Pooja Singh · Rajeev Pratap Singh
Vaibhav Srivastava *Editors*

Contemporary Environmental Issues and Challenges in Era of Climate Change

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*Dedicated with affection to Our Parents,
Teachers, and Family Members for their
constant encouragement and support*

Climate change increasingly poses one of the biggest long-term threats to investments

Christiana Figueres

The proper use of science is not to conquer nature but to live in it

Barry Commoner

Preface

The last few decades have witnessed the prodigious population growth worldwide that led to increased demand for food and shelter. Consequently, extraction of the natural resources beyond the resilient capacity of the Earth is being performed that results in a devastating effect on ecosystems and environmental health. Presently, climate change is of prime concern among the scientific community as it is not only impacting the current world population but will also have a disastrous impact on future generations. Climate change has a significant impact on global hydrological cycle, ecosystems functioning, coastal vulnerability, forest ecology, food security, agricultural sustainability, etc. Therefore, there is a need for judicious management of natural resources and comprehensive and preventive policy approaches such as adoption of renewable energy and climate resilient agriculture, which would help in reverting the impairment due to human-induced climate change. According to the Intergovernmental Panel on Climate Change (IPCC), only immediate and sustained action will stop climate change from causing irreversible and potentially catastrophic damage to our environment. With this background, the present book attempts to accommodate different scientific views and concepts, researches, reviews, case studies, etc. on contemporary environmental issues under changing climate scenarios and different adaptation measures. This book raises an alarm on the modern-day pattern of climate alteration and, therefore, will facilitate to tackle doubts of environmental scientists, researchers, policymakers, and common people.

Chapter 1 entitled "Ecosystem health and dynamics: An indicator of global climate change" by Gini Rani and others explains the impacts of climate change on the health of various aquatic and terrestrial ecosystems. The detrimental effects, short- and long-term responses like changes in physiology, phenology, and life cycle of organisms, loss of productivity, and loss or migration of species have also been elaborated in detail for every single ecosystem.

Chapter 2 entitled "A comprehensive evaluation of heavy metal contamination in foodstuff and associated human health risk: A global perspective" by Saahil Hembrom and others gives an overall review of heavy metals contamination in foodstuff and its health risk-related issues from a global perspective. Also, different preventive and mitigation measures are nicely explained.

Chapter 3 entitled "Climate change impact on forest and agrobiodiversity: A special reference to amarkantak area, madhya pradesh" by Bhairo Prasad and others highlights the impact of climate change on the forest and agro-biodiversity of Amarkantak region. The study suggests that low average rainfall and rising mean temperature are negatively correlated with the forest and agro-biodiversity in this region.

Chapter 4 entitled "Agricultural sustainability and climate change nexus" by Deepika Pandey focuses on the ramifications of climate change in particular of agricultural sustainability. The author attempts to establish a nexus approach between climate change and agricultural sustainability in a meticulous manner.

Chapter 5 entitled "Heat stress in crops: Driver of climate change impacting global food supply" by Richa Rai elucidates the factor responsible for the rise in temperature and its role in enhancing the frequency of drought and salinity episodes which also affects agriculture production and response of increased temperature on crops phenology, physiology, and productivity.

Chapter 6 entitled "India's major subsurface pollutants under future climatic scenarios: Challenges and remedial solutions" by Pankaj K. Gupta and others offers the state-of-the-art knowledge on challenges and issues related to India's major pollutants under current and future climatic scenarios. The chapter improves our understanding of the behaviors of several major pollutants including As, F, nitrate, hydrocarbons, and salinity under future climatic scenarios. Also, this chapter facilitates to frame and implement remediation and management of major Indian subsurface pollutants under different climatic conditions.

Chapter 7 entitled "Phosphorus sorption characteristics of the surface sediments from industrially polluted GBPS reservoir, India" by Bijendra Kumar and Anshumali analyzed phosphorus sorption kinetics and equilibrium isotherm, and the relationship between phosphorus sorption parameters in 24 industrially contaminated surface sediments of Govind Ballabh Pant Sagar (GBPS) reservoir, India.

Chapter 8 entitled "Spatiotemporal variations of precipitation and temperatures under CORDEX climate change projections: A case study of Krishna river basin, India" by Shaik Rehana and others demonstrates the use of bias-corrected Coordinated Regional Downscaling Experiment (CORDEX) model simulation in analyzing the regional scale climatology at the river basin scale, Krishna River Basin (KRB), India. The precipitation and temperature simulations from CORDEX models with Representative Concentration Pathways (RCP) 4.5 were evaluated for the historical data for the period of 1965 to 2014 with India Meteorological Department (IMD) gridded rainfall and temperature data sets cropped over the basin and projections were made.

Chapter 9 entitled "Microorganisms in maintaining food and energy security in a world of shifting climatic conditions" by Nikita Bisht and Puneet Singh Chauhan provides a good account of microbial ecology for climate change adaptation and mitigation to ensure food and energy security under shifting climate scenario in a multifaceted way.

Chapter 10 entitled "Engineering photosynthetic microbes for sustainable bioenergy production" by Amit Srivastava and others gives an overview of the approaches for strain/process developments through genetic engineering, optimization of bioreactors, and processing technology that may pave the route to produce biofuels that can guarantee global energy retreat in a sustainable fashion.

Chapter 11 entitled “Ensuring energy and food security through solar energy utilization” by A.K. Singh and others focuses on harnessing solar radiation to ensure energy and food security. The chapter provides information of different solar energy operated machineries that can be used in various agricultural applications. Also, solar energy can potentially be used for electricity generation from an agri-voltaic system, which further reduces our dependence on coal-fired power plants.

