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EMPIRICAL ASESSMENT OF CLIMATE CHANGE ON AGRICULTURAL CROPS: PANEL DATA ANALYSIS IN PAKISTAN

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Abstract

The purpose of present study is to empirically analyze the impact of climate change on three major agricultural crops of Punjab, Pakistan. A variant of Cobb-Douglas production function is applied on the panel of districts of Punjab covering period from 1982 to 2014. It is observed that temperature; rainfall and Humidity have different effects on agricultural crops at different stages of production. This study analyzes the impact of climate change at three different stages of production such as; planting, flowering and harvesting. Overall findings of the study reveal that area and fertilizer have positive effect on all three crops at each stage. Temperature has positive impact on wheat production during the planting and harvesting stage. However, temperature negatively affects the production of wheat during the flowering stage. Rainfall has negative association with the production of wheat during all three stages. Further, results indicate that rainfall, minimum temperature and humidity positively affect the production of rice crop during planting and negatively affect during harvesting. On the basis of empirical analysis, this study suggests that Government should develop new varieties of seeds and allocation of more resources should be encouraged to provide the security against the problems of climate change.
Key words: *Climate, Agriculture and Enviornment, Agricultural policy*
Jel Codes: Q54, Q15, Q18

1. Introduction

Climate change has become scourge, which afflicted the whole world. It is changing due to the use of fossil fuels, industrial emissions, burnings of agricultural wastes, use of pesticides and deforestation. These human activities increase the concentration of Green House Gases (GHG) in atmosphere and generate greenhouse effects. Due to these effects, it is observed that average temperature is increasing, rainfall patterns are changing sea level are rising, circle of monsoon rains are disturbing, and glaciers are melting. All these contribute towards extreme events in the form of hurricanes, storms, flooding, drought and heat waves (e.g. see Lobell and Asner, 2003; Chen et al., 2004; Isikand and Dovadoss, 2006; and Prakash et al., 2011).

Moreover, these studies found that climate change is affecting every aspect of the economy including agriculture, ecology, biodiversity, infrastructure, forests, health and life of the people. Food and Agriculture Organization (FAO) has been a major advocate of tackling this problem with a twin track approach (FAO 2014).

Pakistan is an agrarian economy and highly sensitive to climate change. Pakistan is facing large risks due to changing pattern of monsoon rains, huge floods, agricultural devastation, droughts, and food insecurity (Asian Development Bank; 2010). Pakistan is facing flood problems almost every year and climate change is costing 14 billion dollar per year (almost five percent of GDP) to its economy (TFCC, 2010). Some other studies from Pakistan analyzed the impact of climate change on agricultural crops (e.g. Siddiqui et al. 2011; Hanif et al. 2011; Mahmood et al. 2012). They observed the impact of temperature and rainfall on crop and yield variability. However, they missed the humidity, which is an important variable and has significant impact on different agriculture crops at different stages.

Keeping in view the impact of climate change on agricultural production, there must be an incisive analysis of climate change effect on agricultural crops in Pakistan. Therefore, present study is an attempt to quantify the impact of climate change, which is broader and important in twofold ways from pervious studies. First, this study is used the updated data relative to rest of the studies in Pakistan. Further, it also incorporated the important humidity climatic variable, which is vanished from previous studies. It analyzed the joint climatic and non-climatic variables impact on each stage of wheat, rice and cotton crops in Punjab, Pakistan.

Area wise importance of the study considered the Punjab region that is the densest populated province and the second largest province by area. Punjab is occupying 26 percent of the total area of the country and 56 percent of the total population. According to provincial Geographical Department, about 60 percent area is under cultivation, which is almost 57 percent of the country's total cultivated area. The share of the Punjab in major agricultural crops of Pakistan was 75.5 percent in wheat, 70.2 percent in

Rice, 68.5 percent in cotton and 67.8 percent in sugarcane and the share of fruits was 79.6 percent in mango, 5.8 percent in Banana, 96.5 percent in Citrus, 76.8 percent in Guava, and 8.1 percent in dates.

Punjab's land is considered more fertile than other regions of Pakistan therefore, study include this specific area for research purposes (Government of Punjab, 2014).

