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A Systematic Review of Climate Change and Food Security Nexus – Perspectives from India

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Abstract: *The issue of climate change is no longer an environmental matter of concern per se but has several entangled dimensions to it. India has experienced fast GDP growth which fashioned a great opportunity to improve the developmental indicators including food security but in reality the results are much below expectations. There is scientific consensus on the climate change issue expecting to have substantial impacts on food security. Given this background, this paper reviews the issue of food security in the Indian context and the impending crisis that awaits us.*

1. Background

Seasonal patterns, temperature and precipitation constitute the critical components of agricultural production systems. Interestingly, it is anticipated that India will face an increase in the average surface temperature by 2 to 4 degrees centigrade coupled with the decrease in the number of rainy days and an increase in the intensity of cyclonic outbursts [23]. Around 60 per cent of India's total agricultural regions are rain-fed and consequently is greatly vulnerable to climate change impacts all through the rainy season. This burning issue of climate change has posed serious question marks on major crop production in particular wheat. Research papers have already estimated bigger losses in the Rabi season (e.g. in wheat yield) as compared to the Kharif crops [14]. This in turn increases the gravity of disparities in cereal yields between the developed and the developing countries [4]. India has experienced fast GDP growth which fashioned a great opportunity to improve the developmental indicators including food security but in actuality the results are much below expectations. There is an up-and-coming scientific consensus on climate change having substantial impacts on food security.

In this context, the present paper reviews this issue supported by empirical evidences. Moreover, it comprehensively explores the manifold effects that climate change could have on agricultural productivity, food production systems, and food security scenario in India. This review ends with a conclusion that summarizes the findings and highlights the scope for further research.

2. Search Strategy

A narrative literature review was effectively carried out from peer reviewed literatures, working papers, conference & seminar papers and reports from known organizations related to climate change and food security in the Indian context. To include only up-to-date information, a maximum time frame of 20 years has been positioned on the age of the works to be included in this particular review. In a nutshell, the full text documents were reviewed to evaluate the relevance of the papers for this review.

3. The 4F's of Food Security

There exists a rich literature on the concepts of food security and over 200 definitions about food security and its determinants are available [10]. Among these, FAO's definition in 1996 is worth mentioning. This particular definition covers all the three dimensions of food security namely availability, access and utilization of food. It states that "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." [27].

The quantity of food availability during a specific time period in a particular place for consumption of the population reveals the estimate of food security which in turn is a function of domestic agricultural production or imports from surplus areas as articulated by [1, 25]. [3] also defined food security at the national level that mainly refers to availability in the country of sufficient stocks of food to meet domestic demand, either through domestic supply or through imports. In their article, [22], championed the opinion of the Planning Commission (Government of India) that, "everyone having access, at all times, to food needed for an active and healthy life."

To begin with, the effects of climate change on food availability in India are likely to negatively impact agricultural production, crop yields, and soil fertility [6]. To highlight an example, [16], in their study found that massive rains and extreme variation in temperature adversely affects the productivity of Jowar crops which in turn affects the income as well as the food security of the farming families in Karnataka (India).

The ability of individuals to utilize food effectively will take a severe blow as a result of climate change. [21] critically examines how the various forms of diseases, including vector-borne diseases such as malaria, are likely to proliferate in response to climate change. A greater part of the world's poor population lives in South Asia and Sub-Saharan Africa, which amounts to nearly 1.7 billion people [2, 28] and out of this, approximately 860 million people are unable to properly utilize food as countries are incapable to make available sufficient quantities of nourishing food to these people.

The study carried out by [17] is based on data from 1980-2009 and it demonstrates how the four components are highly correlated across 13 major states[1] in India (Refer to Table 1).

Table 1. Pearson correlation coefficient among the 4F's of food security in India

Variables	*Food Security*	*Availability*	*Stability*	*Accessibility*
Food Security	1	0	0	0
Availability	0.89	1	0	0
Stability	0.76	0.56	1	0
Accessibility	0.40	0.33	0.23	1

Table 1 above represents the correlation coefficients for food security index and its components and shows that availability of food is sole and significant component for food security; it means that all components of food security are interconnected to each other [3].

In the last decade, 2002-03 was the only year that India showed negative agricultural growth in addition to average rainfall dropping 20 per cent below normal, 2009-10 experienced the most severe drought in nearly 40 years with total rainfall falling 23 per cent below normal. In this backdrop, putting side by side the changes in kharif and rabi production reveals that the impact was more in the kharif season as compared to the rabi season [13]. In this context, prices will start soaring and as a result of climate change will take centre stage.

