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IMPACT OF VARIABLE CLIMATIC PATTERNS ON THE VALUES OF AGRICULTURAL LANDS IN PUNJAB, PAKISTAN

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ABSTRACT

This study was conducted at Pakistan Institute of Development Economics, Quaid-e-Azam University Campus, Islamabad, Pakistan to instigate the incidence of climate change and its impact on agricultural land values of province Punjab, primarily addressing the adaptation factor. A Ricardian analysis approach was used to walk around the subject how idiosyncratic climate patterns affect land value in Punjab while considering 20 districts of the province. Variable climatic patterns and agricultural land values for each district were taken from Punjab Economic Research Institute for 2004-2010. In order to estimate the climate change model, EGLS technique with cross section white covariance was used. From the assessment it is evident that average rainfall has a highly significant and adverse relationship with agricultural land values. The results revealed that current rainfall level is not enough to get maximum output which results in loss of around Rs. 650214 per hectare. It was concluded that present level of precipitation is inadequate for the agricultural land which results in departure of land value downward.

KEYWORDS: Climate change, agricultural land values, Ricardian approach, adaptation factor, Punjab; Pakistan

INTRODUCTION

The increasing trend of climate change is becoming an imminent threat for the future of world economies particularly for the low income countries like Pakistan. The process of climate change is multi-dimensional, immediate and long-term in its nature. In this context several attempts have been made to evaluate the adverse impacts of climate change on agriculture primarily focusing on those countries which are highly dependent on agriculture sector (Maddison *et al.,* 2007; Mendelsohn, 2005; Seo *et al.,* 2008; Lippert *et al.,* 2009; Thapa & Joshi, 2010). Hence, the impact of climate change on agriculture is a matter of great concern in case of developing countries.

Developing countries in South Asia including Pakistan, India and Bangladesh are predicted as the most vulnerable countries to climate change (Amin *et al.,* 2008). Further, it is evident from the literature that the poor segments of society are most susceptible to climate risks. In addition, IPCC 4th assessment report endorsed the fact that it is the poor in developing countries who are exposed to climatic anomalies. The poorest are on the front line which are hit the hardest by various climatic calamities like floods, droughts and salinity which results in affecting physical environment, ecosystem, agriculture and natural resources.

Climate change can have direct and indirect as well as positive and negative effects on overall well-being of the inhabitants of a country which is highly dependent on natural resources such as agriculture, forests and fisheries for their livelihood. Consequently, these people are likely to be the most vulnerable to climate risks. In this connection there is a general consensus among experts that change in temperature and precipitation can lead to changes in land and water regimes which as a result affects agricultural productivity (World Bank, 2003).

There is an increasing concern that agriculture in developing countries is severely affected by changing global climate (IPCC, 2001). In low income countries, majority of the people use to live in rural areas where a large fragment is greatly dependent on agriculture sector. Agriculture is an economic activity which is very much contingent on climatic settings and highly responsive to climate change.

Thus it is imperative to realize that to what extent these inexplicable climatic variations may affect the agricultural yield and fertility. Therefore, it is crucial to be aware of this redoubtable issue which is threatening the very survival of humanity on earth.

Global perspective of climate change

Historically, the subject of climate change began with the industrial revolution in 18th century when the total concentration of CO_2 emission started to rise due to anthropogenic activities. A series of new inventions became a driving factor for the emission of greenhouse gases. Later on in 19th century this fact was first identified by scientists that human induced emissions of greenhouse gases may possibly change the natural patterns of climate. Today, a large number of scientists agree that human induced global warming pattern is on the rise which is adversely affecting different species and diminishing the adaptive capacity of the ecosystem. The IPCC 4th assessment report (AR4, 2007) also states that climate change; particularly increased risks of torrential rain and droughts are expected to have harsh impact on economies, more especially those which rely on agriculture, forestry and fisheries sectors.

In South Asia, majority of people (about 69%) live in rural areas out of which about 75% are poor, who are the most impinged by the climate change (Parry *et al.,* 2004). Since most of the South Asian population use to live in rural areas which solely depend on agriculture for their livelihood. The changing patterns of rainfall and the break cycles of monsoon alongwith chanting modes of critical temperatures in the region, are more frequent which result in significant change in crop yields. Temporal and special changes in temperature alongwith shortage of water plays key implications for agriculture, especially in relation with decrease in crop yields.

Climatic impacts on agriculture vary according to locality, altitude and other geographical conditions, but it is quite clear from many climate models that have been projected a 15 to 30% decrease in output of most cereals and rice across the region (Seo and Mendelsohn, 2007). In the same line it is expected that overall crop yield will decline upto 30% in the region by the mid 21st century. Further debate reveals the fact that the most negative impacts are more likely in the arid zones and the flood affected areas, where agriculture is already at the edge of climate change risks.