Other section of the paper are organized in following ways; section 2 demonstrates the materials and methods, section 3 explains the results and discussion and forth section provides conclusion and policy review and references are shown in the last section.

2. Materials and Methods

Present study selected the districts of the Punjab province having climate observatory stations and considered major agricultural crops (i.e. wheat, rice and cotton) because of their significant contribution in GDP under agricultural sector. This study considered climatic (i.e. monthly data of rainfall, minimum and maximum temperatures, humidity) and non-climatic (i.e. area and fertilizer off take) variables data at district level for three major agricultural crops for the period 1982-2014. Moreover, data of different climatic factors is taken during planting, flowering and harvesting time. The data of climatic variables is collected from the Pakistan Meteorological Department and the data for non-climatic variables are collected from Agricultural Statistics of Pakistan and National Fertilizer Development Center Islamabad, Pakistan.

For empirical estimation of climate change and non-climatic variables during planting (first), flowering (second) and harvesting (third) stages on the production of rice and cotton crop, model 3, 4 and 5 are estimated by using data of explained and explanatory variables of respective crop.

For classification of planting, flowering and harvesting months of major crops in Punjab, information is collected from Rice Research Institute Kala Shah Kaku (RRIK), Cotton Research Institute Faisalabad (CRIF), Wheat Research Institute Faisalabad (WRIF) and Pakistan Agricultural Research Council (PARC). Stage wise monthly classification of wheat, rice and cotton is reported in Table 1.

Table 1. Seasonal Classification of Crops

Crops	Planting	Flowering	Harvesting
Wheat	December	January-February-March	April
Rice	August	September- October	November
Cotton	May	June - July- August	September-October-November

The relationship between climatic variables and crop's production is non-linear. Crop growth increase with a rise in temperature up-to a certain limit, after that, crop growth may be adversely affected by an increase in the temperature. Similarly, the impact of rainfall on crop productivity is positive and negative with reference to their stages (Mahmood et al., 2012). This non-linear relationship can be estimated by using Cobb Douglas production function. The advantages of Cobb Douglas production function are its easy estimation, and interpretation of estimates. Further, it is more appropriate when observations are not large.

The link between climate change and production is based on two main approaches: Production function approach (agronomic models) [1] and Ricardian approach (hedonic models)[2]. Firstly, the idea of climate change and agriculture is introduced by Decker et al. (1986) and Adams (1989) by using "agronomic models" and analyzed the environmental variables impact on agricultural crop yield. Production function approach is later criticized by Mendelsohn et al. (1994); Deschenes and Greenstone (2004; 2006); Guiteras (2009) and they suggested that when farmers are wise they compensate the weather impact by changing crops and using fertilizers. Due to farmer's adaptation, assessment of climate change in production function approach results in biased results. In order to control the adaptation impact.

Mendelsohn, Nordhaus and Shaw (1994) introduced the "Ricardian Approach" and examine the impact of climate change on agricultural land value. Schlenker and Robert (2006) used the hedonic model and examined the impact of temperature on crop yield in the United States.

Ricardian approach includes the farmer's adaptation measures (variety of fertilizers, changing crops and different farming methods, etc.) that are known and unknown. In the estimation of production function parameters, the OLS is unable to capture the effect of omitted variables and cross section heterogeneity. Therefore, One-Way Fixed Effect method with Feasible Generalized Least Square (Hetroscedasticity, Autocorrelation Consistent Standard error) is used. The major reason to apply this method is its ability to take care of the problem of autocorrelation and hetroscedasticity. Moreover, OneWay Fixed Effect method is suitable to capture the unobserved heterogeneity in regression model (Deschenes and Greenstone, 2004; and Guiteras, 2009). Amiraslany, (2010)used the Ricardian approach and analyzed the impact of climate abnormalities on economies of agriculture system in Canada and applied the fixed effect approach to control the heterogeneity in the regions. Fixed effect estimator basically absorb the unobserved time invariant determinant of the dependent variable which means that intercept differ according to cross-sections but slopes are constant because

[1] Production function approach based on the agronomic models that consist of mostly controlled experimental studies.

