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Working Paper No. 8

Impact of Climate Change on Agricultural Land Values: An Application of Ricardian Model in Punjab Pakistan

Syed Aqrar Hussain
Usman Mustafa

Department of Environmental Economics
Pakistan Institute of Development Economics, Islamabad, Pakistan

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Pakistan Institute of Development Economics, Islamabad

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Usman Mustafa
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PAKISTAN INSTITUTE OF DEVELOPMENT ECONOMICS
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Pakistan Institute of Development Economics
Islamabad, Pakistan

E-mail: publications@pide.org.pk
Website: http://www.pide.org.pk
Fax: +92-51-9248065

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ABSTRACT

This study was conducted in April 2009 to evaluate the incidence of climate change and its impact on agricultural land values of province Punjab Pakistan. The study largely concentrates on the adaptation strategy to deal with the adverse impacts of climate change. The Ricardian analysis approach was used to walk around the subject how idiosyncratic climate patterns affect land value in Punjab while considering twenty districts of the Punjab Province of Pakistan. Data on agricultural land values for each district is taken from Punjab Economic Research Institute from 2004-2008. In order to estimate the climate change model, EGLS technique with cross section white covariance is used in the study. From the assessment it is evident that average rainfall has a highly significant U-shaped relationship with agricultural land values. The results reveals that the current rainfall level is not enough to get maximum output which results in loss of around 650214 Pak Rupees per hectare. On the other hand, the square term of average precipitation shows a positive and highly significant relationship which results in increase in total output around 241411.9 Pak Rupees per hectare while confirming the hill-shaped relationship among land values and climatic variables. This concludes that the present level of precipitation is inadequate for the agricultural land which results in departure of land value downward. In case of humidity, it is evident that humidity level has a positive impact on agricultural crop pattern adding an amount of around 302798.7 Pak Rupees per hectare. The study has given a broader look of the subject matter by including the district wise interactive dummies for each district to further elucidate the analysis. In this connection present study validates that the climate change influences extensively the productivity and the market value of a piece of agricultural land. The way round, ups and downs in agricultural land values are largely impinged by climatic anomalies.

Keywords: Climate Change, Agricultural Land Values, Ricardian Approach, Adaptation Factor

INTRODUCTION

> *"Warming of the climate change system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level"* [IPCC (2007)].

The increasing trend of climate change is becoming an imminent threat for the future of the 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.

Developing countries in South Asia including Pakistan, India and Bangladesh are predicted as the most vulnerable countries to climate change [Amin, *et al.* (2008)]. Furthermore, it is evident from the literature that the poor segments of the society are most susceptible to climate risks. In addition, IPCC 4th assessment report endorsed the fact that it is the poor in the 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. There is an increasing concern that agriculture in developing countries is severely affected by changing global climate [IPCC (1999)]. In low income countries, majority of the people use to live in rural areas where a large fragment is greatly dependent on agriculture sector. Since, agriculture is an economic activity which is very much contingent on climatic settings and highly responsive to climate change. Thus it is imperative to realise that to what extent these inexplicable climatic variations may affect the agricultural yield and fertility.

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)].

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 [Thapa and Joshi (2010);

Lippert, *et al.* (2009); Seo, *et al.* (2008); Mendelsohn (2007) and Maddison, *et al.* (2006)]. Hence, the impact of climate change on agriculture is a matter of great concern in case of developing countries. 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 are agreed 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) 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 sector.

In South Asia mostly people (about 70 percent) live in rural areas out of which about 75percent are poor, who are the most impinged by the climate change (UNCCD). Since most of the South Asian population used to live in rural areas which solely depend on agriculture for their livelihood. The changing patterns of rainfall and the break cycles of monsoon along with chanting modes of critical temperatures in the region are more frequent which results in significant change in crop yield. Temporal and special changes in temperature along with 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 percent decrease in output of most cereals and rice across the region. In the same line it is expected that the overall crop yield will decline up to 30 percent 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 the climate change risks.

Moreover, it is estimated that water demand for arid and semi-arid regions is likely to increase by 10 percent as temperature is increased by 1^0C. 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 percent 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 the 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 shows that about 60 percent of the total area receives less than 250 mm precipitation annually while 24 percent receives 250 to 500 mm. Indus River which is 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 economy, 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 2010.