4. Climate Change, Agricultural Productivity and Food Security : Empirical Review

Any fluctuation in agricultural productivity anchored in high variation in environmental factors such as temperature, rainfall and other socio-economic factors shown in Figure 1 unambiguously affects food security. The inter-relationship between climatic and non-climatic variables and its impact on agriculture, food security and poverty has been shown in Figure 1 below. Coming to the relationship between climate change, agricultural productivity and food security, undesirable implications for agricultural productivity may increase incidence of more poverty, which in turn is intimately related to hunger [22]. Thus, agricultural productivity is a crucial part of food security which is in turn an integral part of poverty eradication and hunger [17].

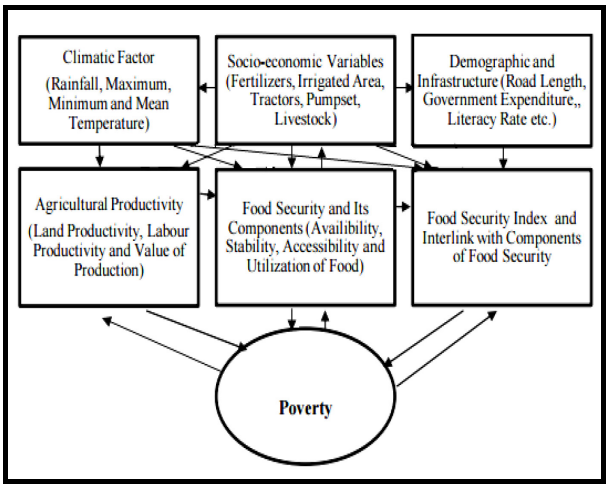

Figure 1. Inter-relationship between climatic and non-climatic variables and its impact on agriculture, food security and poverty

Poverty and climate change are interrelated in many ways, for instance, if temperature increase then warmer climate may increase the spread of diseases like malaria; and it may increase extra burden on poor people consequentially leading to an increase in poverty. Higher variation in rain patterns such as drought or flooding can damage

[1]The States in tropical zone are — Bihar, Orissa, Uttar Pradesh, Punjab, Haryana, Gujarat, Madhya Pradesh, West Bengal, Maharashtra and Rajasthan; and in subtropical zone : Andhra Pradesh, Tamil Nadu and Karnataka.

households' assets and agricultural produce leading to an increment in poverty; and it may be serious threat to food security in agriculturally intensive countries. Generally speaking, agricultural productivity, food security and poverty have a joint relationship [5, 8].

In India, numerous studies have given empirical evidence that climate change has caused decline in the agricultural productivity. Most of the studies examined economic impact of climate change on agriculture and few studies included food security along with agriculture productivity. There is already a rich literature in place in view of this issue. To begin with, [24] analyzed the projected results during 1980-2049 and found that increment in temperature up to 50^{o}C can lead to a continuous decline in the yield of rice in Kerala and interestingly, every one degree rise in temperature will lead up to 6 per cent decline in the yield. Projections by [19], exhibits that for the large scale variations in climate, yields of rice and wheat production would significantly decline which in turn would affect the food security of more than one billion populace in India approximately. In their paper, [12] articulated that an increase in the minimum temperature up to 3.0 degrees celsius above normal has led to decline in productivity of rice and wheat by 3 per cent and 10 per cent respectively in Punjab. [16] in their study found that unwarranted rains and severe variation in temperature has adversely affected the production of Jowar crop, thereby creating a repercussion effect on the income and food security of farming families in Karnataka (India). Shift in rainfall may decrease crop yields by 30 per cent by the mid 21st century which might lead to a decline in arable land and as a result affect agricultural production severely [15].

Shifting the focus to studies in this decade, [26] econometrically forecasted that that climate change will reduce sorghum productivity up to 14 per cent and 2 per cent in the central and south central zone by the year 2020 respectively. Following the same line of attack, [7] concluded that the production of sorghum, groundnut, maize, pigeon pea (arhar), wheat, cotton and onion has decreased up to 43.03, 28.23, 14.09, 34.09, 48.68, 59.96 and 29.56 kilogram (per hectare) respectively in the rainfed regions. The paper by [14] investigates some of the results for India with respect to the current and future trends in two of the most critical components namely temperature and precipitation. Their results show that regionally, this increase has fluctuated between 0.5°–1°C and this is something which warrants attention. Empirical results show that the climatic factors have a statistically significant impact on the productivity of most crops but this effect varies across crops. Productivity of rice, wheat, maize, sorghum (jowar), and ragi crops has been negatively influenced with an increase in the actual average maximum temperature. Actual average minimum temperature has a negative and statistically significant effect on wheat, barley, gram, and rice crops. Productivity of barley, rice, maize and various other rabi crops have worsened due to extreme rainfall and freak weather patterns. The importance of irrigation and the optimum use of fertilizers to alleviate the adverse effects of climate change has been significantly highlighted. Coming to the analysis of [17], the construction of the food security index (FSI) by incorporating all the four dimensions of food security is something very interesting but taking averages of the normalized values is not something wise. In this process, the variability across states with respect to different parameters may be different so the process of giving equal weightage to all the variables under consideration is not justified. Therefore, running the Principal Component Analysis would have made the results much more robust.