Moreover, it is estimated that water demand for arid and semi-arid regions is likely to increase by 10% as temperature is increased by 1°C. Although it is apparent that climate change effects can lead to a significant change in crop production, storage capacity and distribution, but all these changes are not obvious generally because of geographical difference in growing seasons, crop management, etc. Thus the inhabitants of pastoral areas having with low income are the first victims of climatic abnormalities, largely those who rely on conventional agricultural activities or use to cultivate marginal lands (IFAD, 2011).

Other than climatic variables, some socio-economic variables like human pressure jointly with changing hydrology are having a visible burden on production and the resilience of South Asia's agricultural and ecological systems. Similarly, the availability of fresh water is highly dependent of seasonal changes with about 75% of annual rainfall occurring during the monsoon months. As the availability of water is highly seasonal, therefore, these supplies will be threatened by higher temperatures, changes in river systems and the larger events of coastal flooding. Therefore, it is certain that availability of water is likely to shrink intensely particularly in dry seasons.

Generally, it is evident from the literature that global climate is changing exponential and its effects are alarming for inhabitants of the world especially for those living in the developing economies.

An overview of climate change and agriculture in Pakistan

Pakistan is not an exception to climate change. Pakistan is more exposed to climate change due to its geographical location. It is located in a region where the incidence of increase in temperature is predictably higher than the average global temperature. Most of the agricultural land area in Pakistan is arid or semi-arid. Meteorological data show that about 60 percent of the total area receives less than 250 mm precipitation annually while 24 percent receives 250 to 500 mm (Rasul *et al.,* 2012). The Indus River, the main source of agricultural water, is predominantly fed by the Karakorum, Himalayan and Hindu Kush glaciers. However, it is very much obvious from the recent studies that these glaciers are receding rapidly due to climate change. Being the agrarian, Pakistan's economy is highly sensitive to climate change. As a result of this sensitivity, there is an immense threat of variability in monsoon rains which result in droughts and floods as experienced in the year 2010.

Considering these ground realities, it is very much evident that water availability, food security and power generation are in grave danger (TFCC, 2010). Pakistan's geographical area is 79.61 million hectares, excluding the Northern Areas of Pakistan. Out of total area, only 72 percent area has been reported, indicating a major limitation that 28 percent area is not so far surveyed for land use classification. The reported area is further categorized into four classes: forest area which accounts for 4.02 mha, area not available for cultivation is of 22.88 mha, cultivable waste is 8.12 mha while cultivated are of 22.05 mha. Out of total reported area, around 8.1 mha is available for future agriculture and other uses if there is enough water is available (Ahmad and Joyia, 2003). Agriculture and livestock have been the core sectors on which the whole economy lays its foundation. It adds about 22 percent to GDP, which accounts for 60 percent country's exports, endows livelihood to about 68 percent of the country's population while it provides 44 percent employment of the total labor force.

Pakistan's position as a developing country is very much dependent on agriculture sector which makes it extremely vulnerable to the threats of climate change. Agriculture sector alone is contributing 21 percent to GDP and occupying a considerable portion (44 %) of the total labor force. Country's exports are also highly dependent on agriculture sector which contributes about 65 percent of foreign exchange earnings.

Nearly two third of the total population of the country lives in rural areas and their livelihood primarily depends on agriculture and agro-based activities (Government of Pakistan, 2010). Contribution of agriculture sector in GDP, exports and employment level of the country has remarkably decreased. With other reasons of loss in agricultural productivity, climatic variations have been marked as main contributors. Government of Pakistan (2009) draws attention to the fact that agriculture sector has shown a poor performance in the year 2007-08. It grew at 1.5 percent in opposition to the target of 4 percent. In May 2007, agriculture sector suffered from varied reasons specifically heavy precipitation level, high temperature during August and September, 2007 while scarcity of water throughout the irrigation season.

Province Punjab, the current study area, is the second biggest and densely populated province of Pakistan. Agriculture is the main stream economic activity in Punjab province. A major portion of land (about 57.2%) is dominated by agriculture sector. It also contributes (about 53%) to Pakistan's GDP. During the year 2007-08 Punjab's contribution in the country's agricultural production of major crops was; rice 59.1%, wheat 74.5%, sugarcane 63.1%, maize 74.5% while cotton contributes 77.8%. Similarly, in case of major fruits, Punjab contributes a significant portion in the overall country's production (GOP, 2009.)

In terms of production, the share of Punjab was; citrus 96.7%, mango 78.3% and guava 78.3% (Government of Punjab, 2009). During recent past decade, there have been few attempts to investigate the capacity of adaptability of Punjab agricultural sector with regards to changing climate but the study in hand is pioneer to investigate the problem using the methodology more compatible to the topic of adaptability. Thus by taking into account the results and policy implications, policy makers can develop cohesive policies for climate change and adaptability based on facts. The rest of this section is devoted to literature review which examined the impact of climate change on agriculture.

