Agricultural Reviews, 38 (1) 2017 : 67-71
Print ISSN:0253-1496 / Online ISSN:0976-0539

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
www.arccjournals.com

# Climate change : impact, adaptation and mitigation: A review

**Mahendra Singh*, Mahesh Kumar Poonia and Bheru Lal Kumhar**

Krishi Vighan Kendra,
Agriculture University, Borkhera, Kota, India.

Received: 14-09-2016 Accepted: 27-12-2016 DOI:10.18805/ag.v0iOF.7309

## ABSTRACT

Climate and agriculture are intensely interrelated global processes and therefore a change in climate affects agricultural production. One such change is global warming which is projected to have significant impacts on environment affecting agriculture, including higher carbon dioxide emission, rise in atmospheric temperature, higher glacial run-off, changed precipitation and the interaction of these elements. These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. The present paper might help to anticipate and adapt farming to maximize agricultural production.

**Key words:** Adaption, Climate change, Impact, Mitigation.

Globally, climate change (CC) is the most serious environmental threat that adversely affects agricultural productivity. According to inter-governmental panel on climate change (IPCC) report, climate change refers to any change in climate over time, due to natural variability or as a result of human activity. In developing countries like India, climate change is an additional burden because ecological and socioeconomic systems are already facing pressures from rapid increase in population, industrialization and economic development. India's climate could become warmer under conditions of increased atmospheric carbon dioxide (Longerman 1998).

The effects of global climate change could be potentially serious over the next century include regional increases in floods and droughts, inundation of coastal areas, high-temperature events, fires, outbreaks of pests and diseases, significant damage to ecosystem, and threats to agricultural production. Climate change will also pose a major risk to human health and safety, especially among poorer communities with high population densities in areas like river basins and low-lying coastal plains, which are vulnerable to estimate related natural hazards such as storms, floods, and droughts. (IPCC 1998).

IPCC has projected that by the end of the 21$^{st}$ century, rainfall over India will increase by 10-12 per cent with more frequent and heavy rainfall days while the mean annual temperature will rise by 3-6°C (IPCC, 2014). These changes may culminate in adverse impacts on agriculture in terms of productivity loss, pest and disease increases and labor migration that will threaten food security and agricultural employment.

Climatic changes and increasing climatic variability are likely to aggravate the problems of future food security by exerting pressure on agriculture. However, there are lot of uncertainties about the assessment of impact, adaptation and mitigation of climate change in agriculture. It is mainly because the methodology followed for such assessments is not standardized and sometimes is inaccurate and imprecise. Climate change will also have an economic impact on agriculture, including changes in farm profitability, prices, supply, demand, trade and regional comparative advantages. The two-way relationship of climate change and agriculture is of great significance in particular to developing countries due to their large dependence on agricultural practice for livelihoods and their lack of infrastructure for adaptation when compared to developed countries. Agricultural activities are affected by climate change affects due to their direct dependence on climatic factors. In high latitude areas with low temperature, increased temperature due to climate change could allow for longer growing season. Agriculture affects climate through emissions of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide. These emissions come directly from use of fossil fuels, tillage practices, fertilized agricultural soils and livestock manure in large proportion. Conversely, agriculture could be a solution for climate change by the widespread adoption of mitigation and adaptation actions. This happens with the help of best management practices such as organic farming, agroforestry practice and manure management etc. This paper reviews various articles and documents on current knowledge about adaptation in agriculture from studies of climate impacts, adaptation and vulnerability, and from research on the dynamics of agricultural production and economics.

*Corresponding author's e-mail: mskvktonk@gmail.com

**Impact of climatic changes on agriculture:** There are aspects of the relationship between climate change and agriculture. First, climate change has a direct bearing on the biology of plant growth. Secondly, any assessment of the impact of climate change on agriculture must consider the interaction between the direct biological effects of climate change on the one hand, and other (often dynamic) aspects of the biosphere and geosphere for example soil conditions, seed, water, fertiliser, pesticide technologies and plant anatomy. Thirdly, we must consider the impact of climate change on society and economy, and the ability of existing social and economic institutions, particularly in rural areas, to deal with the challenges posed by global warming. Climate change is poised to have a sharply differentiated effect as between agro-ecological regions, farming systems, and social classes and groups other impacts are.

