

Impact of Climate Change on Agriculture and Its Allied Sectors: An Overview

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ABSTRACT

Global climate change is one of the rising international issues of modern civilization. It has impacted the way of living of each and every organism. The agricultural sector is one such highly impaired sector that has been affected by climate change. With the rise of atmospheric temperature, soil conditions get worsened; the normal physiology of plants has also changed, ultimately resulting in lesser yield as compared to yield potential yield. The agricultural sector has a significant impact on the Economy of the country. The reduction in yield due to climate change has resulted in a decrease in monetary return. The impaired quality of the product in terms of nutrients, minerals, antioxidants, and other biochemical content has induced various diseases and deficiencies in plants and animals. The plant becomes highly susceptible to pests and pathogens. Other allied sectors like animal husbandry, fishery, poultry etc., also get affected due to the changes in weather parameters. Climate change has a clear and profound impact on the food web, health and Economy of every living being on the Earth. Researches and experiments should be conducted to find out future trends and mitigation techniques to cope with global climate change.

Keywords: Nutrients, Minerals, Antioxidants Climate change

INTRODUCTION

Climate change depicts the deviation of the climatic phenomenon from normal trends to various extreme forms over a long period of time and becoming major serious concerning issues for the entire world. Many times the term "global warming" and "climate change" are conceptualized as the synonymous term. Still, actual global warming is the increase in

temperature of the surface of the Earth. In contrast, climate change includes changes in temperature, rainfall, cyclonic behaviour, glacier retreat, oceanic circulations, rise in sea temperature and many more. It has been predicted that by the year 2100 the average surface temperature will be increased by 1.4⁰C-5.8⁰C (IPCC, 2001).

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In India, nearly 54.6% of the total population are directly or indirectly engaged in agriculture and allied activities for their livelihood. According to the Census 2011, the net sown area is 139.42 million ha, out of which only 68.65 million ha area is net irrigated and rest 70.77 million ha cultivated area is dependent on rainfall (Land use Statistics 2016-17). As a consequence, erratic rainfall with the rise in temperature sometimes creates a hindrance to agriculture in several ways. India is one of the worst affected countries due to climate change and global warming, mainly through its impact on agriculture and human health.

Effect of climatic factors on different plant processes:

- The temperature has a major influence on photosynthesis, respiration, germination, flowering and production of phytochemicals.
- Humidity also has an enormous effect on photosynthesis, uptake of nutrients from the soil, transpiration, pollination and incidence of diseases.
- Precipitation had also influenced the photosynthesis, spread of diseases, development, transpiration, pollination, competitive suppression, life period.
- Wind affects the photosynthetic rate, transpiration, lodging, chilling injuries and pollination.

Climatic changes and agriculture

From the era of industrialization, the rate of emission of greenhouse gases like CO₂, CH₄ and N₂O are gradually and continuously increasing resulting in warming of surface of globe which is also termed as “Global Warming” (Myhre et al., 2013). Intergovernmental Panel on Climate Change (IPCC) has reported an increase of 0.8-1.2⁰ C surface temperature due to global warming to date. Among various anthropogenic activities, the activities related to agriculture alone contribute 50% of total methane and 75% of total N₂O emission to the globe (FAO, 2021). The various agricultural activities mainly land preparation, application of fertilizers etc.

contributes about 14% of total CO₂ emission and the energy use inland preparation with machineries like tractor, power tillers mainly responsible for emission of CO₂ to the atmosphere (Le Quere et al., 2018). Thus, global warming could be mitigated to 1.5⁰ C by reducing CH₄ and N₂O from agricultural sector (Leahy et al., 2020).

Impact of climate change on Agriculture

Impact on soil condition

Soil conditions mainly refers to the physical, chemical and biological conditions of soil and the optimum condition of these factors plays an important role in the production of crops. Global climate change has mainly affected the physical properties by altering the water content of the soil. Among the various climatic factors, precipitation plays an important role in both soil formation and soil erosion processes. For the formation of soil, weathering of rocks and minerals is carried out in the presence of water which is supplied by precipitation. But excess and erratic distribution of precipitation has been the prominent factor for flood in many areas resulting in the removal of top fertile soil. Water erosion and wind erosion is becoming prominent hazard for agricultural land due to climatic changes.

