Chapter 8
Scenario of Climate Changes in the Context of Agriculture

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1 Introduction

Every creature requires certain conditions to sustain life. In the solar system, only earth supports life. Earth is heated by sun emitting different radiations and these radiations aid in global warming. Global warming is the rise of earth's atmospheric temperature. This rising of temperature is aided by a number of factors and presently is the most threatened issue which is triggering climatic changes across the globe. The data shows that global warming is the intermediated phase between two ice ages and the distance between two ice ages is approximately 100,000 years (Wallington et al. 2004). The fact that earth revolves around the sun aids in the environmental changes over a long period of time. With the change in earth's orbit, the temperature falls to many degrees. At present we are in the middle of two ice ages and the temperature changes to few tenths of the degree Celsius by every thousand years. There are a lot of factors that indicate to fast approaching ice age including significant retreat of mountain glaciers in many locations all over the world, the continuously decreasing ice that covers the Northern hemisphere, sea level rise and decreased extent and thinning of Arctic ice. Climate change as a result of global warming is considered as the most serious threat to our environment ever encountered in human history (Environmental Protection Agency 2011).

There is nearly 1.5 °F increase in the temperature of earth since 1880 and has been rising since late 1970s. Over the past century, the unusual rise in the average temperature of earth's surface predominantly as a result of release of certain

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greenhouse gases (GHGs) to our atmosphere is global warming. Between the years of 1906 and 2005, the rise in surface temperature of earth was recorded to be 0.6–0.9 °C. In the last 50 years, this rate has nearly been doubled. It has been claimed that temperature will further increase unless protective measures are observed to mitigate the emission of GHGs. The "Intergovernmental Panel on Climate Change" in 2009 speculated that the increasing temperature, floods, drought, desertification, and weather vagaries will severely affect the agriculture and a rise of 4.2 °C in mean temperature of earth is anticipated at the end of the present century, i.e., the twenty first century (Khajuria and Ravindranath 2012). Various international reports suggest that a large disparity will exist among the developed countries as well as the developing nations in the context of agriculture vulnerability to the change in climate (Rosenzweig and Parry 1994).

The origin of climatology dates back to the eighteenth and the nineteenth century. A Swiss Scientist, proposed that our atmosphere is like a greenhouse, protecting both the earth's surface and its inhabitants from temperature extremities. Later John Tyndall (British Scientist) did experiments and confirmed the greenhouse effect. Few scientists at that time feared differing progression of climate change, i.e., global cooling and reappearance of an ice age that could threaten humanity. Louis Agassiz is considered as the very first scholar to put up the history of climate change. Svante Arrhenius (1896), a Swedish chemist, followed Tyndall demonstrating the effects of CO_2 on atmospheric temperature and welcomed the idea and named it as global warming. With the passage of time by 1930, when people analyzed the previous half century, they started to realize that regions of the USA and Northern Atlantic have significant increase in temperature. Most scientists were of the view that it was just a phase of some natural atmospheric cycle of mild affectivity with unknown causes. Among all these, an amateur G.S. Callendar insisted that it was not ordinary phase or any temperature cycle rather it was greenhouse warming on its way everyone thought that it would be better if this continues to happen. He supported Arrhenius findings and refined the understanding of the role played by CO_2 in climate change. By the 1950s scientists were provoked to look into the questions raised by Callender. The thing that gave it way and resulted in a sharp increase of government funds was the weather and the seas during the cold war suffered by the military agencies. At that time it was assumed that carbon dioxide could be trapped up in the atmosphere and be the reason of warming.

In 1950s, modern climatic science was born. Roger Revelle and his colleagues at the Scripps Institution of Oceanography began their work on temperature across the different layers of ocean and made pivotal contribution to the field. Revelle also sponsored the research of Charles David Keeling who measured the atmosphere's level of carbon dioxide which was continuously increasing, known as "Keeling Curve." In 1960, the measurements were observed and it was deduced that with every year the level of this gas is increasing in the environment. In the start, scientists were successful in finding the single matter key to change in climate but after research they realized that climate comprises of an intricate system that responds to a number of influences involving eruption by volcanoes, changes in the solar system, even the human activities. It was a surprise to know that the timings for ice ages had been set by astronomical cycles. Apparently balance between the climates was so delicate that almost any small change in the movement, quality, and behavior might set off a great shift. Chaos may result due to sudden shift as a result of this perturbation. Apart from greenhouse effect concerns, it was also being pointed out that human activity is also resulting in putting the particles of dust and smog into the environment. There they act as a blockade, inhibiting the sunlight to pass through and cool the earth. It was predicted that a cooling trend has begun in Northern Hemisphere in late 1940s, as predicted by the Northern Hemisphere weather statistics. The inhabitants accompanied by mass media were confused whether to wait for a flood over the entire globe or another ice age (Intergovernmental Panel on Climate Change 2001b, c). Panels to carry out studies were set in the USA as well as in many other places which claimed that a severe threat may be posed by one or other kind of climate change in the future. All the scientists agreed that their knowledge regarding climate change is insufficient hence more research is to be done. In order to overcome this problem, schemes aiming the gathering of data were devised in which even the satellites orbiting the earth were mobilized along with the mobilization of oceanographic ships' international fleet.

2 Discovery of Global Warming: Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) defined climate change as "a change of climate which is attributed directly or indirectly due to anthropogenic interventions that alter the composition of the global atmosphere and which are in addition to natural climate variability observed over comparable time periods." In the history of previous 4.5 billion years, our earth has gone through considerable changes. Earth's temperature keeps fluctuating between very hot, very cold, and stable. For eons, the stability remained rendering earth favorable for cultivation and growth of flora and fauna, and subsequently to the ever-growing population of mankind.

The balance that exists between mankind and environment is pretty delicate. The race for development coupled with anthropogenic activities (GHG emissions and land use) has disturbed the environment by threatening the delicate matter of equilibrium between objects. The balance of natural ecosystem (forest, rivers, basins, sea level) and socioeconomic system (agriculture, fisheries, and irrigation) is affected by the climate change. The increased industrialization and human activities over the past 100 years has disturbed the natural balance of the climate, increasing the concentration of GHGs in the atmosphere of earth resulting in global warming.

Scientists have been studying the climate for centuries and basic physics of climate changes has been known for more than a century but in recent decades the science of global warming has been firmly established. History shows that in early nineteenth century, the scientific discovery of changes in the climate rooted for the first time. Spencer R Weart (2003, 2007) demonstrated this history in his famous book "The Discovery of Global Warming." Some of the important events pertaining to the discovery of climate change are illustrated as under.

2.1 1800–1850

The history of climate change is as old as the discovery of carbon dioxide by Joseph Black in 1753. The nineteenth century is the era of industrial revolution. In early nineteenth century the concentration of CO_2 in the atmosphere as measured in ancient ice age was found to be 290 ppm. Jean-Baptiste Fourier (1827) proposed that earth would be much cooler if it lacks atmosphere, an atmospheric effect exists which keeps the earth warmer.

2.2 1850–1900

In 1861, John Tyndall (Irish physicist) conducted research and concluded that the gases present in the atmosphere including CO_2 and water vapors trap infrared radiations and perturbation in the concentration of these gases can lead to climate change. With the prediction made by Svante Arrhenius, a Swedish chemist, in 1896, the predictions about changes in the climate as a result of human activities were also started. Immediately, he took into account the revolution taking place in industrial sector and deduced that the concentration of CO_2, which is being released in the environment, is also increasing. Other than this, he was of the view that the amount of CO_2 in the atmosphere will increase continuously side by side along with the increase in consumption of fossil fuel, particularly coal. Even at that time, his assessment led him to predict the CO_2 role in increasing earth's temperature. He noted that the average temperature of earth is nearly 15 °C. This was due to the ability of water vapor and carbon dioxide to absorb infrared radiations, in other words, the natural greenhouse effect. He was of the view that as a result of CO_2 doubling in earth, earth's temperature would further rise by 5 °C. Chamberlin (1897) demonstrated a model for global carbon exchange.

This topic was long forgotten after the findings of Arrhenius and Chamberlin. In that era, it was thought that human influences were insignificant hence do not aid in global warming as compared to the natural activities like the solar activity and ocean circulation. It was also believed that the oceans will act as carbon sinks and they will automatically clear out the pollution. At that time, water vapors were more feared to be potential threat towards global warming.

2.3 1900–1950

In the 1930s, global warming trend of the whole nineteenth century was observed and reported. It was also reported that the changes in the orbits are the reasons of all ice ages. In 1938, Callendar argued that carbon dioxide, which is a GHG, is the seed of global warming. Several advancements in the field of infrared spectroscopy led to the measurements of radiations with longer wavelength. In that period the hypothesis, greater CO_2 concentration in the environment results in greater absorption of infrared radiations, was proved. It was also discovered that the ability of water vapor and carbon dioxide to absorb radiations is different.

2.4 1950–Onwards

Gilbert Plassa bridged the above results in 1955 and concluded that increased CO_2 concentration in the atmosphere will affect the radiation balance, which is otherwise lost in the space. In 1956, Philips demonstrated a more pragmatic computer model for the global atmosphere. It was still thought that oceans would absorb most of the carbon dioxide. In 1950, evidence was obtained which claimed that CO_2 have a time span of approximately 10 years for which it can stay in the environment but the fate of CO_2 molecule was still not understood. Further investigations revealed that ocean cannot act as a sink for all the CO_2 in the atmosphere. Revelle in 1957 figured out that anthropogenic CO_2 is not readily absorbed by the oceans. Telescope studies in 1958 showed that the temperature of Venus has increased above the temperature at which water boils just because of greenhouse effect.

Charles Keeling took advantage of the available modern technologies and formed concentration curves for the CO_2 present in the atmosphere of Antarctica as well as Mauna Loa. Keeling accurately measured the amount of CO_2 (315 ppm) and detected annual rise of the curves made from 1940s to 1970s presented a downward trend. Simultaneously, research carried out on the ocean sediment showed that nearly 32 cold–warm cycles have been occurred over the time span of past 2.5 million years rather than only 4. This led to the fear of a new ice age. The data was ignored by media and a number of scientists who were in favor of global cooling. Calculations made in 1963 advocated that feedback with vapors of water in the atmosphere could result in climate extremely sensitive to CO_2 alterations. The boulder meeting carried out in 1965 was held on the reasons and causes of upcoming global warming. Lorenz and others pointed out the muddled nature of climatic system and speculated the probability of abrupt shifts. International Global Atmospheric Research Program was established in 1967 with a manifesto to have information in hand for an improved short-range prediction of weather as well as climate. Manabe and Wetherald (1967) made a conclusive calculation that if the concentration of CO_2 will be doubled, the temperature in turn would decrease several degrees. Nimbus III satellite in 1969 (Hanel et al. 1970; National Environmental Satellite Center 1970) reported elaborated measurements on the atmospheric temperature of the globe. Concern regarding environmental effect caused by airplanes emerged which formed the basis of investigation on trace gases concentration in stratosphere and discovered harmful effects to the ozone layer.

