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AN INVESTIGATION OF THE IMPACT OF CLIMATE CHANGE ON RICE CROP IN PAKISTAN: A MULTIVARIATE ANALYSIS

Muhammad Abdul Rahman[1], Abdul Saboor[2], Irfan Ahmad Baig[2*], Usman Shakoor[3] and Humaira Kanwal[4],

[1]Department of Economics, PMAS Arid Agriculture University Rawalpindi–Attock Campus, Pakistan; [2]Department of Economics, PMAS Arid Agriculture University Rawalpindi, Pakistan; [3]COMSATS Institute of Information Technology, Islamabad, Pakistan; [4]Department of Environmental Sciences, PMAS Arid Agriculture University Rawalpindi, Pakistan
[*]Corresponding author's e-mail: irfybaig@gmail.com

Climate change is impacting the human life and allied activities throughout the world. In few regions, the impact is positive while in most of the others, it is negative. Pakistan is among those regions which are experiencing the change in climate in all parts of its territory. The current study is intended to investigate the impact of climate change on rice crop in rice-wheat zone of Pakistan. Data were collected from three districts of Punjab province and two districts of Sindh province. The selection of districts was based on the relative rice production rank of the districts in the country. Multivariate Linear Regression approach was applied to analyze the data. Three different models were used to investigate the impact of climate change on rice crop. The results showed that both rise in temperature and precipitation have positive impacts on rice crop. The present study could not quantify the level of increment in temperature and rainfall and its benefits for rice crop. There is further scope to identify the level beyond which it started impacting the crop negatively.

Keywords: Agriculture production, greenhouse gases, global warming, cash crops, rainfall pattern, temperature change.

Abbreviations: GHG's (Greenhouse Gases); IPCC (Intergovernmental Panel on Climate Change); IFPRI (International Food Policy Research Institute); DFID (Department for International Development); GDP (Gross Domestic Product); IRRI (International Rice Research Institute); NGO (Non-governmental organization); NFR (Net Farm Revenue); SPSS (Statistical Package for Social Sciences).

INTRODUCTION

Climate is a significant element which effect the agricultural production. Unexpected deviation in climatic variables can stanchly affect revenue from crops. A number of researches to identify reasons behind these changes came out with results that the changes stemmed due to proclamation of the greenhouse gases (GHGs). These progressively gather in the atmosphere around us and eventually become rich source of global warming (Aydinalp and Cresser, 2008). It is also evident that the developed nations of the world are main contributors of these emissions whereas developing nations have very little share in this. About 75%discharges related to GHGs are prompted by the developed nations (Farooqi *et al*., 2005).

Climate change can be demarcated like "deviation in climate caused by anthropogenic and natural activities. This change can be sustained for a longer period of time (IPCC, 2007). Bringing the climate change phenomenon under the umbrella of economy of Pakistan, it seems to be much vulnerable and threatened. This is due to the fact that development in economic sector is stanchly hurt by disparity in comportment of climate variables. Nations where the economy is largely dependent on agriculture's share in GDP are more vulnerable to climate change (IFPRI, 2010).

To enumerate impression made by climate change on agronomic production is a complex procedure due to the uncertainties and doubt in forecasting regional climate changes and the reaction showed by crops in response to environmental changes (Roudier *et al*., 2011). This situation can become degradable even with the slight change or variation in the climatic components like temperature and rainfall (DFID, 2011).

In almost all regions of the world extending from Africa to Europe, Asia to America climate is explicating changes in its patterns from the last few decades. In case of temperature, the trend is on increasing side while in case of rainfall or precipitation, changes or deviation has been identified in its pattern of occurrence, where in some regions, there is wide change in occurrence of rainfall. In the Northern European region, there is marked increase in the rainfall while for Eastern and Southern European rainfall has been decreased (Olesan *et al*., 2011). In a study by Shakoor *et al.* (2011), researchers quantified the impact of climate change on wheat crop in Pothwar region of Pakistan. The results revealed that climate change would going to be harmful for the wheat crop.

Climate change was generally marked with increase in temperature especially in Asian region.