Therefore, 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 categorised in to four classes: forest area which accounts for 4.02 million hectares (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 the gross domestic product (GDP), which accounts for 60 percent country's exports, endows livelihood to about 68 percent of the country's population while provides 44 percent employment of the total labour 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 percent) of the total labour force. Country's exports are also highly dependent on agriculture sector which contributes about 65 percent of foreign exchange.

More than two third of the total population of the country lives in rural areas and their livelihood primarily depend on agriculture and agro-based activities [Pakistan (2009)]. 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 had 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 which is 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 percent) in Punjab is dominated by agriculture sector. It also contributes about (53 percent) in total Pakistan's agricultural gross domestic product (GDP) [Punjab (2009)]. According to Punjab Development Statistics, 2009, during the year 2007-08 Punjab's contribution in the country's agricultural production of major crops was rice 59.1 percent, wheat 74.5 percent, and sugarcane 63.1 percent, maize 74.5 percent while cotton contributes 77.8 percent. Similarly, in case of major fruits, Punjab contributes a significant portion in the overall country's production.

In terms of production, the percentage share of Punjab was citrus 96.7 percent, mango 78.3 percent guava 78.3 percent [Punjab (2009)]. During recent past decade there have been few attempts to investigate the capacity of adaptability of Punjab agricultural sector 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 implication, 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.

There is 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 [Mendelsohn, *et al.* (1994) and Seo, *et al.* (2005)]. 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 been emerged as a distinctive problem around the globe especially for low income countries like Pakistan. 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 of those countries where agriculture sector has a substantial portion of GDP (about 24 percent). Therefore, it is needed to regard seriously its adaptation strategy [Khan (2005)]. 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)].

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 favourable 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 having negative impact on productivity [Maddison, *et al.* (2007)]. But in cooler climate zone like Ethiopia and South Africa suffer relatively little. In terms 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 (2008a)]. 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 along with 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 behaviour 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.

Another study [Shrestha, *et al.* (2013)] examines 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 disclose 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, this study validates the notion of non-linearity of climatic patterns as confirmed in our results.

In addition, the study conducted by [Amassaib, *et al.* (2015)] reveals 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 to very much similar to our results except maximum and minimum temperature where in case of Pakistan, these two variables have minimum role in changing net farm revenue.

Finally, it can be concluded that the 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 minimise the severity of the situation before it is too late.

THEORETICAL FRAMEWORK AND METHODOLOGY

Ricardian Theory of Land Rent

Majority of economists subsist in a two-factor world (just labour and capital) disregarding land particularly vital for conventional political economy and ingested into capital and labour and departed [Gaffney (2008)]. David Ricardo one of the leading classical economists propounded the theory of rent. He appeared first time in the field of economics in 1799, took an inspiration from the work of Adam Smith, "Wealth of Nations". Later on he continued his journey in the field of economics for 10 years with increasing interest. In the beginning of 19th century (1810), he came up with his first published work, "The High price of Bullion, a proof of the Depreciation of Bank Notes."

In response to the Corn Laws controversy[1] in 1815, Ricardo emerged with a new idea and published an essay on, "The influence of a low price of corn on the profits of stock." Dealing with the issues raised by the Corn Law controversy, Ricardo and eminent friends of him like Thomas Malthus and Torrens devised a remarkable principle of diminishing returns which afterwards became a milestone in the theory of rent [Deak (1985)].

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 the fertility of the 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.

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[1]In 1815, a controversy arose over the Corn Law in Europe. They were of the view that falling Wheat prices had led parliament, under the Lord Liverpool, to raise the tariff on the imported wheat.

Ricardo defined land rent as:

"That portion of the produce of the earth, which is paid to the landlord for the use of the original and indestructible powers of the soil."