By 1980s, the curve of global annual mean temperature began to rise. People started questioning the theory of new ice age upcoming. It was late 1980s when this curve began to increase in a very steep manner. This was the time when global warming theory began to win terrain rapidly. Environmental NGOs came into action and started to work out methods in order to prevent further global warming. This topic also gained the attention of the press and soon it was a news flash all around the globe. Finally in 1988 acknowledgement was passed that there is an increase in climate more than ever observed. The greenhouse effect theory was named and IPCC was established by UN Environmental Program and the World Metrological Organization with an objective to anticipate, according to the climate models as well as available knowledge in the literature, the impact of greenhouse effect. The panel formed consisted of 60 different countries of the world and more than 2,500 scientists and other technical individuals were part of it. These scientists belonged to different research fields including climatology, ecology, economics, medicine, and oceanography. IPCC is considered as a historical project with the largest peer-viewed scientists' cooperation.

In 1990, due to a number of ambiguities in the model outcomes as well as data set, greenhouse theory was also in question by different scientists. The basis of theory was the global mean temperature recorded annually and it was objected too. They were of the view that there is an ambiguity in the measurements and the data obtained from oceanic study was missing. The global warming data did not explain the cooling trends. Upon observing satellites, totally different temperature records were obtained from the initial zones. The data caught fire that the model generated on global warming had overestimated the trend in temperature increase over the past 100 years. This idea made IPCC to review the initial data they had on global warming. Still they did not reconsider that whether an actual trend exists. From the data obtained, now we are familiar that 1998 was the warmest year on record so far all around the globe which is followed by the years 1997, 2001, 2002, and 2003. Since 1990, the 10 warmest years have occurred. IPCC is keeping an updated record as being challenged by a number of scientists resulting in new research and frequent responses by IPCC. The topic of global warming is still in debate and data is constantly being checked and renewed. Amendments are also made in models to keep them updated and in accordance with new theories.

So far, nothing has been done to control the devastated condition of climate. This is the result of major uncertainties that still hold the theory. It is a global problem, so all countries ought to join hand in hand to solve it. For this purpose in 1998, the Kyoto Protocol was negotiated in Kyoto, Japan with the principle that countries that play a role in it will try to minimize their anthropogenic GHG emissions (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) by at the minimum 5 % below the levels recorded in 1990 during the commitment period, i.e., 2008–2012. 186 countries became part of this commitment and signed Kyoto protocol in Bonn, 2001. The USA and Australia retreated from the pact. The greenhouse effect terminology started to change from 1998 onwards. As a consequence of influence generated by media, the people started using terms like global warming and climate change.

With the advent of revolution in industrial sector, it led to a quest in the utilization of nature's blessings including hydrocarbonaceous fuels leading to increase in the emission of gases such as carbon dioxide and other nauseous gases never reported before in the earth's evolutionary history. This along with particulate matter increases the atmospheric trapping of radiated heat from the sun. Changes are being detected by scientists, who indicate that with every passing day the climate is becoming, on average, hotter and more variable. This variability is the gift of increasing carbon dioxide in the atmosphere. The scientific studies suggest that since last 650,000 years, planet never had more carbon dioxide trapped in it as it does today.

3 Factors Contributing to Global Warming

Among the most prominent reasons of global warming are the GHGs contributing in the greenhouse effect, radiative forcing of climate change, and ozone depletion. The three most prominent reasons of global temperature changes are: (1) high and continuously increased concentrations of carbon dioxide in the atmosphere which is due to the combustion of fossil fuels primarily. The carbon dioxide concentration has been increased from approximately 280 to 394.25 ppm at the end of 2012 since 1750 (Dlugokencky and Tans 2013). This increase in concentration leads to substantial alteration in earth's system, (2) changes in the global nitrogen cycle leading to changes in biogeochemistry, and (3) ongoing changes in the land as one half of the world is being transformed by humans. These three components contribute in the devastating changes in environment and loss of biodiversity (Vitousek 1994). The expected consequences to this problem include flooding in the coastal areas, increase in extreme weather, spreading disease and mass extinctions.

3.1 Greenhouse Effect and Greenhouse Gases

Over the past few centuries, greenhouse effect has drawn a great attention towards itself. The accumulation of CO_2 and GHGs causes this greenhouse effect. The prominent GHGs are (1) carbon dioxide (CO_2), (2) methane (CH_4), (3) nitrous oxide, and (4) chlorofluorocarbons (CFCs) contributing 76 %, 13 %, 6 %, and 5 % to global warming, respectively. Among GHGs, CO_2, CH_4, and N_2O are more closely associated with agriculture activities, contributing 26 %, 60 %, and 14 %, respectively, to total GHGs (Azam and Farooq 2005). Although CO_2 is considered as main driving force behind global warming, water vapors (WV) which accounts for 95 % of greenhouse effect are not considered as GHG in most global warming studies. A significant portion of atmospheric WV originates from agricultural crops.

The study of greenhouse effect goes back to the Jean Baptist era, in 1827. According to the studies, the emission of longer wavelength radiations of sun cool down the earth atmosphere and the shorter ones warm it up. These GHGs block the emission of longer wavelength radiations and thus heats up the earth. The retention of radiations is facilitated by GHGs. According to John Tyndall, ice age is caused by variations in the atmospheric levels of these gases. Large amount of CO_2 is released due to burning of fossil fuels. The heat in the atmosphere is trapped by water molecules, methane and carbon dioxide. The only method of cooling earth is

Table 8.1 Emission and per capita consumption of CO_2 (2011)

Country	CO_2 emission	Per capita emissions tc per person per annum
China	28	4.7
USA	16	2.0
Europe	11	1.8
India	7	0.5
Globe	_	1.4

the emission of infrared radiations. At infrared frequency earth acts as a black body that absorbs all while releasing none.

The greenhouse effect is also important in a way that it keeps the earth's atmosphere warm and heated. In the absence of this, the earth would cool down to the temperature that would not support life at all. In the light of above factors, global warming is the phenomenon of enhanced greenhouse effect that is expected as a result of increase in the atmospheric concentrations of GHGs associated with activities done by humans.

3.2 Carbon Dioxide (CO_2)

The most abundant GHG is the carbon dioxide with the most hazardous outcomes. Estimates of CO_2 emissions depicted that the total global emission is unequal to the sum of the gas released from all the countries. In 2011, the global CO_2 emissions were ruled by emissions China followed by the USA, Europe, and India as shown in Table 8.1. Combustion of fossil fuels primarily contributes to the increased CO_2 concentration in the atmosphere. Before the industrial revolution, gases released from burning of fossil fuels started and became the dominant source of human-induced emissions around 1920 till now, i.e., 2013 (Munhoven et al. 2009; Randerson 2013). These emissions occur in active carbon cycles that are responsible for the circulation of carbon between atmosphere, ocean, and terrestrial biosphere (Archer et al. 2009). During 2002–2011, 89 % of total emissions were caused by fossil fuel combustion and cement production and 11 % by land use change. The total emissions were partitioned as atmosphere (46 %), ocean (27 %), and land (28 %) (Le Quéré et al. 2013; Shakun et al. 2012).

Deforestation plays a major or key role in increasing the concentration of CO_2. The atmospheric burden of CO_2 increases at the rate of "3.3 + 0.2 GtC yr^{-1}" (where GtC stands for Giga tones of Carbon). A study conducted in 2001 showed that at that time CO_2 concentration was 370 ppm and is increasing at a rate of 1.5 ppm per year and this level was 30 % above the preindustrial time. Records show that the current concentration of carbon dioxide is greater than the past 420,000 years. Data published by Dr. James Hansen who is the director of NASA's Goddard Institute for space studies and others show that CO_2 emissions are not the observed atmospheric warming. There are certain other gases more harmful than CO_2 gas.

CO_2 gas emission also produces aerosols and these aerosols have a cooling effect on the global warming. This magnitude equalizes the warming effect produced by aerosols. This claims that there is no net effect produced by the effect of CO_2 on global warming. This issue cannot be justified. Aerosols are short-lived while CO_2 continues to heat the environment for hundreds of years (Cox et al. 2013; Bardgett et al. 2013).

Energy released by fossils is the large reservoir of CO_2. The deep ocean acts as a large sink for the kinetically slow disposing carbon dioxide. The oceans of the world act as large source as well as large sink for carbon dioxide reservoirs and CO_2 is being continuously exchanged between these two. Due to this continuous exchange, it is difficult to predict atmospheric lifetime for CO_2. The atmospheric lifetime for CO_2 is typically stated as 100 years. The trapped CO_2 changes the rain patterns as well. Carbon dioxide is supposed to be disposed of in proper thermohaline currents that have a very large equilibrium capacity. The Mediterranean under current entering the Atlantic is one such current. It has the capacity to absorb all the CO_2 till 2100 produced in Europe only (Marchetti 1976; Sitch et al. 2013).

3.3 Methane (CH_4)

After CO_2, the most harmful GHG is methane. It is the most well mixed gas after carbon dioxide whereas it is removed via chemical reactions with hydroxyl (OH) radicals. The sources of methane are natural as well as anthropogenic. Since the start of industrial revolution, the concentration of methane has increased by 148 % (Riebeek 2010). Natural gas facilities, mines filled with coal, petroleum industry, coal combustion, enteric fermentation, rice paddies, the burning biomass, landfills, animal waste, and domestic sewage are major anthropogenic sources with estimated emission of 40, 30, 15, 15, 85, 60, 40, 40, 25, and 25 $Tg(CH_4)\,yr^{-1}$. Methane produces an effect 21 times greater than CO_2. Since preindustrial times, the concentration of methane has been doubled. Human sources produce 1.5 times methane as all natural sources. The primary natural source of methane is microbial decay. Half of the human-induced warming is due to methane. One hundred million tons of methane is produced every year. Livestock digestive system produces 85 % of this methane while 15 % is released by massive lagoons (Environmental Protection Agency 2013).

3.4 Nitrous Oxide (N_2O)

The large increase in the amount of nitrogen fixation has led to the production of increased amount of nitrous oxide. This stable gas, nitrous oxide, produces greenhouse effect as well. The production of nitrous oxide is 30 % greater than the disposable concentration (Keller et al. 1986). One of the positive effects of large amount of nitrogen fixation in the atmosphere is that it provides more life benefits to all the producers and some of the consumers as well. Symbionts, producers, and consumers all are affected by large nitrogen concentrations. The increasing concentrations of nitrogen in the atmosphere also affect the global nitrogen cycle (Vitousek and Walker 1993). The effect produced by this disturbance is the greatest compared to any other global component. This fixation is also important in the prediction about global warming. Land use change also affects the diversity of the living species along with all other factors.