Climate has mainly affected clay component, organic matter, and nutrient availability, which ultimately impacted one of the important soil chemical properties, i.e., Soil reaction (P^H) (Reth et al., 2005). The change in climatic factor affects the swelling and shrinkage property of the clay component of the soil. Erratic rainfall increases the frequency of wetting and drying of soil, while, high temperature added more adverse impact on soil affecting porosity and permeability. The silty soil is more prone to the severity of climate change than the clayey soil (Bormann, 2012). Surface runoff, erosion, compaction and mechanical disturbances in soil are various conditions that arise due to abrupt rise of atmospheric temperature and unpredicted precipitation rate and distribution. The alteration in soil structure mainly happened due to changes in density and distribution of soil flora and fauna as influenced by climate

change (Varallyay, 2010). Another effect of alteration in precipitation was leaching loss of basic cations that has also resulted in a decrease in CEC of soil (Davidson and Janssens, 2006).

Temperature is directly proportional to the rate of decomposition; hence more decomposition indicates presence of less organic matter content in soil (Davidson and Janssens, 2006). Organic matter content of soil greatly influence the bulk density and porosity of soil. The lesser the organic matter content of soil more is the bulk density that resulted more compaction. The changes in precipitation resulted in erosion of soil which ultimately increased bulk density (Birkas et al. 2009, Singh et al. 2011). Higher temperature has reduced the organic matter content thereby decreasing the cation exchange capacity (CEC). An increase in temperature led to an increase in evapotranspiration rate and ultimately increase the accumulation salt in the root zone of plant, again reduction in precipitation led to a decrease of leaching of salts causing salinization of areas including crop fields (Schofield and Kirkby, 2003; De Paz et al., 2012). In this context, Okur and Orceh, (2020) also stated that the rate of salinization will be increased in the coming decades due to climate change.

Climate change has also influenced the available water regimes for plants. Due to unpredictable rainfall and the occurrence of drought, it affects the water content of soil. It was reported that there will be about 4-15% decrease in available soil water content by mid 21st century (Holsten et al, 2009). Soil water content also influences the nutrient availability in soil and due to extreme weather conditions like drought; it decreased the nutrient content in soil (Gupta, 1993). Excessive rainfall is one of the major causes of removal of nutrients from the soil (Zougmore et al. 2009). While, increase in temperature directly increase the rate of transpiration resulting more nutrient uptake (Bassirirad 2000).

Impact on production potential

Every crop needs a specific range of temperature, definite pattern and quantity of

rainfall and other weather parameters for attaining the potential yield. Researchers reported a significant reduction in crop yield due to increase in atmospheric temperature because of climate change. The impact of climate change is more prominent to horticultural crops than the arable crops in terms of yield reduction (Zarin, 2007).

In rice, with increase in 1⁰C of temperature the grain yield will be decreased by an average of 6.6±3.8% (Chuang Zhao et al, 2017) and with 2⁰C temperature, there will be reduction of about 7.5q/ha rice yield (Sinha and Swaminathan, 1991). Various studies have also indicated that yield may decline up to 6% per degree rise in mean temperature (Saseendran et al., 2000). Due to the rise of 1⁰C temperature, the yield loss may occur up to 6.0± 2.9% in wheat, 3.1% in soybean, and 7.4± 4.5% in maize (Chuang Zhao et al, 2017). The reduction in grain yields due to rise in temperature was also reported by Sinha and Swaminathan, (1991).

Increase in CO₂ concentration has been a boon to plants especially for C₃ plants, but the adverse effect of temperature turned this advantage of increase in photosynthesis to yield reduction. The negative impact of rise in temperature becomes more prominent over increase of CO₂ effect on plant. Researchers have estimated about 5-30% yield loss for the period 2080 to 2100 (Fischer et al., 2002). Similarly early onset of rainfall has negative impact on establishment of proper crop stand and excess of rainfall results in flood condition, finally reducing the marketable yield.

