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Climate Action in India-Challenges and Ways Forward in Agriculture

Asha Gupta *

Department of Life Sciences, Manipur University, Imphal, India

***Corresponding author:** Gupta A, Department of Life Sciences, Manipur University, Imphal, India, E-mail: ashaguptamu@gmail.com

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Abstract

Climate variability and climate extremes have impacts on agricultural production systems. India is a primarily agricultural economy, climate change would have a strong effect on much of the population's livelihoods dependent directly on agriculture to feed a growing population and ensuring future; food and nutritional security becomes a challenging task in a changing climate. The paper describes in the context of India, Changes in temperature and precipitation trends, Emission of Green House Gases, Impact of Climate Change on Crop Production, soil and water resources, adaptation and mitigation through Climate Action in India. Initiatives on Climate action in the context of National Action Plan on Climate change and specifically National Mission for Sustainable Agriculture through Indian Agriculture Research Institute, Indian Council on Agriculture Research, Agricultural Universities through various programmes and Panchayati Raj Institutions at grassroot level are being undertaken to recognise the region undergoing significant climate change, to establish methodologies for evaluating the effect of climate change on agricultural production and to recommend effective steps to reduce the impact of climate change by building resilient agro-ecosystems using climate information through climate-smart agriculture with defined institutional architecture to sustain the focus and integrate activities into ongoing schemes and programs related to sustainable agriculture practices. Technical solutions with community mobilisation will help cope with climate fluctuations. Similarly organising knowledge sharing festivals and meet for all stakeholders help in wider adaptation and mitigation reducing the impact of climate change and weather variability. Climate action is visible in policy decisions, research programmes, capacity building and technology application.

Keywords: Climate Variability;Green House Gas Emission;Crop production;Adaptation;Mitigation;NAPCC

Introduction

Climate change according to IPCC report is defined as the change in the state of climate that can be identified using the statistical tests by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It encompasses temperature increases; sea-level rises, changes in precipitation patterns, and increases in the frequency of extreme weather events [1].

The United Nations Framework Convention on Climate Change (UNFCCC) defined climate change as being directly or indirectly due to human activities which modify the composition of the global atmosphere and which have been observed over comparable time periods in addition to natural climate variability.

The earth's climate is changing rapidly, mainly due to anthropogenic activities. Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures and worsening extremes will impact the agriculture sector more and more adversely.

UN Secretary-General Ban Ki-moon says 'Climate change affects every aspect of society, from the health of the global economy to the health of our children. It is about the water in our wells and in our taps. It is about the food on the table and at the core of nearly all the major challenges we face today [2].

Agriculture and Climate Change

Agriculture is closely interconnected with weather and climate, Climate variability and climate extremes already have impacts on agricultural production systems. Future changes associated with climate change will present additional challenges [3]. This become a continuing source of disruption to ecosystem services, global warming, including temperature, precipitation and glacial run off, is expected to have a major effect on factors impacting agriculture [4]. Both inter annual and intra seasonal rainfall variability, higher growing season temperatures can have dramatic impacts on agricultural productivity, farm incomes and food security. As per FAO, there is sudden-onset disasters-especially floods that increased from 14 per cent of all natural

disasters in the 1980's to 20 per cent in the 1990's and 27 per cent since 2000 [5]. The intensity of tropical cyclones and frequency of heavy precipitation events are very likely to increase during the twenty-first century [6]. At the same time, the proportions of arid land are projected to increase (in the subtropics, low and mid-latitudes). According to IPCC, it is likely that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the twenty-first century over many areas of the globe; and there is medium confidence that droughts will intensify in the twenty-first century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration [7].

(**Figure 1**) shows the Global Scenario of Climate Change (Source-IPCC) projected scenarios of global warming indicate that the global average surface temperature could raise by 1.4 to 5.8°C by 2100. The projected rate of warming is unprecedented during last 10,000 years [8]. (**Table 1**) shows predicted effects of climate change on agriculture over the next 50 years.

