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Impact of Climate Change on Indian Agriculture

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INTRODUCTION

Climate is the long-term average of weather, typically averaged over a period of 30 years. More rigorously, it denotes the mean and variability of meteorological variables over a time spanning from months to millions of years.

There is now clear evidence for an observed increase in global average temperatures and change in rainfall rates during the 20th century (Easterling, 1999; IPCC, 2001; Jung *et al.*, 2002) around the world. The most imminent climatic changes in recent times are the increase in the atmospheric temperatures due to increased levels of greenhouse gases such as carbon dioxide, methane, ozone, nitrous oxide and chlorofluro carbon .because of the increasing concentration of those greenhouse gases, there is much concern about future change in our climate and direct or indirect effect on agriculture (Garg *et al.*, 2001; IPCC, 2001). In India, studies by several authors shown that during last century there is observed increasing trend in surface temperature (Hingane *et al.*, 1985; Srivastava *et al.*, 1992), no significant trend in rainfall on all India basis (Mooley and Parthasarathy, 1984; Thapliyal and kulshrestha,1991) and decreasing/ increasing trends in rainfall in regionalbasis (Chowdhury and Abhyankar, 1979; Rupa Kumar*et al.*, 1992).

The carbon dioxide (CO_2) concentration was in the steady state at 280 ppm till the preindustrial period (1850). It is rising since then at the rate of 1.5 to 1.8 ppm per year. The concentration of CO_2 is likely to be doubled by the end the 21st century (Keeling *et al.*, 1995). Open top chambers and FACE technology are currently being used for the study of the response of crop plants to the elevated CO_2. Results from such studies have shown an increase in plant photosynthetic rate and crop yield (Kimball, 1983).

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The rising temperatures and carbon dioxide and uncertainties in rainfall associated with global warming may or may not have serious direct and indirect consequences on crop production. It is, therefore, important to have an assessment of the direct and indirect consequences of global warming on different crops especially on cereals contributing to the food security. In most climatic change applications, long term historical weather data are used as input for the crop models. The simplest approach is to assume a fixed climate change and to modify the data with a constant number, such as an increase or decrease of 1, 2, 3°C etc. for temperature. Similarly, rainfall and solar radiation can be changed with a certain percentage, such as an increase or decrease of 10, 20, 30% etc. These changes are then applied to the daily water data and the crop simulation models are run with these modified inputs.

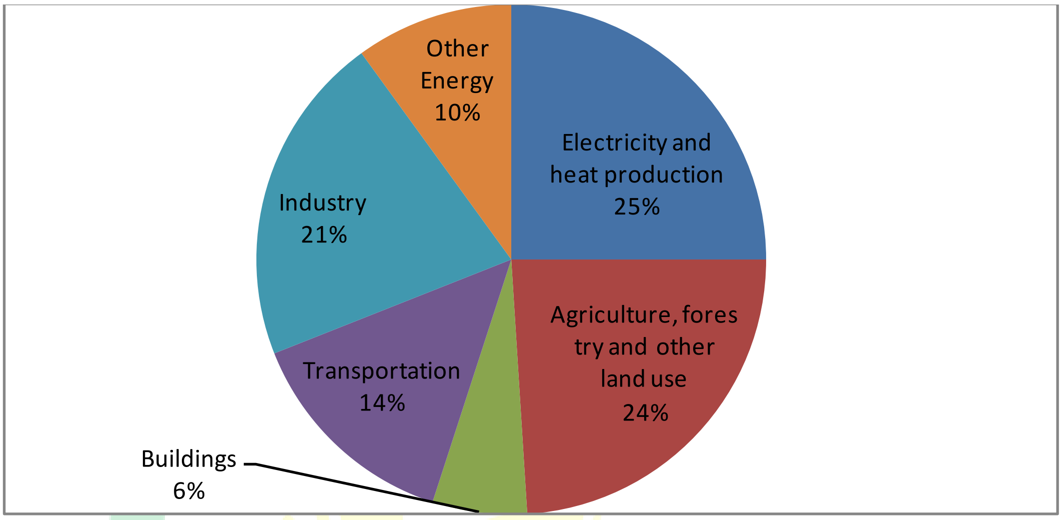
In India substantial work has been done in last decade aimed at understanding the nature and magnitude of change in yield of different crops due to possible climatic change. The objective of this presentation is to discuss the present scenario of Indian condition and status of impact of climate change on Indian agriculture.

