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Assessing the Impacts of Climate Change on Land Productivity in Indian Crop Agriculture: An Evidence from Panel Data Analysis

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ABSTRACT

The current study assessed the climate change impacts on land productivity of major food and non-food grain crops in India. We compiled panel data for 30 years (1980-2009) using fifteen crops across thirteen agriculture intensive states. The value of production for each crop is estimated by farm harvest price (at constant prices, 1993-1994). Aggregate value of production on per hectare land is regressed with different socio-economic and climatic factors using the Cobb-Douglas (C-D) production function model. Estimates based on Driscoll-Kraay standard errors and linear regression and correlated Panels Corrected Standard Errors (PCSEs) (Prais-Winsten) estimation indicate that land productivity decreases with increase in annual average maximum temperature. The study concludes that Indian policymakers need to increase more irrigation facilities and fertilizers for cultivation. Land productivity is positively associated with irrigation area, number of pump set and application of fertilizers on per hectare land. In brief, more irrigation facilities; recommended use of fertilizer; more investment in infrastructure; participation of more literate population in agricultural activities; government expenditure on agricultural and allied sectors, rural development, irrigation and flood control would be useful to mitigate the negative effect of climate change on agriculture and improve agricultural productivity (land productivity). Finally, our projected results based on simulation technique showed that climate change would cause a decline in land productivity by 48.63 percent by the year 2100 and loss of farmers' income in India.

Keywords: Climatic change, Cobb-Douglas production function model, India, Land productivity, State-wise panel.

INTRODUCTION

Most of studies have shown that climate change has a statistically significant and negative impact on agricultural and other sectors of economy (Kumar and Parikh, 2001; Kapur *et al.*, 2009; Hariss *et al.*, 2010; Srivastava *et al.*, 2010; Birthal *et al.*, 2014; Saleh *et al.*, 2014 Kumar and Sharma, 2014; Kumar *et al.*, 2014). Developing countries are highly vulnerable to climate change effects as they have low technology and financial lacuna of farmers to mitigate the adverse effects of climate change; dependence of a large population on agriculture means that agriculture is a major source of national income and contributes a large share to national Gross Domestic Product (GDP). In developing countries most of farmers are marginal and subsistence, and produce for their home consumption. These economies also show severe inequalities across the different sections of the society. The economic growth of several emerging economic giants including India have seen increase in poverty and inter-regional disparities in their developmental pathways. Over and above economic and policy factors, the climatic

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factors also affect the poor more severely due to their inadequate adaptation and coping capabilities. The agricultural sector is identified as having high vulnerability to anthropogenic climate change impacts which would affect other sectors of the economy. For example, increase in atmospheric maximum and minimum temperature above the normal would lead to high fluctuations in rainfall patterns, which adversely affect agricultural productivity. India is an emerging economy and is also distinguished as the second largest agrarian economy in the world. It has several disparities within states due to its geographical location and availability of ecosystem services and natural resources. Agriculture plays a vital role in food security, employment generation and poverty alleviation as around 54% Indian workforce are engaged in agricultural and allied activities (Birthal *et al.*, 2014). Hence, climate change has brought several threats for Indian economy including food insecurity, poverty, reduction of farmers' income and employment opportunities, several health problems, food inequality and regional development disparities across states.

In this context, numerous of studies estimated the influence of climatic factors on productivity of various crops in different regions/states of India (e.g., Hari *et al.*, 2010; Kalra *et al.*, 2008; Hundal and Prabhjyot, 2007; Geethalakshmi *et al.*, 2011; Saseendran *et al.*, 2000; Kumar *et al.*, 2011b; Gupta *et al.*, 2012; Birthal *et al.*, 2014; Mondal *et al.*, 2015; Kumar *et al.*, 2015a, b). Kumar and Parikh (2001); Kapur *et al.* (2009); Hariss *et al.* (2010) and Srivastava *et al.* (2010), showed that productivity of food and non-food grain crops would be declined in coming decades. Kumar *et al.* (2011a) mentioned that climate change has shifted the weather condition; it is affecting seasonal crops and reducing the available growing time of rice and sugarcane crops in Uttarakhand and Uttar Pradesh (India). Nandhini *et al.* (2006) reported that the rice cropped area has declined due to scarcity of inputs and low rainfall in Tamil Nadu. Kar and Kar (2008); Kumar (2009) and Kumar *et al.* (2015a). also assessed the influence of climate factors on land productivity (in monetary term). Based on the brief literature review, it can be concluded that productivity of most of crops has declined or would be decreased in near future due to climate change. However, few studies estimated the influence of climate change on agricultural productivity (in monetary term) at macro level in India. To account for this drawback, the present study assesses the impact of climate change on land productivity in Indian crop agriculture using state-wise panel during 1980-2009. The main focus of the study is to identify how land productivity significantly becomes affected by the variations in climatic factors. The study also applied simulation techniques to identify the loss of land productivity in different climate change scenarios.

