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EFFECT OF CLIMATE CHANGE ON CROP PRODUCTION IN INDIA

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ABSTRACT

Agriculture and climate change are deeply intertwined. Crop production is highly sensitive to climate. It is affected by long-term trends in average rainfall and temperature, inter-annual climate variability, and extreme weather events. Climate change induced increases in temperatures, rainfall variation and the frequency and intensity of extreme weather events are adding to pressures on global agricultural and food systems. Climate change is expected to negatively affect both crop and livestock production systems in most regions, although some countries may actually benefit from the changing conditions. The changing climate is also adding to resource problems, such as water scarcity, pollution and soil degradation. Climate change is likely to contribute substantially to food insecurity in the future, by increasing food prices, and reducing food production. Climate change is already affecting agriculture, with effects unevenly distributed across the world. Future climate change will likely negatively affect crop production in low latitude countries, while effects in northern latitudes may be positive or negative. Climate change will probably increase the risk of food insecurity for some vulnerable groups, such as the poor. For example, South America may lose 1–21% of its arable land area, Africa 1–18%, Europe 11–17%, and India 20–40%. To manage the impact of climate change on agriculture, careful supervision of resources like soil, water and biodiversity is required.

Keywords*: climate change, temperature increase, rainfall, extreme weather events, crop production, agriculture*

INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) predicted that the global mean surface temperature will plausibly increase and may result into uneven climatic changes (Collins et al., 2013). The main characteristics of climate change are increases in average global temperature (global warming); changes in cloud cover and precipitation particularly over land; melting of ice caps and glaciers and reduced snow cover; and increases in ocean temperatures and ocean acidity – due to seawater absorbing heat and carbon dioxide from the atmosphere. (UNFCC, 2007; Singh and Singh, 2012). This diverse topography produces a spectrum of climates over the subcontinent. The anticipated future impacts of climate change, identified by the Government of India (GOI) in its Initial National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) have become of great concern (GOI, 2004). It has been reported over 20th century that rising temperature plays an important role towards global warming (Singh and Singh, 2012). Researchers have confirmed that crop yield falls by 3% to 5% for every 1°F increase in the temperature (Schlenker and Roberts, 2009; Ruchita and Rohit, 2017). Increases of temperature may cause yield declines between 2.5% and 10% across a number of agronomic species throughout the 21st century (Hatfield et al., 2011).

Agriculture plays a key role in overall economic and social wellbeing of India (Sharma, 2012).More than 800 million Indians who live in rural areas and depend on climate-sensitive sectors for their livelihoods: agriculture, forests and fisheries (Kumar, 2008).Rising global temperature is not only causing climate change but also contributing to the irregular rainfall patterns. Uneven rainfall patterns, increased temperature, elevated CO_2 content in the atmosphere are important climatic parameters which affects the crop production (Lobell et al., 2011; FAO, 2015;Ruchita and Rohit, 2017).Shortage of water availability, soil fertility loss, and pest infestations in crops are the significant undesirable impacts of climate change (Baul and McDonald, 2015).

To manage the impact of climate change on agriculture, careful supervision of resources like soil, water and biodiversity is required (CCSP, 2008). To deal with the impact of climate change on agriculture and food production, the Indian government should assist farmers by providing value-added weather services (Lal et al., 2011).The usage of traditional management systems and agroecological management systems, namely biodiversification, soil management, and water harvesting, can help farmers adopt climate- resilient technologies (Altieri et al., 2017).

Climate change in India:

India's geography is comprising the Himalayan mountain range, coastal plains, and the Great Peninsular Plateau. The northern part of the country experiences a continental climate with extreme summer heat andvery cool winters; in contrast, the coastal areas of the country experience year-round warm temperatures and frequent precipitation (MEF, 2004). Rainfall across the country is highly variable, and the country experiences four distinct seasons, described in relation to the monsoon: (a) winter: December to February;

(b) pre-monsoon or summer: March to May; (c) southwest monsoon: June to September; and (d) post- monsoon or northeast monsoon: October and November (MEF, 2004; Attri and Tyagi, 2010).

