

4. Impact of Climate Change on Agricultural Productivity and Food Security

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4.1 Introduction:

Climate is a weather condition prevailing in an area over a long period of time. The climate of an area includes seasonal temperature and rainfall averages, and wind patterns. Different places have different climates. A desert, for example, is referred to as an arid climate because little water falls, as rain or snow, during the year. Other types of climate include tropical climates, which are hot and humid, and temperate climates, which have warm summers and cooler winters. Climate change is a change in the statistical properties of the climate system that persists for several decades or longer. It is a significant change in the average values of meteorological elements, such as precipitation and temperature, for which averages have been computed over a long period. Climate change may be due to natural processes, such as changes in the Sun's radiation, volcanoes or internal variability in the climate system, or due to anthropogenic causes such as deforestation, land use, anthropogenic wastes that cause changes in the composition of the atmosphere, land and water. Anthropogenic activities lead to the emission of greenhouse gas such as CO₂, methane, and nitrous oxide, as well as other substances that lead to ozone depletion in the atmosphere [1]. The past few decades indicate that significant changes in climate at a global level were the result of enhanced human activities that altered the composition of the global atmosphere [2]. The average global temperature is expected to rise by 2°C by 2100 and 4.2°C by 2400, as predicted by probabilistic computations of the IPCC's range of climate sensitivity. So this rising global temperature affects the world many ways. In the recent time there has been a lot of discussion on climate change. So it is evident that impact of climate change is will be felt cross the world in different sectors ranging from water resources to industries to social arenas. It is not like that those people who contributed most to climate change will be affected more but everyone will be affected irrespective of their contribution to global warming and climate change. Though climate change poses a variety of challenges, the present paper would specifically focus on the issues viz. impact of climate change on agriculture and food security which have immense impacts all over the world but particularly in some developing countries like India where still agriculture contributes a significant portion in GDP of the country.

The increasing world population is putting stress on rising demands for crop production. By 2050, global agricultural production may need to be doubled to meet increasing demands [3]. Evidence comes from agricultural science research as well as an analysis of crop production data that climate variability matters as much to crop production as the mean values of climate variables during the crop season [4]. Crop productivity in world faces weather adversities, especially extreme events that jeopardize socioeconomic demands [5]. Climate change not only increases the average global temperature but may also lead to some other effects like stronger storm system, increases frequencies of heavy precipitation events and extended dry periods. These changes have implication for overall food production, food security as well as food safety.

4.2 Climate Change and Crop Production:

Crop production is extremely susceptible to climate change as it can effects the microbial population of the macro-environment (soil, air and water) and population of pest or other vectors. Thus act as a contributing factor to the occurrence of biotic diseases caused by different organisms like fungi, bacteria, viruses and insects.

Abiotic factors such as nutrient deficiencies, air pollutants and temperature or moisture extent can also affect the plant health and productivity which is happening due to climate change. It has been estimated that climate change are likely to reduce the yield of crops in the 21th century [6]. While the impact of biotic and abiotic factors on crop production and food securities are more obvious, it is important to note that these factors may also have significant impacts on safety of food crops. The prevalence of environmental contaminants and chemical residues in food chain is a chief impact of climate change.

The changing climate may also negatively affect the crop production by altering plant-microbes interactions and soil ecology specifically in the rhizosphere region. It is well known that plants and associated microbial interactions are critical factors affecting the growth, survival, yield, and nutritional quality of agricultural crops [7]. Apart from this the changing climate condition may also affect the plant pathogen interaction by altering the pathogen life cycle, expression of host resistance, disease epidemiology and severity of disease epidemics, development of new races or pathotypes, virulence, overwintering or over summering of the pathogen, and so forth [8]. In addition, the warming climate can alter the mobility, leaching, bioavailability, volatilization, and global transport of chemical pollutants in agro-ecosystems [9]. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Pests management become less effective, meaning that higher rates of pesticides will be necessary to achieve the same levels of control but it will negatively impacts human beings as well as environment.

This changing climatic conditions coupled with subsequent changes in biotic and abiotic stress have drastically affected the quantity and quality of agricultural products [10]. Heat waves can cause extreme heat stress in crops, which can limit yields if they occur during certain times of the plants' life-cycle (pollination, pod or fruit set) are changes. Extreme periods of high temperature are particularly harmful for crop production if they occur when the plants are flowering – if this single, critical stage is disrupted, there may be no seeds at all.