MATERIAL AND METHODS

Specification of Econometric Model

The Cobb-Douglas (C-D) production function model proposed by Knut Wicksell (1851-1926), and tested against statistical evidence by Charles Cobb and Paul Douglas in 1928 is used. (http://docentes.fe.unl.pt/~jamador/Macro/cobb-douglas.pdf). The model has some advantages compared to other models like simple estimation and easy interpretation (Mahmood *et al.*, 2012). The C-D model assumes that climatic factors are input factors for growth of crops (Nastis *et al.*, 2012). This model has been used by various authors to estimate the influence of climatic factors on crop and land productivity in agriculture like Nastis *et al.* (2012) in Greece, Lee *et al.* (2012) in 13 Asian countries, Gupta *et al.* (2012); Kar and Kar (2008); Kumar (2009) and Kumar *et al.* (2015a), which also assessed the influence of climate factors on land productivity (in monetary term) in India, and Oduol *et al.* (2011) in Sub-Saharan Africa. The model assumes that agricultural production is a function of many endogenous and exogenous variables like cultivated area, irrigated area, fertilizers, agricultural labor, tractors and pumpset etc. (Nastis *et al.*, 2012,

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Kumar *et al.*, 2015b). In the present study the proposed regression models assume that aggregate value of production for each time period depends upon gross areas sown, gross irrigated area, consumption of fertilizers, agricultural labor, tractors, pump set, literate population, and railway road length as a proxy for infrastructure and government expenditure as well (Nastis *et al.*, 2012; Kumar and Sharma (2014); Kumar *et al.* (2014); Kumar *et al.*(2015a, b). In functional form all these variables with aggregate value of production will be shown as:

$$(VP)_{st}= f\{(AS)_{st}, (IA)_{st}, (TF)_{st}, (AL)_{st}, (TT)_{st}, (PS)_{st}, (LR)_{st}, (RRL)_{st}\} \quad (1)$$

Where, *VP* is aggregate value of production for 15 crops at farm harvest prices (in '000' rupees at constant level, 1993-1994 prices) and *s* is state and *t* is time period in each panel. *AS* and *IA* are the aggregate area sown and irrigated area for these fifteen crops, respectively. *TF*, *AL*, *TT*, *PS*, *LR*, and *RRL* are total consumption of fertilizers, agricultural labor, tractors, pump set, number of literate population in rural area, and railway road length, respectively. Dividing by *AS*, Equation (1) could be written in yield terms that indicate the value of production on per hectare land basis (land productivity) as:

$$(VP/AS)_{st}= f\{(IA/AS)_{st}, (TF/AS)_{st}, (AL/AS)_{st}, (TT/AS)_{st}, (PS/AS)_{st}, (LR/AS)_{st}, (RRL/AS)_{st}\} \quad (2)$$

After substituting small capitals for the quantity of per hectare land production of each variable, Equation (2) will be:

$$(vp)_{st} = f\{(ia)_{st}, (tf)_{st}, (al)_{st}, (tt)_{st}, (ps)_{st}, (lr)_{st}, (rrl)_{st}\} \quad (3)$$

Three climatic factors, annual actual rainfall, average annual maximum and minimum temperatures are included to capture the impact of climatic factors on land productivity. After incorporating these factors, Equation (3) can be written as:

$$(vp)_{st}= f\{(ia)_{st}, (tf)_{st}, (al)_{st}, (tt)_{st}, (ps)_{st}, (lr)_{st}, (rrl)_{st}, (arf)_{st}, (aamaxt)_{st}, (aamint)_{st}\} \quad (4)$$

where, *arf* is annual actual rainfall; *aamaxt* and *aamint* are average annual maximum and minimum temperature, respectively. Equation (4) expresses the value of production on per hectare land (land productivity) as a function of irrigated area per hectare, fertilizers per hectare, labor per hectare, tractor per hectare, pump set per hectare, literate population per hectare, railway road length per hectare, annual actual rainfall (in mm), and annual average maximum and minimum temperatures (Nastis *et al.*, 2012, Kumar *et al.*, 2015a). After applying a C-D model, Equation (4) will take the following specification:

$$\log (vp)_{st} = \beta_0+\beta_1\log(ia)_{st}+\beta_2 \log(tf)_{st}+\beta_3 \log(al)_{st}+\beta_4 \log(tt)_{st}+\beta_5 \log(ps)_{st}+\beta_6 \log(lr)_{st}+\beta_7 \log(rrl)_{st}+\beta_8 \log(arf)_{st}+\beta_9 \log(aamaxt)_{st}+\beta_{10} \log(aamint)_{st}+\xi_{(s-1)}SD_{(s-1)}+€_{(t-1)} TD_{(t-1)}+\psi_{(s-1)+(t-1)} SD_{(s-1)}\times TD_{(t-1)}+\mu_{st} \quad (5)$$