[2] These models are often based on the cross-sectional data and based on the Ricardian approach.

each district has their own ways of agricultural practices. Fixed Effect model is estimated after pooling the data that is based on the time-demeaned variables is called "within estimation" or fixed effect estimation. (Wooldridge2005 and Baltagi, 2008).

Moreover, this study used Hetroscedasticity autocorrelation-consistent standard errors (HAC) to control the problems of autocorrelation and hetroscedasticity. In this regard FGLS method is applied on FE specification in which weights (Omega hat) are assignned to variance-covariance matrix to estimate the coefficients like as given below.

$$\hat{\beta}_{\square\square\square\square} = (X'\widehat{\Omega}^{-1}X)^{-1}X'\widehat{\Omega}^{-1}Y$$

Following Mahmood et al. (2012), a variant of Cob-Douglas production function is used:

$$lnY_{it} = AX_{it}^{\beta_i}exp^{\varepsilon_{it}} \quad (1)$$

Where Y_{it} is the dependent variable and it indicates the wheat production or rice production or cotton production. X_{it} is the vector of explanatory variables included in the regression model and β_i are the parameters to be estimated. A is a constant term and ε_{it} is the error term with zero mean and constant variance.

This present study used the double log form of Cobb-Douglass production function, which is given as:

$$lnY_{it} = A + \beta_i \sum_{i=1}^{n} lnX_{it} + \varepsilon_{it} \quad (2)$$

The impact of climate change on the production of wheat, rice and cotton crops is analyzed for three stages separately. Further, the model given below is used for the empirical estimation of three stages of wheat crop whereas climatic variables rainfall, temperature, and humidity are used differently for all three stages.

$$lnwprod_{it} = \alpha_0 + \delta_i + \beta_1 lnmaxt_{it} + \beta_2 lnrf_{it} + \beta_3 hmd_{it} + \beta_4 mnt_{it} + \gamma_1 lnara_{it} + \gamma_2 lnfer_{it} + u_{it} \quad (3)$$

Equation (3) explains that *i* denotes districts and *t* denotes time period whereas δ_i is the district specific effect. The dependent variable $wprod_{it}$ wheat production is in thousand tones, mxt_{it} is the average maximum temperature (^{0}C) during three stages of wheat crop, rf_{it} is average rainfall (mm) during three stages of wheat crop, hmd_{it} is the average humidity (%) during three stages of wheat crop, mnt_{it} is the average minimum temperature (^{0}C) during three stages of wheat crop, ara_{it} is the area under cultivation in thousands hector under wheat crop *ferit* is the off take of fertilizer, and u_{it} is the random error term in the model.

Impact of climatic and non-climatic variables on rice production is analyzed for three stages in the following model.

$$lnrprod_{it} = \alpha_0 + \delta_i + \beta_1 lnmaxt_{it} + \beta_2 lnrf_{it} + \beta_3 hmd_{it} + \beta_4 mnt_{it} + \gamma_1 lnara_{it} + \gamma_2 lnfer_{it} + u_{it} \quad (4)$$

Equation (4) indicates that δ_i is the district specific effect. The dependent variable is rice production in tones symbolized as *rprodit* . The other independent variables explain that *mxtit* is the monthly averagemaximum temperature (^{0} C) for all stages of rice crop, *rfit* is the monthly average of total rainfall (mm) for three stages of rice crop, *hmdit* monthly average humidity (%), during the three stages of rice crop *mntit* is the monthly average minimum temperature (^{0}C) for three stages of rice crop, *arait* is the area under cultivation in thousands hector by rice crop, *ferit* is the off take fertilizer and u_{it} is the random error term in the model.

The model given below is used for the empirically estimation of cotton crop for planting, flowering and harvesting stage.

$$lncprod_{it} = \alpha_0 + \delta_i + \beta_1 lnmaxt_{it} + \beta_2 lnrf_{it} + \beta_3 hmd_{it} + \beta_4 mnt_{it} + \gamma_1 lnara_{it} + \gamma_2 lnfer_{it} + u_{it} \quad (5)$$

The dependent variable ln*cprodit* is production of cotton crop in thousand bales whereas δ_i is the district specific effect which captures the effect of unobserved variables in the form of soil fertility, decision of the farmers etc. The *mxtit* is the monthly average maximum temperature (^{0} C) for cotton crop, *rfit* is the monthly average of total rainfall (mm) for three stages of cotton crop, *hmdit* monthly average humidity (%), during three stages of cotton crop, *mntit* is the monthly average minimum temperature (^{0}C) for cotton crop, *arait* is the area under cultivation in thousands hectors by crop, *ferit* is the off take fertilizer and u_{it} is the random error term in the model.

