Indira Gandhi National Open University
School of Interdisciplinary and
Trans-disciplinary Studies

MEV-022
IMPACTS OF CLIMATE CHANGE

Block

3

RESOURCES

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BLOCK-3 RESOURCES

Climate change is one of the major global environmental problem. Climate change is likely to have a significant impact on the availability of water and other natural resources. Any change in the climate will affect the soil moisture, groundwater recharge and frequency of flood or drought episodes and eventually, the groundwater level in different areas. As regards the energy resources, access to energy is essential for human development and for poverty eradication. However, evolution and trend in energy use and energy mix determines the energy security of nations, toxic emissions in cities and the extent of greenhouse gas emissions that cause global warming and destabilize climate. Energy demand is expected to grow more rapidly in the future due to population growth and lifestyle changes, increase in the level of economic activities such as mobility, information processing, manufacturing and growth of cities. Developing countries like India have an added challenge of meeting human development goals that will further increase demand for primary energy. Nevertheless, the potential impacts of climate change on energy resources are indeed very significant. Therefore, the challenge before us is to plan its energy transition well.

With regard to biodiversity, climate change is one of the prime factors responsible for the biodiversity loss. Climate as we know is a primary driver of many biological processes, transacting from individuals to ecosystems, and affects several facets of human life. Therefore, changing climate could cause large and likely serious impacts on ecological and social systems. Climate change is not only changing the biosphere and biodiversity in marine and terrestrial environments, it is also modifying ecosystem processes and changes the resilience of ecosystems to environmental change. Climate change and biodiversity are interconnected. Biodiversity is affected by climate change, with negative consequences for human wellbeing, but biodiversity, through the ecosystem services, also makes an important contribution to both climate-change mitigation and adaptation. With respect to infrastructure, the human population is facing challenges due to impacts of climate change on infrastructures like buildings, transportation. This block "Resources" deals with the impacts of climate change on water resources, energy resources, biodiversity and infrastructure.

Unit 9 "Water Resources" discusses the effects of extreme weather and climate events on water resources. The unit also discusses the effects of climate change on soil hydrology and explore the traditional and modern rainwater harvesting systems for artificial recharge of groundwater resources.

Unit 10 "Energy Resources" deals with types of energy sources, their potential and constraints. The unit also deals with energy security from the perspective of climate change, energy consumption, energy efficiency, and renewable energy.

Unit 11 "Biodiversity" delves into the vulnerability of biodiversity to the impacts of climate change, their inter-linkages and simultaneously covers the role of biodiversity in controlling climate change through adaptation and mitigation strategies.

Unit 12 "Infrastructure" deals with the impacts of climate change on buildings and transportation, and also impacts of sea level rise on infrastructure. Further, the unit highlights the measures of climate resilient infrastructure.

Objectives

After studying this block, you should be able to:

- discuss the climate change impacts on water resources;
- Discuss energy security from the perspective of climate change, energy consumption, energy efficiency, and renewable energy.
- Explain the vulnerability and impact assessment of biodiversity to the climate change;
- Identify the role of biodiversity in climate change mitigation and adaptation;
- Discuss the management responses to climate change impacts on biodiversity;
- Describe the impacts of climate change on buildings and transportation; and
- Explain the impacts of sea level rise on infrastructure.

We hope that after studying this block you will acquire an understanding of the effect of climate change on water resources, energy resources, biodiversity, building and transportation.

Wishing you success in this endeavour!

UNIT 9 WATER RESOURCES

Structure

9.1 INTRODUCTION

Climate change is not only a major global environmental problem but is also an issue of great concern to developing countries like India. Several studies around the globe show that climate change is likely to have a significant impact on the availability of water and other natural resources. Therefore, any change in the climate will affect the soil moisture, groundwater recharge and frequency of flood or drought episodes and, finally, the groundwater level in different areas. The good quality data is required for the assessment of the impact and variability to climate change and subsequently working out adaptation needs. This information includes climatic data, such as temperature, rainfall and the frequency of extreme events. This also includes non-climatic data, such as the current situation on the ground for different sectors including water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity, and coastal zones.

9.0 OBJECTIVES

After studying this unit, you should be able to:

- discuss the effects of extreme weather and climate events on water resources;
- explain soil erosion and the effects of climate change on soil hydrology;
- discuss the climate change impacts on water resources; and
- explore the traditional and modern rainwater harvesting systems for artificial recharge to groundwater resources.

9.2 EFFECTS OF CLIMATE CHANGE

The Earth's climate has considerably changed both on global and regional scales since the pre-industrial era. The changes observed in the regional climate have already affected many of the physical and biological systems and there are indications that social and economic systems have also been affected. Climate change is likely to threaten food production, increase water stress and decrease its availability, result in sea-level rise that could flood crop fields and coastal settlements and increase the occurrence of diseases. Water is a precious natural resource supporting human activities and ecosystems, and at the same time, very complex to manage judiciously. The hydrological cycle, a fundamental component of climate, is likely to be altered in important ways due to climate change. The projected climate change resulting in warming, sea-level rise and melting of glaciers will adversely affect the water balance in different parts of India and quality of groundwater along the coastal plains. Climate change is likely to affect groundwater due to changes in precipitation and evapotranspiration. Rising sea-levels may lead to increased saline intrusion into coastal and island aquifers, while increased frequency and severity of floods may affect groundwater quality in alluvial aquifers. Increased rainfall intensity may lead to higher runoff and possibly reduced recharge.

9.4 RAINFALL EXTREMES AND ITS IMPACT ON WATER RESOURCES

Meteorological records maintained since the 19th century, indicate that the Indian summer monsoon is reasonably stable. However, simultaneous occurrence of devastating floods in some areas and parching droughts in others is a common feature. The inter-annual variability of the monsoon is the cause of such contrasting features. It has been observed that regions with low seasonal rainfall also experience high variability, making them chronically drought prone.

The annual rainfall in India fluctuates widely. The long-term average annual rainfall for the country is 1160 mm, which is the highest anywhere in the world for a country of comparable size. You will be surprised that highest rainfall in India is about 11,690 mm, recorded at Mawsynram near Cherrapunji in Meghalaya, with an average of 1040 mm in a day. Rainfall reaches nearly to 2500 mm along almost the entire west coast and over most of Assam and sub-Himalayan West Bengal. Large areas of peninsular India receive rainfall less than 600 mm. On the other extreme are places like Jaisalmer in the west receive barely 150 mm. Annual rainfall of less than 500 mm is experienced in western Rajasthan and adjoining parts of Gujarat, Haryana and Punjab. A third area of low precipitation is around Leh in Kashmir. Rainfall is equally low in the interior of the Deccan plateau, east of the Sahyadris. As much as 21% of the area of the country receives less than 750 mm of rain annually while 15% receives rainfall in excess of 1500 mm. The rest of the country receives moderate rainfall. Snowfall is restricted to the Himalayan region.

A rainy day is defined as a day with a rainfall of 2.5 mm and above, as per the operational practice of the Indian Meteorological Department (IMD). The mean annual number of rainy days over India varies from less than 20 days over the north-western parts (west Rajasthan and Kutch region of Gujarat) to more than 180 days in the North-East (Meghalaya).

9.4.1 Indian Monsoon

The word monsoon is derived from 'mausim', an Arabic word, which means season and the word is applied to winds whose direction is reversed completely from one season to the next season. The Indian summer monsoon is a consequence of the thermal differences between the land and the sea. In general, it is primarily due to the seasonal shifting of thermally produced planetary belts of pressure and winds under continental influences. The normal duration of monsoon in India is about 100 to 120 days beginning from first June. In India, the two monsoon seasons: the southwest monsoon in June to September and the northeast monsoon in November–December, bring forth rains. During May, when the weather is very hot, the south-east trade winds from the south Indian Ocean cross the equator and extend rapidly into the north Indian Ocean. This westerly current, which extends from the Arabian Sea coast to the China Sea across India, is known as the southwest monsoon. The weather disturbances moving from the west result in snowfall as well as rainfall over the Himalayas and north India. In winter season, the wind currents over India blow from north to south. The north-east monsoon picks up moisture over the Bay of Bengal and produces rain over Tamil Nadu, is known as winter monsoon.

9.4.2 Temperature

All India and regional mean seasonal and annual surface air temperature for the period 1901-2000 indicate a significant warming of 0.4º C per hundred years. The data analyzed in terms of daytime and nighttime temperatures indicate that the warming is due to an increase in the maximum temperatures, while the minimum temperatures during 1901-1990 are based on data from 121 stations. It has been observed that over the central parts of India, the maximum temperature recorded exceed 45º C, while along the west coast, the extreme maximum temperatures recorded range between 35º - 40º C. Smaller values of extreme maximum temperature of around 25º C have been recorded in Himachal Pradesh in the north. The low temperature extremes dropping to less than -15º C have been recorded in the northern most parts of India.

9.4.3 Extreme Weather and Climate Events

In India, the climate and weather are dominated by the largest seasonal mode of precipitation in the world, due to the summer monsoon circulation. Over and above this seasonal mode, the precipitation variability has predominant inter-annual and intra-seasonal components, giving rise to extremes in seasonal anomalies resulting in large-scale droughts and floods, and also short-period precipitation extremes in the form of heavy rainstorms or prolonged breaks on a synoptic scale. Indeed, rainfall during a typical monsoon season is by no means uniformly distributed in time on a regional/local scale, but is marked by a few active spells separated by weak monsoon or break periods of little or no rain. Thus, the daily distribution of rainfall at the local level has important consequences in terms of the occurrence of extremes. Further, the Indian climate is also marked by cold waves during winter in the north, and heat waves during the pre-monsoon season over most parts of the country. Tropical cyclones, affecting the coastal regions through heavy rainfall, high wind speeds and storm surges, often leave behind widespread destruction and loss of life, and constitute a major natural disaster associated with climatic extremes. Indeed, it is these extremes that have the most visible impact on human activities and therefore, receive greater attention by all sections of the society.

9.4.4 Droughts and Floods

Indian summer monsoon is a very stable and dependable source of water for the region. Superimposed on this stable picture are seemingly small year-to-year changes that can be spatially quite extensive. However, even such small changes constitute significant inter-annual variability, leading to widespread drought and flood situations. Instrumental records over the past 130 years do not indicate any marked long-term trend in the frequencies of large-scale droughts or floods in the summer monsoon season. The only slow change discernible is the alternating sequence of multi-decadal periods of more frequent droughts, followed by periods of less frequent droughts. This feature is part of the well-known epochal behaviour of the summer monsoon.

9.4.5 Aridity

There are large tracts in north-western India and the interior peninsula that experience arid conditions. Desertification is a complex environmental process involving geomorphologic and atmospheric processes; it is observed that the rainfall regimes generally closely demarcate the arid region boundaries. In general, during extreme deficient years of South West monsoon over the Indian subcontinent, aridity takes over the semi-arid areas and its spatial extent continues deep down south to the peninsula. On an average, about 19 percent of the country experiences arid conditions every year, of which 15 percent is in northern India.

9.4.6 Current Climate and its Variability in India

India is subject to a wide range of climatic conditions from the freezing Himalayan winters in the north to the tropical climate of the southern peninsula, from the damp, rainy climate in the northeast to the arid Great Indian Desert in the northwest, and from the marine climates of its vast coastline and islands to the dry continental climate in the interior. Almost all regions of the country receive their entire annual rainfall during the summer from southwest monsoon, while some parts of the southeastern states also receive rainfall during early winter from the northeast monsoon. Rainfall increases by almost three orders of magnitude from west to east across the country.

Check Your Progress 1

Note: 1) Use the space given below for your answers.

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

1. What are the effects of climate change on biological system?

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2. Define rainy day.

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9.5 SOIL EROSION

9.5.1 Geological Erosion

Soil erosion is an inevitable process. Erosion is a process that transforms soil into sediment. Soil erosion that takes place naturally, without the influence of human activities, is termed geological erosion. It is a natural levelling process. It inexorably wears down hills and mountains, and through subsequent deposition of the eroded sediments, it fills in valleys, lakes and depression. The vast deposits that now appear as sedimentary rocks originated in this way. The rate of geological soil erosion varies greatly with both rainfall and type of material comprising the regolith. Geological erosion by water tends to be greatest in semiarid regions where rainfall is enough to be damaging, but not enough to support dense, protective vegetation. Areas blanketed by deep deposits of silts may have exceptionally high erosion rates under such conditions.

