Research Article

Impact of Temperature and Precipitation on Net Revenue of Maize Growers in Khyber Pakhtunkhwa, Pakistan

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Abstract | This study estimated and forecasted the effect of temperature and precipitation on net revenue of maize growers across Northern, Eastern, Central and Southern zones of Khyber Pakhtunkhwa, Pakistan. 200 maize growers were randomly selected through multistage sampling technique. Primary data on net revenue from maize crop was collected through an interview schedule and secondary data on temperature and precipitation was collected from Regional Metrological Department, Peshawar. Cross sectional Ricardian Model was used to estimate the effect of temperature and precipitation on net revenue. Results of the study revealed that temperature has positive effect and temperature square has negative effect on net revenue at 10% and 5% level of significance, respectively. This means that net revenue from maize crop increases initially, as temperature increases, after reaching critical level (32.14 °C) further increase in temperature decreases net revenue. Rainfall and rainfall square has insignificant effect on net revenue of maize growers. Zone wise analysis of forecasting effects of temperature shows that increase in temperature by 1 °C in 2040-2050 and by 2 °C in 2060-2080 will significantly increase net revenue of maize growers in Northern and Eastern zones, but insignificantly in Central zone. An increase in temperature by 1 °C in 2040-2050 and by 2 °C in 2060-2080 will decrease net revenue in Southern zone. Government needs to encourage research institutes for developing temperature tolerance varieties of maize and other crops grown in Central and Southern zones of the province. Government also needs to encourage farming community of Central and Southern zones for afforestation in order to control increase in temperature.

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Introduction

United Nation Framework Convention on Climate Change (UNFCC) defined climate variation is the change in weather pattern that has circuitously impact on human activity that leads to changes the composition of global atmosphere which is experienced over comparable period of time. In the nutshell, human activities in the search of livelihood and well-being leads to emission of greenhouse gases (GHG). These greenhouse gases mainly consist of carbon dioxide (CO_2), nitrous oxides (NO_2) and methane (CH_4) (Molua, 2002). Agriculture sector of the economy is climate dependent and acts as an important part of the economic activity in developing countries. Climate change is expected to yield significant increase in the amount of hydrological events and is also probable to bring variations in temperature to extreme in this (21st) century (Cline, 2008). Due to climate change, agricultural is softly affected in term of comparative lower prices of agricultural products and rationalization of incomes within agricultural sector, changing structures of the economies as well as pattern of international trade throughout the world (Deke et al., 2001).

Climate change is a grave threat to farmer all over the globe who resides in remote, marginalized areas such as deserts, dry land and mountains and are deficient in natural resource (MoE, 2009). Global temperature in the previous decade, 2006–2015, were up-to 1°C hotter than that of the 20th century mean temperature less than a modest GHGs emissions consequence, raised to as Representative Concentration Pathway (RCP) 4.5, concentrations of atmospheric where CO_2 likely rise up to a level of 280-ppm pre-industrial reference line to further than the present 400-ppm level and on to the value of 540 ppm till the end of 21st century. Climate prediction indicates a probable warming of 1.9–4.0◦C under greater emission situation, known as RCP 8.5, CO_2 absorptions is estimated to extent to 940 ppm by 2100 and will result the temperature to rise by of 4.0–6.8◦C. Even a normal emissions state is expected to results in mean summer temperatures that exceeded the most life-threatening temperatures experienced up-to now around the world. The growing concentration of atmospheric CO_2 improves crop performance by increasing rate of photosynthesis and efficiency of water use. Carbon dioxide (CO_2) concentration increases the growth of C_3 plants more than that of C_4 plants. Climatic shifts may be accompanied with either a reduced or a boost to present yield's trend (Lobell et al., 2011).

Climate variation swings circulations of a set of climatic variables such as temperature, sun shine, rainfall, etc. It is expected that crop might change its growth rate, morphology and yield due to change in wind pattern. To be precise, high breeze speed can be destructive to plants throughout the proceedings of extreme weather conditions (Nobel, 1981; John, 1988).