Chapter 12 entitled “A conceptual framework to social life cycle assessment of e-Waste management: A case study in the city of Rio de Janeiro” by Leonardo Mangia Rodrigues and others explains and analyzes the social impacts of the solid waste management specifically regarding the Waste Electrical and Electronic Equipment (WEEE) in the city of Rio de Janeiro, Brazil. This chapter briefly presents how the reverse logistics contributes to a closed-loop supply chain based on the Life Cycle Thinking philosophy, as well as its crucial role towards the Circular Economy by promoting sustainable practices of handling products in their end of life phase, thus a sustainable solid waste management through reuse and recycling strategies.

Chapter 13 entitled “Unsustainable management of plastic wastes: A threat to global warming and climate change” by Amit Vishwakarma highlights the issue of solid waste management particularly plastic wastes around the globe and how it has become a new emerging source of greenhouse gas (GHG) emission. Also, different management approaches have been discussed in an elegant manner.

Chapter 14 entitled “Assessment of public acceptance of the establishment of a recycling plant in Salfit district, Palestine” by Majd M. Salah and others aims at assessing the public acceptance of Reduce–Reuse–Recycling (3R) principle in Salfit district, Northern West Bank, Palestine.

Chapter 15 entitled “An overview of the technological applicability of plasma gasification process” by Spyridon Achinas offers an overview of plasma-based gasification (PG) technology, a survey of existing PG facilities, a comparison with other thermal techniques, and an identification of its environmental impacts. PG is a thermochemical process whereby wastes are converted into valuable energy in the form of gaseous fuel (syngas) that can be used for heat, power, or biofuels production.

Chapter 16 entitled “Natural gas hydrates: Possible environmental issues” by Sotirios Nik and others gives us a better understanding about natural gas hydrates. Presently, the gas hydrates are known as a potential source of methane that when released to the atmosphere causes more global warming than carbon dioxide, which is the reason for ocean acidification. The chapter suggests that natural gas hydrates may also be considered as a promising future energy source.

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Our special thanks to the almighty God for giving us strength and courage and also for giving us this opportunity.

Varanasi, Uttar Pradesh, India

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Contents

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Dr. Vaibhav Srivastava has completed his doctoral research at the Institute of Environment and Sustainable Development (IESD), Banaras Hindu University, India and M.Sc. in Botany from the University of Allahabad, India. His research interests include solid waste management, composting and vermicomposting, ecotoxicology and sustainable agricultural practices. He is a life member of the Indian Science Congress Association (ISCA), Kolkata, the Indian Botanical Society, Bareilly, the International Society of Environmental Botanists (ISEB), Lucknow, and Prof. H.S. Srivastava Foundation for Science and Society, Lucknow and annual member of the Society of Environmental Toxicology and Chemistry-Asia Pacific, United States. He published 14 scientific articles in respected international journals/books and edited a book with IGI Global, Hershey, PA, USA till date. He is currently serving as a reviewer for various international journals.

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Ecosystem Health and Dynamics: An Indicator of Global Climate Change

1

Gini Rani, Jaskiran Kaur, Ajay Kumar, and K. N. Yogalakshmi

Abstract

Climate change is perhaps one of the major critical problems of recent times. It has become a subject of international concern since its increase at an alarming speed. Although atmospheric gases, surface solar radiations, volcanic activity, cosmic rays and alterations in earth's orbit are targeted as the potential causes of climate change, their consequences or impacts are not well documented. Sea level rise, flooding, extreme weather patterns, heat waves and drought are some of the pronounced consequences of climate change. Changes in biodiversity, ecosystem and ecosystem services and health caused by climate change have received minimal attention. A healthy ecosystem requires a wide diversity of microorganisms, plants and animals at different trophic levels. Removal of a single species from the niche or introduction of an invasive species might lead to ecosystem destruction. Abnormal changes in the climate pattern can alter the ecosystem health through loss of species, extinction of species, migration of species and changes in behavioural pattern. However, these changes are invisible till a species get extinct or endangered. Further the change in ecosystem health due to alterations in climate is difficult to record unlike other impacts. Sustainable practices that can reduce, sequester or capture the greenhouse gas emissions may halt the biodiversity loss, protect the ecosystem from further destruction and restore them. This chapter comprehensively describes the impacts of climate change on the health of various aquatic and terrestrial ecosystems. The detrimental effects, short- and long-term responses like changes in physiology, phenology and life cycle of organisms, loss of productivity and loss or migration of species have also been elaborated in detail for every single ecosystem.

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Climate change · Biodiversity · Ecosystem health · Loss of species · Aquatic · Terrestrial · Ecosystem

1.1 Introduction

According to the World Meteorological Organization (WMO), climate in an area can be depicted by statistically analysing (mean conditions) physical atmospheric variables such as precipitation, ambient temperature, wind, seasonal cycles and weather extremes occurring over a period of 30 years. The classical time period of three decade is considered as an indicator for studying cumulative weather pattern (climate). Climate system is an interaction of five chief components including the hydrosphere, lithosphere, atmosphere, biosphere and cryosphere. They develop under the stimulus of internal dynamics, external forcing (volcanic activities and solar variations) and anthropogenic interferences such as changes in land use pattern. The climatic structure is affected by the forces from outside the earth such as rotation of the earth, solar insolation, geometry between the sun and earth and gradual changing of the earth's orbit. In response to these stimuli over a period of time, the physical and chemical nature of earth change. The phenomena such as continental drift, land erosions, shifting of oceanic floor and change in water vapour result in change in climate.

