

Climate Change: Consequences and Mitigation

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Abstract

Climate change refers to the long-term changes in the climate that occur over decades, centuries or longer. It is caused by rapidly increasing greenhouse gases in the Earth's atmosphere due primarily to burning fossil fuels (e.g., coal, oil, and natural gas). Weather, in contrast to climate, is the daily experience of atmospheric conditions such as temperature, precipitation, humidity, wind, etc. More frequent and intense drought, storms, heat waves, rising sea levels, melting glaciers and warming oceans can directly harm animals, destroy the places they live, and wreak havoc on people's livelihoods and communities. As climate change worsens, dangerous weather events are becoming more frequent or severe. Sea levels are rising and oceans are becoming warmer. Longer, more intense droughts threaten crops, wildlife and freshwater supplies. From polar bears in the Arctic to marine turtles off the coast of Africa, our planet's diversity of life is at risk from the changing climate. Climate change poses a fundamental threat to the places, species and people's livelihoods. WWF works to protect. To adequately address this crisis, we must urgently reduce carbon pollution and prepare for the consequences of global warming, which we are already experiencing. Climate change has been recognized as the foremost environmental problem of the twenty-first century and has been a subject of considerable debate and controversy. It is predicted to lead to adverse, irreversible impacts on the earth and the ecosystem as a whole.

Keywords: Climate Change, WWF, Ecosystem, Mitigation, ecosystem.

INTRODUCTION

Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. Climate System: The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations and anthropogenic forcings such as the changing composition of the atmosphere and land use change. Earth is a

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constantly changing planet since its formation around 4.5 billion years ago and hence, its climate is also witnessing changes from time to time. Weather and climate have a profound influence on life on earth. Over time, the earth has developed a climate that nurtures the life system and the planet is flourished with a whole lot of flora, fauna and human beings. The survival of human beings is solely dependent on the conducive climate that the earth provides. However, human intervention has changed the climate system adversely. Climate change as science has received unprecedented attention from both scientific institutions and academia. Climate change is a global issue that requires worldwide cooperation and negotiations for developing the necessary actions to combat its effects. This requires the integration of adaptation into existing policies and processes, taking into account the broader policy objectives and wider costs and benefits.

Global Climate Change

Atmosphere and Climate (structure and composition) Scientists found no existence of atmosphere at the time when earth came to existence about 4.5 billion years ago. Then, natural volcanic activity was a continuous phenomenon and the Earth existed in the form of hot gaseous mass having surface temperature more than 80000 C. The gases captured inside the magma slowly released. Major gases emitted then were carbon dioxide (CO₂), water vapour and ammonia and the atmosphere were devoid of oxygen i.e., reducing atmosphere. Later, as Earth started to cool down, cloud started to form and as a result, the Earth experienced rain and water bodies like ocean basins got filled up. CO₂ present in the atmosphere dissolved with water and carbonic acid so formed poured down on the Earth and that's how carbonate rock would have formed. Scientists have given many theories behind the formation of Earth's atmosphere and life in particular. It was water and presence of sunlight that has made possible the formation of oxygen over geological time scale and so to the life on the Earth. On planet Earth, life became possible as a result of having blanket of gases called atmosphere which extends up to 9600Km from the Earth's surface. Of course, the gravitational pull of the Earth makes atmosphere inseparable from the mother Earth. As, we move higher in altitude, the density of air declines. Since, atmosphere is made up of gases so it can be compressed. Atmosphere has not only provided the adequate temperature to sustain life but also given other suitable conditions to flourish. More than 97% of the air is concentrated up to 29km from the Earth's surface. In spite of lesser density to that of land (lithosphere) or water (hydrosphere), air exerts pressure on the surface which is called as atmospheric pressure. It is this blanket of gases which provides us O₂ to breath and CO₂ to plants to photosynthesize and much more.

Ozone made life possible by absorbing ultraviolet (UV) radiation. Over geographical time scale i.e., millions of years the atmosphere got thermally stratified which has impacted its composition and vice-versa. Thermal Stratification of Earth's Atmosphere Earth's atmospheric temperature varies with height from the ground. The atmosphere can be divided into five layers. Starting from the Earth's surface, these are troposphere, stratosphere, mesosphere, thermosphere and exosphere.

