Research Article

Climate Change Impact Assessment on Net Revenue of Rice Crop in Khyber Pakhtunkhwa: A Cross-Sectional Ricardian Rent Analysis

Arshad Ayub, Amjad Ali*, Syed Attaullah Shah and Abbas Ullah Jan

Department of Agricultural and Applied Economics, Faculty of Rural Social Sciences, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan.

Abstract | In current study impact of climate change on net revenue of rice crop in Khyber Pakhtunkhwa (KP) Pakistan was assessed by cross-sectional Ricardian method. Data was collected from 180 rice growers in different climatic zone of Khyber Pakhtunkhwa including southern, central and northern regions. Key cost components were identified by simple budgeting technique. It reveals that land rent account for 29.11% of total cost, followed by labor (26.47%), threshing (8.53%) and tractor hours (8.31%). Per acre net returns noted vary across climatic zones, with northern zone yielding the highest at Rs. 30190.76/- followed by southern (Rs. 29957.12/-) and central zone (Rs. 27340.72/-). Temporal analysis having range from 1986-2021 reveals an upward trend for temperature in all three stages across the three zones. While rainfall patterns exhibit hill shaped curve during sowing and vegetative stages and a U-shaped curve during harvesting stage. Controlled variables including tractor hours, labor days, urea, DAP, and irrigation show positive and significant correlations with net revenue. A 1% increase in these variables results net revenue increase by 0.172 %, 0.175%, 0.019%, 0.061% and 0.113%, respectively. Study revealed non-linear relationship between temperature, rainfall and net revenue. Temperature's impact on net revenue follow inverted- U shaped with a critical temperature of 31 C°, beyond which rice crop yield decrease. Rainfall's effect for net return is U-shaped with a minimum rainfall level of 41 mm for study period. It is concluded that temperature increase in southern and central zone adversely affect crop yield because average temperature (34.88 °C, 34.77 °C) already exceeds the optimal level. Based on findings study recommended mechanized farming practices, such as use of rice combine harvester, mechanical drier and automatic planters to reduce production costs. Further, optimizing the use of basic inputs and implementing nature-based measures such as developing vegetative cover to control temperature could enhance net returns. Effective information sharing among stakeholders and timely action are essential to mitigate climate change risk in study area.

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***Correspondence** | Amjad Ali, Department of Agricultural and Applied Economics, Faculty of Rural Social Sciences, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; **Email:** amjad_ali@aup.edu.pk
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Introduction

Climate change, a global phenomenon mainly driven by rising temperature and increased greenhouse gas emissions has far-reaching effects on this planet. It disrupts rainfall pattern, leading to floods and droughts and pose threat to water and land resources. Developing countries bearing vulnerability to these changes are more expose to the adverse impact of climate change. They often lacking the means to mitigate its consequences (Ali *et al*., 2017).

Climate change represent a persistent change in weather pattern of a specific place or region. It exert influence on various sector including agriculture, fisheries, forest, coastal regions and geological process. Importantly, it directly affect food security and human health (Israr *et al*., 2020). Extensively literature has reported climate change (CC) negative impact on agriculture and economies mainly reliant on agriculture. CC leads to increase temperature, susceptibility to pest infestation and diseases, resulting in decrease crop production. Variability in rainfall pattern, flood, cyclone and depression of glaciers are observable impacts of CC (Morton, 2007). The Intergovernmental Panel on Climate Changes (IPCC) assessment report for Asia has underscored Pakistan's vulnerability to CC because of dependence on agriculture. Several factors such as limited adoptive capacity, socioeconomic conditions and demographic trends contribute to the country's vulnerability profile. Pakistan has recognized its vulnerability to climate change which manifests in challenges including, rise in annual mean temperature, prolong heat waves, variability in precipitation pattern and sea level rise. Increased variability in river flows and glaciers melt coupled with elevated evaporation rates have repercussion on overall agriculture particularly the wheat and rice crop. The devastating flood of 2022 in Pakistan has damaged vegetables, cotton and rice crop nationwide. Wheat crop cultivation was delayed due to standing water and water logged condition in Punjab and Sindh province, leading to damage of 3.7 million acres of arable land (Iqbal, 2022) and (ADB, 2017). Current study is designed to investigate net returns, temperature and rainfall trends across different zones along with impact of climate change on net returns of rice growers in Khyber Pakhtunkhwa. Rice is a vital cash and 2nd staple food item in Pakistan, contributing significantly with its Basmati (fine) and coarse varieties. It accounts for 2.4 % of value addition in agriculture. Its area and production for the year 2021 was 3,335 thousand hectares and 8.420 million tonnes, respectively. Agriculture sector engage 37% of total labor force (GoP, 2022). Khyber Pakhtunkhwa (KP), as the third largest economy in Pakistan relies heavily on agriculture, livestock and related agro-based activities for its sustenance. Because of CC direct influence on livelihood nature-based adaptation strategies becomes crucial. The government of Pakistan has formulated a number of policies and initiatives for climate change adoption and mitigation. The National Climate Change Policy (NCCP) of 2012 and subsequent revisions in 2021 provide a comprehensive overview of sector wise vulnerabilities and potential mitigation measures. The National Action Plan (NAP) guide the implementing agencies in execution of policies, strategies and programs. Its national level various measures have been initiated to minimized climate change hazards like direct flood reliefs to victims, support to climate refuges and the stabilization of supply chain. Such sort of study might provide inputs to planners for specifying mitigation (when, what and how) measures. Further, in KP this study has not been conducted yet, therefore it contribute to the existing body of knowledge by addressing these challenges. The study designed to achieve the objectives: Estimating rice production and net returns in KP, to study past trend of rainfall and temperature and to evaluate the impact of climate change on net returns of rice growers in KP.