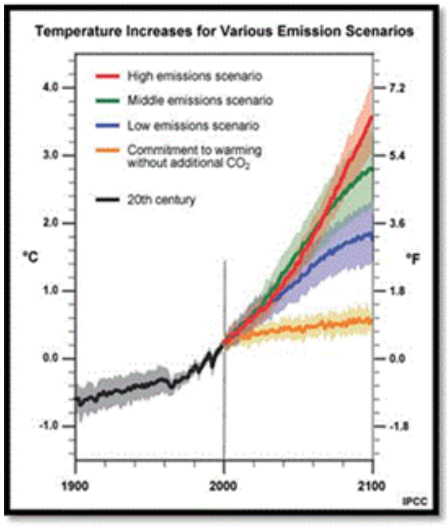

Figure1 Global Scenario of Climate Change (Source-IPCC,2007).

Table 1 predicted effects of climate change on agriculture over the next 50 years.

Climatic element	Expected changes by 2050's	confidence	Effects on agriculture
CO_2	Increase from 360 ppm to 450-600 ppm (2005 levels now at 379 ppm)	Very high	Good for crops: increased photosynthesis; reduced water use
Sea level rise	Rise by 10-15 cm Increased in south and offset in north by natural subsistence/rebound	Very high	Loss of land, coastal erosion, flooding, salinisation of groundwater
Temperature	Rise by 1-2°C. Winters warming more than summers. Increased frequency of heat waves	High	Faster, shorter, earlier growing seasons, range moving north and to higher altitudes, heat stress risk, increased evapotranspiration
Precipitation	Seasonal changes by ± 10%	Low	Impacts on drought risk' soil workability, water logging irrigation supply, transpiration
Storminess	Increased wind speeds, especially in north. More intense rainfall events.	Very low	Lodging, soil erosion, reduced infiltration of rainfall
Variability	Increases across most climatic variables. Predictions uncertain	Very low	Changing risk of damaging events (heat waves, frost, droughts floods) which effect crops and timing of farm operations
Source: Climate change and Agriculture, MAFF (2000)			

India Predominantly an Agricultural Country

India is a primarily agricultural economy, with 52 per cent of the population dependent directly on agriculture as either farmers or agricultural workers; Global climate change would have a strong effect on much of the population's livelihoods especially on 76 per cent population of the villages. In India, food production is susceptible to climate change, such as temperature fluctuations and monsoon rainfall. The increase in temperature has a direct effect on the Rabi crop and reduces the yield of wheat by 4 to 5 million tonnes per 1°C increments. The condition and quantity of fruits, tomatoes, tea, coffee, basmati rice and aromatic and medicinal plants are greatly influenced by a slight change in temperature and rainfall [9].

To feed a growing population and ensuring future food and nutritional security becomes a challenging task in a changing climate. An analysis of climate risks for crops in 12 food-insecure regions to identify adaptation priorities, conducted by Lobell et al. based on statistical crop models and climate projections for 2030

from 20 general circulation models indicated that South Asia and Southern Africa as two regions that, without sufficient adaptation measures, will likely suffer negative impacts on several crops that are important to large food-insecure human populations [10].

Financial Implications

Agriculture accounts for a large share in GDP (gross domestic product) (16%). Indian agriculture remains vulnerable to the vagaries of weather, and the growing threat of climate change may expose further this vulnerability. While analysing the impact of weather shocks on agricultural productivity in the short run, and that of climate change in the long run Hari et al. (2018) found that climate change could reduce farm incomes by 15-18%, and by 20-25% in unirrigated area. Hari et al. found that there has been a steady increase in temperature extremities. The number of 'very hot' days as well as the number of dry days has increased, consistent with models of climate change which predict increased variability in weather – irrigated areas are far less susceptible to weather shocks as far as crop yields are concerned [11].

Guiteras revealed that crop yields will decline by 4.5-9% in the short-run (2010-2039) and by a whopping 25% in the long- run (2070-2099) in the absence of adaptation by farmers [12]. Similarly Burgess et al. noted that a one standard deviation increase in high temperature days in a year decreases agricultural yields and real wages by 12.6% and 9.8%, respectively, and increases annual mortality among rural populations by 7.3% in India [13]. By contrast, in urban areas, they find virtually no evidence of an effect on incomes and a substantially smaller increase in the mortality rate. Hari et al. suggest that after taking these correlations into account, climate change could reduce farm incomes by 15-18% on average, and by as much as 20-25% in un-irrigated areas [11].