Also, heat waves can result in wilted plants (due to elevated transpiration rates) which can cause yield loss if not counteracted by irrigation. In global level global warming have already doubled the chance of “killer” heat waves like the one that scorched Europe in July–August 2003 [11]. Strong evidence indicates that the summer was the hottest in Europe in at least the past 500 years [12]. All-time high temperature records were broken in many countries. High temperatures at night can be particularly damaging to agriculture. Some crops require cool night temperatures. The heat and associated drought and wildfires cost European economies over \$14.7 billion (13 billion Euros) in losses in the agriculture, forestry, and electric power sectors [13]. Specific damages included a 60% reduction in fodder production in France, an 18% decrease for wine in Italy, an 11% fall in grain production for Europe as a whole [14].

Due to the climate change rainfall pattern also have changed. Heavy rainfall may often results in flooding that can also be detrimental to crops and to soil structure. Most plants cannot survive in prolonged waterlogged conditions because the roots don’t get proper aeration for survive. According to the available data, a significant increase in the intensity of precipitation events occurred over the second half of the 20th century. This increase is consistent with the predicted effects of global warming, since higher temperatures speed up evaporation from the land, vegetation and oceans. This increase in the amount of moisture in the warmer atmosphere in the form of water vapour leads to heavier downpours.

Heavier rainfall in turn increases the risk of flooding [15]. One of many extreme flooding events that may have been exacerbated by global warming occurred in December 1999, when Venezuela experienced its highest monthly rainfall in 100 years [16].

Another impact of climate change that affects the crop productivity is drought. Droughts are also expected to be more frequent and severe. Higher temperatures tend to increase the rate of evaporation; if precipitation doesn’t soon replenish the lost moisture, soils grow drier. In drier soils, less solar energy is used up in evaporating water, meaning more energy is available to raise the temperature of the soil and the overlying air, leading to even more desiccating conditions; this kind of self-amplifying cycle can lead to a lengthy and severe drought [17]. Warmer ocean temperatures due to global warming may also increase the severity of droughts. The Indian Ocean and the western Pacific were exceptionally warm between 1998 and 2002, in part because of the overall warming trend in the world’s oceans. In the same period, unusually persistent atmospheric flow patterns resulted in below normal precipitation, high temperatures, and drought conditions across wide swaths of North America, southern Europe, and southern and central Asia [18]. Drought is also associated with another severe environmental condition like forest fire and nature have witnesses this type of natural disaster at many instances. Desiccating heat and lack of precipitation create ideal conditions for major wildfires. In addition, longer warm seasons often translate into longer fire seasons. Warmer temperatures also promote outbreaks of insects that feed on trees, killing many of the hosts and creating large amounts of dry fuel for forest fires. Warmer temperatures also promote outbreaks of insects that feed on trees, killing many of the hosts. In south-central Alaska in the 1990s, the world’s largest recorded outbreak of spruce bark beetles damaged more than 4 million acres (1.6 million hectares) of forest, an area nearly the size of the state of New Jersey. Since 1994, Canada has been afflicted with its largest and most northerly spruce bark beetle outbreak ever, affecting 750,000 acres (300,000 hectares) in the Yukon that severely affects crop production [19].

In 1998, Mexico experienced its worst fire season ever, when 1.25 million acres (506,000 hectares) burned during a severe drought. Smoke reaching Texas triggered a statewide health alert [20]. If wildfires continue to increase in frequency and intensity, the amount of carbon dioxide released into the atmosphere from burning vegetation and soil organic matter could outstrip the amount absorbed by remaining forest and thus strengthening the greenhouse effect and global warming and possibly leading to even more fires in a worsening cycle which again effects on crop production.