9.5.2 Accelerated Erosion

Accelerated erosion occurs when people disturb the soil or the natural vegetation by grazing livestock, cutting forests for agricultural use, plowing hillsides, or tearing up land for construction of roads and buildings. Accelerated erosion is often 10 to 1000 times as destructive as geological erosion, especially on steep hills in regions of high rainfall. Under the influence of accelerated erosion, soil is commonly washed or blown away faster than new soil can form. In severe cases, gently rolling terrain may turn into deep gullies, and once-forested hillsides may be stripped down to bare rock.

9.5.3 Mechanics of Water Erosion

Soil erosion by water is fundamentally a three step process: 1) Detachment of soil particles from the soil mass; 2) Transportation of the detached particles downhill by floating, rolling, dragging, and splashing; and 3) Deposition of the transported particles at lower elevation. On comparatively smooth soil surfaces, the beating action of raindrops causes most of the detachment. Where water is concentrated into channels, the cutting action of turbulent flowing water detaches soil particles. In some situations, freezing-thawing action also contributes to soil detachment.

9.5.4 Types of Water Erosion

Three types of water erosion are generally recognized: 1) sheet, 2) rill and 3) gully. In sheet erosion, splashed soil is removed more or less uniformly, except that tiny columns of soil often remain where pebbles intercept the raindrops. However, as the sheet flow is concentrated into tiny channels (termed rills), rill erosion becomes dominant. Rills are especially common on bare land, whether newly planted or in fallow. Sheet erosion takes place primarily between irregularly spaced rills, it is called inter-rill erosion. When the volume of runoff is further concentrated, the rushing water cuts deeper into the soil, deepening and coalescing the rills into larger channels termed gullies. This is gully erosion. All three types may be serious, but sheet and rill erosion, although less noticeable than gully erosion are responsible for most of the soil moved.

9.5.5 Controlling the Cutting Action of the Flowing Water

Freshly exposed and disturbed subsoil material is highly susceptible to the cutting action of flowing water. Gullies may ruin a grading job, undercut pavements and foundations, and also produce enormous sediment loads. The flow of runoff water must be controlled by carefully planned grading, terracing and channel construction. Most construction sites require a perimeter waterway to catch runoff before it leaves the site and to channel it to a retention basin. The sides and bottom of such channels must be covered with “armour” to withstand the cutting force of flowing water. Where high water velocities are expected, the soil must be protected with hard armour such as riprap (large angular rocks), gabions (rectangular wire-mesh containers filled with hand-sized stone), or interlocking concrete blocks. The soil is first covered with a geotextile filter cloth (a tough nonwoven material) to prevent mixing of the soil into the rock or stone.

In smaller channels, and on more gentle slopes where relatively low water velocities will be encountered, soft armour, such as grass sod or erosion blankets, can be used. Generally, soft armour is cheaper and more aesthetically appealing than hard armour. Newer approaches to erosion control often involve reinforced vegetation (e.g. trees or grasses planted in openings between concrete block or in tough erosion mats). The term bioengineering describes techniques that use vegetation (locally native, non-invasive species are preferred) and natural biodegradable materials to protect channels subject to rather high water velocities. In this technique, live tree branches are tightly bundled together, staked down flat using long wooden pegs, and partially covered with soil. The soil is provided some immediate physical protection from scouring water, and eventually the dormant cuttings take root to provide permanent, deep-rooted vegetative protection.

9.5.6 Effects of Climate Change on Soil Hydrology

Some aspects of predicted climate change are likely to influence soil hydrological regimes considerably. With a global increase in temperature and localized decrease in rainfall, many soils will become drier, especially in continental interiors. Greater winter rainfall and earlier spring snowmelt at higher latitudes and altitudes could partially offset summer drying. However, a poleward shift in the mid-latitude cyclonic belts of high winter rainfall could negate the effect of winter rain on the equator ward side of these belts. This would lead to increasingly frequent failures to return to field capacity in winter and the need for more extensive summer irrigation to maintain agricultural production. In other regions, where rainfall increases, more efficient field and arterial drainage schemes to remove excess winter rainfall will be required.

The effects on plant growth in areas subject to an increasingly arid climate are likely to be greater than in those experiencing increased winter rainfall. Increasing evaporation could lead to greater capillary rise of groundwater and increasing soil salinization. The combined effects of increased desiccation, soil erosion and salinization may well increase the rate of desertification in areas where it is currently already on the increase as a result of unsuitable agricultural activities such as overgrazing and intensive cultivation. Changes in soil moisture are also important because they can lead to feedbacks involving water vapour, which is an important 'greenhouse' gas and a source of precipitation. Higher temperatures increase evaporation from the oceans and wet soils, and the larger amounts of water vapour in the atmosphere and a denser cover of low clouds would then accentuate winter warming. This would probably occur most strongly on the equator ward side of the mid-latitude storm belts, thus shifting the axis of maximum rainfall poleward and accentuating the changes in summer soil moisture. Rainfall is likely to decrease with global warming, in eastern China and southern USA.

Organic-rich peat soils in wetland areas emit CH_4, they also sequester C and N from the atmosphere because of rapid plant growth and decreased mineralization in waterlogged anaerobic conditions. So, although drainage and exploitation of peat soils for agriculture and horticulture have decreased CH_4 emissions slightly, they have probably contributed to global warming in the twentieth century by increasing CO_2 and N_2O emissions.

9.6 GLOBAL WATER RESOURCES

The world's total water resources are estimated 1.37 x 10^8 million ha-m. Of these global water resources, 97.2% is salt water (mainly in oceans) and 2.8% is fresh water. Out of 2.8% of fresh water, 2.2% is surface water and 0.6% is groundwater. Again, out of 0.6% stored groundwater, only about 0.3% can be economically extracted with the present drilling technology. Water is available in a highly irregular fashion. It is not available in places where we want it and at times when we want it. The pace of development and the great increase in population in the urban areas led to the over use of surface supplies and over-exploitation of groundwater. According to the Ministry of Water Resources, the water availability in India may be able to meet the requirements till the year 2050, through integrated water management plans.

9.7 CLIMATE CHANGE IMPACT ON WATER RESOURCES

Climate change will affect water resources through its impact on the quantity, variability, timing, form and intensity of precipitation. Relatively small climatic changes can cause large water resource problems, particularly in arid and semi-arid regions of India. Apart from monsoon rains, India uses perennial rivers, which originate and depend on glacial melt-waters in the Hindu Kush and Himalayan ranges. Since the melting season coincides with the summer monsoon season, any intensification of the monsoon is likely to contribute to flood disasters in the Himalayan catchment. Rising temperatures will also contribute to the raising of the snowline, reducing the capacity of this natural reservoir, and increasing the risk of flash floods during the wet season. About one-fourth of the area of Gujarat and 60% of the area of Rajasthan are likely to experience acute physical water scarce conditions. The river basins of Mahi, Pennar, Sabarmati and Tapi are likely to experience constant water scarcities and shortage. The river basins of Cauvery, Ganga, Narmada and Krishna are likely to experience seasonal or regular water stressed conditions. On the other hand, it is apparent that the projected climate change leading to global warming, sea level rise and melting of glaciers will disturb the water balance in different parts of India and quality of groundwater along the coastal track. Possible effects of climate change on groundwater are reduced groundwater recharge due to changes in precipitation and evapotranspiration, increased saline intrusion of coastal and island aquifers due to rising sea levels and poor groundwater quality in alluvial aquifers due to possible increase of flood events.

9.8 WATER HARVESTING SYSTEMS

Water is fast becoming a scarce resource. Drought is a reality in the rural areas, and water scarcity a part of urban life. The problem is so severe that even Cherrapunji, the place that records the maximum amount of rainfall in the world, is now facing a water crisis. With increasing urbanization and better irrigation management may bring down the demand of water for agriculture a little, domestic water demands, especially the need for potable water, is bound to increase. So to increase the availability of usable water, there is a need to opt for desalination plants, community rainwater harvesting, river bunding, recycling wastewater and roof top water harvesting.

There are years of very good rainfall and even in low rainfall years, high runoff occurs due to flash floods in a short duration and high intensity precipitation. If this flood discharge is harnessed and utilized for recharging the depleted aquifers, there will be sufficient improvement in the availability of quality of groundwater. Due to urbanization, the soil surface exposed to the recharge gets drastically reduced and therefore natural recharge gets diminished. The general methods of artificial recharge are spread or basin method, pit method, induced recharge and well method. Rainwater harvesting to recharge the groundwater resources becomes necessary when in a given basin or area, the annual withdrawal of groundwater exceeds the annual replenishment. This replenishment of water resources brought out by man's action is known as artificial recharge. This can be defined as a process by which infiltration of surface water in the groundwater system is increased by altering natural conditions.

Objectives of Artificial Recharge including Water Harvesting

- To retrieve the depleted aquifer;
- To prevent salt water intrusion into the coastal aquifer;

- To improve the groundwater quality;
- To prevent land subsidence;
- To store fresh water in the underground for subsequent use;
- To provide subsurface distribution system to establish well fields; and
- To facilitate conjunctive use of surface and groundwater reservoirs.

Pre-requisites for Artificially Recharging the Groundwater Reservoirs

- Availability of proper site for artificial recharge;
- Availability of adequate amount of fresh water;
- Availability of good aquifers;
- Availability of adequate head; and
- Cost effective.

Causes for Depletion of Groundwater Levels

- Erratic rainfall;
- Diminishing of water bodies in urban areas;
- Over-exploitation of groundwater resources;
- Increase in the number of groundwater structures annually; and
- Frequent drought periods have an effect on the lowering of water table.

Remedial Measures for Groundwater Depletion

The most widely used practices and methods for artificial recharge of groundwater employ different techniques of increasing the contact area and residence time of surface water with the soil so that maximum quantity of water can infiltrate and augment the groundwater storage. The choice of particular method is governed by local hydrogeological (topography and geology) and soil conditions, and the quantity of water to be recharged.

- **Rainwater Harvesting:** Rainwater harvesting and artificial recharge made compulsory in the areas where groundwater withdrawal has increased over the annual replenishment.

- **Water Conservation:** Water has to be conserved in the water deficit areas adopting better water use techniques like drip and sprinkler systems in agricultural activities.

- **Change of Cropping Pattern:** Cropping pattern has to be changed from high water requirement crops to low water intensity crops in arid and semi-arid areas besides encouraging salinity resistant crops.

- **Recycling of Wastewater:** Recycling the industrial wastewater and sewage to meet the demand of industry and non-domestic uses in urban and industrial areas.

- **Inter-basin Transfer of Water:** There is large amount of surplus water in certain river basins, which can be transferred to deficit river basins to meet the water demand.

9.8.1 Traditional Water Harvesting Systems

Ancient Indians found water harvesting structures so important and useful. In the western and Central Himalaya, diversion channels called kuhis or guhis were built to draw water from hill streams or springs. The "zabo system of cultivation" is a combination of "agriculture", "forestry", and "animal husbandry" with an aim to contain soil erosion. This is practiced in the kikruma village of Nagaland. The ahar-pyre system of irrigation was used in south Bihar**.** The "traditional water harvesting structures" in Karnataka are arakere, volakere, devikere, katte, kunte and kola. In the Kasargod district of Kerala, a water harvesting structure called "Surangam" is popular. The "Surangam" consists of a tunnel which is dug through the hillock made of laterite; water seeps out from the periphery. In Tamilnadu, ancient tanks called "eris" were used to irrigate about 1/3rd of irrigated area. The "eris" has several advantages such as "flood control", "control of soil erosion", "groundwater recharge", etc. In the Nicobar Islands, the indigenous people like the Shompens, and Jarawas use "split bamboos" in their traditional water harvesting structures. Collective action was the most important aspect of people's management of traditional water systems in the northeastern part of India. Several hundred years ago, tribals in Meghalaya developed procedures of harvesting water from hill streams through bamboo pipes for irrigating betel leaf crops on steep slopes. The major traditional water sources in arid Rajasthan were nadis, dugwells and tankas. Kunds found in the sandier tracts of the Thar Desert in Rajasthan, are covered underground tanks with an artificially prepared catchment area to increase runoff. Maldharis are nomadic people inhabit the vast expanse of undulating Banni pasturelands located in the desert areas of the northern Kutch district of Gujarat. The tough climatic conditions and scanty rainfall have forced them to develop the wonderful technology of virdas – shallow wells dug in low depressions tanks.