Where, β_0 is a constant coefficient that is known as Total Factor Productivity (TFP) and assumes that the production function is constant returns to scale and a linear production function with homogeneous degree one. μ_{st} is *white noise error term* with zero mean and constant variance. And β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9, and β_{10} are estimated regression coefficients for corresponding variables. These estimated beta coefficients are also elasticities for respective variables under the C-D model (Nastis *et al.*, 2012; Kumar and Sharma (2014); Kumar *et al.* (2014); Kumar *et al.* (2015a, b). $SD_{(s-1)}$ and $TD_{(t-1)}$ are the states and time dummies; $\xi_{(s-1)}$ and $€_{(t-1)}$ are estimated regression coefficients for state and time dummies, respectively to capture the state-level fixed effects and to control for annual difference in land productivity to all states. $SD_{(s-1)}\times TD_{(t-1)}$ is the combined states and time dummies; $\psi_{(s-1)+(t-1)}$ is estimated regression coefficients for states and time dummies with state-by-year fixed effects to capture the unobserved heterogeneity, to control annual difference (Gupta *et al.*, 2012; Kumar and Sharma (2014); Kumar *et al.* (2014); Kumar *et al.* (2015a, b).

Data Sources and Description

The data set used in the present study covers 30 years during 1980-2009 for thirteen major

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agricultural intensive states: Bihar, Orissa, Uttar Pradesh, Punjab, Haryana, Gujarat, Madhya Pradesh, West Bengal, Maharashtra, Rajasthan Andhra Pradesh, Tamil Nadu and Karnataka. All these states are the major food grain and non-food grain crop producers of the country. The study estimated the monetary value of 15 crops which includes wheat, barley, gram, rice, maize, sorghum, bajra, arhar, ragi as food grain; and linseed, sesamum, cotton, groundnut, potato, and sugarcane as non-food grain crops. Crop-wise production, area sown, irrigated area, gross sown area, gross irrigated area, tractor, pump set and consumption of fertilizers; crop-wise farm harvest price; and railway road length are taken from Centre Monitoring Indian Economy (CMIE); Directorate of Economics and Statistics Ministry of Agriculture (GoI). Number of agricultural labor and cultivators are taken from various publication of Census (GoI). Number of literate population is taken from Planning Commission (GoI).

Minimum, maximum temperatures and rainfall are taken from the Indian Meteorological Department (IMD) (GoI) database. These data were 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 geographical regions were identified. Then from the groups of such stations different geographical regions were linked to arrive at the state level data points. These data were converted in monthly averages city-wise, after which the data was transformed in state-wise monthly maximum and minimum temperatures for selected specific city. This was collected from 354 meteorological stations in thirteen states of India. To process basic information on climatic factors i.e. rainfall, minimum, and maximum temperature data, the C^{++} software was used. The SPSS software was used to extract and convert data to excel format. Regression analysis was run by STATA and

Table 1. Brief description of dependent and explanatory variables

Symbol	Variables	Units	Brief description	Source
vp	Value of production	in '000' rupees	Aggregate value of production of 15 crops	Author's estimation
as	Area sown	in '000' hectare	Aggregate area sown under 15 crops	CMIE
ia	Irrigated area	in '000' hectare	Aggregate irrigated area under 15 crops	CMIE
tf	Total fertilizers	in '000' tonnes	Aggregate application of fertilizers under 15 crops	CMIE
al	Agricultural labours	in number	Utilization of total agricultural labour for 15 crops	Census (GoI)
tt	Tractors	in number	Total tractor used under 15 crops	CMIE
ps	Pumpset	in number	Total pumpset used under 15 crops	CMIE
lr	Literate population	in number	Total literate population in rural area	Planning Commission (GoI)
rrl	Railway road length	in kilometer	Railway road length	CMIE
arf	Rainfall	in mm	Annual actual rainfall	IMD (GoI)
aamaxt	Maximum temperature	in ^{0}C	Annual average maximum temperature	IMD (GoI)
aamint	Minimum temperature	in ^{0}C	Annual average minimum temperature	IMD (GoI)

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SPSS softwares to fit the proposed regression models. (Table 1)

Results of Hypothesis Testing

In this study several regression models were used to select an appropriate model. Random effects model is applied by assuming that the variation across states is to be random and uncorrelated with land productivity. (Kumar *et al.*, 2015a, b). After that, to capture the unobserved heterogeneity in states and to control annual difference in land productivity, a fixed effects and time fixed regression model was used that is described in Equation (5) (Gupta *et al.*, 2012; Kumar and Sharma, 2014; Kumar *et al.*, 2014; Kumar *et al.*, 2015a, b). Brief summary of all models are presented in Table 2.