The loss of crop yields can increase food prices, and can have an absurd effect on agriculture welfare globally, with a 0.3% annual loss of future GDP globally by 2100 [21]. However, it has been found that climate change has limited influence on the world food supply, but the developing countries will face severe negative consequences [22]. In India, the temperature is predicted rise between 2.33°C and 4.78°C along with a doubling of CO₂ concentration and longevity of heat waves, which could have a detrimental effect on the agriculture sector [23]. Although the detrimental impact of climate change will be enormous in developing countries tropical regions but it will also depend on the region's climate scenario. The drier region of Sri Lanka (north and east) will experience huge losses in agriculture compared to the cooler central highland region, the output of which is expected to remain the same or even increase with rising temperatures [24]. In the arid region of Rawalpindi, Pakistan, an annual loss of INR 4180/acre is to be borne by farmers by 2100 with a 1°C increase in temperature, while the net revenue can be increased by INR 377.4 and INR 649.21 with an increase in rainfall of 8% and 14%, respectively [25]. The yield losses in rice, maize, and wheat are projected to worsen by 10 to 25% with a 1°C increase in mean surface temperature globally. In sub-Saharan Africa, the average crop yield is projected to be reduced by 6–24% due to climate change [26].

The change in climate or weather pattern of an area is predicted to increase a crop's susceptibility to various pests, diseases, and weeds. There are projections of a 10–25% increase in losses due to insect pest infestation with an increased temperature of one degree [27]. Climate change has the potential to increase the pest population and its migration, which can have an adverse impact on agricultural yields and even viability, as the pest population depends mainly on abiotic factors such as humidity and temperature. In Brazil, the infestation of coffee nematodes and leaf miners is expected to increase due to an increase in the number of generations in a month compared to the climatic conditions of 1961–1990 [28]. Climate change is projected to have a favorable influence on the weeds of wheat crops, which are very vital to world food security [29]. In the wake of climate change, new geographical horizons are being opened up for weeds, and their management can only be possible if new management practices are being planned while considering climate change. Pest infestations of various crops is predicted to worsen with climate change, as warmer and humid conditions are more favorable to pest proliferation. Pest infestation thereby has led to huge pesticides costs for pest management.

The increasing average temperature of earth could lead to changes in the range of latitudes at which certain fungi are able to compete. Since 2003, frequent hot and dry summers in Italy have resulted in increased occurrence of *Aspergillus flavus*, the most xerophilic of the *Aspergillus* genus, with consequent unexpected and serious outbreak of aflatoxin contamination, uncommon in Europe, even in the southern regions. Also in United States serious outbreaks of *A. Flavus* have been reported for similar reasons.

Generally moist, humid conditions favour mould growth. Moist conditions following periods of heavy precipitation or floods would be expected to favour mould growth with the expectation of greater production of mycotoxins. There are reports that periods of higher than average temperatures and reduced annual rainfall in Kerman Province in Iran has been linked to nut deformity and increased levels of aflatoxin contamination [30]. Mycotoxins can diffuse into the grain and can be found in all ground fractions and, due to their thermo-resistance properties, also in products subject to thermal processing [31]. Such products make a serious threat to the consumers health and some of the toxins are enumerated among carcinogenic compounds for humans and animals. Aflatoxin that belongs to human carcinogens induces liver tumors, and ochratoxin A has nephrotoxic effects. Trichothecenes, and deoxynivalenol (DON) among them present a wide range of toxic influence on human beings and animals resulting in their lack of appetite, nausea, diarrhea, hemorrhages and anemia. Loss of food commodities due to pest infestations is a major reason of food crisis particularly in tropical countries [32].

Mycotoxins contamination in cereals intended for human and animal consumption, is a serious food safety issue regarding productions from all over the world. In particular, cereals and by-products could be contaminated by different class of mycotoxins including one of the most dangerous to human health and animal found in nature, aflatoxin B1. Mycotoxins occurring in food commodities are secondary metabolites of filamentous fungi, which can contaminate many types of food crops throughout the food chain. Although hundreds of fungal toxins are known, a limited number of toxins are generally considered to play important roles in food safety. Around a quarter century back itself, the World Health Organization estimated that approximately 25% of the world's grains were contaminated by mycotoxins. This has most certainly grown since then due to an increase in global import and export of grains and cereals and the changing environmental and weather patterns which is an effect of climate change. Climate change may make production of certain crops difficult in some areas thus posing an obvious food security problem. Climate change impacts not only on primary production but some conditions like increasing average temperature could increase hygiene risks associated with storage and distribution of food commodities. Reduced availability and quality of water in food handling and processing operations will also give rise to a new challenge to hygiene management. It is anticipated that these risk management measures and adaptation strategies will pose greatest challenge for developing countries. Climate change is very likely to affect food security at the global, regional, and local level. Climate change can disrupt food availability, reduce access to food, and affect food quality. For example, projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability may all result in reduced agricultural productivity. Increases in the frequency and severity extreme weather events can also interrupt food delivery, and resulting increases in food prices after extreme events are expected to be more frequent in the future. Internationally, these effects of climate change on agriculture and food supply are likely to be similar to those seen in the United States. However, other stressors such as population growth may magnify the effects of climate change on food security. In developing countries, adaptation options like changes in crop-management or ranching practices, or improvements to irrigation are more limited than in the United States and other industrialized nations. Any climate-related disturbance to food distribution and transport, internationally or domestically, may have significant impacts not only on safety and quality but also on food access.