Change in Temperature and Precipitation Trends over India

Indian Meteorological Department (IMD) data report significantly higher average temperatures (by 1oC) and higher average rainfall (by about 100 mm per year). Average annual temperatures have risen by around 0.48 degrees (between 1970 and 2016) and average monsoon rainfall has declined by 26 mm (between 1970 and 2016). Rise in temperature is one of the predicted impacts of climate change with significant implications for agricultural productivity. In order to assess the long-term trends in temperature, the minimum and maximum temperature data for 47 stations across the country for more than 50 years was analysed. Overall, 55 to 80% stations located across the country showed increasing trends in average annual temperature. About 75, 60 and 54% of the stations in south, east and central India, respectively, showed increasing trend in maximum temperature, whereas only 8 and 13% of the stations in central and west India, respectively, showed decreasing trend. Similarly 80, 78 and 75% of the stations in east, north and south, respectively, showed increasing trends in minimum temperature [14].

Battisti and Naylor used observational data and output from 23 global climate models to show a high probability (>90 per cent) that growing season temperatures in the tropics and subtropics by the end of the twenty-first century will exceed the most extreme seasonal temperatures recorded from 1900 to 2006 [15].

Causes of Climate Change

The underlying causes of climate change are human actions. The measurements made in the last 50 years show that there has been a rise in air temperature of around 0.1°C per decade. The key reasons for the rise in temperature are industry, trade, power supply.

Emission of Green House Gases

Agriculture, forestry and agriculture, on the one hand, are vulnerable to the effects of climate change and, on the other, are also contributing to pollution. Agriculture accounts for 13.5% of global emissions of greenhouse gases from fertilised soils, enteric fermentation, combustion of wood, cultivation of rice, and production of manure and fertiliser [16].

As per IARI estimate [14], the world emits about 50 billion tons CO_2 eq., with contribution of India as of about 5%. In India the energy, agriculture and industry sector contribute GHGs respectively as 65% 18% and 16%. Within agricultural sector, enteric fermentation, soil and rice fields contributed 56%, 23% and 18% respectively Field experiments and a validated Info Crop model were used to estimate emissions of methane (CH4), nitrous oxide (N2O), and carbon dioxide (CO_2) from rice systems in India. Global warming potential (GWP) of these GHGs was calculated. Burning of crop residues on-farm and manure management contributed 2% and 1% of the emission. (**Figure 2**) shows Annual emissions of methane, nitrous oxide, carbon dioxide, and global warming potential from Indian rice fields.

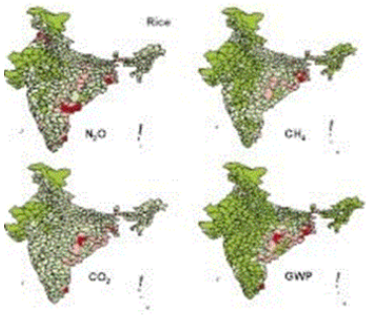

Figure 2 Annual emissions of methane, nitrous oxide, carbon dioxide, and global warming potential from Indian rice fields.

Legend	Emission Per district			
	Methane (Gg C)	Nitrous oxide (Mg N)	Carbondioxide (Gg C)	GWP (TG CO2 equiv.)
	<1	<1	<1	<0.001
	Jan-20	1-100	1-500	0.001-2.0
	20-40	100-300	500-1000	2.0-4.0
	40-80	300-500	1000-2000	4.0-10.0

Annual emissions of methane, nitrous oxide, carbon dioxide, and global warming potential from Indian rice fields. The spatial distribution of GHG emission and their GWP from the rice-growing areas of the country is presented at the district scale

The spatial distribution of GHG emission and their GWP from the rice-growing areas of the country is presented at the district scale. It was estimated that methane emission from Indian rice fields is about 3.5 million tons; the highest emission was from the irrigated continuously flooded rice (34%), followed by rain fed flood-prone rice (18%) and irrigated single aeration (18%). Rain fed drought-prone, deep water and irrigated multiple aerations rice ecosystems contributed 16%, 8% and 6% of methane, respectively. The emission of nitrous oxide ranged from 0.5–2.0 kg ha-1. Fertilizer was the largest source contributing about 75-80% to the total nitrous oxide emission from Indian agriculture [14].

Livestock sector is one of the main contributors to greenhouse gases emission (**Table 2**) shows Total methane emission from Indian livestock in 2003.

Table 2 Total methane emission from Indian livestock in 2003.