Testing for Random Effects

To decide either random effects or a simple ordinary least square regression model is appropriate, Breusch-Pagan Lagrange Multiplier (LM) test was applied (Gupta *et al.*, 2012; Kumar and Sharma, 2014; Kumar *et al.*, 2014; Kumar *et al.*, 2015a, b). Null hypothesis is that variance across states is zero and there is no significant difference among all states, no panel effect. Here null hypothesis is rejected and it is concluded that random effects model cannot be used. (See Table: 5). Regression results based on random effect and fixed effect models are presented in Table: 3 and 4 respectively.

Hypothesis Testing for Fixed or Random

Hausman test is used to check the quandary of fixed and random effects (Saleh *et al.*, 2014). Here null hypothesis is that the preferred model is random effects, and the unique error (u_i) terms are not correlated with regressors. Under this specification if null hypothesis is rejected, it suggests that unique error (u_i) term significantly correlated with regressors (See Table 5). Thus fixed effects model is selected for further regression analysis (Gupta *et al.*, 2012; Kumar and Sharma, 2014; Kumar *et al.*, 2014; Kumar *et al.*, 2015a, b).

Testing for Cross-sectional Dependence/Contemporaneous Correlation

Cross sectional dependence is a major problem in macro panel data sets (over 20 years). If outcomes are correlated with across region then there is presence of cross sectional dependence in fixed effects model. To identify the cross sectional dependence, Breusch-Pagan Lagrange Multiplier (LM) and Pesaran's (CD) tests are incorporated (Gupta *et al.*, 2012; Kumar and Sharma, 2014; Kumar *et al.*, 2014; Kumar *et al.*, 2015a, b). The null hypothesis under B-P (LM) test is that the residual across states are not correlated. In this case null hypothesis was rejected (See Table 5). It means that residual across states are correlated and data sets have a cross sectional dependency. Similar, hypothesis test is used for Pesaran's (CD) test and this also shows

Table 2. Brief summary of model and methods.

Name of the model/methods	Application of model/methods
Breusch-Pagan Lagrange multiplier (LM) test	Random effect model
Hausman test	Fixed or random effect model
Breusch-Pagan Lagrange multiplier (LM) and Pesaran's (CD) test	To identify cross-sectional dependence/contemporaneous correlation
Modified Wald test	To identify heteroskedasticity
Wooldridge test	To check serial correlation
Panels corrected standard errors (PCSE) and Driscoll-Kraay standard errors estimation	To remove the presence of heteroskedasticity, serial-correlation, and auto-correlation

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Table 3. Regression results with Random-effects GLS regression

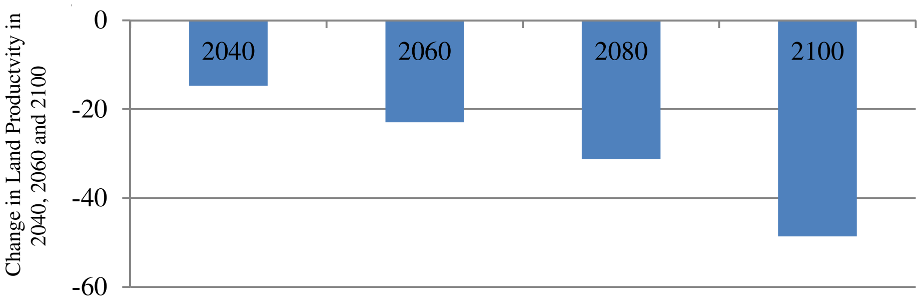
No of Observation		390	*R-sq:* Within		0.8416	
No of States		13	Wald $Chi^2(10)$		721.62	
No of Obs./States		30	*Prob>* $Chi^2(10)$		0.0000	
Variable	Regression Coefficient	*Std.* Errors	*z*	*P* > |z|	95% Confidence Interval	
ia	0.134439	0.11451	1.17	0.240	-0.09002	0.35889
tf	0.71608*	0.06478	11.05	0.000	0.58912	0.84304
al	0.00001	0.00004	0.31	0.758	-0.00006	0.00009
tt	0.14421*	0.02809	5.13	0.000	0.08915	0.19927
ps	0.07159**	0.02920	2.45	0.014	0.01437	0.12881
lr	0.51392*	0.12388	4.15	0.000	0.27110	0.75669
rrl	0.01499	0.21268	0.07	0.944	-0.40185	0.43184
arf	-0.01681	0.07322	0.23	0.818	-0.12671	0.16032
aamaxt	-3.38328*	0.94455	-3.58	0.000	-5.23456	-1.5320
aamint	-0.20632	0.52633	-0.39	0.695	-1.23791	0.82527
Con. Coef.	9.45682*	1.20178	7.87	0.000	7.10138	11.81226

Source: Author's Estimation; *, ** are statistically significant at 1% and 5% significance level respectively.

