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Climate Change Impacting the Wheat Crop in Pothohar and Northern Punjab Region

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Abstract

Changing climate is impacting all the field of life and jolting the daily businesses f mankind. It is now and established fact that climate is changing. In case of Pakistan, it has become a challenge for the economy of Pakistan which is based mainly on agriculture and its allied sectors. There is a serious threat on the cropping sector of the country and it is vulnerable to change in two major parameters of climate viz., rainfall and temperature. The current study is conducted on tracing the likely impact of changing climate on cropping sector of Pothohar region, Mianwali and Sargodha with main focus on Wheat crop by using a cross sectional data. The data was collected through a structured questionnaire in Rawalpindi division which is then regressed against time series data of climatic variables obtained from metrological stations. Ricardian model was used to test the relationship between Net Farm Revenue (NFR) and climate variables along with socio-economic variables. The results of the model show that escalation in temperature has significant but negative impact on wheat production. Interestingly, increase in revenue was obtained with the escalation in rainfall. However, overall extent of negative impact of increase in temperature is more than positive impact of rainfall in the Pothohar region. The role of extension department has doubled in the changing scenario of climate with more monetary support is needed to the farmers from government side to invest in climate smart agriculture techniques and to adapt to climate change and its impacts.

Introduction

Climate change is growing as one of the leading environmental problems that are being faced by the modern world. The Greenhouse Emission (GHG), increase in amount of gases like carbon dioxide (CO2) and methane (CH4) are accountable for making changes in the global climate. The studies have confirmed that climate change will produce swings such as rise in sea level, changes in rainfall sequences

and movement of climatic regions due to increased temperatures. Intensities of climatic events like storms, droughts and flood are expected to be increased due to change in climate patterns. Accumulation of GHGs is increasing and resulting in the increase in the world temperature, thus making the world a warmer place to live (IPCC, 2007). IPCC, a renowned global research think tank on climate change claimed based on its studies that the international temperatures will increase by 1.8^{o}C to 4^{o}C and there would be overall average increase of 2.8^{o}C in temperature (IPCC, 2007). In reality, man is responsible for this emerging Carbon Dioxide enriched world because since the pre-industrial time CO^2 concentration has increased from 280ppm to 380ppm due to deforestation, massive use of fossil fuels etc. (Stern, 2006). According to a recent study by NASA, the mean temperature on earth has increased about 0.8°C since 1880. On the other hand, two-third of warming has been increased since 1975 roughly at the rate of 0.15-0.20°C per decade (Carlowicz, 2017). Agriculture as we know is the direct victim of climatic variables. Any deviations in production due to abnormal behavior of climatic variables due to changing climate will weak the fragile socio-economic structure South Asian Region (SAR) societies. There are already predictions regarding SAR that global warming will render many parts of this region unlivable for humans as well as for the animals (Worland, 2017)

Agriculture is an economic activity highly dependent on climate conditions. Changing climate has threatened the productivity of agriculture sector making it vulnerable both economically and physically to climate unevenness and change. Productivity is being affected by a number of climate change variables including rainfall pattern, temperature hike, changes in sowing and harvesting dates, water availability and land suitability. Climate change may not have huge over all effects but regional effects are more extensive. Some region will benefit from climate change while some regions will be severely affected. Climate change will not only effect the production of agriculture commodities but also disturbs the economic steadiness affecting the supply and demand balance of agriculture commodities, profitability, trade and prices of these commodities (Kaiser and Drennen, 1993). Rising GHGs will affect the agricultural farms in low developing countries as compared to the developed countries (Kurukulasuriya et al. 2006; Seo and Mendelsohn 2008). Developing economies are more climate sensitive for they rely on labor intensive technologies whereas developed economies can cope climate sensitivities as technology is available with better adoption adjustments (Mendelsohn et al., 2001).;There is a growing literature around the world analyzing the impact of climate change on agriculture. As temperature and rainfall are direct inputs to agricultural production. The fluctuation has affected the agriculture productivity and profitability. The temperature change has more serious and disastrous effect. It has greatly affected the crop revenues. In Kenya a few degrees of warming have increased the crop yields of moderate regions while the crop yields of regions nearer to the extreme temperature decreased. Dry land farms are affected more due to a few degree warming but the benefits are more for irrigated farms (Maraia and Karanja, 2007). Studies also highlighted that crop yield in a number of areas in Africa will be adversely affected by warming above the present levels (Kurukulasuriya and Mendelsohn, 2008). Overall rainfall effects are positive showing that early summer and winter rainfall are useful in South Africa (Benhin, 2008).

