ANALYSIS

Volume 6 (Issue 21), 2020

ISSN 2394–8558
EISSN 2394–8566

Climate Change

Future Climate Change impacts on Crop Productivity in Coastal Regions of India: A Panel Estimation

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Article History
Received: 27 November 2019
Accepted: 30 January 2020
Published: January - June 2020

Citation
Surendra Singh, Alka Singh, Sanatan Nayak. Future Climate Change impacts on Crop Productivity in Coastal Regions of India: A Panel Estimation. *Climate Change*, 2020, 6(21), 100-108

ABSTRACT

By using large-scale district-level data and the panel-FGLS regression model, the present study attempted to examine and predict climate change impacts on crop yield. A semi-log model was adopted to calculate trends of rainfall and temperatures over 1966-2011. Spatial and temporal analysis of rainfall and temperatures revealed that annual rainfall had been increased in all regions except the central plateau and hills region (i.e., 0.39mm/year). The FGLS- regression results revealed that adverse impacts of climatic factors, i.e., rainfall and temperature were cancel out by adaptation strategies. Without adaptation, projected results revealed that

the majority of all crops would be decline in all regional scenarios. In the light of analysed results, regional adaptations are prerequisites for negating adverse impacts of climate change on crop yields.

Keywords: FGLS-panel model, VDSA, Adaptation, Regional vulnerability, Food security.

1. INTRODUCTION

Climate change has emerged as the most potent global risk to the food security and agriculture-based livelihoods, impeding the pathway to sustainable development especially among the developing nations. As per Intergovernmental Panel on Climate Change (IPCC, 2018), greenhouse gas accumulation owing to increased anthropogenic emissions has caused 1^0C of global warming above pre-industrial levels which is likely to reach 1.5^0C between 2030 and 2052, causing greater frequency of extremes weather events (droughts, floods, heat waves). For such a change in global climate, indigenous populations and local communities dependent on agricultural or coastal livelihoods are highly susceptible to climatic aberrations. Over the past years, scientific research has well established the sensitivity of agriculture sector to changing climatic conditions under different plausible scenarios (Mendelsohn et al. 2006; Lobell and Field, 2007; Nelson et al. 2010; Lobell et al. 2011; Mishra et al., 2013), with concomitant implications for food security. Agriculture production and productivity are directly affected by change in temperature, precipitation, and carbon dioxide (CO_2) concentration in the atmosphere (Aggarwal, 2009; Falkenmark et al., 2009; Nelson et al., 2010 and IFPRI, 2010). Temperature when exceed the critical physiological thresholds adversely affect crop yield via increased heat stress on crops, water loss by evaporation and proliferation of weeds and pest (Singh et al., 2012). Besides, greater erraticism in the distribution of rainfall resulting in drought or flood like situations induces crop failures through higher runoff, soil erosion and loss of nutrients (Singh et al 2012). Elevated atmospheric carbon dioxide are expected to positively affect physiology of crops due to higher water-use efficiency and accelerated plant photosynthesis (Tubiello and Ewert 2002; Cline, 2007), however the net response of crop depends on the complex interaction of CO_2 with variables like irrigation, fertilizer, rainfall, etc. Agriculture also remains a major contributor to GHG emissions via crop cultivation, livestock, forestry and fisheries (Solomon, 2007), the magnitude of which is further likely to increase in the future (FAO, 2016).

Crops, however in different regions respond differently to climate induced changes depending upon geographical and technological aspects. Moreover, inclusion of adaptations while evaluating impacts produces wide variation in the final outcomes and projections. For instance, Gornall et al., (2010) showed that a 2^0C local warming in the mid-latitudes could increase wheat production by nearly 10 percent, whereas at low latitudes the same amount of warming may decrease yields by nearly the same amount. While the impact of climate variations on yield could be both positive and negative, the past evidences on observed and projected effects generally postulates a negative impact of warming on crop production (Porter et al., 2014). Globally during the period from 1980-2008 climatic changes reduced yield of maize and wheat by 3.8 and 5.5 percent (Lobell et al., 2011). For South Asia, maize and sorghum are projected to reduce by 16 and 11 percent (Knox et al., 2012). Though it has been construed that till 2030, the positive and negative effects of climate will try to counterbalance each other at the global scale however, beyond the time frame negative impacts will become more prominent (FAO, 2016).