Impact on plant physiology

Recent studies have effectively evaluated the various effects of climate change on plant morphology and physiology. The effects of climate change like reduction in photosynthesis, increase in transpiration rate are well established. Anthropogenic activities are the main cause for the accumulation of carbon dioxide in the atmosphere, that leads to an increase in Earth's surface temperature. Increase in concentration of carbon dioxide has resulted in decrease in size of stomatal

aperture which in turn reduces the rate of transpiration of the crop. The extent of reduction in transpiration may be up to 30% (Kumar and Malik, 2018).

The increase in CO₂ concentration positively influences agricultural crop production, but it also leads to global warming which eventually increase the temperature and reduce crop yield. With the increase in carbon dioxide concentration by 0.0075%, there will be an increase of 5q/ha rice yield, whereas with per degree increase in atmospheric temperature grain yield reduction will be about 6q/ha. The main cause behind this yield reduction is the spikelet sterility which is mainly happened above 35⁰C (Matsui et al., 1997). The major concerns related to climate changes are the disturbance of normal physiological processes, including respiration, uptake of nutrients from the root zone and life cycle or life period of the plants. These normal functions are weather dependent and greatly affected by the variation of weather parameters. It has been reported that with the rise of CO₂ concentration, the cooling mechanism of plant get hampered, which inhibits the normal respiration process which greatly affect the tillering process of various crops, including rice.

Impact on quality of produce

There are many instances where an increase in temperature leads to deterioration of quality of produce. Many scientists had given many explanations, but the main established reason is increase in respiration and water stress which resulted in reduction of marketable potential of the crop. It has been reported that in certain crops like strawberry and pea, increase in temperature is one of the main reasons of reduction of taste of the produce as sugar accumulation is badly affected by rise of temperature which is main contributor of taste in various crops (Wien, 1997). Protein content is also reduced to a significant level mainly in crops like pea (Myers et al., 2014). They also reported a reduction of zinc up to 9.3% and iron up to 5.1% in wheat. The main change in the quality of produce is the decrease in mineral contents of the grains. It has been

reported that in wheat, rice and barley, the reduction of mineral elements is up to 7.6%, 7.2% and 6.9%, respectively.

Impact on pest outbreak

One of the worst situations that have been faced during the last few years was a locust attack. The locust attack has become the havoc to the farmers of the northern India in last few years. The rise in temperature due to climate change has shortened the hatching period of grasshopper egg. Along with shortening of the hatching period, the interaction of increase of temperature and abnormality in intensity and distribution pattern of precipitation the active period of locust has increased. The congenial environment of northern India attracted the locust shift towards this direction, and a longer feeding period resulted in competition among the species of the locust populations resulting heavy feeding of the crop and economic and financial loss of the farming community (Sharma and Singla, 2022). With the increase in global warming and decrease in frequency of precipitation the nematode population and density greatly increased resulting in crop failure (Xiaohui et al. 2021).

Entomophily has a great impact in case of gaining maximum yield from the crops and insects are important pollinators for many species. Honeybees play an important role in pollination not only in mustard but are also responsible for pollinating about one third of total crops in the world. Similarly, in the case of mango, house flies are important pollinating agent. The changes in climatic patterns have resulted negative impact on synchronization of pollination and pollinator (Sharma and Singla, 2022). It was reported that, *Helicoverpa armigera* will become the major trouble for the farmers as the climatic changes has resulted the development of resistance of its against present chemical pesticides and also decreases the population of natural enemies. In addition to these, rapid reproduction and longer active period has added advantages over it (Sharma et al., 2005).

Diseases

Climate change is one of the major reasons for increasing pest population in the ecosystem.

The interaction of plant-pathogen relationship is negatively influenced by changing climatic pattern. Hence, outbreak of numerous diseases has been used as indicators of climate change phenomenon (Garett et al., 2006). The effect of an increase in temperature can be observed in both host and pathogen. In the case of host, the plant lost its inherent resistant capacity against infectious agent. Whereas, in case of pathogen the rise in temperature provides favorable condition for pathogen to induce infection. It has been reported that the changes in climatic phenomenon have altered the morphology, physiology, tolerance and resistibility of host plant (Chakraborty and Dutta, 2003). In case of rust disease of wheat and oats, the increase in temperature induces the susceptibility of crops against the pathogen (Coakley et al., 1999).