3.5 Other Factors

There are certain other chemicals that affect the change in the global environment. They also add their bit of affect in warming of the atmosphere. Some of them are discussed below.

3.5.1 Worldwide Distribution of Synthetic Organic Compounds

The most persistent compounds such as dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs) have been used all over the world and have globally disturbed the biota. The CFCs have affected the ozone layer in the stratosphere, depleted it, and increased the entry of ultraviolet radiations into the atmosphere over the Antarctic region resulting in decreasing the marine life (Rowland 1989).

3.5.2 Alteration in Biogeochemistry of Global Element Cycle

Human activity has also affected the sulfur cycle along with carbon and nitrogen. The concentration of sulfur dioxide produced from burning of fossil fuel exceeds the concentration of all other natural gaseous emission combined (Charlson et al. 1992). The sulfur dioxide emissions lead to sulfuric acid rain and increased sulfur aerosol concentration (Keller et al. 1986). These aerosols act as effective nuclei for cloud condensation (Fan and Harden 2012).

3.5.3 Biological Interruptions by Non-native Species

The immense increase in the GHGs and other factors that affect the atmosphere also affect the living species. The species that are transferred from one area that forms their habitat to other, directly or indirectly affects the climate of the atmosphere. For example, certain annelids like earthworms reside in soil and provide fertility to it. If earthworm is transferred to a barren land and its life is supported there, it can fix nitrogen and provide fertility to soil which results in provision of support to the plants for their growth. This would take a couple of years for trees to grow but they will affect largely the environment. Certain nitrogen-fixing bacterial species may also lead to changes. All these small changes group up to form a reason of global changes.

3.5.4 Volcanic Eruptions

A volcano is an opening in the earth surface that allows or aids the eruption of hot magma, volcanic ash, and gases from the earth's crust into the environment. The climatologists may not agree on what percentage of earth's warming is natural and how much is aided by humans but all scientists agree on the fact that volcanism acts as a wildcard in the climate change and produces a significant cooling effect for at least some years following a major eruption (Houghton et al. 1996; NASA 2011).

The activity of volcanoes is a continuously on-going process with more or less a dozen volcanoes active at any given time. Most of these eruptions are small with minimal effects, shortly living and contained within lower atmosphere near volcano. Occurrences of major volcanic activities are extremely rare. These volcanic activities and eruptions are able to release gases and eject ashes like sulfur dioxide (SO_2) as high in the atmosphere as 80,000 ft or more. The ashes from the eruptions fall out within 6 months to a year. The sulfur dioxide is immediately converted into aerosols of sulfate and can stay for 2 or more years in the high atmosphere, which is pretty stable. These aerosols may block some of the incoming solar radiations and result in the lowering of earth's temperature overall. Over the period of 2–3 years, an average lowering in temperature is from 0.2 to 0.5 °C (de Silva 2010).

Little volcanic activity was observed during the period of 1920–1940. This coincided with immediate increase in the solar radiations and warming in the oceans that continued for a number of decades. This resulted in the warmer temperature all around the globe. Sun and oceans are believed to be the main culprits in the warming of globe but lack of volcanic ash may have also aided in the warming. In this perspective, 1960s became highly active as a number of significant eruptions took place in those years. These eruptions kept aerosol levels higher in the atmosphere. This followed lesser degree of radiations from the sun resulting in a quitter sun and relatively cooler cycles in Atlantic and Pacific Oceans. Those were the coldest 10 years in the last 5 decades. Temperatures began to rise with increased solar activity and warm temperature at Pacific and lower globe temperatures gave rise to a number of eruptions in different parts of world. This is clearly evident that volcanic eruptions are somehow linked to the percentage of aerosols in the stratosphere, which is represented as optical thickness of aerosols to the satellite-derived lower troposphere temperatures.

3.5.5 Oceans as Heat Reservoir

Seventy-five percent of all earth is water whereas the rest 25 % is the land. Water has a great potential to absorb large amount of heat. With more than 1,000 times as compared to the strength of atmosphere to tolerate heat, the oceans, all over the world, are the biggest reservoir to absorb heat produced as a result of global warming. Oceans are thermodynamically stable and their overall temperature is not easily affected because of their large heat capacity. Long-time and continuous effect only will be able to bring any change in it. The temperatures of air and land can be easily changed by short-term activity when compared with the oceans. Their temperatures can easily be changed even without the warming effect produced due to the increasing temperature of earth. This characteristic of air and land makes it difficult to obtain valuable data as a great deal of "noise" is generated due to continuous and fast changes. But since the ocean water is much less sensitive to short-term effects, there is a low level of noise in oceans. If the warming up of oceans is detected, this will enable us to know that long-term effect is occurring and it can be used as a reliable indicator to detect and study this warming trend.

Since 1955, ocean temperature is being measured which is necessary for making such evaluations. With the improvement in technology, the databases are becoming more and more extensive as well as reliable. All the previously recorded information reveals that the temperature of oceans is continuously increasing over a period of time and the greatest increase in temperature is happened in recent years.

3.6 Arguing the Possible Reasons

The heating that is occurring inside the earth is largely due to the radioactive decay of stable isotopes inside the earth. These isotopes are scattered at an uneven percentage in the earth's interior and they also observe movement along with the convection occurring underground. Therefore, it can be deduced that the convection, that moves the isotopes underground, may bring them together and lead to increase in the radioactive decay. The probability of this decay cannot be accurately calculated until and unless the size and distribution of isolated isotope concentration is not known. However, when further investigation of this matter was carried out, this became clear that this phenomenon was not actually happening. The reasons of global warming are widespread and are occurring on short notice by certain geological as well as human standards. This contradicts with the idea of large amount of interlinked activity that brings the isolated concentrations of isotopes together within the interior of earth. This activity would require a time frame from 100 to 1,000 decades. If the assumption is made that this activity has occurred in the past and the effects are now visible, even then it is not something that has happened suddenly or forms itself with uniformity over time. The measurements that were carried for calculating the infrared radiations of the surface of earth have not shown large areas of unusual rise in temperature. There are some of the isolated hot spots where such activity has been observed such as Yellow Stone National Park in the US state of Wyoming (that extends to Montana and Idaho). However these spots are limited in both; spatial dimensions and in changes occurring in temperatures. The heating produced on such levels do not equate the global temperature changes. They might contribute to a small fraction of increase in temperature. Studies show that these spots are active for many millenniums and are also included in global heat budget so they might not be contributing to this warming. The evidence provided by the level of geological activity observed on the map is insufficient and could not possibly account for the observed increased heat (Taylor et al. 2012).

Furthermore, if it may be considered that the heating is due to earth's internal activity, inverse gradient to distribution of temperature within oceans would be observed. The ocean floor, i.e., the ocean bed forms the thinnest crust on planet. Most of the heat that would escape from the surface into the atmosphere would occur from there. The geological activity such as volcanic or seismic events would have made this happen. The direct conduction via rocks may also help in this phenomenon. The evidence contradicts this scenario. It says that temperature drop occurring at the oceans is dramatic and uniform all over the world. As depth increases, the temperature further cools. The ocean is the coldest at the depth of ocean floor. If this is accepted that short-term heating within the earth is occurring, then we would observe the opposite of it. Via research, we consider that upper portions of oceans are heating up and yet there is no evidence that this heating has affected the lower portions of oceans. This proves that the oceans are getting heated up from top to bottom and not the vice versa. The earth's activity, hence proved, is not aiding much for heating up the earth's temperature.

If speed and magnitude of observed global warming is considered and recorded data is analyzed, then it will be evident that warming cannot be an attribute of increase in interior warming of earth. This also supports that only a small percentage of heating is aided by earth's internal activity. The only possible explanation about the internal heating can be in a way that sizable increase in global temperature can be aided by naturally occurring warming up of the globe. This would be occurring if the sources inside the earth produce small increase in temperature over a time span of many years. Plus, this heating is trapped or retained in the atmosphere by some trapping force. This would also require the greenhouse activity otherwise all heat will radiate into the space and a thermal equilibrium would be attained.

Now considering manmade effects, we can realize by observing statistical data that human activity has increased dramatically. Over a last few centuries, population and industrial sector has progressed exponentially. This gave rise to increased heat produced by humans. It is justified to consider the fact that any manmade heat produced would stay in the atmosphere and aid in the global warming before radiating into the space. Nearly 10 years of energy or heat release in the environment was observed. According to it, heat would retain in the environment. This is possible only in the case if atmosphere has increased its efficiency of greenhouse effect. More importantly, the recorded data only shows the heating of oceans and does not speak for the heating in the atmosphere. It does not have any information about the heat produced by land masses and heat radiated into the space. All energy-generating sources are the main reservoirs of energy addition to the environment. The prominent energy-generating sources are solar, wind, and hydroelectric power units.

These arguments rule out the possibilities of internal heating either contributed by humans or naturally occurring as the sole reason for global warming. This only leaves one possibility that it would be a gift of external heating. If the solar activity is questioned and claimed as a possible source of warming, then we can pin out two ways by which it can be achieved: (1) either by increase in solar radiation absorption rate or (2) by increase in the value of solar constant. If the first possibility is considered, then this would support the hypothesis of greenhouse effect.

Second is the measurement of solar irradiance and in this regard it is observed that it is decreased over a period of time. According to the observations made, over the past 20 years solar forcing has declined whereas the temperature of the surface has risen continuously. The contradictions revealed the mechanism that resulted in any kind of solar variability effects on the climate. Such mechanisms have ceased in the twentieth century and it was due to certain other factors. It is also being claimed that the changes in the solar irradiance is responsible for nearly 50 % of the observed global warming. Another theory that contributes to global warming is the theory of solar/cosmic ray. This theory states that clouds are formed by cosmic rays and they decrease the earth's temperature. The activity of solar radiation has increased its magnitude and delivers a better protection to the charged particles that form cosmic rays. This ends up in failing of cloud formation which eventually results in less cooling effect. As a result of this, warming trend around the globe is observed (Rogelj et al. 2012).

Along with all these arguments, there are many other claims. There are many possible hypotheses but a few possess the stronger evidence. The temperature changes are dependent upon large number of factors hence it is nearly impossible to evaluate all of them and come up with a satisfying theory.

4 Effect of Changes in Climate Variations

Climate change is explicit. The perturbations in climatic system modify all sustainable development dimensions and hence the potential development pathways for a given nation or a region. It is even considered as the "mother" of all problems to show its irreversible impacts (Kumar and Yalew 2012). The set of mechanisms in which climate change affects economic and environmental outcomes are too vast and complex to investigate comprehensively. Its impacts, vulnerability, and adaptation issues have drawn many scholars from the political, academic, and research sphere. Climate change specifies general and overall changes in an atmosphere of a region or area because of different disturbances in that particular area. These disturbances may occur due to natural reasons, human activities in that area like urbanization, deforestation, air pollution, etc. One of the main reasons of the major climatic changes occurring all over the world is global warming plus the factors influencing and involving it. These factors are described in detail in the portion related to global warming above. In this chapter only the type of climatic changes and the reasons of their occurrence will be discussed in detail. The effects are already being observed in various regions of the world with more droughts, floods, storms, and heat/cold waves (Frank et al. 2013; Goldman et al. 2012; Hansen et al. 2013; Harris et al. 2013).