9.8.2 Modern Water Harvesting Systems

Urban Areas

Rooftop Water Collection and Recharge: Commonly runoff water from rooftops in the urban areas is let off into the drains. Instead of this, the outlets can be connected through a pipe to a storage tank and let into gravel filled trenches, pits or existing wells, etc., to serve as recharge pits. It also helps in reducing the water scarcity problem of cities and towns. This method is less expensive and very effective.

Storm runoff Collection and Recharge: The storm runoff generated within an area can be utilized for groundwater recharging by diverting it into suitably designed structures near pavements, parking lots, municipal parks, play grounds, stadium, airports, etc.

Recycling of Household Water: Recycling and reusing of water is another important activity, which needs to be adopted by urban households. All the water from wash basins and bathrooms (other than sewage) can be let out into the garden or backyard and excess water, if any, can be let into soak pits that can regenerate the groundwater.

Rural Areas (Runoff Conservation Structures)

Different measures applicable in runoff zone, recharge zone and storage zone of watershed are available in rural areas.

Gully Plug: Gully (channel cut by stream) plugs are the smallest runoff conservation structures built across small gullies and streams rushing down the hill slopes carrying drainage of tiny catchments during rainy season.

Bench Terracing: Sloping land with surface gradients up to 8% having adequate soil cover can be leveled through bench terracing for bringing under cultivation.

Contour Trenching and Bunding: Contour trenching and bunding is watershed management practice to build up soil moisture storage. This technique is adopted generally in low rainfall areas where the monsoon runoff impounded by putting trenches and bunds on the sloping ground all along the contour of equal elevations.

Rock fill Dam or Nala Bund: A series of small bunds or weirs are made across selected nala sections such that the flow of surface water in the stream channel is impeded and water is retained on pervious soil/ rock surface for longer time.

Check Dam: A check dam is a masonry structure of small length and low height constructed across a stream to arrest surface runoff of the stream.

Percolation Tank: A percolation tank is essentially the same as that of normal tank without sluice, supply channel and an identified ayacut.

Sub-surface Dam: A subsurface dam is constructed below ground level and arrest the flow in a natural aquifer.

Check Your Progress 2

Note: 1) Use the space given below for your answers.

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

1. What is artificial recharge?

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2. Suggest remedial measures for ground water depletion.

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9.9 LET US SUM UP

The changes observed in the regional climate have already affected many of the physical and biological systems and there are indications that social and economic systems have also been affected. The average annual rainfall in India fluctuates widely from 1160 mm to 150 mm. The temperature extremes vary widely from 40ºC to less than -15º C have been recorded in the northern most parts of India. The climate extremes have most visible impact on human activities and therefore, receive greater attention by all sections of the society. Desertification is a complex environmental process involving geomorphologic and atmospheric processes. Three types of water erosion are generally recognized. The climate change is likely to influence soil hydrological regimes. Climate change will affect water resources through its impact on the quantity, variability, timing, form and intensity of precipitation. Increasing urbanization and better irrigation management have brought down the demand of water for agriculture, domestic water demands, especially the need for potable water has increased.

9.10 KEYWORDS

Indian Monsoon : The seasonal shifting of thermally produced planetary belts of pressure and winds under continual influences.

Hydrological Cycle : The general circulation of water between land, atmosphere and sea in a cyclic manner.

Desertification : It is a complex environmental process involving both geomorphological and atmospheric processes.

Water Harvesting : Method used for recharging the depleted groundwater resources.

9.11 SUGGESTED FURTHER READING/ REFERENCES

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Agarwal A., and Narain, S. (1997). Dying Wisdom – Rise, fall and potential of India's traditional water harvesting systems, Centre for Science and Environment, New Delhi.

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9.12 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. The climate change effects on the biological system include negative impacts on agricultural production system, public health, and increased occurrence of vector-borne diseases, etc.

2. A rainy day is defined as a day with a rainfall of 2.5 mm and above as per the Indian Meteorological Department, IMD.

Check Your Progress 2

1. It is defined as a process by which infiltration of surface water in the ground system is increased by altering natural conditions.

2. Remedial measures for ground water depletion are:

   a. By rainwater harvesting and increasing artificial recharge;

   b. By conserving water resources and changing crop pattern; and

   c. Recycling of waste water and inter-basin transfer of water.

UNIT 10 ENERGY RESOURCES

Structure

10.1 INTRODUCTION

Growing population and associated developments increase the energy demand. We constantly transform energy into heat, light and motion. Access to energy is essential for human development and for poverty eradication. However, evolution and trend in energy use and energy mix determines the energy security of nations, toxic emissions in cities and the extent of greenhouse gas emissions that cause global warming and destabilize climate.

Energy demand is expected to grow more rapidly in the future due to population growth and lifestyle changes, increase in the level of economic activities such as mobility, information processing, manufacturing and growth of cities. Two-third of world's energy is consumed in cities – by half of world's population. By 2030, cities will be consuming 73 per cent of world's energy.

At the same time, developing countries like India have an added challenge of meeting human development goals that will further increase demand for primary energy. India's current consumption of energy is quite low and so is the energy related greenhouse gas emissions compared to the industrialized countries. This is mainly because millions of poor households do not have access to modern energy. But this is expected to grow with growing affluence and increased access to electricity and other energy sources.

Therefore, the challenge before India and other developing countries is to plan its energy transition well. They can avoid energy intensive growth with energy efficiency and conservation measures and low carbon strategy during the early stages of growth. They need to ensure equitable access to energy. This can curb energy demand without compromising human development and poverty eradication goals. This can avoid substantial increase in future emissions, and, strengthen energy security. You will learn about these issues in this unit.

10.2 OBJECTIVES

After studying this unit, you should be able to:

- explain different types of energy sources, their potential and constraints; and
- discuss energy security from the perspective of climate change, energy consumption, energy efficiency, and renewable energy.

10.3 OVERVIEW OF ENERGY SOURCES

Let us first understand the primary energy sources that drive our economy and lifestyle. We can harness an amazing range of conventional and non-conventional or renewable energy sources.

- **Fossil Energy:** Petroleum, natural gas, and coal are examples of stored chemical energy in fossil fuels.
- **Nuclear Energy:** It is stored in the nucleus of an atom and very large amounts of energy can be released when the nuclei are combined or split apart.
- **Renewable Energy:** These include geothermal heat; gravitational force of tides and hydropower, rotational forces of ocean currents, the solar flux including wind, waves and sunlight, etc. These can be extracted, collected, concentrated, transformed, transported, and distributed as needed.

The mix and extent of the use of these energy sources vary quite widely across sectors and countries.

10.3.1 Non-renewable Energy Sources

The conventional energy sources, mainly the fossil fuels that dominate our energy system today are exhaustible. Fossil fuels such as petroleum, natural gas, and coal take millions of years to form and are practically considered 'non-renewable'. Fossil fuels dominate the global energy markets to meet the ever-increasing demand for heat, electricity and transport fuels. These fuels are responsible for both toxic pollution and heat trapping gases like carbon dioxide. Combusting fuels at increasing rates will release more carbon and add to the existing carbon stock. At a global scale, fossil fuel account for around 70-80 percent of total energy related warming emissions including carbon dioxide, methane and some traces of nitrous oxide. In most of our cities combustion of these fuels spew sulphur dioxide, carbon monoxide, particulate matter, nitrogen oxides and a range of toxic gases that have serious health effects.

In India, fossil fuels dominate the fuel basket just as in other parts of the world. The share of coal in India's primary energy is more than 40 percent, nearly same for oil and gas. In the specific sector of electricity generation, coal continues to dominate at 72 percent. Coal will remain important energy source until 2030. World and India will require massive transformation in energy system to reduce dependence on fossil fuels to combat global warming.

10.3.2 Renewable Energy Sources

Energy that can be naturally replenished is renewable energy. This includes traditional biomass like firewood, agro-waste, dungs and also new renewables like small hydro, biofuels wind, solar, geothermal, tides, and geothermal heat. These are considered environmentally sustainable as they are low to zero carbon fuels.

The actual share of modern renewables of solar and wind energy, etc. in India is significantly low (about 2 percent of the total). But the renewable energy's share of total electric capacity is more than twice that of the US, and India is among the top five countries in renewable capacity. Future strategies will have to enable more rapid expansion of the renewable energy programme.

Why traditional biomass is low carbon fuel? Biomass has carbon. But this carbon is part of the current carbon cycle. The carbon that already exists in the atmosphere is absorbed during the growth of the plants. During photosynthesis, the trees store carbon in their woody tissue and oxygen is released back to the atmosphere. As the wood is burned, the carbon stored in the woody tissue combines with oxygen to produce carbon dioxide, this is emitted back and returned to the atmosphere. As a result, a sustainable balance is maintained between carbon emitted and absorbed. There is no net addition of carbon. The challenge is therefore to innovate to burn this fuel clean to minimise health impacts while benefiting from its low carbon potential.

Check Your Progress 1

Note: 1) Use the space given below for your answers.

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

1. Elaborate the different types of energy sources.

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2. Why traditional biomass is carbon neutral?

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10.3.3 Trends in Energy Consumption

Global primary energy demand has grown phenomenally. International Energy Agency projects that this will continue to grow by more than half between 2005 and 2030. Fossil fuels will form 84 per cent of overall increase in global demand between 2005 and 2030. In the global fossil fuel basket, oil is the single largest fuel though coal has witnessed the biggest increase in consumption. Currently, the industrialized countries have the maximum share of energy consumption. The developing countries are also expected to see significant increase as their economies begin to grow.

India's Integrated Energy Policy of 2006 says that if India needs to sustain 8-10 per cent increase in economic growth rate over next 25 years to eradicate poverty and meet human development goals, India will have to increase primary energy supply by 3-4 times and electricity capacity generation by 5-6 times from 2003-04 levels. As a result, India will have to expand its energy resource base, seek new energy sources, and make energy use more efficient.

However, despite the growth in energy demand by 3.5 per cent per annum, energy demand per capita has remained extremely low in India – one of the lowest in the world. It is one tenth of the average of the OECD countries. This is largely because of India's large rural population. Also the gains from recent growth have not flowed proportionately to the poor. In 2005 the bottom 40 percent still consumed only 13 percent of electricity demand. The World Bank estimates that despite declining poverty rates, the absolute number of poor in Indian villages has hardly reduced. Therefore, leapfrogging to modern renewable and sustainable use of traditional biomass will play a role in Indian villages. However, economic growth, urbanization and changing lifestyle will be the main drivers of energy demand.

10.3.4 Trends in Energy Intensity

It is also possible that while absolute energy consumption increases, efficiency of energy use can improve. There is a difference between the absolute increase in energy consumption and trend in the energy intensity. If we can use our energy more efficiently to produce a unit of output the energy intensity will decline and make our energy use more efficient. The energy intensity is the measure of total energy per unit of gross development product.

The projected global primary energy intensity is actually falling on an average by about 1.8 per cent per annum globally over 2005-2030 period. Why? Rapid changes in the economy that is moving away from heavy manufacturing towards lighter industries; increase in share of less energy intensive service activities; and overall efficiency gains due to improved technologies.

According to the India's Integrated Energy Policy energy intensity of India's growth is falling and is about half of what it used to be in early seventies. The Integrated Energy Policy estimates that India's energy intensity can be cut by up to 25% from current levels through efficiency measures. Currently, India consumes 0.16 kg of oil equivalent (kgoe) per dollar of GDP expressed in purchasing power parity terms. India's energy intensity is lower than the 0.23

kgoe of China, 0.22 kgoe of the US and a World average of 0.21 kgoe. Lowering the energy intensity of GDP growth through higher energy efficiency is important for meeting energy challenge and ensuring energy security.

India's advantage is the rapid growth of the service sector at a rate well above industry growth. Services are less energy consuming than manufacturing. Services contribution to the economy has grown from 44 percent in 1990 to 54 percent in 2018. If this continues, energy intensity will decline further. Another reason is relatively high prices of industrial energy and electricity. This has restrained energy demand and reduced energy intensity of industries. Steel and cement industries are important examples. All new industrial plants can adopt technologies that can improve energy efficiency from the current 36 percent to at least 38-40 percent.