Consistent increase in warming has been observed across Asia. Climate scenarios forecasted a temperature

increase in this part of world. The cooler regions are becoming warmer. Changes in rainfall are less certain making Asia wetter. Heavy rainfalls are expected during wet seasons thereby increasing the chances of flood while on other hand, dry season are getting drier. These climate changes are threatening to agriculture productivity thereby reducing agricultural productivity, decreasing income growth (ADB, 2009). Impacts of climate change are more devastating in South Asia. 50% reduction in wheat productivity is to be expected by 2050 (MOE, 2009).

Pakistan's agriculture is also under threat of climate change. Pakistan is an agriculture country as 47% of its people make their living by agriculture. This sector contributes about 20% to the GDP. Due to the climate change temperatures are raising and rainfall is reducing. A rise by 3 degrees by 2040 and up to 5-6 degrees is the forecast in temperature by the end of the century. These climate changes has made agriculture sector economically vulnerable. Climate change has affected the water availability in form of water shortage altering the cropping patterns and different crop rotations thereby crop yields are greatly affected. Pakistan is at 28th place amongst the countries that is going to be hurt hugely by climate change. Since 22 out of 28 countries are in Africa. Pakistan is in the top ten outside Africa. (MoE. 2009).

Pakistan is included in World Bank's list of 12 highly exposed countries to climate change. Temperatures rise, intense rains, droughts and production losses in agricultural sector are expected in Pakistan due to climate change. Pakistan has been bearing the impact of climate change without being aware of it. IPCC Fourth Assessment Report (2007) mentioned that rains would intensify in the northern region of Pakistan. The current floods in Pakistan are due to heavy and irregular rains (UNDP, 2010).

As the previous studies concluded that the dry lands are greatly affected due to climate change (Eid et al., 2007, Kurukulasuriya and Mendelsohn.,2008). Substantial losses are observed in crop yields reducing earnings of the dry land farms. Dry lands of Pakistan are also affected by the changing climate. As Pothohar areas of Pakistan are highly dependent on natural climatic conditions. Climate changes have disturbed the agriculture output and earning of this area. Increased warming and reduction in rainfall has made Pothohar areas more vulnerable to climate change. The question arises that as warming has increased over the time what will be consequences of the climate change on local farmer of Pothohar areas. As the global warming is devastating what will be the economic losses and what will be the adjustments made to improve economic conditions of their farms. The warming has greatly exposed the Pothohar area farmer's to climate change producing remarkable differences in expected yields.

The objective of this study is to address the impact of climate change in Pothohar region and its allied districts. The study will analyze the economic impact of climate change in these areas .It will address the research gaps that how the different climate variables are affecting wheat production and profitability and also what will be the adaptive tools to be used by the farmers in Pothohar region so as to avoid the impact of climate change.

Material and Methods

Econometric Model

Ricardian model was employed to estimate the economic impact of changing climate on wheat crop in selected area. The model is actually an empirical approach to study sensitivity of crop production. This approach is named after David Ricardo (1772-1823). Ricardo was of the view that that value of land or land

rents reflects the net productivity of farm and he estimated the effect of climatic variables. He also estimated the impact of other variables on farm revenues through this model. This method is further developed by (Mendelsohn et al. 1994) with the aim to address economic impact of climate change on land prices in USA and developing countries like Brazil (Sanghi 1998) and South Africa (Gbetibouo & Hassan 2004) .

