Research Article

Assessing the Impact of Climate Change on Wheat Productivity in Khyber Pakhtunkhwa, Pakistan

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Abstract | The central theme of this research study was to assess the impact of climate change on wheat productivity in Khyber Pakhtunkhwa (KP) Province, Pakistan. The nexus of wheat productivity with selected climatic variables that includes temperature, precipitation and humidity was also inquired through this research. Panel data of wheat crop's input and aforesaid climatic variables for the period of thirty years (1985-2015) was employed to figure-out the major findings. Econometric diagnostic tests were used to verify the model stability. Therefore, LM test was encompassed to detect the serial correlation. The result of Hausman test has suggested applying "Fixed Effect Model" for further analysis. Major estimates of the overall 30 years data reveal that among non-climatic variables, area under wheat cultivation and seed are highly significant to the wheat yield at 1 percent level of significance. Whereas, contribution of fertilizer to wheat crop in KP province was observed insignificant. Furthermore, the computation of climatic variables depicts that temperature contributes significantly but has inverse association with wheat yield in KP province. This implies that surge in temperature by one Celsius degree centigrade (^{0}C) can drop-down the wheat yield by 0.074 percent. The impact of precipitation was also observed negative with wheat crop in the panel data since 1985 to 2000. This study concludes that temperature and precipitation have inverse association with wheat production while humidity is positively associated. Overall scenario concludes that not only climatic variable but also major wheat crop's input are significantly associated to wheat yield in the study area. This research study recommends that government and concerned policy-makers may give due attention to construct the climate change policy for climate change adaptation strategies and provide heat resistant wheat crop varieties to the farming community.

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Introduction

The current global scenario and evidences of changing climate has drawn the attention of think-tanks to keep track on the considerable association between climate trend and agriculture sector. Climate change is one of the emerging issues of the world which need to be tackled through coping mechanism to provide the safeguard to the concerned stakeholders. Over the period of time, potential impact of climate is being testified on ecological, economic and social features of the human life. Deviation in climate variables such as variation in temperature, solar radiation, evaporation, humidity and rainfall pattern is experienced across the globe (Aggarwal et. al., 2010).

Agriculture sector is deemed as more vulnerable to climate change as its variation can directly affect the crop productivity as evident by Amiraslany (2010). The International Panel on Climate Change (IPCC) has highlighted that agriculture system, energy, seaside constructions and water are considered to be more prone to the variation in climate. Agricultural production is predominantly based on meteorological conditions and irrigation system. More importantly, the rain-fed areas are highly dependent upon the rain water availability therefore, long dry spell holds severe extortions to the economy of the country (Manickam, 2012).

Pakistan being a developing country and having agrarian based economy is visibly susceptible to the climate change. The United Nations Development Program (UNDP, 2015) has figured-out that Pakistan is measured to be one of the supreme liable countries which are climatic sensitive on the globe. Climate change is believed to be one of the major risks to the agriculture realm and livestock of Pakistan. Climate change interruption in Pakistan has more antagonistic impacts on the farming zone, livestock and famer's socio-economic condition in rural areas of Pakistan. These variations knockout poor and populated areas that are dependent on agriculture sector for their livelihood. Pakistan is counted to be one of the 12 extremely climate sensitive countries reported by World Bank. Surge in temperature, torrential rains, famine due to dry spell and inconsistency in production are the significant hinderers to economic sector of Pakistan (Shakoor, 2011).

The consequences of changing climatic have a close nexus to farming sector specially crops production. Climate parameters which directly affect the agriculture crops encompassed trends in rainfall pattern, variation in time of propagation and harvesting and deviation in temperature. Moreover, changing climate wreaked the crop production along with causing health issues to livestock, which leads to the dearth of food grains in the country.

