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IMPACT OF CLIMATE CHANGE ON AGRICULTURE: EMPIRICAL EVIDENCE FROM ARID REGION

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Climate change has become a great challenge for the agrarian economy of Pakistan. A serious threat is to the crop sector which is vulnerable to change in temperature and rainfall. This study traced the impact of climate change on the agriculture of arid region by employing a cross sectional data collected through a structured questionnaire in Rawalpindi division in addition to using time series data of climatic variables obtained from metrological stations. A Ricardian approach was operated to test the relationships between Net Farm Revenue (NFR) and climate across the arid region. Wheat crop was the core of the subject matter. It was found that temperature increase has significant negative impact on agriculture production. Moreover, an increase in revenue was visualized with the increase in rainfall. The overall extent of negative impact of temperature is greater than the positive effect of rainfall in the region. It was revealed that one percent increase in temperature would lead to loss of Rs. 4180 to the net revenue per annum. Dissemination of new farming techniques including new irrigation methods, new methods of crop farming and adapted cropping pattern would be the appropriate derivatives of paradigm shift required in the agriculture sector of arid region.
Keywords: Climate change, wheat crop, arid region

INTRODUCTION

Climate change is evolving as one of the leading environmental problems facing modern world. Emission of greenhouse gases (GHG), increase in amount of gases like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are responsible for generating changes to global climate. 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 droughts, storms and flood are expected to be increased due to changing climatic patterns. Global temperature will increase by 1.8^{o}C to 4^{o}C with an overall average increase of 2.8^{o}C in temperature (IPCC, 2007). Human are responsible for this newly emerging CO_2 enriched world because since the pre industrial time CO_2 concentration has increased from 280 ppm to 380 ppm due to deforestation, massive use of fossil fuels etc. (Stern, 2006).

Agriculture is an economic activity highly dependent on climatic 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 agriculture farms in low developing countries as compared to the developed countries (Kurukulasuriya *et al*., 2006; Seo and Mendelsohn, 2008). Developing economies are more climates sensitive as economy relies on labor intensive technologies, whereas; developed economies can cope climate sensitivities as technology is available and better adoption adjustments (Mendelsohn *et al*., 2001).

In Asian perspective, consistent increase in warming has been observed across the region. Climate scenarios forecasted a temperature increase in this part of the world. The cooler regions are becoming warmer. Changes in precipitation are less certain making Asia wetter. Heavy rainfalls are expected during wet seasons increasing the chances of flood while on other hand dry season are getting drier. These climate changes have become threatening to agriculture productivity reducing agricultural productivity, decreasing income growth (ADB, 2009). Climate change poses serious threats to farmers of Asia who live in isolated, marginal areas such as mountains, dry lands and deserts areas who are deficient in natural resources. Temperatures rise are expected in the arid areas of northern Pakistan and India and western China. Out of 500 million rural poor in the Asia majority of them are surviving farmers who are occupying rain-fed land. Production of rice, maize and wheat in the past few decades has gone down due to ever increasing water stress arising mainly from temperature rise

(UNFCCC, 2007). Impacts of climate change are more devastating in South Asia and may result 50 percent reduction in wheat productivity by 2050 (MoE, 2009).

Pakistan's agriculture is endangered by the whims of Climate Change. Pakistan is an agriculture country as 47 percent of people make their living by agriculture. This sector contributes 21 percent 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 forecast in temperature by the end of the century. These climate changes has made agriculture sector economically vulnerable. 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. Rising temperatures, 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.

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 due to high degree of dependence on natural climatic conditions. Climate changes have disturbed the agriculture output and earning. Increased warming and reduction in rainfall has made arid areas more vulnerable to climate change. The question arises about the consequences of increased warming on the local farmer of arid 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 arid areas farmer's to climate change producing remarkable differences in expected yields. In this perspective, the objective of this study is to address the impact of climate change on the agriculture of arid areas. The study will analyze the economic impact of climate change in these areas. The study addresses the research gaps that how the different climate variables have affected the agriculture production and profitability and also what will be the adaptive tools used by the farmers of arid areas so to avoid the odd impact of climate change.

METHODOLOGY

Data and sampling design**:** The study is based on climatic and socio-economic data. Data of climatic variable like temperature and precipitation was obtained from Pakistan metrological department for the last twelve years (1999 to 2010). Unlike similar studies, we used annual climate data only and not monthly or seasonal data due to the small size and geographical location of the studied area and lack of significant variation in climate conditions over the year (Fleischer *et al.,* 2008). The use of monthly or seasonal climate data led to high multi co- linearity in the regression analysis. As a result almost all the monthly or seasonal climate variables were not found to be significantly different from zero. Yearly temperature and precipitation data was collected and represented. These seasonal definitions provided us the best fits of the data.