The studies which have utilized the forecasting approach for estimation also confirmed that climate of planet is changing and wide range is expected in the coming future. In case of temperate in Asia, the crop production is expected to be on the higher side. This is because of the increase in the length of growing period coupled with increment in the carbon dioxide (CO_2) concentration. This all will be witnessed due to warming in climate (Mathews *et al*., 1995).

Rice has shown sensitivity towards climate change. Cobb-Douglas production function approach was used to study Korean rice sector by Kim and Pang during 2009.Their study explained that temperature has positive relation with average rice yield. Interestingly, in China, the rice has positive response towards the increase in temperature (Gerardeaux *et al.,* 2012). Similarly, in India, rice is quite sensitive to minimum temperature. While on the other hand, wheat crop is sensitive against maximum temperature. In case of carbon dioxide, trivial quantity of it can cause an increment of 28 percent and 15 percent in the yields of wheat and rice, respectively (Lal *et al*., 1998).

In numeric terms, increase of 2°C in temperature could affect the rice yield positively by increasing 0.75 tons per hectares. This case holds for the high yield areas of India. On the other hand, an increment of 0.5°C in temperature will reduce the yield of wheat by 0.45 tons per hectares (Guiteras, 2007).

Pakistan's economy depends upon agriculture sector on a large extent. The sector employs more than 40 percent of the labor force. On the other hand, total cultivable land available in Pakistan is about 38 percent of the total area. However, only 26 percent area is only used for cultivation purpose, while rest of the land is barren. The land which is not used for cultivation is due to the shortage of water, salinity and aridity issues that have occupied greatly (Chandio and Anwar, 2009).

It is not a hidden truth that growing of crops demand availability of water which is in fact the major natural resource for cultivation and crop growth. Pakistan's agriculture system uses 90 percent water from the fresh water resources including rivers and canal systems and provide 80 percent of agriculture production (Iqbal *et al*., 2009). Changing climate change is also a big concern for Pakistan. In the current decade, researcher, water experts, agriculturists, policy makers and other stakeholders from public and private organizations, NGO's have shown serious concerns over climate change issue. The impact of this change is now visible on agriculture sector and its production.

Agriculture in Pakistan is very important as a sole source of food to the ever-increasing population. Food crop like wheat, rice, maize and other cereals have remained center of attention in agriculture sector. Rice is a valuable food crop with significant revenue for the farmers. It is also an important constituent of export basket of Pakistan. It has a share of 6.7 percent in value added while 1.6 percent in Gross Domestic Product (GDP) of Pakistan. Country cultivates superior class of rice not only to cover demand at domestic level but also to meet the expert demand. Pakistan exported 3.4 million tons of rice to earn valuable foreign currency to balance its trade deficit (Memon, 2013). As climate controls all activities for crop growth right from germination till harvesting, through its key factors like temperature, rainfall, humidity and others, changing climate has critical importance for the country.

The current study is important as Pakistan is one of the victim of severe climate change and the future climatic scenarios for Pakistan are even more challenging. The latest IPCC 5th assessment report marked Pakistan as a serious future victim of warming where there is an expectation of rise in temperature in next 50 to 100 years (IPCC, 2014). This confirms that the agrarian economy of Pakistan has to suffer. The current study is conducted to quantify the changing climate impacts on rice crop, which is one of the major exports of Pakistan as mentioned earlier. Also, the study will try to capture the impact of mean and maximum (daytime) temperature on rice crop along with the precipitation. The reason of including the variable for maximum temperature separately is that many researches in the region and at global level confirmed a positive impact and significant impact of maximum temperature in rice yield (Karn, 2014; Welch *et al.*, 2010). So, in the light of IPCC's prediction regarding warming in Pakistan and its impact on rice yield will be quantify in the current study.

The current study is exercised to trace the impact of climate change on the net farm revenue obtained from rice crop. The area selected for the study purpose comprised of rice growing districts from Punjab and Sindh province. The objective of the study was to capture the impact of climate parameters or variables on net farm revenue in the rice-wheat zone of Pakistan.

