Chapter 4
Global Warming: Impacts of Temperature Escalation

4.1 Introduction

Since the Industrial Revolution, anthropogenic activities like industrial, economic, land use, and population growth have significantly impacted climate by increasing atmospheric CO_2 and other heat-trapping gases. In 2010, CO_2 continued to be the main anthropogenic GHG, contributing 76% (383.8 Gt CO_2 eq/year) of all anthropogenic GHG emissions. CH_4 contributes 16% (781.6 Gt CO_2 eq/year), N_2O contributes 6.2% (311.9 Gt CO_2 eq/year), and fluorinated gases contribute 2.0% (100.2Gt CO_2 eq/year). According to the IPCC, by 2100, the average surface temperature could have increased by more than 6 °C. From 280 parts per million in the pre-industrial era to 400 parts per million in 2014, the atmospheric CO_2 concentration grew by 42.8% over the course of the twentieth century, and an increase in CO_2 concentration and other GHGs (CH_4, N_2O) led to an increase in the global mean temperature of 0.85 °C (0.65–1.06 °C) (IPCC 2014) (Fig. 4.1).

Continued GHG emissions will result in additional warming of the atmosphere, changes to various climate system components, significant livelihood consequences, and widespread and irreversible effects on people as well as terrestrial and aquatic ecosystem. For natural and human systems, climate change will both increase already present dangers and generate new ones (Ozturk et al. 2011). Risks are unevenly distributed and typically have a greater impact on underprivileged individuals and communities in nations of all developmental stages. Extreme weather events and unexpected precipitation will influence the effects of climate change and have a negative impact on soil, plants, people, and animals. Additionally, it is believed that climate change will increase the severity and frequency of floods, wildfires, glacier melt, dry spells, and the introduction of new diseases, crop shifting, starvation, and insect-pest infestations (Lal 2011). This chapter will provide an information regarding the impacts of climate change on terrestrial, as well as aquatic ecosystems.

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Fig. 4.1 Impacts of global warming. (Source: National Oceanic and Atmospheric Administration (NOAA) https://images.app.goo.gl/kPNM2TsLwAnqbMgw7)

4.2 Climate Change Impacts on Terrestrial Ecosystems

4.2.1 Carbon and Nitrogen Dynamics

The physical, chemical, and biological characteristics of soil offer details about factors affecting germination, root growth, and erosion processes, as well as information about water, air, temperature, microbial activity, and soil reactions. Other chemical and biological activities are supported by a number of soil physical qualities, which may then be further influenced by climate, landscape position, and land use. Significant soil indicators of climate change include mineralization, volatilization, microbial decomposition, salinization, evapotranspiration, and increased greenhouse gas emissions. The carbon and nitrogen dynamics of soil are highlighted as potential soil health determinants.

In climate change settings, the amount of organic matter in the soil is a sign of the quality of the organic matter and the health of the soil, acting as a nutritional agent for microbes during the nutrient cycle process (Gregorich et al. 1994). Reduced SOM can result in microbial biodiversity, duct ion infertility, loss of soil structure, decreased WHC, and an increase in soil erosion. SOM is what controls how the soil operates (Weil and Magdoff 2004). Farm-level land use changes and soil management techniques that encourage the accumulation of organic matter in soil will aid in absorbing CO_2 from the atmosphere, hence reducing global warming and the anomalies associated with climate change. Organic matter can play a crucial part in reducing the effects of flooding during high rainfall events by enhancing soil moisture and water storage. It can also conserve water during droughts, enhancing soil resilience.

4.2.2 Impacts of Climate Change on Soil Salinization

Although salt is required for cooking and food preparation, too much salt in the soil can kill crops and make fields unusable. In both rainfed and irrigated settings, soil salinization is a degrading process that destroys both crop productivity and soil fertility. Higher and more variable temperatures, precipitation patterns, and a greater frequency of extreme occurrences are the main predicted effects of climate change (Al-Najar and Ashour 2012). Water security will be threatened by declining water supplies connected to salt intrusion into surface and subterranean water. Therefore, controlling sustainable water resource consumption depends on recognizing the connection between surface and subterranean water. Food security will be significantly impacted by worldwide soil salinization and water constraint (Teh and Koh 2016). The effects of climate change and global warming are perceived worldwide, but they are more critical in arid regions where soil salinization is most likely to occur. The soils of Central Asia greatly speed up the formation of salt. The manner that salt is redistributed in the soil profile is determined by climatic factors, particularly precipitation. Rainfall in the winter and spring means that readily soluble salts are carried across more quickly. The following factors will cause climatic changes to widen the areas with saline soils: first, rising temperatures and aridity have a direct impact on salt transport and soil salt balance; second, changes in land use have an indirect impact on salt dynamics (Szabolcs 1990). Low-lying coastal areas commonly experience salt water inundation as a result of sea-level rise, which continuously contaminates the soil nearby. Rainfall can disperse these salts, but climate change is also increasing the frequency and intensity of extreme weather events, such as heat waves and droughts. Due to increased groundwater consumption for irrigation and drinking, the water table is further drained, increasing the amount of salt that can seep into the soil. The warming of the water and rising ocean temperatures from climate change have an impact on soil salinity. Even with greater reductions in GHG emissions, scientists now forecast that global mean sea levels would rise by at least 0.25 to 0.5 m by 2100. Globally, soil salinity will lead to higher food costs, more food shortages, and poorer yields from many farmers, which means reduced income.