Troposphere: The troposphere is the layer nearest to Earth's surface. The height of the troposphere varies with location, being higher over warmer areas and lower over colder areas. The boundary where troposphere ends is called the tropopause. It varies with location i.e., from 5-6 km at colder areas like pole and 18 km at the warmer area like equator. This layer has the highest density in comparison to the rest and contains 80% of the atmospheric mass. Nitrogen is predominant (78% by volume) followed by oxygen (20.9%), argon (0.93% by volume), carbon dioxide (0.04%), etc. This layer is very turbulent and has strong vertical movement of air. Due to this vertical movement of air mass, air pollution gets diluted from the point of its origin and settles to the ground as a result of precipitation. All weather phenomena occur in this layer. As you go up in the troposphere, atmospheric temperature decline at the rate of 6.50 C per km. As we move up the air mass get colder in this layer and so it becomes heavier and tries to push down air mass beneath which is warmer and that's how creates the vertical movement of air mass.

Stratosphere: The Stratosphere is the layer next to the troposphere. "Strat" means layer and this layer of our atmosphere has its own set of layers. This layer has increasing temperature trend with height and air mass becomes stable. The boundary where stratosphere ends is called the stratopause. This layer ends at about 50 km above ground. Ozone (O_3) is predominant in the stratosphere. O_3 absorbs ultraviolet radiation from the sun that causes heating of air and so temperature increases with height and temperature inversion got noticed. The air mass in this layer is much drier and much less dense than troposphere.

Mesosphere: The layer next to stratosphere is called mesosphere. It starts from about 50 km and extends until 85 km from the ground. The upper most part of the mesosphere is called the mesopause. The temperature in this layer decreases with height like troposphere. This layer has nitrogen (N_2) and oxygen (O_2) but the concentration are 1000 times less and with little water vapor present, there occurs no weather phenomena. The mesopause becomes the coldest part of Earth's atmosphere. Thermosphere (Ionosphere): The thermosphere is the uppermost

layer of the atmosphere. In this layer the temperature increases with height because it is being directly heated by the sun. It extends from about 90 km to between 500 and 1,000 km. It is so close to the Sun that temperatures can be as high as 1,5000 C and as a result ionization occurs. Ionization is the process of conversion of atoms or molecules into ions in the presence of solar radiation. This is the layer where horizontal layers get formed and as a result radio wave gets reflected from this layer. This is the layer from where the aurorae occur too. Aurorae are the natural light displaying phenomena in the Earth's sky called as, northern polar lights i.e., in Arctic as Aurora Borealis and in Antarctic, southern lights as Aurora Australis.

Exosphere: The last layer, the exosphere, the last-layer, is quite thin and is where the atmosphere mingles into the outer space. It consists of very widely dispersed particles of hydrogen and helium. Atmospheric Pressure as we move higher in altitude, atmospheric pressure declines but rate of decline reduces with height.

Greenhouse gases; (GHGs) are gases that absorb reradiated (long wave) radiation from the earth and emit it back to the atmosphere. Increase in GHGs in atmosphere enhances trapping of radiation and so add on to warming of the Earth and vice versa. CO₂, CH₄, N₂O, water vapour, Black carbon (BC) etc. are responsible for warming of the Earth. Concentrations of GHGs are commonly given in percentages as well as mixing ratios of gases to total air volume (v/v), such as parts per trillion (ppt), parts per billion (ppb), and parts per million (ppm). Potential sources of GHGs are burning of fossil fuel. Fossil fuel is any hydrogen and carbon rich substance that was created by the decomposition of prehistoric plants and animals that can be burned to produce heat or energy. This includes coal, petroleum, and natural gas products. GHGs like CO₂, CH₄, etc. whose percentages vary diurnally, seasonally, and annually, interact with incoming solar radiation (insolation) and infrared radiation which is also called long wave radiation re-emitted from the earth which affect the energy balance. Even though, the GHG concentration is in ppm levels, they can significantly alter the global energy balance and temperature over a period of time. The CO₂ concentration, in 2009, was about 385ppm, and is increasing at an average global rate of 1.9ppm per annum. Presently, the carbon dioxide concentration is about 410 ppm. a) Carbon dioxide (CO₂) CO₂ is the most dominant GHG in the atmosphere (excluding water vapor). In its natural occurrence it helps keep the earth at a comfortable and life sustaining temperature. However, it is also registered to be the main culprit behind global warming. Anthropogenic activities like burning of fossil fuels, deforestation, biomass-burning and cement production are notable sources of CO₂ production. Natural sources include respiration and volcanic eruptions. CO₂ is removed predominantly from the