Shift in climatic and agriculture zones
Impact on Agriculture soil
Effect on soil organic matter and soil fertility
Effect on biological health of soil
Soil erosion and sediment transport
Reduced soil water availability
Impact on soil processes
Salinization and alkalization
Pest, diseases and weeds
Impact on plant growth
Impact on crop production

NATCOM I from India was submitted to the UNFCC in 2006 and it provided a preliminary basis for understanding the country level impact of climate change on India. The following is a broad-brush summary of the expected impact of climate change on India as provided by NATCOM I (Government of India, Ministry of Environment and Forests (2004), NATCOM I).

Temperature increases have already been observed in the Indian subcontinent. Over the last 100 years, an increase of 0.4°C in annual average surface air temperature has been recorded. By the 2050s maximum temperatures are expected to rise by 2°C–4°C over south India (i.e. south of latitude 25°N) and by more than 4°C over northern India (north of latitude 25°N). Minimum temperatures are expected to rise by more than 4°C all over India over the same period.

So far there has been no significant change in the total rainfall delivered by the monsoon. Regional variations, however, are observed, and range from increases of 10–12 per cent over some regions to decreases of 6–8 per cent in some others. Total rainfall from the monsoon is expected to be relatively unchanged through to the 2050s. The spatial variability of rainfall, on the other hand, is likely to increase. A decrease in the number of rainy days is expected, with a corresponding increase in rainfall intensity in terms of rainfall per day ranging from 1 mm/day to 4 mm/day.

While the average frequency of cyclonic storms over the period 1887–1987 appears to have been unchanging, there appears to be a slight increase in the frequency of severe cyclonic storms in recent decades.

Surface water runoff patterns are likely to change, with reduction of runoff in many river basins, although calculating the final runoff requires detailed modeling.

Varying levels of water shortage are likely to appear across different basins. Perennial water shortages are expected in the Mahi, Pennar, Sabarmati and Tapti basins. Seasonal water shortages and regular water-stressed conditions are expected in the Ganga, Cauvery, Narmada and Krishna river basins. The Godavari, Mahanadi and Brahmani basins are likely to experience only moderate water shortage at a few locations.

Himalayan glaciers and snowfields are generally on the decline, though there is need for substantial further scientific work to accurately establish the changes that are taking place.

Groundwater supplies are likely to be affected by a number of factors, including higher runoff leading to lower recharge, increase in flooding (which will affect the quality of alluvial aquifers) and saline intrusion into coastal aquifers.

The rise in sea level along India's coastlines currently ranges between 0.4 and 2 mm per year, with the highest increases being registered along the coast of the Gulf of Kutch and West Bengal. Though substantial uncertainty is involved in estimating the rise in sea level in the future along specific stretches of the coastline, it is estimated that a general rise of up to 1 mm may be expected by the end of the century.

The severity of droughts and intensity of floods are likely to increase. Preliminary results suggest that peak discharge under climate change could be as high as twice the current peak discharge in some basins.

Conventional climate impact scenarios usually focus on the changes in average (mean) temperature and moisture. Some have also considered other climate characteristics such as the growing season length and the timing of frosts, and climate-related factors such as pests and diseases, invariably for an average year sometime in the future (Bryant *et al*. 2000; Brklacich *et al.* 2000 and Smit *et al*. 2000).

According to Saini and Dadwal, (1986); Nagarajan *et al*., (2010) a simple approach to quantify the effect of temperature on a crop in the field is to sow the crop on different dates, thereby testing across the large seasonal changes in temperature for different thermal regimes. This method of creating different environments to study the impact of climatic factors is widely used. Either a large number of sowings are done in the same crop season at short intervals or four to six sowings are done in three or more consecutive years.

Krishnan and Rao, (2005) revealed that, soil system responds to short-term events such as rainfall and also undergoes long-term changes such as physical and chemical weathering due to climate change. The potential impacts on soil health due to climate change would be in the organic matter supply, temperature regimes, hydrology and salinity. Soil carbon levels are expected to decrease due to decreased net primary production. Any gains by the increased plant water-use efficiency, due to elevated $CO_2$, are likely to be outweighed by increased carbon mineralization after episodic rainfall and reduced annual and growing season rainfall. The quality of soil organic matter may also shift where the more inert components of the carbon pool prevail. The increase in soil temperature increases N mineralization but its availability may decrease due to increased gaseous losses through processes such as volatilization and denitrification.