4.1 Shrinking of Arctic Ice

The global warming has not imparted uniform effects on the entire globe. The Arctic region is going through rapid and severe climatic changes (Hassal 2005). Arctic summer ice is constantly decreasing because of continuous changes in climate and global warming. Arctic sea ice extent for January 2013 is 13.78 million sq km, which is 1.06 million sq km below with respect to 1979 to 2000 average for the month (Vizcara 2013). This thing is an attractive plus immediate concern for the weather and climate analysts and scientists all over the world because this decrease in ice cover triggers ocean waves and storm surges striking the coastlines harder and longer breaking the permafrost which will cause the release of CO_2 and CH_4 to the atmosphere that has been frozen for millennia (Bosnjakovic 2012). This means that further melt down of Arctic region ice cover will result in more emissions of CO_2 contributing further towards climate change and global warming. This will result in loss of whole Arctic ice within next 2–3 decades. This is also thought that the pace of this effect is increasing. The scientists working in this regard are proposing in view of their careful calculations and evaluations that this constant and continuous melt down is going to impose and have serious consequences on our future well-being. This is because Arctic summer ice or Arctic region in general helps in regulating climate by reflecting the excess and harmful sunlight off, hence cooling the earth's climate. Plus if excessive meltdown occurred then due to less ice in Arctic region, this will cause more moisture entrance in the atmosphere from oceans. As a result, more powerful and much frequent storms will occur. This rate of increase in storm intensity and frequency would likely to affect most populated areas of the world, which in turn would lead to excessive damages like life and resource loss, etc.

The Arctic region is the first and foremost point when it comes to impact upon climate change. We should consider it seriously but unfortunately we keep on forgetting that impact of climate change will not stop at Arctic region but will eventually spread further on to the entire world because it is a global phenomenon that, if preventive measurements will not be taken immediately, will only increase in magnitude and power in its impact upon world over the passing minute.

4.2 Extreme Rainfalls in the Tropical Region

The serious issue of global warming prevailing in the world because of which change in climate is occurring continuously resulting into constant rise in temperatures is the major cause of excessive rainfalls in the tropical region. Although the well-documented literature is available on rise of global temperature, no clear estimates on long-term trends in global precipitation are available (IPCC 2001b) because of lack of dependable oceanic rainfall estimates. Recent studies have shown that there is a significant increase in precipitation since 1950s in tropical regions. It is now being confirmed recently that every 1 °C rise in temperature will result in 10 % heavier rainfalls in the tropical region, according to the latest.

Research study performed at MIT. This eventual increase in rainfalls can have utmost and major impact on flooding in populated regions of tropical region. Scientists involved in this particular research are convinced and of the view that excessive rainfalls occurring in tropics are mainly because of global warming. Lau and Wu (2007) confirmed the earlier studies, which showed that extreme rain events in tropics will be more sensitive to the warming climate. However, the guess behind this increased and heavy rainfalls in tropics are basically well known. When some GHGs like carbon dioxide (CO_2) are emitted in the atmosphere, the more the GHGs in the atmosphere, the higher the temperature will be and then because of this, the amount of water vapors increases in the atmosphere. If more amount of water vapors is present in the atmosphere, heavier will be the rainfall due to increase in overall humidity of the region, which helps in facilitating the increase in the frequency and intensity of the resulting storms.

Scientists from MIT have confirmed by satellite observations and study of occurrence of excessive rainfall between latitudes of 30° north and 30° south that global warming is the major issue ruling this climatic change in tropics. Researchers also discovered one clear pattern that showed strong evidence of excessive rainfalls because of El Niño in tropics.

4.3 Forests: Feelers of the Heat of Climate Change

The climatic changes have many negative impacts on forests regarding many different angles. Increase in temperature is not only causing forest fires, heat stress, and drought conditions but also becoming a serious and hazardous cause of widespread insect population (Kumar and Yalew 2012). Scientists and researchers from various parts of the world are already studying forest mortality. As a matter of fact that not all species of trees are affected or impacted upon in the same way as some of the species are more resistant than other ones, regarding factors like age, size, nutritional requirement, etc. of the tree.

It is being feared by many researchers from all over the world that in the prevailing condition of global warming, many forests will cease to exist in the coming 3–4 decades and eventually turn into grasslands at the least or even barren lands like deserts. This factor could further increase the bad impact upon climate change because forests in world act as major and large carbon sinkers. If deforestation is not prevented or forcefully stopped on global level, then because of the decomposition and break down of dead trees, more CO_2 will be released into atmosphere, hence more increase will occur regarding global warming. The leftover debris from cut or dead trees is also an important contributing factor in increased risk of forest fires which will eventually result in even more CO_2 release in the atmosphere. In the USA, Canada, Europe, and Australia, outbreak of pests and diseases, hurricanes, heat waves, and increased risk of forest fires are affecting forest lands (Kirilenko and Sedjo 2007).

So in order to avoid the serious threat of further increase in the prevailing levels of global warming, deforestation should be stopped worldwide forcefully in order to protect and preserve nature. Also if in any part of world, some forest area has been demolished, then the trend of reforestation should be encouraged on the national level (Sugde et al. 2008). This should also be done practically on the whole world basis because nothing artificial can replace the role of forests. Forests play an important and vital role in not only absorbing CO_2 back from atmosphere but are also the major contributors in regulating weather and climate of the general area plus water purification. Forests are also an important factor regarding water, nitrogen, and nutrient cycles plus also provide fodder and homage for millions of different species of animals and plants.

4.4 Warm Climate: Short-Term Extinction of Species

Fossils and geological records, going back around 540 million years ago, are being reexamined recently by the British scientists and researchers from the universities of York, Glasgow, and Leeds. This reexamination was undertaken so that to discover and confirm connection between biodiversity and global warming in the world. This reexaminational study of fossils clearly showed that warmer time spans in the past at first were accompanied by increase in the rate of extinction of some species. Also it was seen through fossil record study that after a period of long time span, environmental and climatic changes promote devolving of new species causing an increase in overall world's biodiversity.

Through careful calculations, analysis, and examination, it was concluded that in normal conditions biodiversity in the world increases as the world warms up. Exclusive climatic changes and rapidly rising trends of continuous increase in temperature hinder the increase of global biodiversity because of rapid climatic changes. However, researchers and scientists from all over the world disagree that current and rapidly increasing levels of global warming and impact of climatic changes are good for existing species, in view of the present scenario at least. This is so because large variations in earth's biodiversity need billions of million years. Right now we can only predict one thing with surety and with reasonable evidences, provided through proper and careful studies and scientific calculations, is the short-term losses in the present biodiversity of earth.

4.5 Impact on Human Health

Climate change can affect human health by four means: (a) some diseases such as kidney stones are aided by the rise in the mean temperature of the earth (Brikowski et al. 2007), (b) heat stress and cardiovascular disease prevalence is increased due to extreme weather, (c) the reproduction, spatial and seasonal distribution of some disease causing vector (such as mosquito) and bacteria (e.g., salmonella in food poisoning) are affected by the temperature, precipitation, and wind variability, and (d) drought, flooding, and tropical cyclones affecting indirectly. In a nutshell, climate change leads to morbidity and mortality rate of human beings (Kumar and Yalew 2012).

The prevailing rate of the level of variations in climatic changes and the factors influencing them have an important effect of enhancive nature upon emerging of new infectious diseases, reemerging of the previous strains of infectious entities and the modified form of infections caused by them (Patz et al. 1996). This is happening in addition to the multiple human determinants, including biological and ecological factors. A rise in temperature by 2 °C will bring various serious and (in some cases) yet incurable infectious diseases.

In the last 2–3 decades, the incidence of insect-borne diseases through various species of mosquito has increased and come forward to global concern in the form of epidemics. Some examples include malaria, dengue, and viral encephalitis. These diseases are among those, which are sensitive to climate and the changes influencing it (IPCC 2007a). It can be said with evidence provided by scientific and geographical studies that climatic changes directly affect disease transmission and its epidemic form by shifting geographic range, increased reproduction levels, and the level of biting rates of the specific infectious entity containing vector and pathogen incubation period is also affected as it becomes shortened. It has also been observed by scientists from world over that some climate-related changes can be a cause of increase in the temperature of sea surface and in the sea level. This can be a leading cause of the higher rates of incidences of the water-borne infections and bacterial and industrial toxin-related diseases like water-borne cholera, shellfish poisoning, etc.

The increase in urbanization and human migration from one part of the world to another in pursuit of better lifestyle may influence and damage health infrastructure of that particular region. As a result of this massive human movement, from different parts of the world (particularly towards the cooler regions of the world) cause an increase in deforestation to stand multistory buildings in order to provide working places and housing to them. This will cause a major climatic change in that region as forests (natural buffers of nature) will be demolished in order to accommodate human population explosion over there. This irreversible increase in climatic variability can indirectly contribute to disease propagation and transmission as temperature of that region will increase dramatically due to many humans living in already congested areas.

There is also a main issue regarding climatic stress upon agricultural assets and products that can result into general malnutrition conditions, which can prevail through whole of the world. Also some potential mutations or alterations in immune system of humans, which may be caused by increased flux of the ultraviolet radiation due to continuous erosion of ozone layer can altogether increase humans' susceptibility towards infectious diseases.

The analysis of special and highly influential role played by climatic changes in the emergence of the infectious diseases requires global cooperation among medical physicians, geobiophysicists, climatologists, biologists, and social scientists. The increasing disease surveillance which includes the observation, check, and maintenance along with use of data systems based on geographical studies can afford much anticipatory measures by the medical society from the world over. If the understanding will be made of the linkages between climatological and ecological changes as determinants of disease emerging contributing factors, redistribution will eventually and ultimately help in order to optimize preventive strategies to slow down the increase in threat of emergence of new and resistant infectious diseases (Diffenburg 2013).

4.6 CO_2 Emissions from Soil Because of Global Warming

There can be one major accelerative influence of global warming upon rate of decomposition of soil organic matter which increases release of carbon dioxide (CO_2) into the atmosphere which will in turn further increase and tend to enhance the trend of global warming (Jenkinson et al. 1991). CO_2 is responsible for approximately 55 % of increase in radiative forcing which arise from anthropogenic gas emissions into the atmosphere. Plus it has also been calculated by conduction of various experiments that round about twice as much amount of carbon is present in top 1 m of soil crust as present in the atmosphere.