An extensive bunch of literature has been found on impact of climate change on agriculture where two different types of models are generally used to estimate the climate change. Numerous studies that measure the climate change impact on agricultural sector have been using Cobb Douglas production function or Hedonic price model, mostly carried out on a single year's data (Mendelsohn *et al.,* 2001; Mendelsohn, 2005 and Seo and Mendelsohn, 2008). But the current study is focusing on Ricardian approach which is widely used because of its nature to capture the adaptability factor of the farmer which is absent in other approaches. For this reason, the study in hand is highlighting literature based on different econometric models including Ricardian approach.

Economists from all over the world have spent decades to quantify the impact of climate change on agriculture. In this line IPCC fourth assessment report (AR4) sets out more clear than ever that the "Warming of climate system is unequivocal". Climate change has emerged as a distinctive problem around the globe especially for low income countries like Pakistan. Similarly in case of China, under most climate change incidents rising temperature and more precipitation have generally a positive impact on agriculture. But in most scenarios, spring effects for the most parts of China are negative (Huiliu *et al.,* 2004).

There is a growing consent that effects of climate change are very obvious and malicious for developing countries, where a large segment of world's poorest use to live. Pakistan is among those countries where agriculture sector has a substantial portion of GDP (about 24%). Therefore, it is needed to regard seriously its adaptation strategy (Khan, 2005).

In spite of broad studies and interest of environmental economists in computing economic impact of climate change globally, few efforts have been done in relation with South Asia. In south Asian perspective, it is expected that climate change has beneficial outcomes for mild regions whereas moderate and extreme settings yield slightly injurious and considerable harsh outcomes (Mendelsohn, 2005). This trend of climate change is reinvestigated for Sri-Lanka which reveals that increasing amount of rainfall is favorable for the country as a whole while the incident of rising temperature is predicted to be harmful for the Sri-Lankan agriculture sector (Seo *et al.,* 2005). In addition to this, it is discerned from inquisitions based on different climatic scenarios that small house hold farms are more vulnerable than large commercial farms to climate change because they have fewer substitution options (Schlenker *et al.,* 2005). In the perspective of Sub-Saharan Africa, climate change could have devastating impacts on agriculture with negative impact on productivity (Maddison *et al.,* 2007). But in cooler climate zone like Ethiopia and South Africa the agriculture suffers relatively little. In terms of productivity, soil type and irrigation water availability have significant positive impacts on farm profit level. Beside this positive impact of soil type and irrigating water, farmer's age which reflects experience is a significant basis for increase in farm profit level (Fleischer *et al.,* 2008).

In the same way, adaptation has a great significance with a positive impact on farm output by settling down existing climate anomalies. It is evident from the experience of American farmlands that farm land value decreases with increase in temperature while precipitation level has an increasing trend. It further reveals that as a whole, small farms are more susceptible to temperature than large commercial farms (Seo and Mendelsohn, 2008a). The study goes on with unique role of farm type and effects of temperature and precipitation in depreciating farm land values (Seo and Mendelsohn, 2008b). The study also enlightens that warmer temperatures and heavy precipitations are harmful, reduce farm value immediately. Lippert *et al.,* (2009) assessed the impact of climate change on German agriculture using Ricardian method. The analysis yields an increase of land rent alongwith both rising mean temperature and declining spring precipitation.

Similarly, Thapa and Joshi (2010) examined a relationship between net farm revenue and climatic variables in Nepal. This study tells a very interesting story which unveils a positive impact of high temperature and low precipitation on net farm income during fall and spring seasons. High temperature in summer season causes to decrease net farm income while high precipitation level results in increase in net farm income. Thus, the general picture of climate change is becoming very critical for the Asian economies, especially for the developing countries.

In recent studies, the estimates show that it is inevitable to incorporate farmer's adaptation approach to compensate the climate vulnerability. From the experience of Greek agricultural productivity, it is apparent that climate characteristics which have abrupt impacts on agricultural productivity are the rising heat waves and the aberrant behavior of precipitation level (Nastis et al, 2012). Thus, empirical evidence of the study suggests that adaptation of agriculture to climate change includes both the improvement in crops along with changes in crop growing practices.

Ali *et al.* (2012) studied the impact of temperature and relative humidity on the biology of cotton mealy bug. The results showed a negative impact on life span of both male and female of mealy bug which results in decline in total output of cotton crop. This confirms the harsh impacts of increasing temperature and humidity level.

Another study (Shrestha *et al.,* 2013) examined midterm economic impact of climate change on EU agriculture. The study reveals that there are minor impacts of climate change on agriculture in EU in general. However, the impacts are much stronger at regional levels. In line with this, Bezabih *et al.* (2014) explores the effects of both weather and climate change on Ethiopian agricultural productivity. The main findings of the study disclosed non-linear effects of temperature in case of both weather and climate measures, having consistently negative effects across seasons and crop type. In this relation, present study validates the notion of non-linearity of climatic patterns as confirmed in the results of present study.