Table 4. Regression results with Fixed-effects (within) regression

No. of Observation		390	*R-sq:* Within		0.8819	
No. of States		13	*F(10, 367)*		274.11	
No. of Obs/States		30	Prob > F		0.0000	
Variable	Regression Coefficient	*Std.* Errors	*t*	*P* > |t|	95% Confidence Interval	
ia	-0.19741***	0.10190	-1.94	0.053	-0.39779	0.00297
tf	0.60130*	0.07686	7.82	0.000	0.45017	0.75244
al	-0.00005	0.00004	-1.27	0.204	-0.00012	0.00003
tt	0.33752*	0.03627	9.31	0.000	0.26621	0.40883
ps	0.08576***	0.04714	1.82	0.070	-0.00694	0.17846
lr	1.54699*	0.18893	8.19	0.000	1.17546	1.91852
rrl	-1.38060*	0.22815	-6.05	0.000	-1.82924	-0.93196
arf	0.14234*	0.04749	3.00	0.003	0.04895	0.23573
aamaxt	-1.46330***	0.78066	-1.87	0.062	-2.99843	0.07182
aamint	-0.06575	0.42653	-0.15	0.878	-0.90451	0.77301
Con. Coef.	7.28395*	1.07958	6.75	0.000	5.16101	9.40689

Source: Author's Estimation; *, *** are statistically significant at 1% and 10% significance level respectively.



Source: Author's Estimation.

Figure 1: Predicted land productivity (in %) in different climatic scenarios (2040, 2060, 2080, and 2100) over the base period 1980-2009

the presence of cross sectional dependency in panel .

Testing for Heteroskedasticity

Modified Wald test is applied to identify whether heteroskedasticity exists or not (Gupta *et al.*, 2012; Kumar and Sharma, 2014; Kumar *et al.*, 2014; Kumar *et al.*, 2015a, b). The null hypothesis is that there is homoskedasticity (or constant variance). Here Modified Wald test has rejected null hypothesis since Chi^2 value was statistically significant at 1% level and is concluded that there was homoskedasticity in the panel data. (See Table 5).

Testing for Serial Correlation

If serial auto-correlation exists in fixed effects model then outcomes are correlated across years for a given state. To address the presence of autocorrelation, Wooldridge test is used (Gupta *et al.*, 2012; Kumar and Sharma, 2014; Kumar *et al.*, 2014; Kumar *et al.*, 2015a, b). Null hypothesis is that land productivity is correlated with across year. Here null hypothesis is rejected meaning that there is presence of serial correlation and it can be concluded that data have a first order auto-correlation (See Table 5). Finally, Panels Corrected Standard Errors (PCSEs) estimation and Driscoll-Kraay standard errors estimation were applied to remove the presence of heteroskedasticity, serial correlation, auto-correlation and serial correlation in panel data. (Gupta *et al.*, 2012; Kumar and Sharma, 2014; Kumar *et al.*, 2014; Kumar *et al.*, 2015a, b).

RESULTS AND DISCUSSION

Empirical result of the ordinary least square (OLS) regression with Driscoll-Kraay standard errors and linear regression, correlated Panels Corrected Standard Errors (PCSEs) (Prais-Winsten) estimations (Tables 6 and 7) indicates that annual average maximum temperature appears statistically significant at 1% significance level. The elasticity of annual average maximum temperature with land productivity is -3.2854 (P> |0.010|). Annual average minimum temperature also has a negative effect on land productivity because it has a negative association with land productivity. Here, it can be concluded that climate change, through increase in annual average maximum and minimum temperature has resulted in a decline in land productivity. This empirical result is consistent with earlier studies by Kumar (2009) which showed that climate change resulted in 9% reduction in agricultural farm revenues. Kumar *et al.* (2015a) also observed that maximum and minimum temperatures have a negative association with land productivity of Kharif and Rabi crops. Land productivity will increase with rise in annual actual rainfall even though the regression coefficient is statistically insignificant because its elasticity has a positive association with land productivity. This regression coefficient is consistent with earlier studies such as Kar and Kar (2008);

Table 5. Results for hypothesis testing.