For this purpose, Rothamsted model was employed for use in order to do turnover of organic matter of the soil to calculate the exact amount of carbon dioxide expected to release from world's store of soil organic matter, if the rise in temperatures occurred as it has been predicted but keeping constant the annual return of plant debris to soil. The temperature of the earth if rises by 0.03 °C per year (this increase is considered most likely by Intergovernmental Panel on Climate Change), we can estimate upon that additional or excess release of carbon dioxide from soil organic matter will be approximately 61 10^{15} gC in the coming 60 years. The estimate is that of approximately 19 % of carbon dioxide that will eventually get released by consumption and combustion of the fossil fuels in the coming 60 years if the present use of this irreversible natural resource continues excessively in an unchecked manner.

4.7 Unique Impact of Increase in Urban Population

It has been found out that the ever-increasing growth rate in the urban population can lead to more than 25 % rise in the CO_2 release in the atmosphere in some of the developing countries. Increase in the economic plus social growth and ever bending interests towards the achievement of much better lifestyle associated with people moving into the cites or already situated dwellers over is directly related and proportional with increase in CO_2 emissions. This is largely because of the higher formation and consumption of resources preferred by an urban population.

5 Climate Change and Agriculture

Agriculture is an important sector of many of the world economies. It provides us with food, fiber, shelter and feed for the livestock. In addition to it, it contributes billions of dollars to the economies of many countries especially the agricultural-dependent economies and is the most dependent area as climate change is the main determining factor for agricultural productivity (Adams et al. 1998) and has threatened world agriculture productivity both economically and physically (Shakoor et al. 2011). Various elements shape and drive the agricultural sector. It is influenced by market fluctuations, national and international policies, practices in management, trading terms, technology availability, biophysical factors, etc. (Kurukulasuriya and Rosenthal 2003). Being dependent on resources present naturally, agricultural produce is at the mercy of uncertainties driven by climatic variability. Hence, vulnerability of agriculture sector can be classified in two broad categories of effects induced by climate: (1) effects having direct impact due to variability in temperature, precipitation, and content of carbon dioxide and (2) changes in soil quality and the occurrence, dispersal of infestation by pests and diseases having indirect impact. Therefore, susceptibility of agriculture sector can be assessed with the understanding of three major factors that are: environmental, biophysical, and socioeconomic factors. Some impacts are anticipated to be adverse while others being favorable. The distribution of impacts will change depending upon the ability to respond to these effects along with what sort of resources is used across various nations.

Changes in agricultural sector due to impacts of climatic variability are anticipated to manifest directly from changes in water resources and land. Climatic variability is expected to result in water and other resource shortages, affecting soil properties, variation in intensity, and frequency of droughts, flooding, sea-level rise, and storm surges, desertification and disease and pest outbreaks on agricultural lands and livestock. The areas susceptible to climate change will experience losses in crop yields (Rosenzweig et al. 2002). Dell et al. (2008) reported that 1 °C rise in temperature will reduce economic growth in poor countries by 1.1 %. He used the per annum variability in temperature and precipitation from 1950 to 2003 on 136 panel of world countries and reported devastating effects of climate change on economic growth especially of the poor countries and significant loss in industrial output (food, brewery, and textile) too. With respect to crop production, it is anticipated that change in climate will come along with impact as well as opportunities (FAO 2008) and would significantly affect the living patterns, the ability to access food and socioeconomic conditions of the majority of the people living in different regions of the world especially the arid, semiarid, and coastal areas (Chijioke et al. 2011; IPCC 2007b; Schmidhuber and Tubiello 2007). In contrast, it will bring beneficial effects in temperate regions and high latitude regions (Mendelsohn and Nordhaus 1999).

According to various international reports, it is projected that developing countries will be most affected for three reasons that are: (a) the changing climate will have its most negative effects in tropical and subtropical regions (Rosenzweig et al. 1993; IPCC 2001b), (b) most of the expected population growth will occur in developing world in 2030 (United Nations Population Division, DoEaSA 2009), and (c) more than half of the entire labor force in the developing world is engaged with agriculture (FAO 2005). This will exacerbate the situation in rural community. Earlier estimates depict 4–24 % agricultural losses in developed countries while 14–16 % in developing countries (IPCC 1996). The report of FAO published in 2008 indicated that the number of hungry and malnourished people have increased from 90 to 225 million from the years 1970 to 2008 and has anticipated further 100 million by 2015.

Although agriculture soils contribute about 15 % of global GHGs emissions (Gitz and Ciais 2003), these emissions include both exchange of GHGs in the arable fields, and indirect emissions from the use of agricultural inputs. The agro-ecosystems contribute emissions of nitrous oxide (nitrification, denitrification, and use of N-fertilizers), carbon fluxes between soil–plant interaction system and atmosphere, and methane exchanges to the atmosphere (Lehuger et al. 2007). But agriculture as emitter of GHGs is not an important issue rather how to protect the agriculture from changing climatic scenario is of paramount importance to ensure food security for the coming generations.

From various reports, it is evident that within and across the regions the vulnerability to changes occurring in climate will vary. In the absence of pragmatic policies to long-term climate changes, region-specific impacts will become more evident. The regions where strategies to address the issue of climatic variability are poorly structured will cause the high cost of maladaptation. Therefore, in the coming decades such policies should be devised which minimize the devastating effects of climate change and aid in increasing the agricultural productivity to meet the requirements of continuously increasing population and ensuring access to food for future generations.

5.1 Climate Change and Productivity of Plants

Our planet Earth has undergone an ecological shift. Plant productivity globally is thought to be at the verge of decline, mainly due to stress due to droughts caused by global warming. This global turnaround was discovered during an observation conducted by NASA satellite. The data was obtained by Maosheng Zhao and Steven Running from the University of Montana in Missoula. This data was analyzed against a data containing only a 6 % increase, which was obtained 2 decades ago. It is being observed that the recent decade's decline is slight which is just 1 %. However, this global shift can have an impact on food security, biofuels, and nitrogen, carbon and nutrient cycle.

In accordance with previous knowledge based upon old researches, it was held that productivity of plants was rising steadily. It has been confirmed through proper observations that rate of global plant productivity has increased by 6 % between the years 1982 and 1999. This was what occurring for two whole decades and it was reasonably thought that variations in temperature, solar emissions, and availability of water which are altogether influenced by climate changes affected by global warming are hence favorable for the growth of the plants . But these results were challenged and then nullified because new research through modern technology and analysis showed that the effect of global warming upon climatic changes which in turn influence productivity of land plant growth and vegetation need not to be positive (Nemani et al. 2003). It is also observed that the effect of the regional drought overruled the positive influential effect of longer growing season which in turn has driven down the global plant productivity between the years 2000 and 2009.

Scientists have predicted a very serious type of warning that in future, the much warmer and ever rising temperatures will be dangerous for plant growth. This has been discovered through a carefully conducted analytical study of plant productivity data with the help of an instrumental machine known as MODIS (Moderate Resolution Imaging Spectroradiometer) placed upon one of the NASA's satellites that is known as "Terra." The observations made by using MODIS about plant productivity were in combination with increase in the rate of ever growing and seasonal climatic variations, which include change in temperature spectra, range and intensity of solar radiations, and water availability. An algorithm was made based upon the data obtained by observation done upon and study of factors influencing and affecting plant growth and variations in climate which describes and explains about restricted growth of plants at different geographical locations in the world. It has been observed through careful analytical study by using this particular algorithm that plant growth is generally restricted and limited at high latitudes by steady rise in temperature and in desertificated areas by less water availability. The countries of north latitude indicate net positive impacts of climate change but projections for most developing countries are negative (Reynolds 2010). But one thing, which should be, kept in mind is that such varying and restricting plant growth regional limitations can also vary in their degree of impact and effect on growth of vegetation throughout the growth season around the world.

The above conducted analysis depicted that since the year 2000, the ecosystems flourishing in northern hemisphere with high latitude have continued to get benefited by the warmer variations in temperature and periods of longer growth season (Zhao and Running 2010). It has been seen that this particular effect was counterbalanced by the droughts associated with global warming which in turn has restricted and limited the plant growth in the southern hemisphere which, as it has been feared, resulted in the net global loss of land plant's productivity.

The steady and fast decline in terrestrial plant productivity in the last 3–4 decades depicts that in future, a complex type of interplay between ever rising temperature variations, amount and frequency of rainfalls, the patterns of cloud formation, concentration of CO_2 in the atmosphere, nutrients' availability and the programs and phenomena of land management, in combination will determine the patterns and trends in vegetative productivity around the world. Various scientists and researchers are now considering upon maintaining the record of the trends of variations of such atmospheric and environmental factors. This is the major concern of them because for one thing, the global plantation act as the carbon dioxide "sink" and the ever shifting of plant productivity levels towards constant decline is linked with the shifting levels of the influence of GHGs into the atmosphere. The other reason due to which the scientists are much bothered is the fact that the extent of such environmental and atmospheric fluctuations also exerts huge and negative stress upon the plant productivity and growth throughout the world which can seriously challenge food production and threaten meeting its requirements in the present and continuously growing situation of population explosion.

In the future, the potential damage that the global warming will cause further and multiple decline in global plant production plus availability of natural resources is not promising well enough and also the ability of the world's biosphere to support and maintain multiple demands of the population of the world for meeting agricultural needs and production, fiber production needs, and the increase in the rate of demand and need of biofuel and its production in the world (Zhao and Running 2010). It has been demonstrated on the basis of various observations and careful study that even if the declining trends in the rates of ever reducing plant productivity, etc. as depicted by the study of rates of the past 3–4 decades does not continue to proceed, still the managing forests and croplands for getting and meeting the requirements and the multiple benefits for the world's population including food production, biofuel harvesting, and carbon resource's storage will become excessively and increasingly full of challenge for the world in the near future, in the present scenario of the negative and immensely possible impacts left by these decline inducing changes in (sometimes irreversible) resources like forests, carbon reservoirs, biofuels, etc.

An observation of the earth was made in the year 2003 in the form of a snapshot, which traced the rates of plant productivity in the regions of the world having increased plant productivity and decreased plant productivity. But recently it has been observed by pattern study done by NASA scientists that the plant productivity tracked between the years 2000 and 2009; the global net decrease in plant productivity was because of the regional droughts under the influence of global warming.

5.2 Impact on Crop Production

Extensive literature has been developed on the impacts of climate change on agriculture sector, mainly focusing on the sensitivity of this sector. The available literature depicts that the extent of vulnerability of this sector to climatic perturbations is dependent on various local environmental and management factors which includes local conditions that are biologically active such as soil physical properties, type of crop, awareness about the climate change, the support from government, and the ability of stakeholders to undertake necessary measures for remedies to address the impact of changes in climate. The increased uncertainty of climatic effects poses an additional problem that farmers have to take into account. For example, the poor condition of soil, financial limitations, and lack of access to market can limit agricultural output to begin with, regardless of climatic effects.

