Research Article

Impact of Climate Change on Wheat Growers' Net Return in Khyber Pakhtunkhwa: A Cross-Sectional Ricardian Approach

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Abstract | This study employs a cross-sectional Ricardian Model to investigate impact of temperature and rainfall on wheat growers' net-return in Khyber Pakhtunkhwa (KP) province of Pakistan. Data for this purpose are collected from 255 wheat growers, selected from Southern, Central and Northern climatic zones of KP. Results from descriptive statistical analysis demonstrate that net-return per acre from wheat crop is highest in the Central zone because of conducive agro-climatic conditions. The estimated Cross-sectional Ricardian Model reveals that temperature and rainfall have non-linear relationships with net-return per acre. The relationship between growers' net-return and atmospheric temperature, represented with a temperature response curve, is inverted U shaped having a yield maximizing temperature level of 25°C. The rainfall response curve for net-return is U shaped and the minimum net-return rainfall level is 89.6mm. Forecasting of net-returns for the whole KP reveals that an increase in temperature by 2°C from current average level could reduce wheat growers' net-return by 37 percent. Increase in rainfall by 20 percent from current level could increase net-return by 6 percent. In the Central and Southern climatic zones of KP, where average monthly temperature in wheat season is above 25°C, wheat growers' net return per acre could be hugely affected by temperature increase due to climate change. This change in temperature could positively affect wheat growers' net-return in the Northern zone. Development of new seed varieties with increased heat tolerance and provision of timely and sufficient water for irrigation would be helpful in reducing future potential losses to wheat growers.

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Introduction

Climate change is a long-term change in the earth's climate, specifically a change due to increase in the average atmospheric temperature. This change is more apparent during the last five decades and attributed largely to the increased level of greenhouse gases (GHG) produced by the use of fossil flues. The release and accumulation of GHG, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water vapor (H_2O), have resulted increase in global atmospheric temperature. Recent studies found that the global atmospheric temperature has increased by 0.13°C during the last 50 years, and for 2100, the projected increase is 5.8 °C. This rise in atmospheric temperature has increased evaporation from water bodies and has indirectly changed the intensities and frequencies of rainfalls in different regions. Storm, drought and floods, induced by climate change, are potential threats to humans and other living organisms (Abou-Shleel and El-Shirbeny, 2014).

Climate change has threatened agricultural production in most parts of the world. High atmospheric temperature adversely affects crops, animals and farmers. It causes aridity and land degradation by reducing water supply. Modified rainfall patterns result water scarcity and droughts which creates stress for crops and livestock. Generally, the consequences of climate change for agriculture will be more severe for countries having higher present temperature, greater climatic variation, and low level of development. The IPCC Report (2007) predicted that the arid and semi-arid regions of the world will be severally affected. Countries located in these regions are mostly developing and have agricultural based economies.

Pakistan is highly vulnerable to climate variability and extremes. Vulnerability in general is a consequence of over exploitation of natural resources and economic poverty of the people. These two factors enhance each other and make people and ecosystems extremely vulnerable to climate variability and extremes. Change in climate is closely linked to food security and poverty alleviation, which are main challenges for the agricultural sector of the country.

Agriculture is second largest sector in Pakistan that contributes around 20 percent to GDP and absorbs 44 percent of the workforce (GoP, 2013-14). Though there is evidence of increase in agricultural production, the nation is not self-sufficient yet. In this scenario, the investigation of the impact of climate change on agricultural production and policies recommendation for improving farmers' mitigation and adaptive capacity to climate change are important research questions. It is documented in final report of Task Force, Planning Commission on climate change that there is a dire need to quantify the impact of climate change on different sectors of the economy for planning and policy making. That's why this research work is designed to investigate the impact of climate change on wheat production and growers' returns.

Wheat is Pakistan's main staple food and accounts for 42 percent of total daily caloric consumption per person. Beside as the main food crop, wheat is also a main income source for farming communities in rural areas. It is grown by 80 percent of the farmers and occupies 40 percent of the country's cropped area. The share of wheat in total value-added in agriculture is over 12 percent. Pakistan's yield for wheat is significantly lower than other wheat producing countries, such as United Kingdom, Germany, France and China. This yield gap might be due to low adoption of high yielding varieties, under utilization of recommended inputs or unfavourable climatic conditions. A number of studies have investigated the effect of improved varieties and important inputs on wheat yield; however, only few studies have focused on climatic conditions and climate change (Siddiqui et al., 2012; Shakoor et al., 2011). This study is conducted with the objective to quantify the impact of climate change on wheat growers' net return in KP province of Pakistan and forward recommendations for improving farmers' adaptive capacity to climate.