Drake *et al.,* (1997) found that increasing atmospheric carbon dioxide concentration and simultaneous rises in temperature are influencing the global climate, henceforth affecting growth, development and functioning of plants. The primary effects of increased concentration of $CO_2$ include higher photosynthetic rate, increased light-use efficiency, reduction in transpiration and stomatal conductance and improved water-use efficiency.

Rawson *et al,.* (1995) revealed that increasing temperatures and carbon dioxide levels in the atmosphere along with the uncertainties in annual precipitations will have adverse effects on the Indian agriculture. Biomass and yield tend to decline with increasing temperature, as higher temperatures shorten crop duration, enhance respiration and reduce time for radiation interception.

Sutherst, (1991) and Root *et al.*, (2003) find that climate change impacts on pests may include shifts in species distributions with species shifting their ranges to higher latitudes and elevations, changes in phenology with life cycles beginning earlier in spring and continuing later in autumn, increase in population growth rates and number of generations, change in migratory behavior, alterations in crop pest synchrony and natural enemy-pest interaction, and changes in interspecific interactions.

Fraser, (2008) revealed that, climate and agriculture are intensely interrelated global processes and therefore a change in climate affects agricultural production (IPCC, 2007). One such change is global warming which is projected to have significant impacts on environment affecting agriculture, including higher carbon dioxide emission, rise in atmospheric temperature, higher glacial run-off, changed precipitation and the interaction of these elements. These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. The overall effect of climate change on agriculture will depend on the balance of these effects.

Watson *et al.* (1998) revealed that, the climate change scenarios used were 0.1°C increase in temperature and 416 ppm $CO_2$ (2010 scenario) and 0.4°C temperature and 755 $CO_2$ (2070 scenario) as the optimistic scenario, whereas increase of 0.3°C temperature and 397 ppm $CO_2$ (2010 scenario) and 2.0°C temperature and 605 ppm $CO_2$ (2070 scenario) as the pessimistic scenarios of climate change.

**Mitigation:** On the other side, agricultural sector has large potential to mitigate and adapt climate change. According to IPCC, mitigation is an intervention to reduce the emissions sources or enhance the GHG sinks, whereas adaptation is the adjustment in natural or human systems in response to actual or expected climatic change or their effects, to reduce harm or exploit beneficial opportunities. Sustainable and organic agricultural systems can help reduce agricultural GHG emissions through energy conservation, lower levels of carbon-based inputs, lower use of synthetic fertilizer and other features that minimize GHG emissions and sequester carbon in the soil.

Debnath *et al.* (1996) possible strategies for mitigating methane emission from rice cultivation can be made by altering water management, particularly promoting mid-season aeration by short-term drainage. Improving organic matter management by promoting aerobic degradation through composting or incorporating into soil during off-season drained period, is another promising technique. Organic amendments to flooded soils increase methane production and emission. However, application of fermented manure, like biogas slurry, reduces the emission . In addition, nitrification inhibitors have been shown to inhibit methane emission. Another mitigation option may be selection of low $CH_4$ emitting rice cultivars, as cultivars grown in similar conditions show pronounced variations in methane emission (Mitra 2000). Screening of rice cultivars with few unproductive tillers, small root system, high root oxidative activity and high harvest index are ideal for mitigating methane emission from rice fields. Combined with a package of technologies, methane emission can best be reduced by (a) the practice of mid-season drainage instead of continuous flooding, (b) direct crop establishment like dry seeded rice and (c) use of low C: N organic manure and biogas slurry.

Smit *et al* (2000), adaptation of crops to gradual change in the climatic conditions needs to be included in the existing crop growth models, as it is not well understood. Moreover, the suitable agronomic and resource management options may nullify the ill effects of climate change on growth and yield of crops.

Aggarwal and Kalra (1994) adopted wheat growth simulator (WTGROWS), developed at IARI, New Delhi, has been extensively tested for different agro-environments. In past, it has been successfully used for the resource management, forecasting of wheat yields and climate variability related studies. Using WTGROWS, a strong linear decline in wheat yield was noticed with the increase in January temperature.

Aggarwal and Kalra (1994), by using WTGROWS, demonstrated the shift of iso-yield lines of wheat in India with 425 ppm of $CO_2$ concentration and 2°C rise in temperature. The rise in carbon dioxide concentration of the atmosphere effectively influences the productivity of crop plants.