ecosystem as a result of photosynthesis by plants and through oceanic absorption. From year 1957, atmospheric CO₂ is measured at the South Pole and 1958 at Mauna Loa, Hawaii. Methane (CH₄) CH₄ is more commonly known as swamp gas. This is the second most abundant greenhouse gas and it is 21 times more efficient at warming than CO₂. CO₂ is much more abundant in the atmosphere and remains in the atmosphere for a much longer period of time than methane and therefore has a larger overall warming effect in the atmosphere than methane does. Methane is produced anthropogenically by landfills, ruminant livestock, biomass burning and natural gas systems. Some natural sources are wetlands and termites. Methane is the largest component of natural gas, which is used as a fuel source once the contaminants are removed. The atmospheric lifespan of a molecule of methane is estimated to be around 12 years. Until industrial revolution, CH₄ concentration recorded was 730 ppb but it has increased more than three times in the last decade, 1774 ppb. Total annual emission of CH₄ has been estimated as 600 Tg, 60% of the total share is by anthropogenic activities like agriculture, burning of fossil fuel and from waste. CH₄ has a mean absorption band at 7.7 μm and has residence time of 9 to 15 years. c) Nitrous oxide (N₂O) Nitrogen being dominant in share by volume, formation of nitrous oxide (N₂O) also known as laughing gas is one of the naturally occurring greenhouse gases (GHGs) in the atmosphere. This is 200 times more powerful GHG than a unit of CO₂ in terms of global warming potential calculated over a period of 100 years. In recent past, its concentration has increased from 275ppb to 320ppb. Ocean and wet forest soils (9 Tg/year) are two predominant natural sources of nitrous oxide emission followed by anthropogenic i.e., deforestation and nitrogenous fertilizer (6Tg/year) to atmosphere. Nitrous oxide has an absorption band at 7.8 μm and 8.6 μm. d) Halocarbons (CFCs) Halocarbons are the substances responsible for the hole in the ozone layer. Though they have been heavily regulated, they are still responsible for some amount of global warming. Halocarbons are mostly man-made gases consisting of both carbon and at least one of the halogens (fluorine, chlorine, iodine, and bromine). The majority of them fall into the category of Chlorofluorocarbons or CFCs. It is carbon-to-fluorine bonds in halocarbons that oscillate and hence absorb at 9 μm. It has ability to destroy stratospheric ozone, but they are also very strong greenhouse gases. On average, they are thousands of times more efficient at warming than CO₂. Fortunately, their concentrations are very small, so their powerful greenhouse effect is limited. Their atmospheric lifespan can range from 1 to 50,000 years. The sources include refrigerants and propellants. Most of these gases have been highly regulated by the Montreal Protocol (1989) and the vast majority of them are decreasing. Though emissions of CFC- 12

have almost stopped, it is such a long-lived gas that it is still responsible for some global warming as well as the ozone hole.

Aerosols: Aerosols are defined as microscopic liquid or solid particles of less than 10 μm diameter, dispersed in the atmosphere. Aerosols are non-uniform in shape and size so equivalent aerodynamic diameter determined by comparing them with perfect spheres having same settling velocity. Aerosols come from volcanoes, dust storms, fires, vegetation, sea spray, burning of fossil fuels and land use. Aerosols live only for days to weeks in comparison to other GHGs in the troposphere. Aerosols are more complicated than the typical greenhouse gas. It can do both the cooling and heating of the atmosphere. They affect the Earth's energy balance in three ways: by enhancing albedo i.e., by reflecting back the incoming solar radiation, by providing cloud condensation nuclei and by more absorption of incoming solar radiation.

Solar Radiation:

Solar radiation is radiant energy emitted by the sun from a nuclear fusion (hydrogen into helium) reaction that creates electromagnetic energy. This indicates the surface temperature of Sun as about 5800 K. Sun emits not only in visible range but also UV-rays, infrared ray, X-rays, and even radio waves. Out of these, about half of the radiation is in the visible range only. The other half is mostly in the near-infrared part, with some in the ultraviolet part of the spectrum. UV-rays range from 0.1 to 0.4 μm ., visible (VIBGYOR) ranges from 0.4-0.7 μm and infrared ray varies from 0.7 μm -1mm. The surface temperature of the earth is controlled by the balance between the absorbed solar radiation and the emitted infrared radiation. During the past 150 years the amount of CO₂ in the earth's atmosphere has increased from 280 parts per million (ppm) to more than 400 ppm by burning of fossil fuels. Urbanization, deforestation and desertification, agriculture and livestock activity have been categorized as important sectors in emitting CO₂, CH₄, N₂O, particulate matter containing Black Carbon (BC), volatile organic carbon (VOCs), etc.