GLOBAL WARMING

Global warming is the long-term heating of earth's climate system observed since the pre-Industrial period due to human activities, primarily due to fuel burning, which increases heat trapping greenhouse emission levels in earth's atmosphere.

Since the pre-industrial period, human activities are estimated to possess increased Earth's global average temperature by about 1 degree centigrade. Most of the present warming trend is extremely likely the result of act since 1950's and is proceeding at an unprecedented rate over decades to millennia. Global warming occurs when CO_2 and other air pollutants and greenhouse gases collect within the atmosphere and absorb sunlight and radiation that have bounced off the earth's surface. Normally this radiation would escape into space but these pollutants, which may last for years to centuries within the atmosphere, trap the warmth and cause the earth to urge hotter. Melting glaciers, early snowmelt and severe droughts will cause more dramatic water shortages and increase the danger of wildfires. Rising sea levels will cause coastal flooding on the eastern seaboard. Forests, farms, and cities will face troublesome new pests, heat waves, heavy downpours, and increased flooding. All those factors will damage or destroy agriculture and fisheries. Disruption of habitats like coral reefs and alpine meadows could drive many plants and animal species to extinction.

Fig (I). Global gas emission by different sectors. (IPCC 2014)



CLIMATE CHANGE IN INDIAN CONTEXT

The first Assessment of climate change over the Indian region has been published by the Ministry of Earth Sciences (MoES). It is India's first ever national forecast on the impact of global warming on the subcontinent in the coming century. The highlights of findings are discussed as below.

1. **Temperature:**
    1. In a worst-case scenario, average surface air temperature over India could rise by up to 4.4°C by the end of the century as compared to the period between 1976 and 2005.
    2. The worst-case scenario is defined by the Representative Concentration Pathway (RCP) 8.5 that calculates a radiative forcing of 8.5 watt per square meter due to the rising greenhouse gas (GHG) emission in the atmosphere.

3. Radiative forcing or climate forcing is the difference between sunlight energy absorbed by the Earth (including its atmosphere) and the energy that it radiates back into space.
4. Under an intermediate scenario of RCP 4.5, the country's average temperature could rise by up to 2.4°C.
5. The rise in temperature will be even more pronounced in the Hindu Kush-Himalayan region where the average could reach 5.2°C.
6. By 2100, the frequency of warm days and warm nights might also increase by 55% and 70% respectively, as compared to the period 1976-2005 under the RCP 8.5 scenario.
7. The incidence of heat waves over the country could also increase by three to four times. Their duration of occurrence might also increase which was already witnessed by the country in 2019
8. Between 1900 and 2018, the average temperature of India rose by 0.7°C.
9. This rise in temperature has been largely attributed to global warming due to GHG emissions and land use and land cover changes.
10. However, it has also been slightly reduced by the rising aerosol emissions in the atmosphere that have an overall cooling characteristic.

2. Rainfall:

1. Another significant highlight of the assessment is the projected variability in the rainfall, especially during the monsoon season which brings 70% of the rainfall received by India and is one of the primary drivers of its rural agrarian economy.
2. Monsoon rainfall could change by an average of 14% by 2100 that could go as high as 22.5%. It is not mentioned if this change will be an increase or decrease but still represents variability.
3. Overall rainfall during the monsoon season has decreased by 6% between 1950 and 2015.
4. In the past few decades, there has been an increased frequency of dry spells during the monsoon season that has increased by 27% between 1981 to 2011, as compared to 1951-1980.

