

# CLIMATE CHANGE AND ITS IMPACT ON PRODUCTIVITY OF INDIAN AGRICULTURE

**Shayan Javeed\* and Anupam Manuhaar\*\***

*The main focus of this paper is to give an account of the impact of changing climate on productivity of Indian agriculture. Climate is considered to be the main determinant of agricultural productivity. Hence, agriculture has been one of the major issues concerned with discussion on climate change. As agriculture represent the core sector of the Indian economy and is the main source of livelihood for majority of Indian population, it becomes further necessary to make an assessment of impact of climate change on the productivity of Indian agriculture. The predicted medium term impact of climate change on agricultural productivity is negative as it is estimated the yield of majority of the crops would decrease by 4.5% to 9% for period ranging from 2010-2039. The long term (2070-2099) impacts of changing climate are more severe as it shows that the yield could decrease by 25% if no adaptation measures are taken. If such predictions come out true it means it would impose a significant cost on Indian economy if no adaptation and mitigation techniques are used.*

**Keywords:** Agriculture, Yield, Crops, India, Temperature.

## INTRODUCTION

Climate change and agriculture have a very strong linkage. Agriculture still depends fundamentally on the weather. Climate change is already responsible for the decrease in the agricultural productivity because of the severely changing weather patterns. Climate change is responsible for continuous occurrences of floods, worsening desertification process and disrupts growing seasons. The Food and Agriculture Organization (FAO) in their reports have warned that if the global temperature increases by two or four degree Celsius, it would severely affect the productivity of agricultural outputs. Due to this increase in temperature crop yield in agriculture in Africa and western Asia would reduce by 15-35 % and in Middle East this decrease could be around 25-35%. An increase of 2°C in the mean temperature would reduce the productivity of most crops and further cause the extinction of millions of species.

Climate change can affect agricultural productivity in many ways. Beyond a certain temperature range, warming cause a decrease in the annual yield because more warming cause the process of development of crops speedier, thereby producing less than normal grains in the process. With the increase in temperature evaporation process of the soil accelerates and plants increase the rate of transpiration i.e. plants lose more moisture from their leaves. The combined effect is called "evapotranspiration". This process of evapotranspiration further decreases the productivity of crops. Extreme events which occur due to climate change also play a role in decreasing productivity as frequent floods and droughts increase the agricultural losses Adams et al (1998). Even after so much modernization and industrialization, a large part of the Indian agriculture still depends on monsoons. Any change in the monsoon pattern has its direct impact on agriculture. Since climate change is having a greater influence on weather patterns, it can potentially affect millions of small and marginal farmers whose livelihood is dependent on agriculture (Mitra Amit, 2009). Agriculture has been shown to produce significant effects on climate change, primarily through the

---

\*Research Scholars, Dept. of Economics, University of Jammu

production and release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide, but also by altering the earth's land cover, which can change its ability to absorb or reflect heat and light, thus contributing to radioactive forcing. Saseendran et al. (2000) reported that a small increase of one degree in the annual temperature tends to reduce the yield of rice by 6 %. Since the concentration of greenhouse gases is continuously increasing, this cause a much serious concern as it would have a direct as well as indirect affect on agriculture productivity (IPCC, 2001; Bhatia et al., 2004). International Symposium on "Agro-meteorology and Food Security" organized in February 2008 in Hyderabad. The most serious concern of the symposium was the continuous decrease in agricultural productivity has come down over a period of time. It is expected that by the year from 2000 to 2030 the agriculture output would decrease by 1.5% per year and further to 0.9% per year in the next 20 years to 2050. The decrease in agriculture productivity could cause the serious problem of food security and may threaten the livelihood activities upon which much of the population depends. Climate change has severely affected crop yield as well as the type of crop that can be grown in a certain area, by influencing agricultural inputs like water for irrigation, amounts of solar radiation etc. Increasing crop failures and livestock deaths are already imposing high economic losses and undermining food security. More frequent droughts and increasing water scarcity may demolish large parts of the tropics and further undercut water used for irrigation and drinking purpose in communities of poor and vulnerable people (World Bank, 2009). Water supply for irrigation also gets influenced due to changes in volume of water as precipitation and evaporation rates are altered. Groundwater recharge rates and aquifer exploitation may also be altered (McCarl and Reilly (1999). Due to droughts caused by changing climate the fertility of soil decreases would further decrease the productivity Joubert et al. (2008). It was further analyzed that agricultural productivity investments (agricultural research, irrigation expansion, etc) of US \$7.1-7.3 billion per year is required at the global to make up for the negative impacts of climate change on productivity and raise the raise the calorie consumption of the people especially children. In case of South Asia the investment required is about US \$1.5 billion per year Nelson et al (2009).