India, being located close to the equator and in the tropics is relatively at a higher risk to the climatic aberrations. The country has diverse geographical and climatic conditions which translate into differential regional impacts. Between 1901 and 2017, annual mean temperature in India has increased by 1.2°C (CSE, 2018) and is projected to increase more rapidly in the future (Kumar et al., 2011, Van Oldenborgh et al., 2018). In addition, regional studies reveal a changing pattern/ variation in rainfall (Goswami et al., 2006, Jain and Kumar, 2012, Mallya et al., 2016). Inter-annual variability in monsoon resulting in drought and floods like conditions adversely affects food grain production (Selvaraju and Parikh, 2001; Kumar et al., 2013). Moreover, prolonged breaks in southwest monsoon have increased the frequency of droughts (Udmale et al., 2015, Zhang et al., 2017, Choudhury and Sindhi, 2017) with consecutive drought periods being witnessed in different parts of the subcontinent. This poses enormous challenges for Indian agro-ecosystem, which provides livelihood to 48 percent of the total workforce and where 55 percent of the net sown area is still rainfed (Udamale et al., 2015). The system is heavily dependent on south-west monsoon (June-September) accounting 70-90 percent of the annual mean rainfall. In addition, majority of the farm landholders are small and marginal with limited technical and financial resource base (Acharya, 2006; Khan et al., 2009; Jain et al., 2015; Patnaik and Das, 2017) and access to infrastructure to invest in appropriate adaptation measures.

Over past years substantial empirical work has been undertaken to quantify and examine the climate impact on crop yields in India. Under different temperature and precipitation scenarios a significant fall in the productivity of major crops like rice, wheat, maize and millets have been observed in the country (Sanghi and Mendelsohn 2008; Guiteras 2009; Lobell et al. 2011; Auffhammer et al., 2012; Rao et al., 2014; Birthal et al., 2015). Pathak et al. (2003) found that from 1985 to 2000, rate of change in potential yield of rice in the Indo-Gangetic plains ranged from -0.12 to 0.05 Mg ha^{-1} (megagram per hectare). Such a declining trend has been attributed to the decline in solar radiation and an increase in minimum temperature. During the period 1966–2002, rice yields decreased by around 5-10 percent (Auffhammer et al. 2011). In their district level analysis for the period 1971–2009, Rao et al. (2014) found reduction in *kharif* paddy yields by 411–859 kg/ha/_C rise. Padakandla (2016) showed that rice, tobacco and groundnut were significantly impacted by climate variations during 1981–2010 in the state of Andhra Pradesh and crops grown in *rabi* were more susceptible to changes in climate than those in *kharif* season.

In aforesaid studies, the researchers used crop growth and yield simulation models to establish the impact of climate variability, climate change, and expected change in climate parameters like rainfall and temperature on different crops.

None of these studies, however, have attempted to predict future impacts of climate change on crop yields in plateau and hills regions of India using socio-economic, demographic, and climate data. In this study, we have tried to assess the effects of spatial and temporal climatic variation and predict possible impacts on food and non-food crops in two main cropping seasons, viz., Rabi, and Kharif. This study estimates the temperature and rainfall trends over the Coastal and Hill regions of India during 1966-2011. Also, it estimates the impact of rainfall and temperatures on crop yields. We have used large-scale district-level data of various indicators covering socioeconomic and environmental dimensions. The findings are expected to improve our understanding of climate change impacts on agriculture in Coastal and Hill regions of India.

2. METHODS AND MATERIALS

2.1. Study Area

The Coastal Plains and Hills Region covers about 9.69 percent of the country's total biological area, with about 14.04 percent of its total population residing in rural areas in the majority (Census, 2011). As far as agricultural statistics are concern, the region covers about 8.21 percent gross cropped area and has about 1.72 ton/hectares crop productivity of food grains (Table 1). The major crops are Rice, Groundnut, Ragi, Jwar, Bajra, Gram and Tapioca. While annual rainfall varies from 1100.96 millimetres in East Coast Plains & Hills to hills regions to 2417.93 millimetres in the West Coast Plains & Ghats. Temperatures are considerably affecting the crop yield in this region. The estimated trends from 1966 to 2011 reveal that annual minimum temperature varies from 20.60 ^{0}C in central West Coast Plains & Ghats to 22.38^{0}C in the East Coast Plains & Hills. Similarly, annual maximum temperature varies from 30.36 ^{0}C in the West Coast Plains & Ghats to 31.34 ^{0}C in the East Coast Plains & Hills. In totality, rainfall and temperature trends show an increasing trend over the years and regions.