10.4 ENERGY SECURITY

To meet the basic needs of economic and human development, countries have to ensure adequate, affordable, reliable supplies of energy, diversity of primary energy mix and fuel substitution. This reduces risks in an energy constrained world and in nutshell called energy security.

India cannot satisfy its full energy needs from the energy produced domestically. India's import dependence is steadily increasing. India's Integrated Energy Policy states that India would need to import some 40-45 percent of its total commercial energy requirement by 2030 compared to the current level of under 30 percent today. Even to ensure that import dependence does not exceed 40 per cent, domestic commercial energy supplies will have to rise four times in aggregate over the next 25 years.

India is already importing nearly 75 per cent of its petroleum crude requirements. It is also importing liquefied natural gas and coal. This makes India vulnerable to vagaries in international fuel supplies and prices. Therefore, the energy transition will have to be well managed to maximize energy efficiency and savings and substitution with low carbon energy.

10.4.1 Energy and Climate Change

Increasing energy consumption results in diverse environmental problems. Greenhouse gases emissions too increase due to increased energy consumption particularly the burning of fossil fuels. As per the Paris Agreement, we must take measures to limit GHG so that global mean surface temperature is well below 2^{o}C from the pre-industrial levels. To achieve the WB2C (well below 2^{o}C) goal, we must take measures to "reduce the GHG emissions by 50-85% on 2000 levels by 2050". The IPCC also has stated that in order to stabilize the GHG emissions, the global emissions must plateau and thereafter reduce. In order to achieve the goals of Paris Agreement, we need to be innovative and also transform the energy use strategies.

Reducing fossil fuel energy consumption is a difficult challenge. For instance, despite the commitment of the industrialized countries under the Kyoto protocol of the international climate convention to reduce their CO_2 emissions from the 1990 levels, emissions have actually increased. Their emissions from energy producing facilities have jumped by 24 per cent and transport emissions by 28 per cent between 1990 and 2005. Emissions are still increasing when emissions will have to be cut by 50-85 per cent.

Since the fossil fuel energy is comparatively cheap and abundant, their use is difficult to contain. Indeed, fossil fuel meet 80% of world primary energy demand and also it is reported that its use is likely to increase in the coming 30 years, provided if the policies pertaining to "low carbon emissions" are promoted on war footing. As regards GHG emissions by India, the energy sector contributes about 60% and hence there is a dire need to promote low carbon emission technologies and low carbon pathways.

10.4.2 Energy Consumption and Equity

Even as the world takes step to drastically cut energy use and emissions, it must not compromise human development goals. We need to use commercial energy more equitably to protect every human's development rights and use new technologies and save fuels to deliver a threshold level of development.

Do you know, there is enormous difference in the carbon emissions of nations? The more prosperous a country's economy is, and the higher its per capita income and fossil fuel use, higher is the per capita emissions. Although every human being contributes to carbon dioxide concentrations in the atmosphere, the person's life-style decides the amount that is emitted.

The prosperity of the industrialized nations have caused years of 'historical' emissions that have been accumulating in the atmosphere since the start of the Industrial Revolution. The CO_2 emissions stay in the atmosphere for more than 100 years. The emissions since the 1800, when the western world was industrializing, is still in the air and has caused most of the warming already.

Now, what will developing countries do? Their per capita emissions are still comparatively low. But their emissions will increase as they industrialize rapidly and build their infrastructure. They therefore need the atmospheric space to emit and grow but sustainably. India with over 17 per cent of the world's population has access to only about 3.8 per cent of world's commercial energy. Even though India is the fourth largest emitter of carbon dioxide in the world, its per capita carbon footprint is less than one-tenth of that in high-income countries. The per capita emission of CO_2 from fuel combustion in the US is still roughly 20 tonnes per year; between 6 tonnes and 12 tonnes for most European countries; and in case of India, it is only 1.1 tonnes.

To meet its human development and poverty eradication goals, India would need to increase its energy use by 2031-32. But even then India's per capita energy consumption will remain just about 74 percent of the current global average. On considerations of equity alone, therefore, India will need a certain level of energy consumption by 2031-32. India and other developing countries can grow only if there is an international agreement by which the industrialized countries reduce their fossil energy consumption and emissions drastically to create atmospheric space for the developing and poor countries to grow. Through the United Nations Framework for Climate Change, the global emissions budget will have to be distributed among nations equitably recognizing that each individual has equal entitlement to global atmospheric commons. This requires sharing of the growth between nations and between people while future growth happens on the basis of low carbon energy pathways.

10.4.3 Managing Energy Transition

The energy impact of the economic growth can be minimized in a variety of ways. Countries can use technologies that are more energy efficient, adopt energy conservation measures in all sectors so that absolute fuel savings is possible, expand use of low carbon and carbon neutral energy sources, achieve zero emissions and curb demand for energy. But each of the energy systems and approaches has their unique potential and constraints that need to be understood for effective planning and implementation.

10.4.4 Energy Efficiency

Lesser the energy input per output more efficient is the process and less fuel we use. Energy efficiency is the ratio between output of an energy service like light, heat, mobility – and the input of energy. There is considerable scope for further improvement in energy savings in sectors that are still inefficient.

Various strategies have been identified in the Enhanced Energy Efficiency Mission under National Action Plan on Climate Change in India. This has proposed market based mechanism to promote energy efficiency in large industry and facilities; rapid shift towards energy efficient appliances and use of demand management programmes for reducing demand for energy. This also includes energy efficiency regulations for vehicles that guzzle enormous amount of fuel. As coal is a dominant fossil fuel in our energy basket, efficiency measures are very important. Synthesis of five climate studies in India under the aegis of Ministry of Environment and Forests shows that India will massively expand energy infrastructure between now and 2030. This needs technologies viz. clean coal and otherwise to 'avoid' substantial increase in emissions. The average gross efficiency of coal power plants can be improved substantially from 30.5 percent to 38-40 percent. Thus, a very high priority should be given to increasing the thermal efficiency of current technology. For example, Integrated Gasification Combined Cycle (IGCC) can give 50 per cent efficiency. The challenge is to lower costs and make it work with different kinds of coal. The other emerging option is the CO_2 from the power plant is captured, compressed and transported for underground storage. But this technology of carbon capture and storage are uncertain. This is currently being done in Norway, North Dakota and Algeria. But there are concerns over costs and safety.

10.4.5 Potential and Constraints of Less Carbon Intensive Fuels

Shift to fuels with lower carbon content and carbon intensity is the need of the hour. For instance, coal emits almost 75 percent more carbon per unit of energy contained in the fuel than natural gas and one third more than oil. So switching from coal to oil and from oil to gas reduces emissions per unit of energy consumed. However, each energy system will have its unique potential and constraints.

Hydro Power

There is large unexploited hydro power potential in India. But this will have to be planned to overcome constraints. For instance, storage of water for hydel projects often involves displacement of people and submergence of land as in the case of Narmada dam and Tehri dam. Also, storage schemes may have other environmental consequences. These problems are not unsurmountable. But they have not been adequately attended to in the past.

Natural Gas

Natural gas is less carbon intensive than conventional liquid fuels. It is estimated that global demand for gas will expand by over half between 2006 and 2030. Most of this will be used in the power sector. Its use in the power sector accounts for 57 per cent of the projected increase in world gas demand to 2030. In India, Gas Authority of India Ltd (GAIL) is expanding the national gas grid. Nearly 200 cities can come within its ambit. However, domestic availability of natural gas cannot meet the full demand in different sectors. India is already importing natural gas.

Nuclear Energy

Nuclear power supplies about 6 percent of the world's primary energy and 15 per cent of electricity (less than renewables and hydro supply). The bulk of this, about 85 percent is in industrialized countries. Future addition of at least 1,000 megawatts of electricity by 2050 can help 'avoid' 1,800 million tonnes of carbon equivalent emissions from coal-fired plants globally. But this is possible only if costs reduce substantially. The capital costs of nuclear plants are more than double the cost of pulverized coal plants.

India is also planning to expand this power source to ensure long-term energy security. Integrated Energy Policy estimates that even if a 20-fold increase takes place in India's nuclear power capacity by 2031-32, the contribution of nuclear energy to India's energy mix is, at best, expected to be 4.0-6.4 percent. The major barriers are: long-term fuel resource constraints without recycling; economics; safety; waste management; security; proliferation, and adverse public opinion. India is also constrained by limited availability of Uranium.

Biofuels

Biofuels are processed from vegetative sources. The biofuels widely used today are largely ethanol from corn and sugarcane and are blended with petrol. Biodiesel produced from variety of crops including soyabean, jatropha, pongamia, etc. is blended with diesel. But these traditional biofuels have marginal climate benefits as their production and processing are energy intensive on a lifecycle basis. But the new generation biofuels that include cellulosic feedstocks derived from waste, agricultural residue, energy crops grown on degraded lands can give GHG benefits of 50-80 percent. Therefore, biofuels should be assessed on the basis of lifecycle emission. India is also expanding biofuel programme based on non-edible tree crops—jatropha for example—grown on wasteland. This will need proper policy safeguards to protect food and ecological security.

On the flip side, energy plantation can lead to extensive land-use changes. Cropped areas and forests can be diverted to produce biofuels. This can adversely affect food security. The Food and Agriculture Organization (FAO) says food prices will increase between 20 and 40 percent in the next 10 years or so because of this switchover. Also if forests are cut to expand biofuel crop cultivation; this will accelerate climate change. Biofuels can be a part of the climate solution, if they are used to help the world's poor to leapfrog to a non-fossil fuel-based energy future. Most of the Indian or African villages are not connected to the electricity grid. Instead of bringing fossil fuel long distances to feed these villages, biofuels can power their future.

10.4.6 Potential and Constraints of New Renewable Energy

The transition from "fossil fuel based economy" to "low or zero-carbon energy economy" would create "environmental space" which provide enabling condition for economic growth. Nevertheless, the new renewables such as solar, wind, geothermal energy, etc. contribute about 0.5% of world's primary energy usage. The renewable energy contribute about 18% of global electricity production. Globally, the renewable energy market is steadily growing. The "National Solar Plan" of India states that about 5000 trillion Kwh of energy is estimated as the solar energy potential of India. In fact, most parts of India receive about 4-7 Kwh per square meters per day. Solar energy can be used to cater the needs of "rural electrification" and also to meet the "peak power demand". Presently, the solar technologies are said to be expensive. However, the technology development and economics of scale would reduce the cost involved in solar technology. As regards the wind energy, about 70% of renewable energy in India is contributed by wind energy. It is reported that the contribution of wind energy to India's energy mix would be less than 10 Mtoe.

10.4.7 Enabling Renewable Energy

Renewable energy will need policy support to achieve scale and cost reduction. Large scale generation will encourage innovation, improve efficiency and reduce marginal costs. Its cost can even become competitive with coal. India's Solar Mission has proposed various measures. These include solar rooftop or onsite solar photovoltaic application. Solar generation capacity to be at least 5 percent of total installed capacity of all thermal power stations. State governments will have an obligation to buy solar power. Feed in tariff, tax holiday and duty reduction will enable rapid expansion. There can be stand-alone village power plant with micro-grid for rural electrification. All fiscal incentives are to be linked with actual generation of renewable energy instead of capital subsidy for only installation of capacity.

10.4.8 Traditional Biomass

In developing countries like India, traditional biomass is the bulk of the renewable energy use. This poor persons' fuel has so far saved the world from the tipping point of climate change. In India, the share of renewable energy is estimated to be 39 per cent, because bulk of this is biomass used by the poor to cook food and lighting. Though falling in its share of the total energy mix, biomass dependence will continue to rise till 2031-32 and beyond. This energy is managed by women who face backbreaking drudgery and health problems. This also leads to environmental damage. Therefore, there is a need to make this energy resource more sustainable, more efficient and more convenient to use. For example, wood gasification or biogas plants. Also wood plantations offer the best option for biomass based supply sources along with possessing a huge employment generation potential. Wood plantations with a potential of yielding up to 20 tonnes of wood per hectare per year in a sustainable way can significantly expand the domestic energy resource base. Wood can be burned directly or gasified for power generation. This will reduce the need for future gas/coal imports.