In relation with high rates of precipitation and temperature, Safdar *et al.,* (2014) discloses that there is a positive impact of rising temperature on different crops as it leads to expanding the growing season of crops. It is also reported that increasing rainfall above the adequate level is injurious for agriculture. This result is similar to our results related to square term of rainfall. This elucidates that heavy rainfall badly affects the agricultural productivity.

In addition, Amassaib *et al.* (2015) observed an overall negative relationship between maximum temperature and net farm revenues whereas it is positive and significant in case of minimum temperature. These results are similar to present results except maximum and minimum temperature where in case of Pakistan, these two variables have minimum role in changing net farm revenue.

Finally, impact of climate change is very much obvious and significant, leading to a low farm revenues, facing a heavy lose of agricultural revenues by farmers in the long run. Therefore, it is dire need to take necessary actions to minimize the severity of the situation before it is too late.

METHODOLOGY

This study was conducted at Pakistan Institute of Development Economics, Islamabad, Pakistan. Majority of economists subsist in a two-factor world (just labor and capital) disregarding land particularly vital for conventional political economy and ingested into capital and labor and departed (Gaffney, 2008).

David Ricardo instigated the theory of rent from two fundamental conjectures regarding agricultural production. The first inevitable supposition of diminishing returns which is very much linked to the existing situation of production on piece terrain whereas the second assumption of marginal returns which is quite controversial practically, related to farmer's preferences preceding to the presence of rent.

Ricardo's differential rent

The theory of rent instigated by David Ricardo is the concept of differential rent. He opined that land rent arises because of the variation in fertility of land. For him some lands are rich in productivity while some are less productive. So rents arise for land with high productivity while there would be no rent for low-grade land. Moreover, he says that if an excess amount of fertile land is available in a country, there will be no rent. But in reality the fertile land is not unlimited. Ricardo in his discussion of land rent restricted the idea of land rent/value to agriculture because for him the amount of land available was fixed, with a vertical supply curve and that law of diminishing returns hold best in agriculture sector.

Rationale to choose Ricardian approach

In prior empirical studies, majority of the climatic analyses are primarily based on experimental studies like agro-economic simulation models as used by Parry (1998) and Adams (1989). These studies are very much analogous to controlled experiments where different climatic or other key variables are amended with the situation and estimated the impact on crop productivity accordingly. In this line, Mendelsohn and Dinar (1999) outlined a chain of criticism of the production function approach and other models. The first severe criticism comes out with the argument that production function and other such approaches have a tendency of overestimating the damages of climatic variables. The primary limitation of these studies is that they do not incorporate the adaptation factor while specifying the model. Thus the primary assumption of these models is unrealistic in a sense that farmers would not adjust or take into account the climate change factor. Similarly, Dinar and Beach (1998) suggested that the result made by agro-economic models could be inaccurate given the fact that since agricultural markets are normally global so the agricultural prices can’t be satisfactorily incorporated in domestic level models. On the other hand, current studies have initiated the topic of adaptation. To accomplish this endeavor in economic research, the application of Ricardian approach has been introduced. This approach implicitly incorporates the influence of climatic, economic and other environmental factors on farm income or land values (Mendelsohn *et al.,* 1994). This technique is more favorable as compared to conventional methods because the Ricardian approach includes all adaptation factors implicitly. Thus, keeping in view the advantages of this approach, it has been chosen to estimate the model.

Functional form of the model

Thus literature suggests that there should be a hill-shaped relationship among land values and climatic variables. As the response of land values to climatic variables is not linear, thus a quadratic functional form has been used in the study. Therefore, the standard model of quadratic form is given as:

$$LV_{it} = \alpha_{it} + b_{it} F_{it} + c_{it} F^2_{it} + d_{it} Z_{it} + \epsilon_{it}$$

Here LV_{it} shows land value per hectare in PAK rupees in i^{th} district for time period t. α_{it} is constant term in the equation. F_{it} represents the vector of climatic variables (temperature, rainfall and humidity) in i^{th} district of Punjab for the period t while, F^2_{it} is the quadratic form of vector of climatic variables. Z_{it} is vector used for non-climatic variables (population density) for i^{th} district in time period t and, ϵ_{it} is error term in the model.

Symbols F_{it} and F^2_{it} show single and multidimensional effects of climatic variables (average temperature, precipitation and humidity) employed in the equation. The quadratic form of climatic variables in the equation represents the non-linear relationship among land values and climatic variables. Different models were estimated to test the robustness of the model. For this purpose five models were tested and in each model one extra variable was introduced [1]. We also included interactive district dummies to capture district-wise impact of climate change.

