Siachen, Gangotri and Zemu are the common examples of valley glaciers.

- Glaciers is eastern Himalaya receive maximum amount of their annual snowfall during monsoon season, and the glaciers in western Himalaya receive maximum amount of snowfall during winter season through "Western Disturbances". Accordingly, the glaciers in eastern and western Himalaya are known as summer and winter accumulation type glaciers, respectively.
- An ice age is considered to be that time period when there is significant reduction in the temperature of the Earth's surface and atmosphere, which results in the formation of new or expansion of existing continental and polar ice sheets and alpine glaciers.
- Every year glaciers receive snow from snowfall especially during winter season, and melt when the temperature gets higher especially during the summer season.
- Glacier retreat is the backward shifting of its terminus point, known as snout, leading to reduction in length of the glacier.
- Meltwater from glaciers during the lean period, makes Himalayan rivers and thousands of their tributaries, perennial in nature, with water availability throughout the year.
- Hydrology of glacierised regions is thermally controlled and the increasing temperature is affecting both the quantum as well as timing of runoff. Increase in temperature lead to earlier onset of melting season and higher runoff.
- Rainfall over 100 mm per hour occurring in a small geographical area is referred as cloudburst. High temperatures lead to excessive built up of moisture levels in the atmosphere and extreme condensation. This moisture content then falls in the form of cloud bursts in mountainous regions.
- Glacial lakes are formed due to impoundment of water at the glacier terminus due to landslide or huge ice blocks detached from the main glacier or debris deposited by the retreating glacier. Cloudburst, earthquake or other intense events may lead to failure of dam impounding glacial lake, causing flash floods in the downstream region.
- Diversity of life present on Earth is referred as biodiversity. India accounts for 7-8% of all recorded species, including over 45,000 species of plants and 91,000 species of animals. Four of 34 globally identified biodiversity hotspots: The Himalayas, the Western Ghats, the North-East, and the Nicobar Islands, are found in India.
- Ecosystem services refer to all the benefits that nature provides to human beings. Different types of services provided by an ecosystem are grouped into 4 categories: Provisioning services, Regulating services, Habitat services and Cultural services.

- Barriers in migration and the rate of change in climatic envelope being higher than the rate of species migration are leading to extinction of species i.e., disappearance of a type of organisms or a group of similar organisms, from Earth.
- Timberline refers to the highest altitude in a mountain or hill up to which the trees can survive, and Snowline refers to the lowest altitude above which snow is present throughout the year. The zone between tree line and snowline in mountains is covered with shrubs and grasslands.

11.9 KEY WORDS

Glacier: A perennial mass of land ice that originates from compressed snow, shows evidence of past or present flow and is constrained by internal stress and friction at the base and sides.

Ice age: An ice age or glacial period is characterized by a long-term reduction in the temperature of the Earth's climate, resulting in growth of ice sheets and glaciers.

11.10 SUGGESTED FURTHER READING/REFERENCES

IPCC, 2013: Annex III: Glossary [Planton, S. (ed.)]. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Web Links

http://www.ipcc.ch/report/ar5/wg1/

http://www.ipcc.ch/report/ar5/wg2/

http://www.ipcc.ch/report/ar5/wg3/

http://www.ipcc.ch/report/ar5/syr/

11.11 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Refer to section 11.3.1
2) Refer to section 11.3.3
3) Refer to section 11.4
4) Refer to section 11.3.1
5) Refer to section 11.3