Species	Enteric emission (Tg/year)	Manure management (Tg/year)	Total Fermentation (Tg/year)
Indigenous cattle	3.34	0.41	3.75
Crossbred	0.63	0.08	0.71
Buffalo	3.34	0.46	3.8
Sheep	0.31	0.01	0.32
Goat	0.62	0.02	0.64
Others	0.09	0.06	0.15
Total	8.33	1.04	9.37
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Total	8.33	1.04	9.37

Impact of Climate Change

The effect of climate change on agriculture could contribute to food security problems and endanger subsistence practises on which a large part of the population relies. Climate change, as well as the types of crops that can be grown in many regions, can influence crop yields (both positively and negatively) by influencing agricultural resources such as water, the amount of solar radiation influencing plant growth and the prevalence of pests.

Despite complex spatial variations in climate change, the predictions agree the climate will become less desirable for farming activities in many developed countries, which they are now undertaking due to hotter and wetter atmospheres. Nicholas Stern's 2007 Stern Report, Director of the United Kingdom Government Economic Service and Adviser to the Government on the Economics of Climate Change and Progress, estimated that a 2°C rise in average temperature will decrease the world's gross domestic product by approximately 1%, while climate change would cause a decrease in annual growth [17].

According to the World Bank Study 'Switch down the Heat: Climate Anomalies, Regional Impacts and the Case for Adaptation' 2013, India's summer monsoon would be extremely volatile owing to a projected 2°C increase in the world's average temperature in the next decades. For power generation, drainage and, in some situations, also for drinking, changing rain cycles will leave some places under water and others without water. The study cautions that, due to excessive weather, India will see a substantial decline in crop yields by 2040. The situation in India, where groundwater supplies are already at a critical level and about 15% of the country's groundwater tables are over-exploited, is likely to be exacerbated by decreased water supply due to increases in precipitation levels and declining groundwater tables. More than 60% of the crop area in India is rain fed, rendering it extremely vulnerable to climate-induced shifts in the patterns of precipitation. It is projected that water for agricultural production in the river bases of the Indus, Ganges and Brahamputra will further decline by 2050 and will have an effect on the adequacy of food for some 63 million people [18].

Impact on Crop Production

According to the Intergovernmental Panel on Climate Change rising global temperatures and growing food demand will pose a large danger to global and regional food protection. It finds that a detrimental effect on major crops such as wheat, rice and maize can be seen even at just 1°C of warming [7].

The outlook for India and China is that the stress on the staple wheat crop will rise adversely, impacting the continent's overall food security. Total food production will decline after 2030, although certain areas will still see a slight increase in food

production [19].

(**Table 3**) shows Estimated Impact of Climate Change on Crop production in South-Asia 2050's.

Abrol et al. concluded that expected increase in CO_2 concentration will enhance the wheat yield by 30-40%. Shifting of wheat growing areas towards north is imminent as a result of global warming. In India, the adverse effects of rise in temperature could be absorbed with 5-10% increasing in precipitation [20]. The grain yield increase of 20-30% may be possible about 70% of the area under rice and wheat. In northern Indian warming could compensate the losses in yield by early pod set in winter legumes like chick pea.[21].

Impact on soil

Global climate change would have a detrimental impact on soil processes and resources that are critical for soil fertility and productivity regeneration. Increased temperature would decrease soil carbon storage due to increased carbon dioxide emission decomposition of soil organic matter, contributing eventually to low water holding and nutrient supply capacities. Several agricultural land management strategies like establishment of permanent vegetative cover as in the Conservation Reserve Program [22,23]. Conservation tillage practices such as no-tillage (NT) increased return of organic C to soil through perennial crops [24,25]. The greater yields of annual crops and reduction of fallow periods improve soil organic carbon storage [26,27]. For the alluvial soils of New Delhi, India, increase in grain+straw yield (biomass production) with increase in SOC concentration by 1% in the root zone was 1.6 Mg/ha for cowpea (Vigna unguiculata L.), 7.9 Mg/ha for maize (Zea mays L.), and 12.7 Mg/ha for wheat (Triticum aestivum L) [28]. The additional advantage of carbon sequestration is not only to offset the rising levels of carbon dioxide in the atmosphere but also to improve the quality of soil, so important for sustainable agricultural production. The loss of SOC pool, attributed to historic land misuse and soil mismanagement, can yet be remediated by conversion to a restorative land use and adoption of recommended management practices (RMPs) which can create positive C and nutrient budgets, conserve water, control soil erosion, improve soil structure and minimize soil disturbances thus enhancing the SOC pool and sustaining agronomic productivity under most conditions. These practices include appropriate afforestation of degraded/desertified soils, conversion of degraded croplands to pastures and tree cover, conservation agriculture with no-till farming and crop residue mulching along with cover cropping, integrated nutrient management based on appropriate use of organic and inorganic sources of plant nutrients, use of compost/manure and biochar in conjunction with other soil amendments, and complex crop rotations including agroforestry [29].