[1] In our analysis we have estimated five different models to check the robustness of the model. The first model is estimated with five key variables (Max.tempt, Max.tempt square, Min.tempt, Min.tempt Square and average rainfall) with constant term. In the later models, Average rainfall square, Humidity, Humidity square and population Density are brought in one by one respectively.

Selection of dependent variable

For this analysis we can use either the land rent or the land value as a dependent variable. Hence, land value was used as a dependent variable in this study. Moreover, land value or assets price is the value of holding title of assets to perpetuity (Deacon and Kolstad, 2000). On the other hand land rent is the price of a piece of land for a short time span. The reasoning for choosing land value as a dependent variable is that land value is the direct variable used in most of the Ricardian analyses (Hanif *et al.,* 2010, Seo and Mendelsohn, 2008a). But in case of developing countries, data on land value are not so easily available. Consequently, net farm income or revenue was used as a proxy for land value.

Nature of data used in the model

Numerous studies which measure the climate change impact on agriculture sector have been using Cobb Douglas production function or Hedonic price model, mostly carried out on a single year's data (Mendelsohn *et al.,* 2001, Mendelsohn, 2005, and Seo and Mendelsohn, 2008). But the study to play with is using a panel data with cross sectional units (districts) over a particular time period. The spirit of panel data is that it helps estimate district-wise climate sensitivities and temporal changes. Data on dependent and independent variables were collected from different sources as presented in data description table. Annually data on crop land value for the selected 20 districts of Punjab over a given time period (2004-2008) were collected from Punjab Economics Research Institute (PERI), Lahore while for each climatic variable annually average data for 30 years were taken from Pakistan Meteorological Department, Islamabad. Then we got a single value for each variable by taking 30 years average. The purpose of taking 30 years average was to fulfill the preliminary condition of climate change phenomenon. In other words, to capture climate change phenomenon it is imperative to consider a minimum span of three to six decades.

Data and discription of variables

Study area: Punjab province agriculture stands first in the race of GDP share in Pakistan's agricultural GDP. Punjab is the most densely populated province in Pakistan [2]. The total population of Punjab province is around 93 million. It also contributes about 62.02 percent to total GDP of Pakistan. Being the major contributor and self-sufficient in food crops and livestock, it is usually known as the granary of Pakistan (Government of Punjab, 2009).

In terms of area, Punjab is the second largest province in Pakistan. The total area of the province is approximately 205344 km^2 which is about 26 percent of the total area of Pakistan. The total farm area of Punjab is about 12.51 million hectares and it is about 67 percent of total cultivated area. To execute the study, 20 districts of Punjab were selected.

Definition of variables

Twenty districts of Punjab were selected as cross sections in the study. Similarly, five points in time were chosen on the basis of availability of data. Variables used in the study are categorized into climatic and non-climatic variables. The dependent and independent variables alongwith their definitions are presented in Table 2.

[2] According to the Census Report (1998), the total population of Punjab province is 73621290. The province's population density was 359 persons per sq.km. The urban population was 31.3 percent and the rural population was 68.7% with an average household size of 6.9 persons.

Table 1. Agricultural share of Punjab in agricultural GDP of Pakistan. (Rs. in million)

S. No.	Agricultural production sector	2008-2009			2009-2010		
		Pakistan	Punjab	% Share	Pakistan	Punjab	% Share
1	Major crops	1195031	635444	53.2	1218873	646281	53.0
2	Minor crops	136601	287347	59.7	135008	84641	62.7
3	Livestock	622531	260344	41.8	648106	268327	41.4
4	Fisheries	21319	5003	23.5	21626	5044	23.3
5	Forestry	14094	1202	8.5	14404	1484	10.3

Source: Government of Punjab, 2009

Table 2. Description of Variables

Variable	Title	Definition	Source of data
Dependent variable	LV	Annual average price of agricultural land at district level (Pak .Rs./hectare)	Punjab Economic Research Institute (PERI) (2004-2008)
Independent variable	**Climatic- variables**		
	MAX_TMP	Average annual maximum temperature (Degree Celsius =0C) at district level	Pakistan Meteorological Department (1978-2008)
	MIN_TMP	Average annual minimum temperature (Degree Celsius =0C) at district level	Pakistan Meteorological Department (1978-2008)
	RAIN_AVG	Average annual precipitation (millimeters= mm) at district level	Pakistan Meteorological Department (1978-2008)
	HUMID_AVG	Annual average humidity (percent= %) at district level	Pakistan Meteorological Department (1978-2008)
Independent	**Non- climatic**		
Population density	PDNS	The number of people living per kilometer square at district level	Punjab Development Statistics (2004-2008)

Independent variable (Non-climatic): The current study divides the independent variables into two categories i.e. climatic and non- climatic variables. Only one non-climatic variable is used in the study and that is population density measured in terms of persons per km^2 (P density). The intention of using this variable is to capture the magnitude of off-farm usages of the agricultural land.

