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Climatic Effects on Food Grain Productivity in India

A Crop Wise Analysis

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ABSTRACT

Climate change is likely to affect the agricultural production adversely and becomes more serious concern for developing countries because they do not have enough resources to mitigate the adverse effect of climate change. Statistics show that the amount of undernourished people is still alarmingly in developing world, so as the case of India. In India more than 700 million populations directly depend on agriculture and allied activities of which 52% directly dependent on climate-sensitive sectors like agriculture, forestry and fishery for their livelihood. Agriculture sector is most sensitive to climate change and it affects the food security of India. 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 for a panel of 13 states have been employed during 1980-2009.Empirical results show that climatic factors have a statistically significant impact on productivity of most of food grain crops but this effect varies across crops. Productivity of rice, maize, sorghum, and ragi crops negatively influenced with increase in actual average maximum temperature. Actual average minimum temperature has negative and statistically significant effects on wheat, barley, gram, and rice crops. Productivity of barley, rice, maize, and ragi crops lead to declined due to excessive rain and changing in rainfall pattern. 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. Major finding of present study indicates a need to adapt separate policies for various crops to mitigate the adverse effect of climate change in India. The results also highlight the important of irrigation and optimum use of fertilizer to mitigate the adverse effect of climate change. The study also suggests that policy makers should ensure adequate and consistent pricing for the farmer's product during the harvesting season.
Keywords: *Climate Effects; Food Grain Productivity*

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1. Introduction

Climatic change is a serious concern for developing as well as developed countries as it significantly influences agriculture production in these economies previous studies suggested that in mid, high latitude and higher income countries, climate change has positive impact on agricultural production or crop yields; and lower-latitude and lower income countries experience a negative effect on agricultural production (Lee, 2009). It is expected that climate change may increase the number of food insecure children to 50 million by 2050 in South Asia (Greg et al., 2011). Masters et al. (2010) also mentioned that food insecurity get worse under climate change, threatens many millions of people and increased the severity of disparities in cereal yields between developed and developing countries (Parry et al., 2004). It is estimated that agriculture output and yield in lower developing countries may decline by 20% and 15% respectively in the presence of climate change on average (Masters et al., 2010). Further, that food insecurity broadens the poverty in developing country (Kramer, 2007).

Oluoko-Odingo (2009) observed that a rise in temperature will lead to either drought or flood, a reason for the severe shortage of food availability and income of households, lead to poverty and food insecurity. Therefore, researchers took climatic change as one of the main reason to food insecurity inability of a nation to feed its people through agricultural (Ahmad et al., 2011). There is a very serious concern that at present more than 870 million populations does not have secure resources to feed their self at global level.[1] Moreover, 1.2 billion population suffer from deficiency of calories and protein; similar population suffer from obesity (excess of fats and salts, often accompanied by deficiency of vitamins and minerals); and 2 to 3.5 million population have micronutrient deficiency (Ramasamy and Moorthy, 2012). There are alarming situation that somewhere a child dies every five second in the world (Ramasamy and Moorthy, 2012). This is a serious matter that hunger and malnutrition situation due to poverty kill more people every year compared to other serious diseases like AIDS, malaria and tuberculosis (Ramasamy and Moorthy, 2012). Malnutrition often leads to disease, devastating the lives of hungry poor economic peoples (Ramasamy and Moorthy, 2012).

Numerous of factors that can be affected Indian agriculture due to climatic change. Firstly, more than 60% of India's total agricultural area are rain-fed; secondly, more than 80% Indian farmers are small and marginal (having less than 1 ha of land) thus having less capacity to cope with climate change impacts (Ranuzzi and Srivastava, 2012). A third problem is more than 52% populations (around 700 million) depend on climate-sensitive sectors like agriculture, forestry and fishery for their livelihood (Sathaye et al., 2006). It is also very serious issues that India is home to largest number of hungry and deprived people in the world to be precise 360 million undernourished. It has more than 40% child malnutrition and around 325 million hunger population (Dev and Sharma, 2010). India is home to the largest number of hungry and deprived people in the world – to be precise 360 million undernourished and 300 million poor people (Ahmad et al., 2011). More than 320 million Indian goes to bed even without food every night. India's malnutrition level is almost just double compared to many countries in Africa (Dev and Sharma, 2010).