Impact on Water Resources

Climate change will affect the predictability and instability of water supply, as well as the rise in the incidence of floods and droughts. Climate forecasts produced for India in the 2050's suggest an average temperature rise of 2-4°C during that time, an overall decrease in rainy days of more than 15 days in Western and Central India and an increase of 5-10 days near the foothills of the Himalayas and North-East India. Climate change will modify rainfall, evaporation, runoff, and soil moisture storage. Demand of irrigation water would increase with increased temperature and higher evapo-transpiration resulting in lowering of groundwater table. Increase in runoff is projected in the wet season that may lead to increase in frequency and duration of floods and also soil erosion. However, the excess water can be harvested for future use by expanding storage infrastructure, and the quality of groundwater along the coastal track will be more affected due to intrusion of sea water. Reduction in yield in the rain fed areas due

Table 3 This shows Estimated Impact of Climate Change on Crop production in South-Asia 2050s.

Crops	Crop production (year 2000)	Crop as % of total Production	Projected yield improvement No. Climate Change (% p.a.)	Crop production 2050s, No Climate Change	Crop Production 2050 2050s with Climate Change and No Co_2 Fertilization Effect	Average Annual yield change with Climate Change
Rice(mmt)	120	48%	0.90%	169	145	-0.20%
Wheat(mmt)	97	38%	1.60%	191	103	-1.30%
Maize(mmt)	16	6%	0.60%	19	16	0.10%
Millet(mmt)	11	4%	1.50%	12	11	0.00%
Sorghum(mmt)	8	3%	1.20%	10	8	1.40%
Total(mmt)	252			401	282	
Cereal Availability	185			174	122	
Source: World Bank Report, June 2013 „Then Down the Heat; Climate Extremes Regional Impact and the case for Resilience						

to increased crop water demand and changes in rainfall pattern during monsoon season. Increase in temperature will lead to increased water requirement for crops due to high evaporative demand and crop duration due to forced maturity.

The occurrence of moisture stress during flowering, pollination, and grain-filling is harmful to most crops and particularly so to corn, soybeans, and wheat. Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress; as a result there will be a need to develop crop varieties with greater drought tolerance.

Rewarding farmers/land managers for providing ecosystem services would be a strong incentive towards adoption of recommended management practices for sustainable management of water resources.

Adaptation and Mitigation

The Intergovernmental Panel on Climate Change (IPCC) describes mitigation as "An anthropogenic intervention to reduce greenhouse gas sources or improve them''. Development of long-term adaptation strategy in agriculture depends on addressing similar issues in the short-term, recognizing the fundamental understanding that adaptation is a location-specific and continuous learning process [5]. It refers to a system's capacity to respond to climate change, including climate instability and extremes, to minimise possible harm, to take advantage of opportunities or to live with the implications. Hansen et al. reiterated that uncertainty associated with climate variability, combined with risk aversion on the part of decision-makers, causes substantial loss of opportunity in climatically favourable and even average years [30].

Climate Action in India

NAPCC

The National Action Plan on Climate change was formally launched on June 30th, 2008. The NAPCC identifies measures that promote development objectives while also yielding co-benefits for addressing climate change effectively [30]. There are eight “National Missions” which form the core of the National action plan. They focus on promoting understanding of climate change, adaptation and mitigation, energy efficiency and natural resource conservation. In this connection, India is determined that its per capita greenhouse gas emission will at no point exceed that of developed countries even as we pursue our development objectives. Eight National Mission of the NAPCC focused on multi-pronged, long-term and integrated strategies for the key goals in the context of achieving the adaptation and mitigation of climate change.

