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IMPACT OF TEMPERATURE ADN PRECIPITATION ON RICE PRODUCTIVITY IN RICE-WHEAT CROPPING SYSTEM OF PUNJAB PROVINCE

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ABSTRACT

Pattern of temperature and precipitation are changing due to global warming, resulting in having impact on crop productivity. The objective of this study was to estimate the impact of climatic variables on rice productivity in the rice-wheat cropping system of the Punjab. Aggregated time series data were used for rice crop. Cobb Douglas type production function was employed with rice yield as dependent variable and climatic factors as independent variables. Results showed that an increase in temperature by 1.5^{o}C and 3^{o}C would enhance rice yield by 2.09% and 4.33%, respectively compared to the base year regression estimates. However, an increase in precipitation by 5% and 15% during September-October could adversely affect rice productivity by 5.71% and 15.26%, respectively. However, its decrease is positively related with rice yield. Evolving and disseminating rice varieties having adaptation to climate change should be the focus of future research and development. Improved farm management practices, creating awareness among farmers about climate change and strengthening extension department are some measures to be taken for adaptation to climate change in the rice region.

Key words: Basmati rice; Temperature; Rainfall; Productivity; Punjab.

INTRODUCTION

There are also many other factors, significantly contributing to rice productivity. These factors include climatic factors, such as temperature and rainfall.

Climate is one of the most important input factors in the agriculture productivity in all over the world. There is considerable interest about its possible impacts and its changing situations on agricultural productivity. Researchers and administrators are very much interested in potential costs and benefits that may come into face in future from possible impacts of climatic changes on agriculture that will ultimately affect the national and international policy options, trade patterns, resource use and food security. The researchers argue that crops would respond very good to increased CO_2 in the absence of climatic variability, the associated impacts of increased temperatures, altered pattern of rainfall and possibly high frequency of damaging events like drought and floods, would probably unite to decrease yields and increase risks in agricultural productivity in different parts of the world (Sushila, 2001). Some studies show that the reduction in rainfall may decrease wheat yield in Turkey (Kayam *et al*., 2000) whereas an increase in temperature and rainfall is found to be negatively related with rice productivity (Saseendran *et al*,. 2000). Peng *et al*. (2004) estimated a possible 10% decline of rice productivity from 1% rise in minimum temperature in dry season. Considering previous studies relating to climate change impact on agriculture in Pakistan, very little research work has been reported. Moreover, it is confined to wheat crop only. For example, Hussain and Mudasser (2007) used Ordinary Least Square (OLS) method to assess the impact of climate change on two regions of Pakistan, Swat and Chitral. Results showed that increase in temperature would result in positive impact on Chitral district being located on high altitude and negative effect on Swat, since it is located on low altitude. Likely impacts on its yield can have substantial impacts on the economic conditions of farmers and the country as well. The present study makes an attempt to bridge this information gap through considering rice crop and impact of climate change.

MATERIALS AND METHODS

The present study covered rice-wheat cropping zone of the Punjab province where the world's famous Basmati rice is planted. We considered rice crop for the present study because rice is the dominant crop during the Kharif season and this cropping zone is also among the highest rice producing region of the Punjab province. We used time series monthly data of rainfall and minimum and maximum temperatures covering the period from 1978 to 2007. The climate data were collected from the Pakistan Meteorological Department. Rice yield data for the same period were collected from secondary sources, such as Pakistan Economic Survey, Agricultural Statistics of Pakistan and Punjab Development Statistics.

Regression analysis is used to relate crop yield data to weather data considering the same area (Parry *et al*., 1988a). Regression analysis approach is useful in providing quite effective estimates of crop yield when crop yield is affected by weather factors such as rainfall or temperature (Parry *et al*., 1988b). Thus regression analysis is used in the present study to estimate impact of temperature and rainfall on rice productivity. It is more likely that relationship between climate variables and crop yield is non-linear as crop growth increases with a rise in temperature up-to a certain limit, after that, crop growth may be adversely affected by an increase in the temperature. The same is the case of rainfall impact on crop productivity. Thus non-linear form of regression analysis is taken using Cobb Douglas production function. The advantages of selecting Cobb Douglas production function are that it is easy to estimate and interpret the estimates and it is more appropriate in the situation when observations are not large. Cobb Douglas production function can be written as

$$Y = AX_i^{\beta i} exp^{\varepsilon} \quad (1)$$

Where Y is a dependent variable (rice yield), X_i is a vectors of independent variables included in the regression analysis and β_i are parameters to be estimated. A is constant term and ε is the error term with zero mean and constant variance. This non-linear form of Cobb Douglas production function can be estimated through ordinary least squares by taking natural log on both sides of equation (1). Estimates of this form of production function give direct elasticities of variables. Log linear form of Cobb Douglas production function used in the present study is given as