Another important fact that in India, food demand will increase just double by 2050 due to high growth rate of population and it may increase the competition for resources such as land, water, capital, labour and other precious natural resources (Ahmad et al., 2011). India has a 17.5% global population but just 2.1% of the world's arable land (Census (Government of India), 2011; and Planning Commission (Government of India). Therefore, in India food security is major concern in many perspectives like increasing demand of food with growing population, poverty, declining arable land due to higher industrialization and urbanization, and declining agricultural productivity due to climate change or another reason.

In India, large numbers of studies show that climate change has decreased the productivity of most of food grain crop in different states. Most of the studies have been analyzed the impact of climate change on agricultural productivity with special reference to a single crop or a maximum of four crops for a particular region. There is limited research on account of the impact of climatic change on crop productivity of various food grains at country level. Against the drawbacks of earlier studies, present study analyzes the impact of climate change on productivity of major food grain crops of thirteen major agriculture intensive states of India using panel data for time period, 1980 - 2009. The study also tries to figure out the most vulnerable crop with respect to climatic change.

1.1. Overview of Climate Change at Global Level

Climate change is not a new phenomenon in the world and it changing since ancient era. There are many examples that give the clear evidence of climatic change in rising temperature of earth surface, declining ground water, drought, fluctuation in rainfall, flooding, soil erosion, fluctuation in wind speed, rising sea level due to melting of glacier, cyclone, hail storm, fog, earthquakes and landslide,

[1] http://foodsecurityindex.eiu.com/

increasing ocean temperature and acidification of the oceans due to elevated carbon dioxide in atmosphere.[2] Natural and human activities both are responsible for climate and its variability. Natural activities include earth motion, sun's intensity volcanic eruption, forest fires and the circulation of the ocean etc. Volcanic eruption is another natural cause that contributes to short term changes for its variability and it also increases the large volumes of SO_2 (sulphur dioxide) and fires in forest area increase the carbon dioxide and carbon mono-oxide. Sun's intensity also increases the many harmful gases in the atmosphere.

Human activities are also responsible for climate change and environmental damage such as growing population, rapid urbanization, higher industrialization, use of modern technologies, innovation, higher economic growth and development, transport, building construction, reduction in forest area, burning fossil fuels, increasing development of land for farms, grazing cattle, etc. (Ahmad et al., 2011). These all activities emit green house gases (GHGs) in the atmosphere; and these also make the global carbon cycle in the world. According to scientific studies, rising quantity of green house gases (GHGs) in the atmosphere is key determinant factor for climate variability. Thus human driven activities increase the quantity of carbon dioxide, methane, nitrous oxide, chloro fluorocarbons (CFCs) and other gases has lead to global climate change. The concentrations of methane (CH_4) have increased in atmosphere more than two-and-half times pre-industrial levels due to human activities and atmospheric CO_2 concentrations have increased by almost 40% since pre-industrial times, from approximately 280 parts per million by volume (ppm) in the 18^{th} century to 390 ppm in 2010 and human activities currently release over 30 billion tons of CO_2 into the atmosphere every year. Nitrous oxide is another green house gas produced by natural and human activities; mainly through agricultural activities and natural biological processes, fuel burning and some other processes also create N_2O. Nitrous oxide also have risen around 18% since the start of the industrial revolution, with a relatively rapid increase towards the end of the 20th century.

1.2. Agriculture as a Cause of Climate Change

Agriculture is a cause and consequences of climate change and both are directly link to each other (Ranganathan et al., 2010). It is a major contributor of green house gases like nitrogen oxide, nitrous oxide, carbon dioxide, ammonia and methane (Masters et al., 2010). First, any variability in climatic factors adversely affect to agriculture production and again use of adaptation or mitigation techniques in agriculture; and second these mitigation techniques increase the probability to change in climatic parameters. Pant (2009) also showed the cause and effect relationship between agricultural sector and environmental degradation in the economy in the form of increase in GHGs and GHGs further affects environmental condition and agricultural productivity. The study was based on multiple regression analysis and relates to carbon emissions, energy consumption and other agriculture productivity with respect to 120 countries. Application of inorganic fertilizers and pesticides in agricultural sector is another cause for environmental problem as this leads to increase in emission of GHGs (Wallace, 1997; Ranuzzi and Srivastava, 2012). Fertilizers have a short-term positive effect on agricultural productivity but a long-term negative affect on agriculture and environment like crop yields, contaminating ground water and surface water (Chandrashekar, 2010). Another harmful effect of overuse of fertilizer will be increased in presence of fluoride, heavy minerals and arsenic. These all are toxic for soil and it may make agriculture to fade quickly (Srisubramanian and Sairavi, 2009).