10.4.9 Reducing Energy Demand

We need active steps to reduce overall demand for energy. A combination of energy pricing, regulations on energy efficiency, energy saving options can help to reduce demand for energy. For example, energy demand from transport is expected to grow very rapidly due to increase in personal vehicle numbers. Enormous fuel saving is possible if usage of public transport can be increased to reduce dependence on personal vehicles. On a per passenger basis, a bus uses several times less energy than a car. Also, if railways are able to win back the freight traffic from trucks and manage to carry 50 percent of freight billion tonne kilometre (Bt-km), then oil requirement can reduce substantially. These initiatives together, can reduce our transport oil requirement by over 25 percent from the most oil intensive scenario in 2031- 32. Similarly, demand for electricity can be reduced, if consumer demand for energy efficient equipment, lighting, and energy efficient buildings can be stimulated.

10.5 ADVERSE IMPACT OF CLIMATE CHANGE ON RENEWABLE ENERGY SOURCES

While we need to shift to renewable energy to mitigate climate impacts, climate change itself can adversely affect the renewable energy sources. Take for instance, hydropower. This is world's largest renewable energy source. But climate change may adversely affect the water bodies, the riverine system and the flow of water. This will constrain hydro power generation. Climate change will also affect the wind resource – its intensity and duration. This can affect the wind turbine capacity and extreme gales can damage the turbines, shortening the working life. Solar radiation can reduce by 20 per cent in some regions of the world due to cloud cover and can affect solar collection capacity. Even biomass can experience lower yield. Climate change can even reduce availability of cooling water in power plants when in competition with drinking water and irrigation. Climate mitigation is therefore critical for energy security and human survival.

Check Your Progress 2

Note: 1) Use the space given below for your answers.

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

1. Briefly elaborate why energy intensity of our economic growth is coming down?

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2. List out the strategies needed for low carbon energy pathways.

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10.6 LET US SUM UP

Energy is the prime mover of economic growth and human survival. But more fuel we burn, more toxic and warming gases we emit. This harms public health as well as destabilizes climate. But energy demand and energy consumption will continue to grow to meet the economic and human development goals. There are solutions. Share the energy budget of the world equitably to allow all to meet the minimum threshold level of development. Specific strategies will be needed to shift to the low carbon energy systems. These include significant improvement in energy efficiency, adoption of low carbon energy pathways, renewable energy sources and curbing of energy demand. Proactive policies can accelerate energy transition.

10.7 KEYWORDS

Renewable Energy : Energy source like solar, wind, etc. that can be naturally replenished.

Non-renewable Energy: Fossil fuels that take extremely long time - millions of years to form.

Energy Intensity : Using energy more efficiently to produce a unit of output. The energy intensity will decline, if energy use is more efficient.

Energy Efficiency : Energy efficiency is the ratio between output of energy like light, heat, etc. and the input of energy. Lesser the energy input per output, more efficient is the process and less fuel we use.

Energy Security : To ensure adequate, affordable, reliable supplies of energy, diversity of primary energy mix and fuel substitution.

Demand Management : Policies that help to reduce consumer demand for targeted resource.

10.8 SUGGESTED FURTHER READING/ REFERENCES

World Energy Outlook, 2007, International Energy Agency

World Energy Outlook, 2008, International Energy Agency

Integrated Energy Policy 2006, Government of India

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/

https://www.globalchange.gov/climate-change/glossary

10.9 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. The different types of energy sources are
   a. Fossil energy – Petroleum, Coal, etc.
   b. Nuclear Energy
   c. Renewable energy – Geothermal, Wind, etc.
2. The traditional biomass is carbon neutral because the carbon that already exists in the atmosphere is absorbed during the growth of plants. During photosynthesis, the carbon is stored in the plant tissues and the oxygen is released. As the wood is burnt, the carbon present is released as CO_2 into the atmosphere.

Check Your Progress 2

1. The energy intensity of our economic growth is coming down and is about half of what it used to be in early seventies. This is done by adopting the efficiency measures.
2. The strategies needed for low carbon energy pathways are shifting to fuels with low carbon content and carbon intensity and also making use of renewable energy resources.

UNIT 11 BIODIVERSITY

Structure

11.1 INTRODUCTION

Anthropogenic environment has given rise to the sixth major extinction event in the history of life, which has culminated in widespread changes in the global distribution of organisms. The remarkable loss of biodiversity, with an estimated extinction of a species every 20 minutes, indicates that a “sixth mass extinction” is proceeding. There is now astounding evidence that climate change is one of the prime factors responsible for this exceptional biodiversity loss, with further accelerated extinction envisioned during the next decade. Climate as we know is a primary driver of many biological processes, transacting from individuals to ecosystems, and affects several facets of human life. Therefore, changing climate could cause large and likely serious impacts on ecological and social systems. Climate change is not only changing the biosphere and biodiversity in marine and terrestrial environments, it is also modifying ecosystem processes and changes the resilience of ecosystems to environmental change. This has consequences for services that humans derive from ecosystems. There is an urgent need to minimize the large ecological and societal ramification of changing biodiversity due to climate change.

Climate change and biodiversity are interconnected. Seemingly addressing climate change and the loss of biodiversity are key challenges for humanity in the 21st century as they are closely interlinked. Biodiversity is affected by climate change, with negative consequences for human wellbeing, but biodiversity, through the ecosystem services, also makes an important contribution to both climate-change mitigation and adaptation. Climate change on the other hand affects biological diversity, including speciation, redistribution, local adaptations, and extinction events in a very significant manner. Therefore, a coherent approach is needed on biodiversity and climate change to make sure that:

i) Impacts of climate change on biodiversity are reduced,

ii) Biodiversity and ecosystems together can contribute solutions related to climate adaptation and mitigation and

iii) Climate change adaptation and mitigation measures do not negatively impact biodiversity through changes in land management.

Keeping above in view, this unit delves into the vulnerability of biodiversity to the impacts of climate change, their inter-linkages and simultaneously covers the role of biodiversity in controlling climate change through adaptation and mitigation strategies.

11.2 OBJECTIVES

After studying this unit, you should be able to:

- recognise the biodiversity and climate change interactions;
- explain the vulnerability and impact assessment of biodiversity to the climate change;
- identify the role of biodiversity in climate change mitigation and adaptation;
- discuss the management responses to climate change impacts on biodiversity; and
- explain the approaches for reducing the impacts of climate change on biodiversity.

11.3 BIODIVERSITY

11.3.1 Concept

Biodiversity is the very basis of human survival and economic well-being. Biodiversity is the variety of life on earth. The term 'Biodiversity', a contraction of the term 'biological diversity' was first coined by Walter Rosen in the 1986 Forum on Biodiversity. Biodiversity includes different animals, plants, micro-organisms and their genes, terrestrial, fresh water and marine ecosystems in which they all are present. The Convention of Biological Diversity (CBD) defined biodiversity 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". It refers to the number of species of plants, animals and microorganisms and the ecosystems. It also refers to the variety of the ecosystems on the planet, such as rainforests, deserts, mangroves, grasslands, coral reefs and so on. Biological diversity is the basis for live itself. Its ecosystems provide vital services. This variety can be observed at three levels:

➢ the genetic variability within a species (Genetic Diversity)

➢ the variety of species within a community (Species Diversity)

- the organization of species in an area into distinctive plant and animal communities (ecosystem diversity)

Biodiversity provides people with basic ecosystem goods and services. It provides goods such as food, fiber and medicine, and services such as air and water purification, climate regulation, erosion control and nutrient cycling. Biodiversity also plays an important role in economic sectors that drive development, including agriculture, forestry, fisheries and tourism. People rely on marine and coastal biodiversity, and forests and non-timber forest products (e.g. the fruits from trees) for their livelihoods.

Biodiversity is necessary for our existence as well as valuable in its own right. This is because it provides the fundamental building blocks for the many goods and services which provides a healthy environment to lead our life. Biodiversity include fundamental things to our survival and wellbeing such as clean air and fresh water. As resource provider, biodiversity provides biological resources like food, medicines and pharmaceuticals, ornamental plants, wood products and breeding stock, and providing medicinal and genetic resources for preventing and treating communicable and non-communicable diseases. Secondly, it is essential for the regulation of natural processes and the Earth's life support systems, e.g., carbon sequestration, soil formation, waste assimilation and purification of water, biochemical cycle, etc. It build ecosystem services for example provisioning services, regulating services, cultural services, and supporting services. Biodiversity is also a source of spiritual and religious enrichment and well-being. Perhaps most important of all, biodiversity is the basis for evolution and adaptation to changing environments, making it essential for survival of life.

Biodiversity values include:

1. **Economic values:** Biodiversity goods and products are sold for income or used as inputs to other economic activities. e.g. ecotourism.
2. **Social values:** Employment, health, quality of life, social security, appreciation.
3. **Intrinsic values:** In many cultures and societies, all or some components of biodiversity have "intrinsic" value in their own right, irrespective of any material contribution to human wellbeing.

The value of biodiversity for sustaining and nourishing human communities is endless. To take an example, the ecosystem services from the forested watersheds of two great mountain chains, the Himalayas and the Western Ghats, indirectly support several million people in India. Biodiversity also plays an important role in economic sectors that drive development, including agriculture, forestry, fisheries and tourism. Many people rely on marine biodiversity, coastal biodiversity, and on forests and non-timber forest products (e.g. the fruits from trees) for their livelihoods. Many people depend directly on the availability of usable land, water, plants and animals to support their families. In other words, we can say that ecosystems and their biodiversity are the base of all economies.

11.3.2 Why Biodiversity Loss is a Concern?

Extinction is a natural process. The geological record indicates that hundreds of plant and animal species have disappeared over the time as they failed to adapt to changing conditions due to geological events like continental drift, massive volcanic eruptions or asteroid impacts. In the Anthropocene, humans are the most powerful agents of environmental change driving the latest wave of extinction. Human activities have already caused the destruction of over one third of the world's forest. The rapidly escalating human demand for natural resources is causing genes, species and habitat to disappear at an unprecedented rate.

The total number of species on Earth as per the current estimates vary from 5 to more than 100 million. Current rates and magnitude of species extinction far exceed normal background rates. Conservative estimates indicate that human activity has increased the extinction rates of plants and vertebrates to between 10 and 100 times the normal "background" rate. The IUCN Red List of Threatened Species indicates that species extinction is on an increasing spiral. Since the earliest date of recorded history, the fundamental social, ethical, cultural and economic values of humans have directly or indirectly revolved around biological resources. Diversity in genes, species and ecosystems has contributed immensely to the productivity of agriculture, forestry, fisheries and industry and loss of all these is a matter of great concern.

We have been living through an alarming global decline in species and natural habitats at up to 1,000 times the natural rate. Most of our ecosystem services are 'degraded' and no longer able to deliver those basic and largely unknown, yet vital services such as crop pollination, clean air and water, and control of floods or erosion. Furthermore, it has impacts on the ecosystem services on which people's livelihoods depend, such as rainfall and soil fertility which are essential to agricultural production. Human, animal and plant health are affected through increased transmission of vector-borne diseases. The trends of habitat loss, over exploitation, invasive alien species, pollution and climate change coupled with the ever-growing demand of bio-resources continue to threaten the functioning of our life-sustaining biosphere.

Current global warming is already affecting species and ecosystems around the world, particularly the most vulnerable ecosystems such as coral reefs, mountains and polar ecosystems. The rate and magnitude of climate change induced by increased greenhouse gases emissions has and will continue to affect biodiversity either directly or in combination with other drivers of change. It is estimated that by 2050, the global population will have risen to 9 billion people. As the very functioning of life in the planet depends upon biodiversity and the ecosystem services and livelihood security offered by it, the loss and imbalance of the web of life hurt us in multiple ways.

Conserving and sustainably managing natural terrestrial, freshwater and marine ecosystems and restoring degraded ecosystems with their genetic and species diversity, is necessary for the overall goals of both the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change. As ecosystems play a key role in the global carbon cycle, in adapting to climate change, providing a wide range of ecosystem services that are essential for human well-being its conservation is fundamental to the achievement of the Sustainable Development Goals.

Check Your Progress 1

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

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

1) What do you understand by the term biodiversity and its value?

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2) Why biodiversity loss is a cause of concern?