The constituents of the atmosphere are crucial in shaping the climate of an area. Nitrogen, oxygen and argon are permanent gases and constitute 99.9% of the total atmospheric gases. The other fraction of the gas (0.1%) is constituted by carbon dioxide, nitrous oxide, methane, oxide and surface level ozone, which despite being in trace amount have a strong effect on the earth's energy budget. These climate pertinent gases along with water vapour absorb solar radiation emitted from the earth's surface and reradiate it back to the surface of the earth causing greenhouse effect, and the gases are named greenhouse gases. The major changes in the composition of the atmosphere are caused by natural phenomena which include water in different forms such as cloud of liquid water/ice crystal, hail, permafrost, snow and rain. A change in any single component of the climate system causes change in the entire climate system.

Human activities such as indiscriminate combustion of fossil fuel and deforestation are emerging factors which has strengthened greenhouse effect inducing climate change. Most of these activities have pronounced effect similar to natural forces. Land use changes including deforestation for expanding agricultural land area and road and building construction are some of the factors affecting climate. Deforestation and fossil fuel combustion have resulted in slow buildup of atmospheric GHGs, changing the composition of atmospheric gases by interfering with the solar radiation. Since the advent of the industrialization, atmospheric CO_2 level has increased by 30% (Trenberth and Fasullo 2013). The concentration of CO2 is projected to increase two folds in next 100 years if the relentless deforestation and industrial release is not controlled. Urban heat island is a very common phenomenon of local climate change arising from usage of electrical/electronic appliances, burning of fossil fuel and industrial release of toxic gases. In contrast to urban heating, a cooling effect known as suburban cooling effect has also been observed.

Aerosols of size less than 1 μm play an important role in influencing climate. The natural processes that induce aerosols are wind in desert and eruption in mountains. The anthropogenic source of aerosols are power plants and burning of biomass. While aerosols directly absorb sunlight causing enhanced warming, sometimes it reflects some radiation back into the space, causing cooling effect. The absorption and reflection of sunlight by clouds are mainly determined by the aerosols because it acts as nuclei around which the water droplet condenses and forms cloud. When sulphur dioxide (SO_2) from industrial plume is released into the atmosphere, it gets oxidized and get transformed into sulphate aerosols. The sulphate aerosols are responsible for the appearance of milky haze over the land surface.

The global warming affects oceans and causes melting of ice caps. The increasing level of CO_2 alters the chemical nature of oceans, which ultimately affect the ecosystem. Atmospheric warming increases the temperature of oceans and decreases its salinity. The melting of ice caps causes sea level rise which largely affects coastal and offshore habitat, as mentioned in Fig. 1.1. The pressure put by the driving forces have negative impact on the flora and fauna of that habitat. Recurring drought can

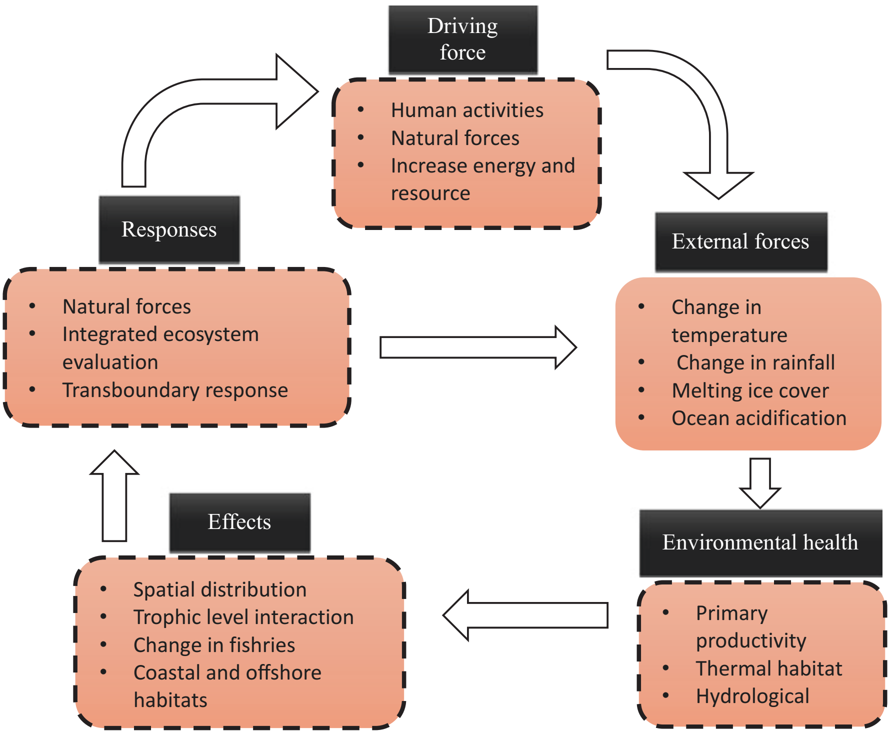

Fig. 1.1 Forces leading to change in different components of ecosystem and its effect in the climate system

trigger frequent forest fires destroying numerous species. Global warming resulted by climate change is supposed to cause extinction of vulnerable species because the rate of climate change is more rapid for the species to be able to adapt to the changing climate. The population of Himalayan snow leopards has been assumed to have declined by around 20% in the last two decades. This is mainly because of disruption and fragmentation of habitation mediated by climate change and illegal poaching. This holds true for the population of tigers too, which has reduced to mere 3200 only.