2. Review of Literature

In India, numerous of studies have been carried out on climate change and its impact on agriculture. Empirical and descriptive studies gave the clear evidence that climate change negatively affect the agricultural productivity (in term of quantity and monetary) of major food grain and non-food grain crops. In India, it is expected that total farm net revenue may decline between 9% and 25% for a temperature rise of 2–3.5% (Masters et al., 2010). Gupta et al. (2012) and Kumar (2009) undertook a macro level study in India about climate change and its impact on agriculture productivity. Further, many researchers also did research at micro level in different regions/states of India. Ninan and Bedmatta (2012), based on cross section analysis of crops, mentioned that climate change will vary across crops and regions and increase in temperature is most responsible cause for declining agricultural production of crops in different parts of India. This study also argued that there is require better understanding of the long term path of innovation, land use and dynamic behavior of

[2] http://www.epa.gov/

managed ecosystem to mitigate the adverse effect of climate change.

Gupta et al. (2012) observed that climate change is likely to reduce the yields of rice, sorghum, and millet crop productivity in 16 major agriculture intensive states of India. Kumar (2009) investigated that climate change is result in 9% reduction in agricultural revenues in 13 states of the country. Kalra et al. (2008) shows that productivity of wheat, mustard, barley, and chickpea has decreased due to rise in seasonal temperature in northern states of India; namely Punjab, Haryana, Rajasthan, and Uttar Pradesh. Geethalakshmi et al. (2011) found similar result for rice, and mentioned that productivity of rice has declined by 41% with 4^0C increase in temperature in Tamil Nadu (India). Kumar, Sharma, et al. (2011) reached at different argument based on their study in Uttarakhand and Uttar Pradesh (India), that climate change has already shifted the weather condition and it is affecting to seasonal crops and reduced the available growing period for rice and sugarcane crops. Kaul and Ram (2009) examined about the impact of rains and temperature on productivity of jowar production; and found that excessive rain and extreme variation in temperature is adversely affect the jowar production, thereby negatively affects the incomes and food security of farming families in Karnataka (India). Kar and Kar (2008) (based on Cobb-Douglas production model) observed that low rainfall in Orissa affects the crop production and income of the poor farmers and suggest that investment in irrigation would be improve farm income. Nandhini et al. (2006) mentioned that rice cultivable land has declined due to scarcity of inputs and scanty rainfall in Tamil Nadu (India).

Hundal and Prabhjyot-Kaur (2007) shows (by simulation method) that an increase in minimum temperature up to 1.0^0C causes a decrease in yield of rice and wheat by 3% and 10% respectively in Punjab (India). Saseendran et al. (2000) investigated (by CERES model for time period, 1980 -2049) that change in temperature up to 5^0C can lead to continuous decline in the yield of rice and every one degree increment in temperature will leads to a 6% decline in yield of rice in Kerala (India). Simulation model was used by Kumar and Parikh (2001) for two crops, viz., rice and wheat, and projected large-scale changes in the climate would lead to significant reductions in crop yields, which in turn would adversely affect agricultural production by 2060 and may affect the food security of more than one billion people in India. Kumar, Aggarwal, et al. (2011) mentioned (based on Info-crop simulation model) that irrigated area for maize, wheat and mustard in northeastern and coastal regions; and rice, sorghum, and maize in western ghats of India may lose production due to climate change. Hariss et al. (2010) found (based on Info-crop simulation model) that rice production may decline of 31% in 2080 due to climate change in Bihar (India). Srivastava et al. (2010) shows (by Info-crop-sorghum simulation model) that climate change is to be reduce monsoon sorghum grain yield up to 14% in central zone (CZ) and up to 2% in south central zone (SCZ) by 2020; and this model also indicates that yields are likely to be affected even more in 2050 and 2080 scenarios; climate change impacts on winter crop are projected to reduce yields up to 7%, 11%, and 32% by 2020, 2050, and 2080 respectively in India.