Materials and Methods

Universe of the study

Khyber Pakhtunkhwa (KP) was the universe of the current study. It is the third largest provincial economy which accounts for 11% of national population. Main crops of the province are wheat, maize, rice, tobacco and sugarcane and large variety of fruits and vegetable. Province utilizes mineral resources, beautiful valleys, and hydroelectric energy potential for increasing economy (GOKP, 2015). KP is situated in northwest of country and is divided into three zones (as given in Figure 1), based on climatic condition and ecological landscape i.e., northern, central, and southern. There is considerable climate variability in these three zones. Climate is harsh in south region, temperate in central and positive climate impact in northern zone (Baber *et al*., 2014). Southern zone is dry, with scorching summers, mild winters, and little rainfall. Rice, sugarcane, wheat, cotton, maize and pulses are main crops. Here, yearly precipitation ranges from 300 to 300 mm. The central zone of land is sub-humid and also known as central plan valley is the most fertile zone of KP. The majority of the time, regions around the Indus, Kabul, and Swat rivers are fertile and ideal for agriculture. The average rainfall in this area ranged from 450 to 750 mm. In central zone, where farmers have considerably easier access to major markets for their products and inputs as well as other services like agricultural loans and new information. This region experiences hot summers and chilly winters, with substantial rainfall occurring during the summer monsoon. Tobacco, sugarcane, sugar beet, wheat, and maize are the main crops. The northern zone of land is semi-arid and semi humid. The Northern zone runs from the Peshawar Valley in the South to the Hindu Kush and Western Himalayan mountains in the North. The climate in the higher part of this zone is semi-arid with average rainfall of 250-500 mm. Northern region farmers have limited access to agricultural markets, information, agricultural extension, and other government services, and they are slower to embrace new technology. They are also located distant from the province capital.

Figure 1: *Climatic Zones of Khyber Pakhtunkhwa.*
Sources: *Reproduced from (Samreen and Amin, 2012).*

Sampling and sample size

A multistage sampling technique was used for data collection. In stage first KP is divided into zones i.e. southern, central, and northern. In each zone three (3) major rice growing districts were selected in 2nd stage. In third stage one village was select from each district. One village selection from each district serves the purpose because of same climate in overall district. In fourth and final stage 20 farmers were randomly selected for interviews. A total of nine villages and 180 respondents were selected from all three climatic zones.

Table 1: *Rice farmers selected from different climatic zones.*

Climatic zones	Districts	Village	Sampled rice growers
Southern	D.I. Khan	1	20
	Lakki Marwat	1	20
	Bannu	1	20
Central	Charsadda	1	20
	Mardan	1	20
	Swabi	1	20
Northern	Dir Lower	1	20
	Swat	1	20
	Batagaram	1	20
Three Zones	9 Districts	9 villages	180

Data collection

The study was based on primary data as well as on secondary data. Primary data on rice area, inputs used and cost incurred was obtained by survey. Research objectives were translated into questions. Questionnaire was designed in English but during face-to-face interview local language was used and immediately converted to English accordingly. Ghalib *et al*. (2017) has also followed the same procedures. Survey technique helps the researcher to study more and more field related problems (Gall *et al*., 1996). For trend analysis secondary data on temperature and rainfall from 1986 to 2021 was obtained from Provincial Metrological Department and relevant Directorates. Temperature and rainfall data for crop year 2021 was bifurcated according to rice crop growth stages i.e. sowing, vegetative and harvesting stage.

Econometric model

According to Mendelsohn *et al*. (2001) first economic studies on climate change and agricultural productivity was conducted in Brazil and India, due to the reason of good agricultural record in these countries. In these studies Ricardian method developed by Mendelsohn *et al.* (1994) was employed. David Ricardo a British political economist (1772-1823) was the first to discuss ideas of comparative advantage theory, labor theory of value and theory of rent. According to rent theory benefit accrue to the owner of assets due to their ownership rather than contribution to any actual productive activity. He was of the view that the benefit of rise in grain prices accrued to the owner of agricultural lands in the form of rents paid by tenant farmers. The Ricardian Method application in agriculture start from the assumption that land rent reflects the expected productivity of agriculture. Most of the economic studies on developing countries rely on the Ricardain method. In Ricardain method, land values or net revenues are regressed on climate and other confounding factors (soil, geographical and economic variables). Ricardain approach is a cross-sectional analysis and assumes that farmers adjust their practices, inputs and outputs to best for taking advantage of farm location including climate. It is a comparative static analysis and has the strength to measure long-run impacts of climate change on agriculture while taking into account the ability of each farmer to adopt. Mendelsohn *et al.* (1994) capture this principle by the Equation 1:

$$V = \sum Pi * Qi\ (Xi, C, S, G, H) - \sum Px * Xi \ \ldots (1)$$

In Equation 1 *Pi* represent market price for crop produce, *Qi* represent output, Xi represent putchased inputs (other than land), C is vector of climate variables, S stands for vector of soil variables, G is economic variables, H is for water and *Px* represents input prices. V is for net revenue. Study assume that rice grower's is rational, looking to optimize profits by changing inputs level, crop or practices accordingly. Inputs and output prices are expected values in the market. Because of cross-sectional Ricardian model reliance on quadratic formulation of climate the net value of land can be expressed as:

$$V = \beta_0 + \beta_1 C + \beta_0 C^2 + \beta_0 S + \beta_0 G + \beta_0 H + \mu_t \quad \ldots(2)$$

Where β's are coefficients of variables and μ_t is an error term. "C" is for climate response and is expressed by quadratic term. According to Mendelsohn *et al.* (1994) quadratic term reflect the nonlinear relationship of net revenue and climate. According to Huong *et al.* (2019) Ricardian approach takes adaptation into account by measuring economic losses like decrease in net revenue due to environmental factors. Double-log Model using STATA software was used to fit the model as follow:

$$Ln\ (V_{net)} = \beta_0 + \beta_1 Ln_{(}\ T_i\ ) + \beta_2\, Ln\ T\text{^}2 + \beta_3\, Ln_{(}Rnf) + \beta_4\, Ln\ (Rnf)\text{^}2 + \delta i\ Ln\ Xi + \mu_i \quad \ldots(3)$$

Where Ln is ntural log, T and Rnf are linear and quadratic terms for temperature and rainfall, X_i are inputs, μ is error term and β,s and δ are the coefficients.

According to Shakoor *et al.* (2011) the quadratic term of temperature and precipitation reflects the nonlinear relationship between net revenue and climate. In order to arrive net return cost was defined as "entire crop season expenditure made by the grower on raising crop, Labor days, tractor hours, seed amount, chemical fertilizer, and pesticides are all examples of inputs etc. were asked and valued at current market price. Simple budgeting technique was applied to calculate net returns of rice crop.

Results and Discussion

Average inputs: Zone wise and overall

In current study during survey all inputs and activities, generally practiced in study area were considered. Average quantity of input in each zone was worked out for calculating cost of production. Table 2 summarize main inputs on per acre base. Literature argued that among other factors optimum use of input ensure maximum crops. Table 2 shows that per acre seed used in northern zone was (12.76 kg) followed by central (12.52 kg) and southern (11.0 kg). The space of nursery for per acre field was found high in central zone (3.10 marla) followed by northern and central zone. Similarly, DAP application was found high (31.17 kg) in southern zone compare to central and northern zone. The possible reason observed during survey was that in southern zone the application of farmyard manure was negligible. The quantity of labor days per season were noted high in central zone (27.12) followed by northern (25.18) and southern zone (18.26). Similarly, overall tractors hour at provincial level were noted 3.02 hours/acre. An increased pesticides use was noted in central zone (2.70 liter/acre) followed by northern (2.08) and southern (0.93), respectively.

Table 2: Average inputs utilized per acre on rice production (2021).

Factors	Southern	Central	Northern	Overall KP
Seed (kg)	11	12.52	12.76	12.09
Nursery (Marla)	2.46	3.10	2.67	2.74
Tractor (hrs)	1.86	4.28	2.93	3.02
Urea (kg)	59.27	161.96	65.92	95.71
DAP (kg)	31.17	2.64	19.16	17.65
Pesticides (liters)	0.93	2.70	2.08	1.90
Labors (No. of Days)	18.26	27.12	25.18	22.29

Source: *Survey data (2021). KP: Khyber Pakhtunkhwa; Kg: Kilogram; DAP: Di Ammonium Phosphate.*

Cost of production: Zone wise and overall KP

Cost items observed during the field survey were valued at market prices. The figure in table has been arrived by multiplication of inputs quantity and its price. The Table 3 represent that in cost items land rent is highest 29.11% followed by labor cost (26.47 %), fertilizers (13.08 %) and tractors hours (8.31%). During survey it was observed that respondents have no written record for inputs use, their response depend on memory. Further, at is pertinent to mention these prices were recorded during the crop season 2021. Similarly, the lend rent thy responded was for one year, while the crop under study is of the eight months duration, therefore possibility of over or under estimation might be there. Average overall per acre cost of production was noted Rs. 44,482.54/. In northern zone was Rs. 49,365.88/, followed by Rs. 48,575.15/ in Central zone and Rs. 35,505.51/ in Southern zone. During survey it was noted that in Southern zone the production is sold out in the field except the involvement of a slight transportation cost.