Oceans are supposed to be largest carbon sinks, which help in maintaining atmospheric CO_2 level. However, rising temperature and increased concentration of CO_2 than normal level make ocean acidic. In present scenario, large-scale change is observed in marine habitat at temperature of 1 °C. At projected increase in temperature of 1.5 °C, coral reefs are suspected to decline by 70–90%. Likewise, the climate change shows both short- and long-term impacts on ecosystem resulting in loss, migration and change in the living habits of plants, animals and even microorganisms. The detailed impact of climate change on different ecosystems will be discussed in the forthcoming sections.

1.2 Climate Feedback to Ecosystem Health and Dynamics

The influence of long-term changes in temperature, rainfall, humidity and clouds on the plant and animal productivity and ecosystem heath is discussed in detail for different ecosystems.

1.2.1 Terrestrial Ecosystem

Terrestrial ecosystems are characterized by the interaction of biological and physical component present on the land surface (Mirkhani et al. 2009). They are also termed as land-based ecosystems. The interwoven network of biological community with the physical entities on the continents and islands are called as terrestrial ecosystem. Terrestrial ecosystem is formed by the combined effect of different natural physical processes such as nutrient cycles; earthquakes and volcanic activity; flow of river, ice and sediments; and many others. The occurrence of tectonic forces such as earthquake and volcanoes certainly reshapes existing ecosystem in remarkable ways by modifying the spatial distribution of the ecosystem services. During the vibrations of landmasses and eruption of hot lava, carbon storage function, soil preservation and water withholding capacity get altered. A huge destruction, alteration and shift in the biological community also occur during such natural disasters. Terrestrial ecosystems tend to have higher thermal fluctuations compared to aquatic ecosystems on daily and seasonal basis (McNaughton 2014). Moreover, light and gases are abundantly available in terrestrial ecosystem compared to aquatic ecosystem due to the transparency. Light and gases play a central role in vital processes, for instance, CO_2 in photosynthesis, O_2 in aerobic respiration and N_2 in nitrogen fixation.

Terrestrial ecosystems are of four major types: forest, grassland, mountain and desert ecosystem. These ecosystems are invariably influenced by the existing climate. Climate is an important factor that influences the formation and interaction of terrestrial ecosystem. The ecosystem responses to the climatic variation are extensively complicated due to a number of reasons. The implications of different individual feedbacks are usually suppressed or amplified by several other mechanisms that occur on broader range of spatial and temporal level having different repercussions on different levels, and they possibly influence various aspects of climate extending from local rainfall intensity to worldwide scale temperature, and more importantly they are closely involved with human activities as inducers and responders (Field et al. 2007). The principle mechanisms involved in the climate feedback of terrestrial ecosystem are by either magnifying or suppressing climate forcing which comprise (1) changing concentration of atmospheric GHGs (greenhouse gases) such as CH_4, CO_2 and N_2O and (2) changing absorption or distribution of net solar irradiance in different layers of the atmosphere or on the earth's surface. The change in radiative forcing leads to either positive feedback loops or negative feedback loops. The climate change feedback to different terrestrial ecosystems is elaborated in the forthcoming sections.

1.2.1.1 Forest Ecosystem

Around 30% of the earth's land surface is covered under forest area. Forest cover is characterized by huge biodiversity and resources which provide a wide range of ecosystem services including ecological, social, economic and aesthetic services to humans and other natural systems. As forest resources are renewable in nature, humans since ancient times have relied on forests for fuel wood, shelter, medicines, food and other forest products. Additionally, forests play a key role in major ecological functions. It is not only responsible for the protection of soil but formation of most of the soil on the earth. Soil is nothing but disintegrated rock mixed with dead parts of plants and community of microorganisms. Forests help in the regulation of hydrological cycle as they uptake water and release it into the atmosphere through transpiration process and release it in the soil as liquid excretion. They maintain water supply by storing water like natural sponge. When rainfall occurs, it falls on the canopy of the tress rather than directly hitting the ground, thus saving from land erosion. The water is absorbed by roots and transported through the trunks and branches to the leaves. The excess water is released into the atmosphere through the leaves. When sufficient moisture is transpired by the leaves into the atmosphere, clouds are formed and precipitation occurs, and similarly cycle repeats as such. Forests help in maintaining nutrient/mineral cycle as forests take up nutrients from soil and return it in the form of dead leaves, which form rich humus. Forest influences climate at large by exchanging different gases, water and chemicals. Carbon cycle is a crucial aspect in understanding climate and its feedback in forest ecosystem. Around 33% of total anthropogenic carbon emission including fossil fuel combustion and land use change was reported to be sequestered by forest (Solomon et al. 2007). In general, forest utilizes around 2.6 GtC/year (Norby et al. 2005). The terrestrial net primary productivity (~50%) from forest is more than its carbon storage (~45%). In response to rising CO_2 level, plants can create either negative climate feedback in which warming is decreased or positive feedback which amplifies warming. Climate models (terrestrial and oceanic carbon cycle) suggest positive feedback mechanism between climate change and carbon cycle which increases anthropogenic CO_2 emission, thereby magnifying global warming (Friedlingstein et al. 2006). Increasing concentration of CO_2 triggers increased photosynthesis process and transpiration by plants, which increases atmospheric moisture and in turn more precipitation, which ultimately brings cooling effect. As part of negative feedback mechanism by plants, the increased CO_2 is dissolved in rainwater and is stored in sea and oceans.