Asha et al. (2012) observed that the yields of sorghum, maize, tur, groundnut, wheat, onion, and cotton has decreased by 43.03, 14.09, 28.23, 34.09, 48.68, 29.56, and 59.96 kilogram per hectare respectively in rainfed area in Dharwad district in Karnataka (India). This study also show that almost 100% and 92.22% small and marginal farmers respectively reported that the reduction in the rainfall was the major reason for reduction in the yield levels. Further this study represents that changes in temperature and seasonal patterns were reasons for the reduction in the yield by 42.22%. Kapur et al. (2009) mentioned that projected surface warming and shift in rainfall pattern may be decreased crops yields by 30% by the mid 21st century, due to this reason there may be reduction in arable land and would be enormous pressures on agriculture production in India.

3. Material and Methods

A panel of 13 states and 30 years from 1980-2009 has been used in the study. A separate panel has been created for 9 crops as we tries to understand the sensitivity of different crops under different climatic and non climatic condition. These 13 states of India covers Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. Total nine major food grain crops are taken like rice, arhar (pigeon pea), maize, bajra, gram, wheat, jowar (sorghum), ragi, and barley. Based on availability of crop wise data the states in each panel includes: thirteen states for gram, arhar, rice, maize, and millet; twelve states for wheat and sorghum; nine states for ragi; and eight states for barley. The detailed description of different sources of agricultural, socio-economic and climatic variables gives in the sub section.

Agricultural Data: State wise and crop wise total production, area sown, irrigated area; use of fertilizers, and tractors and farm harvest price of each crops are taken from Centre *for Monitoring Indian Economy* (CMIE). This data of farm harvest price available in current prices so this is converted into constant level based on 1993-1994 as a base year. Agricultural labour related information is collected from the different publication of Census (Government of India). The data were available in decadal basis as 1981, 1991, 2001 and 2011. Hence, we converted into time series data by interpolation method.

Demographic Data: State-wise number of literate rural population is taken from different publication of Planning Commission (Government of India). It was also available in decadal period; 1971, 1981, 1991, 2001 and 2011. To convert this data into time series, interpolation method is applied.

Climatic Data: Minimum and maximum temperature are collected from the Indian Meteorological Department (IMD, Government of India) database. This data was available on daily intervals with latitude and longitude information of monitoring stations. Due to unavailability of city wise data of temperature, the stations pertaining to specific latitude and longitude information were identified. Based on this information so generated, geographical regions are identified. Then from the groups of such stations different geographical region were linked to arrive at the state level data points. Monthly district wise rainfall information was taken from Hydromet Division, Indian Meteorological Department (IMD) (Government of India). These all data were converted in monthly averages city wise, after that data transformed in state wise monthly maximum and minimum temperature for selected specific city, it was collected from the 354 meteorological stations for the thirteen states of India. To process basic information on climatic factors like rainfall, minimum and maximum temperature data C^{++} and SPSS software were used to extract and bring data to excel format. For each crops actual average minimum and maximum temperature; and actual rainfall in growing time of each crops were taken for the regression analysis.

3.1. Empirical Analysis

The present study employed Cobb-Douglas production model to assess the impact of climate change on crop wise productivity. This model was applied by Kar and Kar (2008); Gupta et al. (2012) in India. Crop production is a function of endogenous variables like cultivated area, irrigated area, fertilizers, labours, and tractors.; the function also include the exogenous factors like, literacy rate etc. In mathematically functional form this may be:

$$(TP)_{it} = f\{(AS)_{it}, (IA)_{it}, (TF)_{it}, (AL)_{it}, (TT)_{it}, (LR)_{it}, (FHP)_{it}\} \quad (1)$$

Where, *TP* is total production for each food grain crop separately (in 000 Tonnes); and *i* is cross sectional groups of states for each crop and *t* is the time period for 1980-2009; and *AS*, *IA*, *TF*, *AL*, and *TT* are area sown (in 000 Hectare), irrigated area (in 000 Hectare), agricultural labour (in Numbers), and tractors (in Numbers) respectively for each crop. *LR* is literacy rate (in Numbers) [*LR*= (number of literate rural population/gross sown area) multiply by sown area for respective crops]. *FHP* is farm harvest price (in Rupees/Quintal) for respective crops (at constant level, 1993-94 prices). Now, divide by *TP* to *AS* (for production per unit land or land productivity) than equation (1) will become:

$$(TP/AS)_{it} = f\{(IA)_{it}, (TF)_{it}, (AL)_{it}, (TT)_{it}, (LR)_{it}, (FHP)_{it}\} \quad (2)$$