Methodology

Study area

KP province is located in the Northwest of Pakistan. Based on climatic conditions, Environmental Protection department of KP has divided the whole province into Northern, Central and Southern zones. The Northern zone starts from Hindu Kush and Western Himalayas ranges in North and extends to Peshawar valley in South. This zone receives little monsoon rains in summer, while in winter, heavy snowfall occurs from mid-December to late March. Agriculture is the major domain of people activities, and major crops grown are wheat, maize, onion and potato. The Central zone, also called Peshawar valley, is the most fertile zone of the KP province. This zone remains cold in winter and hot in summer, heavy rainfall occurs during summer monsoon. Main crops are tobacco, sugarcane, sugar beet, wheat and maize. Most of the agricultural fields are irrigated through canal water from Indus, Kabul and Swat Rivers. The Southern zone extends from Peshawar valley in North to D. I. Khan in South. This zone is arid with hot summers and relatively cold winters and scanty rainfall. Substantial increase in agricultural production occurred after Chasma Right Band Canal and Gomal Zam Dam water supply projects. Increase in agricultural production was recorded in rice, sugarcane, wheat, cotton, maize, pulses and orchard.

Sampling and data collection

A multistage sampling technique is used to select a sample of 255 farmers. In the first stage, KP is divided into Northern, Central and Southern climatic zones. From these zones, districts having metrological stations, are purposively selected (Table 1 provides more details). From each selected district, one village is randomly selected. As within district, climatic conditions remain same, and for Cross-sectional Ricardian model variation in climatic conditions are required over spatial scale, thus the number of villages is limited to one per district. In the final stage, at least 35 wheat growers are selected randomly from each village. Thus in total a sample of 255 wheat growers are selected from all the three climatic zones. Financial and time factors constrained the selection of more villages and large sample size of wheat growers.

Table 1: *Wheat growers selected from different climatic zones*

Climatic zones	Districts	Village	Sampled Wheat growers
Northern	Chitral	1	35
	Swat	1	35
	Mansehra	1	35
Central	Peshawar	1	35
	Charsadda	1	35
	Abbottabad	1	35
Southern	D.I. Khan	1	45
Three zones	7 Districts	7 Villages	255

Both primary and secondary data are used. Primary data on wheat cultivated area, production, cost of production and socio-economic characteristics are collected from sampled farmers through face-to-face interview. Secondary data on atmospheric temperature and rainfall are obtained from metrological stations located in selected district.

Ricardian analysis

Theoretical concept: As farmer's objective is profit (net-return) maximization and this is the main force behind his decision on allocation of farmland for different crops. For a single crop, net-return can be calculated as a difference between total revenue from production and total cost of production, while total revenue is the summation of market value of the main product and by-product:

$$R = P.Q - V.I$$

Where R is net-return per acre from a crop; Q is yield per acre from the crop; I is a vector of production inputs utilized by the farmer for crop production; P is the price per kilogram of the crop's product; and V is a vector of inputs prices. Assuming prices of inputs and output constant, then farmer's net-return from a crop depends on crop yield and quantity of inputs utilized. For given production technology a crop's yield depends on the quantity of inputs (I) and climatic conditions (C), such as atmospheric temperature and rainfall. The given equation can be written as;

$$R = P.f(I,C) - V.I$$

This equation is the theoretical base for Ricardian model and it shows farmer's net-return from a crop as function of inputs and climatic conditions. The Ricardian model has been used to measure climate impacts using cross-sectional evidence (Mendelsohn et al., 1994, 1996; Mendelsohn and Dinar, 2003; Schlenker et al., 2005). It is a comparative static analysis. It reflects all the adjustments that farmers and ecosystems make in response to climate change. It is a measure of the long-term consequences of climate change. As it is not a dynamic analysis, so it does not measure the transition costs of moving from one climate to another (Mendelsohn, 2008).

Functional form

The standard Ricardian model relies on a quadratic formulation of climate variables and use cross sectional data instead of time series. Variation in climate variables comes in data collection from different agro-climatic zones.