On the other hand, data on desired socioeconomic aspects was collected from three districts and ten tehsils of arid region. A total of twelve villages were selected randomly from different agro-ecological settings of the arid region and were believed that they are the best representative of the whole region. Ten observations were made from each village. Villages were selected so that there was a differentiable variability in climatic conditions, i.e. temperature and rainfall in each village and also the prevailing agriculture techniques, crops and soils etc. Three type of farm size/type: small, medium, large were chosen for data collection. Survey contained the information such as household 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 was collected using a structured and detailed questionnaire. The research objectives were translated into questions. Detailed questions about farm revenue, farm costs, income and expenditures of the respondent were designed and asked. Data was collected by conducting a face-to-face survey among a representative sample of farmers. Questionnaire was designed in English language but communication with the farmer was done in local language for the ease of the farmers and exact reply was noted down instantaneously the data provide us with a relatively high quality measure for the dependent variable i.e. net crop revenue for each household and also some of the dependent variables.

Estimation models**:** Ricardian model was employed to analyze the economic impact of climate change on agriculture in arid areas. A Ricardian model is an empirical approach for studying the sensitivity of agriculture production (Ricardo, 1817). It was named after David Ricardo (1772-1823) observation that value of land or land rents reflects the net productivity of farm land and estimates the impact of climate variables and also the impact of other variables on farm revenues. This method has been developed by (Mendelsohn *et al.,* 1994) to address the economic impact of climate change on land prices in USA and in some developing countries–Brazil and South Africa (Gbetibouo & Hassan, 2004) to examine the sensitivity of agriculture to changes in climate. The Ricardian approach examines the direct effect of climate on agriculture productivity and also the farmer's adoptions to the local climate, the direct effect of climate on crop yields and also indirect substitutions of variety of inputs, introduction of different activities and other possible adoptions to different climates. This model can be used to identify both regional and country level impacts.

The Ricardian method used is a cross- sectional approach studying the agriculture production. It accounts that how changes in climate variables affect the net farm revenues. The principle is explained in the following equation.

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

Where R is net revenue per acre, 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 farmer is assumed to choose X to maximize net revenues given the characteristics of the farm and market prices. The Ricardian model is a reduced form model that examines how several exogenous variables, F, Z and G, affect net revenues. The standard Ricardian model relies on a quadratic formulation of climate:

$$R = B_0 + B_1 F + B_2 F^2 + B_3 Z + B_4 G + \mu \; \ldots\ldots \; (2)$$

Where μ is an error term while F and F^2 show level and quadratic terms for temperature and precipitation. The quadratic terms of temperature and precipitation reflects the non-linear relationship between net revenues and climate. It is non linear because up to a specific range of temperature and precipitation, there is increase in yield but beyond that threshold, there may be decrease in crop yield. These non linear relationships provided us with best definitions of the extent of climate variable affecting net revenues. When the quadratic term is positive there will be a U-shaped net revenue function and when the quadratic term is negative there will be a hill-shaped function net revenue function.

***Calculation of net farm revenues*:** Net revenues were estimated by subtracting the farmers all costs incurred on production of a selected crop from the sale revenue of that particular crop at market prices. The cost of production includes the cost of seed, fertilizer, irrigation, pesticide, herbicides, machinery, hired labor etc. a total of one hundred twenty observation of farm net revenues were obtained, ten observation from each village and from each village average of five net revenues observation were defined as average net revenues of those five farms so two average net revenues readings were obtained from each village, a total of twenty four reading of average net revenues were obtained from twelve villages. These calculated averages gave us better estimation of the required results.net revenues per acre were calculated which gave us the best estimation for results.

$$\text{Net Revenues per Acre} = \frac{\text{(Gross Revenue – Fertilizers, labour costs etc.)}}{\text{Total Area}}$$

RESULTS

***Survey statistics of climate change impacts*:** The survey analysis gave us the estimated results which are in accordance with our estimated regression analysis. Survey analysis provided us the information about the farmer's observation about climate change. A change in climate on their respective farms is observed by 94 percent of the farmers contrary to only 6 percent farmers who did not observe any specific change in climate of their respective farms. About 95 percent of the farmers commented that temperature increase and rainfall decrease is the main cause in changing climate. The rains have been dried up causing dramatic changes in the agriculture productions. Temperature increase has caused a change in overall production. Only 6 percent informed that climate change has a appositive impact on crop production. Forty four percent farmers reported that temperature has increased over time. Twenty eight percent of the farmers told that rainfall is increasing over time. Fifty one percent of the farmers reported that rainfall has decreased over time. Only 13 percent farmers observed a decrease in temperature. Overall decrease in rainfall was observed. Sixty five percent of the farmers reported a severe loss in wheat production due to changing climate. As wheat crop is highly sensitive to the changing climatic conditions increase in temperature and decrease in rainfall both has alarming effects on wheat production.