The anticipated future impacts of climate change, identified by the Government of India (GOI) in itsInitial National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) include (GOI, 2004, IPCC, 2007a;GoI, 2008;Meister et al., 2009):

- Decreased snow cover, affecting snow-fed and glacial systems such as the Ganges and Brahmaputra; 70per cent of the summer flow of the Ganges comes from snowmelt;
- Erratic monsoons with serious effects on rain-fed agriculture, peninsular rivers, water and power supply;
- Decline in wheat production by 4-5 million tonnes with as little as a 1°C rise in temperature;
- Rising sea levels causing displacement along one of the most densely populated coastlines in the worldand threatening freshwater sources and mangrove ecosystems;
- Increased frequency and intensity of floods; increased vulnerability of people in coastal, arid and semi-arid zones of the country; and
- Over 50 per cent of India's forests are likely to experience a shift in forest types, adversely impacting associated biodiversity and regional climate dynamics, as well as livelihoods based on forest products. Most of the temperature trend studies in India have focussed on the analysis of mean maximum andminimum temperatures (Hingane et al. 1985; Srivastava et al. 1992; Rupa Kumar et al. 1994; Arora et al.2005; Kothawale and Rupa Kumar 2005; Dash et al. 2007; Pal and Al-Tabbaa 2010). In general, theyhave found increasing trends in both maximum and minimum temperatures over India (Jaswal et al.,2015). Also a strong interannual link between mean temperatures of India and sea surface temperatures ofeastern Pacific and Indian Ocean have been found by Kothawale et al. (2010), who have concluded thatEl Nino Southern Ocean (ENSO) phenomenon is impacting Indian temperatures significantly(Jaswal et al., 2015). Chaudhury et al. (2000) have concluded that the impact of heat waves over Bihar, Punjab, andparts of Maharashtra is more. Analyzing 100 years temperature records in India, Sinha Ray and De (2003)have found increasing trend of 0.35◦C. They have also reported increasing trend in extreme maximum andminimum temperatures in the south and a decreasing trend in the north (Jaswal et al., 2015). Over theperiod of time average temperature in India has been increased (Fig 1). Rainfall is a key part ofhydrological cycle and alteration of its pattern directly affect the water resources (Mehrotra and Mehrotra,1995; Yang et al., 2011; Islam et al., 2012a; Stagl et al., 2014). Changes of rainfall quantities andfrequencies directly changing the stream flow pattern and its demand, spatiotemporal allocation of run-off, ground water reserves and soil moisture. Consequently, these changes showed the widespreadconsequences on the water resource, environment, terrestrial ecosystem, ocean, bio-diversity, agricultural and food security. The drought and flood like hazardous events can be occurred frequently because of theextreme changes of rainfall trend (Islam et al., 2012b; Srivastava et al., 2014, 2015).