$(TP/AS)_{it}$ is production of per hectare land for each crop (in Kg./Hectare) in the equation (2). Cobb-Douglas production model assume that climatic factors are inputs for growth of crop (Nastis et al., 2012). After incorporate the climatic factors in equation (2), will become following specification:

$$(TP/AS)_{it} = f\{(IA)_{it}, (TF)_{it}, (AL)_{it}, (TT)_{it}, (LR)_{it}, (FHP)_{it}, (ARF)_{it}, (AMAXT)_{it}, (AMINT)_{it}\} \quad (3)$$

Where, *ARF, AMAXT* and *AAMINT* are the actual rainfall (in mm), actual average maximum (in ^{0}C) and actual average minimum temperature (in ^{0}C) in growing time of each crop (sowing time to harvesting time), respectively. In the original functional form of Cobb-Douglas production function model, equation (3) will be in following specification:

$$\ln (TP/AS)_{it} = \beta_0 + \beta_1 \ln (IA)_{it} + \beta_2 \ln (TF)_{it} + \beta_3 \ln (AL)_{it} + \beta_4 \ln (TT)_{it} + \beta_7 \ln (LR)_{it} + \beta_8 \ln (FHP)_{it} + \beta_9 \ln (ARF)_{it} + \beta_{10} \ln (AAMAXT)_{it} + \beta_{11} \ln (AAMINT)_{it} + \mu_{it} \quad (4)$$

Where, β_0 is constant coefficient that is also known as '*Total Factor Productivity (TFP)*' or '*Solow Residual*' where it is assumes that the production function is constant returns to scale. This is a liner production function of homogeneous degree one. β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9, β_{10} and β_{11} are the regression coefficient to be estimated for respective variables and μ_{it} is error term in the model. Equation (4) implies the real functional form of Cobb-Douglas production function model. Similar model was also used by Nastis et al. (2012) to analysis the climatic impact on agricultural productivity in Greek. Cobb-Douglas production model also was used by Gupta et al. (2012) to investigate the climatic impact on rice, sorghum and millet productivity utilizing panel in India. Mahmood et al. (2012) also employed Cobb-Douglas production function model to capture the climatic effects on rice productivity in Pakistan. To estimate the regression coefficients for proposed model, STATA and SPSS softwares are used to fit the equation (4).

3.2. Hypothesis Testing and Selection of Appropriate Model

***Panel Unit Root Test*:** In this study several regressions model are applied to select an appropriate model. Firstly the authors do experimented Im-Pesaran-Shin test to check the individual stationary of the data set for all crops. if individual data set is non -stationary then it would leads to spurious regression and the standard asymptotic properties of the regression estimation can be useless and misleading in inferences of empirical findings (Kim and Pang, 2009; Poudel et al., 2014). We tested the null hypothesis that all panels contain a panel unit roots within panel for all crops. Here we reject the null hypothesis at 1% significant level for all the crops. Hence we can conclude that all individual time series data sets are stationary in each panel for all crops.

***Random Effects*:** To check the appropriateness of random effects versus simple ordinary least square (OLS) regression model, Breusch-Pagan Lagrange multiplier (LM) test is applied (Baltagi, 2005). We tested a null hypothesis is that preferred model is OLS; variance across countries is zero; there is no significant difference within states; and there is no panel effect on productivity of all the crops. We failed to reject the null hypothesis for most of food grain crops because the estimated Chi^2 statistics are 0.00 ($Prob > |1.000|$), it means that there is in-significant different among all the states and can be justified that random effects model can be used. But in case of bajra crop the authors rejected the null hypothesis since Breusch-Pagan Lagrange multiplier (LM) test is produced a statistically significant results (see table 1 in Appendix A).

Fixed Effects: To check that quandary of fixed effect model, Hausman specification test is used (Baltagi, 2005). Here null hypothesis is that the preferred model is random effects and the unique error (u_i) terms are un-correlated with regressors. But the estimated Chi^2 values are statistically in-significant for wheat, barley, gram, arhar, maize, bajra, sorghum, and ragi crops. It means that unique error terms are un-correlated with independent variables and can be concluded that fixed effect model also can be used to estimate the regression coefficient (see table 1 in Appendix A). In case of rice crop, fixed model cannot be considered since Chi^2 value is statistically significant at 1% significance level (see table 1 in Appendix A).

