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ECONOMIC IMPACT OF CLIMATE CHANGE ON AGRICULTURAL SECTOR OF PUNJAB

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ABSTRACT

Climate change impact is a multidimensional phenomenon which leaves diverse implications on environment and economic lives of the people. Its effects are more deep rooted in the economies which are agrarian, as they are dependent upon the vagaries of nature. Climate change has passed through an evolutionary process since the advent of this world. The industrial revolution in England, the development of manufacturing industries on massive scales in the United States, Western European and Eastern European countries have been responsible for accentuating and also aggravating the problems which now are being encountered by the lesser developed economies. The use of fossil fuels mainly oil and coal for power generation as motive power are life blood for running machines and have been listed as the most dominant reason for climate change.

Seen in this perspective, the study of climate change on both physical resources as well as human resources have been necessitated. The realm of study has been narrowed down to change in climate on the rural economy in Punjab. In the author's opinion this premises will hold / holds good on the over all agricultural growth and development in the sister provinces of Pakistan.

The main objective of the study is quantification of the impact of change in climate normals in order to have a viable and sustained development of agricultural sector both at the regional and country level. It may be said that the study in hand can be listed as the first of its analytical value in Pakistan. A one way fixed effect panel model for eleven districts over the time horizon 1970-2009 has been estimated

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with Feasible Generalized Least Square panel regression technique. The results of panel regression of precipitation, maximum and minimum temperature are derived on Punjab agricultural land.

The assessment has brought it that mean precipitation and mean minimum Kharif temperature have significant positive (∩) relationship with land prices. Mean maximum Kharif temperature is not significant with land prices.

Precipitation in Rabi has significant negative (∪) relationship, Mean minimum temperature has significant negative (∪) and mean maximum Rabi temperature has significant positive (∩) relationship with land prices. Results have indicated that with decrease in Rabi precipitation coupled with an increase in maximum Rabi temperature will tend to increase the land price in the season.

The study has confirmed the hypothesis that climate change impinges considerably the price of agricultural land which is a long run variable for net revenues.

The aggregate global effects on agricultural productivity are expected to be negative by the end of this century, and developing countries are expected to suffer sooner and worse.[1]

1. Introduction

Naturally occurring greenhouse gases (GHGs) accentuate a critical function in the Earth's atmospheric system. These gases are transparent to the incoming solar radiation, and block the outgoing radiation from the Earth's surface. This phenomenon is known as the greenhouse effect which cause rise in the Earth's average temperature. The onslaught has been taking place since times immemorial. As back as the Industrial Revolution, anthropogenic activities namely, power generation from fossil fuels and deforestation activities have been continuously increasing, the atmospheric concentration of GHGs beyond their natural limits resulting in an enhanced greenhouse effect, vis-à-vis, an increase in global temperature. The rise in temperature could be coupled with changes in rainfall pattern, rise in sea level, frequency and severity of extreme events namely, cyclones and droughts etc. The aggregate of all these changes is referred to as climate change.

Viewed in the context of climate change and its effects, the achieving of sustainable development from considerations of social, economic and environmental is a challenge. Climate change affects economic development in many ways, especially the agrarian economies have always depended on vagaries of nature. Change in temperature, precipitation averages and extreme climate events can alter yield, income, health, sociology and physical safety. In the ultimate, it affects the paths and levels of future development. Climate change is a global phenomenon and no country is immune to it. (World Development Report, 2010)[2].

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[1] Climate Change, Human Vulnerability and Social Risk Management . *Social Developmet Group, The World Bank Group* (Rasmus Heltberg., Steen Lau Jorgensen. & Paul Bennet Siegel., 2008).

[2] World Development Report: Development and Climate Change, 2010.

Agriculture has been one of the oldest economic activities all over the world. It is not only the backbone of foodgrain supply to the work force but also supply raw material to industries.

Climate change has raised serious concerns for developing countries and Pakistan is not alone to face tremendous social, environmental and economic impacts. The various impacts on agriculture due to climate change have received high contemplations in Pakistan, as the change in climate is closely linked to food security and poverty of a vast majority of the country's population.

Pakistan's status as a developing country is dependent mainly on agricultural sector making it highly vulnerable to the effects of climate change. Agricultural and allied activities are the single largest sector, contributing 21 per cent to GDP and employing 44per cent of workforce. As much as 65 per cent foreign exchange is earned from export of goods manufactured from raw materials obtained from agricultural sector. More than two-third of Pakistan's population lives in rural areas and their livelihood depends on agricultural and agro-based activities (Pakistan Economic Survey, 2007-08).