4.2.3 Impacts of Climate Change on Evapotranspiration

Climate change has an impact on evapotranspiration (ET), one of the key components of the hydrologic cycle. The weather is changing over long periods of time, which is a sign of climate change (IPCC 2014). Evapotranspiration rates will fluctuate as a result of a shift in climatic factor patterns brought on by climate change (Helfer et al. 2012). Potential evaporation (ET_P), which measures the combined impact of numerous meteorological parameters, including solar radiation, wind speed, ambient temperature, vapor pressure, and humidity, can be thought of as a measure of atmospheric evaporative demand (Dinpashoh et al. 2018). On both a regional and a global level, atmospheric temperature is regarded as the most widely utilized indicator of climatic change. According to the IPCC report (2013), between 1913 and 2012, the average global temperature increased by 0.91 °C (Stocker et al. 2014). This increase in temperature is expected to continue throughout the twenty-first century, changing the hydrological cycle by changing both precipitation and evaporation (Huntington 2006). Water availability, quality, and quantity may be significantly impacted by this, especially in underdeveloped semiarid locations (Dastorani and Poormohammadi 2012). Potential evapotranspiration (ET_P), which describes a significant water loss from catchments, is widely acknowledged as a crucial hydrological variable. It can be used to calculate actual evapotranspiration (ET_a), scheduled irrigation, and other management methods in the crop field. It is related to groundwater recharge, runoff, and water movements in soil, some key forms of hydrological processes (Zhang et al. 2011; Xu and Li 2003). Climate change will likely result in more drought conditions by increasing potential evapotranspiration and increasing crop water use in areas with limited water resources (Thomas 2008). Climate change models predict that ET_P will rise during the next few years as a result of anticipated temperature acceleration (Goyal 2004; Liu et al. 2018).

4.2.4 Impact of Climate Change on Plants and Animals

Due to escalated temperatures due to climate change, shifts in life cycles are expected (e.g., early flower blooming, birds hatching earlier in spring, and many species shifting their migration pattern). Due to global warming, plants and animals will migrate toward poles, and the species which may fail to migration shall perish. Some scientists opine that 20–50% of the species could be committed to extinction with 2–3 °C of further warming.

4.2.5 Impact of Climate Change on Weather

Polar regions of Northern Hemisphere will heat up more than other areas of the planet, glaciers will melt, and sea ice will shrink. Winter and night temperatures will tend to rise more than summer and daytime temperatures. Warmer world will be more humid (because of more water evaporating from oceans). Water vapor is a GHG and induces warming phenomenon, but, on the other hand, more water vapor will produce more clouds which reflect sunlight back. More clouds may cause flash floods due to probability of cloud bursts.

Contrarily, enhanced greenhouse effect will lead to more evaporation of soil water; therefore, droughts are projected to become more intense. Weather patterns are expected to be less predictable and more extreme.

4.2.6 *Impact of Climate Change on Health*

Diseases like malaria, dengue fever, yellow fever, Japanese encephalitis, allergies, and respiratory diseases shall proliferate due to high temperature.

4.3 Climate Change Impacts on Aquatic Ecosystem

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

Ocean ecosystems are being significantly impacted by climate change, although the extent of these changes is still not fully understood. Despite the oceans' enormous capacity to absorb heat and carbon dioxide, the warming trend seems to be accelerating. More than 90% of the Earth's warming since 1950 has been observed in the oceans. As a result of climate change, ocean stratification has increased, ocean current regimes have changed, depleted oxygen zones have expanded, the geographic ranges of marine species have changed, and the growing seasons, diversity, and abundance of species communities have changed. As a result of atmospheric warming, inland glaciers and ice are melting, leading to rising sea levels that have a significant impact on shorelines (coastal erosion, salt water intrusion, and habitat destruction), as well as coastal human settlements. According to the IPCC, the global mean sea level will rise by 0.40 (0.26–0.55) m from 1986–2005 to 2081–2100 under low emission scenarios and by 0.63 (0.45–0.82) m under high emission scenarios. Furthermore, growing GHG emissions are expected to result in an increase in the frequency of extreme El Niño episodes.