Ricardo (1821) underlined four key propositions about rent: for him land rent can be regarded as the indestructible powers of the soil, rents are not equal to profits. He also opines that land is heterogeneous in fertility while price of the commodities is not determined by the rent but the way other round. According to Ricardo, "whenever I speak of the rent of land, I wish to be understood as speaking of that compensation which is paid to the owner of land for use of its original and indestructible powers" [Ricardo (1821:34)]. His argument is based on the idea that all other feature of the land exhaust over time except novel and unyielding powers. Therefore, he was of the view that all replacement cost must be subtracted from the rent. The second key proposition Ricardo talked about rent was that rent is not equal to profits. Furthermore, he says that the factors that control the rent to rise are quite different from that of profits and hardly ever move in the same trend.

Rationale to Choose the 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) outline 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) come up with the opine 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 endeavour 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 favourable as compared to conventional methods because the Ricardian approach includes all adaptation factors implicitly. Thus, keeping in view the advantages of this approach, the same approach has been chosen to estimate the model.

Functional Form of the Model

The assumption of perfect competition in Ricardian model allows free entry and exits and this notion of free entry-exit guarantees that additional profits are driven to zero. As a result, land rents will be similar as the net income per hectare [Ricardo (1817)]. This indicates that land values are the mirror image of the present value of net farm income. It is very obvious that any agricultural farm that is located to a city has more chances to be employed than other non-farm activities like construction of buildings, shopping malls, roads etc. This can also affect directly or indirectly the land value. Thus it is imperative to deem very carefully such characteristics while measuring farmland values near cities using Ricardian approach.

The Ricardian approach was initially developed with the purpose to predict the cost of impairment from climate change [Mendelsohn, *et al.* (1994, 2001, 2005)]. It is evident from several studies that land value per hectare is sensitive to climatic variables like precipitation and temperature [Mendelsohn, *et al.* (2005, 2007); Mendelsohn and Dinar (2003) and Kurukulasuriya, *et al.* (2006)]. Previous empirical work reveals that there is a certain level of precipitation and temperature which is conducive for many crops. So, the temperature and precipitation beyond that certain level reduces productivity and that results in decrease in land values. This approach is more practical in a sense that it not only incorporates the direct effects of climate change but also regard adaptation as a response from farmers to their native climate. 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:

$$LV_{it} = \alpha_{it} + b_{it} F_{it} + c_{it} F^2_{it} + d_{it} Z_{it} + \epsilon_{it} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where; LVi shows land value per hectare in PAK rupees in *i*th district for time period t. α_{it} is constant term in the equation. Fit 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.

Here, 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 have been estimated to test the robustness of the model. For this purpose five models have been tested and in each model one extra variable is introduced[2]. We have also included interactive district dummies to capture district wise impact of climate change.

Selection of the Dependent Variable

For this analysis we can use either the land rent or the land value as a dependent variable. Hence, land value is used as a dependent variable in the study in hand. 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 [Uzma, *et al.* (2010); Seo and Mendelsohn (2008)]. But in case of developing countries, data on land value is not so easily available. Consequently, net farm income or revenue has been used as a proxy for land value.

Nature of the Data Used in the Model

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 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 to estimate district wise climate sensitivities and temporal changes. Data on dependent and independent variables was collected from different sources as presented in data description table. Annually data on cropland value for the selected districts (twenty districts) of Punjab over a given time period (2005-2008) has been collected from Punjab Economics Research Institute (PERI), Lahore while for each climatic variable annually average data for thirty year have been taken from Pakistan Meteorological Department, Islamabad. Then we got a single value for each variable by taking thirty years average. The purpose of taking thirty years average was to fulfil 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 stands first in the race of agricultural GDP share in Pakistan's agricultural GDP. Punjab is the most densely populated province in

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[2]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.

Pakistan.[3] The total population of Punjab province is around 93 million people but it also contributes about 62.02 percent to the 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 (2010)].

In terms of area, Punjab is the second largest province in Pakistan. The total area of the province is approximately 205344km^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 about 67 percent of the total cultivated area. Table 1 shows a detail summary of the agricultural share of Punjab province in the agricultural GDP of Pakistan.

Table 1

Agricultural Share of Punjab in Agricultural GDP of Pakistan

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	Live Stock	622531	260344	41.8	648106	268327	41.4
4	Fishing	21319	5003	23.5	21626	5044	23.3
5	Forestry	14094	1202	8.5	14404	1484	10.3

Source: Punjab Development Statistics, 2010.