Applied Test	$H:_0$	$H:_1$
Breusch-Pagan Lagrange multiplier (LM) test for random effects	Rejected	Accepted
Hausman test for fixed or random effects	Rejected	Accepted
Breusch-Pagan Lagrange multiplier (LM) test for cross-sectional dependence correlation	Rejected	Accepted
Pesaran's (CD) test for cross-sectional dependence correlation	Rejected	Accepted
Modified Wald test for heteroskedasticity	Rejected	Accepted
Wooldridge test for serial correlation	Rejected	Accepted

Source: Author's Estimation.

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Table 6. Regression results with Driscoll-Kraay standard errors estimation.

No. of Observation		390	R-squared		0.4850	
No. of States		13	F(10, 29)		207.97	
No. of Obs./States		30	Prob >F		0.0000	
Variable	Regression Coefficient	Panel Corr. Std. Errors	*z*	*P* > |*z*|	95% Confidence Interval	
ia	0.26513	0.17444	1.52	0.139	-0.09163	0.62189
tf	0.42283*	0.12052	3.51	0.001	0.17634	0.66931
al	-0.00003	0.00004	-0.65	0.520	-0.00012	0.00006
tt	0.05463	0.04518	1.21	0.236	-0.03778	0.14703
ps	0.03327*	0.00800	4.16	0.000	0.01690	0.04963
lr	0.18372**	0.07724	2.38	0.024	0.02574	0.34171
rrl	0.23155*	0.07802	2.97	0.006	0.07199	0.39111
arf	0.08916	0.11701	0.76	0.452	-0.15015	0.32848
aamaxt	-3.2854*	1.18692	-2.77	0.010	-5.71292	-0.85788
aamint	-0.37286	0.36520	-1.02	0.316	-1.11979	0.37407
Con. Coef.	8.55834*	2.06088	4.15	0.000	4.34336	12.77331

Source: Author's Estimation; *, ** are statistically significant at 1% and 5% significance level respectively.

Table 7. Regression results with linear regression, correlated panels corrected standard errors (PCSEs) estimation

No. of Observation		390	R-squared		0.4850	
No. of States		13	Wald $Chi^2(10)$		896.33	
No. of Obs./States		30	Prob> $Chi^2(10)$		0.0000	
Variable	Regression Coefficient	Panel Corr. Std. Errors	*z*	*P* > |*z*|	95% Confidence Interval	
ia	0.26513*	0.10044	2.64	0.008	0.06827	0.461996
tf	0.42283*	0.08087	5.23	0.000	0.26432	0.58134
al	-0.00003	0.00002	-1.24	0.214	-0.00007	0.00002
tt	0.05463***	0.02923	1.87	0.062	-0.00267	0.11192
ps	0.03327*	0.01075	3.09	0.002	0.01220	0.05434
lr	0.18372*	0.05221	3.52	0.000	0.08139	0.28606
rrl	0.23155*	0.08785	2.64	0.008	0.05937	0.40372
arf	0.08916	0.08244	1.08	0.279	-0.07241	0.25073
aamaxt	-3.2854*	0.66640	-4.93	0.000	-4.59152	-1.97928
aamint	-0.37286	0.35938	-1.04	0.300	-1.07723	0.33151
Con. Coef.	8.55834*	1.18060	7.25	0.000	6.24440	10.87227

Source: Author's Estimation; *, *** are statistically significant at 1% and 10% significance level respectively.

Nandhini *et al*. (2006) which observed declining crop productivity due to low rainfall. Improvement in irrigation area is also a crucial factor to increase the value of production per hectare land because this directly improves crop yields (Kar and Kar, 2008). Mondal *et al.* (2015) also reported that better access to sustainable irrigation facilities would be crucial to increase food production in India. Similarly, Singh *et al.* (2014) also suggested that creation of a better irrigation infrastructure would be useful to improve sustainable agricultural production. Kumar *et al.* (2015b) estimation also suggested that irrigated area has a high yielding capacity compared to non-irrigated area. This recommendation would be most crucial for Indian agriculture as it has 60% of the total cropped area under rainfed or dependency on uncertainties of monsoon rainfall (Mall *et al.*, 2006; Birthal *et al.*, 2014).