6) Refer to section 11.3.4
7) Refer to section 11.4.4
8) Refer to section 11.5.1

Check Your Progress 1

1) Refer to section 11.6
2) Refer to section 11.6
3) Refer to section 11.6.2

UNIT 12 HUMAN HEALTH

Structure

12.1 Introduction

12.2 Objectives

12.3 Direct Impacts on Human Health

12.3.1 Increased Frequency of Heat Stress

12.3.2 Vector-borne Diseases

12.3.3 Non vector-borne Diseases

12.4 Indirect Impacts on Human Health

12.4.1 Malnutrition and Hunger

12.4.2 Food Insecurity

12.5 Climate Change Impacts on Human Settlement, Migration and Livelihood

12.5.1 Climate Change Impacts on Human Settlement and Migration

12.5.2 Climate Change Impacts on Livelihood

12.6 Let Us Sum Up

12.7 Key Words

12.8 Suggested Further Reading/References

12.9 Answers to Check Your Progress

12.1 INTRODUCTION

This unit details how weather and climate can affect the health of mankind. These include both direct and indirect effects. Our planet's species are dependent on the ecosystem service functions which are driven by climate stability. Good health is the most important aspect for every human being without which life becomes a burden. Our health is directly linked to the state of our environment. Have you ever wondered why you get sick after rains and floods? Most of us are affected by viral flu, conjunctivitis, gastrointestinal upset, and so on. In regions where there is heavy flooding people wade in these waters and are affected by skin diseases, helminthiasis etc. Changes in weather and climate have influenced the health of human populations in the past and caused several epidemics and pandemics such as Cholera, plague and the Spanish Flu. Presently we are facing the great pandemic from Coronavirus which has affected millions of people in the entire world and the world's economy has been hit badly. The entire globe is under a lockdown as this virus is infectious. This virus is transmitted from bats and mammals and is contagious as it causes human to human transmission. Do you think climate could be related to health issues? Yes, climate is directly responsible for the distribution of different types of insects, mollusks and even species of the higher genera which are vectors for several

diseases. Recently India has experienced a spike in diseases such as Chikungunya, West Nile Fever and Dengue viruses. Why do you think this is so? This unit will explain the factors responsible for the same and will introduce you to some extreme weather events, such as heat stress and their risks to health. The health risks are under-nutrition, poor mental health, food and water-borne diseases. We should understand that health risks arising from climate change will be distributed inequitably. There exist links between climate variability and human health. We are already seeing the impacts of climate change and this will further increase in the coming decades. It may also lead to several novel emerging infectious diseases. Scientists and researchers are presently studying the exposure pathways in humans and animals for understanding the impacts of climate change on health. This involves conducting studies over time and in different locations, among different communities. The developing countries have a high under-five mortality rate (key indicator of a health status of a country). Most of this is due to drought, extreme climate events and vector-borne diseases. Good health is the key to a country's progress and economy. Together we can reduce the underlying health disparities by strengthening each country's fundamental public health services and policies. When we focus on the links between climate variability and health, there are three important exposure pathways by which climate change affects our health. These include through (1) direct exposure through extreme weather events, such as heat and storms; (2) indirect exposure pathways through changes in the ecosystems which affect disease vectors and disease transmission. Let us now understand these processes in detail in the following paragraphs.

12.2 OBJECTIVES

After studying this unit, you should be able to:

- understand the linkages between weather and climate to human health;
- describe the direct and indirect effects of climate change on human health; and
- explain the impacts of climate change on migration and livelihoods.

12.3 DIRECT EFFECTS ON HUMAN HEALTH

According to a report of the World Bank in 2010 the baseline health of a country is related to the amount of impact that could be caused due to climate change and also the costs for its adaptation. Therefore the likely risks and impacts of climate change vary between countries. A small change in the global climate will affect the normal functioning of the earth's ecosystems. Some countries may experience extreme cold temperatures and people living in such areas would want warmer climates; for example the USA. Likewise certain areas may receive very hot temperatures and people would want cooler temperatures. These changes in climate can lead to beneficial and/or

adverse effects. The changes that may be witnessed initially may be some changes in the seasonality of some infectious diseases. This includes vector-borne infections such as mosquito-borne diseases: dengue, chikungunya and so on that strike during the warmer periods. Some plant and animal varieties may die or even go extinct due to changes in climate variability, whereas some species are able to adapt themselves to the changed conditions. Some other significant impacts of climate change include changing food productions, agrarian distress and socio-economic issues. The table 12.1 given below gives you an idea of some environmental changes, the diseases caused therein and the different pathways responsible for bringing about infectious diseases in human beings.