Ozone (O_3) formation also increases with increasing temperature, principally above 32°C causes hindering of crop photosynthesis and its growth, as well as reducing weight of the grain and its yields particularly in maize and in other corps (Bell et al., 2007). Predicted scenarios of climate variation generally implies that global warming will decrease yields for maize and higher yield damages for the maize are projected in tropical regions. Effects of CO_2 concentrations in the air laterally with that of temperature, obtainability of water, and nitrogen restraint will tip to 25% yield losses on average for low-latitude maize (Challinor et al., 2014). International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model forecasts that inflation-adjusted prices of three of the most significant staple food like wheat, rice, and maize will be rise up to 31–106% by 2050, and expectations about climate change adaptation, mitigation, income growth, and population growth will govern the exact estimate within the given range (Nelson et al., 2010).

The events of increased temperature and extreme rainfall is also associated with climate change, it changes relationships among crops, pathogens, pests, and weeds. Thrilling weather conditions can weaken agricultural systems and abolishing crop fortifications. Extravagances in precipitation both in case of augmented rainfall and protracted drought will leads to amplified exposure of plant to parasites, pathogens, mycotoxins, and a host of injurious viruses. Amongst 612 species of pathogens and pests, investigators practiced an average pole-ward shift of 2.7 km/year in last couple of years. The whole effect of climate change on pollinators' leftovers and uncertain decrease in animal pollination is likely to decrease yields of plentiful pollinators' dependent food crops that plays a vital role in providing food and micronutrients to human. Heat confine agricultural labors in subtropical and tropical areas at a specific time, and climate change is likely to execute further bars on human concert in the years to come. Under RCP 8.5 scenario, labors during the warmest months of the year become prevalent across subtropical and tropical regions. Aquaculture perceived some remunerations from climatic affects over higher food adaptation productivity and growth rate of fish under high water temperatures, larger potential variety and protracted growing season, for aquaculture actions at advanced latitudes due to declines in sea level (Springmann et al., 2016).

Recently, both natural phenomenon, for example, atmospheric carbon dioxide variations, changes in the earth's orbital attributes, volcanic eruptions and variations in solar outputs (Masih, 2010) and human activities, such as, the speedy industrialization resulted in increased emission of carbon dioxide (CO_2), global warming, greenhouse gasses (GHGs) effect etc. (Segalstad, 1996).

Agriculture sector in terms of production and economy is greatly dependent on climate change but throughout the world including Pakistan. Maize is the third major crop after wheat and cotton grown in Pakistan. It can be grown under varied climatic conditions. It is the only crop that can be grown at any surface and any climatic region that why it is also know queen of the crops. Kharif season is the core rising season for maize and it can be sown any time during March to October. Maize needs extensive moisture and temperateness from sprouting to flowering. The appropriate temperature for propagation is 21°C and for growth 32°C. Enormously maximum temperature and little humidity through flowering injury the foliage dehydrates the pollen and delay with proper pollination, subsequent in poor grain formation. Maize is delicate to standing water, predominantly through its early periods of growth (Arain, 2013).

The susceptibility of Pakistan's agriculture is due to demographic, topographical, and dissimilar climatic situations. Mainly, the environment variations dangers to water, energy and food security. Its influences are being sensed through swelling intensity and frequency of thrilling climatic calamitous events, as well as minor, but incremental changes gradually distressing many sectors of government actions. Agricultural production eventually hinge on a vigorous balance of suitable biophysical resources, counting soil quality, water accessibility, sunlight, CO_2, temperature aptness as confirmed by works that climate variation affects the productivity of agriculture sector. Expanding of greenhouse gases will disturb the agriculture farms in developing country (Seo and Mendelsohn, 2008). Pakistan is also developing country with fewer nature resources. Climate change changes the dispersals of a set of climatic variables. Temperature and rainfall are the two most imperative climate change variable which disturb the productivity of many crops including maize. They have thoughtful influences on agricultural land values or crop yields. Along with other crops maize is also measured as one of the most susceptible crop to climate variation in terms of production and net revenue.

Hence this study was conducted across different climatic zones of Khyber Pakhtunkhwa for finding out climatic impact on maize productivity and net revenue by fulfilling the literature gap. Many countries are large enough so that different regions will have different effects within national border (Mendelsohn et al., 1994). Similarly, Khyber Pakhtunkhwa has diverse climate condition and also affected by climate change. This study may be helpful for policy makers in framing agricultural policies regarding maize crop and research institutes in developing temperature tolerance varieties of maize. This study is therefore an attempt to estimate and forecast impact of temperature and precipitation on net revenue of maize growers in Khyber Pakhtunkhwa, Pakistan.