So far four population censuses have been conducted in Pakistan. The last census was conducted in 1998 which is the most recent available census report. But to fulfill the data requirement of the study, data on population density for the year 2004-2008 were collected from the Punjab Bureau of Statistics, Lahore [3].

Independent variable (climatic): Climatic variables are the second group of independent variables in the study. Yearly average data from 1978 to 2008 were used to capture the climate change impact. The standard minimum stretch of time consists of 30 years to address climate change phenomenon.

Maximum and minimum average temperatures are measured in degree Celsius (°C), whereas square terms of both minimum and maximum temperature are also included in the regression. Another climate variable which is very crucial for the land value assessment is the annual average rainfall. It is measured in millimeters (mm). Relative humidity is also introduced as a climatic variable in the study. It is the relative amount of water contents in the air at a certain temperature and pressure (Vaisala, 2012).

In addition, it has two prong effects on the way in which water reacts with plants and the growth of leaf. It also affects the process of photosynthesis which results in raising the incidence of diseases. It is further confirmed from the results of study that average humidity level has a positive relation but square term of the variable has a devastating impact on agricultural land. The data on all climatic variables was collected from Pakistan Meteorological Department, Islamabad. Some districts in the study area had no climate observatory stations. Thus to overcome this

[3] The Punjab Statistical Bureau is the centre for the statistical data collection in the whole province and is responsible for the reliable data compilation and distribution of statistical data throughout the province.

issue adjacent districts were chosen to collect the required data.

RESULTS AND DISCUSSION

The study has a broad scope considering five points in time and 20 districts from the province Punjab. Results of the study have been wrapped up using Estimated Generalized Least Square (EGLS) with white cross section standard error technique. The EGLS (White cross-section) model results (Table.3) depict a quadratic relationship between the dependent variable (land value) and some climatic and non-climatic variables. Further, some relevant statistics are also presented in Table 3.

Table.3. Ricardian Panel Estimation Results.

Variables	Model
Constant	-3667379 (-0.36)
Rain_avg	-650214.7 (-8.532)***
Rainsq_avg	241411.9 (13.641)***
Pop_density	806.1 (3.806)**
Humid_avg	302798.7 (3.367)**
Humidsq_avg	-2132.7 (-3.029)**
Min_tmp	495678.1 (3.544)**
Min_tmpsq	-14061.9 (-4.389)***
Max_tmp	-772058.4 (-1.430)
Max_tmpsq	13613.9 (1.584)
R-Square	0.391
F-Stat	6.43

***, **, 1 and 5 percent level of significance, respectively. The dependent variable is land value in Pak Rs. per hectare of land in 2004-2008.

To check out the asperity and irregularities, quadratic forms of climate variables are also introduced alongwith linear form in the equation. Using quadratic form is logical and quite consistent with the previous studies (Schlenker *et al.,* 2005, Seo and Mendelsohn, 2007, Fischer *et al.,* 2007, Hanif *et al.,* 2010). The rationale of quadratic forms of climate variables is to capture the possible climatic abnormalities and sensitivities. The linear form in the equation shows the marginal impact of climate change on land values while the square terms represent how much land values are responsive to severity of climate. The quadratic relationship shows the direction and nature of the correlation among climatic variables and land values. Sign of the coefficients depicts the U-shaped or hill-shaped of the relationship. The negative sign confirms a U-shaped relationship amid land values and climatic variables. In the same way a positive sign indicates the hill shaped relationship (∩) among the dependent (land value) and independent variables (climatic variables). A U-shaped relationship concludes that value of land will decrease with increase in climatic variables upto a certain point, that is the bottom of the U-shape, then after this point land values will start to increase with climate variables. In case of hill-shaped relationship (∩), it reveals that land value will increase upto a certain point (maximum of inverted U-shape); from this point land values will start to decline as increase in climate variables.

Climatic variables

Average rainfall has been a very important and significant role in Punjab's agriculture sector. Agricultural land values in Punjab region are explicitly dependent on average rainfall because almost 68% of total geographical region comes under annual rainfall of 250 to 500mm while there is only 8% of the area where rainfall exceeds the limit of 500mm (Alam, 2000). In comparison with the findings of Alam (2000), present analysis illustrates very much similar results in relation with the dependency of agriculture on average rainfall. The results of this study show that average rainfall has a highly significant U-shaped relationship with agricultural land values. It implies that 1mm decrease in rainfall will result in decrease in agricultural land values by Rs. 650214 per hectare (Table 4). Average precipitation is highly statistically significant at 1 percent of significance level. The rationale behind this relationship is that current magnitude of rainfall is not sufficient for the agricultural lands in Punjab. In other words land value will decrease to a certain level (minimum of U) and after that point both rainfall and land value will start to increase. The hill-shaped and U-shaped relationship in this study is also evident from the study conducted by Hanif *et al.* (2010) on impact of climate change on agricultural sector of Punjab.