Application of fertilizer per hectare land has a positive and statistically significant impact. Fertilizer's elasticity with land productivity is 0.422 (P> |0.001|). More precisely, use of fertilizer could increase the productivity of most crops thus land productivity will also increase. However, application of fertilizer would be effective in those area where farmers are using less fertilizer than recommended otherwise unnecessary use of fertilizer leads to severe problems like reduction of land productivity, soil fertility, soil quality, and environmental degradation (Aggarwal, 2008; Ranuzzi and Srivastava, 2012, Kumar *et al.*, 2015b). SriSubramaniam and Sairavi (2009) also showed that overuse of fertilizers, chemical and untreated waste water in agriculture negatively affect the ground water quality and land productivity as well. Similarly, Ramsundar and Jaydeb (2011) also reported that over exploitation, excessive use of chemical fertilizers, insecticides and pesticides has declined soil fertility. Number of agriculture labor per hectare land caused a decline in land productivity (Nastis *et al.*, 2012). More specifically, more utilization of human power may not be useful to improve the crop yields and brings about a decline in land productivity. Mechanization, measured in terms of utilization of tractors per hectare land has a positive and statistically significant impact on land productivity. Estimate suggests that application of more mechanization could be a good option to increase land productivity. However, in India more use of tractor cannot be recommended because agriculture is characteristically human labor intensive. Number of pump set has a positive and statistically significant impact on per hectare land and the pump set elasticity with land productivity is 0.033 (P> |0.000|). This estimate can be justified similar to the earlier stated result for irrigation area, showing that irrigated area has positive association with land productivity. Pump set is a crucial instrument to complete irrigation requirement in cultivation and increase crop yield.

Land productivity would be indirectly improved with better transport facilities because elasticity of railway road length has a positive and statistically significant impact on it; and elasticity of railway length is 0.2313 (P> |0.006|). Estimate can be justified in many ways like more transport facility would increase good communication of rural farmers with cities and farmers could buy new verities of seeds, fertilizer and new instruments for cultivation from the city market. This would help to increase crop and land productivity in the long term. More participation of literate population per hectare land is a significant variable since the elasticity of literate population on land productivity is positive and statistically significant; and elasticity of literate population with land productivity in 0.183 (P> |0.024|). There are several reasons like literate farmers having more understanding to apply new technology in proper way (Rukhsana, 2011), to choose an appropriate crop; suitable sowing time of crop, irrigation time, how much fertilizer and when to use in cultivation. Literate farmers are able to select appropriate adaptation techniques to mitigate the adverse effects of climate change (Falco *et al.*, 2011).

Figure 1 presents the projected results based on simulation technique implying that climate change would decrease land productivity by 14.72, 22.98, 31.23 and 48.63 percent by the years 2040, 2060, 2080 and 2100, respectively. These results are predicted by assuming that rainfall would increase by 4, 5, 6 and 7 mm; and surface temperature would increase by 0.5, 0.75, 1.0 and 1.5°C in the given years (as per various emissions scenarios of IPCC). The percentage change in land productivity due to change in climatic variable with different scenarios is estimated by the following formula (Gupta *et al.*, 2012):

$$\Delta \mathrm{vp} = \left[\left(\frac{\delta \mathrm{vp}}{\delta \mathrm{arf}}\right) \times \Delta \mathrm{arf} + \left(\frac{\delta \mathrm{vp}}{\delta \mathrm{aamaxt}}\right) \times \Delta \mathrm{aamaxt} + \left(\frac{\delta \mathrm{vp}}{\delta \mathrm{aamint}}\right) \times \Delta \mathrm{aamint}\right] \times 100 \qquad (6)$$

Where, *Δvp* is change in land productivity; *Δarf* is increase in annual actual rainfall; *Δaamxt* is increase in annual average maximum temperature; and Δaamint is increase in annual average minimum temperature in different scenarios. (δvp/δarf), (δvp/δaamxat), and (δvp/δaamit) are estimated by the model equations (Gupta *et al.*, 2012).

CONCLUSIONS

This study analyzes the impact of climatic factors on land productivity (in monetary term) in India. Empirical findings of the study show that annual average maximum and minimum temperature have a negative effect on land productivity. Land productivity may go down by 3.29 at 1% increase in annual average maximum temperature whereas annual rainfall has a positive impact on land productivity. But positive effect of rainfall cannot compensate the loss of land productivity due to increase in maximum and minimum temperatures. Estimates argue that climate change impact on Indian agriculture would be largely driven by change in temperature (Birthal *et al.*, 2014). It can be concluded that climate change has a role in declining land productivity of food and non-food grain crops and reduction of farm revenues as well. Small and marginal farmers would likely be more vulnerable due to climate change because they have poor accessibility to modern technology, agricultural inputs, weather information and financial lacuna for mitigation and adaptation (Birthal *et al.*, 2014).

