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Climate Change Impacts on Indian Agriculture: *Staple Crops and Food Security Scenarios*

Dr. Veena Vidyadharan, Policy Analyst, CUTS International & Deputy Head CUTS Centre for International Trade, Economics and Environment (CUTS CITEE)

Susan Mathew, Senior Programme Officer, CUTS International

Abstract

Climate change and demographic changes in India have affected key natural resources, such as land and water. One visible aftershock of these effects is changing food production scenarios in India. Numerous General Circulation Models (GCMs) have been designed to quantify the physical impacts of climate change on food production scenarios. The discussions in this paper are based on the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model analysis by International Food Policy Research Institute (IFPRI) on selected crops in different sub-regions of India and draws from conclusions of the 4th Intergovernmental Panel on Climate Change (IPCC) assessment report. The paper argues that staple food crops have the potential to be compatible to transitional climate aberrations if supported with technology and policies. Given that the four pillars of food security are directly linked to food production and entitlement mechanisms, the paper also includes suggestions for improving mechanisms.

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Climate Change and Indian Agriculture

India's latest country-wide 15th census held in 2011 reports that the country has close to 1.2 billion people and is also one of the fastest growing economies in the world. However, it is important to note that having the largest human capital in the world has also resulted in inopportune movement of the climate as well as the food production systems in the country.

Climate change and population are concomitant through mitigation[i] (reducing the causes for climate change) and adaptation[ii] (reducing the effects of climate change). These dynamic simulations between climate change and demographic changes in India have affected key natural resources, such as land and water. One of the many visible aftershocks of these effects is changing food production scenarios in India.

India has witnessed remarkable increase in the staple crop production in the past decade. Despite the weather aberrations, which have become a common phenomenon in one part of the country or other, the staple crop production has maintained its momentum of growth mostly due to the adoption of improved crop varieties, technological innovations, and management practices.

However, meeting the growing demand, that too with shrinking natural resources in the backdrop of climate change is a real challenge for farmers, agricultural scientists and policymakers in the country. The 5th IPCC assessment report also finds that climate change will affect food production in South Asia (IPCC 2014).

Impact of climate change on food security is at multiple levels. Agricultural production is likely to suffer from the combined effects of unstable water supply, the impacts of sea-level rise and resulting salt water intrusion, and rising temperatures (World Bank 2013). This coupled with increasing pressure on land resources due to urbanisation and sea level rise will threaten food production. Thus, there exists an intricate linkage between climate change and safety nets in reassuring food security.

However, a suitable discourse on the impact of climate change on the production of major staples crops is still lacking. This paper attempts to discuss the impact of climate change on the staple crop production and food security scenario in India, based on the assessment of IFPRI using the IMPACT model (Msangi 2015). Going a step further, the paper will analyse the production gains and losses of these crops due to climate change and its implications on the country's food security[iii].

Mapping of Indian States using the IMPACT model

Impacts of climate change can be broadly categorised as physical and economic. While physical impacts directly influence agriculture through loss of biodiversity and change in weather etc., economic impacts may comparatively be slower in affecting the agriculture scenario. Numerous GCM[iv] have been designed to quantify the physical impacts of climate change on food production scenarios.

The IMPACT developed at the IFPRI has been able to integrate information from such climate models, crop simulation models (e.g. DSSAT[v]), and water models for projecting global food supply, food demand, and food security to 2020 and beyond.

Table 1: Mapping of Indian States to Macro Sub-regions

Macro sub-region	Indian states contained in sub-region
North	Uttarakhand, Uttar Pradesh, Bihar, Sikkim, Delhi
Northwest	Gujarat, Rajasthan, Punjab, Haryana, Jammu & Kashmir, Himachal Pradesh
Northeast	Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Meghalaya
East	Jharkhand, West Bengal, Odisha, Chhattisgarh
Central	Andhra Pradesh, Maharashtra, Madhya Pradesh
South	Goa, Karnataka, Tamil Nadu, Kerala, Andaman & Nicobar Islands, Lakshadweep

Source: (Rosegrant, et al. 2008)

The discussions in this paper are based on the IMPACT model analysis by IFPRI using CSIRO and MIROC models on selected crops in different sub regions of India and draws from the conclusions of the 4th IPCC assessment report. The sub-regional results for the IMPACT model in India were aggregated from 12 sub-regions to 6 sub-regions. The list of the Indian states covered under each sub region is shown in the Table 1.

Due to the prevailing uncertainties with simulation models in presenting scenarios and plausible outcomes of climate change, the IMPACT model has also relied on more than one climate model like CSIRO[vi], MIROC[vii], NCAR[viii] etc. (Msangi 2015, Lupo, et al. 2014).