Table 1 Spatial characteristics of Coastal Plains and Hills Region

Variables	East Coast Plains & Hills	West Coast Plains & Ghats
Climate	Semi-Arid to Dry Sub-Humid	Dry Sub-Humid to Per Humid
Annual Rainfall (mm) (1966-2011)	1100.96 (12.74)	2417.93 (31.01)
Annual MinT (^{0}C) (1996-2011)	22.38 (0.05)	20.60 (0.05)
Annual MaxT (^{0}C) (1966-2011)	31.34 (0.07)	30.36 (0.10)
States@	Andhra Pradesh (8, 39.93), Odisha (13, 27.45) Puducherry (4, 0.25), Tamil Nadu (17, 32.37)	Goa (2, 3.12), Karnataka (7, 34.39), Kerala (14, 32.75) Maharashtra (6, 25.90, Tamil Nadu (2, 3.84)
Area$ (km^2)	199900 (6.08)	118634 (3.61)
Population (Persons)	94280839 (7.79)	75722655 (6.25)
Gross cropped area^p (ha.) (2016-17)	8584138 (4.51)	6860436 (3.61)
Food grains yield (Ton/ha.) (2016-17)	2.076	1.366
Major Crops*	Rice, Groundnut, Ragi, Jwar, Bajra	Rice, Ragi, Gram, Tapioca

Source: Authors Estimation, 2020. Census of India (2011), Singh (2006), NICRA District Agricultural Contingency Plans, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers' Welfare and others. Note: Total Geographical Area of India: 3287469 sq. km (Census, 2011) and Total Gross Cropped Area 190247147 ha (Authors estimation). $ Figures in the parentheses includes percentage share of ACZ in the total geographical area. ^{p}Figures in the parentheses includes percentage share of ACZ in the total Gross Cropped Area.@Figure in the parenthesis represents (Number of Districts, Total percentage area of state under ACZ)

2.2. Data Source

The present study uses district-level data collected from various sources. Data on agriculture (area and production of crops) and socioeconomic and technical factors (i.e., road length, literacy, number of tractors and pump sets, and fertilizer consumption) were decoded from the database maintained by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) under the Village Dynamics Studies in Asia (VDSA) project under of the agro climate zone (ACZs). While, climate data of rainfall and temperatures were collected and decoded at the district level using district boundary (Census, 2011) from the Indian Meteorological Department (IMD), Government of India. Later on, data of rainfall and temperature were divided into three plant growing periods, i.e., sowing, germination and harvesting using National Food Security Mission classification (MoA & FW, 2019). The present study covers 215 districts, 11 states and 46 years (1966-2011) of data.

2.3. Estimation Method

The present study used the following model,

$$logY_{dt} = c + a_d + \partial_t + \gamma logX_{dt} + \beta logW_{dt} + \epsilon_{dt} \dots .(1)$$

Where, Y_{dt} represents crop yield, W_{dt} is a vector of climate parameters (rainfall, minimum and maximum temperatures), X_{dt} denote socioeconomic and other factors (irrigated area, road length, rural literates, tractors, fertilizer consumption and pump sets) and ϵ_{dt} is the error term for the dth district-level fixed effects, a_d which controls for unobserved district-specific heterogeneity variable. We have adopted Deschenes and Greenstone (2007) methodology, as they incorporated entity fixed effects to eliminate the omitted variables bias. Further, a time trend has been incorporated in the model, as a proxy to absorb the technological effects and other farm-level adaptation strategies (i.e., application of fertilizer and pump sets for irrigation) adopted by the farmers in the course of changing climatic conditions within an ACZ.

In order to ensure the robustness of the applied panel regression, we employed certain residual diagnostics tests. Serial correlation biases the standard errors and reduces the efficiency of the parameters (Drukker, 2003); hence for necessary corrections, we tested for the first-order autocorrelation in the residuals of a linear panel-data using the Wooldridge test (Woolridge, 2002). The homoscedasticity of the error process across cross-sectional units was investigated (Greene, 2000). Based on the aforesaid verifications, we applied feasible generalized least squares (FGLS) method with necessary corrections for autocorrelation and heteroscedasticity to estimate model (1), under the assumptions that; within panels, there is AR (1) autocorrelation and that the coefficient of the AR (1) process is common to all the panels. However, it is important to note that FGLS is feasible and tend to produce efficient and consistent estimates of standard errors, provided that N<T that is panel time dimensions, T is larger than the cross-sectional dimensions, N (Beck and Katz, 1995; Hoechle, 2007). In our case, this assumption was satisfied as under each ACZ, the number of districts, representing the cross-sectional units (N) was less than the time period of 46 years.