Net revenue

Table 4 summarize zone wise and provincial average yield during crop season 2021. Table 4 show that yield is high in northern zone (877.85 kg/acre) followed by central (832.55) and southern (799.73). Average yield was noted 837.37 kg/acre. This is the yield of rough rice i.e. grain with hull. During survey it was noted that per kg price for rough rice was Rs. 88.33/ in northern, Rs. 63.33/ in central and Rs. 55/ in southern zone. Multiply yield with its respective price and subtracting per acre cost zone wise the table reflect that net return is high in northern zone Rs. 30,190.76/ followed by southern Rs. 29,957.12/ and central zone Rs. 27,340.72/, respectively. Average net return for whole study area was noted Rs. 29,162.86/.

Table 3: *Per acre cost of rice production for crop year 2021.*

Particulars cost (Rs.)	Southern	Central	North-ern	KP	%age
Land	15903.33	11280.53	11666.66	12950.17	29.11
Seed	588.06	793.38	1133.38	838.27	1.88
Nursery	1647.79	2763.47	4421.20	2944.15	6.62
Tractor hours	2416.89	4858.88	3820.36	3698.71	8.31
Fertilizers	6538.47	5877.89	5055.56	5823.97	13.09
Irrigations	1228.3	691.45	317.88	745.87	1.68
Pesticides	833.06	1633.78	1064.07	1176.97	2.65
Labor days	4554.27	13140.16	17618.65	11771.02	26.47
Threshing	1482.23	6591.04	3314.30	3795.85	8.53
Transport	314.19	944.52	953.76	737.49	1.66
Total	35506.61	48575.15	49365.88	44482.54	100.00

Source: *Survey data (2021). Rs: Pakistani Rupees.*

Table 4: *Yield, gross revenue and net return of rice crop in study area (Rs.).*

Product	Southern	Central	Northern	KP
Output (kg)	799.73	832.55	879.85	837.37
Per kg price (Rs.)	55	63.33	88.33	68.88
Gross revenue (Rs.)	65463.74	75915.88	79556.64	73645.42
Total production cost (Rs.)	35506.61	48575.15	49365.88	44482.54
Net revenue (Rs.)	29957.12	27340.72	30190.76	29162.86

Source: *Survey data (2021). Rs: Pakistani Rupees.*

Zone wise average temperature and rainfall for crop year 2021

Temperature data on monthly basis was obtained from provincial metrological stations. Accordingly, crop bearing months were divided into sowing, vegetative and harvesting stages. Table 5 shows that average temperature in KP for sowing time was 36.40°C. It has been decreased to 35.43 °C and 27.14 °C in vegetative and harvesting stages respectively. For entire crop average temperature has been recorded 32.99 °C. In southern zone average temperature 34.88 C° was found high compare to central 34.77 °C and northern zone 29.32 °C.

Table 6 shows that average rainfall in northern area is high (67.3 mm) compare to central (31.53 mm) and southern zone (28.19 mm). According to Shakoor *et al*. (2011) longitude, latitude and altitude has effect on rainfall of an area. In northern zone longitude is 72°10′ 66″ while in southern zone it is 70°53′ 42″, while in central zone it is 34°12′ 22″.

Table 5: *Zone wise average atmospheric temperature (°C) during different growth stages of rice crop.*

Growth stages	Southern zone	Center zone	Northern zone	KP
Sowing	38.85	38.33	32.03	36.40
Vegetative	36.81	37.66	31.83	35.43
Harvesting	28.98	28.33	24.11	27.14
Average	34.88	34.77	29.32	32.99

Source: *Government of Khyber Pakhtunkhwa, 2021.*

Table 6: *Zone wise average rainfall (mm) during different growth stages of rice crop.*

Growth stages	Southern zone	Center zone	Northern zone	KP
Sowing	16.03	23.07	53.68	30.92
Vegetative	58.56	53.89	116.62	76.35
Harvesting	10	17.65	31.6	19.75
Average	28.19	31.53	67.3	42.34

Source: *Government of Khyber Pakhtunkhwa, 2021. Mm: millimeter.*

Trend graph

Southern zone: Trend graph analysis was included to see changes in temperature and rainfall during various stages of rice crop in study area. In econometric model only crop year 2021 data was incorporated.

Figure 2A, C, E highlights past trend of temperature during rice sowing, vegetative and harvesting stages. Trend graph for the period 1986-2021 shows significant warming trend during sowing and a relatively flat upward trend in vegetative and harvesting stages. Farooqi *et al.* (2005) has also reported rising tendency in mean temperature. He has analyzed Pakistan metrological department (PMD) station data for the period 1951-2000. According to ABD (2017) increasing trend in temperature indicate adverse impacts on agriculture productivity, it increased water requirement and rate of respiration.

Rainfall trend graph in southern zone for the period 1986-2021 is given Figure 2B, D, F. trend graph shows increases up to 2000 and then decrease for sowing and vegetative stage. While for harvesting stage it seems U-shaped and has increased. Increase in rainfall during harvesting stage decrease yield and ultimately net revenue of the growers.