Materials and Methods

Universe of the study

This study was conducted in four zones of Khyber Pakhtunkhwa. Khyber Pakhtunkhwa lies at 30° to 47′E, latitude and 69° to 74′E, longitude. Its altitude from 160 m in Dera Ismail Khan to 1100 m in Chitral (Appendix 1). Khyber Pakhtunkhwa province has been divided into four agro- ecological zones namely zone A, B, C and D (Inamullah and Khan, 2017). Zone A is Northern mountainous zone comprising of Chitral, Swat, Upper Dir, Lower Dir, Shangla, Buner, and Ranizai. The climatic condition of upper part of this zone is semi-Arid with mean rainfall of 250-500 mm while lower part has semi-humid climatic condition along with average rainfall of 600-750 mm. Zone B is known as Eastern mountainous zone, its upper part has sub humid climate and its mean rainfall ranging from 800-1000 mm whereas its lower part has Humid climate with average rainfall of more than 1000 mm. Districts fall in this zone are Mansehra, Batgram, Kohistan, Toorghar (Kala Dhaka), Haripur and Abbottabad. Zone C is known as Central Plain Valley. Mean rainfall in this zone ranging from 450-750 mm and climate of this zone is sub humid. Districts include in this zone are Peshawar, Mardan, Nowshera, Charsadda, Kohat, Hangu, and Swabi. Zone D which is Southern Piedmont Plain the average rainfall here is from 300 to 300 mm annually. The climatic condition of this zone is arid and semi- Arid. Districts includes are Dera Ismail Khan and Tank, Karak, Bannu and Lakki Marwat.

Sampling technique and sample size

A multistage sampling was used to select sampled respondents. In stage first, from climatic zones A, B, C and D, one district was randomly selected. In stage second, from each randomly selected district four village, from a list of major maize producing villages, were randomly selected. In the last stage 50 maize growers were randomly selected from each selected district using proportional allocation sampling technique (Cochran, 1977) as follows:

$$ni = n * (Ni/N) \quad (1)$$

Where;
ni = Sample size selected from ith village; n = Total sample size; Ni = Population of maize growers; in ith village; N = Population of maize growers in all selected villages in each district (Table 1).

Primary data on socio-economic variables such as age, education, farm size, area, fertilizers, maize output etc. were collected through a well-structured interview schedule. Secondary data on climatic variables such as temperature and precipitation were gathered from Regional Metrological Center Peshawar of Pakistan Metrological Department.

Analysis

Conceptual frame work: Impacts of climate change on agriculture is generally investigated by using two approaches. The first approach is panel-data approach (Deschênes and Greenstone, 2012) wherein long-run average land values are regressed on long-run climatic averages on year-to-year weather vacillations. Second one is the hedonic approach (Mendelsohn et al., 1994; Mendelsohn and Nordhaus, 1996; Mendelsohn and Dinar, 1999; Schelenker et al., 2005; Schelenker et al., 2006) wherein land profits (net revenues) or crop yields is regressed on weather changes in a cross-sectional setting.

Most of the past studies on climatic effects were based on experiments like agro-economic simulation models as used by Parry et al. (2004) and Adams and McCarl (1994). These studies have similar features to controlled experiments. In these studies impacts of crop yield were estimated by amending the key climatic variables. Mendelsohn et al. (1994), Mendelsohn and Nordhaus (1996) and Mendelsohn and Dinar (1999) criticized these approaches with the argument that the functions used in such studies have the tendency to overestimate the damages of climate. These studies did not include the adaptation factors in models. Thus, farmers' adaptations to climate change over time would not be captured in these models. Mendelsohn et al. (1994) and Mendelsohn and Nordhaus (1996) initiated their work to address this issue of adaptation in economic research. Mendelsohn, et al. (1994) introduced the application of Ricardian approach (Ricardo, 1817) for measuring impacts of climatic variables on agriculture.

Mendelsohn utilized two models to the impacts of climatic factors on crops. In one model, crop revenue was used as dependent variable while in second model cropland was used as regress and (Mendelsohn et al., 1994). Crop-revenue model has the advantage that it also implicitly encompasses the adaptation response by farmers to local climate (Darwin, 1999).

The elementary clue of the Ricardian approach is that agricultural and land values accomplishes are linked with climate (ecological variable): the productivity of a crop is a function of an environmental factors like mean temperature and precipitation. Environmental influences affect output by altering the productivity of inputs, by changing output that are produced, or by dropping the actual supply of inputs.