MATERIALS AND METHODS

Current study utilized two different types of data sets. Climate variable's data were secondary in nature including the parameters like temperature either minimum or maximum, mean temperature and the precipitation. Climatic data have been collected for the last 25 years and thus it is a blend of time series and cross sectional data. The data for Sialkot, Jacobabad and Larkana were obtained from Pakistan Meteorology Department Headquarters Islamabad, while for Narowal and Shiekhupura districts; data were collected from the office of the District Officers Agriculture (Extension). It is worthy to mention here that rice is a Kharif crop, so the data for climatic variables were used for only Kharif season. The season prevails in the country during May to September (Chaudhry and Rasul, 2004; Adnan and Khan, 2009; Baig *et al*., 2014). Mean values were calculated for the data to get one value for each district for mean temperature, and precipitation.

An important task in the study was to collect primary data through field surveys. Data were collected form three districts of Punjab and two districts of Sindh that come under rice-wheat zone. From Punjab, certain locations such as; Sialkot, Narowal and Shiekhupura were selected. While from Sindh, Larkana and Jacobabad were included in the study. This selection was based on the ranking of these districts in terms of rice production. According to the ranking, Sialkot ranks second, Sheikhupura ranks third and Narowal is at number ten among the rice production districts of Punjab. In Sindh, Jacobabad and Larkana rank first and second, respectively for rice production (API, 2010).

Initially sample size chosen was 100 respondents and data were collected from 105 respondents. However, during the phase of cleaning and analysis, data from 25 respondents was not included in the final analysis. This is because of the misleading information, removal of out liars and some other issues. Figure 1 highlights the pathway followed to collect data, using stratified simple random sampling method.

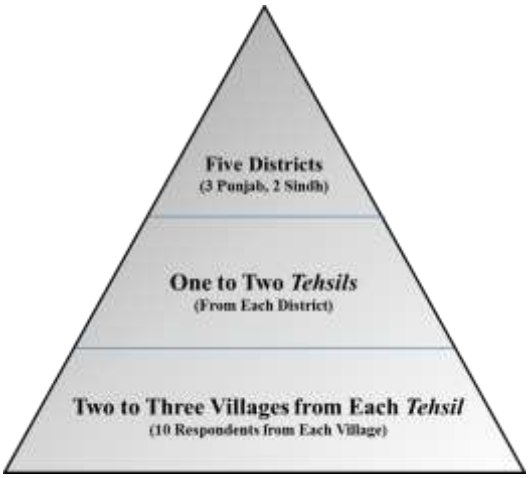

Figure 1. Sampling pyramid.

A total of five districts were selected from the two provinces, then form each district, two Tehsils were selected. This selection was not random but was based on a pre-defined mechanism. These *Tehsils* were selected in such a manner that one Tehsil from eastern part of district and the other from western part so that wide range of geographical area can be covered. After selection of *Tehsil*, two villages were selected from each *Tehsil*. The selection of villages took place in the same mode as the selection of *Tehsils*.

The first task was the calculation of net farm revenue. To accomplish this task, input price data was required initially. Similarly, revenue earned from the sales of crops is also needed to get the profit. In input data, farm size, total members of household to get size of household, area under crop and rate at which wages are given to the labor were included. In addition to this, cost associated with use of farm machinery for fertilization, ploughing, spraying of pesticides, and harvesting of crops was obtained from the farmers.

As there are many farmers in the sample which have large pieces of lands where some farmers have small area of land. So, there is a need of getting the uniform value of Net Farm Revenue (NFR). This is done by finding the ratio among the profit and total area under cultivation. Native or local language of the area is used to gather data from respondents.

Units for calculation of price, quantity and land were made uniform so that there will be no complications during analysis. This is because; different units are in operation in different areas of Pakistan. In this study, for area measurement, 'acre' is used as unit. All the quantities are converted into 'kilograms' while monetary values are used in terms of 'rupees'.

***Empirical investigation*:** Analysis is done by using Statistical Software Package (SPSS). Multiple regression analysis was employed, on the gathered data for the analysis. The given approach was used to investigate the impacts of climate change on agriculture based on an experiential production function. The linear function was employed to study the relationship between climate change and the agricultural production (Mendelsohn *et al*., 1994). Linear function was estimated, incorporating climate variables, temperature and rainfall (only for current study) as inputs in the production process assuming farmers in similar areas do react to adapt to climate change and effectiveness of their adaptation reflects in net farm revenue through changes in their total cost. Based on various realistic assumptions, variations in yield induced by variations in climatic variables were measured and analyzed (Olesen *et al*., 2000; Alexeandrov and Hoogenboom, 2000; Southworth *et al*., 2000).