Staple Crop Production in India

In much of the policy discussion revolving around food security in India in the context of climate change, cereal crops have always grabbed the attention. Out of the 1659 notified varieties of cereal crops, 1102 are for paddy and 458 are for wheat (Seednet India Portal 2016). This also indicates that the country has been actively engaged in increasing food security with focus on cereal crops (Table 2).

Table 2: Average Estimates of Area and Production of Rice, Wheat, Maize and Potato for India (2010-2015)

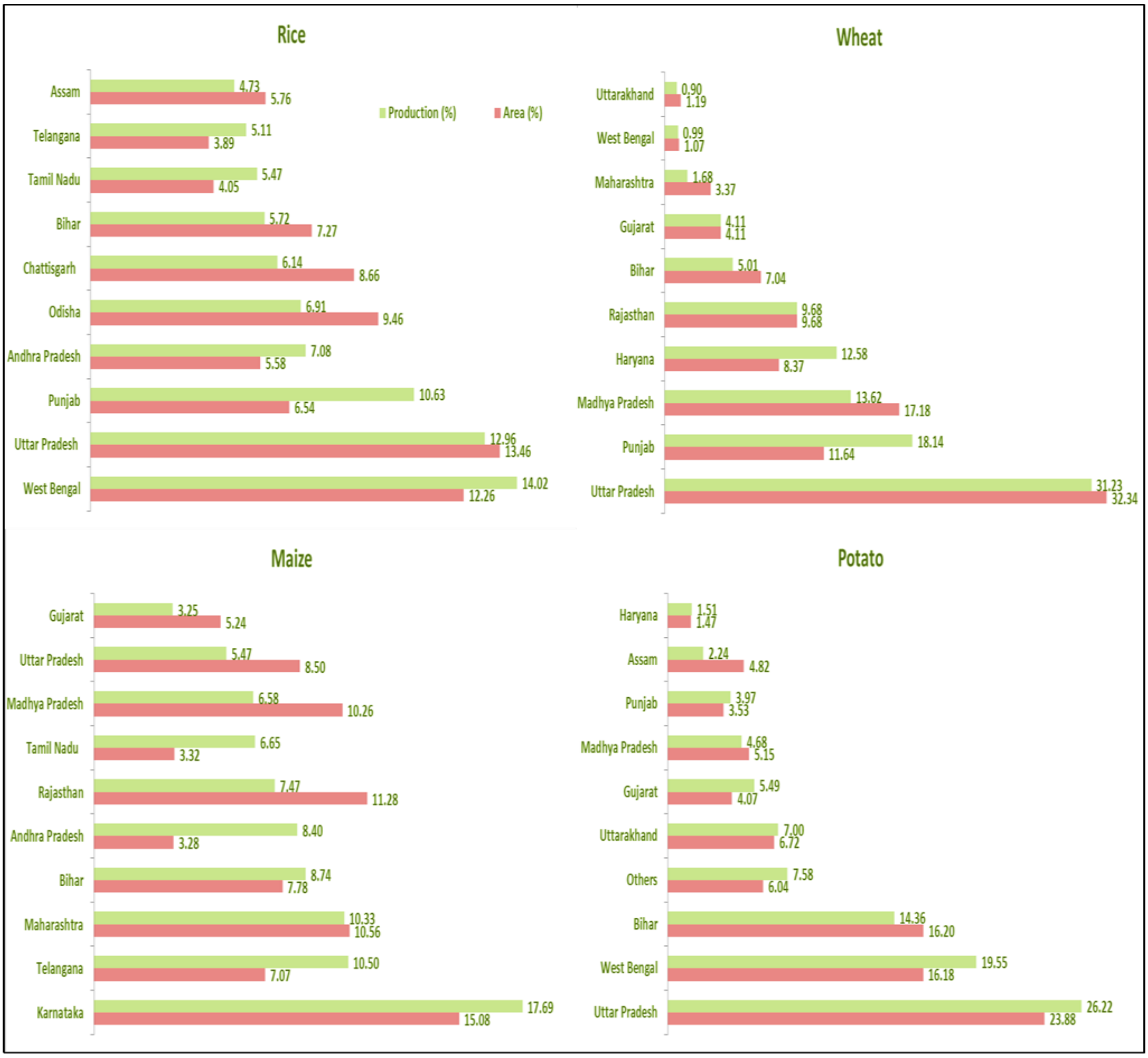
Staple Crops	Area ('000 Hectares)	Production ('000 Tonnes)
Rice	43573.81	103728.02
Wheat	30173.50	91527.79
Maize	8851.87	22835.10
	Area ('000 Hectares)	Production ('000 MT)
Potato	1962.30	43746.08

Source: Author's calculations from data available on (GoI, 2015)

While rice and wheat lead the bandwagon in cereals, potatoes and onions comprise the majority of the non-cereal staple crops consumed in India. In addition, maize has also shown to be the 'competing crop' for demand and supply for cereals like rice and wheat in India by 2025 (Ganesh-Kumar, et al. 2012). According to the high demand and production growth scenarios, by 2020, almost 19 percent of the additional potato output in developing countries will be from India (Scott, Rosegrant and Ringler 2000).