In 2006, the share of agricultural sector in GDP, exports and employment level have markedly decreased. Amongst other reasons of declining agricultural productivity, change in climate has been marked a major contributor. According to Economic Survey (2007-08), agricultural sector has performed poorly in 2007-08, it grew at 1.5 per cent against the target of 4 per cent. The sector had suffered from multifarious reasons which also included heavy rainfall in May 2007, high temperatures during August and September, 2007 and shortage of water in the overall irrigation system.

Changes in climate especially increase in temperature and also decrease in rainfall would have a negative impact on the future projections of major crop production in Pakistan. It is said that North is the driver for the carbon emissions but South is the victim. In Pakistan, inadequate monitoring system, assessment of the likely changes in the weather patterns and its impacts on agricultural sector make it difficult to have an effective national agro-climate policy. (Roohi, 2004).

The study has been carried out because it impacts on measurement of climate change for the Punjab province of Pakistan. Punjab is the most populous and the second largest province of Pakistan. Agricultural sector dominates the Punjab landscape both in the percentage of land (57.2per cent) in agricultural sector and also the percentage share (53 per cent) of Pakistan's agricultural Gross Domestic Product (Punjab Development Statistics, 2009).

In the year 2007-08, the share of Punjab Province in Pakistan's agricultural production of major crops was wheat 74.5 per cent. Rice 59.1 per cent, Gram 81.7 percent, Jawar 61.2 percent, Maize 74.5 percent, Bajra 73.4 percent, Cotton 77.8 percent, Sugarcane 63.1 percent, Barley 33.3 percent, Rapeseed and Mustard 58.5 percent. For major fruits, Punjab's share in the overall country's production was Mango 78.3 percent, Banana 6.3 percent, Citrus 96.7 percent, Guava 78.3 percent, Dates 7.9 percent and Apple 0.7 percent (Punjab Development Statistics, 2009). The

capacity of Punjab agricultural sector adaptability to the changing climate has never been investigated. Developing a comprehensive understanding of this adaptation capacity will facilitate efficient and viable agricultural policy reforms in the context of climate change. Study in hand is pioneering in quantifying the economic impact of climate change. By considering the results and policy recommendation, the policy makers can develop climate policies based upon ground realities.

3.1 Study Area

The major contributor to Pakistan GDP is the agricultural sector. On farm practices have been undertaken under different climate conditions, special biophysical and socio-economic conditions prevalent in rural areas of Punjab province. These being the reasons for selecting the Punjab agricultural sector for the study. The total land area of Punjab province is 20.63 million hectares which is about 26 per cent of the total area of Pakistan. The cultivated area of Punjab is 12.51 million hectares, or 67 percent of total cultivated area of Pakistan. As mentioned in the earlier paragraph, the contribution of Punjab in the Agricultural Production is overwhelming. In respect of the major fruits, Punjab's share in the overall country's production was Mango 78.3 percent, Banana 6.3 percent, Citrus 96.7 percent, Guava 78.3 percent, Dates 7.9 percent and Apple 0.7 percent (Punjab Development Statistics, 2009).

The Indus, and its tributaries, Jhelum and Chenab are the main rivers from which canals have been taken out to supply water for irrigation in Punjab. The requirements of water for cultivation are also met from tubewells. For carrying out the study, the data of eleven districts which are also representative of different climate conditions have been used. The reason for selection of these districts namely, Lahore, Faisalabad, Sargodha, Sialkot in central region; Jhelum, Rawalpindi, and Mianwali, in northern regions; Multan, Bahawalpur, Bahawalnagar, and Rahim Yar Khan in southern region was that these places had climate observation stations.

Table 3.1: Share of Agricultural GDP of the Punjab in Agricultural GDP of Pakistan (at Constant Factor Cost of 1999-00)

Sr. No	Agricultural Production Sector	2008-09			2009-10		
		Pakistan	Punjab	Per cent Share	Pakistan	Punjab	Per cent Share
01	Major Crops	1195031	635444	53.2	1218873	646281	53.0
02	Minor Crops	136601	287347	59.7	135008	84641	62.7
03	Live Stock	622531	260344	41.8	648106	268327	41.4
04	Fishing	21319	5003	23.5	21626	5044	23.3
05	Forestry	14094	1202	8.5	14404	1484	10.3

Source: Punjab Development Statistics, 2010

3.2 Climate of Punjab Province

There has occurred a rise in maximum temperature in Punjab province but the rise is not significant. There has also been observed a significant rise in the minimum temperature all across the province. As reported in Climate Change Indicators of Pakistan, 2009 Punjab, as a whole, has experienced a significant rise in precipitation.