The production function is as follows:

$$Q_i = Q_i(K_i, E) \quad (2)$$

Where; Q_i is quantity produced; K_i is vector of purchased input while E is exogenous environmental inputs like temperature, rainfall, sunshine etc.

Empirical model: For analyzing impact of temperature and precipitation on net revenue, cost of maize production, total revenue and net revenue were estimated as follows (Debertin, 2012; Varian, 1992):

$$Net\ Revenue = Total\ Revenue - Total\ Cost \quad (3)$$

Where;

$$Total\ Revenue = PY_i * Y_1 + PY_2 * Y_2 \quad (4)$$

$$Total\ Cost = \sum PX_i * Xi \quad (5)$$

Net Revenue = Net Revenue from maize output (Rs per acre); Total Revenue = Total revenue from maize output (Rs per acre); Total Cost = Total cost of maize production (Rs per acre); PY_1 = Price of main product (maize grain) (Rs per kg); PY_2 = Price of by-product (maize straw) (Rs per kg); Y_1 = Output of main product (kgs per acre); Y_2 = Output of by-product (kgs per acre); Xi = Inputs applied (units per acre); PX_i = Prices of inputs (Rs per unit).

Cost of production of maize crop was estimated as the sum total of land rent, seed cost, cost of tractor, cost of bullock plough, cost of labor, cost of DAP, cost of urea, cost of FYM, cost of chemicals, cost of irrigation, and threshing cost. All these cost items were estimated on per acre basis. Prevailing market prices of inputs and output were considered for cost estimation and net revenue.

After estimation of net revenue, model (6) was used to model the impact of temperature and precipitation on net revenue of maize growers. Additionally, control variables such as seed, tractor, labor, fertilizers, irrigation etc. were also included to capture their effect on net revenue of maize growers as follows:

$$NR_i = \alpha_0 + \alpha_1 T_i + \alpha_2 T_i^2 + \alpha_3 P_i + \alpha_4 P_i^2 + \Sigma\, \partial j\, Fji + \mu_i \quad (6)$$

Where;
NR_i = Net revenue of ith farmer (Rs/acre); T_i = Temp in °C; T_i^2 = (Temp)^2 in °C; P_i = Precipitation in mm; P_i^2 = (Precipitation)^2 in mm; F_1 = Seed dummy; Hybrid seed = 1, Local seed = 0; F_2 = Tractor (hours/acre); F_3 = Labor (labor days/acre); F_4 = DAP (bags/acre); 1 bag = 50 kg; F_5 = Urea (bags/acre); 1 bag = 50 kg; F_6 = Farm Yard Manure (trolleys/acre); 1 trolly ≈ 3000 kg; F_7 = Chemicals (milliliters/acre); F_8 = Irrigation dummy; irrigated farm = 1, Rain fed = 0; α_0 = Intercept α_i = Parameters of temperature and precipitation to be estimated; ∂j = Parameters of inputs to be estimated; μ_i = Stochastic error term.

Post estimation diagnostic tests: Histogram of residuals was constructed to check the normal distribution of error terms. Histogram depicts symmetric distribution suggesting normality of residuals (Appendix 2). VIF results show that the explanatory variables are not linearly correlated with each other. Higher VIF values of temperature, temperature^2, rainfall and rainfall^2 are due to the fact that there square terms are also included in the model to capture their intensive effects on net revenue. Moreover, it is the requirement of functional form of the model to incorporate square terms of these variables (Appendix 3). Breusch-Pagan/Cook-Weisberg test was used to check heteroscedasticity in the model. The estimated Chi Square value was 57.99 and statistically significant at 0.01 α (p-value = 0.0000) suggesting that the model is plagued with the problem of heteroscedasticity. To overcome this problem, robust command was used in Stata 12.

Results and Discussion

Gross and net revenue from maize crop
Table 2 shows that the average gross revenue per acre from maize main product as well as by product in all districts was Rs. 30014.148 per acre. On average, gross revenue was Rs. 27134.091, Rs. 27924.921, Rs. 32342.290, and Rs. 32655.290 in Upper Dir, Abbottabad, Peshawar and Lakki Marwat, respectively. Net revenue was calculated by subtracting total cost of production from total gross revenue. On average net revenue in all districts was Rs. 5251.621 per acre. Highest net revenue per acre from maize crop was in Peshawar (Rs. 6805.850) followed by Lakki Marwat (Rs. 6284.540), Abbottabad (Rs. 4908.801) and Upper Dir (Rs. 3007.291).