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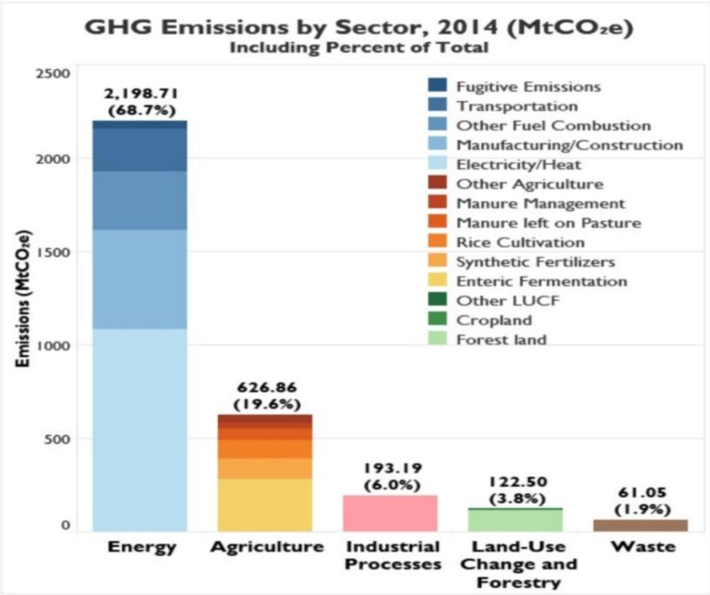
5. The intensity of wet spells has also increased over the country, with central India receiving 75% more extreme rainfall events between 1950 and 2015.



Sources: WRI CAIT 4.0, 2017, FAOSTAT, 2018

Fig (II). Contribution of different sectors in India to climate change.

IMPACT OF CLIMATE CHANGE ON INDIAN AGRICULTUR (FOOD PRODUCTION)

Estimating the effects of changing climate on crop production in the India is difficult due to the variety of cropping systems and levels of technology used. However, the use of crop growth models is one way in which these effects can be studied, and probably representing the best method we have at present for doing so. Although a large number of simplifying assumptions must necessarily be made, these models allow the complex interaction between the main environmental variables influencing crop yields to be understood.

There have been a few studies in India which aimed at understanding the nature and magnitude of yield gains or losses of crops at selected sites under elevated atmospheric CO2 and associated climatic change. Saini and Nanda (1986) showed that there was a decline of 600-650 grains/m^2 in wheat crop with every 1°C increase in mean temperature above 17-17.7°C during the terminal spikelet initiation to anthesis. Integrated impact of a rise in

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temperature and CO_2 concentration on yield of crops may be negative (Sinha and Swaminathan, 1991). They estimated that a 2^{o} C increase in mean air temperature could decrease rice yield by about 0.75 ton/hectare in the high yield areas and by about 0.06 ton/hectare in the low yield coastal regions. Further, a 0.5^{o}C increase in winter temperature would reduce wheat crop duration by seven days and reduce yield by 0.45 ton/hectare. An increase in winter temperature of 0.5^{o}C would thereby translate into a 10% reduction in wheat production in the high yield states of Northern India. Achanta (1993) simulated irrigated yields for Pant Nagar district under doubled CO_2 be positive in the absence of nutrient and water limitations.

Aggarwal and Sinha (1993) reported that at 425 ppm CO_2 concentration and no rise in temperature, wheat grain yield at all levels of production (*i.e.,*irrigated and rainfed) increased significantly. In northern India, a 1^{o}C rise in mean temperature had no significant effect on potential yields but irrigated and rainfed yields increased in most places. An increase of 2^{o}C in temperature reduced potential wheat yields at most places. The effect on irrigated and rainfed productivity varied with location. The natural climatic variability also had considerable effect on the magnitude of response to climatic change. Evapotranspiration was reduced in irrigated as well as rain fed environments.

Gangadhar Rao *et al.* (1995) studied the impact of climate change on the crop productivity of sorghum (*Sorghum bicolor* (L.) Moench) in three diverse sorghum growing areas in India *i.e.,* Hyderabad, Akola and Solapur. Crop growth was simulated using the CERES-sorghum (Ritchie and Alagarswamy, 1989) simulation model with climate change scenarios generated by the three GCMs namely; Goddard Institute of Space Studies (GISS), Geophysical Fluid Dynamics Laboratory (GFDL), and United Kingdom Meteorology Office (UKMO). The simulated results indicated a decrease in yield and biomass of rainy season sorghum grown at Solapur on stored soil water showed a marginal increase in yield. The positive effects of increased CO_2, if any, were masked by the adverse effects of predicted increase in temperature resulting in shortened crop growing seasons. The study also has shown that the effects of climate change on the same crop would depend upon the season it is grown.