The Eight National Missions are namely:

- National Solar Mission;
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for a Green India
- National Mission for Sustainable Agriculture and
- National Mission on Strategic Knowledge for Climate Change.

Indian Agricultural Research Institute (IARI)

The Indian Agricultural Research Institute, New Delhi, studied the susceptibility of agricultural development to climate change and gave the following predictions:

1. Wheat output

a) The analysis showed that in most areas, rising temperatures by around 2°C would decrease grain yields in future. Climate change has had a weaker effect on regions with higher productivity potential comparatively, such as in northern India, than areas with lower potential.

b) Climate change would also lead to a change in borders in areas suitable for growing such crops.

c) Climate change yield declines are expected to be more pronounced for rain-fed crops as compared to irrigated crops due to no mitigation mechanism for fluctuations in rainfall.

d) The yield differential is impacted by the baseline climate. The decrease in possible wheat yield varies from 1.5 to 5.8% in subtropical areas; however the decrease is comparatively larger in tropical regions, meaning that hotter regions should expect higher crop yields.

(**Figure 3**) shows the Impact of climate change on wheat yields in India (HaDCM3 scenarios for 2020 and 2050).

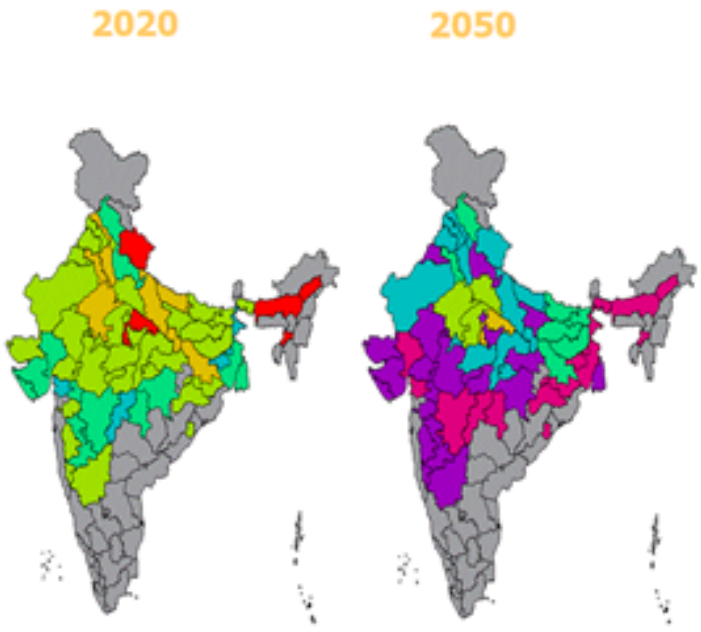

Figure 3 Impact of climate change on wheat yields in India (HaDCM3 scenarios).

2. Rice production

a) The average rise in temperature is expected to decrease the yield of rice.

b) Eastern areas are expected to be more affected by higher temperatures and reduced radiation, leading to comparatively fewer grains and shorter durations of grain filling.

c) While crops may benefit from additional carbon dioxide, an increase in temperature has nullified this effect.

Initiatives taken by ICAR

The Indian Council of Agricultural Research (ICAR) has given high priority to understanding the effects of climate change and designing solutions for adaptation and mitigation through its Network Research Initiative, the National Climate Change Project, in order to resolve the challenges raised by climate change in the agricultural system (NPCC). Its ultimate objectives are to recognise the region undergoing significant climate change, to establish methodologies for evaluating the effect of climate change on agricultural production and to recommend effective steps to reduce the impact of climate change [30].

Building Resilient Agro-Ecosystems by Using Climate Information

Attempts of climate-smart agriculture (CSA) to be understood and appreciated by decision makers at all levels are being undertaken. Structured trainings to build the capacity of officials of relevant departments to sensitize them and to understand impacts of global climate change events at local levels are being organised with defined institutional architecture to sustain focus and integrate activities into ongoing schemes and programs related to sustainable agriculture practices. The institution of a Panchayat in India has the capacity to obtain funds for a number of eco-friendly activities that will help to adapt and build resilience to climate change.