[3]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 percent with an average household size of 6.9 persons.

To execute the study, twenty districts of Punjab have been selected. Districts have been selected on the basis of the accessibility of climate observatory stations. The list of the selected districts is given in Table 2.

Table 2

Districts of Punjab Province

1.	Bahawalpur	11.	Multan
2.	Bhakkar	12.	Nankana
3.	Chakwal	13.	Okara
4.	D.G Khan	14.	R.Y Khan
5.	Faisalabad	15.	Rawalpindi
6.	Hafizabad	16.	Sahiwal
7.	Jhang	17.	Sarghodha
8.	Khushab	18.	Shiekhupura
9.	Khanewal	19.	Sialkot
10.	Layyah	20.	Vehari

DEFINITION OF VARIABLES

Districts of Punjab are selected as cross sections in the study. Similarly, five points in time have been chosen on the basis of the availability of data. Variables used in the study are categorised in to climatic and non-climatic variables. The dependent and independent variables along with their definitions are presented in Table 3.

Dependent Variable

The dependent variable engaged in the study is the average land price per acre (market sale price of the land per acre). It is very evident from the literature that the use of agricultural land price as a dependent variable is consistent with other Ricardian approach analyses [Mendelsohn, *et al.* (2001); Seo and Mendelsohn (2007); Seo and Mendelsohn (2008)]. It is clearly mentioned in final report of task force on climate change, 2010 that computing the upshots of climate change on different sectors of the economy is of crucial importance to devise a pragmatic procedure to develop country's development plans in the finest way and confine them within the limited available resources. In this connection the study in hand is a breakthrough to figure out the issue of impact of climate change on agriculture sector. For this purpose twenty districts from the province Punjab were selected. Data on agricultural land price was collected from Punjab agricultural research institute since 2005 to 2008.

Table 3

Description of Variables

Variable	Title	Definition	Source of Data
Dependent Variable	LV	Annual average price of agricultural land at district level (PAK .RS/acre)	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 (millimetres= mm) at district level	Pakistan Meteorological Department (1978-2008)
	HUMID_AVG	Annual average humidity (percent= %) at district level	Pakistan Meteorological Department (1978-2008)
Independent Variables		**Non-climatic**	
Population Density	PDNS	The number of people living per kilometre 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 fulfil the data requirement of the study, data on population density for the year 2005-2008 were collected from the Punjab Bureau of Statistics, Lahore.[4]

Independent Variable (Climatic)

Climatic variables are the second group of independent variables in the study. Yearly average data from 2007 to 2008 is used to capture the climate change impact. The standard minimum stretch of time consists of thirty years in order to address climate change phenomenon.

Maximum and minimum average temperatures are measured in degree Celsius (^{0}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 millimetres (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 the water reacts with plants and the growth of leaf. It also affects the process of photosynthesis which results in raise the incidence of diseases. It is further confirmed from the results of the study in hand that the average humidity level has a positive relation but the square term of the variable has a devastating impact on agricultural land. The data on all climatic variables is collected from Pakistan Meteorological Department Islamabad. Some districts in the study area had no climate observatory stations. Thus to overcome this 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 twenty districts from the province Punjab. Results of the study have been wrapped up using Estimated Generalised Least Square (EGLS) with white cross section standard error technique. The EGLS (White cross-section) model results shown in Table 4 depict a quadratic relationship between the dependent variable (Land Value) and some climatic and non-climatic variables. Furthermore, some relevant statistics is also presented in the table.

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[4]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.

Table 4

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

***, **, * denotes 1, 5 and 10 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 along with linear form in the equation. Using quadratic form is logical and quite consistent with the previous studies [Seo and Mendelsohn (2007); Schlenker, *et al.* (2005); Fisher, *et al.* (2007); Uzma, *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-shape or hill-shape of the relationship. The negative sign confirms a U-shape 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 up to a certain point, that is the bottom of the 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 up to 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 agricultural sector. Agricultural land values in Punjab region are explicitly dependent on average rainfall because almost 68 percent of the total geographical region comes under annual rain fall of 250 to 500mm while there is only 8 percent of the area where rainfall exceeds the limit of 500mm [Alam (2000)]. In our analysis 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 650214 Pak rupees per hectare. 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 (minimum of U) and after that point both rainfall and land value will start to increase.