Previous research study undertaken by Ashfaq et al. (2011), illustrates that the influence on the wheat production owing to climatic factors is more prevailing than non-climatic factors in Pakistan. The same positive impact on the wheat productivity was confirmed in Punjab. According to the annual report of the State Bank of Pakistan (SBP), it was elucidated that climate change was considered to be a huge disaster towards economic condition of Pakistan leading food insecurity in the country. It was forestalled that by 2020 there will be 1.5 to 2.6 percent decline in wheat production. It is also observed that due to climate change the wheat and rice season has been shorten which can leads to bad harvest of the said food crops in Pakistan.

Khyber Pakhtunkhwa province is an iconic province that is considered as horticultural zone of country's agriculture sector. While, cereal crops such as wheat and maize are the major focus of the peasants in this province. Particularly wheat crop is cultivated more by the famers as this is a staple food of the province as well. Wheat is grown on large area of KP province and it occupies 48 percent of the total cropped area and 57 percent of the area grown to cereals in the province.

Justification of the study

Regardless of the fact that Pakistan is among the most vulnerable countries to climate change, there is still dearth of research endeavors undertaken in the realm of climate change impact on agriculture sector. Several international research studies have confirmed that there will be substantial decline in per hectare yield of the major crops such as wheat, rice and maize owing to climate change. According to the recent study carried out by Israr et al. (2016) reported that change in climate has caused detrimental influences on the agriculture production and productive resources all over the KP province. This scenario can lead to complications to feed the burgeoning population of the Pakistan. Therefore, this study has made an attempt to inquire the nexus between the climate parameters and wheat crop productivity of KP province, Pakistan.

Objectives of the study

The specific objectives of this research endeavor are (1): To examine the impact of selected climatic variables on wheat productivity in study area and (2): To assess the non-climatic factors that can significantly contribute to the wheat yield.

Materials and Methods

Study universe

This research study has made an attempt to consider the overall Khyber Pakhtunkhwa (KP) Province as study universe. The KP province situated in North

West of Pakistan covering an area of 75521 square kilometers. However, the research study was restricted to those districts. However, to narrow down the selection criteria those districts were chosen which were nearby to the Climate Stations and are deemed as wheat producing districts. The climate stations and selected districts are mentioned in Table 1.

Table 1: *Name of climatic stations and selected districts.*

S. No.	Climate Stations	Selected Districts
1	Peshawar	Peshawar, Charsadda, Mardan
2	Dera Ismail Khan (D.I. Khan)	D. I. Khan, Lakki Marwat
3	Cherat	Nowshera, Sawabi
4	Dir	Dir Upper, Dir Lower
5	Kakul	Haripur
6	Balakot	Mansehra
7	Saidu Sharif	Swat
8	Chitral	Chitral

Source: *Pakistan meteorological department.*

Data type and description

Panel data: This type of data contains observations on the same individual or cross sectional entity over several period of time. This research study involves wheat season's panel data (both crop's input and climatic variables which prolong up to 6 months in Pakistan) for the period of 30 years. In more pragmatic way the researchers are now in better position to use blend of cross-sectional and time-series data to observe matters that could not be studied thoroughly in single data set like cross-sectional or time-series (Greene, 2002). The general form of regression of panel data can be presented by:

$$y_{it} = \alpha_i + x_{it}\beta + \varepsilon_{it} \quad i=1\ldots\ldots N,\ t=1\ldots\ldots T \quad \ldots\ldots (1)$$

Where;
subscript *i* shows the cross sectional aspect while *t* indicates time series dimension. Baltagi (2008) stated that majority of panel data estimation uses one-way error factor model for disturbances.

$$u_{it} = \alpha_i + \varepsilon_{it} \quad \ldots\ldots (2)$$

Where;
Composite error term, μ_{it} is the blend of city specific error factor, α_i and individual specific error factor, ε_{it}.