Trend graph central zone

Figure 3A, C, E are past trend graphs of temperature during sowing, vegetative and harvesting stages. Figure 3A, C shows that trend line lies in between 35 °C to 40 °C during sowing and vegetative stages. In harvesting stages Figure 3E it also shows increasing trend. The data trends are according to key findings of past trends of climate change indicators reported by Iqbal *et al.* (2009).

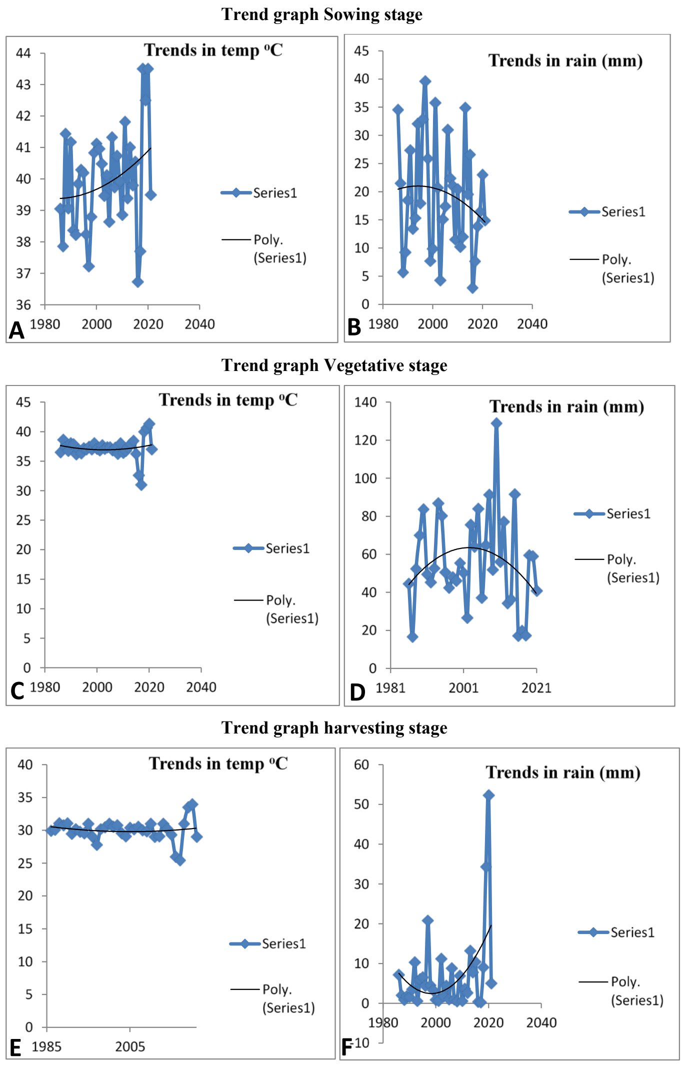

Figure 2: *Trend graph in Southern zone at sowing stage (A, B), vegetative stage (C, D), harvesting stage (E, F).*
Source: *Government of Khyber Pakhtunkhwa, various relevant Directorates and Department.*

Rainfall past trend for the period 1986-2021 is given in Figure 3B, D, F. Graph shows that rainfall pattern is invested U-shaped in harvesting stages. ABD (2017) has reported 20.8 mm increase in rainfall for time series data 1914-2007 in Pakistan. Increase in rainfall during harvesting stage might increase labor cost.

Trend graph northern zone

Figure 4A, C, E are trend line graphs for temperature in northern zone of study area. These graphs show that in all stages sowing (Figure 4A), vegetative (Figure 4C) and harvesting (Figure 4E) the trend is increasing. In northern zone the trend line increase is more compare to central and southern zone. In this regard Zahid and Rasool (2012) has also reported that temperature increase in northern zone is higher than southern zone.