3. Results and Dicussion

One-way fixed effect with feasible generalized least square technique is used to determine the impact of temperature, rainfall, humidity, area and fertilizer on agricultural crops (Wheat, Rice and Cotton) for the eight districts of Punjab. Empirical results of wheat, rice and cotton model are given in Table 2, 3 and 4 respectively.

Table 2. Estimates of Fixed Effect with FGLS for Wheat Crop

Variables and Cross Sections	Wheat first stage	Wheat second stage	Wheat third stage
Constant	-6.69*** (-4.14)	-6.92*** (-3.47)	-7.52*** (-5.94)
Area	0.79*** (15.61)	0.82*** (22.85)	0.85*** (20.48)
Fertilizer	0.38*** (12.06)	0.38*** (10.92)	0.36*** (9.06)
Rainfall	-0.004 (-0.85)	-0.02* (-1.86)	-0.011* (-1.75)
Maximum Temperature	0.39* (1.67)	-0.30 (-0.73)	0.96*** (3.39)
Humidity	0.70*** (2.60)	1.23*** (4.27)	0.42*** (3.46)
Bahawalpur	-0.18	-0.17	-0.26
Bahwalnagar	-0.13	-0.11	-0.19
Faisalabad	-0.02	-0.07	-0.067
Jhelum	0.54	0.66	0.62
Lahore	0.03	0.14	0.11
Multan	-0.32	-0.32	-0.34
Rawalpindi	-0.03	-0.04	0.049
Sialkot	0.02	-0.08	-0.0092
R2	0.99	0.99	0.99
F-Stat	3472.65***	5581.42***	6256.12***

Notes: Most important or significant temperature is used for robust estimation.
*, **, *** shows the significance level at 10%, 5% and 1% respectively.

For planting, flowering and harvesting stages of the wheat crop, climatic features of the month of December; February and March; and April are considered, respectively. The significance of the cross section effect for each cross section shows that Bahawalpur, Bahwalnagar, Faisalabad, Multan and Rawalpindi produce, 0.18, 0.13, 0.02, 0.32 and 0.03

respectively less than average production (-6.67) in thousands tons, Whereas Sialkot, Lahore and Jhelum produce more (in thousands tons) 0.02, 0.03 and 0.54 respectively than average production. The impact of area is highly significant and relatively large in the model and the size of its coefficient is 0.79. Similarly, the impact of fertilizer is also significant at 1% level of significance in the estimated results.

The results shown in Table 2 explained that non-climatic variables area and fertilizers have significant positive impact on wheat production. Hussain and Saed (2001) explained that the marginal value of area is greater than labor and capital. The Fixed Effect estimated results determine that the humidity, rainfall and maximum temperature are showing statistically significant impact on wheat production. This study includes temperature, which is more significant than other in order to avoid the problem of multicolinerity in the model. Further, rainfall has negative impact on planting stage of wheat crop because during the germination period seed start to grow and still its head is not arise from the earth properly but this impact is not significant. However, at flowering and harvesting stage rainfall has significant negative effect on wheat production, which is similar to Ashfaq et al. (2011) and Siddique et al. (2011).

Table 3. Estimates of Fixed Effect with FGLS for Rice Crop

Variables and Cross-Sections	Rice first stage	Rice second stage	Rice third stage
Constant	-9.78*** (-3.79)	-6.82*** (-5.23)	1.95 (0.67)
Area	1.018*** (28.83)	1.040*** (25.75)	0.94*** (13.57)
Fertilizer	0.21*** (4.60)	0.17*** (3.014)	0.22*** (3.85)
Rainfall	0.002 (0.32)	-0.012* (-1.50)	-0.016** (-2.19)
Minimum Temperature but for third stage maximum temperature	1.64*** (3.14)	0.48 (1.16)	-0.71 (-0.86)
Humidity	0.52* (1.63)	0.84*** (3.56)	-0.33* (-1.60)
Bahawalpur	0.018	0.055	-0.07
Bahwalnagar	-0.11	-0.054	-0.13
Faisalabad	-0.085	-0.063	-0.15
Lahore	0.18	0.16	0.15
Multan	-0.16	-0.099	0.23
Sialkot	0.14	-0.010	0.20
R2	0.96	0.96	0.97
F-Stat	429.44***	459.81***	377.85***

Notes: Most important or significant temperature is used for robust estimation.
*, **, *** shows the significance level at 10%, 5% and 1% respectively.