Cross-sectional dependence/contemporaneous correlation: The presence of cross sectional dependence is tested using Pesaran's (CD) test on the assumption that outcomes are correlated across states (Baltagi, 2005). We rejected the null hypothesis of estimated residuals across states are un-correlated for wheat, arhar, rice, maize, millet, and sorghum crops as the calculated values are highly statistically significant (see table 1 in Appendix A). Panel data set for barley crop does not have cross sectional dependence since Pesaran's (CD) test is produced in-significant results (see table 1 in Appendix A).

Serial correlation and autocorrelation: To address the presence of the autocorrelation, Wooldridge (Lagram Multiplier) test is applied. The authors found presence of serial correlation as well as first order autocorrelation for wheat, gram, arhar, rice, maize, millet, sorghum, and ragi crops because estimates F values are statistically significant (see table 1 in Appendix A).

Heteroskedasticity: Ordinary least square (OLS) estimation assumes that there are constant variances with zero mean and is known as homoskedasticity (Baltagi, 2005). Heteroskedasticity emerges when this assumption violates and provides an unbiased estimate for the relationship between the predictor variable and the outcome. In order to check the heteroskedasticity, Modified Wald test is applied (Gupta et al., 2012). Here null hypothesis is that there is a presence of homoskedasticity (constant variance) in fixed regression model. In this case, we do fail to accept the null because estimated Chi^2 values are statistically significant for wheat, barley, gram, arhar, rice, millet, sorghum, and ragi crops (see table 1 in Appendix A).

Final Estimation: Above statistical tests shows that our panel data sets have the problems like presence of cross sectional dependence, serial correlation and autocorrelation; heteroskedasticity. Hence, to reduce these statistical problems, Prais Winsten models with panels corrected standard errors (PCSEs) estimation is applied for most of crops. To estimate the regression coefficient for maize crops, feasible generalize least square (FGLS) estimation is employed since these crops are free from heteroskedasticity.

4. Results and Discussion

Table 1, shows the results of effects of climatic and non-climatic factor on productivity of wheat, barley, gram, arhar, rice, maize, bajra, and ragi crops based on Prais Winsten models with panels corrected standard errors (PCSEs) estimation. But in case of maize crop

Table 1: Regression results for impact of different factor on various crops

Variable/Crops	Wheat	Barley	Gram	Arhar
No. of Obs.	360	240	390	390
No. of Groups	12	8	13	13
Wald Chi²	2747.74	487.49	307.67	242.51
Prob > Chi²	0.0000	0.0000	0.0000	0.0000
R-squared	0.7118	0.6884	0.3223	0.3550
IA	0.1546*	-0.0057	-0.0240*	0.0863*
TF	0.0106	0.1976*	0.0170	0.0074
AL	-0.1237*	-0.1011*	0.0716*	-0.0348**
TT	-0.0945*	-0.0149*	0.0398**	0.0573*
LR	0.1741*	0.0993*	-0.1174*	-0.1318*
FHP	0.2976*	0.1958*	0.0791*	-0.0081
ARF	0.0465*	-0.1292*	0.0220*	0.2126*
AAMAXT	-0.1486	0.1828	-0.3870	0.0561
AAMINT	-0.9447*	-0.4571*	-0.2478*	-0.4084
Con. Coe.	1.4159*	0.8620***	0.0359	-0.3700

Source -*Estimated by Authors; and *, ** and *** indicates the 1%, 5% and 10% significance level of for respective variables in the table.*