4.3 Impact of Climate Change on Agricultural System of India:

Food production in India is sensitive to climate changes such as variability in monsoon rainfall and temperature changes within a season. Studies by Indian Agricultural Research Institute (IARI) and others indicate greater expected loss in the Rabi crop. Pathogens and insect populations are strongly dependent upon temperature and humidity, and changes in these parameters may change their population dynamics. Indian climate is dominated by the southwest monsoon, which brings most of the region's precipitation. It is critical for the availability of drinking water and irrigation for agriculture. Agricultural productivity is sensitive to two broad classes of climate-induced effects:

- a. Direct effects from changes in temperature, precipitation or CO₂ concentration and
- b. Indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases.

Rice and wheat yields could decline considerably with climatic changes [33]. However, the vulnerability of agricultural production to climate change depends not only on the physiological response of the affected plant, but also on the ability of the affected socio-economic systems of production to cope with changes in yield, as well as with changes in the frequency of droughts or floods. The adaptability of farmers in India is severely restricted by the heavy reliance on natural factors and the lack of complementary inputs and institutional support systems. Agriculture in the coastal regions of Gujarat, Maharashtra, and Karnataka is found to be the most negatively affected. Small losses are also indicated for the major food-grain producing regions of Punjab, Haryana, and western Uttar Pradesh. On the other hand, West Bengal, Orissa, and Andhra Pradesh are predicted to benefit to a small extent from warming. In a recent study, the International Commission for Snow and Ice (ICSE) reported that Himalayan glaciers – that are the principal dry-season water sources of Asia's biggest rivers - Ganges, Indus, Brahmaputra, Yangtze, Mekong, Salween and Yellow – are shrinking quicker than anywhere else and that if current trends continue they could disappear altogether by 2035 [34]. Agriculture is not provided the food only but also the primary source of livelihood for 38.6 percent of the world's total workforce [35]. If agricultural production in developing countries of Asia and Africa is adversely affected by climate change, the livelihoods of large numbers of the rural poor will be put at risk and food insecurity will be highly vulnerable. India will also begin to experience more seasonal variation in temperature with more warming in the winters than summers [36, 37]. All the models of climate predict that there will be more extreme weather conditions, with more droughts, heavy rainfall and storms in agricultural production regions. Such extreme weather events will heavily imposing severe risks and potential crop failure. With rapidly increasing population, climate change has been become a more threat to developing countries like India. The tropical climate of India could become warmer under conditions of increased atmospheric carbon dioxide.

Wheat yields are predicted to fall by 5-10% with every increase of 1°C and overall crop yields could decrease up to 30% in South Asia by the mid-21st century [38]. India could experience a 40% decline in agricultural productivity by the 2080s [39]. Rise in temperatures will affect wheat growing regions, placing hundreds of millions of people at the brink of chronic hunger.

4.3.1 Impact of Climate Change on Agricultural System of North Eastern Region:

North eastern states primarily based on agriculture, so agriculture is considered as the driving force in these states. Nestled in the Himalayas, the North Eastern Region of India comprises the 'Seven Sister States' of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, plus the 'Brother' state of Sikkim. Climate change affects directly and indirectly in the production of agricultural crops. This can take place through changes in average temperatures, rainfall, and climate extremes; changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations; changes in the nutritional quality of some foods. The region is a global biodiversity hotspot, as well as being home to many different ethnic groups with a rich cultural heritage and traditional knowledge of the environment. Climate change has dramatic impacts on natural resources, economic activities, food security, health and physical infrastructure. Wherever, livelihoods of people are particularly dependent on natural resources.