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11.4 BIODIVERSITY AND CLIMATE CHANGE INTERACTIONS

The issues of climate change and biodiversity are interconnected, considering the climate change effects on biodiversity and through changes in biodiversity that affect climate change. According to the Report of the Second Ad Hoc Technical Expert Group on Biodiversity CBD, it was estimated that "about 2,500 Gt C is stored in terrestrial ecosystems, an additional ~ 38,000 Gt C is stored in the oceans (37,000 Gt in deep oceans i.e. layers that will only feedback to atmospheric processes over very long time scales and ~ 1,000 Gt in the upper layer of oceans) compared to approximately 750 Gt C in the atmosphere. On an average ~160 Gt C cycle naturally between the biosphere (in both ocean and terrestrial ecosystems) and atmosphere." We can infer from this that small changes in ocean and terrestrial sources and sinks can have large implications for atmospheric CO_2 levels. Anthropogenic climate change caused by the accumulation of anthropogenic emissions in the atmosphere (primarily from fossil fuels and land use changes) could shift the net natural carbon cycle towards annual net emissions from terrestrial sinks, and weaken ocean sinks, thus further accelerating climate change. Hence, small changes in ocean and terrestrial sources and sinks of CO_2 can have large implications for atmospheric CO_2 levels.

As discussed previously, ecosystems provide a wide range of provisioning (e.g. food and fiber), regulating (e.g. climate change and floods), cultural (e.g. recreational and aesthetic) and supporting (e.g. soil formation) services. These services are fundamental to human well-being e.g. human health, livelihoods, nutritional and food security, social security and cohesion. While ecosystems are generally more carbon dense and biologically more diverse in their natural state, the degradation of many ecosystems is significantly reducing their carbon storage and sequestration capacity, resulting in increased emissions of greenhouse gases and loss of biodiversity at genetic, species and ecosystem level.

Due to climate change, the stress on ecosystems increasing continuously and it is also intensifying the effects of other stresses like habitat fragmentation, habitat loss and degradation, over-exploitation, invasive alien species, population pressure and pollution. Climate change is constantly altering the biosphere, both in marine and terrestrial environments, on large and small scales through biodiversity loss. It is causing shifts in the distribution of species and ecosystems, and increased risk of extinctions. However, biodiversity enhances ecosystem resilience, contributing to both climate change mitigation and adaptation. Observed changes in climate have already affected biodiversity at the species and ecosystem levels, including by changing the timing of key life events, Climate change is forcing biodiversity to adapt either through shifting habitat, changing life cycles, or the development of new physical traits. Climate change biology is a new discipline devoted to the study of these changes. Species ranges are shifting in response to climate change. The most important biotic alterations due to climate change have come as the result of changed species interactions. Few examples are:

- Coral bleaching, an alteration of the relationship between corals and their symbiotic algae due to high water temperatures has occurred in all tropical reefs.
- Massive tree mortality associated with bark beetle outbreaks has been triggered by a temperature-driven change in emergence of bark beetles. As a result, entire ecosystems are being rearranged, either by species range shifts or by the consequences of changing interactions or phenology.
- Trends that have intensified due to climate change include
  - pole ward and upslope range shifts, formation and disappearance of novel ecosystems;
  - Extinctions, expansion of invasive species, and the opening and closing of corridors;
  - major losses of freshwater and marine habitats;
  - changes in the timing of biological events;
  - Increasing vulnerability to pests and natural disasters, and changing habitat conditions.
- Beside this, climate change will also have a negative impact on the ability of biodiversity to deliver ecosystem services.
- Furthermore, climate change will have a negative impact on local economies and livelihoods. Due to the reliance of the poor and other vulnerable groups such as women and local and indigenous groups on biodiversity and ecosystem services, these negative impacts are likely to drastically affect their well-being and will compromise many development objectives.

The findings of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) Working Group II (WGII) on Impacts, Adaptation and Vulnerability has categorically stated that “recent changes in climate have caused impacts on natural and human systems on all continents and in all oceans”. The report has found that evidences of climate change impacts is strongest and most comprehensive for natural systems.

On the other hand, biodiversity and healthy ecosystems are also important resource for increasing resilience and reducing the risks and damages associated with negative impacts of climate change. They can serve as natural buffers against extreme climate and weather events such as changing patterns of rainfalls, droughts, storms, and other disasters. Diversified and integrated production systems offer more options for adapting to a changing climate. Ecosystem based production systems reduce the reliance on synthetic inputs and the associated emissions of greenhouse gases. Breeding drought, salt and disease resistant plant varieties, livestock breeds and fish will become important to ensure food security in the advance of climate change. The efforts to protect and restore habitats not only benefit biodiversity but also offer cost-effective and proven measures to mitigate and to adapt to climate change. Ecosystems such as forests, rangelands, croplands, peat lands and wetlands represent globally significant carbon stores. Their conservation, restoration and sustainable use is included as a part of many Intended Nationally Determined Contributions, and is therefore a critical element for the fulfillment of the Paris Agreement under the United Nations Framework Convention for Climate Change, a global commitment toward the mitigation of dangerous changes to the Earth's atmospheric temperature and climate system. Few biodiversity and climate change interactions are given in the box 11.1.

Box 11.1: Biodiversity and Climate Change Interactions

Case Studies

1. **Drought tolerant species provides 'biological insurance'**

   Field study conducted in Panama by Bunker *et al.*, 2005 concluded that biodiverse ecosystems are likely to show greater resilience to a drying climate as the presence of several drought tolerant species provides 'biological insurance' to counter the loss of other species. website: https://www.birdlife.org/projects/6-biodiversity

2. **Warming in the southern Californian current system is driving seabird declines.**

   Seabird communities are declining in the southern Californian current system. Presented as part of the BirdLife State of the world's birds (See: BirdLife International (2008). wesbite: www.biodiversityinfo.org/casestudy.php?id=97

3. **Climate change hastens extinctions of reptiles and amphibians in Madagascar**.

"New research from the American Museum of Natural History provides the first detailed study showing that global warming forces species to move up tropical mountains as their habitats shift upward. Christopher Raxworthy, Associate Curator in the Department of Herpetology, predicts that at least three species of amphibians and reptiles found in Madagascar's mountainous north could go extinct between 2050 and 2100 because of habitat loss associated with rising global temperatures. These species, currently moving upslope to compensate for habitat loss at lower and warmer altitudes, will eventually have no place to move to." (See on www.sciencedaily.com).

11.5 VULNERABILITY AND IMPACT ASSESSMENT OF BIODIVERSITY TO THE CLIMATE CHANGE

The impacts of climate change on biodiversity are already being felt, especially in some of the most vulnerable ecosystems. At a global level, the second AHTEG on biodiversity and climate change examined available scientific literature, including reports from the Intergovernmental Panel on Climate Change (IPCC), in order to summarize how climate change is impacting biodiversity and ecosystem services. The latest report from the IPCC is the Fifth Assessment Report (AR5). The AR5 finds that climate change has impacted human and natural systems on all continents, and in all oceans, and that natural systems are most severely impacted. Examples of specific projected impacts on species and ecosystems are presented in Box 11.2 below:

Box 11.2: Examples of projected impacts of climate change on biodiversity

1. Many terrestrial species of plant and animal have shifted their ranges, altered their seasonal activities and experienced changes in abundance;
2. A large proportion of terrestrial and freshwater species will face increased extinction risk;
3. Coastal ecosystems are susceptible to increased submergence, flooding and erosion due to sea level rise;
4. Ocean temperature increases have resulted in large-scale distribution shifts of species, and have caused changes in ecosystem composition;
5. Aquatic freshwater habitats and wetlands, mangroves, coral reefs, Arctic and alpine ecosystems, and cloud forests are particularly vulnerable to the impacts of climate change;
6. Montane species and endemic species have been identified as being particularly vulnerable because of narrow geographic and climatic ranges, limited dispersal opportunities, and the degree of other pressures.

Source: IPCC (2014 a, b)

Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change concluded that changes in the climate and in atmospheric CO_2 levels have already had impacts on natural ecosystems and species. Some species and ecosystems are demonstrating capacity for natural adaptation, but others are already showing negative impacts under current levels of climate change (an increase of 0.75ºC in global mean surface temperature relative to pre-industrial levels), which is modest compared to future projected changes (2.0-7.5 ºC by 2100 without aggressive mitigation actions). Information in Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4) suggests that "approximately 10% of species assessed so far will be at an increasingly high risk of extinction for every 1°C rise in global mean temperature, within the range of future scenarios modeled in impacts assessments (typically <5°C global temperature rise)". Continued climate change will have considerably adverse and often irreversible impacts on many ecosystems and their services, with significant negative social, cultural and economic consequences. However, the extent and speed at which climate change will impact biodiversity and ecosystem services, and the thresholds of climate change above which ecosystems are irreversibly changed is still not certain.

Check Your Progress 2

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

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

1) Give few examples of projected impacts of climate change on biodiversity?

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2) Discuss with examples how climate change and biodiversity affect each other?

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11.6 ROLE OF BIODIVERSITY IN CLIMATE CHANGE MITIGATION AND ADAPTATION

Biodiversity has a potentially significant role to play in both climate change mitigation and adaptation.

1. Biodiversity can support efforts to reduce the negative effects of climate change. Conserved or restored habitats can remove carbon dioxide from the atmosphere, thus helping to address climate change by storing carbon (for example, reducing emissions from deforestation and forest degradation).

2. Conserving intact ecosystems such as mangroves, for example, can help reduce the disastrous impacts of climate change such as flooding and storm surges.

3. Biodiversity can enhance the resilience of ecosystem structure to environmental changes such as prolonged drought.

However, biodiversity is changing across many different taxonomic groups and biomes, including mountains, oceans and forests, as a result of a wide range of recent environmental changes such as increasing temperature, and increased frequencies of extreme floods and droughts. Environmental changes and ecosystem disruption, including the loss of biodiversity, have often been shown to increase the risk to people from zoonotic and other emerging diseases, as well as from wildlife species that present dangers for humans, livestock and agriculture. Direct human activities such as hunting, can exacerbate the effects of climate change on biodiversity.

Effective sustainable management requires understanding both the ecological and socioeconomic dimensions of the problem and requires coherent policies at all levels of government. Possible solutions include community-based projects that provide economic or other benefits, carefully designed restoration projects, and/or appropriate incentives to support ecologically sustainable land-use practices.

In particular, the conservation and sustainable use of biodiversity may contribute to adaptation by increasing resistance to natural disasters through, for example, flood control and coastal protection and maintaining ecosystem goods and services, such as the provision of food, clean water and raw materials. As one concrete example, adaptation linked to agricultural biodiversity is expected to avoid 10-15% of the projected reductions in yield under changing climatic conditions. Protecting biodiversity and ecosystem services from climate change is a necessity, because if they are destroyed or degraded, climate adaptation efforts will likely be more expensive and less sustainable.

Although there are many links between climate change and biodiversity, a very important one is through ecosystem-based approaches for adaptation to climate change (EBA), which link the conservation, restoration and sustainable use of biodiversity and ecosystem services with climate change adaptation. As stated by the Second Ad Hoc Technical Expert Group (AHTEG) on Biodiversity and Climate Change: "Ecosystem-based adaptation, which integrates the use of biodiversity and ecosystem services into an overall adaptation strategy, can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity".

The role of living organisms in the production and sequestration of greenhouse gases is reasonably well understood. The consequences of climate change like the changes in the extent of tropical forests, or phytoplankton in the oceans are already incorporated in general circulation models. Ecologists also agree that climate change is already changing the world's biota. It is affecting species distributions and abundance, the timing of reproduction in animals and plants, animal and bird migration patterns, and the frequency and severity of pest and disease outbreaks. Species are moving from lower to higher elevations and from lower to higher latitudes. Species that are unable to move are at risk. At the same time, changes in the world's biota from other causes are affecting the ability of ecosystems to adapt to climate change. The simplification of many ecosystems to make them more 'useful' to people reduces their flexibility. By eliminating species that are 'redundant' given current climatic conditions and current uses, we have reduced the capacity of many ecosystems to function, if climatic conditions change.

11.7 MANAGEMENT RESPONSES TO CLIMATE CHANGE IMPACTS ON BIODIVERSITY

Climate change and its interactions with human modification of the biosphere will result in major changes in species and ecosystem distributions, dynamics, and interactions. Here, we discuss major categories of management responses to climate change impacts on biodiversity.