## CLIMATE CHANGE AND AGRICULTURE PRODUCTIVITY

In India agriculture contribute about 15% to the GDP and provides employment to about 52% population and majority of worker are from the poor section of the society, the impacts of climate change on agriculture assume significant importance for India (FAO, 2006). For India it is projected that up to 2100 the temperature would increase by 2-4°C coupled with increase in the rate of precipitation (Mall et al. (2006). The available evidence shows that such a scenario results in significant drop in the productivity of important cereal crops like rice and wheat. The economic impacts of climate change on agriculture have been studied extensively world over and it continues to be a hotly debated research problem. Two broad approaches have been used so far in the literature to estimate the economic impact of climate change on agriculture:

(1) The first approach is called as production function approach or crop modeling approach. This approach is based on controlled agricultural experiments where specific crops are exposed to different climatic conditions in laboratory and then yields are compared across different climates.

(2) The second approach is known as Ricardian approach and was propounded by Mendelsohn et al. (1994). This approach allows all mitigating behaviors by performing cross-sectional regressions of land prices on county-level climate variables. If markets functions normally land prices will reflect present discounted value of profits from all fully land. So, in principle, this approach explains the direct impact of climate on specific crops as well farmers.

Using the production function approach it was shown that if the doubled carbon dioxide concentration level in doubled, then in the later half of twenty first century under different climate change the gross domestic product would decline by 1.4 to 3 percentage points under various climate change situations the GDP of India would decrease by 1.4% to 3% Kumar and Parikh (2001a).

In the alternative approach called as Ricardian approach, researchers tried to link the value of land to the climate scenario by using cross-sectional evidence. Since this approach is based on the observed evidence of farmer behavior it could include all adaptation possibilities. This approach was also used for India and it was found that a 2°C rise in temperature and seven percent increase in rainfall would lead to almost 10 percent loss in farm level net revenue (Kumar and Parikh (2001b) and Sanghi and Mendelsohn (2008). It was also analyzed that 4° C rise in temperature could reduce the grain yield in India by 25%–40 %. It was further estimated that if by 2100 the temperature increases by 2° C and precipitation by 8 percent, then net revenue in agriculture decrease by 12.3 percent in the case of India Rosenzweig and Parry (1994). The Indian Council of Agricultural Research (ICAR) has estimated that annual wheat output may decline by four to five million tons with every 1°C rise in temperature.

According to A K Singh, Deputy Director-General (Natural Resource Management) of the Indian Council of Agricultural Research (ICAR), medium-term climate change predictions have projected the likely reduction in annual crop yields due to climate change between 4.5% and 9% by 2039. A 1°C rise in temperature may reduce yields of major food crops by 3-7%. Studies done at the Indian Agricultural Research Institute indicate that for every 1°C rise in the temperature in the growing season, there is possibility of loss of 4 – 5 million tons of wheat. It was also revealed that showed that a 2°C increase in temperature would decrease wheat yields in most places in India Agarwal and Sinha (1993). Another study reveals that an increase of 2°C in temperature could decrease the yield of rice by about 0.75 ton per hectare in the high yield areas; and an increase of 0.5°C in winter temperature would result in wheat loss by 0.45 tons per hectare (Sinha and Swaminathan (1991). It was projected that without taking the CO<sub>2</sub> fertilization effects wheat yields could decrease between 28-68% due to climate change (Rao and Shina (1994). Saseendran et al. (2000) an increase of 1°C in the mean annual temperature tends to decrease rice yield by about 6% Saseendran et al. (2000). Horticultural crops are more vulnerable to changing climatic conditions than cultivable crops. Temperature changes will specifically affect field vegetables more. Water deficits will have a direct affect on the productivity of fruits and vegetables (Zarin, 2007). Impact of climate change on agricultural productivity is very location specific which includes soil types, crops and even the socio-economic conditions of the farmers (Rao et al 2008). There is now a growing concern regarding the decline in fertility of soil, decrease in water table, rising salinity, resistance to many pesticides and degradation of irrigation water quality in north-western India and these have really affected the productivity of this region (Sinha et al., 1998; CGWB, 2002). It is clear that as a result of changing climate more nutrients have been removed from the soil, and the farmers have to apply more fertilizers to get the same yield, they were getting 20–30 years ago. It is further concluded that negative trends in solar radiation and an increase in minimum temperature has resulted in declining trends in productivity of rice and wheat in the Indo-Gangetic plains of India Pathak et al. (2003). Recent international report indicates a probability of 10 – 40% loss in crop productivity in India with increases in temperature by 2080 – 2100 IPCC (2007). Continuous and increasing rate of melting of glaciers in Himalayas will affect the availability of water for irrigation purposes especially in the Indo-Gangetic plains thereby severely affecting the agriculture productivity of the region. M.S. Swaminathan, the pioneer of Green Revolution in India predicted