Agriculture is an economic activity, dependent on many biophysical factors. Change in climatic variables could have significant impact on plant growth and development. The climatic variability may pose direct implications on biophysical factors including plant and growth of animals and the physical infrastructure related to processing of food and its distribution (Schmidhuber and Tubiello 2007). Most of the models designed for crop response to climate change take into account temperature, moisture, and carbon dioxide. But many other processes not integrated into these models could have significant effects including incidence of pests and diseases, exposure to heat waves, elevated ozone, loss of irrigation water, and an increase in inert-annual climatic variability related with a phenomenon like El-nino (Reynolds 2010).

Different crop simulation models have been designed to estimate the implications of changing climatic scenario on the crop production. The quantitative projections on impacts of climate change have been primarily based on the studies from experiments as well as cross sections. The experimental methodology includes agro-economic models, which is similar to controlled experiment where climatic variables are adjusted and their effects on crops are estimated. Similarly, agro-ecological zone analyses are carried out where estimates are made about specific agro-ecological zone. In the end, the results are merged into models of economic and general circulation to anticipate the impact's range as well as scale.

Using these simulation models, scientists undertook studies to estimate and quantify the impacts. Newman (1980) concluded that the corn belt of the USA would shift to northeast with every 1 °C increase in temperature. Rosenzweig (1985) reported that under changing climatic scenario winter wheat production in Canada would increase.

The continent of Africa is anticipated to be 2–6 °C warmer on an average according to the third report of IPCC on assessments. Sivakumar (1992) reported the shift in rainfall pattern from 1965 to 1988 in Niger and depicted reduced growing season by 5–20 days in Pearl millet (staple crop) across various locations in the country. He observed reduction in the net absolute amount of rainfall and change in its timing. Fischer and Van Velthuizen (1996) concluded that the agricultural productivity of Kenya will robust under changed climate if amount of precipitation is increased along with elevated levels of CO_2 and warmer air temperature. In Zimbabwe maize production is anticipated to decrease by 11–17 % (Makadho 1996) because of reduction in the grain filling period. Yates and Strzepek (1998) speculated that high dependency of Egypt on natural resources will make it more vulnerable to impacts of climate change. Benson and Clay (1998) using information from countries like Namibia, Zimbabwe, South Africa, Mozambique, Malawi, Lesotho, and Botswana demonstrated that industrial economies of these countries will be more vulnerable than the developing countries of Africa.

Numerous studies indicate that the agricultural sector of Asian countries will be more vulnerable especially the tropical zones (South and Southeast Asia). Impacts of climate unevenness are more devastating in southern part of Asia and may result in 50 % reduction in wheat productivity (MoE 2009). Rosenzweig and Parry (1994) reported reduction in grain yields by 25–40 % with a 4 °C rise in the temperature in

India. Seshu and Cady (1984) anticipated a decrease in rice yield with minimum temperature increasing from 18 to 19 and 0.5 °C rise in temperature in winters could decrease duration of crop by 7 days and 0.45 tons/ha yield and 2 °C increase would reduce yield in many parts of India (Aggarawal and Sinha 1993). Murdiyarso (2000) reported 7.4 % decrease in rice production of Asia. Mirza et al. (2003) reported changes in inundation of land will significantly implicate on rice production and cropping pattern in Bangladesh. Pakistan is ranked 28th among the countries which will face massive vagaries of climate change (Shakoor et al. 2011). Since 22 out of 28 countries are in Africa, crop production is affected by the following physical effects of climate change (Hulme 1996; Chijioke et al. 2011):

- Variability in temperature
- Effect of CO_2 concentration
- Change in precipitation amount and pattern
- Incidence of pests and diseases
- Extremity of weather events
- Rise in the level of sea

5.2.1 Variability in Temperature

The IPCC report (2007a) by combining the results of GCMs (general circulation models) predicted that the temperature rise in the coming 7 decades would be more than 5 °C. Variability in mean, maximum, and minimum temperatures is anticipated for most regions of the world due to climate change and northern countries would expect a higher temperature rise (Milanova 2012). Variability in temperature will affect the soil moisture content and the duration of growing season in different parts of the world. It is projected that countries lying in low latitude would be generally at a risk of reduced crop yields even at 1–2 °C of warming (Parry et al. 2007) especially in those areas where temperatures are close to or at optimum level for a crop growth to start with because levels of transpiration and evaporation with low levels of soil moisture content benefit in a predominant manner (IPCC 2007c). As a result some cultivated areas and some tropical grassland may become arid at increasing pace (IPCC 2001a). In temperate regions, the higher temperature will predominantly bring benefits to the agriculture by expanding the cropping areas and increased growth period and posing positive effects on crop yields (Kurukulasuriya and Rosenthal 2003; Schmidhuber and Tubiello 2007). The decreased fertility of soil of higher latitude will affect some of the fruits of an extended growing season (Rosenzweig and Hillel 1995). A moderate warming in temperate and some humid regions may increase productivity of pasturelands whereas in arid and semiarid regions pasture yields will decline (IPCC 2007a).

Plant growth rate is dependent on temperature, increases from a base value and decreases beyond an ambient limit. The plant biomass yield is a product of rate of biomass deposition and the growth period. The biomass accumulation is governed by the rate of photosynthesis of canopy. The period of growth is directly proportional to the temperature. Higher temperature leads to increased respiration rate, lesser time period for seed formation and hence lower biomass production. The increase in temperature will result in shorter period for grain filling, lighter grains, and lower grain quality. Increased temperatures will lengthen the duration of vegetative growth and reduce the risk related to spring and winter frosts (Milanova 2012). Plants photosynthesize at optimum temperature, which is generally higher in C4 plants than C3. Temperature affects dark respiration, increasing exponentially with rising temperature and hence net photosynthesis rate becomes sensitive to temperature response (Rosenberg et al. 1983). Vu et al. (1997) proposed that the response of doubling the carbon dioxide concentration at 35 and 32 °C for rice and soybean increased the photosynthetic rate but decreased with further increase in temperature. The results from the various scientific studies indicate that temperature increase may offset the luxuries of increasing CO_2 concentration on crop yield. The warm air temperature accelerates the rate of grain growth, reduces the period of grain filling and grain weight. The reduction in grain weight of cereals is considered as the effect of temperature on rate and length of grain growth period (Fuhrer 2003). The range of many pests may also expand and the ability of pest population to withstand the cold climate and attack on the spring crop will increase (Schmidhuber and Tubiello 2007).

5.2.2 Effect of Carbon Dioxide Concentration

Agro-ecosystems may be influenced strongly by the expected increase in carbon dioxide content and related climate unevenness and change. Plants respond to their surroundings, $CO_{2,}$ and temperature. Increasing CO_2 has positive effects on the plant growth because water use efficiency is increased and photosynthetic rates will be higher as CO_2 gradient will increase between leaf and atmosphere (Streck 2005). The current amount of CO_2 379 ppm in the atmosphere (Chijioke et al. 2011) is inadequate to saturate the ribulose 1,5-biphosphate that drives photosynthesis in C3 plants (Taiz and Zeiger 1991). The concentration of CO_2 is expected to rise by 57 % by 2050 (Hulme 1996) but projected to rise about 550 ppm under IPCC scenario by 2100 and business scenario greater than 800 ppm (Schmidhuber and Tubiello 2007). But if the atmospheric CO_2 increase will be accompanied by the rise in air temperature, it may offset the advantages of an increasing CO_2 concentration.

Stomata do not have a direct response to the CO_2 concentration. CO_2 concentration is regulated in the stomatal cavity (Ci) by plants and there is a constant ratio with atmospheric concentration (Ci/Ca) at a given vapor pressure deficit (Mott 1990). This ratio under stationary condition is 2/3 for C3 and 1/3 for C4 plants (Wong et al. 1979). Therefore it can be concluded that the partial closure of stomata at elevated CO_2 concentration will be the result of Ci/Ca regulation. The possibility of acclamation stomatal movement to exposure, to escalated CO_2 has been pointed out. Rice crop has shown marked acclimation and soybean appears to be less affected (Campbell et al. 1988). Wheat did not show any down-regulation of photosynthesis to elevated CO_2 concentration in the field (Nie 1995) in contrast to when raised in pots (Sage 1994).

In commercial greenhouses, CO_2 enrichment has been practiced since long time. The history of this practice has been reviewed by Wittner (1967) and reported increase in yield and ameliorated quality has been achieved in lettuce, tomato, cucumber, and some flower crops. A small number of studies have reported decreased yield at escalated CO_2 concentrations (Rosenberg et al. 1983). Lawlor and Mitchell (1991) reported that if C3 and C4 crops were provided with sufficient water, nutrients, and pest control, the yields of these crops grown at 700 μmol CO_2 mol^{-1} would increase by 40 % and 9 %, respectively. Only at very extreme conditions, there is deleterious effect of CO_2 concentration.

Where CO_2 metabolism is considered in plants, three major categories exist: C3, C4, and CAM. Each of these categories responds differently to the higher concentrations of CO_2. Generally the photosynthetic pathway of C3 is considered as less efficient when compared with C4 pathway. In C3 plants, the increase in optimum CO_2 concentration suppresses photorespiration. The increased concentration of CO_2 increases carboxylation and decreased rubisco activity and hence reducing the loss of CO_2 through photorespiration. Therefore, a net photosynthetic increase occurs (Taiz and Zeiger 1991). The concentrating mechanism of C4 and CAM plants tends to allow the leaves of these plants to maintain increased photosynthetic rates when internal concentration of CO_2 levels are lowered Therefore, photosynthetic rates of C4 and CAM plants are considered as less prone to heightened CO_2 concentration. The yields of crops are expected to increase nearly 10–30 % in C3 plants (wheat, rice, and soybean) and 0–10 % in C4 plants (maize, millet, sorghum, and some grasses) (IPCC 1996; Streck 2005; Schmidhuber and Tubiello 2007). An atmosphere with elevated CO_2 would result in higher photosynthetic rates but the quality with higher yields may not increase. Some cereals and forage crops showed lower protein content at higher CO_2 (IPCC 2001a). About the effect of increasing CO_2, a great many uncertainties exist and the response of different species to this increase may be different.