Das and Kalra (1995) evaluated the fertilizer and resource management for enhancing crop productivity under inter-annual variations in weather conditions. The results revealed sensitivity of crop yields to climatic variability and the need of inputs management in relation to climatic variability. Simulation models for judging the soil nutrient availability and subsequently relating to growth and yield of crops are available, but needs to be refined and thoroughly tested for the climate change event.

Bryant *et al* (2000), adaptation of agriculture to moderate climate change can be facilitated by improving irrigation, developing less water-demanding and more heat-resistant crop varieties, using minimum tillage and other practices to improve nutrient and moisture retention in soil, and changing timing of planting/ harvesting and other management activities.

Bhatti and Khan (2012) revealed that, various soil management practices *viz*., integrated plant nutrient management, variable rate fertilizer technology (precision agriculture), use of N inhibitors, restoration of crop productivity of marginal lands, crop residue management, and moisture conservation measures increase crop production per unit area through increasing fertilizer and water use efficiency This will ultimately mitigate the emission of GHGs into the air and improve the sequestration of $CO_2$.

According to National Initiative on Climate Resilient Agriculture Resilient Agriculture Project (2012) 4 components are strategic research, technology demonstration, sponsored or competitive research and capacity building programme to sustain crop production in India and addressed yet to be identified problem arising at farmer field and prepare the contingency planning to reduce the adverse effect of climate.

**Adaptation:** A synthesis of research on adaptation options in Indian agriculture identifies four main categories:
(i) Technological developments,
(ii) Government programs and insurance,
(iii) Farm production practices, and
(iv) Farm financial management.

In addition to these 'direct adaptations', there are options, particularly information provision, that may stimulate adaptation initiatives. The results reveal that most adaptation options are modifications to on-going farm practices and public policy decision making processes with respect to a suite of changing climatic (including variability and extremes) and non-climatic conditions (political, economic and social). For progress on implementing adaptations to climate change in agriculture there is a need to better understand the relationship between potential adaptation options and existing farm-level and government decision-making processes and risk management frameworks.

Conservation tillage is a generic term that includes a wide range of tillage practices, including chisel plough, ridge till, strip till, mulch till and no till (CTIC, 1998). Adoption of conservation tillage has numerous ancillary benefits. Important among these benefits are the control of water and wind erosion, water conservation, increased water-holding capacity, reduced compaction, increased soil resilience to chemical inputs, increased soil and air quality, enhanced soil biodiversity, reduced energy use, improved water quality, reduced siltation of reservoirs and waterways, and possible double-cropping.

**What Are Our Research and Development Needs**

1. Development of drought-resistant crops that have been tested for strong yields when subjected to periods of extended water shortage.
2. Improvements in plant nitrogen and water use efficiency and development of cost-efficient nitrogen uptake delivery systems and low-cost, high efficiency irrigation techniques.
3. Development of global testing sites and data collection and dissemination efforts, using standard data protocols, to assess the performance of existing and new genetic material and management systems in today's range of agroclimatic conditions.
4. Continuous field testing to track climate change, breeding for resistance to new diseases and pests and to address changes in pollinator distribution have been identified as avenues to confront adaptation of crops in the face of climate change.
5. Development of assessment tools that incorporate the biophysical constraints that affect agricultural productivity and include climate and socioeconomic scenarios, including improved characterization of policy and program environments and options.

## CONCLUSION

The findings of this paper related to thresholds in climate effects on crop yields need careful consideration by researchers and policy makers. On the policy side, it may be important to invest in new seed varieties that can better adjust to rainfall and temperature thresholds. There is also need for further research to explore the implications of adaptation responses such as adjustments in the sowing season. Such studies can be further improved by including additional factors such as the milk production, egg production, animal rearing and diversified agriculture.

## REFERENCES


Aggarwal PK and Kalra N (1994) Analysing constraints limiting crop productivity; New opportunities using crop growth modeling. In: Natural Resource Management for Sustainable Agriculture and Environment, [Deb DL (ed)]. Angkor Publishers (P) Ltd., New Delhi, pp 315–332.

Bhatti AU and Khan MM (2012) Soil management in mitigating the adverse effects of climate change a Review. *Soil Environ*. **31:** 1-10.