Table 1: *Sampling procedure and sample size.*

Climatic Zones	Sampled districts	Sampled villages	Population of maize growers	Sampled maize growers
Northern Zone (A)	Upper Dir	Usheri	50	10.87 ≈ 11
		Khas Chappar	60	13.04 ≈ 13
		Wari	65	14.13 ≈ 14
		Gul Banda	55	11.95 ≈ 12
		Sub total	230	50.00
Eastern Zone (B)	Abbottabad	Dothar	60	16.67 ≈ 17
		Banda Saeed Khan	39	10.83 ≈ 11
		Sherwan	45	12.50 ≈ 12
		Sunyara	36	10.00 ≈ 10
		Sub total	180	50.00
Central Zone (C)	Peshawar	Shahi Payan	52	08.52 ≈ 8
		Regi	110	18.03 ≈ 18
		Wazir Colony	66	10.82 ≈ 11
		Faqeer Kalay	77	12.62 ≈ 13
		Sub total	305	50.00
Southern Zone (D)	Lakki Marwat	Taja Zai	50	09.30 ≈ 9
		Gandi Umar Chaki	110	20.45 ≈ 21
		Shahbaz Khel	55	10.22 ≈ 10
		Kot Kashmir	54	10.04 ≈ 10
		Sub total	269	50.00
All Zones	All Districts	Total	984	200

Source: *Govt. of Khyber Pakhtunkhwa, 2017.*

Descriptive statistics
Table 3 depicts descriptive statistics of variables used for model estimation. Mean value of net revenue was

5251.621 with std. dev. of 11083.120 ranging from -13757.330 to 59010.000. Mean value of hybrid and local seed was 0.20 with std. dev. of 0.401 ranging from 0 to 1. Average tractor hours applied for land preparation was 2.553 with std. dev. of 1.802 ranging from 0 to 5.556. Mean number of labor days was 15.446 with std. dev. of 6.631 ranging from 10. 234 to 25.000. Mean quantity of DAP applied was 0.496 with std. dev. of 0.435 ranging from 0.000 to 1.000. Average quantity of urea used was 1.145 with std. dev. of 1.035 ranging from 0.000 to 2.760. Mean value of FYM was 0.471 trolley with std. dev. of 0.555 ranging from 0.000 to 1.500. Mean quantity of chemical sprayed was 0.404 liters with std. dev. of 0.763 ranging from 0.000 to 1.216. Mean value of irrigate and rain fed was 0.490 with std. dev. of 0.501 ranging from 0.000 to 1.000. Mean temperature for given season was 27.500 °C with std. dev. of 3.210 ranging from 24.000 to 32.000. Mean rainfall for given season was 74.500 mm with std. dev. of 28.481 ranging from 25.700 to 96.500.

Estimates of regression analysis

Table 4 presents estimates of regression analysis of maize growers. Results show that hybrid seed has positive and significant effect on net revenue at 1% level of significance. Farmers used hybrid seed has Rs. 12916 more net revenue by per acre as compared to those farmers who applied local varieties. DAP has positive and significant effect on net revenue at 1% level of significance. The use of 1 bag of DAP increased net revenue by Rs. 3791.697 per acre. Irrigation has positive and significant effect on net revenue at 1% level of significance. Farmers having irrigation water earned more net revenue of Rs. 11584.57 per acre as compared to rain fed farmers. Tractor, labor, urea, FYM and chemicals have insignificant effect on net revenue of maize growers.

Temperature and temperature square has significant effect on net revenue at 10% and 5% level of significance, respectively. The coefficients of linear and squared temperature terms are statistically significant. The significance of the coefficients for the squared

Table 2: *Gross and net revenue from maize crop (Rs/Acre) .*

Variables	Upper Dir	Abbottabad	Peshawar	Lakki Marwat	KP
GR from main product	18751.980	18527.191	22351.290	22567.600	20549.515
GR from by-product	8382.111	9397.730	9991.000	10087.690	9464.633
Total GR	27134.091	27924.921	32342.290	32655.290	30014.148
Total cost of Production	24126.800	23016.120	25536.440	26370.750	24762.528
Net Revenue	3007.291	4908.801	6805.850	6284.540	5251.621