Summarizing some of the important results of the empirical review, we see that climate change has negatively affected the food grain productivity in India (Refer to Table 2).

Table 2. Climate change and food security in India : significant findings from various studies

Review Articles	***Methodology Adopted***	***Major Findings***
[18]	This paper uses the Ricardian technique of regressing land value measured by annual net income on a set of inputs which are environmental in nature and hence measuring the contribution of each input to net income.	Rice yields will fall by 15-25 per cent and wheat yields by 30-35 per cent in a dummy variable set-up for different soil conditions and economic pressures.
[24]	Using data for the period of 1980-2049 (projected values), regressed the temperature change on yield of rice.	Increment in temperature up to 50^{o}C can lead to a continuous decline in the yield of rice in Kerala.

[12]	Dynamic crop growth simulation models for rice and wheat were used to study the effect of climate change on growth and yield of these crops under non-limiting water and nitrogen availability using data from 1975.	Increase in the minimum temperature up to 3.0 degrees Celsius above normal has led to decline in productivity of rice and wheat by 3 per cent and 10 per cent respectively in Punjab.
[9]	This paper estimates the effect of random year-to-year variation in weather on agricultural output of 6 major crops including rice, wheat, jowar, bajra, maize and sugar using a 40-year district-level panel data set covering over 200 Indian districts.	• Projected climate change over the period 2010-39 reduces major crop yields by 4.5-9 per cent. • The long-run (2070-2099) projected impact is dramatic, reducing yields by 25 percent or more in the absence of long-run adaptation.
[16]	It examines the effect of fertilizer,labour inputs and also looks into the impact of climatic variables, such as rainfall, temperature, etc. on the productivity of jowar under different stylized climatic conditions for India as a whole and especially for the state of Karnataka.	Kaul and Ram (2009) in their study found that unwarranted rains and severe variation in temperature has adversely affected the production of Jowar crop, thereby creating a repercussion effect on the income and food security of farming families in Karnataka.
[26]	Using the InfoCrop-SORGHUM simulation model analyzed the impact of climate change on sorghum productivity in India.	Econometrically forecasted that that climate change will reduce sorghum productivity up to 14 per cent and 2 per cent in the central and south central zone by the year 2020.
[17]	This study estimates the impact of climatic and non-climatic factors on food grain productivity to facilitate the development of appropriate farm policies to cope with climate change. Cobb-Douglas production function for wheat, barley, gram, and rice crops for a panel of 13 states have been employed during 1980-2009.	Estimates suggest that the agricultural productivity in India is sensitive to climate change which is adversely affecting the food grain productivity and it may become a serious threat to food security in India based on the construction of a Food Security Index (FSI) (incorporating all the four dimensions of food security).
[14]	Using data during 1850-2010 on temperature and precipitation from the Indian Meteorological Department, this study examines some of the results for India with respect to current and future trends in temperature and precipitation, the two most critical climate variables for agriculture.	• Their results show that regionally, this increase has fluctuated between 0.5°-1°C. • Empirical results show that the climatic factors have a statistically significant impact on the productivity of most crops but this effect varies across crops. • Productivity of rice, wheat, maize, sorghum and ragi crops has been negatively influenced with an increase in the actual average maximum temperature.

Source : Compiled by the author

Most studies have empirically analyzed the impact of climate change on agricultural productivity based on single crop or two to three crops and restricted their study to a particular state or region. Also, in addition to this, a handsome majority of the studies have analyzed the overall impact of climate change on food security through food grain productivity or yield per hectare. But, there are loads of additional factors which may influence the level of food security *viz*. income of people, geographical regions, educational attainment, level of employment, decline in cultivated land and higher population growth, etc. So, there needs to be a broader dimension of the analysis by incorporating these variables and then checking out the results.

5. Threat of Climate Change and Food Insecurity: India's Endeavour

Building climate resilience is the buzz word in the present context. Adaptation strategies such as modifying crop management practices, making farmers conscious about the cropping techniques through Kisan Mandis, improved water management techniques, crop diversification, improving pest management, crop insurance, proper advisory set-up to analyze the freak weather conditions [20]. Coming to India's Twelfth Five Year Plan's theme of 'faster, more inclusive and sustainable growth' — for the first time ever, a five year plan has zeroed in on the concept of sustainability with a prime focus on low carbon strategy for development that aims at inclusive growth.