On the other hand, square term of average precipitation shows a positive and highly significant relationship which confirms the hill-shaped relationship among land values and climatic variables. The relationship is significant at 1%

significance level. This again concludes that the present level of precipitation is inadequate for the agricultural land which results in departure of land value downward. From this end of analysis, it is confirmed that increase in rainfall above average level has a positive and optimistic impact on agricultural land values. This result is quite similar with the study conducted by Seo and Mendelsohn (2008a) in case of American farmlands.

In case of humidity, linear relationship between land value and humidity is positive and statistically significant at 5 percent level of significance. It predicts that if humidity increases by 1 percent it results in increase in land value by Rs. 302798 per hectare (Table 4). However, the quadratic term of humidity foretells a statistically significant negative relationship which again verifies the U-shaped relationship. Hence with higher level of humidity, land values are extremely sensitive and will start to decline sharply.

Minimum temperature has a hill- shape (∩) positive impact on land values. It implies that there is a direct relationship between mean minimum temperature and agricultural land values. This illustrates that 1˚C increase in minimum temperature will raise the land values by Rs. 495678 per hectare (Table 4). Both the land value and mean minimum temperature shows an increasing trend upto the maximum point of (∩) and then departure from this point means that both the agricultural land value and minimum temperature are decreasing simultaneously. Mean minimum temperature is significant at 5 percent level of significance.

Table 4. Robustness check & sensitivity analysis.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Max_tmp	-945151.1 (-0.7252)	-53882.68 (-0.0428)	-396337.4 (-0.485)	-880415.0 (-0.8487)	-772058.4 (-1.0393)
Max_tmpsq	14415.74 (0.6999)	812.5262 (0.0411)	6550.365 (0.7176)	14192.38 (0.8752)	13613.85 (1.1847)
Min_tmp	412731.8 (3.2871)*	215227.6 (1.9734)*	196547.2 (2.3874)*	246987.8 (2.3712)*	495678.1 (3.5444)*
Min_tmpsq	-10508.2 (-5.9299)*	-5544.881 (-4.3108)	-4907.5 (-6.340)	-5692.1 (-2.7360)*	-14061.66 (-4.3897)*
Rain_avg	-11303.81 (-0.2807)	-581643.8 (-4.7746)*	-526996.4 (-3.543)*	-420856.9 (-5.223)*	-650214.7 (-8.5322)*
Rainsq_avg	__	216106.1 (5.3324)*	195901.2 (4.2068)*	153116.6 (6.813)*	241411.9 (13.6418)*
Humid_avg	__	__	23108..94 (1.1371)*	343737.7 (3.531)*	302798.7 (3.3679)*
Humidsq_avg	__	__	__	-2455.6 (-3.148)*	-2132.776 (-3.0294)
Pop_density	__	__	__	__	806.1216 (3.8065)
C	11856871 (0.5976)	-2219352(-0.1165)	-3350597 (0.2160)	-72648.83 (-0.0438)	-3667379 (-0.2966)
R-Squared	0.010	0.056	0.125	0.212	0.391
F-statistic	0.203	0.931	1.884	3.070	6.432

Minimum temperature square has an inverse relationship with land values. The relationship becomes U-shaped which means if minimum temperature square increases, agricultural land values tend to decrease. The underlying principle is that if the variation in minimum temperature would too high, it would be less beneficial for the land values but if the change is normal, it will affect agricultural productivity positively hence land values.

Maximum temperature and maximum temperature square have U-shaped (U) and hill-shaped (∩) relationship, respectively. However, this relationship is not established to be statistically significant. The reason is that farmer's decisions about agricultural land value are not so attached with maximum temperature as compared to other factors in case of Pakistan. They do care of factors like access to road; access to market, soil quality, precipitation level, etc. It is also evident that in Punjab maximum temperature has not been increased significantly during 1960-2008 (Rasul *et al.,* 2009). In relation with maximum temperature, this study shows very much similar results. Thus this validates the consistency of present results from the recent literature. Similarly, the expected signs and the direction of relationships are in line with the previous studies (Mendelsohn, 2005, Fisher *et al.,* 2007; Hanif *et al.,* 2010). Again present results are analogous with those of Hanif *et al.,* (2010) in case of maximum temperature.

Non-climatic variables

It is imperative to be acquainted that land value is not the only factor that reflects the agricultural land price but there are some other regional variations might be non-climatic or geographical like irrigation, soil fertility, population, etc. that might influence the land values directly or indirectly as well. In the same line this study has introduced a diverse variable that is the population density (persons/ km^2) at district level. The rationale for introducing this variable is that if population increases, it results in increase in persons per kilometer square. Thus, to accommodate the more persons, we need to supply additional amount of land that shorten the availability of land for agricultural purposes. Consequently, the demand supply effect will give rise to agricultural land prices. From the analysis it can be concluded that there is positive and strongly significant relationship between land values and population density. It predicts that one unit increase in population density will cause to increase land prices by Rs 801 (Table 4). It is statistically significant at 5 percent level of significance. From this, it can be concluded that land is a fixed factor of production, as population density increases, demand for agricultural land also increases.