This approach helps in quantifying direct effect of climate on productivity of agriculture. The advantage of this model is that it also addresses the farmer's adaptions to the local climate, the direct effect of climate on crop yields and also indirect substitutions of variety of inputs in response to climate change, introduction of different farming activities and other possible adoptions to different climates. Another advantage of this model is that it can be used to identify both country level and regional impacts.

Coming to the structural form of Ricardian model, this method uses a cross- sectional approach to study agriculture production in response to climate change. It estimates how changes in climate variables affect net farm revenues from crop production. The model's principle is presented in the following equation;

$$\mathbf{R = \Sigma P_i Q_i (X, F, Z, G) - \Sigma P_x X \ldots\ldots\ldots\ldots\ldots (1)}$$

In this equation, R shows net revenue, P_i the market price of the crop i, Q_i is the output of crop i, X is the vector of purchased inputs (other than land), F is a vector of climate variables, Z is a vector of soil variables, G is a vector of economic variables such as market access and P_x is a vector of input prices. The model assumes to select X to maximize net revenues given the characteristics of the farm and market prices. The Ricardian model is a reduced form model that estimates how various exogenous variables like F, Z and G, affect the net revenues. The standard Ricardian model relies on a quadratic formulation of climate presented below.

$$\mathbf{R = B_0 + B_1 F + B_2 F_2 + B_3 Z + B_4 G + \mu\ldots\ldots (2)}$$

Here μ is an error term, F_1 and F_2 shows levels and quadratic terms for temperature and rainfall. The quadratic terms of temperature and rainfall reflects the non-linear relationship between climate and net revenues. The nonlinear relationships provided with best definitions of the extent of climate variable affecting net revenues in agriculture. When the quadratic term is positive, a U-shaped net revenue function is obtained and when the quadratic term is negative a hill-shaped function net revenue function is obtained.

Dependent Variable

In this research, the dependent variable used is the net crop revenues. This is obtained from the primary study conducted in the sampled area. Net crop revenue is total sales for each crop less than expenditures on production, including expenditures on seed, irrigation, fertilizer, herbicide, pesticide, machinery, hired labor etc. In addition to this, the output consumed by each household was given a value based on the market price of the output as if it was sold on the market.

Independent Variables

The independent variables included temperature, rainfall and socioeconomic variables. Primary survey provided the data for socio-economic variables. The data for climate variables was obtained from Pakistan Metrological Department. The data comprises of last 20 years from 1998 to 2017. Unlike similar studies, annual climate data is used only. This is because the selected area of research was geographically small and thus

there is a chance of lack of significant variation within the climate conditions over the year (Fleischer et al, 2008). If monthly data is used, then it will lead to high multi co-linearity in the regression analysis. So, yearly temperature and rainfall data was collected and represented. The socioeconomic data was collected from three districts of Pothohar region viz. Rawalpindi, Chakwal and Attock. The study also included allied districts of Sargodha and Mianwali. The reason to include Sargodha and Mianwali mainly was because the topography, rainfall pattern and temperature prevalence is quite similar to Pothohar region and also to add more variation in data. A total of 20 sample size was taken from each district. The tehsils were selected randomly from these five districts keeping in view the time and budget constraints. Still it is ensured that the data collected should be best representative of the whole region. Survey collected information such as house hold size ,years of education, size of farm, type of soils, cost of inputs, wage rate, area under plantation, machinery used, crop yield, income and expenditure. Data collected was entered in Statistical Package for Social Sciences and was cleaned for analysis purpose.

Calculation of Net Crop Revenues

Net revenue per farm was estimated by reducing all costs incurred on production of wheat crop from the sale of crop at the market prices. A total of one hundred observations of farm net revenues were obtained as mentioned earlier. Following formula is used to calculate the net farm revenue.

Net Revenues per Acre = (Gross Revenue – Fertilizers, labor costs etc.)

Results and Discussion

There are two regressions being operated here. In the first regression, the net farm revenue is regressed only with the climatic variables as presented in table 1. In the second regression, the socio-economic variables are introduced. The results of this regression are presented in table 2.