Causes And Consequences

Climate change is caused due to emission of greenhouse gases into the atmosphere. The effects of global warming have been experienced by humans, animals and plants alike. In this block, we will discuss the impact of climate change on agriculture, ocean ecosystem, mountain and hill ecosystems and human health. In this block, the two-way link between climate change and agriculture is discussed. Changing climate will impact agricultural productivity and production.

Climate change influences many properties of the ocean, while changes in the ocean also play a central role in regulating weather on local to global scales. The ocean has huge thermal inertia and dynamic capabilities. Being a huge reservoir of heat, the ocean plays as a moderator of climatic variations. It controls the formation of wind and rain. The ocean also traps and stores carbon dioxide (CO₂), thereby preventing an extreme greenhouse effect in the atmosphere. Increased ocean stratification, changes in ocean current regimes and an increase in depleted oxygen zones are now being observed due to climate change. Climate change also impacts the mountain ecosystem. Mountain and hill ecosystems are also characterized by their unique type of vegetation, floral and faunal diversity as well as distinct living habitats. This diversity itself varies with the altitude of mountains, with taller trees being found at lower altitudes giving way to shorter trees, grasslands etc. at higher altitudes. The highest altitudes of mountains are completely devoid of any vegetation. The consequences of climate change on the mountain ecosystem include glacier melting, cloudburst and flash floods, and Glacial Lake Outburst Floods (GLOFs). This block also discusses the impacts of climate change on human health.

Changing Climate

Climate variability has ripple effects on crop production, food prices and food security at local and global levels. Production shocks in one part of the world can have immense impact on the food prices and hence food security of various parts of the world due to the market dynamics. Sudden changes in food prices could be particularly harsh on the food security of the poor who spend a large chunk of their income on food. Understanding the nature of changing weather patterns is particularly important for this very reason. “Global surface temperatures have risen by almost a degree in the last century. Sea levels have risen, while snow and ice cover has dropped significantly. Coral reefs are being destroyed and weather patterns are becoming wilder and less predictable. And the major cause of this climatic mayhem is now clear. It is the work of humans, who are burning ever increasing amounts of fossil fuel and have raised carbon dioxide levels in the atmosphere by 40% in the past 250 years” (McKie, 2013). The plant and animal species specific to a particular region are a reflection of the climate to which they are adapted. Once a change in their natural climate occurs, they tend to migrate to areas having more favourable environment. Species that are less mobile are the worst affected as they have to suffer a loss of their habitat combined with competition from new invading species. This results in such species becoming extinct and as a result there is loss in biodiversity. Changing Precipitation with increase in temperature due to global warming, the air becomes warm, resulting in more evaporation of water from the Earth’s surface. Higher evaporation translates

to higher precipitation. On average, the world is already getting more precipitation now than it did 100 years ago: 6 percent more in the United States and nearly 2 percent more worldwide (US EPA, 2013). Precipitation is expected to lower in areas near equator and increase in higher latitudes. The changing rainfall pattern can cause the pests and weeds to spread to newer areas. El Nino and La Nina: El Nino phenomenon occurring in the eastern Pacific Ocean is primarily due to the build-up of warm water in the eastern Pacific Ocean. The warm ocean surface enables the moisture laden winds to form rainstorms. On the other hand, La Nina occurs due to the building up of cool Ocean waters in the eastern Pacific Ocean. The cool ocean surface leads to cooling of the atmosphere leading to lesser evaporation of water and making the air dry. “El Niño and La Niña reflect the two end points of an oscillation in the Pacific Ocean. The cycle is not fully understood, but the times series illustrates that the cycle swings back and forth every 3-7 years. Often, El Niño is followed immediately by La Niña, as if the warm water is sloshing back and forth across the Pacific. The development of El Niño events is linked to the trade winds. El Niño occurs when the trade winds are weaker than normal, and La Niña occurs when they are stronger than normal. Both cycles typically peak in December” (NASA, 2009).