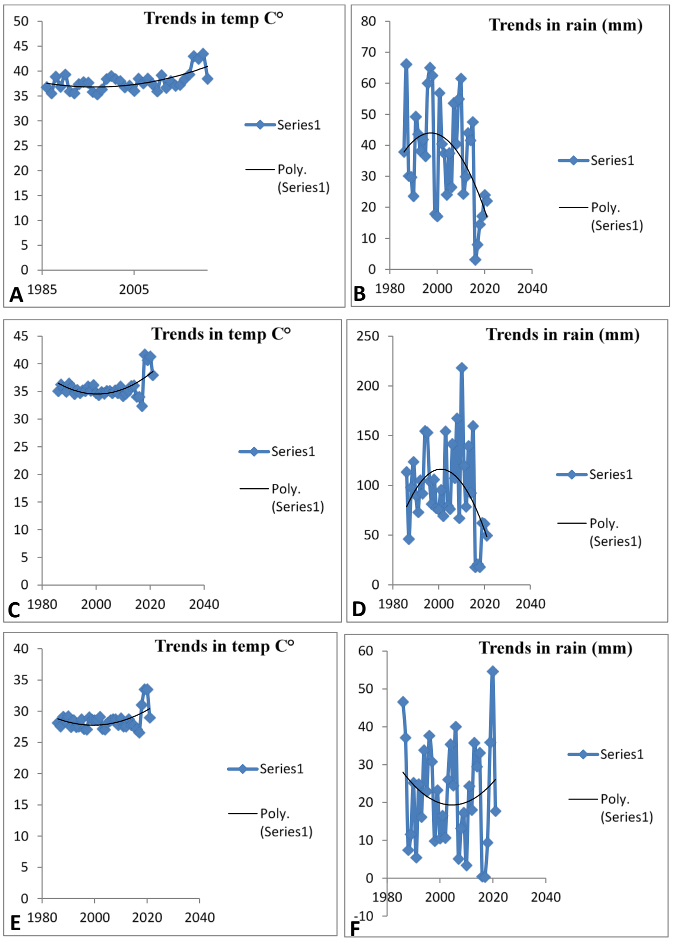

Figure 3: *Trend graph in central zone at sowing stage (A, B), vegetative stage (C, D), harvesting stage (E, F).*

Source: *Government of Khyber Pakhtunkhwa year wise data.*

Rainfall trend in northern zone is shown in Figure 4B, D, F. the graph is inverted U-shaped in sowing and vegetative stage while flat in harvesting phase. Net revenue in northern is high Rs. 30,190.76/ compare to southern Rs. 29,957.12/ and central Rs. 27,340.72/. This shows that rainfall possible increase cost and reduce net revenue of the growers. In this regard Haq *et al.* (2021) has reported 20.5% decrease in rice crop due to climate change in past few years.

Descriptive statistics

Table 7 shows descriptive statistics of all variables in this study. Table 7 consists of variable name, unit and its mean value, standard deviation and range from minimum to maximum. Table revealed that per acre average seed use was 11.99 kg up to maximum 19.35 kg. Average tractor use for land preparation was noted 3.11 hours. Average urea use was 111.62 kg up to maximum 250 kg. DAP average amount was 20.81 kg ranging from minimum 0 to maximum 66.6 kg.

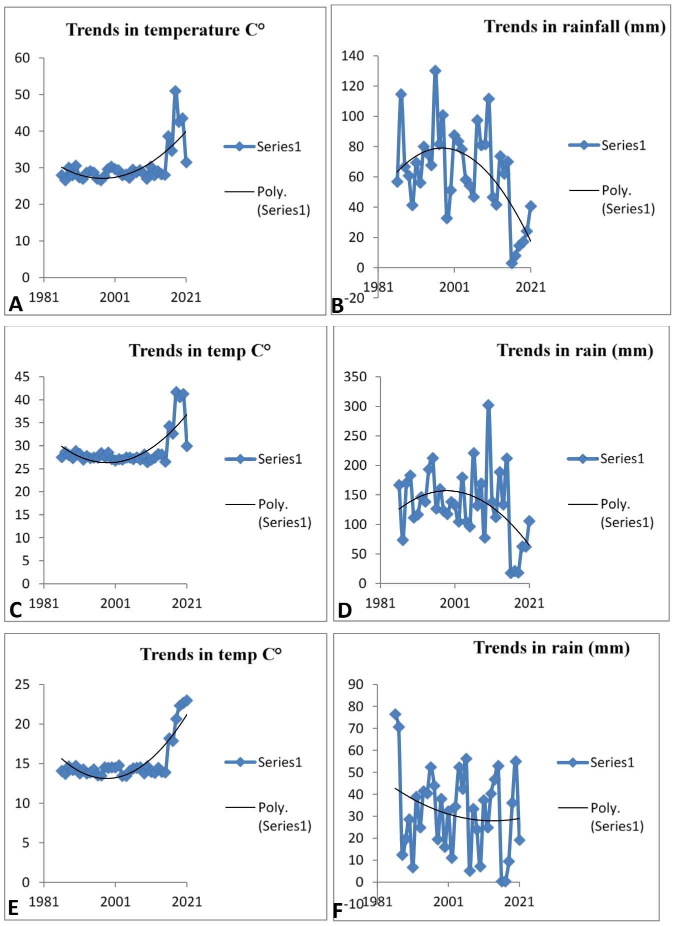

Figure 4: *Trend graph in northern zone at sowing stage (A, B), vegetative stage (C, D), harvesting stage (E, F).*

Source: *Government of Khyber Pakhtunkhwa, year wise metrological data.*

In study area during survey, it was noted that conventional practice of flood irrigation is common. Irrigation are given frequently to maintain soil moisture in beds at saturation level. Respondents response was in numbers, however it was converted to millimeter (mm) by multiplying water discharge with the number of irrigation. Same method has also been applied by Pakistan Council of Research in Water Resources (Soomro *et al.*, 2015). Estimated mean irrigation was 101.6 mm, ranging from minimum 81.28 to maximum 134.62. In climate variable, for entire crop season average temperature was noted 33.33 °C. Average rainfall values during sowing, vegetative and harvesting stages were noted 31, 76.36 and 19 mm respectively. Being the kharif crop it faces heavy monsoon during vegetative stage. Therefor maximum value for rainfall was noted 133.6 mm.