Figure 1 displays the top 10 states in production and area for rice, wheat, maize and potato in India during 2010-2015. The average estimates for area and production of rice from 2010-2015 show that West Bengal, Uttar Pradesh and Punjab lead in rice production whereas Uttar Pradesh, West Bengal and Odisha have higher proportion of area under rice cultivation in India. Uttar Pradesh and Punjab also top the list for average estimates for wheat production from 2010-2015. Madhya Pradesh and Haryana follow closely with ±2 percent increase in state-level production estimates. With regard to maize, Karnataka leads in production followed by Telangana and Maharashtra whereas Uttar Pradesh, West Bengal and Bihar record higher production of potato.

Figure 1: Top 10 States in Production and Area for Rice, Wheat, Maize and Potato in India (2010-2015)



Impact of Climate Change on Staple Production

The IMPACT projections indicate production losses of rice across all the macro sub-regions[ix] in India, the greatest being in north-west. Production impact on wheat is positive in central, south and east India; however north-west region is expected to experience production loss. Maize was found to benefit in north east, central and south India but potato benefitted from climate change across all the sub-regions, the highest being projected in the East (Msangi 2015).

The juxtaposition of production data given in Figure 1 with the projections of IMPACT on the staple production in sub-regions in India indicates that staple food crops have the potential to be compatible to transitional climate aberrations if supported with technology and policies. Despite having large areas under rice cultivation, states leading in rice production show a dismal production of below 14 percent of the total rice production in India. The leading state of West Bengal falls in the eastern sub-region. Eastern regions are predicted to be most impacted by increased temperatures and decreased radiation, resulting in relatively fewer grains and shorter grain filling durations. Hence, the emphasis on smart and climate resilient agricultural practices is necessary to ensure the sustainability of rice production. This includes cultivation of heat tolerant/flood tolerant, hot duration varieties and adjusting sowing time.

With regard to potato, the data reveals that Uttar Pradesh, West Bengal, and Bihar together have been able to contribute to close to 60 percent of the potato production in the country. The heat sensitive potato crop is mostly confined to Indo-Gangetic plains under irrigated conditions due to climatic constraints, hence north Indian states are found to be high producers of potato in India.

In case of wheat, Uttar Pradesh, Punjab and Madhya Pradesh are the three leading states with 31.23, 18.14 and 13.62 percent respectively. As per the projections by IMPACT there will be yield reductions in Uttar Pradesh, Punjab and Haryana. The terminal stress also causes reduction of leaf surface, short tillers and decline in yield. This can be attributed to heat stress which is evident in recent years which shortens the grain filling period (Mishra, Singh, et al. 2013).

Out of the total maize production in India 46.92 percent comes from Karnataka, Telangana, Maharashtra and Andhra Pradesh which comes in the central and south sub-region. Maize being a C4 crop benefits from CO_2 fertilisation. Increased growth rate with better temperature regimes resulting in increased number of grains and grain weight leading to overall increase in biomass in case of winter maize (Haris, Biswas, et al. 2013).

Linking Climate Change Impacts to Food Security

Given that staple crops are commodities traded all over the world, crop improvements in one part of the world can be tweaked for research across the world. Increasing investment in climate resilient food system research should take the primary focus. The second core component should be recognising that food distribution and pricing policies being followed since the pre-Independence era might require deliberations in the context of climate change.

The physical aspects of climate change models can be quantified and understood by research, but the process to convert these assessments into real time decisions is still difficult for policymakers at the national level. Since food security is built on four pillars: availability, access, utilisation and stability (FAO 2009), all these have to be addressed through a multi-pronged policy strategy.

Food availability has direct relation with food production within the country. Taking into account possible impact of climate change on agriculture, especially on key staples, due importance has to be given for adaptation strategies. The uncertainties prevailing around the possible implications on monsoon patterns due to climate change has resulted in variations in impact results of different models. In any case, use of stress-tolerant varieties for cultivation, adjusting sowing time, shifting to crops with less water requirement and to those which have comparative advantage of temperature rise (winter maize to wheat), enhancing water use and nutrient use efficiencies are some of the strategies that would improve the resilience.