Multiple variants approach using Ordinary Least Square (OLS) estimation has some marked advantage as it forecasts the way according to which climatic variables impact on yield more reliably. The secret behind this approach is that the effect of changing climate on harvesting of crops is determined through measured experiments. However, the model is not capable to regulate or control for adaptation (Mendelsohn *et al*., 1994). For example the adaptive strategies adopted by the farmer to the changing climate and allied factors, by both varying and mixing the crops, changing the time of harvesting, plantation, pesticide and fertilizer application, in order to minimize the forcible threats posed by the climate change. In addition, the model lacks flexibility to include new crops, variation in the land use and the technological advancement in the agricultural sector (Mendelsohn *et al*., 1994).

Linear function analysis was the most appropriate method for the current study due to smaller geographic sample area. The same approach has verified results when employed on Bangladesh rice to estimate climate change impact on it. Chowdhury and Khan (2015) used a multiple regression analysis using OLS method for this purpose (Chowdhury and Khan, 2015). Similarly, Sarker and his team used OLS

regression method to estimate the proposed climate change impact on rice crop which is also proved successful (Sarker *et al*., 2012).

Mathematically the function is denoted as;

$$Y = f(X_1, X_2 \ldots\ldots X_n)$$

Or, it can be represented as,

$$Y = f(\sum X_1, X_2 \ldots\ldots\ldots X_n)$$

Where Y represents the quantity of output, which is Net Farm Revenue of rice crop in our study. X_1, X_2, X_n represent the climatic variables that enter into the model as independent variables.

The present study used the simplest form of model as two types of data were used. Net Farm Revenue was obtained through cross sectional analysis while data for climatic variables was of time series in nature. So, to avoid complexities, the simplest form of multivariate regression function was utilized. Models used in the paper are given below.

***Model 1*:** Relationship between Net Farm Revenue and Maximum Temperature + Precipitation

Net Farm Revenue = $\beta + \beta_1$_Max_Temp + β_2_Precipitation + Standard Error

***Model 2*:** Relationship between Net Farm Revenue and Mean Temperature + Precipitation

Net Farm Revenue = $\beta + \beta_1$_Mean_Temp + β_2_Precipitation + Standard Error

***Model 3*:** Relationship between Net Farm Revenue and Mean Temperature + Precipitation + Family Size

Net Farm Revenue = $\beta + \beta_1$_Mean_Temp + β_2_Precipitation + Family Size+ Standard Error

In the third model, the study used a new variable that is 'family size'. The significance of this variable is that it is helpful in estimating the impact of climate change on rice crop from the household size. It will also help in estimating the increase or decrease in NFR from an additional inclusion of a family member. Family education data was also gathered. However, due to insignificant results, we have excluded its analysis from the overall analysis.

RESULTS

The results obtained after running model 1 on the data showed the relationship between NFR and maximum temperature and precipitation. Looking at the fitness of model, the adjusted R^2 for model turns to be 96 percent which is acceptable. The results of the model are significant. In this case, maximum temperature has significant relationship with NFR. The result signifies that an increase of 1°C in maximum temperature will increase NFR by Rs. 7382 per acre. The precipitation has also a significant relation with NFR. An increase of 1mm in precipitation increased the NFR by Rs. 111 per acre.

The results for model 2 are also given in Table 1. The fitness of model is appropriate with the adjusted R^2 of 0.96. The results are also significant in nature and shows positive relationship among the dependent and independent variables used in the model. According to model 2, mean temperature has significant impact on NFR. It explained that 1°C increase in mean temperature increased the NFR by Rs. 15639 per acre. Similarly, in case of precipitation, 1mm increase in rainfall increased the NFR by Rs. 130 per acre.