The marginal effects of the weather parameters were calculated at their mean values from the regression coefficients (which measure elasticity). Thus, the combined marginal effect of climate variables, viz., rainfall, minimum and maximum temperature on crop yield was quantified using equation (2).

$$\frac{dy}{dc} = \left(\beta_{MT} * \left[\frac{\overline{Y}}{\overline{MT}}\right] + \beta_{MNT} * \left[\frac{\overline{Y}}{\overline{MNT}}\right] + \beta_R * \left[\frac{\overline{Y}}{\overline{R}}\right]\right) \dots \dots (2)$$

Where, $\frac{dy}{dc}$ is combined marginal effect of change in climate variables on the crop yield, β denote coefficients which are determined from the model, $\overline{MT}$ is mean maximum temperature, $\overline{MNT}$ is mean minimum temperature, $\overline{R}$ is mean rainfall, and $\overline{Y}$ is the mean crop yield during the period in an ACZ.

2.4. Projected impact of climate change

we used CORDEX South Asia multi-RCM reliability ensemble average estimate of projected changes in annual mean of daily minimum and maximum temperature over India for the 30 year future periods: near-term (2016-2045), mid-term (2036-65) and long-term (2066-2095) changes in future climate over India under RCP 4.5 scenario, relative to the base 1976-2005 to project the changes in crop yields.

Further, the projected change in crop yield was calculated using equation (3),

$$\Delta Y = \left(\frac{\partial Y}{\partial R}\right) * \Delta R + \left(\frac{\partial Y}{\partial T}\right) * \Delta T \ \ldots (3)$$

Where, ΔY denote change in crop yield, ΔR in rainfall and ΔT in temperature under different scenarios and $\left(\frac{\partial Y}{\partial R}\right)$ and $\left(\frac{\partial Y}{\partial T}\right)$ are their marginal effects.

3. RESULTS AND DISCUSSION

3.1. Variability in Rainfall and Temperatures

A semi-log model was adopted to calculate trends of rainfall and temperatures over 1966-2011 (Table 2). The annual rainfall trends revealed that rainfall had been increased in all regions (i.e., 0.39 mm/year in East Coast Plains & Hills and 1.1999 mm/year in West Coast Plains & Ghats). Further, Kharif rainfall trends show that the rainfall had been increased in East Coast Plains & Hills by 0.4319 mm/year in one hand and on the other hand, rainfall had been declined in West Coast Plains & Ghats by -1.1063 mm/year, while rainfall trends in Rabi season show increasing trends in the both agro climatic zones.

As far as minimum and maximum temperatures are concern, the calculated results show a sharp increase in annual, Kharif and Rabi seasons. The annual temperature has increased relatively higher in the East Coast Plains & Hills (i.e., 0.0008^{0}C/year) than that of West Coast Plains & Ghats.

Table 2 Trend in Rainfall and Temperature across ACZs, 1966-2011

ACZ	Annual			Kharif			Rabi		
	Rainfall (mm)	Min Temp (°C)	Max Temp (°C)	Rainfall (mm)	Min Temp (°C)	Max Temp (°C)	Rainfall (mm)	Min Temp (°C)	Max Temp (°C)
East Coast Plains & Hills	2.6227*** (0.6880)	0.0166*** (0.0008)	0.0143*** (0.0008)	1.7288*** (0.4319)	0.0144*** (0.0010)	0.0125*** (0.0010)	0.2327 (0.4548)	0.0188*** (0.0009)	0.0163*** (0.0009)
West Coast Plains & Ghats	0.5458 (1.1999)	0.0108*** (0.0007)	0.0118*** (0.0007)	-2.2155** (1.1063)	0.0073*** (0.0009)	0.0100*** (0.0012)	2.5912*** (0.3787)	0.0146*** (0.0009)	0.0150*** (0.0008)
All India	-0.4718 (0.2614)	0.0188*** (0.0005)	0.0128*** (0.0004)	-0.5511 (0.2385)	0.0117*** (0.0006)	0.0063*** (0.0005)	-0.0654 (0.0602)	0.0228*** (0.0006)	0.0167*** (0.0004)

Note: Trend has been estimated incorporating district-fixed effects. Significance level: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.2. East Coast Plains & Hills

East Coast Plains & Hills spans over the districts of Andhra Pradesh, Odisha, Pondicherry and Tamil Nadu. An examination of climate impact on crop yields in East Coast Plains & Hills reveals that higher minimum temperature lowers yield of rice, groundnut, sugarcane and wheat, while it benefits rapeseed & mustard (Table 3). On the other spectrum, rise in maximum temperature increase yield of all except groundnut. Higher rainfall significantly increase yield of groundnut and sugarcane while reduces that of rice. Irrigation has a positive (significant) impact on rice, groundnut and rapeseed & mustard. An increase in fertilizer consumption on the other hand, reduces rice and groundnut yield.