Research at ICAR and the state agricultural universities (SAUs)

Focus on agricultural research and innovation to ensure efficiency in resources (water; nutrient) use; carbon sequestration; assessment of GHG emissions from agriculture sector, etc., are being made with enhanced allocation of budgetary support and collaborations/partnerships. Governments at both central and state levels are providing funding support for development of technologies and approach those suit local crops, affordable insurance products to create safety net for the small holders who are often the neglected part of agricultural community. ICAR and SAUs are creating knowledge sharing festivals and meet for all stakeholders for wider adaptation and mitigation to the climate change and weather variabilities [31,32].

National Climate Resilient Agriculture Initiative (NICRA)

A major project entitled NICRA was initiated in 2010-11 to deal with climate change in agriculture with an outlay of 350 crores with the objectives:

I. Improve the resilience of Indian agriculture covering grains, livestock and fisheries to climate instability and climate change.

II. In several of the model districts, the project has been well received. Farmers in NICRA villages throughout the country have been introduced with innovations like on-farm water storage in reservoirs, augmented irrigation, increased drainage in water logged areas, site-specific nutrient management and implementation of early maturing drought resistant varieties etc. Overall, the project has created great awareness among farmers who now expect that technical solutions with community mobilisation will help cope with climate fluctuations.

In the Twelfth Plan under the NICRA network project focus was placed on:

I. Improving current network research on adaptation and mitigation with better infrastructure and capacity development.

II. Setting up phenotyping platforms and temperature, CO_2, ozone gradient facilities at established institutions.

III. Strengthening research on climate-sensitive crops such as cotton, corn, sugar cane, onion, etc.

IV. Studies on emerging coping mechanisms by water saving technology at a number of locations.

V. Implementation of a pest and disease monitoring scheme at national level.

VI. Expanding demonstration and distribution of technologies to disadvantaged districts [33].

National Mission for Sustainable Agriculture (NMSA)

A mission, NMSA was initiated during the twelfth plan for better farming practices implementation especially in rain-fed areas with synergization of resources and organised farming to increase agricultural productivity. Given that climate variability will have an effect on food production in the future, it is crucial that the schemes are being devised by improving the areas, i.e. Phenotyping/breeding projects for seeds, horticulture and livestock, the demonstration of technologies in the vulnerable districts [30].

Conclusion

Globally, climate change and farming are inseparably related, both affecting and impacting each other. Important steps being initiated through the National and State Action Plans on Climate Change are yet to deliver effective means of adaptation implementation and hence, it's needed that the networks of close coordination between the various implementing agencies be strengthened. Fully exploiting the resource use efficiency among the farm enterprises will improve the agriculture situations. Knowledge gaps and the need for capacity building based on the understandings of key stakeholders are highly relevant to practitioners and policy makers. Establishing common research consortia of all researchers working on problem solving and formulation of the long, medium and short term plans will help in achieving the needed goals in relation to the climate change.