Effects of Climate Change on Agriculture

Agriculture, livestock and fisheries are highly dependent on specific climatic conditions. Crops need specific conditions to thrive like right kind of soil, specific temperature, and enough water. Changes in climate could make it difficult for us to grow crops and rear livestock in the way and at places; we used to do in the past. Climate change and variability has potential to influence crop geography, crop production and productivity, and exacerbate the risks associated with crop farming activities (Scherr et al. 2012; Venkatramanan and Shah 2019). IPCC Assessment reports reiterate the gravity of climate change impacts on agricultural production and productivity in several agricultural regions of the world, and firmly expressed the vulnerability of developing countries and island and low-lying countries to negative impacts of climate change (IPCC 2014). Impacts from extreme weather events like droughts and floods, heat and cold waves, must be reckon with in the coming decades through devising appropriate climate resilient pathways (Venkatramanan and Shah 2019). “Research has shown that crop yields reduce in response to extreme daytime temperatures particularly around 30°C. High daytime and night time temperature was reported to reduce the growth, yield and quality of rice and wheat crops which are the staple food crops of South Asia” (Venkatramanan and Singh 2009a, b; Venkatramanan and Shah 2019). “Estimated impacts of both historical and future climate change on cereal crop yields shows that yield loss can be up to 35% for rice,

20% for wheat, 50% for sorghum, 13% for barley, and 60% for maize depending on the geographic location, climate scenarios and projected year” (Porter et al. 2014; Khatri- Chhetri et al. 2017). The negative effects of climate change on “food production, food prices and accessibility, consumption and utilization” result in marked effect on “all the dimensions of food security” (Porter et al. 2014). Further, climate change on account of its effects on “access to drinking water, income, health, sanitation, income and food supply chain” exacerbate the food insecurity. FAO (2009) reports that vulnerable and disadvantaged group in particular the small and marginal farmers and food insecure are most likely to be the first affected from climate change (FAO 2009). Monsoon Dependent Agriculture The International Food Policy Research Institute (Gerald C. Nelson, 2009) conducted research to “quantify the climate-change impacts on agricultural production, consumption, prices and trade”. To meet this end, the study employed a “global agricultural supply and demand projection model” and “biophysical crop model” to assess the impact of climate change on five important crops: “rice, wheat, maize, soyabean and groundnut”. The results of the study on various aspects of agriculture have been summarized below: Atmosphere and Climate According to the study, while the crop yields in the rainfed region are influenced both by rainfall and increases in temperature, the irrigated crop yields are influenced only by temperature factor. The study further points out that in case of developing countries, while the crop yield declines are found across most crops, the irrigated crops of rice and wheat are more vulnerable to climate change. In the regions like East Asia and Pacific region, higher temperature in fact increases crop acreage as the potential temperature increase provide congenial crop growth environment than the present environmental condition. South Asian region will be affected more by climate change, as the study found yield declines for most of the crops. Nevertheless, rainfed maize and wheat crops are more vulnerable to climate change. The results for the Latin American and Caribbean region, and SubSaharan Africa were mixed in terms of yields of crops grown in these regions. Enhanced CO₂ on Crop Growth “Crop species vary in their response to CO₂. Wheat, rice, and soybeans belong to a physiological class (called C₃ plants) that respond readily to increased CO₂ levels. Corn, sorghum, sugarcane, and millet are C₄ plants that follow a different pathway. The latter, though more efficient photosynthetically than C₃ crops at present levels of CO₂, tend to be less responsive to enriched concentrations. Higher levels of atmospheric CO₂ also induce plants to close the small leaf openings known as stomata through which CO₂ is absorbed and water vapour is released... Thus, under CO₂ enrichment, crops may use less water even while they produce more carbohydrates. This dual effect will likely improve water-use efficiency, which is the ratio between crop biomass and the amount of water

consumed. At the same time, associated climatic effects, such as higher temperatures, changes in rainfall and soil moisture, and increased frequencies of extreme meteorological events, could either enhance or negate potentially beneficial effects of enhanced atmospheric CO₂ on crop physiology". (Hillel, 1995). Weeds, Pests and Diseases Increased CO₂ leads to strong vegetative growth in both crops and weeds alike as a result of which weeds become more prolific and are expected to spread to newer places. There are also studies which prove that higher levels of CO₂ lead to herbicide resistance as a result of which more and more herbicides have to be applied. This may also have serious health implications in time to come. Besides, higher temperatures are favourable for insects and pest proliferation. Longer growing seasons will enable insects and pests to complete larger number of reproductive cycles. Changed wind patterns would lead to spread of wind-borne pests and diseases to newer areas. Warmer winter temperatures may shorten the overwintering period of pest larvae resulting in higher proliferation in the next season. Thus, an increase in weeds, pests and diseases could soon be a problem calling for immediate. Crop Quality Food systems can be vulnerable to climate change. Grain quality of wheat (e.g., protein content) is highly susceptible to current variations in climate and affects the type of foods that can be produced through, for example, gluten levels and related dough strength (Porter & Semenov 2005). Other examples of the effects of climate on crop quality include pests and diseases, such as dangerous levels of mycotoxin contamination of groundnuts (Julia M Slingo, 2005). Livestock Climate change is expected to impact both crops and livestock alike. Increased temperature is bound to increase stress levels among livestock. This may result in decline in the rate of reproduction, increased incidences of diseases and also loss of appetite. Increased levels of CO₂ in the atmosphere may result in production of less nutritious feed and forage which may be required to be supplemented by additives, thus adding to the cost to the grower.