Source: *Authors' estimates from survey data, 2017;* **GR:** *Gross revenue.*

Table 3: *Summary statistics of variables used in the model.*

Variables	Units	Mean	Std. Dev.	Min	Max
Net Revenue	Rupees	5251.621	11083.120	-13757.330	59010.000
Seed	Dummy	0.200	0.401	0.000	1.000
Tractor	Hours	2.553	1.802	0.000	5.556
Labor	Man days	15.446	6.631	10.234	25.000
DAP	Bags	0.496	0.435	0.000	1.000
Urea	Bags	1.145	1.035	0.000	11.000
FYM	Trolleys	0.471	0.555	0.000	1.500
Chemicals	Liters	0.404	0.763	0.000	1.216
Irrigation	Dummy	0.490	0.501	0.000	1.000
Temp	Centigrade (°C)	27.500	3.210	24.000	32.000
$(Temp)^2$	Centigrade (°C)	721.079	214.727	386.123	979.690
Rainfall	Millimeter (mm)	74.500	28.481	25.700	96.500
$(Rainfall)^2$	Millimeter (mm)	6061.316	3255.713	470.890	9312.250

Source: *Authors' estimates from data, 2017.*

Table 4: *Estimates of regression analysis (Dependent variable = Net revenue).*

Variable	Coefficients	Std. Dev.	t-ratio	p-value
Constant	- 44523.100	34366.700	- 1.300	0.197
Seed (dummy)	12916.020	2069.557	6.240	0.000***
Tractor (hours/acre)	70.974	433.765	0.160	0.870
Labor (days/acre)	- 138.890	102.402	- 1.360	0.177
DAP (bags/acre)	3791.697	1562.159	2.430	0.016**
Urea (bags/acre)	- 606.714	607.824	- 1.000	0.319
FYM (trolleys/acre)	264.177	1276.846	0.210	0.836
Chemicals(liter/acre)	896.871	875.209	1.020	0.307
Irrigation	11584.570	2676.543	4.330	0.000***
Temp. (°C)	4414.253	2622.068	1.680	0.094
Temp. square (°C)	-68.652	34.560	- 1.990	0.048**
Rainfall (mm)	- 416.870	307.250	- 1.360	0.176
Rainfall square(mm)	0.161	2.545	0.060	0.950
F (12, 187)	10.96			
R-squared	0.4875			

Source: *Authors' estimates from data, 2017; ** indicates 5% level of significance and *** indicates 1% level of significance.*

temperature term indicate that the relationship between farmers' net revenue from maize crops and temperature is non-linear. The coefficients of the linear term is positive and that for the squared term is negative indicating that initially, net revenue from maize crop increases as temperature increases. After reaching critical level further increase in temperature decreases net revenue. These results are in conformity with the findings of Arain (2013), Gbetibouo and Hasan (2005), Shakoor et al. (2011), Ghalib et al. (2017) and Zhang et al. (2017). Rainfall and rainfall square has insignificant effect on net revenue of maize growers. Similar results were also found by GoP (2008) and GCISC (2009). According to GoP (2008) and GCISC (2009) projected rainfall will increase slightly in summer and will decrease in winter with no significant change in rainfall. Spatial pattern shows a non-significant increase in rainfall (5–15 %).

Measuring non-linear effects of temperature on net revenue

As the estimated coefficients of linear and squared temperature terms are statistically significant. The significance of coefficient for the squared temperature indicates that the relationship between net revenue and temperature is non-linear. The coefficient of linear term is positive and that of the squared term is negative. These estimated coefficients indicate that initially net revenue increases as temperature increase. After reaching critical temperature level further increase in temperature decreases net revenue (Figure 1).

Critical temperature was estimated by using the short version of estimated model as follows:

$\partial NR / \partial T = 4414.253 - 137.303\, T$ (7)

∂ NR / ∂ T = 0 (First order condition for net revenue maximization w.r.t. temperature) (8)

$4414.253 - 137.303\, T = 0$ (9)

$T = 4414.253 / 137.303 = 32.14$ °C (10)