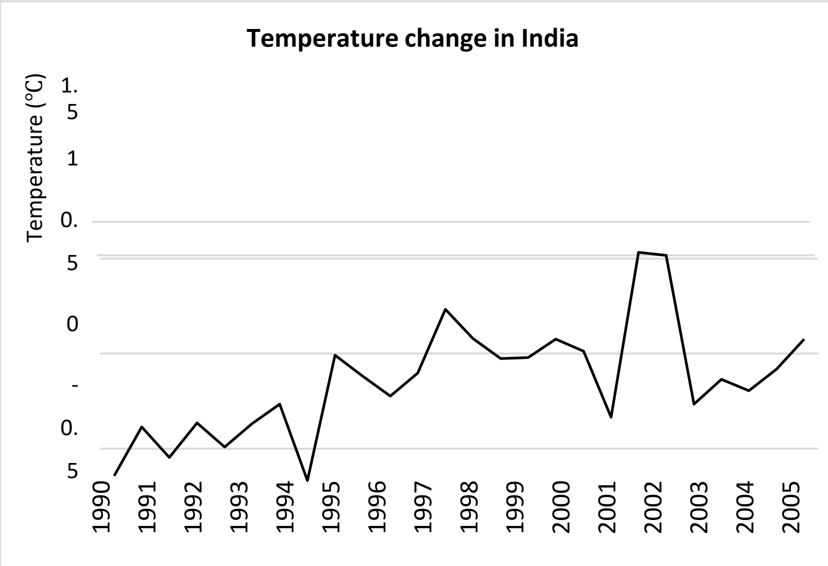

Fig 1. Temperature change in India (1990-2014) (Source: http://www.fao.org/faostat/en/#data/ET) The monsoon rainfall plays a vital role for agriculture in India. Hence, the research on the climate changeor most specifically on the changes of rainfall occurrences and its allocation are the most significant way for sustainable water resource management (Meshram et al., 2017). Most importantly, a complete understanding of the precipitation pattern in the changing environment will help in better decision making and improve the adapting-capacity of the communities to sustain the extreme weather events (Mall et al., 2006; Meshram et al., 2017). India receives almost 75% of the annual rainfall in the summer monsoon (southwest monsoon) season from June through September. The summer monsoon rainfall plays a vital role in agriculture, water resource management and power management (Singh et al., 2002).

The annual as well as seasonal (June through September) monsoon rainfall over India shows significant decreasing trend over the core monsoon zone, north-eastern parts and southern parts of west coast (Fig 2) (Kumar et al., 2010). As per a report, total number of consecutive dry days with spell length more than five days has increased significantly, while the total number of consecutivewet days has shown significant decrease (CCCR, 2017) Some past studies relating to changes in rainfall over India have concluded that there is no clear trend of increase or decrease in average annual rainfall over the country (Mooley& Parthasarathy, 1984; Sarker& Thapliyal, 1988; Thapliyal &Kulshrestha, 1991; Lal, 2001). Though no trend in the monsoon rainfall in India is found over a long period of time, particularly on the all-India scale, pockets of significant long-term rainfall changes have been identified (Koteswaram&Alvi, 1969; Jagannathan & Parthasarathy, 1973; Raghavendra, 1974; Chaudhary & Abhyankar, 1979; Kumar et al., 2005; Dash et al., 2007; Kumar & Jain, 2009). According to Sinha Ray & Srivastava (1999), thefrequency of heavy rainfall events during the southwest monsoon has shown an increasing trend over certain parts of the country, whereas a decreasing trend has been observed during winter, pre-monsoon and post-monsoon seasons.

Analysis of rainfall data for the period 1871–2002 indicated a decreasing trend in monsoon rainfall and anincreasing trend in the pre-monsoon and post-monsoon seasons (Dash et al., 2007). Mall et al. (2007) inferred that there has been a westward shift in rainfall activity over the Indo-Gangetic Plain region. An increase in intense rainfall events leads to more severe floods and landslides. The number of cyclones originating from the Bay of Bengal and the Arabian Sea has decreased since 1970, but their intensity has increased (Lal, 2001). Moreover, the damage caused by intense cyclones has risen significantly in India.In three consecutive years since 2002, there were large floods in the northeastern states of India, on 26–27July 2005, a record 944 mm of rain fell in Mumbai, but the seasons of 2006 and 2007 saw deficient rainfall. Severe floods were observed in many parts of Gujarat and Rajasthan during the monsoon seasons of 2006 and 2007 (India Meteorological Department, 2006, 2007).