Regression of Net Revenue with Climatic Variables Only

Table 1 shows the results of the response of net farm revenues to climatic variables only. Significant values are obtained for the linear terms of the temperature and rainfall. Linear term for temperature is positive and significant while the values for rainfall are negative and also highly significant as well.

Table 1: Regression of climate variables with net revenue

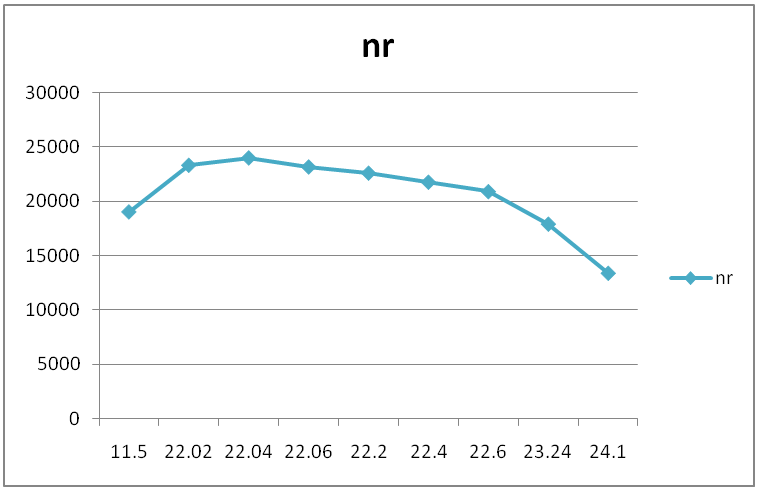
Variables	Coefficient	Std. Error	T. Value	Probability
AVG.TEMP	13583.11	3245.71	4.23	.000
AVG.TEMP^2	-396.76	94.89	-4.56	.000
AVG.RAIN	-419.97	94.87	-4.77	.000
AVG.RAIN^2	2.53	.46	4.11	.000

a. Dependent Variable: NET REVENUES α=5%

The squared terms for the climate variables are significant in the model, which is steady with the hypothesis that the relationship between climate and net farm revenues is non-linear (Mendelsohn et al. 1994, 1996). The negative quadratic coefficients imply a hill shaped relationship between net revenue and

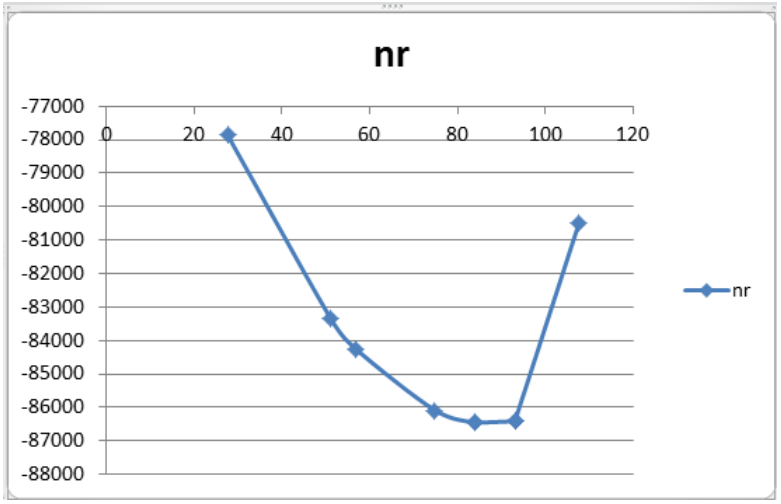
temperature shown in figure 1.

Figure 1: Hill-shaped Relationship of Temperature with Net Farm Revenue



The squared mean temperature indicates an inverse quadratic relationship between net revenues and temperature variable. This result implies that increases in temperatures tend to benefit farm net revenue, with diminishing marginal benefits up to a maximum turning point, after which further increases in the temperature starts to have negative effects on farm net revenues. The square term for average yearly rainfall has a positive value stating an increasing trend for increase in rainfall. A U-shaped relationship is observed defining exact nonlinear relationship b/w net revenues and rainfall as shown in figure 2. Values are found to be highly significant. The coefficient of rainfall square term found positive stating that net revenues will overall increase due to increase in rainfall. As arid areas are highly deficient in rainfall and whole farming production depends hugely on expected rains so increase in rainfall will have a significant impact on net revenues as stated by the model.