Table 1: Conti…

Variable/Crops	Rice	Maize	Bajra (Millet)	Sorghum	Ragi
No. of Obs.	390	390	390	360	270
No. of States	13	13	13	12	9
Wald Chi²	1049.74	377.37	462.69	326.16	649.24
Prob > Chi²	0.0000	0.0000	0.0000	0.0000	0.0000
R-squared	0.6560	-	0.4120	0.4571	0.7049
Log likelihood	-	143.6638	-	-	-
IA	0.0832**	-0.0156	0.2363*	-0.0358*	-0.0201
TF	0.1618*	0.4232*	-0.0290	0.0766	0.4392*
AL	-0.2597*	-0.2825*	-0.1140**	0.1289*	-0.0953*
TT	0.0551*	-0.0695**	0.0171	-0.0181	-0.0274
LR	0.0708*	-0.0879***	-0.0488	-0.0962*	-0.1661*
FHP	0.1568*	0.31895*	0.2842*	0.0654***	0.04054
ARF	-0.2185*	-0.1176*	0.1195***	0.3297*	-0.2876*
AMAXT	-2.2306*	-3.2197*	-0.1339	-1.6684*	-3.5863*
AMINT	-0.6341**	0.1729	-0.2689	1.8675*	1.9499*
Con. Coe.	5.4646*	5.6829*	-0.3031	-1.9450*	3.6462*

Source -*Estimated by Authors; and *, ** and *** indicates the 1%, 5% and 10% significance level of for respective variables in the table.*

the regression coefficients are estimated by feasible generalize least square (FGLS) estimation. Actual average maximum temperature has negative and statistically significant effects on productivity of rice, maize, sorghum, and ragi crops; and these estimates indicates that if actual average maximum increases by 1% then productivity decrease by 2.23%, 3.22%, 1.67% and 3.59% respectively.

Productivity of wheat, gram, and bajra crop also affects negatively however, the coefficients are insignificant. Negative influences of maximum temperature on these crops can be matched with earlier studies like Gupta et al. (2012); Saseendran et al. (2000); Kalra et al. (2008); Geethalakshmi et al. (2011). On the other hand, actual average minimum temperature has negative and statistically significant influences on the productivity of wheat, barley, gram, and rice crops. Further, estimates suggests that 1% increase in actual average minimum temperature leads to a decrease in productivity of these crops by 0.94%, 0.46%, 0.25%, and 0.63% respectively.

Arhar and millet productivity also negatively influenced with increase in actual average minimum temperature however, produces an insignificant effect. These estimated coefficients are consistent with earlier studies of Kumar and Parikh (2001); Ranuzzi and Srivastava (2012); Hundal and Prabhjyot-Kaur (2007).

Actual rainfall on the other hand influences crops productivity on both ways, positively and negatively. Crops like wheat, gram, arhar, millet, and sorghum increased by 0.05%, 0.02%, 0.21%, 0.12% and 0.33% respectively with 1% increase in actual rainfall, similar to the results produced by Kaul and Ram (2009); Gupta et al. (2012). On the other hand, productivity of barley, rice, maize, and ragi crop negatively affects this can be interpreted in tow ways, first excessive rainfall and second uncertainty in rainfall, both can be negatively effects affects on crop productivity. These estimates are similar with earlier research undertaken by Kaul and Ram (2009); and controversial with studies by Kar and Kar (2008); Nandhini et al. (2006); Asha et al. (2012); Kapur et al. (2009). Based on empirical results, we can conclude that climate change through increase in average maximum temperature and average minimum temperature and fluctuation in rainfall pattern have a negative and statistically significant impact on productivity of most of food grain crops. The effects of various climatic factors on crops are varies across crops in India (Ninan and Bedmatta, 2012).

In case of non-climatic variables, irrigation is crucial factor to increase the productivity of wheat, arhar, rice and millet crops because irrigation area has positive and statistically significant effects on these crops. Estimates implies that 1% increment in irrigation area for wheat, arhar, rice and millet crops turns to an increase in productivity of these firms by 0.15%, 0.09%, 0.08% and 0.24% respectively. It could be better option to reduce the adverse effect of climate variability for these crops. While, productivity of gram and sorghum crop negatively affected with irrigated area since the regression coefficients of irrigation area with these crops are negative and statistically significant. These negative regression coefficients of irrigation area is consistent with earlier study by Kumar, Aggarwal, et al. (2011) but these results are contradicting with study by Kar and Kar (2008).