3.3. West Coast Plains & Ghats

West Coast Plains & Ghats encompasses States of Goa, Kerala and parts of Karnataka, Maharashtra and Tamil Nadu. The estimated regression as shown in Table 4 reveals that rapeseed & mustard yield is positively impacted by higher temperatures and rainfall, suggesting its capacity to withstand increasing climatic variation in the region. Barring finger millet all other crops yield appears to be benefitted from higher rainfall. Rise in maximum temperature lowers yield of rice, groundnut, finger millet and wheat while an increase in minimum temperature negatively impact groundnut only. Irrigation variable is highly significant and positively impacts rice, groundnut rapeseed & mustard yield. On the other hand, higher fertilizer consumption appears to lowers yield of rice, groundnut and wheat.

Table 3 Estimated regression coefficients of climate impact on crop yields: East Coast Plains & Hills

Variables	Rice	Groundnut	Sugarcane	Wheat	Rapeseed & Mustard
Ln Rainfall	-0.0151*** (0.0058)	0.0326*** (0.0085)	0.0212*** (0.0070)	-0.0013 (0.0022)	0.0043 (0.0069)
Ln Min Temp	-0.1056 (0.0907)	-0.0965 (0.1144)	-0.3602*** (0.1159)	-0.1562*** (0.0547)	0.9319*** (0.1444)
Ln Max Temp	0.0126 (0.0478)	-0.0577 (0.0540)	0.0495 (0.0800)	0.0232 (0.0244)	0.0132 (0.0623)
Ln Irrigation	0.8637*** (0.0370)	0.4584*** (0.0316)	-0.0443 (0.0336)	-0.0884*** (0.0153)	0.0766*** (0.0225)
Ln Fertilizer	-0.0006 (0.0028)	-0.0058 (0.0036)	0.0112*** (0.0038)	0.0022 (0.0018)	0.0192*** (0.0048)
Ln Road length	-0.0017 (0.0011)	-0.0017 (0.0016)	0.0002 (0.0012)	-0.0007 (0.0007)	0.0048** (0.0023)
Ln Ruliteracy	-0.0050 (0.0121)	0.0318** (0.0131)	-0.0249 (0.0221)	-0.0118* (0.0068)	-0.0193 (0.0172)
Ln Tractors	0.0081** (0.0036)	-0.0069* (0.0040)	0.0262*** (0.0061)	-0.0014 (0.0021)	0.0298*** (0.0053)
Ln Pumpset	0.0043 (0.0034)	0.0000 (0.0040)	-0.0021 (0.0047)	-0.0056*** (0.0020)	0.0277*** (0.0054)
Year	0.0003 (0.0007)	0.0031*** (0.0006)	0.0081*** (0.0011)	0.0087*** (0.0003)	0.0096*** (0.0009)
Constant	-3.6637*** (1.2968)	-7.1290*** (1.0547)	-13.2903*** (1.9954)	-15.7731*** (0.6303)	-22.6853*** (1.6372)
District fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	721	721	721	721	721
Wald chi2(26)	11088.04***	1393.72***	1187.62***	7717.82***	5874.56***
F(1, 16)[1]	993.58***	422.492***	1373.45***	2.759	3856.206***
chi2 (17)[2]	0.08	1.36	0.69	3.34	1.01

Note: Authors' estimation, 2020. Significance level: * p <0.10, ** p <0.05, *** p< 0.01. Figures within the parentheses are standard errors.

Table 4 Estimated regression coefficients of climate impact on crop yields: West Coast Plains & Ghats