The following quadratic model is used to estimate the effect of atmospheric temperature and rainfall on farmer's net-return per acre from wheat crop. Other control variables, such as fertilizers, pesticides, number of irrigations and labor days, are used to capture and control their effects on net-returns.

$$R_i = \beta_0 + \beta_1 T_i + \beta_2 T_i^2 + \beta_3 P_i + \beta_4 P_i^2 + \sum_{j=1} \delta_j I_{ji} + \mu_i$$

Where Ri is ith farmer's net return per acre from wheat; T and P are atmospheric temperature and rainfall, respectively; I is a vector of important production inputs; and βs and δs are coefficients. By studying the quadratic terms of atmospheric temperature and rainfall, the relationship between the net-return and climate is calculated. The relation is non-linear in nature due to the variation in net-return and crop's yield, as it may inflates or reduces. Nonlinear relationships portray a very clear picture of the effects of climate change on net return.

Results and Discussion

Climatic conditions during wheat season

Table 2 shows average atmospheric temperature and rainfall during different growth stages of wheat crop. In KP, the average atmospheric temperature during sowing stage of wheat crop is 23.6°C. The sowing of wheat crop starts in November, except in the Northern zones, where due to snow fall, sowing starts in early October. During flowering stage, average atmospheric temperature remains 22°C. In the Central and Southern zones, wheat flowering starts in March, while in Northern zones it starts late because of low atmospheric temperature. The average atmospheric temperature during harvesting stage in KP reaches 37.7°C. Harvest of wheat crop starts in late April and May in Southern and Central Climate zones, while in Northern Zone, it starts in June.

The same table also presents average rainfall during different growth stages of wheat. Most of the rainfall occurs during flowering and harvest stages, and sowing stage is mostly dry. The table shows that in KP average rainfall during sowing, flowering and harvest stages are 33.5mm, 95.6mm and 62.1mm, respectively. In the Central and Northern zones, high rainfall occurs during flowering and harvest stages. Harvest stage rainfall results loss in wheat yield and quality of grains.

Net returns from wheat crop

Table 3 shows that average wheat yield in KP is 20 maunds per acre, and highest yield are reported in Charsadda (25 maunds), Mansehra (24 maunds) and Peshawar (22 maunds) districts. Total revenue per acre is calculated by adding value of grain product (at Rs.1500/ maund) and value of by product. The table demonstrates that average total revenue per acre from wheat crop is Rs.43012. Total revenues per acre at district level are also reported in the same table. Total production cost for this study is derived by adding fixed cost and variable costs per acre. The total cost per acre of wheat crop is on average Rs.38069. Total production cost per acre of crop is highest in Central zone (see Table 3 for more details).

From total revenue figures the respective production costs per acre are subtracted to get net-return. The last row of the table shows that in KP net-return per acre from wheat crop is on average Rs.4770. Maximum net-returns are found for Charsadda (Rs.12952) and Mansehra (Rs.11562). Net-return is negative for Abbottabad because of rain-fed ecology and low yield.

Estimated Cross-sectional Ricardian Model

The cross-sectional Ricardian model is estimated using Ordinary Least Square (OLS) estimation method. In quadratic regression model, the problem of multicollinearity is likely in the independent variables X and X2. As the square of temperature and rainfall

Table 2: *Average temperature and rainfall in KP's climatic zones (2011-2016).*

Wheat growth stages	Central Climatic Zone		Northern climatic zone		Southern Climatic Zone		KP Average	
	Temp. (°C)	Rainfall (mm)	Temp. (°C)	Rainfall (mm)	Temp. (°C)	Rainfall (mm)	Temp. (°C)	Rainfall (mm)
Sowing	21.3	51.2	22.25	44.6	27.2	4.7	23.6	33.5
Flowering	21.6	120.5	17.9	127.5	26.4	38.7	22.0	95.6
Harvesting	29.3	135.5	33	46.6	38.9	4.2	33.7	62.1
Average	24.1	102.4	24.4	72.9	30.8	15.9	26.4	63.7

Table 3: *Total and net-return from wheat production*

Product	Central Zone			Northern zone			Southern zone	KP
	Peshawar	Charsadda	Abbottabad	Mansehra	Swat	Chitral	D. I. Khan	
Grain production (Maund)	22	25	13	24	18	21	19	20
Revenue from main product (PKR)	33000	37500	19500	36000	27000	30750	28500	30321
Revenue from by-product (PKR)	14446	14436	10100	14763	11983	12000	11228	12691
Total Revenue (PKR)	47446	51936	29600	50763	38983	42750	39728	43012
Total production cost (PKR)	42594	38984	29784	39201	38193	41000	36726	38243
Net-return (PKR)	4852	12952	-184	11562	790	1750	3002	4770