Based on our empirical findings several policy suggestions can be given like policy makers need to provide more irrigation facilities. Land productivity positively associated with number of pump set per hectare land. It means that pump set is a crucial instrument to complete the irrigation requirement in cultivation. Here, it can be concluded that more irrigation facilities in agriculture would be useful to increase productivity of crops. Land productivity would increase with the application of recommended fertilizers in agriculture. It can be justified that productivity of a specific crop will increase with additional utilization of fertilizers. More participation of literate population in agricultural also could be an important factor to increase land productivity. Railway road length is also a significant factor that has a positive relationship with land productivity. More precisely, transport facility would increase good communication of rural farmers with cities and farmers could buy new verities of seeds, fertilizers and new instruments for cultivation from the city market. Thus, land productivity would be increased for the long-term as providing good transport facilities. Hence, more irrigation facilities, ample use of fertilizer and more investment in infrastructure may mitigate the harmful effect of climate change.

There are several suggestions that can be given to increase land productivity such as providing bio-fertilizers, credit facilities, high yielding varieties of seeds and modern techniques to farmers; more government expenditure in agriculture and allied sectors, and rural development; public spending on agricultural R and D; and investment in infrastructure. (Kumar *et al.*, 2015b). These all suggestions could works as conductive development policies in order to enhance land productivity. Most importantly, India has a high probability to improve agricultural productivity using modern technologies in cultivation because it has lowest yield compared to other agrarian economies like China, Brazil and USA. There can be provided short term training to farmers to increase their awareness towards climate change. Thereby farmers will be able to choose those crops for cultivation which are less sensitive to climate change. Climate change related information (i.e. cyclone, floods, and droughts) to farmers on time would be quite beneficial to farmers to take precautionary actions and to avoid loss of land productivity. For this, Agriculture Extension Offices and District Rural Development Agencies (DRDA) would play

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a significant role to provide climate related information to farmers. Water harvesting and conservation scheme through micro-irrigation techniques (e.g., sprinkler and drip irrigation) could be useful to increase land productivity and water surplus as well (Birthal *et al.*, 2014). Finally, there is also a requirement to reduce pollution of water, air, land, less use of chemical fertilizers, insecticides and pesticides, forestation, plantation andbio-diversity, which would be helped to sustain the common property of natural resources and agricultural sustainability in future (Ramsundar and Jaydeb, 2011). Similarly, Saleh *et al.* (2014) also argued that adoption of appropriate technology would performed a vital role for environment sustainability.

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ارزیابی اثرات تغییرات آب و هوا بر بهره وری در تولیدات کشاورزی هند: شواهد از تجزیه و تحلیل داده های پانل

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چکیده

مطالعه حاضر اثرات تغییرات آب و هوایی بر بهره وری زمین از دانه مواد غذایی و غیر غذایی محصولات زراعی عمده در هند ارزیابی شده است. ما داده های پانل برای ۳۰ سال (۱۹۸۰–۲۰۰۹) از پانزده محصول در سیزده ایالت هند که در آنها کشاورزی رواج دارد را مورد استفاده قرار دادیم. ارزش تولید برای هر محصول از قیمت برداشت در مزرعه برآورد شده است (به قیمت ثابت ، ۱۹۹۳–۱۹۹۴). رابطه ارزش کل تولید در هر هکتار زمین با عوامل مختلف اجتماعی و اقتصادی و آب و هوایی با استفاده از مدل تابع تولید کاب داگلاس (CD) بررسی گردید. برآوردهای مبتنی بر اشتباه معیار دریسکول – کرای و رگرسیون خطی ، و اشتباه معیار تصحیح شده پانل های همبسته (PCSEs) (پریس–وینستن) نشان می دهد که بهره وری زمین با افزایش حداکثر درجه حرارت متوسط سالانه کاهش می یابد. این مطالعه نتیجه می گیرد که سیاستگذاران هندی باید امکانات آبیاری و کود برای کشت را افزایش دهند. بهره وری زمین به طور مثبت با سطح مورد آبیاری ، تعداد دستگاه پمپ و کود در هر هکتار زمین در ارتباط است. به طور خلاصه، تجهیزات آبیاری بیشتر، استفاده از کود، سرمایه گذاری بیشتر در زیرساخت، مشارکت جمعیت با سواد تر در فعالیت های کشاورزی، هزینه دولت در بخش کشاورزی و بخشهای مرتبط، توسعه روستایی، آبیاری و کنترل سیل برای کاهش اثر منفی تغییرات آب و هوایی بر کشاورزی و بهبود بهره وری کشاورزی(بهره وری زمین) مفید خواهند بود. در نهایت، نتایج پیش بینی ما بر اساس روش شبیه سازی نشان داد که تغییرات آب و هوایی تا سال ۲۱۰۰ موجب کاهش بهره وری زمین به میزان ۴۸,۶۳ درصد و از دست رفتن درآمد کشاورزان در هند خواهد شد.

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