9.6.6 Prices, Production and Food Consumption

The results reveal that though, even without climate change, the prices of rice, maize, soyabean and wheat are bound to rise between 2000 to 2050, however, with climate change, there will be additional price increases to the extent of a total of 32 to 37 percent for rice, 52 to 55 percent for maize, 94 to 111 percent for wheat, and 11 to 14 percent for soybeans. Though the study does not show any direct effect on livestock due to climate change, the effects of higher feed prices caused by climate change pass through to livestock, resulting in higher meat prices. For example, the prices of beef will be 33 percent higher due to no climate change by 2050 and 60 percent higher with climate change. Importantly, the negative impacts of climate change and variability shall be markedly observed in Sub-Saharan Africa and South Asia. The results have also shown that climate change reduces the consumption of meat slightly and of cereals

substantially indicating negative welfare effects due to climate change. The results of the study showed that without climate change, the calorie availability increases throughout the world by 2050 whereas with climate change, the calorie availability showed marked reduction relative to 2000 levels. Further, climate change and variability encompass increased frequency of extreme weather events like heat waves, droughts, etc. Heat waves, specially occurring during some crucial stages of plant life cycle like pollination or pod set can limit yields. Heat waves can also cause wilting due to excessive transpiration, unless they are provided with irrigation. Droughts result in long term lack of water availability in plants resulting in famines. Strong winds can damage the leaves and heavy rains can cause flooding, both of which can be detrimental to the crops. If the temperature rise occurs in cooler areas of the world, those places will become more habitable and we may witness crops moving their ranges. In areas where crops are being grown in their warmest productive temperature ranges already, heat stress or increased disease could reduce yields. When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep drop in net growth and yield. If night time temperature minima rise more than the daytime maxima--as is expected from greenhouse warming projections--heat stress during the day may be less severe than otherwise, but increased night time respiration may also reduce potential yields. Another important effect of high temperature is accelerated physiological development, resulting in hastened maturation and reduced yield.(Hillel, 1995). Since agriculture is dependent on rainfall, any change in its pattern or total precipitation will significantly affect agriculture. Moisture stress, especially during important stages of plant growth like pollination, flowering and grain filling is harmful. Increase in temperature may lead to higher rates of transpiration causing moisture stress in plants and would call for increased need for irrigation. In coming years, the demand for water for irrigation may increase due to warmer climates and agriculture may have to compete with other industries for water. Less rainfall also results in falling water tables which would also increase the energy needed to pump underground water. Scientists and plant breeders are working towards developing new drought resistant varieties of various crops.

Species Emergence and Extinction

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

programmes and other data indicate increased sea levels currently compared to the past 2000 years. Sea expands when its water temperature increases. Likewise, melting of glaciers and polar ice leads to rising in sea level. Human activities like draining wetlands, groundwater withdrawal, dam construction, and land use change also contribute to sea level rise. Sea level rise is a serious concern as 41% of the world's population lives within 100km of the coast. The current rate of increase in sea levels (3.1mm per year), is higher than that the values predicted by the IPCC for 2100. However, these rates are not similar globally and have special variability. Changes to the Ocean's Major Current Systems Changes in ocean temperatures and wind patterns will affect and alter oceanic currents. As the ocean currents play a significant role in maintaining Earth's climate, changes in the ocean's major current systems will have major repercussions for the global climate. Oceanographers have observed changes in the North Atlantic Ocean currents on account of increase in sea surface temperature and increase in melting of ice. The Atlantic plays a key role in managing global ocean currents. The sinking of large amounts of cooler water in this ocean creates currents in the Southern and Pacific oceans. Hence a slowing down of the currents in this region has global impacts. The entire Northern Hemisphere cools, Indian and Asian monsoon areas dry up, North Atlantic storms get amplified and less ocean mixing results in less plankton and other life in the sea. Also, it would lead to heating up of the southern hemisphere. The IPCC concluded that the circulation may reduce up to 54% by this century if temperature increases by 4 degrees C and GHG emissions keep increasing.