PKR: Pakistani rupees

Table 4: *Estimated Quadratic Model for wheat grower's net-return*

Variables	Coefficient	t-value	P-value
Number of irrigation	856.33	4.18	0.00
Urea fertilizer (Kilogram/acre)	41.74	3.58	0.00
DAP fertilizer (Kilogram/acre)	6.33	0.33	0.74
Pesticides (Liters/acre)	2367.22	8.14	0.00
Average monthly rainfall (mm)	-306.11	-2.47	0.01
Average monthly rainfall square (mm)	1.72	2.29	0.02
Average monthly Temperature (C)	36734.09	6.35	0.00
Average monthly Temperature square (C)	-723.14	-6.20	0.00
Constant	-456833.00	-6.71	0.00

Number of obs = 255; F(8, 246) = 181.47; Prob> F = 0.0000; R-squared = 0.8056

are used to test for non-linear relationships between net-return per acre and climatic factors, we ignored this problem.

Average monthly atmospheric temperature in wheat season

The coefficients for the linear and squared temperature terms are statistically significant. The significance of the coefficient for the squared temperature term indicates that relationship between growers' net-return from wheat crop and atmospheric temperature is non-linear. The coefficient of the liner term is positive and negative for the squared term. These estimated coefficients indicate that initially, net-return per acre from wheat crop increases with increase in atmospheric temperature, and after reaching a critical (optimal) temperature level further increase results decrease in net-return. Differentiating the estimated model w.r.t. atmospheric temperature gives a marginal revenue change of 36734.09 – 1446.38T. Equating this first derivative to zero and solving for T, gives optimal atmospheric temperature level which maximizes KP wheat growers' net-return per acre. The optimal temperature level for net-return maximizing wheat growers of KP is 25°C (see Figure 1).

Average monthly rainfall in wheat season

The coefficients for the linear and squared monthly rainfall are also statistically significant. The significance of the coefficient for the squared rainfall term indicates that relationship between wheat growers' net-return and average monthly rainfall in wheat season is non-linear. The coefficient of the liner term is negative and positive for the squared term. These estimated coefficients indicate that relationship between net-return from wheat crop and monthly rainfall is U shaped (see Figure 2). Putting the first derivative of the estimated net-return with respect to rainfall equal to zero and solving for P, gives minimum net return level of rainfall (89mm).

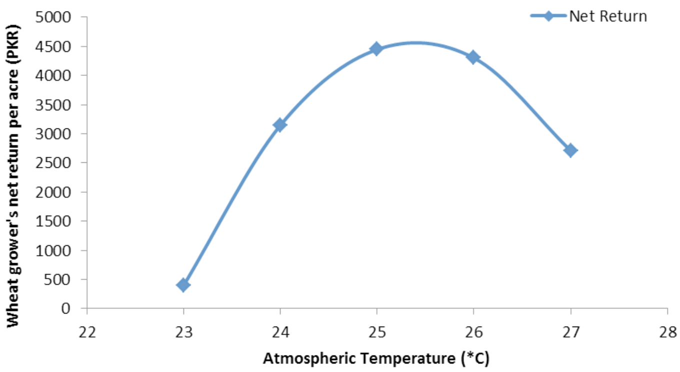

Figure 1: *Temperature response curve for wheat grower's net-return*

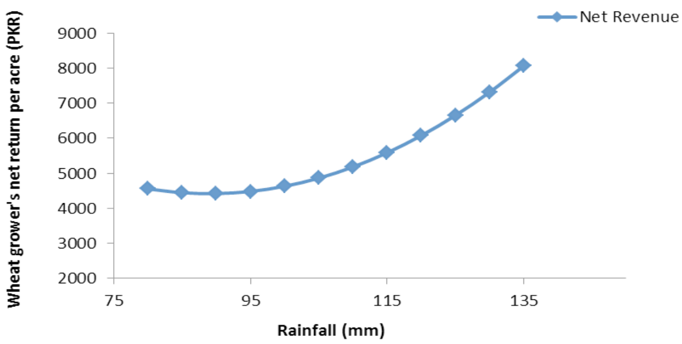

Figure 2: *Rainfall response curve for wheat grower's net-return*

Production inputs

Estimated result shows that all production inputs, except the DAP, have significant effects on net-return per acre for wheat growers.

Urea: The coefficient for urea fertilizer is positive; the value of 41.74 indicates that holding other variables constants, a 1 kg increase in urea per acre would increase wheat grower's net-return per acre by Rs.41.74.

Pesticides: The coefficient value of 2367.22 for pesticide shows that at the mean level of other variables, an increase in pesticides use by 1 litter per acre would increase wheat grower's net return per acre by Rs.2367.22.