References

1. Bates BC, Kundzewicz ZW, Wu S, Palutikof J (2008) Climate change and water. Intergovernmental Panel on Climate Change, Techical paper of the IPCC, IPCC Secretariat, Geneva p: 210.
2. Ban Ki-moon (2009) Opening remarks to the World Business Summit on Climate Change. UN Secretary-General, Copenhagen, Denmark.
3. Karl TR, Meehl GA, Miller CD, Hassol SJ (2008) Weather and climate extremes in a changing climate. US Climate Change Science Program,USA pp: 1-137.
4. Howden SM, Soussana JF, Tubiello FN, Chhetri N (2007) Adapting agriculture to climate change. Proc Natl Acad Sci 104: 19691-19696.
5. FAO (2008) The state of food insecurity in the world 2008. High food prices and food security threats and opportunities,Rome,Italy pp: 1-2.
6. Knutson MC, Bride TR, Chan JL, Emanuel J (2010) Tropical cyclones and climate change. Nat Geosci 3: 157-163.
7. Field CB, Barros V, Stocker TF, Qin D, Dokken DJ (2012) Managing the risks of extreme events and disasters to advance climate change adaptation, Cambridge University Press, Cambridge, UK pp: 582.
8. Adger N, Aggarwal P, Agrawala S, Alcamo J, Allali A, et al. (2007) Climate Change: Impacts, adaptation and vulnerability. Working Group II Contribution to the 4th Assessment Report. Cambridge University Press, Cambridge, UK pp: 1-22.
9. Anant TCA, Jeyalakshmi S, Parameswaran V, Mathew J, Panwar RK (2013) Statistics Related to Climate Change in India. Ministry of Statistics and Programme Implementation pp: 1-280.
10. Lobell DB, Burke MB, Tebaldi C, Mastrandrea MD (2008) Prioritizing climate change adaptation needs for food security in 2030. Science 319: 607-610.
11. Hari S, Khare P, Subramanian A (2018) Climate change and Indian agriculture. Voxdev pp: 1-1.
12. Guiteras R (2009) The impact of climate change on Indian agriculture.Econdse pp: 1-54.
13. Burgess R, Deschene O, Donaldson D, Greenstone M (2014) The unequal effects of weather and climate change: Evidence from mortality in India. MIT pp: 1-56.
14. Indian Agriculture Research Institute (2019) Department of Agriculture, Co-Operation and Farmers Welfare.
15. Battisti DS, Naylor RL (2009) Historical warnings of future food security with unprecedented seasonal heat. Science 323: 240-244.
16. Swaminathan MS, Kesawan PC (2012) Agricultural Research in an Era of Climate Change. Agricultural Research 1: 3-11.
17. Lybbert T, Sumner D (2010) Agriculture technology for climate change mitigation and adaptation in developing countries: Policy options for innovation and technology diffusion. Int Food and Agri Trade Policy Council pp: 231-243.
18. World Bank (2013) Warming climate in India to pose significant risk to agriculture, Press Release.
19. Dutta AP (2014) Climate change: IPCC report warns of looming food crisis. Down to Earth.
20. Abrol YP , Bagga N ,Chakravarty N.V. K Wattal PN (1991) Impact of rise in temperature on the productivity of wheat in India. In prodeedings of Indo-US workshop on impact of global climate change on photosynthesis and plant productivity PP: 787-798.
21. Mahi GS, Hundal SS (2002) Climate and Agriculture, recent advances in agronomy, Indian society of Agronomy, IARI, New Delhi pp: 37-58.
22. Huggins DR, Allan DR, Gardner JC, Karlen DL (1997) Enhancing carbon sequestration in CRP-managed land. Lewis-CRC Press, Boca Raton, FL pp: 323-334.
23. OgleSM, Breidt FJ, Eve MD, Paustian K (2003) Uncertainty in estimating land use and management impacts on soil organic carbon storage for U.S. agricultural lands between 1982 and 1997. Global Change Biol 9: 1521-1542.
24. Halvorson AD, Weinhold BJ, Black AL (2002) Tillage, nitrogen, and cropping system effects on soil carbon sequestration. Soil Sci Soc Am J 66: 906-912.
25. Bernacchi CJ, Hollinger SE, Meyers T (2005) The conversion of the corn/soybean ecosystem to no-till agriculture may result in a carbon sink. Global Change Biol 11: 1867-1872.
26. Huggins DR, Buyanovsky GA, Wagner GH, Brown JR (1998) Soil organic C in the tallgrass prairie–derived region of the corn belt: Effects of long-term crop management. Soil Till Res 47: 219-234.
27. Machado S, Rhinhart K, Petrie S (2006) Long-term cropping system effects on carbon sequestration in eastern Oregon. J

Environ Qual 35: 1548-1553.

28. Kanchikerimath M, Singh D (2001) Soil organic matter and biological properties after 26 years of maize-wheat-cowpea cropping as affected by manure and fertilization in a Cambisol in semiaridregion of India. Agric Ecosyst Environ 86: 155-162.

29. Purakayastha TJ (2011) Evaluating the potential of biochar to increase carbon sequestration in soil for mitigating climate change. Deputation Report, Indian Council of Agricultural Research, Krishi Anusandhan Bhavan, New Delhi.

30. Hansen JW, BaethgeW, Osgood D, Ceccato P, Ngugi RK (2007) Innovations in climate risk management: Protecting and building rural livelihoods in a variable and changing climate. J Semi-Arid Trop Agric Res pp: 4.

31. National Mission for Sustainable Agriculture (2020) Department of Agriculture Cooperation & Farmer's Welfare, Government of India.

32. Central Research Institute for Dryland Agriculture(2020) Ministry of Agriculture and Farmers' Welfare,Government of India.

33. National Innovations in Climate ResilientAgriculture (2020) Indian Council of Agricultural Research, Government of India.