***Estimation of temperature and rainfall variations*:** To empirically estimate the temperature and rainfall variation within the different localities and settings of the arid region, a simple regression analysis is performed. The longitude, latitude and altitude of a particular sampled place are regressed with temperature and rainfall of that particular location, a single village separately. The temperature and rainfall averages for the year 2010 were analyzed by running Ricardian regressions.

Longitude has a significant impact on temperature. An increase of one degree of longitude will make the temperature to fall by 0.39^o. Latitude does not have a significant impact on temperature changes as t values are very much small not having a high significance. Distance from sea level also showed a significant impact on temperature so the areas with more distance from sea levels tend to have low temperatures. The regression coefficients showed an inverse relationship with the increase of the temperature. Coefficients explained that by increase in altitude by 1 foot, the temperature will decrease by $-.956^o$.

An area of barani region having high altitude tends to be cooler and have comparatively low temperatures. But as the distance from the sea level starts to fall temperature starts rising and the weather tends to be hotter comparatively to those of high altitudes. The coefficient of correlation shows a strong effect of these variables on temperature changes.

Similarly, the longitude, latitude and altitude affected the rainfall intensity. Longitude has a very significant impact on rainfall changes. With the increase in longitude rain fall also increases. The coefficient explained a defined relationship between changing longitude towards increase or decrease of rainfall. An increase in longitude by one degree will increase rainfall by 0.6 mm. Latitude does has a significant impact on rainfall intensity showing a positive relationship between latitude and rainfall. An increase in latitude by one degree will make rainfall to increase by 0.55 mm. Height from sea level did not affect significantly on rainfall intensities. The significance was not high for height from sea levels. So the areas which are at high from sea level do not have necessarily high rainfall accumulation. The rain fall intensities highly depended on changes in longitude and latitude changes.

***Impact of climate on NFR: Without socio-economic parameters*:** Table 1 shows the results of the response of net farm revenues to climate variables only. The linear terms of the temperature and precipitation showed significant values. The linear term for temperature is positive and significant and linear terms of rainfall are negative and highly significant as well. The squared terms for the climate variables are significant in the models, which is steady with the hypothesis that the relationship between climate and net farm revenues is non-linear (Mendelsohn *et al*., 1994). The negative quadratic coefficients imply a hill shaped relationship between net revenue and temperature. 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 precipitation. A U-shaped relationship was observed defining exact non-linear relationship between net revenues and rainfall.

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. 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 and Mendelsohn, 2008). 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.

***Impact of climate on NFR: With socio-economic parameters*:** Table 2 shows the results of net revenues of year 2010 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. 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 barani 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 arid region is hugely 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 a 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 effect of years of schooling may be lacking of mechanized farming habit which are not adopted by the educated farmers as well.

The empirical regressions measure the climate sensitivity of arid region of Punjab. In this section, we explore the impact a broad range of climate scenarios might have on agriculture production in sampled area of arid region. These simulations provide a sense of the magnitude of potential impacts. The estimates, however, must be interpreted vigilantly because many factors may change over the next fifty to hundred years and they may well change the results. For example, population growth, economic development, changing prices, and changing technology may all have shrewd impacts on the agriculture sector. The prime objective was to investigate the effect of climate change on future productions. Future analyses must take these other important factors into account as well.

Table 1. Ricardian Regression: Without socio-economic variables

Model summary

Model	R	R Square	Adjusted R Square	Standard Error of the Estimates
1	0.834[a]	0.696	0.632	590.27108

ANOVA[b]

Model	Sum of Squares	Df	Mean Square	F	Sig.
1 Regression	1.513E7	4	3782180.024	10.855	0.000[a]
Residual	6619979.066	19	348419.951		
Total	2.175E7	23			

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	-81286.262	19230.211		-4.227	0.000
AVG.TEMP	13483.103	3145.648	45.217	4.286	0.000
AVG.TEMP 2	-395.750	93.883	-46.469	-4.215	0.000
RAIN	-418.965	92.980	-11.318	-4.506	0.000
RAIN 2	2.401	0.494	8.570	4.855	0.000

a. Predictors: (Constant), RAIN2, AVG.TEMP, RAIN, AVG.TEMP 2
b. Dependent Variable: REV 2010