Table 12.1 Environmental changes and infectious diseases in human beings

Environmental Changes	**Outbreak of Diseases**	**Pathways responsible**
From Dams and irrigation	Malaria; Schistosomiasis	Breeding sites for mosquitoes; Snail host habitat – human contact
Agricultural intensification and activities related to agriculture	Malaria	Crop insecticides, vector resistance
Urban crowding	Cholera; Dengue	Sanitation, hygiene, water contamination; Water collecting trash, Breeding sites for mosquitoes
Deforestation	Malaria; Visceral leishmaniasis	Crop insecticides, vector resistance; Sand-fly vectors
Reforestation	Lyme disease	Tick hosts, outdoor exposure
Ocean warming	Red tide	Increase in toxic algal blooms
High precipitation	Rift valley fever; Hantavirus pulmonary disease	Breeding sites for mosquitoes; Increase in rodent food, habitat abundance

(Source: Wilson, 2001)

We are exposed to changing weather patterns, changes in water, air, food quality, agriculture, livelihoods and infrastructure (Confalonieri et al., 2007). These direct and indirect exposures have already resulted in a number of health impacts. This will continue and most of them are anticipated to be negative and will profoundly worsen if the present trends continue. Most of the health impacts resulting from extreme weather events can be prevented

through early warning systems and public health preparedness and response action.

Climate change can have direct effects on human health. These are through extreme weather events and are referred to as primary pathways. Let us now understand some direct effects of climate change on human health.

12.3.1 Increased Frequency of Heat Stress

Health can be defined as 'a complete state of physical, mental and social well-being and not merely the absence of disease or infirmity' (WHO). A normal healthy human has the internal temperature of around 37°C. When we have an illness there can be an increase in body's temperature. There can also be subtle changes with weather and seasonal fluctuations. Through various metabolic pathways the body copes up with these changes. The hypothalamus in the human brain controls and regulates our temperature, balances salt concentrations and several other involuntary functions such as breathing, digestion, heart functioning and so on. Through the processes of sweating, convection and radiation the transfer of heat from the body takes place. When the temperature around us (outside) is the same as the human's skin temperature, then there is usually no radiant heat loss or gain. When the body gets warm the hypothalamus and nervous system instruct the sweat glands to draw water from the dermis, which causes evaporation and cools the skin. Heat causes heat stress in humans and also in animals. It has adverse effects on the population too. Industrialization and urbanization have resulted in increasing urban heat island effects. In extreme hot conditions the rate of "heat gain" is more than the rate of "heat loss". As a result, our body temperatures increase which results in various health disorders. High heat exposures can result in exhaustion, fatigue, dehydration and heat stroke. In extreme cases and among the elderly or in children it can also lead to sudden death. Heat stress has influences on our mental health. It can lead to nervous and psychological disorders, anxiety pangs and disturbed sleep patterns.

Heat stress can cause the following diseases.

- **Heat Rashes:** They occur as small red spots with a prickling sensation. It is caused due to the inflammation of the sweat glands.
- **Heat Cramps:** This occurs due to salt imbalance.
- **Heat Exhaustion:** This occurs due to excessive sweating. It can result in fatigue, weakness, dizziness, eye disorders, intense thirst, nausea, headache, vomiting, diarrhea, muscle cramps, breathlessness, palpitations, tingling and numbness of the hands and feet.
- **Heat Stroke:** This may be fatal and occurs when the body temperatures are above 41°C.

Some other important diseases caused due to heat include:

- **Diseases of the Kidney:** High and long exposures to very high temperatures can cause major kidney diseases. It can be due to impaired water regulating abilities of the human body.
- **Diseases of the Heart:** Very hot temperatures can cause cardiac dysfunction, heart stroke and increase cardiovascular diseases.