The changes in climatic conditions have increased not only the intensity of diseases but also altered the distribution of pathogens. It has been observed that the pathogens are able to invade newer regions which have been studied in the case of bacteria (Kudela, 2009). Higher CO₂ concentration favors the growth and development of crop canopies causing denser plant population in the field which results in higher infection potential of pathogen. The higher C: N ratio decreases the decomposition process hence the pathogen gets enough space and time for overwintering and causing disease in the successive crop.

Impact on fishery or aquaculture

Fishery is one of the important sectors in term of economic and food security of a country. It is one of the largest cash revenues generating areas of a nation, livelihood source of majority of people residing in coastal area. Climate change has greatly affected the crop as well as fishery component. The rise in surface temperature of water bodies has greatly affected the life cycle of marine organisms. Fluctuations in marine temperature has impacted the physical, physiological and biochemical processes of aquatic organisms including decline in population of fishes (Abowei, 2010). Various effects of

climate change that has been observed are degradation of natural habitat, littering of ocean or other aquatic bodies, dominance of exotic breed causing imbalance in marine ecosystem (Brander, 2010).

Rise in seawater level has been predicted to 9-90 cm by next century (Church et al., 2001). This increase in seawater level has affected the reproduction and fecundity of various fish species, as the rise of water level has submerged the wetland and other natural habitat disturbing normal trend of reproduction as some of the fishes which are dependent on such ecosystem for regeneration (Hlohowskyj et al., 1996). Acidification of water bodies occurred due to increase in concentration of CO₂, which get dissolved in water bodies forming carbonic acid and decrease in pH creates imbalance of the aquatic habitat (Dupont and Wickett, 2003).

Change in salinity of ocean or sea water is also occurred due to the effect of climate change on water bodies. Imbalance of salt concentration in water bodies created intolerance in aquatic plants and organisms. Various effects were studied in phytoplankton and fishes' population due to the imbalance in salt concentration which finally distort the food chain involving aquatic flora and fauna (Schallenberg et al., 2003). Climate change has also influenced the distribution of marine species within the globe impacting the migratory behavior of fishes and there would be a reduction of around 30% marine fish in tropical area due to movement towards higher latitudes region (Cheung et al. (2009)

Impact on livestock

Climate change and animal husbandry are interrelated aspects, as rearing of livestock are very much vulnerable to effects of climate change and also rearing of livestock is one of major cause of emission of green house gases. Animal husbandry alone contributes around 14.5% of total greenhouse gases emission (Gerber et al., 2013). According to food and agricultural organization report about 43 crore people are engaged directly or indirectly in the rearing of livestock. These impacts of climate change have multidimensional effects not only

on animals but also in forages and fodder. Erratic rainfall increases the chances of infection of bacteria and viruses that resulted in yield reduction of fodder. Variation in temperature also creates stress condition in physical and physiological processes of live stocks, including growth and development of animals, milk production potential, diseases and availability of fodder, feed and water etc.

The main negative impact of climate change can be seen as frequent occurrence of various diseases in livestock population. Some of the vectors require high temperature for rapid multiplication and infection in animals. Mosquitoes, flies, ticks also create uneasy condition in livestock and about 18-20% weight reduction occurs in animals due to *Rhithicephalus microplus* (tick) infestation (Wittmann et al., 2001). Acclimation is the term used to refer to the stress condition in livestock due to increase in body temperature. Such conditions resulted in loss of appetite-reducing the intake of fluids and other feeds that hampered the reproductive and other growth processes of animals (Nardone et al., 2010). Temperature above 30° C is highly injurious for poultry population (Esminger et al., 1990).

Climate change has induced the disfunction of various internal organs, including the liver, heart salivary gland etc., and also affect some pathways like glucose, protein and lipid metabolism (Bernabucci et al., 2006). With the rise of temperature between 1-5° C results in an increase in mortality and morbidity rate in livestock population. In case of other livestock also the main impacts can be seen in the fertilization and disease component. Various vector-borne diseases are more prone due to climate change. The minor pest has been established as a major pest resulting in higher mortality and morbidity in animals.