Table 2. Ricardian regression: With socio-economic variables

ANOVA[b]

Model	Sum of Squares	Df	Mean Square	F	Sig.
1 Regression	1.650E7	6	2749507.055	8.900	0.000[a]
Residual	5251656.834	17	308920.990		
Total	2.175E7	23			

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	-60954.336	20558.402		-2.965	0.009
AVG.TEMP	9926.243	3423.936	33.289	2.899	0.010
AVG.TEMP 2	-293.602	101.178	-34.474	-2.902	0.010
RAIN	-349.416	95.165	-9.439	-3.672	0.002
RAIN 2	1.983	0.537	7.079	3.689	0.002
AGE	115.210	55.312	0.572	2.083	0.053
EDU	-52.569	301.356	-0.044	-0.174	0.864

a. Predictors: (Constant), RAIN2, AVG.TEMP, RAIN, AVG.TEMP 2
b. Dependent Variable: REV 2010

Global temperatures are predicted to increase from 1.5 to 5.8 1°C by 2100 an overall average increase of 2.8°C in temperature (IPCC, 2007) while the Global Precipitation is predicted to increase from 0 to 14 percent with a best guess of an 8 percent increase (IPCC, 2007). Forecast of 0.5-2°C by 2030 indicates an increase in temperature for Asia. The new expected temperatures and rainfall increase are added to the base year temperature and rainfall for future forecasting. Using these climate change scenarios on our study following table 3 gave us the expected impact of changing temperature and rainfall on future net revenues. Table 3 shows the impact of expected increased temperature and rainfall on future net revenues. Results clearly show the damaging effect of increased temperature. The net revenues will be hugely affected by temperature increase according to the

Table 3. Forecasts of NFR according to different climate change scenarios

Expected temperature and rainfall changes by year 2100	Welfare effect on NFR per Acre (Rs.)
1°C increase in temperature	-4180.2
1.5°C increase in temperature	-6560.2
2.8° C increase in temperature	-13672
8% increase in rainfall	+377.4
14% increase in rainfall	+649.21

predicted climate change scenarios. A 1^{o}C in temperature will produce a loss of 4180 rupees. As temperature goes on increasing, great losses are observed. Rainfall increase will increase in net revenues in coming years. Around 8 percent increase in rainfall from the base year has led to an increase of 377 rupees though the gains from increasing rainfall are small as compared to the temperature losses but a slight safeguard from severe losses. Temperature increases will definitely reduce the net revenues of the farmers.

CONCLUSION

The arid region of Punjab is also going to be effected by climatic changes. An economic effect of climate change on agriculture of arid region was estimated by using Ricardian technique. Primary data was collected from the farmer fields while secondary data of temperature. After estimating the NFR, it was regressed on climate and other control variables across farms. The estimated regression results were applied to climate scenarios. The scenarios with losses had overall harmful temperature impacts, with offsetting precipitation benefits. In the beneficial scenarios, there were increases of precipitation. Overall increase in temperature is observed in the arid region. Increase in temperature has significantly reduced net revenues and also the future forecast predicted a loss in net revenues. The increased temperature has made the farmers of the arid areas more vulnerable as land holding are mainly small. So increase in temperature will lead the farming community to increase in overall poverty of the region due to dry arid land conditions. The overall extent of negative impact of temperature is greater than the positive effect of rainfall in the region. It was revealed that one percent increase in temperature would lead to loss of Rs. 4180 to the net revenue per annum. Dissemination of new farming techniques including new irrigation methods, new methods of crop farming and adapted cropping pattern would be the appropriate derivatives of paradigm shift required in the agriculture sector of arid region.

POLICY RECOMMENDATIONS

It is drawn from the findings that government can play its role by monitoring climate change and its likely impact of agriculture and then disseminate the results of this monitoring in addition to level play field for adaptation practices of the wheat farmers. New crop varieties along with conservation agriculture practices should be followed which are more suited to a warmer climate of the arid region. New crops with increased heat and drought tolerance will help reducing potential damages. Policies that increase farmer flexibility would also help allow farmers to adjust to new conditions. Finally, the government could help organize irrigation and other development projects. As temperatures rise in this region and no irrigation system are installed. Irrigation water and the availability of modern irrigation technologies could become increasingly valuable. Different research groups have to evaluate new methods of crop farming and also revaluate cropping patterns according to new world of climate change. Accessibility of the farmers to seeds, fertilizers and pesticide before the new season will certainly improve the net revenues of the farm. Extension services role are very important for dissemination of scientific based information to the farmer on the farm.

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