In these vulnerable areas, climate adaptation measures are of central importance for the protection of rural livelihoods and for ensuring sustainable development. The impact of climate change is more likely to have an adverse effect in the developing countries due to high dependency on climate sensitive livelihood like rain-fed agriculture, water, and forestry [40]. Climate Change will reduce access to drinking water, affects the health of the poor, will pose a threat to food security.

Additionally, poor people in developing countries tend to be more vulnerable due to limited opportunities and choices, small land holdings and lack of access to market. Tea yields in the North East are expected to decline by up to 40 % by 2050 (Tea Board of India). In NE 2006, 2008, 2014, 2015, 2016, 2020 is considered as the warmest year.

Besides, the growing human population and livestock pressure gradually widening the gap between demand and supply of natural resources. These impacts will cut across multiple dimensions of day to day life affecting not just the environment but the communities as well. Climate change thus could impose a variety of stress on sustainable livelihood of the poor inhabitants of Northeast India through stresses on ecosystem function. The major concerns are irregular rainfall patterns, longer dry spells, and implications on agriculture calendar, productivity, new pests; food security; health and disasters like flash floods. It is presumed that there would be a change in distribution, abundance of species, more particularly wild, endemic species, crop plants, pests and vectors. Due to change in habitat condition, displacement both human and other wilderness would take place. Apart from these, the food security, mitigation of hazards and addressing the epidemics like malaria, encephalitis etc is other issues of major concerns for the region. Under such circumstances, there is possibility of conflicts over reduced natural resources causing strained social relations taking toll on to the cultural and spiritual services provided by ecosystems. The gap in information and lack of scientific comprehensive data base on climate change and its implications has become a hindrance for taking up appropriate site specific adaptation and mitigation strategies and action plan. The overall interpretation of regional forest statistics suggest the drivers of loss of forest cover in terms of threats and pressures being enhanced by erratic changes in local climatic factors due to global change.

Timing and magnitude of climate changes still remain uncertain, it is clear that climate change would affect many ecosystems particularly the terrestrial forest ecosystems and human activities in the remote eco-region of North East India at the foot hills of Himalayas. One of the major factors affecting forest cover is the growth of human populations throughout the Northeast India and the forests are the best place to accommodate the growing pressure of additional people [41].

4.3.2 Impacts of Climate Change in the Agriculture System of Assam:

Climate change and environment directly influences the livelihoods of the people of Assam. The geographic proximity to the delta region and poor socio-economic conditions makes Assam to be extremely vulnerable to climate change. This vulnerability is reflected in the exposure, sensitivity and adaptive capacity of the local population to climate induced extreme events such as floods. Human activity like coal mining, deforestation, overgrazing etc causes climate change drastically. The state is characterized by high rainfall and a subtropical climate. It gets annual floods and frequent droughts, both of whose severity has risen due to adverse climatic conditions. As a result of flood and erosion, there has been a decline in the agricultural land, and beside these thousands of hectares of fertile agricultural land in different parts of Assam has become waste land as a result of deposition of sand brought by the flood over the fertile land. However, like most developing regions, climate change issues have received short shrift in the state, and efforts are more focused on recovery than creation of adaptive capacity. The poor are more vulnerable to extreme climate events and the drastic climate change projections are particularly worrisome for Assam as almost 32% of its population lives below the poverty line. Further, a majority of this population is dependent for its income on agriculture, which in turn is highly dependent on climatic factors such as precipitation and weather, and is frequently disrupted due to damage from floods and droughts. The state's low adaptive capacity further exacerbates the situation and makes the populace dependent on agriculture highly. Frequent droughts have affected the produce of the bountiful state and have often led to economic consequences. Drought causes lower the agricultural production. According to the State Action Plan for Climate Change, the annual mean temperature in the state has increased by 0.59 degrees Celsius over the last 60 years (1951 to 2010), and is likely to increase by 1.7-2.2 degree Celsius by 2050. Climate projections in the state action plan also predict that extreme rainfall events will increase by 38%. Drought conditions lower the production of agricultural commodities, which in turn push their prices up. One can easily imagine the result of low incomes and high prices in the face of events such as droughts and floods. In 2006, 15 district of Assam had below normal (nearly 40%) rainfall in the region. More than 75% of the 26 million people associated with livelihoods related to agricultures were affected. State suffered a loss of more than 100 cores due to crop failure and other peripheral affects [42].