According to multi-model analysis, rising airborne CO_2 increases carbon storage in the ecosystem causing 12–76% increase in net primary productivity (NPP) (Solomon et al. 2007). According to one of the reports, ~50% increase of atmospheric CO_2 level for over several years results in enhanced NPP by 23% (Norby et al. 2005). But in longer run, the outcome is different because of the interactions of other natural species and factors. The biogeophysical performance of forest is altered as ecological reaction to changing climate leading to climate feedback. These climate feedbacks consist of altered stomatal activity, leaf area index and composition of species. Rising atmospheric CO_2 decreases stomatal conductance which diminishes the rate of evapotranspiration leading to warming.

The implication of warmer climate would be lengthened growing season in plants and increased uptake of water and evaporation by plants causing condition of water stress in the soil. The jeopardy of drought would increase leading to reduced forest productivity and making trees vulnerable to insects and diseases. The predicted rise in temperature will bring changes in atmospheric moisture, snowfall and precipitation, which will invariably change water cycle. Snow cover is likely to diminish increasing water runoff. Climate change is expected to amplify the threat of invasive plant intrusion resulting in decreased productivity in forest.

The potential effect of changing climate on the wildlife would be change in physiology as well as population of native animals. Mammals are affected by climate change through change in food availability and shelter, direct thermal stress condition and infestation of parasites and disease. Brown bats are susceptible to change in hibernation condition and food resources. Change in vegetation and heat stress will affect many species of mammals. Amphibians are potentially sensitive to fluctuating ambient temperature and precipitation caused by climate change scenario because the breeding ground for most of the amphibians is standing water. Increased temperature and evaporation may lead to drought affecting breeding in amphibians.

Among other taxonomic groups, birds are focused much because several decades of studies on birds survey indicates significant change in the migration pattern, quality and number of habitat of birds in forest ecosystem and their abundance and distribution (Rustad et al. 2012). In response to climate change, a shift in earlier breeding and arrival of migratory birds have been observed. Birds that are restricted to high elevation forests and colder climate are much vulnerable to altered climatic conditions.

Climate change is also known to be linked to change in insects' range. Insects are base of many food webs and significant to biodiversity. Shift in the range of European butterflies has already been reported (Rustad et al. 2012).

With rising temperature, the structure of microbial community changes which speeds up the process of methanogenesis, respiration and fermentation. Climate change accelerates the process of organic matter degradation by microbes such as bacteria, archaea, fungi and algae. Increased microbial activity increases respiration rate and releases more CO_2 as waste product causing global warming. The enzymatic activity and physiology of microbes are directly affected by the climate change.

1.2.1.1.1 Tropical Forest

Tropical forest covers around the earth's 2 billion hectare of land area and is home to 13 million types of different species (70% of the earth's total flora and fauna). Most of these species of tropical forests are endemic (Anon 1996). Tropical rainforest forests play a central role in stabilizing the earth's climate. They influence local and global climate by absorbing atmospheric CO_2 and replenishing it with O_2. They also help in maintaining humidity. But the increasing population and ever-growing advancement have led to extensive deforestation. Agriculture, mining, dam construction, ranching and oil extraction are some of the major reasons for deforestation. Deforestation of tropical rainforest is the second most driver of climate change as it contributes in 18–25% of annual global CO_2 emissions. According to one of the recent reports published by the World Resources Institute, every year nearly 18 million hectares of forest is cut down (Graham et al. 2018). Throughout the 1990s, deforestation of tropical forest resulted in the emission of 0.9 to 2.2 GtC/year carbon dioxide (McCarthy et al. 2001; Eva et al. 2004). If deforestation of tropical forest is carried out with same pace as present scenario without any strict measures to prevent deforestation, then the emission of GHGs could reach 87 to 130 GtC/year by the year 2100 (Moutinho and Schwartzman 2005). These emissions are likely to accelerate because of logging, forest fires and tree mortality brought by drought. Moreover, the climate change is projected to alter forest ecosystem by changing mean ambient temperature and precipitation, along with extreme climatic conditions such as storms, droughts, wildfires and cyclones. This will ultimately bring alterations in the composition of forest and distribution of species, flowering and fruiting pattern and change in tree phenology in the long run (Butt et al. 2015). Natural phenomena such as El Niño which causes disruption in normal weather pattern due to changes in oceanic temperature (Pacific Ocean) distress the tropical rainforest by bringing in drought and heavy rainfall to different parts of the world. The events of El Niño are expected to double under the effect of climate change and may degrade forest ecosystem. According to Boulton et al. (2013), the Amazon forest suffered enormous degradation driven by drought events mediated by climate change. The outcome of global climate change is reported on life cycle pattern of plants (Bertin 2008). Out of all forest ecosystems, tropical forest has suffered greatest forest degradation in the last decade with yearly forest loss of 811.2 mi^2/year (Deb et al. 2018). The degree of tropical forest loss is massive in South America