1. Adaptation or adjustment of natural or human systems should be explored, which may include common conservation strategies, protected areas, and landscape and seascape connectivity. Ecosystem-based adaptation is

defined and explored, to highlight the benefits of conserving ecosystems for the inherent services they provide to humans.

2. Introduced invasive species can act as a trigger for dramatic changes in ecosystem structure, function, and delivery of services. For example, the introduction of the carnivorous ctenophore *Mnemiopsis leidyi* (a jellyfish-like animal) in the Black Sea caused the loss of 26 major fisheries species and has been implicated (along with other factors) in the subsequent growth of the oxygen deprived "dead" zone.

3. Halting deforestation and appropriately implementing reforestation could make important contributions to climate mitigation and protection of biodiversity. Major reductions in greenhouse gas emissions and improved energy efficiency are required to keep global warming below 2°C, while also reaching human development goals. Biodiversity objectives can only be attained if massive deployment of biofuels is avoided. A substantial degree of climate change by 2050 and beyond is already committed due to long lags in the Earth's climate system, so adaptation plans for biodiversity are needed. For example, adaptation will require anticipating climate change in the design of protected area systems

4. Reduced Emissions from Deforestation and Degradation (REDD +) policy have great potential to reduce greenhouse gas emissions from clearing of forests in subtropical and tropical countries. Conservation needs to be concerned with both the direct impacts of climate change on biodiversity, but also the positive indirect effect of REDD + and negative indirect effects of biofuel production.

11.8 REDUCING THE IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

The resilience of biodiversity to climate change can be enhanced by reducing non-climatic stresses in combination with conservation, restoration and sustainable management strategies. Conservation and management strategies that maintain and restore biodiversity can be expected to reduce some of the negative impacts from climate change; however, there are rates and magnitude of climate change for which natural adaptation will become increasingly difficult. Options to increase the adaptive capacity of species and ecosystems in the face of accelerating climate change include:

1. Reducing non-climatic stresses, such as pollution, over-exploitation, habitat loss and fragmentation and invasive alien species.

2. Wider adoption of conservation and sustainable use practices including through the strengthening of protected area networks.

3. Facilitating adaptive management through strengthening monitoring and evaluation systems.

4. Relocation, assisted migration, captive breeding, and ex-situ storage of germplasm could contribute to maintaining the adaptive capacity of species.

Check Your Progress 3

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

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

1) Describe role of biodiversity in climate change mitigation and adaptation.

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2) How deforestation and reforestation will influence the climate change impact on biodiversity?

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11.9 LET US SUM UP

In this unit, we have learned about the interaction between climate change and biodiversity and how both affect each other. Management strategies to reduce the impact on biodiversity and climate change were also discussed. As we know now, biodiversity is a contraction of the phrase "biological diversity". Biodiversity means the richness and variety of life viz. genes, species and ecosystems. Biodiversity provides people with basic ecosystem goods and services. It provides goods such as food, fiber and medicine, and services such as air and water purification, climate regulation, erosion control and nutrient cycling. Biodiversity also plays an important role in economic sectors that drive development, including agriculture, forestry, fisheries and tourism. People rely on marine and coastal biodiversity, and forests and non-timber forest products (e.g. the fruits from trees) for their livelihoods. Many people depend directly on the availability of usable land, water, plants and animals to support their families. Biodiversity underpins the functioning of ecosystems and the provision of ecosystem services essential for human wellbeing such as food, clean water, pest control and protection against erosion. Important reservoirs of carbon are stored in forests, wetlands and other ecosystems. By contributing to ecosystem resilience, biodiversity can help both ecosystems and people to adapt to climate change. Thus protecting biodiversity and restoring ecosystems are important parts of both climate change mitigation and adaptation. Actions need to address both biodiversity loss and climate change in parallel and thereby discouraging a vicious cycle of ecosystem degradation and stopping the loss of species and habitats.

11.10 KEYWORDS

Adaptation : Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Carbon Sequestration : The process of removing carbon from the atmosphere and depositing it in a reservoir.

Ecosystem Services : Ecosystem services are (by recent convention) the goods (e.g. food, fiber and clean water) and the services (e.g. water purification, pollination and climate regulation) which are provided by ecosystems and sustain human well-being

Extinction : The evolutionary termination of a species caused by the failure to reproduce and the death of all remaining members of the species; the natural failure to adapt to environmental change.

Mitigation : In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases.

Protected Areas : An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity and of natural and associated cultural resources, and managed through legal or other effective means. A protected area can be under either public or private ownership.

Sustainable Use : The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

11.11 SUGGESTED FURTHER READING/ REFERENCES

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11.12 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

Your answer should include:

1. The Convention of Biological Diversity (CBD) defined biodiversity 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”. It refers to the number of species of plants, animals and microorganisms and the ecosystems.

   Biodiversity values include:

   a) Economic values: Biodiversity goods and products are sold for income or used as inputs to other economic activities, e.g. ecotourism.

   b) Social values: Employment, health, quality of life, social security, appreciation.

   c) Intrinsic values: in many cultures and societies, all or some components of biodiversity have “intrinsic” value in their own right, irrespective of any material contribution to human wellbeing.

2. Biodiversity provides people with basic ecosystem goods and services. It provides goods such as food, fiber and medicine, and services such as air and water purification, climate regulation, erosion control and nutrient cycling. Biodiversity also plays an important role in economic sectors that drive development, including agriculture, forestry, fisheries and tourism. People rely on marine and coastal biodiversity, and forests and non-timber forest products (e.g. the fruits from trees) for their livelihoods. Because of its value in sustaining the ecosystem and providing ecosystem services, its loss is a concern.

Check Your Progress 2

Your answer should include:

1. Examples of projected impacts of climate change on biodiversity

   - Many terrestrial species of plant and animal have shifted their ranges, altered their seasonal activities and experienced changes in abundance,
   - A large proportion of terrestrial and freshwater species will face increased extinction risk,
   - Coastal ecosystems are susceptible to increased submergence, flooding and erosion due to sea level rise.
   - Ocean temperature increases have resulted in large-scale distribution shifts of species, and have caused changes in ecosystem composition.

2. You can discuss the given case studies.

Check Your Progress 3

Your answer should include:

1. Biodiversity can support efforts to reduce the negative effects of climate change. Conserved or restored habitats can remove carbon dioxide from the atmosphere, thus helping to address climate change by storing carbon (for example, reducing emissions from deforestation and forest degradation). Conserving in-tact ecosystems, such as mangroves, for example, can help reduce the disastrous impacts of climate change such as flooding and storm surges. Biodiversity can enhance the resilience of ecosystem structure to environmental changes, such as prolonged drought.

2. Halting deforestation and reforestation could make important contributions to climate mitigation and protection of biodiversity by reducing greenhouse gas emissions and improved energy efficiency and keeping global warming below 2°C.

UNIT 12 INFRASTRUCTURE

Structure

12.1 INTRODUCTION

The evidences of climate change are increasing frequency and intensity of extreme climatic events, heat waves, rise in sea level and storm surges and intense precipitation. The population is facing challenges due to impacts of climate change on infrastructures like buildings, transportation. In this unit, we would endeavour to discuss the impacts of climate change on buildings and transportation; impacts of sea level rise on infrastructure; and the implications of climate change on energy sector. Further, we would discuss the measures of climate resilient infrastructure.

12.2 OBJECTIVES

After studying this unit, you should be able to:

- describe the impacts of climate change on buildings and transportation;
- explain the impacts of sea level rise on infrastructure;
- discuss the implications of climate change on energy sector; and
- explain the measures of climate resilient infrastructure.

12.3 GLOBAL CHANGES IN TEMPERATURE AND PRECIPITATION

According to IPCC (2018), the human beings are responsible for 1.0°C rise due to global warming. This rise was with respect to pre-industrial levels. The estimated range of this rise is of 0.8°C to 1.2°C. They also confirmed that if this rate of increase prevails, there is chance of reaching 1.5°C between 2030 and 2052. The observed global mean surface temperature (GMST) for the decade 2006–2015 was 0.87°C (likely between 0.75°C and 0.99°C) higher than the average over the 1850–1900 period. The estimated anthropogenic global warming is currently increasing at 0.2°C (likely between 0.1°C and 0.3°C) per decade due to past and ongoing emissions.

The changes occur in the water cycle by two means. The heat which is trapped by the atmosphere causes more evaporation and more precipitation creating hotter or drier conditions. Another is that, warmer atmosphere holding more water vapour which also traps the heat due to its warming potential (USGCRP, 2009). There were strong reports of global change in surface temperature and variation in rainfall pattern and intensity over the last few decades (Vose et al. 2012; National Oceanographic Centre (2014); NOAA, 2016).

12.4 IMPACT OF CLIMATE CHANGE ON BUILDINGS

The energy consumption in buildings and construction is around 40 percent of global total energy usage (2010). The emission of greenhouse gases from energy consumption in buildings is around 39 per cent. The direct total anthropogenic greenhouse gas (GHG) emissions in 2010 from different economic sectors namely electricity and heat production, agriculture, forestry and other land use, buildings, transport, industry and other energy use contributes 25 percent, 24 percent, 6.6 percent, 14 percent, 21 percent and 9.6 percent respectively. And the indirect GHG emission contribution were 12 percent, 11 percent,1.4 percent, 0.87 percent, 0.3 percent from buildings, industry, energy, agriculture, forestry and other land use and transport respectively.

The energy consumption in buildings in 2050 is supposed to double or triple from present usage. The estimates state the annual increase in carbon dioxide emission during 1971-2004 for commercial buildings and residential buildings were 2.5 percent and 1.7 percent respectively. The energy use by buildings has increased from 119 exajoules in 2010 to nearly 125 EJ in 2016. The annual carbon emission from buildings in 2016 was 9.0 $GtCO_2$ (IEA, 2017). The emissions from building construction were 3.7 $GtCO_2$ (IEA, 2017). The floor area in the world continued to grow by 2.3 percent and so is the future the energy demand from building sector and its emissions will be difficult to manage.

The energy consumption pattern is different for developed and developing countries. Similarly, the energy consumption in building sectors of those countries also vary. The energy consumption in buildings in developed countries are higher. For example the energy consumption in buildings in USA (in 2008) by source are 73 percent from electricity, 21 percent natural gas, 4 percent petroleum and 2 percent by others (EIA, 2009).

The 25-33 percent of black carbon and two-thirds of halocarbons are emitted from building sector (Ürge-Vorsatz et al., 2012). The compounds used for refrigeration and insulation and other appliances in the buildings also contribute to halocarbons which are more potent greenhouse gases.

The different factors that are essential for the urbanization and urban development are directly linked to pollution and climate change. This bounces back and affects the wellbeing of the urban population. The urban areas are more exposed to extreme temperatures. It results in increased cooling requirements and hence more energy consumption. In cold areas, the rise in temperature reduced the demand on heating the building. At many places, shortening of summer season was observed. In the changing climate, it is difficult to maintain a temperature of acceptable comfort level at indoors.

The urban areas near coastal zone are more prone to inundation and under threat of increased coastal floods. The extreme damages may lead to rehabilitation and resettlement of urban population. These areas are vulnerable to drought, floods causing loss of lives and properties.

Check Your Progress 1

Note: 1) Use the space given below for your answers.

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

1. Why buildings are major emitters of greenhouse gases?

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2. How the intense precipitation affects the infrastructure?

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12.5 IMPACT OF CLIMATE CHANGE ON TRANSPORTATION INFRASTRUCTURE

The climate change increase the risk of delays, disruptions, damage, and failure across roadways, ice roads, vehicles, and railways. Roads are considered as lifeline for economic and agricultural livelihood. The benefits of roads are they are directly connected with economic development of a country. In developing countries, these roads are lifeline of agricultural livelihoods. The indirect benefits are easy access to healthcare facilities, education and improves standard of living. The climate change impacts of temperature, rain, snow and ice, wind, fog, and coastal flooding on roads are (NRC, 2008; USGCRP, 2014):

- Softening and expansion of roads further leads to rutting and potholes. It is common in high-traffic areas. It also exerts stress on bridge joints.
- Flooding from heavy rains disrupt traffic, erode or wash out the soil and culverts that support roads, tunnels, and bridges.
- Heat waves and flooding delay construction activities and so increase cost of construction.
- Shortened life expectancy of roads due to exposure to flooding and extreme snow events.
- Coastal flooding from sea level rise and storm surges.
- Winter flooding from winter precipitation as rain.
- Landslides and wash-outs.
- Drought induced wild fires reduce visibility.