Check Your Progress 1

Note: i) Write your answer in about 50 words.

ii) Check your progress with possible answers given at the end of the unit.

1) List the various diseases caused by heat stress.

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12.3.2 Vector - borne Diseases

These diseases will increase with climate change as predicted by the World Health Organization (WHO). Vectors are living organisms that can transmit infectious diseases among human beings and from animals to humans. Majority of the diseases are spread by bloodsucking insects. These insects while taking their bloodmeal infect another person when they bite. Mosquitoes, ticks, flies, sandflies, fleas, bed bugs and some freshwater aquatic snails are known vectors. Historically, vector-borne diseases have been recorded in different countries in various climates. The African sleeping sickness caused by *Trypanosoma brucei* (vector is the tsetse fly) and the Chagas fever caused by *Trypanosoma cruzi* (vector is the triatomine bug) are some examples. However, the vector-borne diseases are steadily increasing as an indirect result of climate change. These diseases are highest in tropical and subtropical areas. These diseases infect millions of humans each year and are mostly transmitted through mosquitoes, ticks, and fleas. The vectors are carriers of viruses, bacteria and protozoans. These diseases can be severe and debilitating. Climate variability in recent years has caused several people to be affected by dengue, West Nile fever, chikungunya, zika and nipah viruses.

Let us now learn about some of the vector borne diseases in the following paragraphs.

1) Mosquito-borne diseases

a) Dengue: It affects millions of people globally every year. In India dengue epidemics have occurred and are affecting the population every year. Early monsoons and unusually wet and warm weathers have resulted in several dengue outbreaks in the Asia-Pacific regions. Aedes mosquitoes transmit the dengue virus that is sensitive to environmental conditions. A. *aegypti* and *A. albopictus* mosquitoes are vectors for dengue virus. Approximately 40% of the global population lives in dengue-risk regions. Unlike chikungunya, a person infected with dengue can be infected a second time and this can be severe and sometimes fatal. The symptoms observed include high fever, headache, rash and muscle and joint pain, sometimes bleeding and shock. Higher temperatures reduce the time required for the virus replication and disseminate in the mosquito. This is known as the "extrinsic incubation period". This occurs before the virus reaches the salivary glands of the mosquitoes to infect humans. When the mosquito becomes infectious due to warmer temperatures, it has a greater chance of infecting man before it dies. Dengue is endemic in many countries with tropical climates.

b) Chikungunya: Changing weather and climate variability has caused the re-emergence of chikungunya. It is caused by the chikungunya virus and is spread through the mosquitoes *Aedes albopictus* and *Aedes aegypti*. Chikungunya is caused by the arbovirus. The symptoms usually occur after a week of exposure and results in high fever, severe headache, rashes on the body, severe myalgia, joint pain, immobility, swelling in the ankles, toes, finger joints and extreme pain in all the joints including shoulder, finger and toe joints that stay for months together. The pain can be as long as 6 months to a year and can recur in some people. The disease also causes post stress severe hair fall and vitamin deficiencies. The disease was first reported in Tanzania in 1952. The word chikungunya comes from the African Kimakonde language meaning "bent posture or to become contorted". Epidemics began in 2004 and spread to the islands of the Indian Ocean. In 2005, it affected more than a million people in India and in the French island of Réunion in the southwest Indian Ocean. The disease has re-emerged in South India and several people have been affected with this virus. It appears that the chikungunya re-emergence depends on several factors – climate being an important one. With drought and heavy rainfall events disease vectors will spread quickly and vector-borne chikungunya prevalence is likely to increase, with the possibility of becoming endemic globally. Chikungunya is a major threat in the developing countries.

c) Zika Virus: Zika virus is also transmitted through mosquitoes and is a flavivirus. It was first noticed among monkeys in Africa in 1947. In the year 1952 the disease was observed in humans in Uganda and the United Republic of Tanzania. In 2013 a large outbreak was reported in French