4.4 Case Study Regarding Changes and Economic Loss of our State:

- a. Assam, in North-east India, produces one of the finest, and most expensive, types of silk in the world. Produced by the semi-domesticated silkworm *Antheraea assamensis*, which is only found in the Brahmaputra Valley, this silk is called Muga – Assamese for “yellow” or “amber” – and is often called golden silk.

This silk has been produced in the region from as far back as 321 BC, and is an inextricable part of the life and culture of Assam. Unfortunately silkworms are highly sensitive to climatic conditions since they are grown outdoors. Recently unpredictable rainfall patterns, a rise in temperature and persistent floods have endangered Muga cocoon production across the state. Due to the long history of sericulture, Muga silk occupies a special place in the lives of the indigenous people, inextricably linked to their cultural life. Moreover Muga silk is one of the most expensive silks in the world due its durability and beauty. The luster of the fabric increases with each wash, making it a product that is treasured – and which lasts – throughout the lifetime of its owner. In 2007, Assam received the Geographical Indication (GI) tag for Muga silk. A GI tag is given to products that are produced in a particular area, and boosts the reputation of the product [43].

- b. Another example of the adverse impact of climate change on the economically marginalized communities is that of Majuli, the largest riverine island in the Brahmaputra River. Majuli has a very high poverty rate at around 21.47% (according to Jorhat district administration). Climate change has resulted in continuous shifts in rainfall pattern as well as an increase in temperatures of the island. It has also lost visibly large tracts of land due to erosion over the last century. The already low income of island's population is further declining due to lower farm productivity caused by frequent floods, erosion, and siltation. The loss of livelihood due to climate induced events has resulted in forced migration to neighboring urban centers such as Jorhat.
- c. This deeply troubling economic implication of climate extremes resulting in the loss of livelihood options is reflected in other parts of the state. A 2012 study by the Centre for Environment, Social and Policy Research (CESPR), in collaboration with the Indian Network on Ethics and Climate Change, noted the widespread loss of livelihood options for thousands of people across Assam due to climate disasters, particularly floods and erosion. Climate change is even endangering the abundant tea plantations that are synonymous with Assam, as several modeling results have pointed towards decreasing tea yields in the region. Tea production in July 2014 in Assam down by 3.22 % compared to the same period in 2013 [44]. 35 years from now, the suitability of these regions would reduce drastically across all the tea growing regions and shifting of tea would be observed in comparatively higher altitude areas of Karbi Anglong, Dima Hasao and Tinsukia district. In 2011 early onset of winter resulted in loss 15 million KG of tea. In that time upper Assam estates in the South Bank of the Brahmaputra experienced severe drought condition, net estimated loss of tea production is 60% of normal (about 26 million on KGs). In the year 2014 abnormally below normal per monsoon rainfall during Feb-April (less 30% of normal) badly affected tea production in Upper Assam.
- d. Apart from the economic loss, the effect of climate distortion on the population's health and wellbeing is also overlooked, further weakening the region's human resource base. While previously unheard of, heat strokes are becoming commonplace in Assam as summer temperatures are touching 40 degrees Celsius. There is a dearth of data on climate change induced rise in diseases in the region, but it shouldn't be surprising if such a study does indeed establish a correlation between spread of diseases, particularly communicable diseases.
- e. Climate change has the potential to modify host physiology and resistance and to alter stages and rates of development of the pathogen. The most likely impacts would be shifts in the geographical distribution of host and pathogen, changes in the physiology

of host-pathogen interactions and changes in crop loss. Another important impact may be through changes in the efficacy of control strategies. Increases in temperature can modify host physiology and resistance. Agricultural crops and plants in natural communities may harbor pathogens as symptomless carriers, and disease may develop if plants are stressed in a warmer climate. Host stress is an especially important factor in decline of various forest species.