At planting stage of wheat crop maximum temperature and humidity are highly significant variables, which show positive impact on wheat production at 1% level of significance and 10% level of significance, respectively. During flowering stage of wheat crop maximum temperature has negative impact because it reduce the period of grain filling by increasing the development cycle of wheat crop. At harvesting stage maximumtemperature has positiveimpact.

Table 4. Estimates of Fixed Effect with FGLS for Cotton Crop

Variables and Cross-Sections	Cotton first stage	Cotton second stage	Cotton third stage
Constant	-1.23 (-0.48)	-7.17 (-1.38)	-12.42*** (-5.83)
Area	0.98*** (16.45)	0.95*** (17.19)	1.059*** (13.68)
Fertilizer	0.53*** (9.36)	0.61*** (6.89)	0.40*** (6.26)
Rainfall	0.010* (1.56)	0.0056 (0.35)	0.0019 (0.12)
Maximum Temperature but for third stage minimum temperature	-1.15* (-1.63)	-0.0019 (-0.0014)	1.52*** (2.47)
Humidity	-0.34 (-1.47)	0.13 (0.30)	1.99** (2.14)
Bahawalpur	0.072	0.032	0.0037
Bahwalnagar	-0.043	-0.021	-0.038
Faisalabad	-0.53	-0.53	-0.31
Jhelum	0.57	0.73	0.54
Multan	-0.13	-0.21	-0.21
R2	0.99	0.99	0.99
F-Stat	3811.41***	3214.33***	2084.95***

Notes: Most important or significant temperature is used for robust estimation.
*, **, *** shows the significance level at 10%, 5% and 1% respectively.

The results reported in Table3 show that minimum temperature during planting stage has positive and momentous impact on rice production. Mahmood et al. (2012) also analyze the impact of minimum temperature during first stage on rice production and they conclude that minimum temperature in first stage has positive impact on rice crop. The rainfall during first stage has insignificant but positive impact on rice production, whereas, humidity during this stage has significantpositive impact on rice production. The significance of the cross section effect for each cross section shows that Bahwalnagar, Faisalabad and Multan produce,0.11, 0.08 and 0.16 respectively less than average production (-9.78 in thousands tons) whereas Sialkot, Lahore and Bahawalpur produce more 0.4, 0.18 and 0.018(in thousand tons) respectively than average production. Moreover, the results indicate that the minimum temperature at second stage has positive but statistically insignificant effect. As flowering stage is more sensitive to the planting stage so the heat stress during this stage of crop is adversely associated with rice yield. Siddiqui et al. (2011) and Mahmood et al. (2012) also verify these results for the rice productivity. Humidity is helpful for the second stage of rice crop and shows significant positive effect at 1% level of significance. Further in this model, both non-climatic variables have significant positive effect during this stage of rice crop.

From above Table3, it is found that during the third stage of rice crop, maximum temperature is insignificant and rainfall is significant. The main reason of temperature having insignificant effect is that actually in the month of November the maximum temperature remains at its optimal level mostly from 20^0C to 25^0C for the whole period of this crop, therefore, it is negligible but further increase has negative impact because it reduce the thickness of the rice grain after ripening. Chaudhary et al. (2002), Siddiqui et al. (2011) confirms that the maximum temperature during third stage has no effect on rice yield. Impact of rainfall during third stage of rice crop indicates that during harvesting time rainfall disturbs the soil but harvesting requires that the soil should be dry and clear however the wet plants of rice make it difficult to harvest and decrease in rice production. Furthermore, normally period of monsoon cycle is from July to October, but if this cycle includes the month of November it adversely affect the quality of rice and rice production. Area and fertilizers are positively related with rice crop and has significant impact. Humidity during last stage has significant negative relation with rice production because in the month of November the weather starts to get change and become little cold which leads to increase in humidity and rice crop at this stage is ready to harvest and humidity cause to wet the plant which create difficulty to harvest the rice crop.