Polynesia and other countries in the Pacific. Symptoms of the disease include fever, rash, conjunctivitis, muscle and joint pain, malaise, and headache. The infection lasts for 2–7 days. Severe storms and increasing temperatures are some environmental factors for the sudden resurgence of this disease.

d) Malaria: Malaria is also another important vector-borne disease that has affected millions of people globally. It is transmitted by the female Anopheles mosquito. The causative organism causing malaria is the protozoan Plasmodium sp. transmitted through the mosquitoes. So far five species are known to cause malaria in humans. They are *P. vivax*, *P. ovale*, *P. falciparum*, *P. malariae*, and *P. knowlesi*. Plasmodium parasites multiply in the human liver after an infected mosquito bites and then it destroys the red blood cells. The symptoms of malaria are characterized by high fever with shivering, headaches, seizures, vomiting, fatigue, pain. Scientific research has proven that the linkages between malaria and extreme climatic events are directly related. Excessive rainfall and high humidity are some factors responsible for increasing mosquito breeding and survival. Studies have brought out the relationship between climatic variables and biological parameters in malaria epidemics. The vector breeding, survival, mosquito biting rates, and parasite incubation rates are directly linked to climate variables. Therefore, climate change affects vector and parasite biology and disease transmission. The World Bank report estimates that by the year 2050, climate change will bring about a 50% higher probability of malaria in previously unexposed regions of South America, sub-Saharan Africa and China (World Bank report, 2012).

2) Tick-borne diseases

a) Spotted Fever Rickettsia: This disease is caused by certain groups of bacteria and spread to humans through the bite of infected mites and ticks. The bacteria causing it belong to the order Rickettsiales and genera Rickettsia, Anaplasma, Ehrlichia, Neorickettsia, Neoehrlichia, and Orientia. Rickettsia spp. are classified into the spotted fever group and the typhus group. The disease transmission is through bites from ectoparasites such as lice, fleas, mites and their infectious fluids. People have been affected by inhaling bacteria and when on travel in endemic areas. It is frequently reported with people going on safaris, walking in bushes, hunting especially in Africa.

b) Tularemia: This disease infects animals especially rabbits and then to human beings. Hares are also infected with this disease. Human beings can be infected by tick and deerfly bites, contact with the infected animals, drinking contaminated water and also by the inhalation of contaminated aerosols or from agricultural dust. Recently scientists from Stockholm University, Sweden have developed a method for predicting impacts of climate change on tularemia outbreaks in humans. Their study

emphasizes that the disease will increase in high-latitude regions due to temperature rise and be favourable for the vectors of this disease.

3) Flea-borne diseases

a) **Plague:** This disease is caused by the bacterium *Yersinia pestis*. It affects human beings when we are bitten by rodent flea which are carriers of the bacterium or when we touch an infected animal or through the infectious droplets in the air. The infected people show large swollen lymph nodes in the groin, armpit or neck, fever accompanied with shivering, muscle pains. The disease spread in the Democratic Republic of the Congo, Madagascar and Peru in the year 2017. Historically the disease was prevalent in the 14th century leading to 50 million deaths and is referred to as the "Black death".

12.3.3 Non vector-borne Diseases

These diseases also cause infection in human beings every year. They are transmitted from birds, cattle and so on. The Avian influenza and Swine flu epidemics were infectious and affected several people world-wide. Climate variability is a factor for the increasing incidence of these diseases.

a) **Brucellosis:** This disease is a zoonotic infection caused by bacteria of the Brucella genus. Human beings get infected when in contact with infected cattle, or through ingestion of contaminated food products or by inhaling infected aerosols. It is also commonly known as Mediterranean fever, Malta fever, gastric remittent fever, and undulant fever. Human beings are usually accidental hosts. Brucellosis is the most common zoonotic infection world-wide. The bacteria occur as small aerobic intracellular coccobacilli and live in the reproductive organs of animals such as cattle and lead to sterility and abortions in cattle. The bacteria are excreted in large numbers in the animal's milk, urine, placental fluid, and other fluids.