(16% of total forest cover), while the rate of forest loss is highest in tropical Asia with 634.4 mi^2/year forest loss between the year 2000 and 2012 (Hansen et al. 2013). Climatic extremes are projected to affect tropical Asian forest by clearing 3/4 of its existing forest and decreasing its biodiversity to 50% by the year 2100 (Deb et al. 2017). The major reason of deforestation in tropical Asia is extensive conversion of forest cover into agricultural land. This accelerates susceptibility of tropical rainforest in Asia to the evident climate change. Forests innately release number of volatile organic compounds (VOCs) such as isoprene. These biogenic VOCs combine with different atmospheric gases and result into positive or negative radiative forcing following different indirect pathways. When biogenic VOCs rapidly react with atmospheric O_2, it increases the concentration of GHGs such as CH_4 and O_3, causing warming. In case of negative radiative forcing, the biogenic VOCs react with molecules in the atmosphere to form aerosol particles. These aerosols shift the compactness and the elevation of the clouds which scatter sunlight and increase the brightness of the clouds. In case of deforestation, less biogenic VOCs are released which leads to more warming effect. However, when the phenomenon of albedo is concerned, the dark green hue of the tropical forest has lower albedo as it absorbs relatively more sunlight and reflects less, compared to grasslands and crop land. Tropical deforestation leads to more albedo and negative radiative forcing, resulting to net global cooling (Shindell et al. 2013). But it is not yet clear as to whether warming brought by biogenic VOC interaction or cooling brought by increased albedo is pronounced.

1.2.1.1.2 Temperate Forest

The vegetation found in temperate forest ecosystem is by and large deciduous and evergreen trees. Broad leaved trees such as oak and maple generally dominate deciduous forest. These forests are found in Northeast Asia, Western Europe and Eastern North America. Climatic factors such as sunlight, water and nutrients are limiting factors for vegetation growth in the temperate forest. In temperate forest ecosystem, rainfall surpasses evaporation; therefore groundwater easily develops in areas having permeable substratum. The abundant precipitation forms shallow water table which influences the temperate vegetation to a large extent. Climate change causes change in precipitation which influences moisture content of the soil and ultimately affects the vegetation. Climate change, i.e. change in temperature, rainfall and CO_2 level, influences vegetation as well as hydrology of that area. In response to temperature rise, the phenology of deciduous trees is affected, and the altered phenology affects the hydrology. Increasing temperature extends growing season, influencing vegetation growth due to extension of carbon assimilation period and respiration. Change in the level of precipitation determines the availability of water for transpiration, interception evaporation, groundwater recharge and soil moisture, thereby limiting the growth of roots and water uptake through roots. Climate change is likely to change the distribution pattern and boundaries of several species, causing altitudinal and latitudinal shift in the vegetation zones.

Vegetation is also expected to shift in response to change in precipitation. Drought-tolerant/drought-enduring species are replaced with wet-tolerant ones and vice versa (Smith et al. 1992). Temperate forest comprises around 20% of the total world's plant biomass and nearly 10% of terrestrial carbon. The net radiative forcing of temperate forest is not yet clearly understood. The annual atmospheric mean temperature is influenced by changing biogeophysical forcing which ranges from low albedo in winters to high evapotranspiration in summer. Either higher albedo followed by deforestation would compensate emission of carbon, causing negligible effect to the temperate forest, or decreasing evapotranspiration because of deforestation would magnify biogeophysical warming.

1.2.1.1.3 Taiga/Boreal Forest

Taiga or boreal forest ecosystems are situated in the earth's Northern Hemisphere. Taiga forest is the largest continuous biome in the world, which spreads across Alaska, inland Canada, Russia, inland Norway, Sweden, Finland, northern Kazakhstan, Japan and Mongolia. Although the biodiversity of boreal forest is low, its forest cover constitutes 29% (1.4 billion hectares) of global forest cover. The carbon reserve in boreal forest is much more compared to carbon reserve of combined tropical and temperate forest. Around 30% of the boreal forest is exploited due to logging and other development projects, and only 12% is safely reserved worldwide. Out of all terrestrial ecosystems, boreal forest is most sensitive to climate change and global warming. The climate change is expected to have acute impact on the boreal forest. In response to climate change, the biodiversity of boreal forest is expected to alter, and the plant growth is predicted to reduce. Different climate models have pointed increased warming in Arctic region compared to global average warming. Over few centuries, the increase in average temperature is twice as rapid in Arctic zone compared to average global temperature (IPCC 2007). While analysing relationship between climate change and boreal forest, it is important to distinguish between old-grown trees and managed trees because managed forest is under big influence of human activity. Boreal forest is supposed to react non-linearly to the changing climatic conditions (IPCC 2007). The emission and sequestration of carbon in boreal forest are controlled by growth of vegetation, extent of forest fires and extent of change in permafrost and decomposition of organic matter. Higher level of CO_2 may directly affect growth of trees by affecting photosynthesis. Disturbances such as forest fires release remarkable carbon into the atmosphere and alter normal carbon budget. These factors are projected to bring modification in boreal forest growth and soil processes. The snow-covered tundra has high albedo. With loss of boreal forest and increased incidence of forest fires, the changing albedo is expected to slow warming. In lower climate of Taiga forest, the low albedo would have warming effect.

1.2.1.2 Grassland Ecosystem

Grassland ecosystems are the ecosystems dominated by graminaceous plant species. It provides shelter to sizable human population and livestock. Except Antarctica, grassland ecosystem occurs in all the continents naturally and covers 24% of the total landmass of the earth. Grassland ecosystem also supports several specifically adapted species of reptiles, plants, mammals and birds endemic to that ecosystem.

The precipitation in grassland is neither surplus enough for the growth and support of forest nor scanty enough for the development of desert ecosystem. Grassland is an area that fall between excessive rain and desert. In grassland ecosystem, mean temperature ranges between 0 and 25 °C, while annual rainfall ranges between 5.9" inches and 47.2" generally. An image of grassland ecosystem is mentioned in Fig. 1.2. Grassland ecosystem is broadly classified into tropical and temperate. Among temperate grasslands, the grasslands that occur in Eurasia are termed steppes, North American grasslands are called prairies and those of Argentina are called pampas. Savannas of northern Australia and sub-Saharan Africa fall under tropical grasslands.