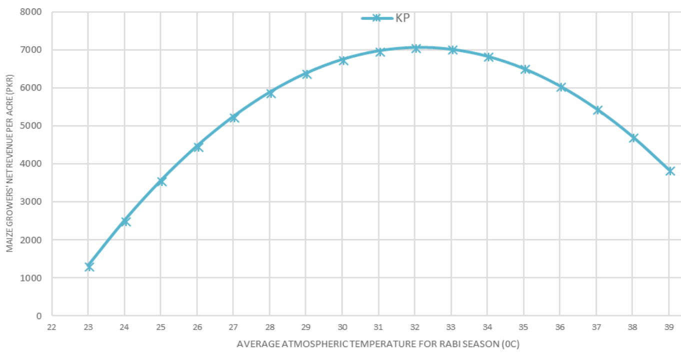

Figure 1: *Measuring non-linear effect of temperature on net revenue.*
Source: *Authors' estimates from data, 2017 and estimated model.*

Table 5: *Forecasting effects of temperature on net revenue in different climatic zones (Rs/Acre).*

Climate change scenarios		Upper Dir (Zone A)	Abbottabad (Zone B)	Peshawar (Zone C)	Lakki Marwat (Zone D)	KP
Average monthy temp. in 2017		24.00 °C	25.00 °C	29.00 °C	32.00 °C	27.5 °C
2017-2018 scenario	Net Revenue (2017)	3007.291	4908.801	6805.850	6284.540	5251.621
Increase in Temp. by 1°C (2040-2050 scenario)	Net Revenue	4057.612	5821.819	7169.654	6236.434	5890.032
	Change in net revenue	1050.321 (34.926%)	913.018 (18.600%)	363.804 (5.345%)	-48.106 (- 0.765%)	638.411 (12.156%)
Increase in Temp. by 2 °C (2060-2080 scenario)	Net Revenue	4970.630	6597.533	7396.156	6051.026	6391.139
	Change in net revenue	1963.339 (65.286%)	1688.732 (34.402%)	590.306 (8.674%)	-233.514 (- 3.716%)	1139.519 (21.698%)

Source: *Authors' estimates from data, 2017.*

$\partial (\partial NR / \partial T) / \partial T = - 137.303$ (Second order condition for net revenue maximization) (11)

Negative sign of the second derivative of net revenue function w.r.t. temperature ensures that the net revenue is maximum at 32.14 °C. Hence optimal temperature level for net revenue maximization of maize growers is 32.14 °C. These findings are in accordance with the results of Arain (2013) and Zhang et al. (2017).

Forecasting effects of temperature on net revenue in different climatic zones

According to Global Change Impact Studies Center (GCISC) and Pakistan Metrological Department (PMD) studies conducted on climate trends, during the past century, average annual temperature increased by 0.6 °C, at the rate of 0.06 °C per decade. These estimates are in accordance with global trend. Several Global Circulation Models project studies shows that average temperature in Pakistan will increase progressively by 2.8 – 3.4 °C up to 2100. Projected increase in temperature in Pakistan 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) and GCISC (2009).

Table 5 presents forecasted net revenue from maize crop in different climatic change scenarios. An increase in temperature by 1 °C in 2040-2050 will increase net revenue by 12.156 % and if temperature increase by 2 °C in 2060-2080 net revenue will increase by 21.698 % for whole Khyber Pakhtunkhwa. Zone-wise analysis shows that an increase in temperature by 1 °C in 2040-2050 will increase net revenue by 34.926 % in Northern zone and by 18.600 % in Eastern zone. If temperature increases by 2 °C in 2060-2080 net revenue will increase by 65.286 % in Northern zone and by 34.402 % in Eastern zone. As average monthly temperature in these zones is below 32.14 °C, therefore increase in temperature in these zones will increase net revenue of maize growers. An increase in temperature in Central zone by 1 °C in 2040-2050 will increase net revenue by 5.345 % and if temperature increases by 2 °C in 2060-2080 net revenue will increase by 8.674 %. As average monthly temperature in this zones is near to 32.14 °C, therefore increase in temperature will not significantly change net revenue of maize growers. In the Southern zone, increase in temperature by 1 °C in 2040-2050 will decrease net revenue by 0.765 % and if temperature increases by 2 °C in 2060-2080 net revenue will decrease by 3.716%. Reason for decrease in net revenue is that average monthly temperature in Southern zone in maize season is approximately equal to critical temperature.

Conclusions and Recommendations

It is concluded that temperature has positive effect and temperature square has negative effect on net revenue. This means that initially, net revenue from maize crop increases as temperature increases, after reaching critical level (32.14 °C) further increase in temperature decreases net revenue. Rainfall and rainfall square has insignificant effect on net revenue of maize growers. Forecasting effects of temperature shows that increase in temperature by 1 °C in 2040-2050 and by 2 °C in 2060-2080 will significantly increase net revenue of maize growers in Northern and Eastern zones, but insignificantly in central zone. An increase in temperature by 1 °C in 2040-2050 and by 2°C in 2060-2080 will decrease net revenue in Southern zone. Reason for decrease in net revenue is that average monthly temperature in Southern zone in maize season is approximately equal to critical temperature.