Early warning systems need to be strengthened for improved weather services and forecasting pest and disease out breaks. Compensation for crop losses due to natural calamities and social safety nets, which includes large scale buffer stocking, will play a significant role as shock absorbers. Nutritional security is another dimension of food security which is often linked with household income and access to food. The government programmes of Integrated Child Development Services (ICDS) and the Mid-Day Meal (MDM) at schools are mainly intended to address under nutrition.

Impact of climate change on water resources is going to be critical to the food production systems in India (Shreedhar, et al. 2012). The irony of Indian agriculture is that most of the irrigated tract lies in semi-arid region and primarily ground water resources are being used for irrigation. Higher variability in monsoon patterns, and increase in evapotranspiration losses and inefficient irrigation practices have raised the threat to both surface and ground water resources. As such, efficient irrigation practices that would sustain crop yields without putting ground water resources at stake needs to be popularised. This would demand stringent measures to regulate ground water use and also promoting water saving technologies in rice cultivation.

Way Forward

In India, rice is an easily available subsidised commodity for consumers despite being a water-intensive crop. While there has been no consensus on more centralised reforms by the government, recent policy changes have moved towards better targeting of food subsidies to low-income consumers. State governments directly purchase grain to meet distribution needs for these consumers. But quite often addressing rice production deficits due to climate change impacts by drawing on rice from buffer stocks has deemed to be a temporary policy solution. The huge transactional costs incurred in the enactment of the Food Security Act are often questioned by development professionals and policymakers.

The option of cash transfer will significantly reduce the transactional costs but sometimes it may lead to usage of money for non-productive purposes. Food security policies for rice should focus on the supply and availability of rice through improved capacity to forecast rice shortages. These policies should also elaborate that regional disparities even within the country are taken into consideration for the distribution mechanisms.

The production and distribution framework for potatoes differs from that of cereal crops. Government intervention is almost negligible in the potato value chain. There is also a need of investment in establishing storage structures, especially cold storages while considering the spoilage of perishable products. There is an absence of centralised price regulation mechanism for the tuber, despite its wide consumption and low water consumption. In the absence of formal regulatory bodies, it will be useful to recognise the supply and demand-side constraints. Also, policy biases that favour trade and tariff agreements for competing agricultural commodities like rice and wheat and ignoring crops like potato should be reflected upon. Interest from the government would also encourage local producers to address potato cultivation as a viable source of nutrition and not as a filler winter crop.

Investments in agricultural systems would make it possible to sustain existing agricultural land resources and reduce the market forces on farmers. Policy actions need to be taken to ensure economic growth that reaches the vulnerable, improve productivity in crops, and strengthen national production. A consensus has to be arrived at to meet the country's food demand in coming years without compromising with the environment that provides us the sustenance.

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[i] The IPCC (2014) defines mitigation as 'an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas (GHG) sources and emissions and enhancing GHG sinks.

[ii] The IPCC (2014) defines adaptation as 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

[iii] The IMPACT model predictions were proposed in 2008 for future impacts extending till 2050. The authors have used average production data for five years from 2009-2014 to analyse whether the predictions are following an empathetic trend.

[iv] GCMs are a type of climate change model which simulates the circulation of the atmosphere. The model consists of the Navier-Stokes mathematical equation to represent certain properties (temperature, pressure, and moisture content, etc) of the Earth's atmosphere. GCMs are primarily used for weather forecasting and understanding climate change.

[v] The Decision Support System for Agro- technology Transfer (DSSAT) is the most widely used crop-simulation model which translates soil moisture levels, daily temperature and crop management characteristic to gain or loss in the crop yields.

[vi] The CSIRO comprises of atmosphere, land surface, ocean, and polar ice models.

[vii] The Model for Interdisciplinary Research on Climate (MIROC) is a general circulation model which consists of five component models viz., atmosphere, land, river, sea ice, and ocean developed by Centre for Climate System Research, University of Tokyo

[viii] The National Centre for Atmospheric Research, US (NCAR) model is composed of a Weather Research & Forecasting (WRF) Model, Community Earth System Model (CESM) and Whole Atmosphere Community Climate Model (WACCM).

[ix] The IMPACT model has categorised the states of India into six macro sub regions, viz., North West, North, North East, East, Central and South.

CUTS International

D-217, Bhaskar Marg, Bani Park, Jaipur 302016, India

Ph: 91.141.2282821 ● Fx: 91.141.2282485

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