b) **Leptospirosis:** It is also known as Weil's disease. Many animals such as pigs, goats, sheeps, horses and deers also carry this bacterium and transmit the same to humans. The disease affects human beings through direct contact with urine from infected animals, from soil, contaminated water with animal urine after rains and so on. It is highly prevalent in warmer climates. Symptoms include high fever, malaise, conjunctivitis, bleeding, vomiting, myalgia and meningitis. When left untreated leptospirosis leads to kidney and liver damage and can also be fatal.

c) **Avian influenza:** This is also known as bird flu or Avian flu. It is a disease caused by a strain of influenza virus and birds are the hosts for this. In the years 2013 to 2017 there were more than 900 human cases of H7N9 cases as reported by the World Health Organization (WHO). Most of the infected people had visited poultry markets or had consumed contaminated poultry products, handling dead infected birds, infected

fluids. The transmission is not human to human but from birds to humans. It can occur as a result of climate, altered breeding grounds. Climate change is an important factor because it can alter the conditions in the persistence of the virus and disease transmission. It is also responsible for changing the migration patterns among birds.

d) Swine fever: It is also referred to as hog cholera. It is a viral disease and contagious among swine (pigs). It is caused by Pestivirus of the family Flaviviridae. It has been reported in the 19th century in the United States. In 1997 there was an outbreak of the flu in Netherlands and killed 11 million pigs. The disease is transmitted from infected pigs. The virus is transmitted through the saliva, nasal fluids, urine and faeces of the swine. Humans are infected when in contact with infected swine, contaminated feed, clothing, vehicles, and so on. The virus can also survive in pork and processed pork products for months and years even when preserved in freezers.

Check Your Progress 2

Note: i) Write your answer in about 50 words.

ii) Check your progress with possible answers given at the end of the unit.

1) Write short notes on vector-borne diseases.

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2) Write short notes on non vector-borne diseases.

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12.4 INDIRECT EFFECTS ON HUMAN HEALTH

These effects can be for example through droughts leading to disease and malnutrition. Drought which is climate related with extended periods on non-availability of water or rains can cause community – level impacts such as water shortages. This can lead to diarrhea, cholera and other infectious diseases. Children are most susceptible to diarrhea. Health responses for such

events are to provide food supplementation and health care, epidemic surveillance and early warning systems, and water safety plans that assess and address the health risks posed by climate variability and change.

12.4.1 Malnutrition and Hunger

Hunger is greatest in Africa, India, and parts of north Asia and the Western Pacific. World over more people are food insecure and under-nourished. Increasing temperatures and variable precipitation will influence the production of staple foods and there will be a decline. This will increase the risk of malnutrition (IPCC, 2014). Crop yields could decline in Central and South Asia by the mid-21st century. Also, greenhouse gas emissions can affect plant growth and nutrient concentrations. Rapid population growth and urbanization will also increase malnutrition and hunger risks. World over there will be enormous inequity in relation to underweight children under the age of five. Large populations, under nutrition and poor health, affect the productivity and economic development of many developing nations. Diarrhea causes high child mortality and morbidity rates globally. It normally occurs due to improper sanitation and hygiene and drinking contaminated water. Globally approximately more than 700 million individuals lack access to improved drinking water and 2.5 billion lack improved sanitation, according to WHO, 2014. In developing countries, children under three years have at least a minimum of three episodes of diarrhea each year. This is responsible for child malnutrition as the necessary nutrients are lost. As a result, stunted growth, vitamin D deficiencies, Beriberi, Kwashiorkor, hypoproteinemia, goitre and so on are common.