The estimated results for cotton crop indicated that the cotton crop is less affected by climate change relative to wheat and rice. Results in Table 4explains that the cotton crop is sown in the month of May, which is hottest month in the region of Punjab and maximum temperature reaches at its record level in this month, therefore, maximum temperature has significant negative effect at 10 % level of significance. Rainfall during first stage of cotton production has positive impact. Humidity has no significant impact on cotton production at their first stage. The significance of the cross section effect for each cross section shows that Bahwalnagar, Faisalabad, Multan produce 0.04, 0.53 and 0.13 respectively less than average production (-1.23) in thousands tons, Whereas Bahawalpur and Jhelum produce more 0.07 and 0.53(in thousand tons) respectively than average production.

All the climatic variables including maximum temperature, rainfall and humidity during second stage of crop has negligible impact on cotton yield. During second stage of crop, rainfall and humidity has positive relation with cotton crop but maximum temperature has negative impact on cotton crop production. The negative impact of maximum temperature on cotton production in the second stage is due to increase in temperature that causes reduction of interval between flowering and boll opening; and results in shortening of time to maturity. The rainfall exerts positive impact on cotton production in second stage because water work as food for the growth of boll size and filled the boll. It also helps the growth of plant to reach at its maturity stage. The size of the coefficients of area, fertilizer and maximum temperature are large in the given model as compared to other variables. Humidity is also positively associated with cotton yield (high humidity controls more demand for water by capture the evaporative demand). The value of F-Stat shows that the model is statistically significant at 1% level of significance.

At picking stage minimum temperature and humidity are the most important variables for the cotton crop. Humidity shows significant positive affect. In these months, the maximum temperature starts to decrease and humidity start to increase therefore, relatively high humidity reduce evaporative demand by atmospheric surroundings and decrease the demand for water to the crops. Rainfall has positive effect but insignificant. In third stage of cotton crop, rainfall is necessary when first time picking is completed while the rest of the bolls are still at their flowering stage and need water. Minimum temperature has positive and significant effect at 1% level of significance. The results of this study is approximately similar to Ozkan and Akcoz (2002); Bange (2007); Gwimbi and Mundoga (2010); and Siddiqui et al. (2011).

4. Conclusion And Recommendations

Climate during each stage of the crop is important determinant of production for three major agricultural crops. During first stage (sowing), minimum temperature has positive and significant impact on wheat production, but in the second stage (flowering) increase in mean maximum temperature decrease wheat production. However, this affect is statistically insignificant. At harvesting stage, increase in maximum temperature enhances wheat production. Additionally, adequate rainfall for the growth of wheat crop is very important particularly at flowering stage and has positive impact. The findings of rice crop indicate that minimum temperature in August, September and, October has significant positive impact on rice production. Although, the average maximum temperature during first and second stage is has negative association with rice production. Rainfall at each stage exerts negative effect on the rice yield. This may be due to existence of growing period for rice crop in monsoon i.e. July to October.

At maturity stage, temperature and humidity has positive and rainfall has negative impact on rice production. Results of cotton production explain that temperature (Maximum and Minimum) at planting time, rainfall at flowering time and average maximum temperature at harvesting time affect cotton crop significantly. The non-climatic variables are most important in all stages of each crop because land is basic variable to grow crops and fertilizer is a food for the better growth of the agricultural crops. Fertilizer play vital role to adaptation when climate change affect agricultural crops. It is concluded from the present study that all the climatic and non-climatic variables are statistically significant for three major agricultural crops. Hence, it confirms that climate change has an impact on agricultural crops and government should support private and public institutions to develop new seed varieties for each crop, which are less affected by extreme weather conditions. Moreover, government should train farmers about new solutions and strategies. Government should also conduct seminars and workshops for the awareness of new climatic conditions.. Moreover, more resources should be allocated for the development of policies for the provision of crop production security to farmers under new climatic conditions.

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