3.3 Definition of Variables

The unit of spatial analysis for the study are the districts of Punjab. The fundamental agent in land use is the farmer or farmland. The dependent and independent variables in the study are defined in Table 3.2. The independent variables are categorized into two groups: climate and non-climate variables. The elaboration of these variables is as given under:

Table 3.2: Description of Variables

Variable	Title	Definition	Source of Data
Dependent Variable	Land price	Average Annual market sale price of agricultural land (Pak RS/acre) at district level.	Mutation registers of land price records. Land Revenue Department, Govt of Punjab.(1970-2009)
Independent Variables	**Non Climate**		
Area under cultivation	AUC	Per year use of land for agricultural purposes including land under crops, vegetables, orchards etc. The unit of analysis is Thousand hectares at the districts Level.	Punjab Development Statistics (1970-2010)
Population density	POPD	The total number of people living per square kilometer at district level.	Punjab Development Statistics (1970-2010)
Per Capita Income	YPC	National per capita income measured in Pak Rs.	Economic Survey of Pakistan (1970-2009)
Independent Variables	**Climate Variables**		
	RABI PPT	Precipitation(millimeters=mm) normal mean for the Rabi months(October -March)	Pakistan Meteorological Department (1970-2009)
	KHARIF PPT	Precipitation (millimeters) normal mean for the Kharif months(April -September)	Pakistan Meteorological Department (1970-2009)
	MIN TM RABI	Minimum temperature(Degree Celsius=^{0}C) normal mean for the Rabi months(October - March)	Pakistan Meteorological Department (1970-2009)
	MIN TM KHARIF	Minimum temperature(Degree Celsius= ^{0}C) normal mean for the Kharif months(April - September)	Pakistan Meteorological Department (1970-2009)
	MAX TM RABI	Maximum temperature(Degree Celsius= ^{0}C) normal mean for the Rabi months(October - March	Pakistan Meteorological Department (1970-2009)
	MAX TM KHARIF	Maximum temperature (Degree Celsius= ^{0}C) normal mean for the Kharif months(April - September)	Pakistan Meteorological Department (1970-2009)

3.3. Dependent Variable

The dependent variable in the study is the annual average sale price per acre (Pak Rs/acre). It is documented in final report of Task Force, Planning Commission GoP[1] on Climate Change that there is a dire need to quantify the impact of climate change on different sectors of the economy for planning and policy making. The report has also noted that it is not easy to assess the economic impact of climate change on different sectors of the economy. But it is of very crucial importance for national planners and policymakers to develop and shape the country's development plans in the most optimal manner within the constraints of limited available resources. Viewed in this perspective, the study in hand is the first effort to quantify the impact of climate change on agricultural sector. It was very tiring, time consuming and enduring drill to collect data of dependent variable. At the district level, town/village /mouza were selected to obtain the average price per acre of agricultural land in order to capture the impact of climate change. Town/village/mouza is the unit which is agricultural land area since 1970 to date. The farm land was not to be situated on the road side but have an easy access to agricultural markets. The annual average sale price of agricultural land was taken from the mutation registers maintained by Patwaris. To select a unit of analysis, tehsildars and patwaris of the respective districts were interviewed. The selected town/mouza/village per acre average agricultural land price was assumed to be representative of all normal agricultural lands in the respective districts. The same method was adopted to collect land price data for the eleven districts across Punjab province.

3.4 Independent Climate Variables

There are two crop sowing and harvesting seasons in Punjab, Kharif season from April to September and Rabi season from October to March. Climate variables in the study are the yearly Kharif and Rabi months mean data from 1970 to 2009.

Kharif crops are rice, sugarcane, cotton (American), cotton (Desi), jowar, bajra, maize, moong, mash, til, gowara seed, fodder, vegetables and orchards etc. Rabi crops are wheat, gram, Barley, masoor, peas, rape and mustard, fodder, vegetables, tobacco, and orchards etc.

Mean of minimum temperature for Kharif and Rabi season, mean of maximum temperature for Kharif and Rabi season measured in degree Celsius (^{0}C), while mean of precipitation for Kharif and Rabi season measured in millimeters have been taken as climate variables. The data were obtained from Pakistan Meteorological Department GoP, Islamabad for the eleven districts for the period 1970-2009. The missing values were assessed by taking three years moving average.