Significant results are obtained after applying model 3 on the data as shown in Table 1. Variables used in this model are the same as of model 2 except, inclusion of family size as a socio-economic variable in the model. This is to check whether family size has an impact on NFR. Starting with the overall fitness of the model, the adjusted R^2 is acceptable with value of 0.96. Other variables in the model have shown positive and significant relationship. In case of mean temperature, 1°C increase in mean temperature increased the NFR by Rs. 17162 per acre. In case of precipitation, 1mm increase in rainfall increase the NFR by Rs. 137 per acre. The variable of family size showed negative and significant relationship. The results

Table 1. Multiple Regression Analysis Showing Relation between Dependent and Independent Variables

Variables	Model 1		Model 2		Model 3	
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
(Constant)	-293696.61	70251.33*	-517405.03	101916.28*	-566651.96	102380.44*
Maximum Temperature	7381.58 (t=4.28)	1724.18*				
Mean Temperature			15638.59 (t= 5.15)	3038.94*	17161.94 (t= 5.61)	3058.79*
Minimum Temperature						
Family Size					-267.34 (t=-2.11)	126.46
Precipitation	111.32 (t= 8.89)	12.53***	129.99 (t= 9.25)	14.05***	137.17 (t= 9.69)	14.16***
R^2	0.959		0.962		0.964	
Adjusted R^2	0.958		0.961		0.963	
F. Statistics	899.05		979.23		683.73	

explained that by increasing one family member, NFR decreased to Rs. 267 per acre.

DISCUSSION

The temperature and rainfall are important climatic variables which affects rice production. From the results presented below in Model 1, it is clear that the precipitation and temperature changes have suited the rice production as rice crop is a high water requiring crop. So, any increment in rainfall has produced increasing effect towards the rice production. While analyzing the temperature effects, the temperature increase has also become advantageous towards high rice production. Rice crop is considered as a crop which grows in humid conditions so both increase in temperature and rainfall has produced significant positive addition in overall rice production. While the analysis of Model 2 and Model 3 showed the same results as that of the Model 1.

From table 1, it is observed that Maximum temperature is supporting the incremental need of rainfall and temperature (in any form) for healthier production ultimately leading towards increased Net Farm Revenues. The results have stressed the importance of changing climatic variables if efficient production is required.

The Model 3 where a socio-economic variable family size was entered in the model made us realize that increasing family size will reduce NFR. The reason for the negative effect of increasing family size is that as the family size increases the deviation from the agriculture sector (as a source of income) increased because they consider the activity not a high-income activity with less land availability to support their running expenditure. Increasing family size has increased the burden on the available land, insisting rice crop growers to shift towards other source of earning, ultimately reducing their attention toward crop production. All the models confirmed that to gain higher rice production, we seriously have to analyze the changing climatic situations.

The global work to assess climate change on rice crop has also showed similar trends as we are able to quantify in this study. Warming is somewhat beneficial for the rice. In a study conducted in Japan, an increase in temperature of 1.6-2°C can result in a notable northward shift of the isochrones of safe transplanting dates for the seedlings of rice. Due to this, farmers will have a flexibility to adjust their cropping dates for rice, and a time margin to avoid any harsh weather changes (Ohta and Kimura, 2007).

Similarly, another study conducted on Pakistani rice and climate change link also confirmed beneficial impact of climate change on rice production. Shakoor and his team used Vector Auto Regression (VAR) model. The results suggest that increase in mean temperature and precipitation would be beneficial for rice crop (Usman *et al.,* 2015).

***Conclusion*:** This study showed that climate change has positive impact on rice production in Pakistan, considering temperature and precipitation. However, these results should be read carefully and only in the light of the historical temperature and precipitation changes since many global climate change models have predicted increase in extreme events in Pakistan with higher changes in the temperature parameter. Though the results are encouraging for Pakistan, still rigorous and scientific gaps are present to be filled the jigsaw of the extent of beneficial impacts. A major gap that should be of concern in continuation of this study is to explore the underlying link of temperature and precipitation with each growth stage of rice crop. Quantification of the threshold level beyond which beneficial impact of increasing temperature and precipitation may deteriorate may describe future pathway of research.

***Recommendations*:**.The importance of the climate change is increasing with every passing year; the responsibility is on the research groups to devote their attentions toward the mitigation and adaptation practices i.e. evaluation of new varieties which can adapt to the climate change and also to derive policies which make them to switch to these developed varieties. As our empirical results showed the importance of water availability, so deriving water retaining technique will safeguard crop production.

Similarly, the role of extension department is central now and in the coming years. Installation of early warning system timely dissemination of accurate information to the farmers will be chief responsibility of the extension workers. Prior to this, modern and innovative formal training should be given to the extension workers.

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