Application of fertilizers has a positive and statistically significant impact on barley, rice, maize and ragi crops. Estimates indicates that the productivity of barley, rice, maize and ragi crop would be increased by 0.20%, 0.16%, 042%, and 0.44% respectively with 1% additional use of fertilizers. Fertilizer has a positive association with productivity of wheat, gram, arhar, and sorghum but statistically insignificant. Thus increase in fertilizers may be another option to improve the productivity of barley, rice, maize, ragi wheat, gram, arhar, and sorghum crops in India however, it can be suggested only for areas which are utilizing less than recommended doses of fertilizers (Ranuzzi and Srivastava, 2012; Wallace, 1997). Another harmful consequence of more consumption of fertilizers would be in reduction in the land quality, soil fertility rate and actual nutritional contents in the soil but also increases water demand for irrigation (Chandrashekar, 2010; Srisubramanian and Sairavi, 2009). Regression coefficients of agricultural labours with gram and sorghum crops are positive and statistically significant which implies that an increment in productivity of these crops with increase in agriculture labour on per hectare land. While the productivity of wheat, barley, arhar, rice, millet, and ragi crop negatively influenced with agriculture labours. These estimations show that more utilization of agriculture labour in cultivation would lead to a decline in productivity of most of crops. Another reasonable justification for decline in productivity is the excessive use of labour may not increase the marginal productivity of land.

Adequate pricing at the right time helps to improve the productivity of most of food grain crops like wheat, barley, gram, rice, maize, millet, and sorghum crops because our estimated regression coefficients of farm harvest prices produces positive and statistically significant influence. These estimates implies that if farm harvest prices increase 1% then productivity of wheat, barley, gram, rice, maize, millet and sorghum crops would be increased by 0.30%, 0.20%, 0.08%, 0.16%, 0.32%, 0.28% and 0.017% respectively. These results also help us to draw a conclusion that farmers will shift their cultivation to those crops that provide adequate and consistent pricing to them at the time of harvesting. Gram, arhar and rice crops get benefits from mechanization because tractor has positive and statistically significant impacts on productivity of gram, arhar and rice crops. While, reaming crops adversely get affect with use of tractors. Increases of participation of literate persons are important for arhar and wheat crops. Participation of literate population has a positive and statistically significant impact on wheat, barley and rice productivity. While rest of crops negatively influenced with literate population.

5. Concluding Notes

This study estimates the impacts of climatic and non-climatic factors on major food grain crops in India. Cobb-Douglas production function for a panel of 13 states during 1980-2009 has been employed. Empirical results based on Prais Winsten models with panels corrected standard errors (PCSEs) estimation shows that productivity of rice, maize, sorghum, and ragi crops negatively influences with increase in actual average maximum temperature. We predict that a 1^0C increment in actual average maximum temperature reduces the productivity of rice, maize, sorghum, and ragi crops by 2.23%, 3.22%, 1.67% and 3.59% respectively. Actual average minimum temperature has negative and statistically significant influences on productivity of wheat, barley, gram, and rice crops. For these crops the elastiticity is measured as 0.94%, 0.46%, 0.25%, and 0.63% respectively with respect to 1^0C increase in actual average minimum temperature. On the contrary to this, sorghum and ragi crop positively get affects. Actual rainfall has positive and statistically significant effect on wheat, gram, arhar, millet, and sorghum crop, a 1 % increase leads to 0.05%, 0.02%, 0.21%, 0.12% and 0.33% productivity increase respectively. However, some of the crops like barley, rice, maize, and ragi get negatively affect rain fall. Based on empirical findings we can concluded that climate change, through an increase in actual average maximum temperature, actual average minimum temperature and changing rainfall pattern has a resulted to a decline in productivity of most of food grain crops. This effects are varies within crops and there is need to adapt different policies for various crop to mitigate the adverse effect of climate change in India. Therefore, this study provides the empirical evidence that climate change adversely affects the food grain crops productivity and thus it may be serious threat for food security in India.

This study also suggest that the policy makers need to provide adequate irrigation facilities to mitigate the adverse effect of climate change for wheat, arhar, rice and millet crops. The study also suggest an optimum us of fertilizer in case of barley, rice, maize and ragi productivity as these products are not benefited from abundant use of fertilizer. Unnecessary use of fertilizer leads to severe problems like reduction of land productivity, soil quality, and environmental degradation. Gram and sorghum productivity may be increased with increasing of agricultural labour for these crops. In case of mechanization i.e. increase in number of tractors has a positive and statistically significant impact on rice, arhar and gram. Another important suggestion is that policy makers should provide appropriate price to farmers for their agriculture production. According to our empirical findings, farm harvest price for all the crops are very crucial to improve the productivity of food grain crops and there may be one important reason that farmers give preference to those crops which will provide more financial benefits and it will also increase the decision of farmers to select more financially beneficial crop for cultivation.

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