3.5. Independent Variables: Non-Climate

[1] Final Report, Task Force on Climate Change, Planning Commission of Pakistan, 2010.

The independent variables in the land climate Hedonic model used in the present research study have been divided into two categories i.e. non climate and climate variables. For non climate variables, district wise yearly population density i.e., persons per square Kilometer (POPD) and per capita income per year (YPC) in Pak Rupees are specified to control the competition for non agricultural land uses.

In Pakistan, four census of population have been conducted. The first census was conducted as back as 1951 and the most recent in 1998. The estimation of year wise population growth rate at the district level in 1961, 1972, 1981 and 1998 were 2.7 per cent, 3.41 per cent, 2.74 per cent and 2.64 per cent respectively. These growth rates were used in the study. The data of population projection from 1999 – 2009 are taken from the Punjab Bureau of Statistics, Lahore.

District wise area under cultivation (AUC) measured in thousand hectares of land is also included as an independent variable. The rationale for taking the area under cultivation as an independent variable is that it covers land use for growing all kinds of crops and orchards as well as current fallow.

The data of population density and area under cultivation were taken from different issues of Punjab Development Statistics and Punjab Bureau of Statistics. The data of per capita income was taken from different issues of Pakistan Economic Survey.

4. Results of Study

The study has taken into account forty points of time and eleven districts of Punjab. The panel fixed effect model for cross section can capture more information on heterogeneity among districts. Feasible Generalized Least Square (FGLS) with cross section SUR (seemingly unrelated regression) technique has been used to run the panel regression.

Table 4.1 shows the FGLS (cross section SUR) model results of all the independent, dependent (climate and non climate), t-statistics R-squared, F-test and other relevant statistics. For estimation, quadratic forms of climate variables have also been considered with linear form. Taking quadratic form is consistent with the literature. Quadratic forms were taken into account to capture the possibilities of nonlinearities in climate sensitivities. The linear term of climate variables show the marginal value of climate at the land price mean, while the quadratic terms show the nature of the relationship among climate variables and land value.

Table 4.1: Panel Estimation Results: Feasible Generalized Least Square (cross section seemingly unrelated regression)

Variables		**Coefficients**
	Climate	
	Rabi precipitation	-877.11**
	Rabi precipitation Squared	8.50***
	Kharif precipitation	168.92***
	Kharif precipitation Squared	-1.17***
	Minimum Rabi Temperature	-3868.66****
	Minimum Rabi Temperature Squared	162.93***
	Minimum Kharif Temperature	6088.82****
	Minimum Kharif Temperature Squared	-188.81***
	Maximum Rabi Temperature	26085.60***
	Maximum Rabi Temperature Squared	-438.47***
	Maximum Kharif Temperature	-3003.86
	Maximum Kharif Temperature Squared	13.03
	Non-Climate (control)	
	Population Density	30.84*
	Area under Cultivation	1.058
	Income Per Capita	54.79*
	Constant	-294035.2
	LPRICE(-1), Lag of dependent variable	0.915*

*denotes 1%,

**5%,

***10% and

****15%

4.1 Climate Variables

Precipitation has been a very important variable in agricultural sector of Punjab.

Mean Rabi precipitation has shown a ∪-shaped relationship with land prices. It has revealed that increase in precipitation in Rabi season will decrease land price. Precipitation is significant at 5 per cent level of significance.

Mean Kharif precipitation also has significant relationship with land values. The relationship is of hill shaped (∩) relationship. It has revealed that with an increase in Kharif precipitation , land prices will increase. The results have been in accordance with expectations. Kharif crops have been sensitive to more precipitations, as Rice, a major Kharif Crop, is more water demanding.

Mean minimum Rabi temperature had a significant relationship with land prices. It had shown ∪ shape relationship with land prices. With an increase in mean minimum Rabi temperature, land price will decrease. It was significant at 10 percent level of significance.

Mean minimum Kharif temperature has a significant hill shaped (∩) relationship with land prices. It indicates that with increase in mean minimum Kharif temperature, land prices will also increase. It is significant at 25 per cent level of significance.

Mean maximum Rabi temperature has a significant hill shaped (∩) relationship with land prices. It reveals that with increase in mean maximum Rabi temperature, land prices will also increase. It was significant at 10 per cent level of significance.

Mean maximum Kharif temperature has ∪-shaped relationship with land prices, but this relationship is not found to be significant.