Overall results

To check the robustness of the model, different models tested and the best model is reported in Table 4. The results show that there is a significant value of R-square with 0.391 which is pretty reasonable in panel data estimations. R-square value shows that 39 percent of the total variation in response variable is due to the independent variables both climatic and non-climatic variables. F- statistic is also presented which predicts the overall good fit of the model. It is the combined significance of explanatory variables (climatic and non-climatic) on land values per hectare of the agricultural land. The Estimated Generalized Least Square method is applied to estimate the random effect model which is opted on the basis of probability value of Chi-square test. To avoid the problem of autocorrelation and multi-colinearity EGLS-technique is used.

Robustness check and sensitivity analysis

To scrutinize the robustness of the model, robustness and sensitivity tests were carried out by adding up new variables in the final model. For this purpose, five different models were estimated using random effect method. In the first model, five key variables were estimated. Maximum and minimum temperatures with their square terms show a U-shaped and hill-shaped relationship with the dependent variable respectively.

Thus, the relationship is very much consistent with the expectations. From the results of second model it is confirmed that signs of relationship are again consistent. In the same way rest of the variables were introduced in the subsequent models and in spite of different specifications the direction of coefficients in all models remained consistent. This clearly proves the robustness of the results in Table 4.

CONCLUSION AND POLICY SUGGESTIONS

Present study validates the extensively influence of climate change on productivity and the market value of a piece of agricultural land. The way round, ups and downs in agricultural land values are largely interrupted by climatic anomalies.

Therefore, it is a dire need to address the issue of climate change and its impact on different segments of the economy specifically the agricultural sector to formulate a strategy for policy making. Consequently, consideration of environmental factors in any growth plan is fundamental for policy makers to utilize the available resources in a sustainable manner. Keeping this in mind, the current study is a good contribution to compute the impact of climate change on agricultural sector.

The study in hand reveals that average precipitation level has a significant negative impact but if the square term of the current precipitation level shows a positive relation. The rationale is that the current amount of rain is insufficient for the crop productivity and the soil fertility of land. Therefore, it is indispensable to manage additional quantity of water to compensate the demand for agricultural purposes.

In case of maximum temperature and maximum temperature square, both are statistically insignificant for Pakistan. The reason is that apart from precipitation, people do not give much weight to temperature in their decision making. Another reason is that there are no extremely hot or cold regions in the study area so that temperature could affect their decision making. Thus its role in case of Pakistan is negligible. These results are similar to Hanif *et al.* (2010) in case of maximum temperature. They also found it insignificant in case of Pakistan.

In contrast to minimum temperature, minimum temperature square has a significant negative impact on land values with a U-shaped relationship. It is further clear from the results that current humidity level has a positive impact on agricultural land. However, if humidity exceeds from the current level, agricultural land values start to decline.

This concludes that it is of great importance to consider the level of humidity and precipitation level which directly affects the agriculture land. The overall results indicate that both climatic and non-climatic control variables explain almost 40 percent of the total variation across the region.

Policy propositions

It is very much clear from the overall outcomes of the current study that except average maximum temperature and its square term rest of the climatic and non-climatic variables are highly statistically significant with agricultural land values. Therefore, it is confirmed that climate change is striking agricultural land values adversely but at the same time it seems beneficial as well because of the adaptation. These benefits show the adaptation factor that allows farmers to adjust their farming activity with changing climate. Thus, adaptation makes them capable to increase their revenues in the long run. Consequently, keeping in view the empirical results of the study, following policy suggestions were formulated for future ventures.

- The growing need is to develop varieties having more climate resistant capacity. In this relation, government should also bring in both public and private institutions and encourage them to develop new varieties of crops that are capable of enduring extreme weather conditions like droughts etc. This will help implement new adaptation tactics.
- It is imperative to introduce farm management practices and innovative approved technologies.
- It is also necessary to educate farmers regarding new varieties which are more defiant to changing climatic patterns.
- Policy makers should develop such policies that help in minimizing costs related to climate change and maximize agricultural benefits. For awareness of the issue, government can conduct workshops and seminars for the farmers to equip them with new solutions and strategies.
- Similarly; there should be flow of information related to climate change for the concerned stakeholders at a zero rate. It can also be helpful if climate policies are enclosed with ground realities.
- High investment in agriculture sector could help to provide food security.

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Usman Mustafa	**Conceived the idea, supervisor, final draft checking and editing**