4.3.2 *Changes in Physical Properties*

Oceanic circulation, sea-level rise, variations in water temperature, and intensified storms are few examples of how ocean physical features are changing.

4.3.3 *Changes in Water Temperature*

Although the ocean has absorbed more than 80% of the heat that climate change has added to the Earth system, the ocean is suffering as a result. Oceanic heat waves have occurred more frequently, by more than 50%, in the last century or so. A marine heat wave is described as having temperatures that are significantly higher than average for at least 5 days, brought on by changing warm currents and heat from blazing sunshine. Globally, there were, on average, more maritime heat wave days per year between 1982 and 2016 than to the prior period. In general, marine habitats are harmed by heat stress and heat waves. Heat waves have significant negative consequences on the environment and the economy, including coral bleaching, mass extinctions of marine species owing to heat stress, kelp forest loss, species migration, and the resulting changes in community structure. According to certain research, fish and mobile invertebrates may seek out uninhabited environments to escape heat waves, which in turn promote diversity. Due to fluctuations in the availability of prey and corals' vulnerability to bleaching at high temperatures, birds and corals both experience poor prognoses. Corals and sea grasses, which frequently serve as habitats and sources of food for numerous other animals, are hardly affected, which causes the negative impacts to spread throughout the ecosystem.

4.3.4 *Melting of the Polar Ice*

Polar ice is melting as a result of rising atmospheric temperature, and over the past 30 years, both the thickness and coverage of sea ice in the Arctic have significantly changed. Studies suggest that, between 1980 and 2008, the thickness of sea ice decreased by 50% to 1.75 meters and, between 1980 and 2008 (28 years), the expanse of sea ice decreased by an average of 11%, with evidence of a recent acceleration.

4.3.5 *Rising Sea Levels*

As compared to the past 2000 years, sea levels have risen, according to data from monitoring programs for the sea level and other sources. When the water temperature in the sea rises, the sea expands. Sea levels rise as a result of glacier and polar ice melting. Sea-level rise is also a result of human actions such the draining of wetlands, groundwater extraction, building of dams, and changes in land use. Since 41% of the world's population lives within 100 kilometers of the coast, sea-level rise is a huge concern. Thus, erosion of beaches and dunes is more prone to occur. Small islands where land is only few meters above sea level will experience salt water intrusion, for example, Tuvalu Island in western Pacific Ocean and Kiribati Island in Central Pacific Ocean. Likewise, the Netherlands (Northwestern Europe), Cyprus, as well as other countries around the "Mediterranean Basin" may need to spend a huge amount of money to protect its shorelines, whereas poor countries like Bangladesh may be forced to simply abandon low-lying coastal areas. The IPCC estimated figures point out that sea-level rise in 2100 was lower than the present rate of rising (3.1 mm per year). These rates, however, vary geographically and are not comparable worldwide.

4.3.6 Changes to the Ocean's Major Current Systems

Oceanic currents will be impacted and altered by changes in ocean temperature and wind patterns. Changes in the primary current systems in the ocean will have a huge impact on the global climate because the ocean currents are crucial in regulating the Earth's temperature. Due to a rise in sea surface temperature and ice melting, oceanographers have noticed alterations in the North Atlantic Ocean currents. The management of the world's ocean currents relies heavily on the Atlantic. The Southern and Pacific oceans experience currents due to the vast amounts of cooler water that sink in this region. Therefore, a slowdown of the currents in this area has effects on the entire world. The North Atlantic storms intensify, the entire Northern Hemisphere cools, the Indian and Asian monsoon regions dry up, and reduced ocean mixing causes a decrease in plankton and other marine life. Additionally, it would cause the Southern Hemisphere to warm up. The IPCC came to the conclusion that if the temperature rises by 4 °C and GHG emissions continue to rise, circulation may decrease by up to 54% by this century.

4.3.7 Changes in Chemical Properties

By absorbing significant amounts of CO_2, the ocean serves as a carbon sink. Due to the fact that CO_2 is instantly reactive in sea water, the ocean's capacity to absorb CO_2 is ten times greater than that of freshwater. The ocean's chemical composition alters as a result of this process.