On the other hand, the 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 percent 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.

In case of humidity, the 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 302798 Pak rupees per hectare. But 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 1^0C increase in minimum temperature will raise the land values by 495678 Pak rupees per hectare. Both the land value and mean minimum temperature shows an increasing trend up to 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.

Minimum temperature square has an inverse relationship with land values. The relationship becomes U-shape 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-shape (U) and hill-shape (∩) relationship respectively. But 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 compare to other factors in case of Pakistan. They do care of factors like access to road; access to market soil quality and precipitation level etc. It is also evident that in Punjab maximum temperature has been not increased significantly during 1960-2008 [Rasul, *et al.* (2009)]. Thus this validates the consistency of our results from the recent literature. Similarly, the expected signs and the direction of relationships are in line with the expectations.

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 the study has introduced a diverse variable that is the population density (persons/km2) at district level. The rationale for introducing this variable is that if population increases this result in increase in persons per kilometre 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 Pak Rs 801. It is statistically significant at 5 percent level of significance. From this we can conclude 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 have been tested and the best model is reported in Table 4 Results of the study 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 the response variable is due to the independent variables both climatic and non-climatic variables. F- Statistic is also presented in the table which predicts the overall good fit of the model. It is the combine significance of explanatory variables (Climatic and Non-Climatic) on land values per hectare of the agricultural land. The Estimated Generalised Least Square method is applied to estimate the random effect model which is opted on the basis of the 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 scrutinise the robustness of the model, robustness and sensitivity tests have been carried out by adding up new variables in the final model. For this purpose, we have estimated five different models using random effect method. In the first model, five key variables have been 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 the relationship are again consistent. In the same way rest of the variables have been introduced in the subsequent models and in spite of different specifications the direction of coefficients in all models remain consistent. This clearly proves the robustness of the results in Table 5.

Table 5

Robustness Check and Sensitivity Analysis

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

CONCLUSION AND POLICY SUGGESTIONS

The empirical investigation of the impact of climate change on agricultural land values primarily focuses on the agricultural land of Punjab province. In this connection present study validates that the climate change influences extensively the productivity and the market value of a piece of agricultural land. The way round, ups and downs in agricultural land values are largely impinged by climatic anomalies.

Therefore, it is of 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 policymakers to utilise 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.

To collect the agricultural land values data at district level, twenty districts from province Punjab were selected. The choice of each district is based on the availability of data on land values for the concerned district. Annual Data on agricultural land values is collected from Punjab Economic Research Institute (PERI), Lahore for the year 2005–2008. Data on all climatic variables is collected from Pakistan Meteorological Department, Islamabad. Average precipitation has a significant negative impact but if we take the square of this current rain, it shows a positive relation. The rationale is that the current amount of rain is insufficient for the crop productivity and the soil fertility of the land rather there is a dire need of additional quantity of rainfall to compensate the demand of water 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. Our results are similar to [Uzma, *et al.* (2010)] in case of maximum temperature. They also found it insignificant in case of Pakistan. Population density is used as a control socio-economic variable which has a significant positive hill-shaped (∩) relationship. It is found from the results that one person per square meter increase in population density increases Pak Rs. 806 per acre of the agricultural land value. The minimum temperature has a significant positive impact on land values.

In contrast, minimum temperature square has a significant negative impact on land values with a (U) shape relationship. It is further clear from the results that the 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 affect 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 excepted 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 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, policy-makers should develop such policies that help in minimising costs related to climate change and maximise agricultural benefits. For this purpose government should come up with new ideas and practices of research. For the awareness of the issue, government can conduct workshops and seminar for the farmers to equip them with new solutions and strategies.

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 to implement new adaptation tactics. Similarly; there should be flow of information related to climate change phenomenon for the concerned stakeholders at a zero rate. It can also be helpful if climate policies are enclosed with ground realities.

Finally, planners should be pragmatic in their policy making and they should primarily focus on regional ground realities.

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