$$lnY = \beta + \beta_i \sum_{i=1}^{7} lnX_i + \varepsilon_i \quad (2)$$

Where lnY shows rice yield (metric tons per hectare), X is a vector of inputs including traditional inputs and climatic factors. Traditional farm inputs are fertilizer, seed and area sprayed. However, we were not able to find time series data available for all farm inputs, except area sprayed and fertilizer. Further, area sprayed under rice crop is taken as traditional input in the present study as the data for this farm input was available[1]. Climatic variables include rainfall and temperature. We considered mean minimum temperature for July and August, mean minimum temperature for September and October, mean maximum temperature for July and August, mean maximum temperature for September and October, mean rainfall for the months of July and August and mean rainfall for the months of September and October. ε is usual error term independently and identically distributed. Descriptive statistics of these variables are detailed in Table 1.

We used three scenarios of climate change for temperature and rainfall to assess the future impact of climate change on rice yield. In the first instance, we considered no change in temperature over the average of calibration period. The second scenario implies that temperature will increase in the range of 1.5-3.0 ^{o}C by year 2050 (IPCC, 2001). Third scenario is related to rainfall. It implies that rainfall changes in the range of $\pm 15\%$ with a step of 5% per decade, over the rainfall of calibration period. We adopted this scenario from Hussain and Mudasser (2007).

RESUTLS AND DISCUSSION

Ordinary least square technique was used to determine relationship between rice yield and climatic variables, namely temperature and rainfall for the rice-wheat cropping system of Punjab. Climatic contribution in rice production has been represented by different variables like rainfall, mean maximum temperature and mean minimum temperature during growing spam of crop. Results of Cobb Douglas production function are given in Table 2. All coefficients of climatic variables had the expected signs. Out of six coefficients of climatic variables, four coefficients were statistically different from zero. One traditional input was included in the model i.e. area sprayed under rice crop. The coefficient of this variable was negative but statistically non-significant, implying no impact on rice production. Significance of the model indicated by F value depicted that overall regression model was good for the present data. Value of R-square showed that variables included in the model explained variation in rice yield by 67%. Results, further, showed that there was no serial correlation in the regression as the Durbin Watson statistic was close to 2. However, very low multicollinearity present was present in the model for variables of mean rainfall during July-August and minimum temperature during July-August. The presence of multicollinearity in the model may be due to the limited number of observations used in the regression analysis. The problem of multicollinearity may be reduced by increasing number of observations but additional data on temperature and rainfall were not available for the concerned crop.

Studies showed that the reproductive stage is relatively more sensitive than the vegetative stage to heat stress in many crop species (Hall, 1992). The same is the case with rice crop. The effects of temperature variables on rice yield are shown in Table 2. Results indicate that temperature variables explain some of the variation in

[1] Fertilizer was also included in the model but due to econometric problems, it was dropped from the analysis.

rice yield statistically significant. The t-values for average minimum temperature and average maximum temperature during September and October and average maximum temperature during July and August associated with their p-values show that these three temperatures variables are statistically significant, showing highly contribution of temperature in rice production in the rice-wheat cropping zone of Pakistani Punjab. Average minimum temperature during September and October months is positively associated with rice yield whereas other two variables are negatively related with rice yield. Although statistically non-significant, average minimum temperature during the months of July and August is positively associated with productivity of rice crop. Sarker *et al*. (2012) also estimated significant climatic variables impact on rice productivity in Bangladesh.

The impact of rainfall during July and August had a negligible impact on rice yield as it was statistically non-significant. But the impact of rainfall during the months of September and October has a negative impact on rice yield and it was statistically different from zero at 1% level of significance. This result implies that a 1% increase in rainfall with no change in temperature would decrease rice yields by 0.104%. This is expected, and is most likely due to the fact that months of September and October are more critical as the rice crop is at its grain ripening stage and the rainfall before the start of harvesting adversely affects rice yield. The normal duration of monsoon rainfall is from July to September but due to the shift of this duration in later months, the rainfall in the months of September and October would negatively affect the rice yield and also quality of the rice grain (Jennings and Magrath, 2008).