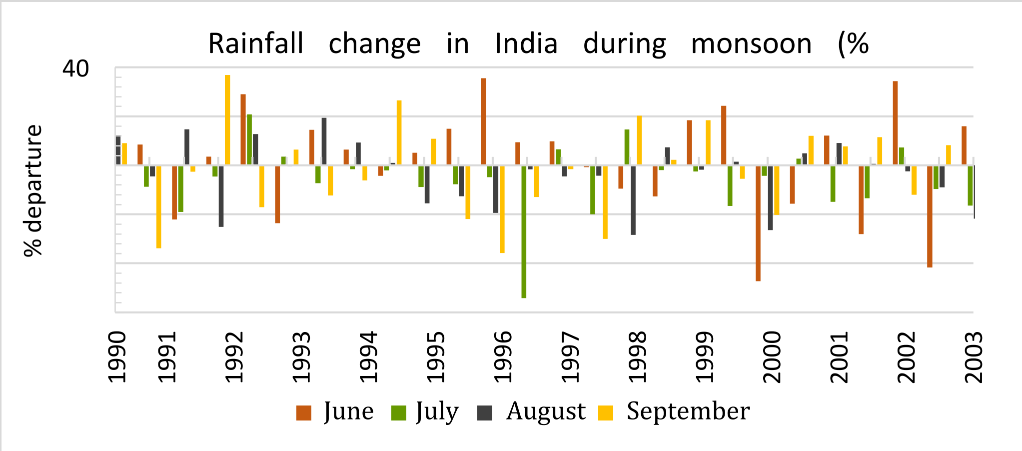

Fig 2. Rainfall change in India during monsoon (% departure) (Source: India Metrological Department, Pune)

With a 1.2 billion but growing population and dependence on agriculture, India probably will be severely impacted by continuing climate change

Crop production and climate change in India:

Climate change has already caused significant damage to our present crop profile and threatens to bring even more serious consequences in the future (Kumar and Gautam 2014).Crop production is highly sensitive to climate. It is affected by long-term trends in average rainfall and temperature, interannual climate variability, shocks during specific phenological[ii] stages, and extreme weather events (IPCC, 2012). Some crops are more tolerant than others to certain types of stresses, and at each phenological stage, different types of stresses affect each crop species in different ways (Simpson, 2017). The nutritional content of leaves, stems, roots, fruits and tubers of C3plants grown at elevated carbon dioxide levels is expected to be lower particularly in protein, minerals and trace elements, such as zinc and iron (Taub *et al.*, 2008; Loladze, 2014). 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 (IPCC, 2001). India could experience a 40% decline in agricultural productivity by the 2080s. Rise in temperatures will affect wheat growing regions, placing hundreds of millions of people at the brink of chronic hunger (IPCC, 2007a; Kumar and Gautam, 2014). As per the ICAR (2012) report, impact of climate change on crop production was assessed using the InfoCrop models. Scenario of yield is predicted to measure crop loss and gain which is as follows:

Crop	**Prediction of crop production under climate change condition**
Timely sown irrigated wheat	Decrease: 6% in 2020
Very late sown wheat	Decrease: 18% in 2020, 23% in 2050 and 25% in 2080
Irrigated rice yields	Decrease: ~4% in 2020, 7% in 2050 and by ~10% in 2080
Rainfed rice yields	Decrease: 6% in 2020 and marginally decrease <2.5% in 2050 and 2080
Irrigated kharif maize	Decrease: up to 18% in 2020 and 2050, 23% in 2080
Rainfed sorghum yields	Decrease: 2.5% in 2020 and 8% in 2050
Rainfed soybean	Increase 8-13% under different future climate scenarios during 2030 and 2080
Groundnut	Decrease: 5% in 2080 rest of the scenarios 4-7% increase
Chickpea	Increase: Average 23 to 54%.
Potato	Increase in Punjab, Haryana and western and central UP by 3.46 to 7.11% in 2030. Rest of India, particularly West Bengal and southern plateau

	region, potato production may decline by 4 - 16%.

Simulation studies using Info-Crop, Coconut model indicated positive effect of climate change on coconut yields in west coast and parts of Tamil Nadu and Karnataka and negative effects on nut yield in east coast of India (ICAR, 2012).

Impact of climate change on growth of the plant:

Further extreme weather events can affect plant growth in many ways. To predict the responses of species to new temperature alterations, it is necessary (although not sufficient) to know how the same species have responded in the past to similar changes. Below are some of the findings from the few phenological studies of sufficient length on annual crops.