Variables	Rice	Groundnut	Finger Millet	Wheat	Rapeseed & Mustard
Ln Rainfall	0.0073 (0.0064)	0.0554*** (0.0088	-0.0268 (0.0326)	0.0029 (0.0025)	0.0171** (0.0079)
Ln Min Temp	0.0407 (0.1211)	-0.3926** (0.1533)	0.2810 (0.5434)	0.0366 (0.0694)	0.6356*** (0.2083)
Ln Max Temp	-0.0513 (0.0495)	-0.0422 (0.0514)	-0.0389 (0.2144)	-0.0065 (0.0402)	0.0679 (0.1116)
Ln Irrigation	0.8773*** (0.0372)	0.4606*** (0.0295)	-0.9399*** (0.0709)	-0.0721*** (0.0177)	0.0721*** (0.0257)
Ln Fertilizer	-0.0034** (0.0014)	-0.0031* (0.0016)	0.0024 (0.0061)	-0.0005 (0.0009)	0.0118*** (0.0027)
Ln Road length	-0.0008 (0.0009)	-0.0018* (0.0010)	-0.0027 (0.0039)	0.0001 (0.0006)	0.0019 (0.0017)
Ln Ruliteracy	0.0070 (0.0092)	0.0077 (0.0092)	0.0770** (0.0386)	-0.0057 (0.0060)	0.0121 (0.0155)
Ln Tractors	-0.0016 (0.0027)	-0.0031 (0.0028)	-0.0046 (0.0115)	0.0005 (0.0017)	0.0054 (0.0047)
Ln Pumpset	-0.0029 (0.0030)	-0.0060* (0.0034)	0.0102 (0.0132)	0.0004 (0.0020)	0.0162*** (0.0057)
Year	0.0003 (0.0006)	0.0042*** (0.0003)	0.0063*** (0.0015)	0.0080*** (0.0003)	0.0106*** (0.0008)
Constant	-4.2440*** (1.1306)	-8.5686*** (0.6880)	-13.0269*** (3.2325)	-14.9332*** (0.5228)	-24.0096*** (1.4053)
District fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	720	720	720	720	720
Wald chi2(27)	10140.20***	1676.33***	4700.76***	5560.14***	3635.13***
F(1,17)[1]	1018.909***	590.165***	2939.778***	7.664**	1989.035***
chi2 (18)[2]	0.86	1.29	2.8	2.2	2.4

Note: Authors' estimation, 2020. Significance level: * p <0.10, ** p <0.05, *** p< 0.01. Figures within the parentheses are standard errors.

3.3. Marginal effects and forecasts

Marginal effects for all crops have calculated using equation (2), while forecast results were calculated using equation (3). Results revealed that rice and wheat crop yield was declined in East Coast Plains & Hills (Table 5), while crop yield of rice and wheat was increased in West Coast Plains & Ghats. Further, Groundnut and sugarcane crop yield was also declined in both the agro climatic zones, while crop yield of Rapeseed & Mustard and Finger Millet has increased during 1966-2011.

The projected results revealed that the crop yield of rice, groundnut, sugarcane, and wheat would be decline in East Coast Plains & Hills Region, while yield of Rapeseed & Mustard would be increase up to 9.10 percent in 2080. Further, the projected results for

West Coast Plains & Ghats regions revealed that yield of Groundnut would be decline by 3.92 percent in 2080. On the other hand, crop yield of Rice, Finger Millet, Wheat and Rapeseed & Mustard would be increase by 4 percent.

As far as food security is concern, there is a need for a holistic food- chain management approach in which food wastage should be reduced as possible to ensure food security in future.

Table 5 Marginal effects of climate change (1966-2011) and projected change for 2030, 2040, 2050 & 2080s

Agro-climatic Zone	Crops	Marginal Effects	2030s	2040s	2050s	2080s
			Δ MinT= 1.36	Δ MinT= 1.75	Δ MinT= 2.14	Δ MinT= 2.63
			Δ MaxT= 1.26	Δ MaxT= 1.50	Δ MaxT= 1.81	Δ MaxT= 2.29
			Δ R= (+/-) 5%	Δ R= (+/-) 7%	Δ R= (+/-) 10	Δ R= (+/-) 12%
East Coast Plains & Hills	Rice	-0.37	-0.57	-0.74	-0.93	-1.13
	Groundnut	-0.49	-0.52	-0.64	-0.74	-0.93
	Sugarcane	-9.91	-12.94	-16.70	-20.26	-24.87
	Wheat	-1.46	-2.01	-2.61	-3.19	-3.92
	Rapeseed & Mustard	3.45	4.71	6.05	7.41	9.10
West Coast Plains & Ghats	Rice	0.01	0.07	0.10	0.14	0.16
	Groundnut	-1.51	-1.82	-2.30	-2.75	-3.39
	Finger Millet	1.10	1.38	1.78	2.14	2.63
	Wheat	0.33	0.48	0.62	0.77	0.95
	Rapeseed & Mustard	2.45	3.37	4.33	6.34	6.53

Source: Authors estimation. Figures are in percentage. Note: Direction of rainfall for the future projections was premised on trend analysis for the period, 2001-2011.