Figure 2: U-shaped Relationship of Rainfall with Net Farm Revenues



The effect of quadratic climate variables on net farm revenues is not obviously determined by looking at the coefficients, as both the linear and the squared terms play a role (Kurukulasuriya & Mendelsohn 2006). What can be determined from the sign of the quadratic term is whether the relationship with net farm revenue is hill-shaped or U-shaped if the sign is positive or negative respectively.

Regression of Climate Variables and Socio-Economic Variables with Net Revenue of

Table 2 shows the results of net revenues with climatic variables and also socio economic variables entertained in the model. The linear term of temperature was significant and gave us the expected signs.

Table 2 Regression of Climate Variables and Socio-Economic Variables with Net Revenue

Variables	Coefficient	Std. Error	T. Value	Probability
AVG.TEMP	993.42	3435.65	-2.97	.008
AVG.TEMP^2	-294.53	102.23	2.90	.010
RAIN	-349.12	96.68	-2.90	.008
RAIN^2	1.92	.5.6	-3.67	.004
AGE	115.22	55.34	3.69	.002
EDU	-53.17	302.30	2.08	.057

a. Dependent Variable: REV .α=5%*

The quadratic term of temperature is highly significant and with negative sign indicating that increase in temperature would have a negative effect on net revenues i.e. decreasing agriculture production of some major crops of the Pothohar and its allied region. The linear term of rainfall is also significant and has the projected signs. Coefficients of quadratic term of rainfall have expected positive signs. Rainfall increase will positively affect net revenues hence increasing agriculture productivity as whole Pothohar region, Mianwali and Sargodha are highly dependent on rainfall especially the wheat crop which is highly dependent on rainfall during different growth stages. Socio economic variables were entered in the model defining a linear relationship with net revenues.

Age of the farmer has a significant impact on the net revenues. Age of the farmer was taken as an experience symbol of the farmer i.e. more the age of the farmer more he has the experience of farming so the age of the farmer has a significant impact on net revenue.

More the farmer is involved in farming over the year's better he can adjust to different farm practices, alteration, crop choices etc. education of the farmer doesn't has a significant impact on net revenues. The "t" values were not significant stating that education i.e. no of schooling years has no determinable effect on net crop revenues. One of the reasons of non-determinable effects of years of schooling may be lacking of mechanized farming habit which are not adopted by the educated farmers as well.

CONCLUSION

The study presented Ricardian analysis operation on the wheat crop of Pothohar and its allied regions. The study measured both temperature and rainfall effects on wheat production. Overall warming showed harmful impacts on wheat crop production in the study area. However, increase in rainfall will be beneficial.

Another natural challenge facing by the farmers in this region is high deficiency in water resources. Coupled with climate change, the situation poses more problems to the farmers. Development of water resources and updated information dissemination will provide help and guard the economic aspects of the farmers in the situation of increasing temperature of the region and drought conditions. Government can help farmers by monitoring climate change and disseminate information about changing climate and necessary adjustment techniques as well. New crop varieties should be developed which are more suited for a warmer and harsh climate of the region. Increased heat and drought tolerance are the desired characteristics that can help in reducing potential damages. Policies which increase farmer flexibility will also aid farmers to adjust to new and changing climatic conditions. Innovative water resource management techniques need to be taught to the farmers of the region. Irrigation water and the availability of modern irrigation technologies could become increasingly valuable. It is also observed that livestock raising is another source of livelihood for the local farmers to gain marginal economic benefits. Promoting livestock rearing as complementary option to crop production in dry areas like Pothohar region will help the to minimize losses associated with crop damages due to climate change. Lastly, easy accessibility of the farmers to seeds, fertilizers and pesticide before the new season will certainly improve the net revenues of the farm in the changing climate scenario.

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