Irrigation numbers: Irrigation is another highly significant production factor; its coefficient value is 856.33, which demonstrates that wheat grower's net return per acre would increases by Rs. 856.33 with additional irrigation.

All these coefficients sign s are in accordance with prior expectation.

Forecasts of wheat grower's net return according to different climate change scenarios

In Pakistan, the Global Change Impact Studies Centre (GCISC) and Pakistan Meteorological Department have conducted research studies on climate trends, and according to their analysis, the climate of Pakistan is changing. During the past century, average annual temperature increased by 0.6°C, at the rate of 0.06°C per decade. This estimated change and rate of change are consistent with global trend. Also, there is an overall increase in the wet events in the country: 41 out of 54 meteorological stations recorded an increasing trend in rainfall.

Studies based on outputs of several Global Circulation Models project that Pakistan's average temperature will increase progressively by 2.8-3.4°C up to 2100. Rainfall is projected to increase slightly in summer and decrease in winter with no significant change in annual rainfall. It is also projected that climate change will increase the variability of monsoon rains and will enhance the frequency and severity of extreme events such as floods and droughts. The projected temperature increases, for Pakistan as a whole in 2020s, 2050s and 2080s are 1.31°C, 2.54°C and 4.38°C respectively in A2 scenario and corresponding 1.45°C, 2.75°C and 3.87°C in A1B scenario (GoP, 2008; GCISC, 2009). The projected change in annual rainfall for Pakistan is insignificant. The spatial pattern shows a non-significant increase of rainfall (5-15 percent) over the KP region.

To forecast changes in wheat growers' net-return per acre in future, the projected/ expected increase in temperature and rainfall are added to the base year's (2015-16) temperature and rainfall. The estimated Cross-sectional Ricardian model is then used to get net-return from wheat crop with the future climatic scenario and same level of production inputs.

The following Table 5 lists the expected impact of changing temperature and rainfall on wheat growers' future net-return per acre. For KP, on average wheat growers' net-return per acre will be significantly affected by temperature increase. A 2oC raise in temperature will produce a loss of Rs.1738.38 (36.95 % loss) to wheat growers' net-return per acre. This loss is very low as compared to forecasted change in net-return per acre by Shakoor et al. (2011). Different climatic conditions and availability of water for irrigation could be the possible reasons for this comparatively low impact of climate change on KP wheat growers' net-return per acre. In the Northern and Central Climate zones of KP, where average monthly temperature in wheat season is below 25°C, increase in temperature will result increase in wheat growers' net-return per acre. In the Southern and Central zones, where average monthly temperature in wheat season is above 25°C, increase in temperature will result decrease in wheat growers' net return per acre.

In KP, increase in rainfall by 10 percent will increase average net return per acre to wheat growers by 9.04 rupees.

Table 5: *Forecasts of wheat grower's net return according climate change scenarios*

Climate change scenarios (2020-2060)	Welfare effect on wheat growers' average net-return per acre (Rs.)
Temperature increase by 1°C	-146.05 (3.10%)
Temperature increase by 2°C	-1738.38 (36.95%)
Rainfall increase by 10 percent	9.04 (0.19%)
Rainfall increase by 20 percent	266.75 (5.67%)

Conclusions and Recommendations

Agricultural inputs such as urea, pesticides and irrigation have positive significant effects on wheat growers' net-return per acre. Climatic factors, such as temperature and rainfall have significant non-linear effects on wheat growers' net-return. Temperature response curve shows that net-return increases with increase in atmospheric temperature. Optimal temperature level is 25 oC, any increase in atmospheric temperature beyond this level will reduce grower's net-return per acre. Rainfall response curve shows that minimum required monthly rainfall level in wheat season is 89 mm. Forecasting of net returns in different climate change scenarios reveals that an increase in temperature by 2°C could reduce wheat growers' net-return by 37 percent, and an increase in rainfall by 20 percent could increase net return by 6 percent.

As in the Central and Southern Climatic zones of KP, where average monthly temperature in wheat season is above 25°C, growers' net-return per acre will be significantly affected by temperature increase. Development of high yielding and drought resistant wheat varieties could help reducing potential decrease in yield and net-returns. The negative effect of temperature increase or drought could be reduced with supply of more water for irrigation. Monitoring of changes in temperature and other climatic factors and their likely impact on wheat crop is required for better adaptation practices.

Author's Contribution

This paper is a part of HHS's MS research work. SAS supervised the research work. AUJ and GA helped in data analysis.

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