Impact on the Economy and society of a region

Various impacts have been observed in the productivity of the crops. An abrupt decline in yield has been observed in major cereals like rice, wheat and maize etc. Since earlier days,

reduction in production and productivity has created hunger and the famine-like situation in many countries. Climate change being the main driver of yield reduction, indirectly contributes to the poverty of a region and ultimately affects the social well-being of human. The income of farm family, sustainability and livelihood security is basically depended on farm productivity (Battisti and Naylor, 2009). It has been estimated that proper intervention of economic welfare schemes of government can increase the yield up to 40-100% (Ewert et al., 2005).

The adverse economical impact on climate change has been observed in rural community (Carleton and Hsiang, 2016). Other allied sectors of agriculture, including livestock, fishery etc., are also negatively affected as the return from these sectors are declining due to the impact of climate change. The changes in global temperature, precipitation and other weather parameters have forced the small and marginal farmers to adopt newer practices/technologies right from selection of crop and adoption of proper management practices to cope with the adverse situation. The uncertainties associated with net return from the agriculture sector even compelled the farmers to shift towards other non allied sectors rather than agriculture (Aragon et al., 2021).

Climate change has induced crop failure, resulting in huge economic loss of the farm family, which in turn led to economic loss of the nation. Around 70% of the population of our country is directly or indirectly dependent on agriculture for their livelihood. The risk of unemployment of such huge population in the country is one of the concerned subjects for the government because of the vulnerability of the agricultural sector to climate change. According to Deloitte Economic Institute report, it has been predicted that, in India, there will be about 12.7% loss of GDP by 2070 and about 5.5% reduction of economic potential per year in the coming 50 years. The cost of climate change in India has predicted the loss of 3-10% of

GDP by the year 2100. It has been estimated that proper intervention of economic welfare schemes of government can raise the yield up to 40-100% (Ewert et al., 2005).

Impact on plant-water stress

Water plays an indispensable role in plant growth and development. It is important for maintaining the turgidity and turbidity of plant cells, has a major role in nutrient uptake right from the germination stage to maturity, moisture content is one of the essential criteria to predict the yield of the crop. Irrigating the crops at a critical stage is one of the utmost requirements for getting higher yield. The water stress condition generally termed as drought occurs mainly due to the deviation of intensity, frequency and distribution pattern of rainfall. The areas under the crops like rice, maize, wheat, barley, soybean and sorghum are becoming more prone to drought condition than earlier. It has been predicted that the area under drought will be increased by about 30% by next decade (Burke et al., 2006). Water stress conditions induced mesophyll resistance which affected the fixation of CO₂ in the leaves (Loreto et al., 1992).

Future thrust area

- 1) Research needed to find out the impact of climate change on environment and soil food web to develop certain strategies giving emphasis on agro ecosystem's management.
- 2) More emphasize should be given on site specific management practices rather than common practices
- 3) The ecosystem as a whole should be taken into consideration while adopting management practices

CONCLUSION

Agricultural sector has always been considered as the foremost sector regarding economic progress of a country. This sector has wider dependency on climatic factors such as rainfall, radiation, humidity, evaporation and wind movement. The global climate change has resulted in altered behavior of various physico chemical properties of the plant. It has enormous impact on soil physical, chemical

and biological properties, physiological and morphological characteristics which ultimately affected quality and quantity of produce. The severe form of climatic changes such as drought, flood, hunger, pest outbreak, disease incidence etc., can affect the plant throughout its life cycle. Climate change has emerged as the important researchable issue at present days due to its severe impact on production and productivity potential. Not only agriculture, livestock population, fishery and poultry sector has also been severely impaired as adverse situation prevailed. Recent trends in fluctuations of climatic pattern have forced the farmers to transform their conventional methods of farming and adopt newer practices. The innovative and modified farming practices might produce enough amount of food to meet the demand of continuously increasing population. Research and proper evaluation of such issues is of utmost importance to cope up with such adverse climatic conditions. Hence, there is a prior need to carry out detailed investigation regarding impact of climate change on agriculture and its allied sector to generate a significant amount of revenue out of it for development of the country.

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