Impact of temperature and rainfall on rice yield: Different scenarios of temperature increase are used to assess impact on rice yield while controlling for other variables at given conditions. Results of these scenarios are represented in Table 3. Results show that rice yields increase for all scenarios except scenario 1. It is due to the fact that the study area may be still short of cumulative temperatures during the. An increase in temperature by 0.3^{o}C is associated with decline in rice yield by 0.05% (scenario 1 in Table 3). The increase in yields is found to be 2.09% and 4.33% when temperature may increase by 1.5^{o}C and 3.0^{o}C, respectively. Although rice yield may rise, an increase in temperature would induce rising demand for irrigation water due to more evapo-transpiration.

Table 1. Descriptive statistics for the data used in the analysis

Variables	Mean	Std. Deviation	Minimum	Maximum
Yield (Metric tons/hec)	1.426	0.269	1.049	2.036
aver_Jul_Aug_min_t (^{o}C)	25.120	0.550	24	26
aver_sept_oct_min_t (^{o}C)	21.960	1.023	20	24
aver_jul_aug_max_t (^{o}C)	34.740	1.091	33	38
aver_sept_oct_max_t (^{o}C)	32.880	0.786	31	34
aver_jul_aug_rain (mm)	240.250	88.078	101	484
aver_sept_oct_rain (mm)	48.050	30.279	8	120
area_sprayed (hec)	253.570	124.314	67	435

Table 2. Estimates of Cobb Douglas Production function

Variables	Coefficients	Standard Errors	t-ratio
Constant	7.146	7.776	0.919
Ln_min. temp_jul_aug	1.672	1.234	1.355
Ln_min_temp_sept_oct	2.590***	0.708	3.657
Ln_max. temp_jul_aug	-1.965*	0.972	-2.021
Ln_max_temp_sept_oct	-3.395***	1.258	-2.698
Ln_rainfall_jul_aug	-0.139	0.095	-1.469
Ln_rainfall_sept_oct	-0.104**	0.045	-2.297
ln_sprayed_area	-0.043	0.049	-0.890
R-square	0.668		
Adjusted R-square	0.563		
F value	6.333***		
Durban-Watson test	1.898		

*** Significant at 1%, ** significant at 5% and * significant at 10%

Table 3. Changes in rice yield under various temperature scenarios

Scenario	Temperature (^oC)	Yield (metric tons/hec)	% change from regression average
1	0.0	1.639	0.00
2	0.3	1.638	-0.05
3	0.6	1.648	0.52
4	0.9	1.657	1.06
5	1.2	1.665	1.58
6	1.5	1.673	2.09
7	1.8	1.681	2.57
8	2.1	1.689	3.04
9	2.4	1.696	3.49
10	2.7	1.703	3.92
11	3.0	1.710	4.33

Table 4. Changes in rice yield under various rainfall scenarios

Scenario	rainfall (mm)	Yield (metric tons/hec)	% change from regression average
1	0	1.64	0.00
2	5	1.55	-5.71
3	10	1.47	-10.61
4	15	1.39	-15.26
5	-5	1.72	4.92
6	-10	1.81	10.68
7	-15	1.91	16.75

Regarding scenarios of rainfall variation, it is found that an increase in rainfall would decline rice yield, controlling for other factors at constant, whereas a decline in rainfall is associated with the increased rice yields. Results relating to variation in rainfall are given in Table 4. Rice yield would decline by 5.71% and 15.26% if an increase in rainfall is 5% and 15%, respectively in future three decades. Similarly we have used scenarios relating to fall in rainfall in the coming years. A decline in rainfall during rice growing season would increase rice yield by 4.92% and 16.75% respectively when a decline of 5% and 15% in rainfall occurs. It may be due to the fact that we include rainfall variable for September and October months in the econometric analysis in addition to rainfall during July-August months, since rainfall occurring during September and October may adversely affect crop yield when rice crop is near to maturity stage. Thus, research should emphasize in the areas where variations in temperature and precipitation would bring substantial changes in crop requirements. One of the research areas needs to focus on evolving and disseminating new heat/moisture tolerant rice varieties having better adaptation to temperature variation and drier conditions. Further, those new developed varieties should withstand future global warming scenarios. Other measures indicated by IPCC (2001) include adoption of better farm practices, namely plant protection measures, fertilizer management and soil conservation, being major adaptation strategies.

Conclusions: The present study was designed to determine the impacts of variation in temperature and rainfall on rice yields using aggregate-level time series data. OLS method was used to estimate the impacts. The findings of the study indicate that temperature and precipitation variables have significant effects on the rice yield. Average maximum temperature during September-October, and July-August and average minimum temperature during July-August are statistically significant. Moreover, rainfall during September-October is significantly and negatively related with rice yield. Future research needs to focus on analyzing data at the district levels to have comprehensive information on the issue of climate change and rice yield.

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