Migration Pattern

The distributions of many marine species including those we rely on for food are shifting because of their dependence on specific water temperatures and nutrient availability. Many marine species are moving toward the poles disrupting fisheries around the world. A recent study noted that more than 800 species of commercially important fish, including halibut, herring, tuna, and cod have migrated north. Many marine species such as whales and salmon time their migratory and reproductive cycles around prey. Whales migrate to the Arctic to prey on krill in the summer and salmon migrate to the oceans for seasonal nutrients. When these patterns are altered due to a changing climate, it results in a change of predator-prey relationships and increases mass strandings', starvation, and poor reproductive success. For Atmosphere and Climate example, warmer sea surface temperatures along the US Northeast continental shelf are forcing a specific zooplankton species to shift to cooler waters. Atlantic Cod that prey on them in the Gulf of Maine and Georges Bank are found to have lower

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

Direct Effects on Human Health

According to a report of the World Bank in 2010 the baseline health of a country is related to the amount of impact that could be caused due to climate change and also the costs for its adaptation. Therefore, the likely risks and impacts of climate change vary between countries. A small change in the global climate will affect the normal functioning of the earth's ecosystems. Some countries may experience extreme cold temperatures and people living in such areas would want warmer climates; for example the USA. Likewise certain areas may receive very hot temperatures and people would want cooler temperatures. These changes in climate can lead to beneficial and/or Atmosphere and Climate adverse effects. The changes that may be witnessed initially may be some changes in the seasonality of some infectious diseases. This includes vector borne infections such as mosquito-borne diseases: dengue, chikungunya and so on that strike during the warmer periods. Some plant and animal varieties may die or even go extinct due to changes in climate variability, whereas some species are able to adapt themselves to the changed conditions. Some other significant impacts of climate change include changing food productions, agrarian distress and socio-economic issues. The table 12.1 given below gives you an idea of some environmental changes, the diseases caused

therein and the different pathways responsible for bringing about infectious diseases in human beings.

Climate Change Impacts on Human Settlements, Migration and Livelihood

Climate Change Impacts on Human Settlements and Migration From time immemorial humans have travelled and settled along coastlines and other places for their livelihood and better opportunities. Some people are displaced due to conflicts, dam construction related issues and also due to catastrophes such the 2004 tsunami where millions were affected and displaced. Drought and extreme climatic events also force people to search for better economic conditions and employment either temporarily or permanently. Another example is the 2008 Kosi floods that displaced many in Nepal and India. These events are sudden and sometimes unforeseen events. Sudden-onset hazards have forced several million to migrate to other areas. The hazards cause physical loss of land and natural resources and people are unable to cope or adapt with the changes. On the other hand, drought is a slow creeping hazard. Slow-onset hazards still give people time to adapt themselves to the situation by regenerating the soil fertility and using appropriate seeds for cultivation etc. There are many factors that influence human migration. They include social, environmental, cultural, economic and political. The Paris Agreement gives references to migration and displacement. In the preamble, it refers to the vulnerability of migrants, and calls on states to ‘respect, promote and consider their respective obligations on human rights’ when taking action to address climate change (UNFCCC, 2015: 1). It also addresses the need for a task force to ‘develop recommendations for integrated approaches to avert, minimize and address displacement related to the adverse impacts of climate change’ (UNFCCC, 2015). The Hyogo Framework for Action also recognized displacement as a potential driver of vulnerability (UNISDR, 2005). The Sendai Framework focuses on displacement in response to extreme events (UNISDR, 2015). Therefore, climate change brings about migration both within and crossborders. Climate Change Impacts on Livelihoods. Livelihoods can be defined as the different types of assets, abilities and activities that enable a person or household to survive (FAO, 2003). These assets include physical assets such as infrastructure and domestic assets; financial assets such as cash, jewellery, savings, mutual funds and pensions; natural assets such as natural resources, land for agriculture; social assets, which are based on the cohesiveness of people and societies; and human assets such as education and skills for survival. All these assets change with time (with cycle of events, we may lose or earn the assets) and are always different for various households and communities. In general, we should have a mix of assets so that we can tide over difficult situations. Our