4.3.8 Ocean Acidification

The oceans are said to absorb around one-third of the CO_2 produced by human activity and released into the atmosphere. The concentrations of the hydrogen carbonate (HCO^{3-}) and carbonate (CO_3^{2-}) ions change as soon as CO_2 from the atmosphere reaches the water because it reacts with water molecules to generate carbonic acid. The ocean has become more acidic as a result, endangering the existence of many marine species and ecosystems, yet this has greatly slowed down global warming. It is discovered that the current ocean acidification is 30 times more severe than the natural variation. The average ocean surface pH has also declined since the Industrial Revolution by around 0.1 unit, which is noteworthy because it results in a 25% rise in acidity. By year 2100, it is predicted that ocean acidification levels will have increased by 144% if CO_2 emissions continue. The ability of marine organisms like corals to build calcium carbonate shells is drastically reduced by higher acidity. Studies have demonstrated that the creation of calcium carbonate is being hampered by ocean acidification. Ocean acidification also worsens current "physiological stresses" and significantly lowers the growth and survival rates of a small number of marine species, especially in the early phases of development.

4.3.9 Hypoxia

Ocean water warms as its heat content rises, which reduces the water's ability to hold dissolved oxygen. The prevalence of low oxygen levels (hypoxia), which makes marine ecosystems more vulnerable, is observed to increase as a result of regional and global climate change as well as coastal eutrophication. The term "hypoxic waters" refers to water with an oxygen content of less than 2 ppm. Additionally, as surface water is warmer, it no longer mixes as much with the ocean's depths. Reduced mixing of warmer, lighter surface water with denser, deeper water obstructs the delivery of dissolved oxygen to aquatic creatures that live deep in the water. This may result in "oxygen minimum zones" where it would be difficult for plants, fish, and other species to thrive. The Gulf of Mexico, the Baltic, the Adriatic, the East China Sea, and the northwestern shelf of the Black Sea are a few well-known examples of these "dead zones." It is a growing issue that has serious effects on marine life, such as changing their habitats and behaviors, causing death, and causing catastrophic alterations.

4.3.10 The Vulnerability of Marine Organisms

4.3.10.1 Coral Bleaching

About one-third of all marine animals have been found to live in coral reefs, making them a significant group of marine life. A number of variables, including temperature (the ideal range is between 22° and 29 °C), nutrients, currents, turbidity, light, pH, calcium carbonate concentration, etc., affect the growth and development of coral reefs. In terms of climate change, coral reefs are vulnerable to temperature increases. Corals expel the algae (zooxanthellae) residing symbiotically in their tissues when the water is warm (warmer than the ideal temperature for coral growth), which gives corals their bleached appearance popularly known as coral bleaching. The corals eventually die as a result of coral bleaching.

Acidification also has a negative impact on coral skeletons by slowing down coral calcification, which results in poor skeleton density and corals that are more prone to breaking. However, the effects of acidification vary depending on the species, possibly because different organisms have varying degrees of control over the pH of their calcification sites. The survival of numerous marine species is also under danger due to rising sea levels. Species that depend on relatively shallow water for photosynthesis, including corals and sea grass meadows, are also in risk. Rising sea levels have an impact on a number of marine species, for example, the Hawaiian monk seal. There is a 4% annual decline in the number of monk seals, according to reports. Numerous marine creatures may be impacted by declining krill and phytoplankton populations.

4.3.11 Vulnerability and Impact Assessment of Wetlands to Climate Change

The hydrological regimes, specifically the nature and unpredictability of the hydroperiod and the frequency and severity of extreme events, may be where climate change has the most noticeable impact on wetlands. However, other climate-related factors, such as elevated temperatures and altered evapotranspiration, altered biogeochemistry, altered levels and patterns of suspended sediment loadings, fire, oxidation of organic sediments, and the physical effects of wave energy, may be significant in determining regional and local impacts. Changes in hydrology, the direct and indirect effects of climate changes, and land use change are expected to act as mediators of pressures on wetlands. According to STRP (2002), changes in base flows could have the following effects: altered hydrology (depth and hydroperiod); increased heat stress in wildlife; expanded range and activity of some increased flooding, landslide, pest, and disease vectors; increased soil erosion; increased tropical cyclone activity, avalanche, and mud slide damage; increased flood runoff resulting in a decrease in recharge of some floodplain aquifers; and decreased water availability. Wetland systems are prone to changes in the quantity and quality of the water supply, and they are particularly susceptible to such changes. Individual wetland habitats' hydrology will be impacted by climate change primarily through modifications to the highly variable global precipitation and temperature regimes. The effects of climate change will vary according to different temperature and precipitation regimes, and so will the restoration strategies, given the diversity of wetland types and their unique characteristics. Ocean animals and habitats are impacted by both ocean acidification and rising ocean temperatures. Oceanic mammals, fish, and seabirds are all in grave danger due to climate change, which will result in mass extinctions, greater death rates, and the loss of reproductive habitats for many species. The metabolism of individuals, species life cycles, connections between predators and prey, and habitat modification are all impacted by physiochemical changes in the properties of sea water.

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