I. The increase in average temperature during the growing season typically causes plants to use more energy for respiration for their maintenance and less to support their growth. With a 1°C increase in average temperatures, yields of the major food and cash crop species can decrease by 5 to 10 percent (Lobell and Field, 2007; Hatfield *et al.*, 2009).

II. With higher average temperatures plants also complete their growing cycle more rapidly (Hatfield *et al.*, 2011). With less time to reproduce, reproductive failures are more likely and this will also lower yields (Craufurd and Wheeler, 2009).

III. In general, photosynthesis in C3 plants is more sensitive to higher temperatures compared with C4 crops (Lipiec *et al.*, 2013).

IV. Higher temperatures can also affect the marketability of fruits and vegetables. The increased rates of respiration caused by higher temperatures lead to a greater use of sugars by the plants. As a result less sugar remains in the harvested product, and this can reduce its market value (Hatfield and Prueger, 2015). These effects become more serious as temperatures continue to rise during the grain-filling or fruit maturation stage (Simpson, 2017).

V. Higher nighttime temperatures may increase respiration at night causing declines in yield (e.g. rice) and flowering or reproduction (e.g. beans).

VI. Most crops can tolerate higher daytime temperatures during vegetative growth, with photosynthesis reaching an optimum at between 20°C and 30°C (Wahid *et al.*, 2007). During the reproductive stage, yields decline when daytime high temperatures exceed 30°C to 34°C (FAO, 2016b).

VII. Extremely high temperatures above 30°C can do permanent physical damage to plants and, when they exceed 37°C, can even damage seeds during storage. The type of damage depends on the temperature, its persistence, and the rapidity of its increase or plants' capacity to adjust (Wahid *et al.*, 2007). It also depends on the species, the stage of plant development. As the climate changes, the frequency of periods when temperatures rise above critical thresholds for maize, rice and wheat is predicted to increase worldwide (Gourdji *et al.*, 2013).

Future projections indicate that there is increased confidence that some weather events and extremes will become more frequent, more widespread and/or more intense during the 21st century and impacts due to altered frequencies and intensities of extreme weather, climate and sea level events are very likely to change (IPCC, 2007b). Climate change can disrupt food availability, reduce access to food, and affect food quality.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 spikes in food prices after extreme events are expected to be more frequent in the future. In India, Climate change will result in additional price increases for the most important agricultural crops– rice, wheat, maize, and soybeans

CONCLUSION

Since the middle of the twentieth century, India witnessed rise in temperature; decrease in monsoon; rise in extreme temperature and rainfall, droughts, and sea levels; and increase intensity of severe cyclones. Developing and applying locally specific and effective climate change adaptation and mitigation strategies for crop production requires the strengthening of scientific and technical capacities at many levels, including the individual and organizational levels, in ways that create an enabling environment for change.The adaptation to climate change results reveal that farmers make many adjustments including switching crops and livestock species, adopting irrigation, and moving between livestock and crops. So, need of integrated assessment of climate change and impact on agricultural production and need toprepare for adaptation and mitigation strategies in near future. Which can be achieved by following steps:

- Crop diversification and improved soil management practices, together with the development of droughtresistant crops.
- The efficient use of water resources will need to be incentivized.
- Improvements in irrigation systems, water harvesting techniques and more efficient agriculture water management can offset some of these risks of water shortage.
- Initiatives designed to achieve sustainable growth in productivity, deliver long-term benefits in terms of improving the adaptation responses to climate change, and reduce and/or remove greenhouse gas emissions, must be planned and address the potential constraints producers face in adopting climate-smartcrop production practices and technologies.
- Forestation can be deployed by either establishing new forests, referred to as afforestation, or re- establishing previous forest areas that have undergone deforestation or degradation, which is referred to as reforestation.
- Implementationof decarbonisation technologies, bioenergy carbon capture and storage, radiative forcing geoengineering technologies for temperature stabilization or reduction

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