ancestors always believed in having mixed assets. In society we have different groups, various communities and not all can adapt to the climate change driven impacts. The marginal groups are those people who have few or lesser resources and power and they are not able to adapt themselves to the changes. In fact, they can be negatively impacted. It is usually people's few productive assets that are at greatest risk from the impacts of climate change. In principle, all the physical assets can be damaged, financial losses can occur, natural assets can be degraded or even destroyed and social assets can be undermined. Climate variability can result in certain food products becoming scarce at certain times of the year. Such seasonal variations in food supply, along with vulnerabilities to flooding etc. can impact livelihoods. Although these impacts might appear indirect, they are important because many marginal livelihood groups are close to the poverty line. Food is a key element of their existence. The main source of livelihood for the marginal groups is agriculture, livestock rearing and fishing. In most instances the challenges encountered by the rural livelihoods drive urban migration. When the numbers of the poor and vulnerable groups in urban slums increase, the availability of employment opportunities which are non-agriculture/non-farm based and the access of urban dwellers to obtain sufficient food products from the market will become increasingly important drivers of food security. A study by the International Labour Organization study (ILO, 2005) reports that there will be significant variations among the low income and middle-income countries in regarding the impacts of climate variability on livelihoods dependent on agriculture. The livelihood groups that are of concern in the context of climate changes include the low-income group affected by drought and flood; those who have poor food distribution and emergency response mechanisms. For example, fishermen living along the coastlines may experience sea-surges, storms, tsunamis and their fishing infrastructures may be damaged. They can lose their homes constructed nearby that are washed away by the storms. What happens to their livelihoods then? In the same way farmers may experience flash floods, wherein their land can be completely submerged and their crops may be destroyed. So, such changing temperature and rainfall conditions can devastate their livelihoods immediately. Therefore, climate change has 225 Atmosphere and Climate serious consequences and affects the lives of a million people around the world. Adaptation measures are necessary to address these concerns. They include preparing heat wave early warning systems, urban planning to reduce the urban heat island effect, better land-use planning, community relocation, reducing the vulnerability of essential services such as water, energy and food, and measures to assist vulnerable sectors and households. In addition, early warning systems and flood and cyclone shelters are also important health related adaptation strategies.

Mitigation

Agriculture As a Sink for Greenhouse Gases

Agriculture sector can also act as a sink to GHG. Firstly, agricultural sector can reduce its own emission. Plants use CO₂ for photosynthesis. Hence, they have the ability to offset emissions from other sectors by reducing CO₂. The biomass generated in agricultural sector can be used to produce biofuels which can be a substitute to fossil fuels which are currently used for energy. Improved management practices in agriculture can help in storage of carbon in plants and soils. Every tonne of carbon added to, and stored in, plants or soils removes 3.6 tonnes of CO₂ from the atmosphere (Paustian et. al, 2006). Agriculture can increase soil carbon by the following:

- 1) Cropland Management: Several management practices can increase cropland soil carbon. Carbon inputs to soil can be increased by increasing crop productivity, growing crops that produce large amounts of residues, doing away with the practice of fallow periods between crops, efficient use of fertilizers, manures and irrigation and use of zero tillage or low tillage practices.
- 2) Management of Grazing Land: Soil carbon of grazing lands can be increased by improved management practices. These management practices include use of proper fertilization, irrigation, cultivation of legumes, improved grazing and use of improved grass species.
- 3) Changes in land use can also help to increase carbon in soil. Conversion of crop lands to forests or grassland can increase soil carbon. Highly degraded areas like reclaimed mines, saline soils and eroded lands have high potential of carbon sequestration if a productive plant cover with high rates of carbon inputs from residues can be achieved.

The Ocean acts as a carbon sink by absorbing large quantities of CO₂. The CO₂ absorption capacity of the ocean is ten times than that of fresh water, as CO₂ is immediately reactive in sea water. This phenomenon causes changes in the chemical properties of the ocean.

Adaptation to Climate Change

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

Early Warning Systems: If the possibility of a potential disaster is known in advance, communities can be motivated to establish safeguards particularly at household levels.

Strengthening Coping mechanisms: New adaptive mechanisms need to be designed based on indigenous knowledge and traditional practices. This would strengthen the capacity of local people to address the issue of climate change within their own communities and social structure.

Mitigation activities to support adaptation: Actions promoting Sustainable Land

Management improve the natural resource base of a region by restoring soil fertility, improving water availability, etc. Joint Forest Management: Conserving and establishing forests by the communities can help in checking moisture and soil loss and improving soil quality. Diversification of Livelihoods: Studies assessing the diverse systems of a region supporting the local livelihoods and their resilience to climate change will help in determining viable new options that provide innovative solutions. Local Governance: Participation of local communities in policy formulations and project development is very essential. The ability of these communities to develop the rationale for new technologies is crucial to their ability to be flexible when there is great uncertainty. Climate Insurance: Financial instruments on which the communities can bank upon at times of unanticipated risks are a priority.

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Web Links

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

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