4. CONCLUSION AND POLICY RECOMMENDATIONS

The present study attempted to calculate and predict the climate change impact on crop yield in Deccan plateau & hill regions. We use large- scale district-level data collected from ICRISAT-VDSA and IMD databases. Most robust results have obtained using Panel-FGLS estimation method. This study provides regional predictions of climate change impacts on main food & non-food crops. Our findings revealed a rise in minimum & maximum temperature; however, positive impacts of rainfall and advancement of socioeconomic and technological adaptations cancel out the adverse impacts of temperatures. Moreover, marginal and projected results revealed that (without adaptations), majority crops would be decline.

As far as food security is concern, there is a need for a holistic food- chain management approach in which food wastage should be reduced as possible to ensure food security in future. Policy of maintain buffer stocks of food helps in managing periods of scarcity. In future, such adaptation strategies would need to simultaneously consider the background of changing demand due to globalization and population increase and income growth, as well as the socioeconomic and environmental consequences of possible adaptation options. Adaptation to environmental change could be in the form of social aspects, such as crop insurance, subsidies, and pricing policies related to water and energy. Policies and incentives should be evolved that would encourage farmers to sequester carbon in the soil and thus improve soil health, and water use and energy more efficiently.

REFERENCE

1. Acharya, S.S. (2006). Sustainable agriculture and rural livelihoods. Agricultural Economics Research Review, 19(2), 205-217.
2. Aggarwal, P. K. (2009). Global Climate Change and Indian Agriculture: Case Studies from the ICAR Network Project. Indian Council of Agricultural Research, New Delhi.
3. Auffhammer, M., Ramanathan, V. and Vincent, J.R. (2012). Climate change, the monsoon, and rice yield in India. Climatic change, 111(2), 411-424.
4. Beck, N. and Katz, J.N. (1995). What to do (and not to do) with time-series cross-section data. American political science review, 89(3), 634-647.
5. Birthal, P.S., Khan, T.M., Negi, D.S. and Agarwal, S. (2014). Impact of climate change on yields of major food crops in

India: Implications for food security. Agricultural Economics Research Review, 27 (347-2016-17126), 145-155.
6. Centre for Science and Environment's (CSE). (2018). IPCC's Special Report on Global Warming of 1.5°C, Assessment and Recommendations. Centre for Science and Environment, New Delhi
7. Choudhury, P.R. and Sindhi, S. (2017). Improving the Drought Resilience of the Small Farmer Agroecosystem. Economic & Political Weekly, 52(32), 41.
8. Cline, W. (2007). Global Warming and Agriculture: Impact Estimates by Country, Washington, DC.
9. Deschênes, O. and Greenstone, M. (2007). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. American Economic Review, 97(1), 354-385.
10. Drukker, D.M. (2003). Testing for serial correlation in linear panel-data models. The stata journal, 3(2), 168-177.
11. Falkenmark, M., Rockström, J. & Karlberg, L. (2009). Present and future water requirements for feeding humanity. Food Security, 1(1), 59-69.
12. FAO. (2016). Climate change, agriculture and food security. The state of food and agriculture. FAO, Rome.
13. Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willet, K. and Wiltshire, A. (2010). Implications of climate change for agricultural productivity in the early twenty-first century. Philosophical Transactions of the Royal Society B: Biological Sciences 365, 2973–2989
14. Goswami, B.N., Venugopal, V., Sengupta, D., Madhusoodanan, M.S. and Xavier, P.K. (2006). Increasing trend of extreme rain events over India in a warming environment. Science, 314(5804), 1442-1445.
15. Government of India. (1989). Agro-climatic regional planning: an overview, Planning Commission, New Delhi.
16. Guiteras R. (2009). The impact of climate change on Indian agriculture. Manuscript, Department of Economics, University of Maryland, College Park, Maryland.
17. Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. The Stata journal, 7(3), 281-312.
18. IFPRI. (2010). International Food Policy Research Institute (IFPRI), Food Security CASE maps. Generated by IFPRI in collaboration with StatPlanet. [Online]. Available: www.ifpri.org/climate-change/casemaps.html [Accessed 21 June 2010].
19. IPCC. (2018). Summary for Policymakers. In: Global Warming of 1.5°C. Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (Eds.)], World Meteorological Organization, Geneva, Switzerland, 32.
20. Jain, M., Naeem, S., Orlove, B., Modi, V. and DeFries, R.S. (2015). Understanding the causes and consequences of differential decision-making in adaptation research: adapting to a delayed monsoon onset in Gujarat, India. Global Environmental Change, 31, 98-109.
21. Jain, S.K. and Kumar, V. (2012). Trend analysis of rainfall and temperature data for India. Current Science (Bangalore), 102(1), 37-49.
22. Khan, S.A., Kumar, S., Hussain, M.Z. and Kalra, N. (2009). Climate change, climate variability and Indian agriculture: impacts vulnerability and adaptation strategies. In Climate change and crops (19-38). Springer, Berlin, Heidelberg.
23. Knox, J., Hess, T., Daccache, A. and Wheeler, T. (2012). Climate change impacts on crop productivity in Africa and South Asia. Environmental Research Letters, 7(3), 034032.
24. Kumar, S.N., P.K. Aggarwal, R. Saxena, S. Rani, S. Jain, and N. Chauhan (2013). An assessment of regional vulnerability of rice to climate change in India. Climatic Change, 18(3-4), 683-699.
25. Kumar, S.N., P.K. Aggarwal, S. Rani, S. Jain, R. Saxena, and N. Chauhan. (2011). Impact of climate change on crop productivity in Western Ghats, coastal and northeastern regions of India. Current Science, 101(3), 332-341.
26. Lobell, D.B. and Field, C.B., (2007). Global scale climate–crop yield relationships and the impacts of recent warming. Environmental research letters, 2(1), 014002.
27. Lobell, D.B., Schlenker, W. and Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. Science, 333(6042), 616-620.
28. Mallya, G., Mishra, V., Niyogi, D., Tripathi, S. and Govindaraju, R.S. (2016).Trends and variability of droughts over the Indian monsoon region. Weather and Climate Extremes, 12, 43-68.
29. Mishra, A., Singh, R., Raghuwanshi, N.S., Chatterjee, C. and Froebrich, J. (2013). Spatial variability of climate change impacts on yield of rice and wheat in the Indian Ganga Basin. Science of the Total Environment, 468, S132-S138.
30. MoEF. (2017). Climate Change over India: An Interim Report, Eds. Krishnan R., and Sanjay J. ESSO-Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Government of India, Pune.
31. Nelson, G. C., Rosegrant, M. W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T. and Ringler, C. (2010). Food Security, Farming and Climate Change to 2050. Research Monograph, International Food Policy Research Institute. Washington, DC.
32. Padakandla, S.R. (2016). Climate sensitivity of crop yields in the former state of Andhra Pradesh, India. Ecological indicators, 70, 431-438.
33. Patnaik, U. and Das, P.K. (2017). Do development interventions confer adaptive capacity? Insights from rural India. World Development, 97, 298-312.

34. Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B. & Travasso, M.I. (2014). Food security and food production systems. In: C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea & L.L. White, eds. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, and New York, USA, Cambridge University Press.
35. Rao, B.B., Chowdary, P.S., Sandeep, V.M., Rao, V.U.M. and Venkateswarlu, B. (2014). Rising minimum temperature trends over India in recent decades: Implications for agricultural production. Global and Planetary Change, 117, 1-8.
36. Sanghi, A. and Mendelsohn, R. (2008). The impacts of global warming on farmers in Brazil and India. Global Environmental Change, 18(4), 655-665.
37. Singh, N.P., Bantilan, M.C.S., Byjesh, K. and Murty, M.V.R. (2012). Adapting to climate change in Agriculture: Building resiliency with an effective policy frame in SAT India. Policy Brief No. 18, RP-MIP, ICRISAT, Patancheru 502 324
38. Tubiello, F.N. and Ewert, F. (2002). Simulating the effects of elevated CO2 on crops: approaches and applications for climate change. European journal of agronomy, 18(1-2), 57-74.
39. Udmale, P.D., Ichikawa, Y., Manandhar, S., Ishidaira, H., Kiem, A.S., Shaowei, N. and Panda, S.N. (2015). How did the 2012 drought affect rural livelihoods in vulnerable areas? Empirical evidence from India. International Journal of Disaster Risk Reduction, 13, 454-469
40. Van Oldenborgh, G.J., Philip, S., Kew, S., van Weele, M., Uhe, P., Otto, F.E.L., Singh, R., Pai, I. and AchutaRao, K. (2018). Extreme heat in India and anthropogenic climate change. Natural Hazards and Earth System Sciences, 18.
41. Wooldridge, J. M. (2002). Econometric Analysis of Cross Section and Panel Data. Cambridge, MA: MIT Press.
42. Zhang, X., Obringer, R., Wei, C., Chen, N. and Niyogi, D. (2017). Droughts in India from 1981 to 2013 and Implications to Wheat Production. Scientific reports, 7, 44552.