Hybrid seed is most profitable and has positive effect on net revenue. It is recommended that farmers should grow hybrid maize verities which will increase their net revenue. The use of water is important for maize net revenue. It is recommended that installation of tube wells in Khyber Pakhtunkhwa is very important for net revenue. DAP is also one of the most important chemical fertilizers for increasing net revenue. It is recommended that government needs to subsidized DAP, because it is costly and marginalized farmers can't afford it. Government needs to encourage research institutes for developing temperature tolerance varieties of maize and other crops grown in Central and Southern zone of the province. It is recommended that government needs to encourage farming community of Central and Southern zones for afforestation which control temperature.

Author's Contribution

Aftab Khan: Conducted the study, reviewed literature, wrote introduction and methodology.
Shahid Ali: Developed main theme of the research, wrote abstract, conclusions and recommendations, provided technical input at every step.
Syed Attaullah Shah: Provided guidance in model

development and in analyzing collected data.
Muhammad Fayaz: performed proof reading of the draft and corrected references.

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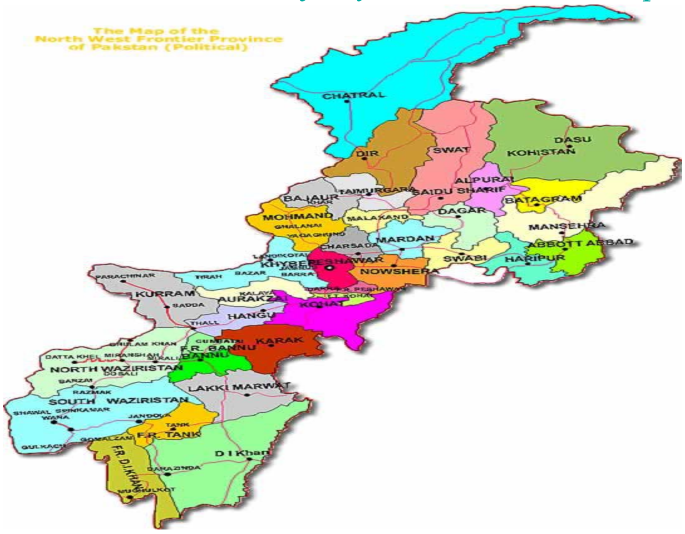
Appendix 1

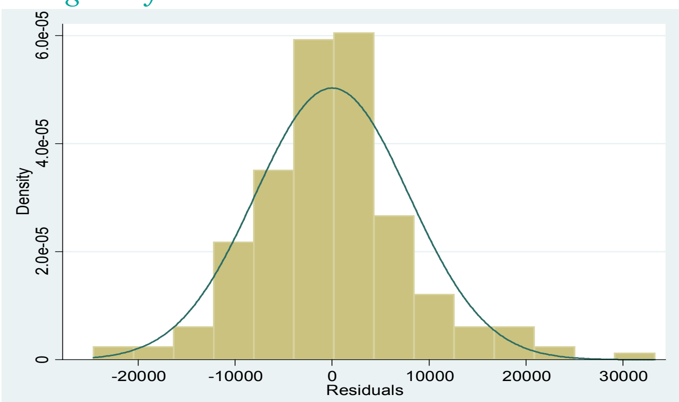
Zones wise distribution of Khyber Pakhtunkhwa, Map.



Source: *SMEDA.*

Appendix 2

Histogram of residuals.



Source: *Estimated from the residuals of estimated model.*

Appendix 3

VIF (variance inflation factors) results.

Variables	VIF	1/VIF
Seed	1.420	0.705
Tractor	1.500	0.668
Labor	1.750	0.571
DAP	1.250	0.800
Urea	1.450	0.692
FYM	1.280	0.778
Chemical	1.250	0.801
Irrigation	3.250	0.308
Mean VIF	1.644	0.665
Temp.	279.740	0.004
$(\text{Temp.})^2$	222.230	0.005
Rainfall	171.310	0.006
$(\text{Rainfall})^2$	131.290	0.008

Source: *Authors' estimates from data, 2017.*