12.4.2 Food Insecurity

Since 1850's there has been an increase in the greenhouse gas emissions due to fossil fuel burning for our energy demands and agriculture intensification for increasing food demands. These activities have brought about a change in the ecosystem and have impacted food security. Agriculture is the lifeline for majority of the people globally. It gives us food and provides a source of livelihood. Agriculture, forestry and also fisheries are directly affected by climate change. Again, climate change influences the growth of plants and animals, their metabolism, biodiversity and nutrient cycling. Climate change can result in the emergence of new diseases and pests that will attack plants and livestock thereby posing risks for food security. All this along with water-borne diseases due to weather extremes can affect human health and for assimilating essential nutrients from foods. Some vectors and diseases are seen to rise during specific humidity-temperature conditions and irrigation management regimes. These changes will expose crops, livestock, fish and eventually humans to new risks. Climate variability will affect food availability, food accessibility, food utilization and food system stability. It will also impact human health, food production and livelihood assets. These effects are already being experienced world over in the food markets. Supply

chains will be disrupted, market prices will increase, livelihood opportunities and health are threatened. The people who are dependent on agriculture-based livelihood systems are the most vulnerable. They are impacted first due to risk of crop failure, pest attacks and diseases, lack of seeds and loss of livestock. Also, inhabitants on the coastlines and mountains also face risk. Both the developed and the developing world will be impacted. Climate change can trigger resource - based conflicts and civil unrest, thereby affecting food systems. We can mitigate this by changing agricultural practices and reducing greenhouse gases.

12.5 CLIMATE CHANGE IMPACTS ON HUMAN SETTLEMENTS, MIGRATION AND LIVELIHOOD

12.5.1 Climate Change Impacts on Human Settlements and Migration

From time immemorial humans have travelled and settled along coastlines and other places for their livelihood and better opportunities. Some people are displaced due to conflicts, dam construction related issues and also due to catastrophes such the 2004 tsunami where millions were affected and displaced. Drought and extreme climatic events also force people to search for better economic conditions and employment either temporarily or permanently. Another example is the 2008 Kosi floods that displaced many in Nepal and India. These events are sudden and sometimes unforeseen events. Sudden-onset hazards have forced several million to migrate to other areas. The hazards cause physical loss of land and natural resources and people are unable to cope or adapt with the changes. On the other hand, drought is a slow creeping hazard. Slow-onset hazards still give people time to adapt themselves to the situation by regenerating the soil fertility and using appropriate seeds for cultivation etc. There are many factors that influence human migration. They include social, environmental, cultural, economic and political. The Paris Agreement gives references to migration and displacement. In the preamble, it refers to the vulnerability of migrants, and calls on states to ‘respect, promote and consider their respective obligations on human rights’ when taking action to address climate change (UNFCCC, 2015: 1). It also addresses the need for a task force to ‘develop recommendations for integrated approaches to avert, minimize and address displacement related to the adverse impacts of climate change’ (UNFCCC, 2015). The Hyogo Framework for Action also recognized displacement as a potential driver of vulnerability (UNISDR, 2005). The Sendai Framework focuses on displacement in response to extreme events (UNISDR, 2015). Therefore, climate change brings about migration both within and cross-borders.

12.5.2 Climate Change Impacts on Livelihoods

Livelihoods can be defined as the different types of assets, abilities and activities that enable a person or household to survive (FAO, 2003). These assets include physical assets such as infrastructure and domestic assets; financial assets such as cash, jewellery, savings, mutual funds and pensions; natural assets such as natural resources, land for agriculture; social assets, which are based on the cohesiveness of people and societies; and human assets such as education and skills for survival. All these assets change with time (with cycle of events, we may lose or earn the assets) and are always different for various households and communities. In general, we should have a mix of assets so that we can tide over difficult situations. Our ancestors always believed in having mixed assets.