Table 7: *Descriptive statistics of variables used in model.*

Variables	Units	Mean	Std..Dev	Min	Max
Seed	Kg	11.99	2.30	5.34	19.35
Tractor	Hours	3.11	1.66	0.8	9
Urea fertilizer	Kg	111.62	87.01	0	250
DAP fertilizer	Kg	20.81	21.50	0	66.60
Irrigation	mm	101.6	26.95	81.28	134.62
Average temp	Centigrade	33.33	2.68	28.42	35.57
Average temp square	Centigrade	1118.16	173.02	808.18	1265.32
Average sowing rain	Millimeter (mm)	31	17.69	14.9	68
Average vegetative rain	Millimeter (mm)	76.36	32.47	40.86	133.6
Average harvesting rain	Millimeter (mm)	19.72	10.68	5	38.5
Average sowing square rain	Millimeter (mm)	1272.24	1429.21	222.01	4624
Average vegetative square rain	Millimeter (mm)	6879.33	5454.46	1669.54	17848.9
Average harvesting square rain	Millimeter (mm)	502.71	509.12	25	1482.25

Source: *Survey data, 2021. Kg: Kilogram.*

Estimates of cross-sectional ricardian model

The cross-sectional Ricardain model was estimated by Ordinary least square (OLS) estimation procedure. Estimated results shows that all production inputs except seed have significant effects on net returns per acre of rice growers in study area. The coefficient of tractor hours is positive and significant at 5% level, the value of o.173 shows that holding other variables constant, a one percent increase in tractor operation would increase rice growers net-returns by 0.173 percent per acre. The production input labor-days is also significant and positive. The coefficient of 0.175 illustrate that a one percent increase in labor-days has increased net returns by 0.175 percent. Chemical fertilizers i.e. Urea and DAP coefficients are also positive and significant. Results shows that one percent increase in urea and DAP application could increase net returns by 0.196 and 0.0614, respectively. The estimated coefficient for irrigation is also positive, which demonstrate that rice grower's net returns per acre would increase by 0.113 percent with additional irrigation. In current study it was clearly confirmed that irrigation is an effective adaptation option to reduce the harmful effects of climate change. Ajetomobi *et al*. (2011) have reported similar findings in their study for irrigation. The coefficients of temperature and temperature square were found significant at 5% level. Results illustrate that atmospheric temperature has significant effect on net returns of rice growers in study area. The negative coefficient for square temperature shows that relationship between net revenue from rice crop and temperature is non-linear. Initially with increase in temperature net returns increase, while reaching to a critical level, further increase in temperature decreases net revenues. The hypothesis that the coefficient of square temperature would be negative when high temperature is catastrophic was supported by this study. Studies conducted by Shakoor *et al*. (2011), Ghalib *et al*. (2017) and Zhang *et al*. (2017) has reported similar findings. Khan *et al*. (2018) has also found similar results. Rainfall coefficient is positive and significant in linear form while non-significant and negative in square form. Khan *et al*. (2018) and Ghalib *et al*. (2017) has reported similar results for rainfall in wheat and maize crop. In this connection GCISC (2009) and GoP (2008) has projected that in Pakistan during summer rainfall will increase while during winter it will decrease. R-squared value is 0.85, showing that the parameters considered in this study explain 85% of the variation in growers' net return, the rest of the 15% variation is due to other factors.

Non-linear effect of temperature on net revenue of sample respondents

Table 8 shows that co-efficient of linear and square temperature terms are statistically significant. Coefficient of temperature in linear form is positive while in squared form it is negative. this indicate that relationship between temperature and grower's net returns is non-linear. The results indicates that initially with increase in temperature net revenue increase. up to a critical optimal level and then decrease. Critical temperature was estimated by differentiating the model with respect to temperature and equating it to zero being the first order condition for revenue maximization. The optimal temperature level for net revenue maximization of rice crop 31°C. At this level the net return per acre is Rs. 28729.25/. Beyond this limit net return has decreased. Figure 5 graphically represent the optimal temperature and maximum net return. The graph seem hill shaped.

Table 8: *Estimates of ricardian model.*

Variables	Coefficient	t-values	P-value
Ln (Seed)	-.07860	-0.68	0.499
Ln (Tractor hours)	. 17257	3.07	0.002
Ln (Labor days)	0.1754	4.80	0.000
Ln (Urea fertilizer)	.0196	7.97	0.000
Ln (DAP fertilizer)	.0613	3.93	0.000
Ln (Irrigation)	0.113	2.00	0.047
Ln (Average temperature)	135.424	11.69	0.000
Ln (Average temperature square)	-19.6549	-11.79	0.000
Ln (Average rainfall)	2.3667	1.70	0.092
Ln (Average rainfall square)	-0.2354	-1.75	0.0.082
Constant	-226.7963	-10.84	0.000
F statistics (9, 170) = 103.55			
Prob > F 0.0000			
Adj R- squared 0.85			