5.2.3 Change in Precipitation Amount and Pattern

The availability of water is a critical factor in determining the impacts of climate change in different regions of the world. Numerous studies demonstrate that it is critical to determine whether the precipitation and duration of growing season will be affected by climate change either in a positive or in a negative way (Hulme 1996; Sivakumar 1992). Rise in the level, timing, and variability of precipitation may be beneficial for semiarid areas by enhancing moisture to the soil, but could exacerbate problems in areas with plenty of water, while a positive effect may be posed by reduced rainfall. It will vary from region to region. It is projected that due to climate change, the temperate region may become wetter and drier areas of tropical region may become drier (FAO 2008). The variability in rainfall will affect rate at which soil erodes and moisture content of the soil, which are important factors in plant growth and development. A temperature increase along with reduced rate of precipitation would result in the loss of cultivated lands due to low moisture, high aridity, salinity, and groundwater depletion (Bals et al. 2008). To overcome the water shortages, more capital and technological requirements will be needed for irrigation, which will cause high input costs.

5.2.4 Incidence of Pests and Diseases

Climate change due to anthropogenic interventions has the ability to influence significantly the biology of all living organisms. Limited literature is available on the variability in the incidence and severity of pests affecting agricultural products and diseases. This factor has not been incorporated into the estimates of climate change impacts. The rise in global mean annual temperature associated with climate change will likely favor winter survival of insects pests that may modify the predictions regarding dynamics of insect population (Denlinger and Lee 2010). Many pests and fungi survive under comparatively warm temperatures, humid climates, and increased carbon dioxide level (Chidawanyika et al. 2012). This would cause new problem for farmers especially for the farmers of developing and the poor world.

Short-term fluctuations in temperature may be stressful for small insects as their body temperatures exist in equilibrium with optimum temperatures. Therefore, it is necessary for these insects to be able to cope with such changes. Physiologically, insects have the ability to adjust themselves with respect to thermal tolerance over short duration, a phenomenon named as “hardening” (Bowler 2005; Lagerspetz 2006). But over a long time period temperature tolerance may be altered to acclimatization in the field in response to changes in the environment (Huey and Berrigan 1996). Environmental factors directly influence the survival, development, reproduction, and dispersal of insect pests. The invasion potential of some pests may increase in response to the changing climate. For example, the maize stem borer, which was accidently introduced in Africa at first was able to survive and establish itself in many African countries, rendering more destruction as compared to species that were indigenous to that place (Sithole 1990).

5.2.5 Extremity of Weather Events

Extreme events are not new to agriculture, but it is anticipated that their frequency and intensity will increase and the areas subjected to these events will expand (Schmidhuber and Tubiello 2007). Huge agricultural losses can occur from extreme weather events like droughts, floods, storms, sudden heat, cold waves, etc. Extreme events can harm crop and reduce yield especially before the harvest period, which will pose serious consequences to food production and food security. Climate variability has been directly linked to the decline in economic activity (Brown 2009). A higher frequency of droughts will put increased pressure on water supplies varying from transpiration of plants to their allocation (Rosenzweig and Hillel 1995).

According to Lobell et al. (2011), yields will reduce by 1.7 % per degree if a day is spent over 30 °C under drought conditions. Whereas increased rainfall intensity in various regions can result in higher rates of eroded soil, leaching of chemicals involved in agricultural sector and runoff that contains agricultural waste to water bodies.

5.2.6 Rise in Sea Level

Sea level is expected to rise as a result of global warming, endangering the coastal and low lying areas triggering coastal inundation, salinization of soils, and intense rainfalls. Climate change will bring inundation in low lying agricultural lands associated with increased runoff from tropical storms while sea level rise will increase level of soil salinity and water logging. Salinity affects the plant growth by increasing the ionic concentration, which causes osmotic stress and the accumulation of these ions in plant tissues impair plant metabolism. Water logging leads to the displacement of air from the soil pores leading to hypoxia. This would cause reduction in the crop production leading to loss of farmer's income and food supply system of the affected region.

The sea level has been increased by 1.7 mm/annum on an average from 1870 to 2000, for a total rise in the sea level of 221 mm (0.7 ft or 8.7 in.). Since 1993, the satellites of NASA reveal that the level of sea is rising more steadily, about 3 mm/year, for a total rise in the level of sea by 48 mm (0.16 ft or 1.89 in.) between the years of 1993 and 2009. Projections on rise in sea level indicate that it will continue to rise for centuries after temperature stabilizes (Reynolds 2010). Satellite measurements depict that the Greenland and West Antarctic ice sheets are losing nearly 125 billion tons of ice yearly, enough to raise sea levels by 0.35 mm/yr (0.01 in./yr). If the melting hastens, the rise in the sea level could be significantly higher (Riebeek 2010).

5.3 Impact on Livestock

Livestock can also be affected by climate change. It can be affected by two ways: (a) reduction in the quality and quantity of forage from pastures and (b) the direct effect of higher temperatures on the livestock. Warmer temperatures are anticipated to have a suppressing effect on the appetite of animals hence leading to lower weight gain (Adams et al. 1998). Extensive evidence exists that properly managed livestock systems have more potential to adapt to climatic variability as compared to crop systems because they are better able to adapt to extreme events.

Livestock may be threatened by heat waves directly. All animals are affected by heat stress either directly or indirectly. Vulnerability to diseases may also be increased with it along with the reduction in fertility and milk production. On the other hand, drought may affect pasture and feed supplies. The amount of forage quality is reduced by drought rendering it unavailable to grazing livestock. Some areas may observe more intense and longer droughts that may in turn result from increase temperatures in summer and deceased precipitation. Changes in crop production due to drought may cause problem for animals relying on grazing. The grasslands of mid to high latitude are anticipated to show higher productivity under changing climatic scenario (IPCC 1996). The arid and semi-arid pastures are projected to have reduced livestock fertility and increased mortality rates (IPCC 2007b).

The incidence of parasites and diseases affecting the livestock may increase with change in climate. The survival of many parasites and pathogens may become easy with the early onset of spring and comparatively warmer winters. Moisture-dependent pathogens could thrive in areas where rainfall is increased. The productivity of pastures may increase with higher CO_2 concentration but there might be a decline in its quality. The increased gas concentration can in turn increase the plant productivity that is utilized as fodder for livestock. However, it has been indicated via studies that decrease in quality of forage found in pasture lands may occur as a result of higher CO_2. In short, more fodder will be consumed by cattle to obtain the same nutritional benefits.

5.4 *Impact on Fisheries*

Along with sectors, the industry of fisheries is also anticipated to affect from global climate change. Fisheries are already going through many stresses, including overfishing and pollution of water. Climate change may heighten these stresses; particularly temperature changes could pose significant impacts (Environment Protection Agency, USA).

Due to climate change, there might be a change in the ranges of many fishes and shellfishes. A lot of marine species have ambient temperature ranges at which their survival is possible. For instance, the North Atlantic cod requires below 54 °F temperature of water. Even temperatures at the bottom of the seas above 47 °F can retard their ability to reproduce. In this century, it is likely that both threshold temperatures would exceed (USGCRP 2009). Many species of the seas are able to find areas of streams with lower temperatures and lakes or move northward along the coast or in the ocean. However, escorting to a new area may put these species into competition over food and other resources with many other living organisms.

The prevalence of some diseases, which affect the aquatic species, may increase with the increase in the temperature of water. For example, in southern New England, lobster catches have dramatically declined. This decline is due to a temperature-sensitive bacterial shell disease, which was the cause of this die-off event. Migration and reproduction timings may be affected by changes in seasons and temperatures (CCSP 2008).

In addition to warming, due to atmospheric CO_2 increase, the acidity of oceans is also increasing all around the world. This increase in acidity could have a harmful effect on shellfish by weakening their shells formed from calcium. The structures of ecosystems that are relatively sensitive may also be threatened by acidification upon which some of the fish and shellfish rely.

Agriculture and fisheries are considered as most vulnerable sectors to the climate changes which, on the other hand, will affect other sectors and future world market and trade. The fourth IPCC assessment report defined vulnerability as "the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change including variability and extremities." The vulnerability of agricultural produce to climate changes depends on the physiological feedback of affected plant and the capability of affected socioeconomic system to tackle with the changes in yields along with the changes in the drought frequency and floods. Adaptive and mitigating strategies are needed to prepare the communities, regions, and countries for the penalties of climate change.

The combined effect of climatic variables (temperature, precipitation, carbon dioxide, extreme events) on crop yields, livestock, and fisheries is estimated to vary from one crop to another, species to species as well as from region to region. From the available literature and research on impacts of climate change it has become evident that there will be regional winners and losers from climate change, given that net reduction potential in the yield will be greater in warmer, low latitude, arid and semiarid areas, and the developing world. It implies that climate change may affect the comparative advantage of agriculture production region, which is expected to shift to the areas in which specific crops are raised, within the borders and across the borders. It would affect the agricultural revenues of various regions and countries and alter the patterns of agricultural commodities trading among countries. The economic consequences of reduction in yield will depend on the adaptations made by the farmers, governments, consumers, and other related institutions.

6 Global Climate Change and Security of Food

Climate change and agriculture are inter-related processes. It is a leading agendum today and a growing concern on global scale in context of its impacts on crop production and food security. It is considered as the biggest challenge to agriculture and security of food because global warming is projected to have significant implications on conditions affecting agriculture. Crop and livestock production both will be influenced by climate change and the way it affects may vary from crop to crop, region to region, and from season to season (Dell et al. 2008). Agriculture is dependent on climatic variables that include: maximum and minimum temperatures, incident solar radiation, precipitation, wind speed, and relative humidity. Other variables include the concentration of CO_2, sea-ice extent, mean sea level pressure, sea level and storm surge frequencies. The increasing climatic variability brought about by these variables is a major environmental challenge to the world today with significant implications to ecosystem, food security, and economic stability and will affect both farm income and food security. It affects production of food directly through changes in conditions of agro-ecology and indirectly by affecting distribution of incomes along with the growth.

The FAO (1996) defined food security as "it exists when all people at all times have physical and economic access to sufficient, safe, and nutritious food to meet their daily dietary requirements to ensure an active and healthy life." It depends on availability and access to food and utilization of food (FAO 2000). Climate change will affect the security of food through its impact on all components of local, national, and global food systems. The main pillars of food security are: food availability, its access and utilization (FAO 2000), which are hierarchical.

Food availability is essential but not enough for access and access is essential but not sufficient for utilization (Webb et al. 2006). These three facets of food security need to be ensured to overcome the risk of food paucity at local, national, and global levels, which may be affected by climatic variability. The first pillar refers to the existence of quality food in sufficient quantities, supplied by either domestic production or import. Changes in agricultural supply result from the changes in yield and crop acreage. The domestic consumption requirements give the estimate of deficit or excess of food availability in a certain region. It is most often used as a measure of food security.

Food accessibility refers to the ability of individuals, communities, and countries to purchase sufficient quantity and quality of food. The access to food is determined by physical and financial resources and social and political factors. Food access consists of affordability, allocation, and preferences. The physical availability of food does not necessarily mean an individual has access to food. It depends on many factors such as poverty, infrastructure, prices, and preference of household. Food costs and capacity to procure food are directly proportional to the changes in commodity supply and resultant price changes.