4.5 Conclusion:

It is evident that impact of climate change is will be felt cross the world in different sectors ranging from water resources to industries to social arenas. It is not like that those people who contributed most to climate change will be affected more but everyone will be affected irrespective of their contribution to global warming and climate change. As a consequence of climate change the occurrence of floods and droughts, heat and cold waves are of common occurrence across the world. Their adverse impact on livelihood of farmers is tremendous especially in the people of developing countries like India where economy is still more dependent on Agricultural sectors. Interestingly, weather extremes of opposite in nature like cold and heat waves and floods and droughts are noticed within the same year over the same region or in different regions of our country and likely to increase which will lead to more crop losses due to climate change. The whole climate change is associated with increasing greenhouse gases and human induced aerosols and the imbalance between them may lead to uncertainty even in year-to-year monsoon behaviour over India. 2020 was eighth warmest year on record since 1901 with annual mean land surface air temperature + 0.29°C. The last decade (2011-2020) was also the warmest decade on record.

Average annual mean temperature during 1901-2020 showed an increasing trend of 0.62°C in 100 years. Recently in 24th May 2021 Guwahati witness highest temperature in last 10 years which is 37.9°C almost 6 degree higher above the normal temperature. Nationwide, reductions to agricultural productivity or sudden losses of crops or livestock will likely have ripple effects, including increased food prices and greater food insecurity.

Therefore, there should be a determined effort from developed and developing countries to make industrialization environment friendly by reducing greenhouse gases pumping into the atmosphere. In the same fashion, awareness programmes on climate change and its effects on various sectors viz., agriculture, health, infrastructure, water, forestry, fisheries, land and ocean biodiversity and sea level and the role played by human interventions in climate change need to be taken up on priority basis. There is an urgent need for coordinated efforts to strengthen the research to assess the impact of climate change on agriculture, forests, animal husbandry, aquatic life and other living beings.

Two major international agreements namely the Paris Agreement and the 2030 Agenda for Sustainable Development were adopted with the objective of manually reinforcing and codependent the risk of climate change to economic development and successful low carbon transition depends on social economic and environmental development. So various climate change mitigation policies has been developed by different policy makers specially to motivate the developing countries for climate action where basic development objectives often outweigh the importance of climate objective [45].

Every nation should reduce their per capita carbon pollution by implementing different policies like a type of carbon tax, negotiated industrial agreements and domestic emission trading scheme etc. More accurate climate policy evaluations can give inform on the analysis of national and global carbon budget, which form the basis of actionable goals for climate stabilization.

From the agriculture point of view, effects of extreme weather events on crops are to be documented on regional scale so that it will be handy to planners in such re-occurrence events for mitigating the ill effects. Also, there is need to guide farmers on projected impact climate change and sensitize them on probable mitigation and adaptation options to minimize the risk in Agricultural sector. We have to introduce stress resistant variety which can survive in extreme environmental conditions. We should improve our irrigation system so that in the winter also people will not suffer water crisis in their production of agricultural crops also introducing water harvesting systems in the rural areas. Our state's economy will increased if we focus on agricultural productions. Development of agriculture in the form of science-based farming practices, that can buffer farmers from climate damage and help make their operations more resilient and sustainable for the long term.

But farmers face many obstacles to changing practices, so it's critical that policymakers shift federal agriculture investments to support and accelerate this transition. We should try to control the climate change because global warming causes extreme hot weather in these climatic conditions farmers are not able to work and their productivity directly or indirectly affected so we should plant more trees and make our mother earth green.

Extension system has to focus more on diversifying the livelihood options, changing suitable cropping patterns to adjust to the change which is occurring in the particular location, planting more drought tolerant crops, promoting increased share of non-agricultural activities and Agro-forestry practices, identifying the traditional coping strategies, improved on - farm soil & water conservation, promoting mixed cropping pattern and making provision for access to various information sources related to weather and other advisories of climate change would minimize the risks and certainty of farmers related to climate change.

Institutional interventions, either by strengthening the existing ones or initiating new ones, relating to seed bank, fodder bank, custom hiring center, collective marketing, and introduction of weather index based insurance and climate literacy through a village level weather station. Farmers should visit the district agricultural office as well as KVK (Krishi Vigyan Kendra) to discuss their issues.

Mitigation comprises measures to reduce the emissions of greenhouse gases that cause climate change in the first place, e.g. by switching to renewable sources of energy such as solar energy or wind energy or nuclear energy instead of burning fossil fuel in thermal power stations. Scientific diagnosis and assessment of the impact of climate change on the agricultural sector is essential for formulating the vision of future agriculture and the direction of agricultural administration. Specifically, it can provide useful information for formulating the long-term agricultural development plan for each region and the adaptive measures for farming households.

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