Lal *et al.*(1998) examined the vulnerability of wheat and rice crops in northwest India to climate change through sensitivity experiments with CERES-wheat and CERES-rice models

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and found that under elevated CO_2 levels, yields of rice and wheat increased significantly (15% and 28% for doubling of CO_2). However, a 3°C (2°C) rise in temperature cancelled out the positive effect of elevated CO_2 on wheat (rice). The combined effect of enhanced CO_2 and imposed thermal stress on the wheat (rice) crop is 21% (4%) increase in yield for the irrigation schedule presently practiced in the region. While the adverse impacts of likely water shortage on wheat crops would be minimized to a certain extent under elevated CO_2 levels, they would largely be maintained for the rice crops resulting in about 20 % net decline in the rice yields.

Chatterjee (1998) used CERES-sorghum model and observed increase in temperature consistently decreased the sorghum yields from the present-day conditions. Increase in temperature by 1 and 2°C sorghum decreased the grain yields by 7 to 12% on an average. A further increase in temperature drastically reduced the potential yields by 18 to 24%, on an average. The magnitude of decreased in yield with increase in temperature was, in general, proportional to the increase in temperature in most years, indicating that there was no large interaction effect between yearly climatic variation and increase in temperature. Increase in 50-ppm CO_2 increase yields by only 0.5%. This was nullified when the temperature increased by 0.08°C. Similarly, the small beneficial effect of still higher CO_2 concentration was nullified by further increase in temperature. The beneficial effect of 700-ppm CO_2 was nullified by an increase of only 0.9°C in temperature. Further increase in temperature always resulted in lower yields than control irrespective of the increase in CO_2.

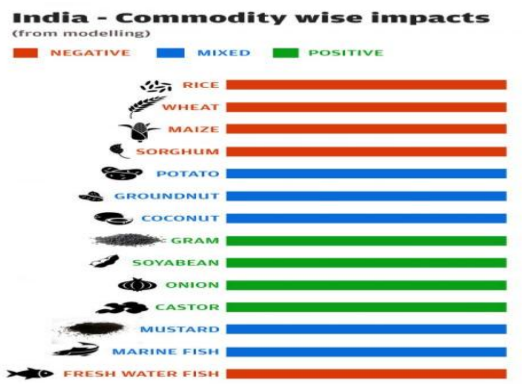

Fig. (III). How different crop would react to climate change by 2030. (CRIDA)

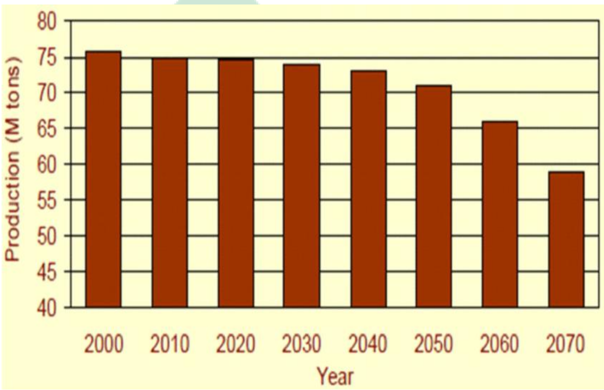

Fig. (IV).Potential impact of climate change on wheat production in India. (Singh, 2009)

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IMPACT OF CLIMATE CHANGE ON INDIAN FISHERY

Evidence of the impact of global climate change on marine environments is ample. But it is regional rather than global climate models that are appropriate for observation and study of climate change impacts (Clark, 2006). Analysing data on sea surface temperature (SST) and other parameters from a variety of global sources, Vivekanandan *et al.* (2009) found warming of the sea surface along the entire Indian coast. The SST increased by 0.2^{o}C along the northwest, southwest and northeast coast and by 0.3^{o}C along the southeast coast during the 45-year period from 1960 to 2005.