The warming temperatures reduced the number of days for active frozen routes of ice roads in Alaska and limits transportation accessibility (USGCRP, 2014). The expansion and buckling of rail tracks due to rising temperature result in frequent track repairs or speed restrictions to avoid derailments (NRC, 2008). The heavy precipitation, tropical storms and hurricanes can cause disruption in rail travel and rebuilt of rails.

The sea level rise and storm surges can cause inundation of rails and subways in nearby coastal zones. The subway and commuter rail systems of New York City and New Jersey with a 14-foot storm surge were affected in 2012 by Hurricane Sandy.

The air travel was also affected by heavy rains, floods, hurricanes in the form of delays, restrictions, flight cancellation and airport closure. Example: Gulf Coast during Hurricane Katrina and throughout the North-East during Hurricane Sandy.

The climatic impacts of extreme events like floods cause degradation of road structures, connectivity loss, and reduction in its lifespan. The impact is on the infrastructure itself, its connectivity and demand on transportation. It increases necessary maintenance and repair imposing a costly hazard that requires adaptation and mitigation steps. The impacts depend on frequency, duration, and severity of the hazard. The heat waves are increasing the wild fires that also damage transportation infrastructure. During drought, the water level get reduced and it affect freight movements. Example: Drought of 1988 in Mississippi River.

There are some benefits or positive impacts of climate change on infrastructure like more open seas in the Arctic, creating new and shorter shipping routes and reducing transport time and costs. In cold regions, rising temperatures could reduce the costs of snow and ice control and would make travel conditions safer for passenger vehicles and freight.

12.5.1 Flash Floods

The flash floods are common and occur rapidly as a result of intense precipitation. This flash floods disrupts the transportation sector (DfT, 2014). Some of the examples of flooding induced transportation disruption are:

- Flooding in eastern China in 2011 damaged 28 rail links, 21,961 roads, and 49 airports, and power supply (Xi, 2016).
- Flooding along 500 miles of the Mississippi and Missouri River systems in 1993.

12.5.2 Sea-level Rise Impacts on Transport Infrastructure

The global sea level rise has drastically increased after industrialization by affecting the stable ice sources. This is mainly by the melting of ice sheets, glaciers and thermal expansion (IPCC, 2014). The impact of sea level rise gets hiked from the combined effect of strong winds and low atmospheric pressure with storm surge. The high tides accelerate the effect of surges (Haigh et al., 2010). In the winter of 2013/2014, United Kingdom's North Sea coast, had highest recorded storm reaching 2m above high tide and cause damage to east England (BBC, 2013; National Oceanographic Centre (NOC), 2014a; Huntingford et al., 2014). Thermal expansion, glaciers, Greenland ice sheet, Antarctica ice sheet are the major drivers of global mean sea level rise (IPCC 2013; 2014). IPCC 5th Assessment Report predicts a global rise by 52-98 cm by 2100 (IPCC, 2013).

The thermal expansion contributes to more than half of the sea level rise. The current rate of thermal expansion leads to about 3 mm of sea level rise per year. The sea level rise is also due to retreating glaciers and thawing of ice. The studies says that climate change induced melting of ice caps increases the sea level by 0.97 m in 2100 (Church et al., 2013). The flooding from sea level rise and from extreme precipitation events increase the threat to coastal transport infrastructure (Hooper and Chapman, 2012)

The sea level rise increases the exposure of settlements and infrastructure in coastal areas and islands. The 80 percent of Maldives is less than 1m above mean sea level. So, the sea level rise combined with the storm surges could easily sweep over entire islands. The melting of glaciers and entire ice at Antarctica and Greenland could increase the sea level by 70 m.

12.5.3 Coastal Flooding

The phenomenon of flooding in dry, low-lying land by seawater is referred to as coastal flooding. It is a coastal process where waves, tides, storm surge, or heavy rainfall from coastal storms cause the flood. The frequency and severity of coastal flooding was increased by coastal storms and storm surge. The topography of the coastal land determines its degree of impact by sea water inundation. The coastal zones are affected by direct flooding, overtopping of a barrier and breaching of a barrier. The direct flooding is common in low lying areas. The overtopping of barriers occurs during storms or high tides and breaching occurs during high waves. The occurrence of extreme events like hurricane has great impact on coastal flooding.

NOAA (2016) reported the average number of floods increased during 2010–2015 in comparison to 1950-59 period in the U.S. Coasts. There was an increase in the average number of days per year in which coastal waters rose above the local threshold for minor flooding especially at 27 sites along U.S. coasts. The shoreline erosion and degradation, amplified storm surges, permanent inundation, saltwater intrusion are major risks to coastal areas.

12.6 IMPACT ON ENERGY INFRASTRUCTURE

The increased number of extreme climatic events and its severity affect the energy sector. The impact is more for the renewable energy systems.

- **Solar Energy:** The increase in cloudiness affect solar technologies; severe storms cause damage to solar equipment. There is reduction in efficiency of solar panels.
- **Wind Energy**: Damage to wind farms and distribution lines.
- **Biomass Energy**: The climate change impact on agriculture reduce the crop yield and quality.
- **Hydropower**: Reduced output from hydropower generation.
- **Coal Industry**: The open pits were filled with water during heavy rainfall and cause floods and landslides. The output from thermal power plants are decreased due to insufficient cooling water.
- **Oil and Gas Sector**: Tropical cyclones with potentially severe effects on offshore platforms and onshore infrastructure, leading to more frequent production interruptions.
- **Energy Transmission Infrastructure** such as pipelines and power lines, are also likely to be affected by higher temperatures and extreme weather events. The pipelines are also at the risk of coastal flooding, thawing permafrost in cold regions, landslides, fires by heat waves in hot regions.
- **Power lines** are affected by heavy winds.
- **Flooding** of electricity substations (land based).
- **Coastal floods** affect the sites and technology of energy production, transmission lines and distribution lines by inundation of sea water.

The increase in production cost of energy due to dry climatic conditions. The hydropower generation in Africa reduced by USD 83 billion and it increased the cost for consumers (Cervigni et al., 2016).

12.7 IMPACT ON TELECOMMUNICATION

The telecommunication and broadcasting are affected by climate change. The study by researchers at the University of Wisconsin-Madison and the University of Oregon (2018) reported that the sea level rise may inundate thousands of miles of buried fiber optic cables in densely populated coastal regions of the United States. The impacts of climate change on telecommunications (Horrocks et al., 2010, Ofcom, 2010, ClimAID, 2011) are:

- The heat waves from rising temperature demand for keeping equipment cool at exchanges and base stations. There are many reports of frequent and longtime shut down of stations.
- Increase in operating temperature, reduces the life span and premature failure of telecommunication system.

- Coastal floods can affect telecommunication cables, network equipment, and base stations.
- Power outages get increased which results in increased cost of energy supply.

12.8 IMPACT ON WATER INFRASTRUCTURE

The climate change affects the design, construction, and maintenance of water sector infrastructure. The natural disasters during 1990 to 2000 period affected annual GDP in developing countries by 2 - 15%. The clean supply of drinking water is essential for maintaining health. The water is required for agriculture, energy production, navigation, recreation, and manufacturing. Water stress will be more prominent in Central and Southern Europe and 44 million people may be affected by 2070.

The operation of water reservoir is affected by climate change. The water quality is deteriorated by siltation, sedimentation and act as potential source for diseases. The reservoirs used for control of flood become the source for upstream floods. The climate change increases frequency and magnitude of floods.

It can reduce hydropower generation and increases cost of electricity production. Madani and Lund (2010) estimated reduction of 1.3% and 19.7% in California's high-elevation hydropower system under a warming-only scenario and a dry warming scenario.

The water demand from agriculture, energy production, industrial uses and human consumption has increased and exerts pressure on ground water. The rapid urbanization reduced the water output in water cycle by exploitation of ground water and solid waste generation. In the extreme rainfall, the municipal sewers over flown into water bodies there by affecting the quality. The shrinkage in water supply occurs by the loss of mountain glaciers, ice sheets and snow cover. The salt water intrusion to the coastal drinking water supplies results from sea level rise and hence affecting water infrastructure. So, in order to adjust with the impacts of climate change the development of climate resilient infrastructure is required.

12.9 CLIMATE-RESILIENT INFRASTRUCTURE

Resilience is defined by UN as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR, 2009). The climate resilient infrastructure is a component in any efforts for enhancing resilience against climate impacts. The climate resilience also helps in accomplishing goals of the Paris Agreement, Sustainable Development Goals and reduction of disaster risks. It include management measures such as flexible maintenance timings and adaptive management, adoption of structural measures like increasing height of bridge, sea walls, etc., improvement in building and industrial energy efficiency, emission reduction from buildings, improving energy efficiency in new and existing buildings – Energy Conservation Building Codes (ECBC) and building standards, GRIHA rating and certification, improving the energy efficiency of household and business appliances- standards and labeling, encouraging energy suppliers to support emission reductions using demand-side management (DSM) activities, replacing fossil fuels with renewable energies for example solar panels, and solar water heaters which help in combating climate change.

The retrofitting and rehabilitation of existing infrastructure is one of the key part of climate resilient infrastructure. It helps in reduction of infrastructure for physical vulnerability. Some of the efforts like low impact infrastructure development, low cost engineering solutions, preparedness for extreme events like early warning systems for drought and floods, restoration of natural ecosystems and various adaptation strategies, improved pavement geomaterials for road construction, buildings and structures with resilient design and materials, resilience of transmission and distribution networks against earthquakes help to protect and safeguard population and infrastructures against variable climatic world.

Check Your Progress 2

Note: 1) Use the space given below for your answers.

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

1. Why sea level increase is different in different locations?

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2. How can you reduce the impact of climate change on infrastructure?

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3. How resilience differ from adaptation?

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12.10 LET US SUM UP

The infrastructure is affected by the change in climate such as increasing temperatures, shifting patterns of precipitation, increased intensity or recurrence of extreme weather events and rising sea levels. The building, transportation, energy, telecommunications, water supply are under constant threat of climate change. The climate resilient infrastructures have to be developed in order to reduce the impacts and the resilience should be an integral part of government especially in urban planning.

12.11 KEYWORDS

Relative Sea Level	:	Along any coast, vertical motion of either the sea or land surface can cause changes in sea level relative to the land (known as relative sea level)
Storm	:	A rising of the sea as a result of wind and atmospheric pressure changes associated with a storm
Storm Surge	:	It is an abnormal rise in the water that is over and above the regular tide level. Storm surges are caused by wind, waves, and low atmospheric pressure from severe storms, such as hurricanes
Flood	:	It is a general and temporary inundation of normally dry land areas
Flash Flood	:	It is a sudden local flood, typically due to heavy rain.
Rut	:	A rut is a depression or groove worn into a road or path by the travel of wheels or skis.
Water Infrastructure	:	Water infrastructure is a broad term for systems of water supply, treatment, storage, water resource management, flood prevention and hydropower
ECBC	:	Energy Conservation Building Code
GRIHA	:	Green Rating for Integrated Habitat Assessment
Urban Development	:	Urban development is defined as the social, cultural, economic and physical development of cities, as well as the underlying causes of these processes.
Power Outage	:	A power outage is a short- or long-term state of electric power loss in a given area or section of a power grid.
UNISDR	:	United Nations International Strategy for Disaster Reduction

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12.13 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. The high amount of energy is consumed in the buildings and construction that emits the carbon dioxide. The electrical appliances and insulation releases some halocarbons which are also having high global warming potential.

2. The heavy rainfall and flooding cause damage to life, assets and infrastructure. It results in complete destruction, cause permanent loss, delay in its services.

Check Your Progress 2

1. The sea level rise depends on shifting surface winds, the expansion of warming ocean water, and addition of melting ice that can alter ocean currents. The tides, storms, and El-Nino also influence the sea level.

2. Climate change impacts on infrastructure may be minimised by climate resilient infrastructure and by adopting management and structural measures.

3. Resilience refers to ability of a system to absorb, withstand and bounce back after an adverse event while adaptation seeks to reduce the risk of the event by different means.