that for 1°C rise in temperature in highly productive areas like Punjab, U.P. and Haryana could result in loss of about 6 million tonnes of wheat annually. The studies conducted by the Indian Agricultural Research Institute (IARI) and other institutions shows the possibility that for every 1°C rise in temperature annual wheat production would decrease by 3% whereas production of rice would decrease by 10% (Aggarwal et al, 2004). The length of the growing period in rainfed areas is likely to decrease, especially in peninsular regions. Growth in agricultural productivity was about 2% where as other sectors are experiencing 8% growth thus causing lots of rural out-migration, farmer suicides and land being lost to non-agricultural use (Krishna (2004).

## ADAPTATION AND MITIGATION STRATEGIES

As the above discussion makes it clear that climate change possesses a serious threat to the productivity of agriculture and thus seriously affecting the whole economy as Indian economy is still dependent on agriculture. The option which remains is the use different adaptation and mitigation strategies so as to lessen the impact of changing climate on the overall productivity of agriculture in India. Before throwing a light on different adaptation and mitigation strategies let us first define these two concepts.

**Adaptation:** Social risk management for reduction of risks and human vulnerability associated with climate change (Heltberg, R., Jorgensen, S. L., and Siegel, P. B., 2008). Adaptation measures, includes cash transfers, asset restocking, nutritional/feeding programmes.

**Mitigation:** climate change mitigation scenarios involve reductions in the concentrations of greenhouse gases, either by reducing their sources or by increasing their sinks to reduce the potential effect of climate change (Molina, M.; Zaelke, D.; Sarmac, K. M.; Andersen, S. O.; Ramanathane, V.; Kaniaruf, D. 2009).

### The Mitigation Methods Include:

1. Improvement in inventories used for greenhouse gas emission by using state of art emission equipments and technique of GIS for upscaling.
2. By enhancing the mitigation potential of biofuels by their genetic improvement and by using engineered microbes.
3. Assessing the biophysical and socio-economic implications of proposed GHG mitigating interventions before forming any policy for their execution.
4. Establishment of 'Green Research Fund' which will be of great help in providing finances for research on various adaptation and mitigation programmes and their implications and impact assessment.

### The Adaptation Methods that can be used include:

1. Developing new genotype of plants which can tolerate stress, heat and droughts.
2. Developing new land use systems by exploring opportunities of restoration or enhancement of soil properties.
3. Enhancing weather management services by making contingency plans for risks related to extreme temperature and less rainfall.
4. Enhancement of research on better transformation of short, medium and long range weather forecasts so as to reduce production related risk.

## CONCLUSION

This paper gives an analysis of climate change impact on agriculture productivity in India and shows that trend is likely to be negative. Since agriculture contribute about 15% of India's GDP, this implies that it would tend to reduce the GDP by about 1 to 1.8% per year up to 2050. Agriculture productivity is severely affected by climate change. Most vulnerable to the effect of climate change would be cereal crops especially rice and wheat. Among the farmers small and subsistence farmers will be the most vulnerable group, as these people have small farm sizes, low capital and technological base. Further social-scientific study of impacts of climate change on productivity of different crops is more concerned when taken with the increased frequency of extreme events. Floods, droughts etc. tend to have a serious repercussion on the agriculture productivity.

What is needed by India is to develop adaptation and mitigation strategies and does research work so as to combat the effect of climate change. Integration of different adaptation and mitigation into sustainable planning is the most important requirement to reduce the vulnerability. It is very crucial for India to take a make planning at national and regional and to take on the climate change and so as to increase the efficiency and productivity of agriculture. In no necessary adaptation and mitigation measures are not taken the long run repercussion on agricultural productivity would be much worse which would further deteriorate the conditions.