Table 4.2: Comparison of Kharif and Rabi Climate Variables and Relationship with Land Price dependent Variable

Kharif	Rabi
Precipitation had significant hill (∩) relationship with land prices	Precipitation had significant (∪) relationship with land prices
Mean minimum temperature observed significant hill shape (∩) relationship with land prices.	Mean minimum temperature had significant (∪) shape relationship with land prices
Mean Maximum temperature had insignificant U shape relationship with land prices.	Mean Maximum temperature had significant hill shape (∩) relationship with land prices.

Rasul et. al (2009) had found that, in Punjab minimum temperature had increased significantly over the period 1960 - 2007. Mean minimum temperature of both Kharif and Rabi has significant relationship with land prices in the current study also. Precipitation had found to have increased during 1960-2007 in Punjab. FGLS(Feasible Generalized Least Square) model results have confirmed the fact by showing significant relationship of precipitation with land prices both in Kharif and Rabi season.

It has also been found that in Punjab maximum temperature had not increased significantly during 1960 – 2007(Rasul. et.al, 2009).

One important parameter that Rasul (2009) had taken into account was the annual mean minimum, maximum and precipitation. Study in hand required to quantify the economic impact of climate change on agricultural sector, therefore, mean maximum, minimum and precipitation split the annual climate variables into two sowing and harvesting seasons i.e. Kharif and Rabi. FGLS model results show that mean maximum temperature do not have significant relationship with land prices, while mean of maximum Rabi temperature has hill shaped relationship with land prices. The study on climate change and wheat production by Global Change Impact Study Centre (2010), had brought that wheat production will increase with the increase in temperature. Wheat is Rabi crop, mean maximum Rabi temperature has significant hill-shaped (∩) relationship with land prices in study in hand. It can safely be deduced that with increase in Rabi mean maximum temperature, wheat production will increase.

Direct interpretation of the regression coefficients within the land climate Hedonic pricing / Ricardian approach is not tenable for specific impact on crop yield. However, based upon the model results, direction of the signs of the coefficients and nature of the relationship, educated speculations to some extent can be made.

Kharif precipitation has hill-shaped (∩) relationship with land values. As moisture soil will increase crop production. Rabi precipitation is not as much demanding as of Kharifs', Rabi precipitation has negatively related to land values, it can be speculated that increase in Rabi mean precipitation will decrease crop yield of wheat. On the other hand, mean maximum Rabi temperature is significant, has positive sign which shows increase in mean maximum temperature will increase crop yield as wheat needs heat for maturation. The results have indicated that Rabi season is winter and partly spring low precipitation and high temperature will tend to reduce risks of fog and frost in Punjab. Both low precipitation and high temperatures are conducive for crop maturation.

5. Conclusion and Policy Recommendation

5.1 Conclusion

One of other distinct features inducted in the study are inclusion of Kharif and Rabi climate variables. This had not been in earlier studies. The two seasons are crop sowing and harvesting in Punjab and at the country level. Precipitation in Kharif season has significant positive (∩), mean minimum Kharif temperature has significant positive (∩) relationship with land prices. Mean maximum Kharif temperature is not significant with land prices.

Precipitation in Rabi has significant negative (∪) relationship, Mean minimum temperature has significant negative (∪) and mean maximum Rabi temperature has significant positive (∩ shaped) relationship with land prices. Results have indicated that with decrease in Rabi precipitation coupled with an

increase in maximum Rabi temperature will tend to increase the land price in this season.

Population density and per capita income have positive relationship with land prices. Both these are very important control variables, and highly significant with price of land. The overall variables namely climate and non climate results explain in 93 percent variation in land prices as revealed by R^2 value.

5.2 Policy Implications

It has come out that all the climate variables, except maximum Kharif temperature, have highly significant relationship with land prices. Climate change is imposing cost, at the same time brings-in benefits of increase in land prices in Rabi season as a result of increase in maximum temperature. Benefits show adaptation made by farmers in changing climate which leads to increase in long run net revenues.

The increase in precipitation in Kharif season tends to increase in land value. The increase in precipitation in Rabi season results in loss from decrease in production. The increase in mean minimum Rabi temperature being negatively significant imposes cost to agricultural sector with increase in temperature in this season. It is for the planners to evolve policies that benefits are maximized and costs are minimized as a result of climate change. To minimize cost, research and development pursuits of the concerned public and private institutions may be encouraged to develop heat and drought resistant varieties of currently cultivated crops. Incentive policies should be framed by policy makers for farmers to make switching from current varieties to the developed ones. There should be flow of information at zero cost about changing climate for stakeholders.

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