To briefly highlight the important issues, initially, conducting environmental impact assessments (EIAs) for vulnerable zones by carrying out a sensitivity analysis in terms of various parameters like net sown area, proportion of wastelands, level of annual rainfall, cyclone proneness, drought and flood proneness, available water holding capacity of the soil and the stage of groundwater development. Maintaining the standard water

quality and quantity through the various pollution control measures of water resources and restoration of wetlands was also in the agenda of the Twelfth Five Year Plan. Emphasis on conservation and sustainable utilization of biodiversity to improve livelihood security, promotion and evaluation of the ecosystem services in the national planning process is another landmark achievement in this regard.

It is worth mentioning that India has taken on board a National Action Plan for Climate Change (NAPCC) in June 2008, which fits in its vision of sustainable development and the steps taken to realize it. Keeping this in mind, several national missions like National Mission for Sustaining Himalayan Ecosystems (NMSHE), National Water Mission (NWM), Green India Mission (GIM) and National Mission for Sustainable Agriculture (NMSA) etc. have been initiated. NMSA deals significantly with the issue of food security by way of promoting dry land agriculture with a view to cultivate drought-resistant crops, safeguarding natural resources such as biodiversity and other genetic resources by building up strategies to make Indian agriculture much more resilient to climate change. Also, the NMSA has extended this mission to the rainfed areas for developing integrated farming system with livestock and fisheries so that agriculture continues to grow in a sustainable manner.

Additionally, the Rain-fed Area Development Programme (RADP) has already implemented a comprehensive approach to boost farmers' income in rainfed areas and it has been implemented across 22 states in 2013-14. Other initiatives under the Indian Council of Agricultural Research (ICAR) include the National Initiative on Climate Resilient Agriculture (NICRA) which aims to develop strategic research through technology demonstration, which is currently subscribed to by over 4.8 million farmers across 600 districts, while Grameenn Krishi Mausam Sewa (GKMS) has initiated these advisory services at block level. By and large, the recent move to substantial carbon taxation coupled with India's proactive solar power program hints at the fact that India can make significant contributions to the forthcoming negotiations on climate change.

6. Concluding Remarks and Future Research Possibilities

Both climate variability and change are significant in the Indian context. The impact of climate change as well as climate variability is strongly felt in agricultural production and food security. While the sustained robustness of Indian agriculture is greatly significant in this context, some major concerns still stay behind. The productivity levels of rice and wheat have sharply declined after 1980 and are far below the global standards. It should be noted that declining fertilizer-use efficiency has also led to the problem of soil-degradation assuming gigantic proportions in India. The empirical review shows that the food security components are highly correlated. From these, several conclusions can be drawn. To sketchily summarize, an increment in rainfall coupled with maximum and mean temperature has a negative and statistically significant impact on the food security index and the 4F's of food security. There exists a bi-directional causality poverty and food insecurity in the Indian context [11]. The states which are better placed with respect to the food security index should make it a point to equitably distribute the excess food capacity among the states which are placed in the lower half. Based on empirical findings several suggestions could be outlined to increase the level of food security in India for instance cropping intensity may augment crop rotation resulting in more food production which may generate a repercussion effect by bringing in more employment prospects. Also, in this context it should be noted that there is a research gap pertaining to the problem of food price inflation and economic growth in the context of climate change and how targeted decision making should take place. The question that whether there is a long run relationship among climate change, food security and economic growth in a Vector AutoRegressive (VAR) framework will add another dimension to this issue by explaining the magnitude of the impact of climate change on economic growth and food security.

This current review also pinpoints some potential research possibilities in this regard. Firstly, the work done by [17] involves panel data from 1980-2009 across 13 major states in India. This work can be extended for all the States in India. Also, a cross-sectional study across all the states in India based on recent data (2015-16) is an exercise which might interest the researcher. Theoretically, trying to model the inter-relationships between the components of food security, agricultural productivity and poverty by including uncertainty in the framework is also important to know. Finally, how the channels of food security *viz*., the Public Distribution System (PDS), the Targeted Public Distribution System (TPDS) will be affected through the 4F's in the context of climate change is something worth exploring.

As a responsible nation, India has already pledged to address the global climate challenge. It is determined to work, both at domestic and

international levels, in accordance with the principle of common but differentiated responsibility (CBDR) under the control of the United Nations Framework Convention on Climate Change (UNFCCC). The enthusiastic contribution of India in the Clean Development Mechanism (CDM) under the umbrella of the Kyoto Protocol (with the second highest number of projects registered for any country; and these have the potential to offset almost 10 per cent of India's total emissions per year) will pave the way for other developing countries to follow the same approach. Only time will tell whether India's actions will guide other nations to reduce their emissions, and to arrive at an effective and rational global arrangement.

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