## References

- Adams, R. M., B. Hurd, S. Lenhart, and N. Leary. 1998 "The Effects of Global Warming on Agriculture: An Interpretative Review". *Journal of Climate Research* **11**, 19-30.
- Aggarwal; Sinha; 1993 "Effect of Probable Increase in Carbon Dioxide and Temperature on Productivity of Wheat in India" *Journal of Agricultural Metrology*.
- Aggarwal; Joshi; Ingram; Gupta; 2004 *Adapting Food Systems of the Indo-Gangetic Plains to Global Environmental Change: Key Information Needs to Improve Policy Formulation*, Environmental Science & Policy, 7, pp. 487-498).
- Bartlett; 2008 *Climate Change and Urban Children: Impacts and implications in low- and middle-income countries Human Settlements Discussion Paper Series: Climate Change and Cities 2* London: International Institute of Environment and Development
- CGWB; 2002 'Master Plan for Artificial Recharge to Groundwater in India', Central Groundwater Board, New Delhi, February 2002, 115 pp.
- FAO; 2006 *FAO Statistical Yearbook 2005*. 2006. Food and Agricultural Organization, 2006.
- Heltberg ; Jorgensen ; Siegel ; 2008 *Climate Change, Human Vulnerability, and Social Risk Management*, The Social Development Department, World Bank, pp. 4-5.
- IPCC (Intergovernmental Panel for Climate Change); 2001, *Climate Change 2001 – The Scientific Basis*, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell and C. A. Johnson (eds.)], Cambridge University Press, Cambridge, UK, 881 pp.
- IPCC ; 2007 *Climate Change 2007 – Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Cambridge University Press, London, UK.
- Joubert ; Rothauge ; G. N. Smit., 2008 *A conceptual model of vegetation dynamics in the semiarid Highland savanna of Namibia, with particular reference to bush thickening by Acacia mellifera*. *Journal of Arid Environments* 72:2201-2210.
- Krishna ; 2004 *Escaping poverty and becoming poor: Who Gains, Who Loses, and Why?* World Development,

- 32, 121-136.
- Kumar ; Kavi ; Parikh ; 2001a “*Socio-economic Impacts of Climate Change on Indian Agriculture*”, International Review of Environmental Strategies, 2(2): 277-293.
- Kumar; Kavi; Parikh; 2001b “*Indian Agriculture and Climate Sensitivity*”, Global Environmental Change, 11(2): 147-154.
- Bhatia; Mall; Lal; Rathore; Singh, ; 2004 ‘*Mitigating climate change impact on Soybean productivity in India: A simulation study*’, Agricultural and Forest Meteorology, **121** (1–2), pp. 113–125.
- Mall; Singh; Gupta; Srinivasan; Rathore; 2006 “*Impact of Climate Change on Indian Agriculture: A Review*”, Climatic Change, 78: 445-478)
- Mc Carl; Reilly; 1999 “*Water and the Agricultural Climate Change Assessment: Issues From the Standpoint of Agricultural Economists*”, Proceedings of American Water Resources Association Special Conference on Potential Consequences of Climate Variability and Change to Water Resources, Atlanta, GA.
- Mitra ; 2009 “*Climate changes: Adaptation Activities in India*”, Gorakhpur Environmental Action Group, Gorakhpur U.P.
- Nelson ; Rosegrant, ; Koo; Robertson ; Sulser; Zhu; Ringler; Msangi; Palazzo; Batka; Magalhaese; Valmonte-Santos; Ewing; Lee 2009 *Climate Change. Impact on Agriculture and Costs of Adaptation*, IFPRI Food Policy Report, Washington, D.C.: International Food Policy Research Institute.
- Pathak; Aggarwal; Peng; Das; Singh; Singh; Kamra,; Mishra; Sastri; Aggarwal; Das; Gupta; 2003 ‘*Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains*’, Field Crops Research **80**, 223–234.
- Rao; Sinha; 1994 *Climate changes and agriculture*. Nature **437**: 102- 109.
- Rao, G.G; S.N., Rao; Vanaja; Rao, V.U.M; Ramakrishna; 2008 *Impact of regional climate changes over India*: In G.S.L.H.V. Prasad Rao, G.G.S.N. Rao, V.U.M. Rao and Y.S. Ramakrishna (Eds) ‘*Climate change and agriculture over India*’. AICRP on Agrometeorology, CRIDA, Hyderabad pp: 13–48
- Rosenzweig; Parry; Fischer; 1995 “*World Food Supply.*” In K. M. Strzepek, and J. B. Smith, eds., *As climate changes: International impacts and implications*. Cambridge, U.K.: Cambridge University Press.
- Sanghi ; Mendelsohn ; 2008 “*The Impacts of Global Warming on Farmers in Brazil and India*”, Global Environmental Change, 18: 655-665.
- Saseendran; Smith ; Matson; 2000 *Ecological and evolutionary responses to climate change*. Science 284: 1943-1947.
- Sinha; Swaminathan; 1991 “*Deforestation Climate Change and Sustainable Nutrients Security*”, Climate Change 16, pp. 33–45.
- Sinha; Singh; Rai,.; 1998 ‘*In: Decline in crop productivity in Haryana and Punjab: myth or reality?*’, Indian Council of Agricultural Research, New Delhi, p. 89.
- Solomon; Qin; Manning; Chen; Marquis; Averyt; Tignor ; Miller, eds. 2007 *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge: Cambridge University Press.
- World Bank ; 2009 *Agriculture for Development, Overview*. Retrieved on Jan 10, 2009.
- Zarin ; 2007 *Global climate changes and its effect on agriculture*. Nature 408: 184- 188.