The low height vegetation of grassland ecosystem makes them recipient of abundant sunlight and therefore susceptible to invasion by alien species. Grasslands due to their extensive area and large no of livestock, play an important role in biogeochemical cycles and climate feedback mechanism. While grasslands are responsible for significant carbon storage, they are also responsible for emission of methane (CH_4) and nitrous oxide (Jones 1997). The structure and function of grassland ecosystem are such that it makes it more vulnerable to climate change compared to other terrestrial ecosystems (IPCC 2001). Pollution; conversion of grasslands into agricultural land; use of grasslands for road construction activities and introduction of invasive species are some of the anthropogenic activities that put the grassland ecosystem under great risk. Pollution generally disturbs the fertility of soil and growth rate of plants. Grassland stores ~20% of the soil carbon globally, and changes in grassland carbon stock are likely to have long-term effect on the carbon cycle.

Different climate scenarios predict that climate change can lead to decrease in soil moisture and hence develop water stress in temperate grasses. In tropical grass,

Fig. 1.2 Grassland ecosystem

water stress condition is a highly growth-limiting factor, and under the predicted climate change, it is considered to be likely affected. In case of increased CO_2 level, the stomatal conductance is decreased in most of the species. The reduced stomatal conductance will cause reduced transpiration at leaf scale and efficient utilization of water for consistent plant growth.

1.2.1.3 Mountain Ecosystem

Mountain ecosystem represents the earth's 25% of the land surface. This unique ecosystem covers all the latitudinal stretch and all the climatic zones. It serves as home to 26% of the population worldwide and provides ~100% of the freshwater resource in arid and semi-arid regions having critical availability issue (Diaz et al. 2003). Mountains have been recognized as biodiversity hotspots so as to commit to the sustainability of its environment which encompasses rich flora and fauna. Mountain ecosystems are at potential risk to natural disasters including landslides and tectonic movements and human-induced land degradation, causing ecosystem alteration. These factors make high elevation ecosystem sensitive and vulnerable to global climate change.

The global warming has led to upward shift in the distribution of the plant species occurring in mountain ranges such as Alps in Europe (Vittoz et al. 2009). The upward shift in plant distribution is also observed in the mountain ranges of Iberian and Norwegian Scandes (Engler et al. 2010). The valuable resources from ecosystem services and rich biodiversity will be negatively affected by the climate change. The weather conditions, vegetation and hydrology change rapidly with the elevation; therefore climate change detection and impact assessment are clear and easy in mountain ecosystem. The species distribution model forecasts massive reduction in plant species by the end of the twenty-first century in mountain ecosystem due to climate change scenario (Dirnböck et al. 2011). According to Rathore et al. (2019), a species found in Himalayan ecosystem named *Taxus wallichiana*, popularly known by the name Himalayan yew, has been projected to shrink in its climatic niche by 28% in representative concentration pathways (RCP 4.5). The compound Taxol derived from *T. wallichiana* is known to possess anticancer properties. In Himalayan ecosystem if the present climate change scenario continues to persist without any mitigation measures, then 25 ± 16% of the total mountain species are predicted to lose their habitat by 2070–2100 (Dirnböck et al. 2011). In the face of changing climate, some studies evidenced evolutionary change in some species. Most of the trend analysis suggest mountain ecosystem to be more exposed to climate change compared to low elevation ecosystems.

Chapter 13 of Agenda 31 documented in the United Nations Conference on Environment and Development (UNCED) held at Rio de Janeiro in June 1992 clearly expresses concern regarding deteriorating environmental health of several mountain ecosystems. The mountain ecosystems are deteriorated because of certain factors such as over grazing, deforestation and cultivation of marginal soils that make mountain ecosystems prone to landslide, soil erosion and loss of biodiversity and habitation. These issues need to be addressed and curbed as part of mitigation and management of mountain ecosystem (Fig. 1.3).

Fig. 1.3 Mountain ecosystem

1.2.1.4 Desert Ecosystem

Desert can be defined as any area that are arid and receive annual rainfall less than 25 cm. Desert ecosystem is characterized by intense sunlight, meagre moisture, high evapotranspiration and lashing wind. The days are extremely hot because the arid soil quickly heats up in cloudless sky of desert, while in night the heat is radiated back through the atmosphere, making it colder. Scanty rainfall and high evapotranspiration promote growth of sparse perennial vegetation and scattered shrubs. Scanty rainfall in desert can be attributed to geographical positioning of desert in rain shadow regions and subtropical high in which high pressure restricts cloud formation and rainfall. On the earth's surface, desert ecosystem occurs near 30° northern and southern latitudes. The air current over the globe creates descending dry air belt over 30° northern and southern latitudes. Despite extreme climatic conditions, desert ecosystems are known for brilliant biodiversity. The desert flora and fauna are well adapted anatomically, morphologically, physiologically and behaviourally to withstand harsh conditions. The vegetation adapted for desert habitat include succulents, ephemeral annuls and desert shrubs.

The apparent climate change has already affected some desert of the world by casting drought and decreasing rainfall by 40% since the past five decades. The increasing temperature will turn desert dryer and elevate the water stress which will put many species under huge risk of loss. Since the past five decades, the vegetation has reduced and caused endangered species such as *Sonoran pronghorn* and *Antilocapra americana sonoriensis* (subspecies of antelope) under the threat of extinction because these animals are dependent on the herbaceous plants, cactus and desert shrubs. The loss of vegetation will ultimately lead to loss of animals.