Utilization of food refers to an individual's capacity to consume or benefit from food (FAO 2011). Climate change will also affect the ability of individuals to use food effectively by altering the conditions for food safety. A household who has physical and economic access to food could be food insecure if it is unable to get a balanced diet.

In future global and regional weather conditions will become more variable with increase in the severity and frequency of extreme events, which will bring greater fluctuations in the crop yields and local and international food supplies that will affect the stability of food supplies and thus food security. No doubt, climate change will impart significant negative impacts on the crop yield, and hence a huge challenge to the livelihood and food accessibility to most of the people. Crop production and food accessibility are key determinants whether a region is food-secured. Climate change will affect all the components of food security. Any change that will affect crop production would have significant implications to food availability, accessibility, and utilization. Climate change is considered as one of the root cause of high food prices. The major negative impact of high prices will be burdensome for small farmers especially of the developing world. The household may be forced to reduce the quantity/quality of food or consume less preferred food to meet other socioeconomic demands of the family. In short, climate change will bring low production and low productivity that will cost high food and feed prices and some people may be unable to access food, leading to malnutrition, poverty, diseases, and starvation (Albaladejo 2013).

All assessments depict that the first decades of the twenty-first century are expected to see less impacts of climate change, but also decreased overall incomes and a higher dependence on agriculture.

7 Adaptations, Mitigation, and Climate Change

The IPCC defines mitigation as "implementation of policies to reduce GHG emissions and enhance sinks" (IPCC 2007a). It is concerned with how to limit the GHG emissions due to anthropogenic interventions. Mitigation strategies are today's world need so as to limit the vagaries of climatic variability. It can only be effective if such measures are organized globally and strong coordination and dissemination linkages are established between various research institutes, universities, governments, etc.

To stabilize the warming climate near 2 °C would require reduction of global emissions about 1.5 % per annum, i.e., about 50–70 % reductions in GHG emissions (World Bank 2010; Johnsson et al. 2012). The climate modeling reports depict that reduction in emission of 50–85 % in carbon dioxide are needed to stabilize atmospheric concentrations of GHGs at 440–490 ppm, corresponding to a global temperature increase in equilibrium of 2–4 °C (IPCC 2007b). By 2050 emission should be 50 % below the 1990 levels and zero by 2100 (World Bank 2010). Currently the per capita emission of CO_2 is 7 tonnes and by 2050 the per capita emission should be 2 tonnes provided the world population is about nine billion by 2050 (Bosnjakovic 2012).

Currently the developed countries are contributing more transmission of GHGs in the atmosphere than the developing nations. In rich countries, even if emissions fall to zero, still poor countries will need to limit emission about 2–2.5 tonnes, because eight billion of the world population resides in poor countries especially Asia which is the most populated region in the world and India and China are considered as key players. Therefore, it is necessary that poor countries should be at the center of any global deal. The USA, Canada, and Australia emit about 20 tonnes per capita of CO_2, Europe and Japan around 10 tonnes, China about 5 tonnes, India about 2 tonnes, and most of the sub-Saharan African countries emit round about less than 1 tonne. At current emission scenario and adopting the principle of equity, the USA, Australia, and Canada would need to cut down the reductions by 90 % up to 2050, European countries to 80 %, and China to a level of 60 % to achieve the target of an average of 2 tonnes globally (Bosnjakovic 2012; Rogelj et al. 2013).

In agriculture sector, GHGs mitigation can be achieved by four basic mechanisms (Khajuria and Ravindranath 2012): (a) reduction of methane and nitrous oxide emissions from agricultural production, (b) producing various forms of biomass for use as energy source as substitute of fossil energy sources, (c) minimizing desertification by supporting forests via reforestation, afforestation, and adopting agro-forestry, and (d) storage of carbon by increasing the organic content of soils (Caldeira and Myhrvold 2012).

It would be difficult to cut back away the emissions from agriculture sector as compared to other sectors. Developed countries have more responsibility to cut down their reduction and would need to have emissions close to zero in case of transport and power sectors in the coming decades. Still it is a complex and controversial issue whether such a mitigation effort is technically, economically, and politically feasible. Mitigatory efforts have to be choked out together by experts from agriculture sector, climatologists, growers, environmentalists, and policymakers (Platz et al. 2007).

Adaptation is defined as "initiatives and measures to reduce the susceptibility of natural and human system against actual or expected climate change effects." It deals with how to tackle the impacts of climatic variability: those which are already being observed, those which are anticipated to happen with a high degree of certainty and those with uncertainty but with more frightening effects. Predictions regarding the variability in climatic parameters at the regional and local levels may lack precision but the trends of impact of climate unevenness and change are emerging clearly. Current and future vulnerability assessments are needed for formulating an effective adaptation strategy. An adaptation strategy aims at reducing the vulnerability and increasing the adaptive capability.

Effective adaptation to change in climate requires a cross-sectional approach in order to avoid possible conflicts among different sectors. Adaptation may be costly, but it is much needed to start it now, because it will cost much higher once the effects of climate change get irreversible. Adaptation measures may be foreseen as an opportunity for triggering alternative, innovative, and pragmatic approaches. The need for adaptation certainly arises from the key question of financing. This is particularly problematic for poor developing countries, which do not have the resources to prepare for and respond to these changes. Under the assumption that global emissions will be reduced by half until 2050, UN Development Programme (UNDP) estimated that additional costs for developing countries amount to US$ 86 billion by 2015 (UNDP 2007/2008). The World Bank anticipates the annual climate funding required for a 2 °C trajectory to US$ 28–100 billion for adaptation and US$ 139–175 billion for mitigation. Beyond 2015, the proper level of development support should account for the further cost from climate change if mitigation fails. The nations with good governance and robust diversified economies shall be less vulnerable to shocks of climate change (Seinfeld and Pandis 2006).

The recognition of the fact that some countries especially the developing ones (particularly poor community) will suffer more from vagaries of climate change has added impetus to promote adaptation (Burton 2001). Numerous studies have led stress on the need to pursue adaptation along with the mitigation strategies. Adaptation is considered as a vital step to strengthen the local and regional capacity to deal with the projected and unexpected climate change (Smith et al. 1999). Agricultural systems are dynamic as producers and consumers are constantly responding to alteration in crop and livestock yields, prices of inputs and food, availability of resources and technological changes. Adaptations can be made at farm level by adjusting sowing and harvesting dates, crop rotation, selection of crop and variety, water for irrigation, use of fertilizers, and tillage practices (Adams et al. 1998). Each adaptive measure can lessen potential losses in yield and can ameliorate yields where climate change is beneficial.

Following measures should be taken to adapt the crops against expected climate change:

- The challenging aspect of adapting crops to expected climate change will be to maintain their genetic resistance against the biotic stress, i.e., pests and diseases. Increasing temperature and variations in humidity affects the responsiveness of agricultural pests and diseases and are likely to introduce new and unpredictable epidemiologies.
- The major expected abiotic stress to crop plants includes heat, drought, salinity, water logging, and inundation. Growth rate is accelerated due to increased temperature but at the expense of photosynthesis, while heat and drought stress may inhibit growth at metabolic level. The harvest index may be reduced if stress occurs at critical developmental stages. Genetic improvement under these circumstances can be achieved by introducing adaptive traits into cultivar of good agronomic background.
- As understanding of physiological and genetic basis of adaptation is improved, this can be expanded in conjunction with molecular approaches to tackle the most challenging aspects of climate change like adaptation to higher temperature without compromising water use efficiency and tolerance to sudden extreme events.
- Genetic manipulation to enhance the specificity of rubisco for carbon dioxide relative to oxygen and to increase the catalytic activity of rubisco in crop plants would increase yield potential.
- Introduction of C4 mechanism in C3 plants can increase yield potential even at warmer temperatures and moderate levels of water deficit.
- Selecting genetic mechanism that enhances nitrogen use efficiency thereby reducing emissions of GHGs.
- Genetic engineering techniques that allow plant roots to release inhibitory compounds to suppress nitrification.
- Practicing reduced or zero tillage in conjunction with crop residue retention can buffer crops against severe weather events.
- Improving the overall environment for the root growth will ensure the optimal expression of genetic potential of the crop plant.
- Diversification of cropping system will aid in preventing the soil-borne pests.
- Cultivation on more robust soil which are less prone to degradation.
- By adopting conservation agriculture techniques which will protect soil from evaporation, wind and water erosion, reduce water runoff, enhanced infiltration thereby reducing inundation and salinity.
- Practicing crop rotation to improve the soil texture and structure (Goldman et al. 2012).

8 Conclusions and Future Perspective

Climate change is unequivocal. Its impacts, vulnerability, and adaptation issues have drawn many scholars from the political, academic, and research sphere. The history of our planet Earth shows us with evident proofs that some time spans of hot and cold periods of climatic changes were naturally exchanging alternatively which affected the entire life on earth. In the last 5–6 decades, humans are the major factor and mainly involved in ups and downs of climatic variations. Because of exclusive usage of fossil fuels, its burning and the resulted increase in carbon dioxide release in the atmosphere generally. Also the climatic changes and variations in their prevailing current stage are actually associated with the main threat of global warming. In the last past three centuries, the average temperature of the world has increased by 0.7 °C. The rise in temperatures is supposed to increase further and thought to be crossing more than 3 °C by the end of this century (Maltais 2012).

The changes in climate have various fearful and terrible faces which would result into flooding, drought conditions, exclusively varying weather events, rise in sea level, and sprouting of new diseases with difficult to find or no cure. This serious and perilous threat may not affect or have any serious influence upon us but our generations to come, our children and grandchildren are at a predictable, eventual and evident risk to pay a high price for our mistakes of today. If preventive measures are not taken into account and done today, then the issue of climate changes will eventually become a struggle for the generations to come (Smith et al. 1999).

Future research thrust on the issue should identify and quantify the immediate and direct impacts of climate change on wealthy nations along with transmission mechanisms of impacts from poor to rich countries. Today's world is more integrated than ever before. Either negative or positive impacts in poor countries soon will be transmitted to the whole world. Transmission mechanisms: from local to national, from national to regional and then global, sector to economy wide, of course, should unambiguously be identified. A loss in agriculture production and productivity may increase population migration from poor to developed countries, which in turn would have political, social, and economic implication (Linda 2012).

The research so far on the arena is more or less concentrated on the impacts of increased temperature on output production and/or factor productivity. But, temperature is only one of the many climate variables. There are few studies on the impacts of climate change via altered precipitation amount and pattern. The economic impacts of increased frequency of extreme weather events such as hurricanes and flooding are less assessed compared to that of temperature. Earlier studies are also more of sector-wise than economy-wide impacts: on agriculture, on human health, on crop production, on livestock production, on forestry, on fishery, on water, and likes. Future studies shall concentrate on economy-wide impacts as it will increase the concern on climate change among stakeholders and will have better policy implication.

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