Sea level rise in the Indian seas:

The Inter-governmental Panel on Climate Change (IPCC) has projected that the global annual seawater temperature would rise by 0.8^{o}C to 2.5^{o}C by 2050. The sea level would rise by 8 to 25 cm. the sea level rise for Cochin (southwest coast) during the past century is estimated at 2 cm (Emery and Aubrey, 1989; Das and Radhakhrishna, 1993). But the rate of increase is accelerating. It may rise at the rate of 5 mm per year in decades to come. This will accelerate erosion and increase the risk of flooding (Nicholls *et al.,* 1999).

Indian mackerel is getting deeper:

The Indian mackerel *Rastrelliger kanagurta* has been descending deeper as well during the last two decades (CMFRI, 2008). The fish normally occupies surface and subsurface waters. During 1985-89, only 2 percent of the mackerel catch was from bottom trawlers, the remainder was caught by pelagic gear such as drift gillnet. During 2003-2007, however, an estimated 15 percent of the mackerel has been caught by bottom trawlers along the Indian coast. It appears that with the warming of sub-surface waters, the mackerel has been extending deeper and downward as well.

False Trevally populations decline in the Gulf of Mannar:

False Trevally (*Lactarius lactarius)* is an economically and culturally important fish in India and found near the Rameshwaram coast of south east India. The species is generally seen at depths ranging from 15 to 90 metres. But over the past few years, there has been a steady decline in the catch of this fish- both because of human disturbance and changes in ocean temperatures. Resulting in the species to move to other regions along the coast including the east coast of Sri Lanka.

Coral reefs may become remnants:

Coral reefs are the most diverse marine habitat, which support an estimated one million species globally. They are highly sensitive to climatic influences and are among the most sensitive of all ecosystems to temperature changes, exhibiting the phenomenon known as coral bleaching when stressed by higher-than-normal sea temperatures. In the Indian seas, coral reefs are found in the Gulf of Mannar, Gulf of Kachchh, Palk Bay, Andaman Sea and Lakshadweep Sea. Indian coral reefs have experienced 29 widespread bleaching events since 1989 and intense bleaching occurred in 1998 and 2002 when the SST was higher than the usual summer maxima. By using the relationship between past temperatures and bleaching events and predicted SST for another 100 years, Vivekanandan *et al.* (2009) projected the vulnerability of coral in the Indian Seas. They believe that the coral cover of reefs may soon start declining.

IMPACT OF CLIMATE CHANGE ON INDIAN LIVESTOCKS

Livestock are homeotherms, which means, that they must regulate their body temperature within a relatively narrow range to remain healthy and productive. The ambient temperature below or above the thermoneutral range creates stress conditions in animals. The approximate thermal- comfort zone for optimum performance of adult cattle is reported to be 5-15^{o}C (Hahn 1999). However significant changes in feed intake or in numerous physiological processes will not occur within the range of 5-25^{o}C (McDowell 1972).

While vulnerability of animal production to climate change has hardly been documented in the context of India, experimental studies have been conducted on effects of season and climate on production, performances and other physiological parameters of dairy animals. These studies have shown milk yield of crossbreed cows in India (*e.g.*, Karan fries, Karan Swiss, and other Holstein and Jersey crosses) to be negatively correlated with temperature-humidity index (Shinde *et al.* 1990; Kulkarni *et al.* 1998; Mandal *et al.* 2002). The average daily milk yield of the crossbred animals in the hot-humid eastern part of the country was significantly reduced by the rise in minimum temperature and not maximum temperature, as

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rise in minimum temperature crossed the critical temperature of comfort while the maximum temperature was already above the comfort zone (Kale and Basu 1993). The influence of climatic conditions on milk production is also observed for local cows which are more adapted to the tropical climate of India. The rising temperature decreased the total dry matter intake and milk yield in Haryana cows (Lal *et al.* 1987). The production of Sahiwal cows also showed a decline due to increase in temperature and relative humidity (Mandal *et al.* 2002).