Brklacich M, Bryant C, Veenhof B and Beauchesne A (2000) Agricultural adaptation to climatic change: A comparative assessment of two types of farming in central Canada In Agricultural and Environmental Sustainability in the New Countryside, Winnipeg, [H. Millward, K. Beesley, B. Ilbery and L. Harrington (eds.)], Hignell Printing Limited, pp. 40–51.

Bryant CR, Smit B, Brklacich M, Johnston T, Smithers J, Chiotti Q and Singh B (2000) Adaptation in Canadian agriculture to climatic variability and change. *Clim Change* **45:** 181– 201.

CTIC (1998) Crop residue management executive summary. Conservation Technology Information Center, West Lafayette, Indiana.

Das DK and Kalra N (1995) Adjustments to weather variation through cropping systems and fertilizer use. *Fertilizer News* **40:**11–21.

Debnath G, Jain MC, Kumar S, Sarkar K and Sinha SK (1996) Methane emissions from rice fields amended with biogas slurry and farm yard manure. *Clim Change* **33:**97–109.

Drake B, Gonzalez-Meler M and Long S (1997) More efficient plants: A consequence of rising atmospheric $CO_2$ *Annu. Rev. Plant Physiol. Plant Mol. Biol.,* **48:** 609-639.

Fraser EDG (2008) Crop-Climate Impact Models: Where are the Farmers?" Invited Research Seminar at French Research Institute, Cemegref. 30 July, Montpellier, France.

Government of India, Ministry of Environment and Forests (2004), India's Initial National Communication to the United Nations Framework Convention on Climate Change (NATCOM I), New Delhi, available at *http://www.natcomindia.org /natcomreport.htm*, viewed on October 25, 2010

IPCC (1998) The IPCC sets up the Task Force on National Greenhouse Gas Inventories (TFI) to oversee the National Greenhouse Gas Inventories Programme. Since 1999 the Task Force has been supported by the Government of Japan.

IPCC (2007) The IPCC publishes its Fourth Assessment Report (AR4) (Working Group I – Climate Change 2007: The Physical Science Basis; Working Group II – Climate Change 2007: Impacts, Adaptation and Vulnerability; Working Group III – Climate Change 2007: Mitigation of Climate Change; Climate Change 2007: Synthesis Report).

IPCC (2014) The IPCC approves Climate Change 2014: Impacts Adaptation and Vulnerability and Climate Change 2014: Mitigation of Climate Change, the Working Group II and Working Group III contributions to AR5. The Fifth Assessment Report was completed in November 2014 with the Synthesis Report.

Krishnan P and Rao SAV (2005) Effects of genotype and environment on seed yield and quality of rice. *J. Agric. Sci. Cambridge*, **143:** 283-292.

Longerman S, (1998). World Bank Technical paper number 402.

Mitra AP (2000) Issues and perspectives of the South Asian region, Global Change Report No. 18, National Physical Laboratory, New Delhi.

Nagarajan S, Jagadish SVK, Hariprasad AS, Tomar AK, Anand A, Madan Pal and Aggarwal PK (2010) Effect of night temperature and radiation on growth, yield and grain quality of aromatic and non-aromatic rice. *Agri. Ecosys. Environ.* **138:** 274-281.

Rawson HM, Gifford RM and Condon BN (1995) Temperature gradient chambers for research on global environment change. I. Portable chambers for research on short-stature vegetation. *Plant Cell Environ*., **18:** 1048-1054.

Root T. L., Jeff T. P., Kimberly R. H., Stephen H. S., Cynthia R. and Alan P. J. (2003) *Nature* 421, pp 57-60.

Saini AD and Dadwal VK (1986) Heat unit requirement during the period of grain growth in wheat and its application for adjusting sowing dates in different regions. *Indian J. Agric. Sci*., **56:** 447-452.

Smit B, Burton I, Klein RJT and Wandel J (2000) An anatomy of adaptation to climate change and variability. *Clim. Change* **45:** 223–251.

Sutherst RW (1991) Pest risk analysis and the greenhouse effect. *Rev. Agric. Entomol.*, **79:** 1177-1187.

Watson RT, Zinyowera MC, Moss RH (eds.) (1998) The Regional Impacts of Climate Change: An Assessment of Vulnerability. IPCC II Report, Cambridge University Press, p 517.