In society we have different groups, various communities and not all can adapt to the climate change driven impacts. The marginal groups are those people who have few or lesser resources and power and they are not able to adapt themselves to the changes. In fact, they can be negatively impacted. It is usually people's few productive assets that are at greatest risk from the impacts of climate change. In principle, all the physical assets can be damaged, financial losses can occur, natural assets can be degraded or even destroyed and social assets can be undermined. Climate variability can result in certain food products becoming scarce at certain times of the year. Such seasonal variations in food supply, along with vulnerabilities to flooding etc. can impact livelihoods. Although these impacts might appear indirect, they are important because many marginal livelihood groups are close to the poverty line. Food is a key element of their existence. The main source of livelihood for the marginal groups is agriculture, livestock rearing and fishing. In most instances the challenges encountered by the rural livelihoods drive urban migration. When the numbers of the poor and vulnerable groups in urban slums increase, the availability of employment opportunities which are non-agriculture/non-farm based and the access of urban dwellers to obtain sufficient food products from the market will become increasingly important drivers of food security. A study by the International Labour Organization study (ILO, 2005) reports that there will be significant variations among the low income and middle-income countries in regarding the impacts of climate variability on livelihoods dependent on agriculture. The livelihood groups that are of concern in the context of climate changes include the low-income group affected by drought and flood; those who have poor food distribution and emergency response mechanisms. For example, fishermen living along the coastlines may experience sea-surges, storms, tsunamis and their fishing infrastructures may be damaged. They can lose their homes constructed nearby that are washed away by the storms. What happens to their livelihoods then? In the same way farmers may experience flash floods, wherein their land can be completely submerged and their crops may be destroyed. So, such changing temperature and rainfall conditions can devastate their livelihoods immediately. Therefore, climate change has

serious consequences and affects the lives of a million people around the world.

Adaptation measures are necessary to address these concerns. They include preparing heat wave early warning systems, urban planning to reduce the urban heat island effect, better land-use planning, community relocation, reducing the vulnerability of essential services such as water, energy and food, and measures to assist vulnerable sectors and households. In addition, early warning systems and flood and cyclone shelters are also important health related adaptation strategies.

12.6 LET US SUM UP

Climate variability affects health and well being. Climate change and its associated diseases are presenting new risks. Climate change introduces new pests, microbial agents, and disease emergence. So, climate change is a critical public health issue. Changes in climate variability result in extreme weather events and changes in the ecosystems. These changes modify the vector habitats and favor the spread of diseases. Therefore, it is important to address climate change and raise awareness of the link between such change and diseases. Also, socio-economic factors such as land use change, population growth and urbanization, migration, and economic development all are impacted by climate change. These need to be understood well for risk assessment studies. We as individuals must help identify areas that are at greatest risk to climate change to help decision makers prioritize protective action plans. In this way we can support adaptation and mitigation of climate change to build healthier and sustainable communities. In this unit we have studied about climate change and its direct and indirect linkages to human health.

12.7 KEY WORDS

Health: Health can be defined as 'a complete state of physical, mental and social well-being and not merely the absence of disease or infirmity' (WHO).

Morbidity: A disease or condition that reduces health and the quality of life. The morbidity rate is a measure of the frequency of disease among a defined population during a specified time period.

Mortality: It is the number of deaths in a defined population during a specified time period.

Livelihood: Livelihoods can be defined as the different types of assets, abilities and activities that enable a person or household to survive (FAO, 2003).

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12.9 ANSWERS TO CHECK YOUR PROGRESS

Answers to Check Your Progress 1

1) Your answer should include the following points:

- Heat edema
- Heat rashes
- Heat cramps
- Heat stroke
- Kidney diseases
- Cardiovascular diseases

Answers to Check Your Progress 2

1) Your answer should include the following points:

- Dengue
- Chikungunya
- Zika virus
- Nipah virus
- Malaria
- Tularemia
- Spotted fever Rickettsia

2) Your answer should include the following points:

- Brucellosis
- Leptospirosis
- Avian flu
- Swine flu