Region/districts	Seasonal normal temperature (°C)			Seasonal milk yield (l/day)		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Southern India:						
Tiruvanthapuram	26.93	28.35	26.74	5.68	5.62	5.70
Belgaum	22.50	27.12	23.50	3.72	3.50	3.64
Northern India:						
Karnal	15.87	30.80	28.87	10.30	8.47	9.10
Western India:						
Akola	23.04	32.01	27.71	3.96	3.80	3.86
Kota	19.5	31.88	29.33	3.07	2.83	2.93

Source: (1) Indian Meteorological Department (2) Directorate of Animal Husbandry, *various states*.

Fig. (V). Seasonal variation in air temperature and productivity of cross bred cows.

MITIGATION AND ADAPTATION STRATEGIES

In spite of the uncertainties about the precise magnitude of climate change on regional scales due to scenarios and crop models on impact assessment, an assessment of the possible impacts of climate change on India's agricultural production under varying socioeconomic conditions is important for formulating response strategies, which should be practical, affordable and acceptable to farmers. The identification of suitable response strategies is Key to sustainable agriculture. The important mitigation and adaptation strategies required to cope with anticipated climate change impacts include adjustment in sowing dates, breeding of plants that are more resilient to variability of climate, and improvement in agronomic practices (Attri and Rathore, 2003).

Attri and Rathore (2003) suggested the adaptation strategies for sustainable production of wheat and ensuring food security. Adaptation measures to mitigate the potential impact of climate change included possible changes in sowing dates and genotypes selection.

Enhancing of sowing by 10 days in late- sown cultivars and delaying of sowing 10 days in normally sown cultivar resulted in higher yields under a modified climate, whereas a reduction in yield was observed.

The results obtained by Mall *et al.* (2004) on the mitigatory option for reducing the negative impacts of temperature increases indicate that delaying the sowing dates would be favourable for increased soybean yields at all the locations in India. Sowing in the second season would also be able to mitigate the detrimental effects of future increases in surface temperature due to global warming at some locations.

However, it should be noted that changing of sowing dates is a no cost decision that can be taken at the farmer level; a large shift in sowing dates probably would affect the agro technological management of other crops, grown during the remaining part of the year. Changes in the cropping sequence, irrigation and agriculture land use can be additional alternative options for adaptation in agriculture. Kumar and Parikh (1998) have showed that even with adaptation by farmers of their cropping patterns and inputs, in response to climate change, the losses would remain significant. The loss in farm-level net revenue is estimated to range between 9% and 25% for a temperature rise of $2^{o}C$-$3.5^{o}C$.

There is need to identify district or agroclimatic regions vulnerable to climate change and identify suitable adaptation practices to be followed in order to sustain the productivity of these regions to some extent. These adaptation strategies may include altered crops and cropping systems to maintain soil fertility in sustainable manner and improved management practices. Modern technologies in agriculture could also be beneficial with or without climate change; government should encourage farmers to shift towards newer technologies. The government should also encourage research on developing crop varieties that can withstand in the climate.

The Government of India launched National Action Plan on Climate Change (NAPCC) on 30th June, 2008 outlining eight National Missions on climate change. These include:

1. National Solar Mission
2. National Mission for Enhanced Energy Efficiency
3. National Mission on sustainable Habitat

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4. National Water Mission
5. National Mission for Sustaining the Himalayan Eco-system
6. National Mission for a Green India
7. National Mission for Sustainable Agriculture
8. National Mission on Strategic Knowledge for Climate Change

CONCLUSION

- 60% of the total cropped area is still rainfed in India and dependent on uncertainties of monsoon. Therefore, it is crucial to conduct more in-depth studies and analyses to gauge the extent of problems that the country may face in future.
- Direct impact on kharif would be small compared to rabi due to larger increase in temperature and uncertainty in rainfall.
- An index of sustainability that included economic (agricultural production, income, and risk) and environmental (ground water level, land degradation and biodiversity) indicators clearly shows that the agricultural production is under threat and needs immediate attention (Joshi et al., 2003).
- By the year 2080, when temperature increases are very large, the Indian agriculture will suffer the most. In other word it can be say that food production is not threatened up to 2050 and does not need to import food, but by the year 2080 food production is threatened.

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