1.2.1.5 Agricultural Ecosystem

Agricultural ecosystem is an artificial ecosystem. It is altered and controlled by humans. It is different from natural ecosystem because it contains few species unlike natural ecosystem which is complex and diverse containing hundreds or thousands of different types of flora and fauna species. Under the threat of climate change, it is challenging to feed increasing global population.

Climate is a determining factor for the growth of agricultural ecosystem. Climate change is supposed to have positive and negative impact on agricultural sector. Climate change can impact agricultural productivity and influence future food security. They may trigger abiotic stress in agricultural crops and may escalate pest/insect and pathogen infestation which can clearly reduce the crop productivity. Water plays a central role in agricultural practice as the world's 70% of the total water withdrawal is for the agricultural practice. Around 80–90% of freshwater is utilized in agricultural sector in developing countries. The water availability is affected by the global warming-driven drought. Moreover, increasing temperature increases rate of transpiration in plants which decreases moisture level in the soil. Agricultural sector is known to be a major driver of climate change. In spite of increase in agricultural land by 10% since the last 40 years, the per capita agricultural land has decreased. It is because of limited available land and growing population. This is evident from the fact that agricultural land in South Asia has remained constant to 223 million hectares since the last two decades. Soil degradation by anthropogenic activities has escalated since 1950s. Every year 12 million hectares of land is deteriorated to desertification. Land degradation, to many extents, can be prevented or reversed by adding nutrients to the soil, buffering soil acidity, rebuilding top soil and re-establishing vegetation.

Likewise, the agricultural productivity has decreased by 13% in Central America and Africa since the last 50 years. Agricultural sector happens to be highly sensitive to the climate change. Therefore, any changes in existing climatic conditions will certainly affect agricultural process and yield. However, sensitivity of agriculture towards climate change is not certain to some extent because of regional variation in climatic conditions such as temperature, rainfall, soils, cropping systems and management practices. The increase in climate change will lead to increase in climate variability and hence losses in crop yield. The response of different crops towards climate change is expected to be complex. It is also challenging to understand and predict the impact of parasites and insects on crop production as several components in crop production system interact concurrently in extremely nonlinear fashion. Crop production generally suffers huge yield loss because of a wide range of insect infestation. These pests are highly influenced by abiotic factors such as temperature, which influence species establishment and abundance in particular region. Most poikilotherms are physiologically adapted to restricted temperature range. Therefore, climate-driven changes in temperature and rainfall pattern, may shift the temperature range of many insects and pests. Sometimes new combinations of insects may arise in response to altered climatic conditions. Similarly, frequent occurrence of extreme events such as storms, heat waves and heavy rainfall may disturb life cycle (growth, development, reproduction) of biological control agents and their pest prey. Therefore, in order to adopt mitigating strategies, modelling tools and approaches must be deployed to forecast distribution of insects at local and global scales in past, present and future climatic scenario. This can be done by understanding insects' requirement of environmental parameters; crop-pest system and the climate data under climate change condition can be obtained from global circulation models.

As agriculture is a key element of global economy, it is challenging to secure sufficient high-quality crop production to meet growing demand while ensuring biodiversity conservation and safeguard and management of natural resources. According to third assessment report of IPCC (2001), vulnerability is function of exposure, sensitivity and adaptive capability. It is, therefore, foremost important to analyse the impact of changing climate on agricultural sector and study its vulnerability for risk analysis. This can help to develop proactive adaptive measures towards climate change, which can ensure sustainable agricultural practice, growth and development.

1.2.2 Wetland Ecosystem

Wetlands, one of the paramount productive habitats on planet earth, are distinguished as a distinct ecosystem where dry land is covered by water bodies. As per Millennium Ecosystem Assessment report, wetlands are known to cover 1.2 million square kilometres globally. According to Ramsar Convention, wetlands include mangroves, flood plains, marshes, coral reefs, forests, rivers, rice fields, peatlands and the edge of a lake or ocean.

The diversity in wetland is governed by climatic, hydrological and geomorphological factors**.** Attributed to the remarkable productivity and diversity, wetlands offer incredible extensive ecosystem goods like food, genetic resources, fossil fuels, water supply and regulation services such as wastewater treatment, nutrient cycling, flood control, erosion control and climate regulation (Llorens 2008). However, since the twentieth century, wetlands are declining by about 64–71%. According to Agardy and Alder (2005), around 20% of coastal wetland is lost every year. Though certain non-climatic drivers, viz. wetlands drainage, deforestation, habitat fragmentation, sewage, eutrophication, pollution, introduction of invasive species, etc., contributed a major portion to wetland losses, still the effects/impacts created by climate change cannot be overlooked (Scavia et al. 2002). More specifically, pressure on tropical wetlands as a result of climate change are expected to be intervened through effects of changes in temperatures/humidity, hydrology (principally those leading to flood or drought conditions) and land use pattern (Ferrati et al. 2005). The coastal wetlands such as mangroves are also altered by the rise in sea level (Mitsch et al. 2010). The climatic impacts range from changes in availability of water in rivers to marine disturbance and changes in biodiversity (Roessig et al. 2004; Chiabai et al. 2018). The detailed devastating effects of climate change on the abiotic and biotic (starting from individual organisms to populations and then to communities) components on different types of wetlands are discussed in the following section.