Source: *Author's estimates from survey data. Ln: Natural log.*

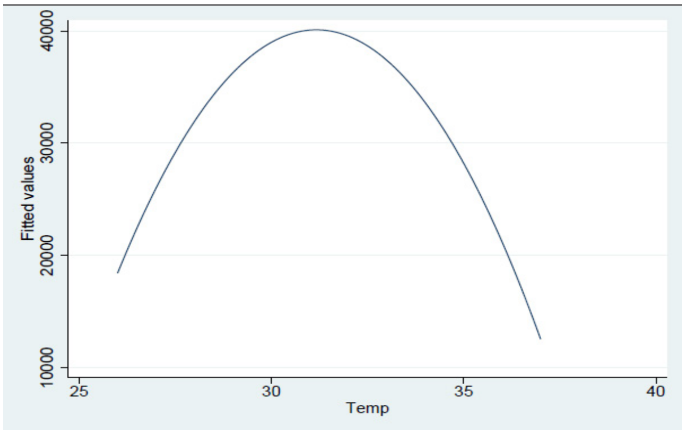

Figure 5: *Rice growers net return response curve to temperature.*
Source: *Authors' estimates from data, 2021 and estimated model.*

Rainfall and net revenue of rice crop in study area

A non-linear relationship between net return of growers and rainfall gives a U-shaped curve (Figure 6). Differencing the model with respect to rainfall give the rainfall range where the net return is minimum (Rs. 23,050/). The U-shaped graph suggest that increase in rainfall above 42 mm increase net returns of rice growers in study area.

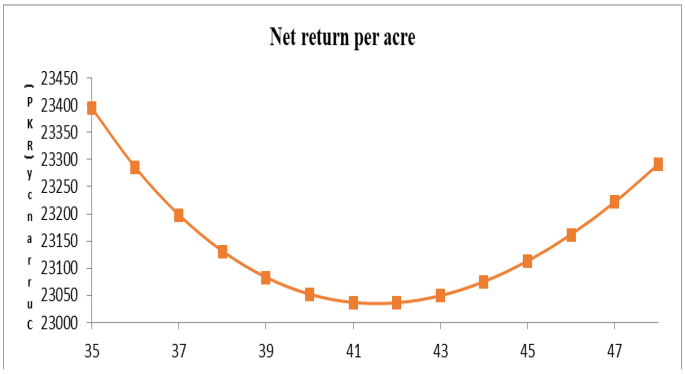

Figure 6: *Rice growers net return response curve to rainfall.*
Source: *Authors' estimates from data, 2021 and estimated model.*

Conclusions and Recommendations

Climate change has impact on net returns of rice crop growers. To evaluate economic impact of climate change on rice growers Cross-sectional Ricardain technique was employed. Primary data was collected through interviews while secondary data was sourced from Provincial Metrological Department. The temperature trend crop ranging from 1986 to 2021 shows a consistent upward slop while rainfall trend graph exhibit both increasing and decreasing lines. Simple budgeting technique was employed to arrive net returns of rice growers. Regression analysis was conducted by taking into account temperature and precipitation and other control variables such as seed, tractor hours, urea, DAP and irrigation. Analysis revealed that temperature had a positive effect on net revenue but it turned negative when temperature exceeds 31°C. The average temperature in KP was recorded 32.99 °C during crop season 2021, while in southern and central zones it was recorded 34.88 °C and 34.77 °C. The average values indicate that further increase in temperature could substantially reduce net revenue in these areas. Study noted that in 2021 southern and central zone received 28.19 mm and 31.53 mm rainfall. This suggest that increase in rainfall could increase net revenue in study area. The response curve for temperature and net revenue exhibits a hill shaped pattern, with the critical temperature value of maximizing net revenue noted at 31 °C. For rainfall, response curve indicates that a minimum average rainfall of 41mm was required having negative linear effect but a positive quadratic effect. Results suggest that rainfall above the threshold of 41 mm could increase net revenue of rice growers. The response graph shows a U-shaped pattern.

In control variables tractor hours, labor days, urea, DAP, and irrigation were noted to have positive and significant effect. An increase of 1% increase in these variables could increase corresponding net returns by 0.172, 0.175, 0.019, 0.061 and 0.113 percent respectively. Based on findings the study suggest mechanized farming practices, implementing nature-based mitigation measure such as plantation, optimizing the use of basic inputs, facilitating information sharing and taking timely actions to reduce the risks associated with climate change in study area.

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Novelty Statement

The study is novel due to the climatic factors (rainfall, temperature) were investigated zone wise in various stages of rice crop in overall Khyber Pakhtunkhwa.

Author's Contribution

Arshad Ayub: Conducted survey for data collection and worked on initial write-up.
Amjad Ali: Did part of analysis and table making.
Syed Attaullah Shah: Did the complete analysis and part of technical writing.
Abbas Ullah Jan: Proof read the manuscript and corrected it technically.

Ethical approval
The authors declare no issue regarding ethical, cultural, religious and national security related aspects in this article.

Availability of data and materials
Data will be provided on request if any.

Conflict of interest
The authors have declared no conflict of interest.

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