Estimation techniques

Pooled model: The nature of pooled model is not very much different from the general regression equation. This model deals with every single observation which varies from other observation irrespective of the time and panels. A general equation of pooled model with n factor can be expressed as:

$$y_{it} = \alpha_0 + \alpha_1 x_{1,it} + \alpha_2 x_{2,it} + \cdots + \alpha_n x_{n,it} + \varepsilon_{it} \quad \ldots\ldots (3)$$

Fixed effects model: Fixed-effects (FE) model depicts the relationship between explained and explanatory variables within an individual variable. Each individual has its own discrete features which may or may not affect the independent variables. This approach is applied when researchers are more concerned to analyze the impact of factors that are time variant because a time invariant features cannot bring changes because it is considered as constant for each individual. Moreover, this model handles the unseen heterogeneity. This model with n factors can be written as:

$$y_{it} = \alpha_i + \beta_1 x_{1,it} + \beta_2 x_{2,} + \cdots + \beta_n x_{n,it} + \varepsilon_{it} \quad \ldots\ldots (4)$$

Fixed effect model does not have any constant term ($\alpha_{0,}$ like in pooled model) but it has an entity specific factor α_i which governs an exclusive intercept for every individual. The parameters (the β slopes) are similar for all the individuals.

Basically, the fixed effect estimator grips the unnoticed time invariant factor of the dependent parameter which means that the variation in the intercept is due to cross sections but the slopes do not change because agriculture production of every district varies from each other. FE model is assessed after data is being pooled which is based on the time demeaned factors, called within estimation (Baltagi, 2008).

Model Specification: The model was specified in log-log form as we were interested to estimate the elasticity through coefficients of the variable. The specific model is given as below:

$$LnY = \beta_0 ++ \beta_1 LnAr + \beta_2 LnSed + \beta_3 LnFer + \beta_4 LnTem + \beta_5 LnPre ++ \beta_6 LnHum + U_{it} \quad \ldots\ldots (5)$$

Where;
Y = Wheat Yield (Mound); β = Coefficient to be estimated; Ar = Area under wheat production (Acre); Sed = Seed used (in Kgs); Fer = Fertilizer application (50 Kgs Bag); Tem = Temperature (^{0}C); Pre =

Precipitation (mm); Hum = Humidity (percent); Ln = Natural Logarithm; i = number of climate station; t = Number of years; U = Composite error term.

Data source used: The data set regarding wheat production and its major inputs was gleaned from office of Agriculture Statistics of Khyber Paktunkwa (KP) Province. The data on climatic parameters are acquired from the Pakistan Meteorological Department (PMD), Peshawar, KP.

Econometric diagnosis

Lagrange Multiplier (LM) test: As panel data is consisted of both cross sectional and time series data so this can cause the problems related to both the datasets. For example, the cross sectional data can be encountered with the problem of multicollinearity, heteroscedasticity and time series data can have the issue of autocorrelation. Apart from this, there could be some other issues regarding panel data such as there could be cross correlation in individual entities at the same spot in time as demonstrated by Gujarati (2003). There are number of tests to check the heteroscedasticity and serial correlation while dealing with panel data. Lagrange Multiplier (LM) was derived by Baltagi and Li (1995) to test the incidence of heteroscedasticity and serial correlation during panel data analysis.

In case of this study Breusch–Godfrey (BG) serial correlation LM test is applied in order to see correlation in the errors in a regression model. As it makes use of the residuals from the model being considered in a regression analysis, and a test statistic is derived from these.

Null (H_0) and alternative(H_1) hypotheses are formulated as:

H_0: No serial correlation of any order up to p
H_1: serial correlation of any order up to p

Hausman test: Practical work with panel data set necessitates a choice on how to deal with individual specific effects which means that whether to choose fixed effect model or random effect model (Hausman,1978). This test gauges the steadiness of an estimator when it has been compared to another, less effectual, estimator which is already identified to be reliable. They further added that it is a Chi-square ($\chi2$) test which is based on Wald criterion (W). The Wald Criterion is expressed as:

$$W=(b^{RE}-b^{FE})[Var\ (b^{RE}-b^{FE})]^{-1}(b^{RE}-b^{FE})\sim\chi^2(k) \quad \dots (6)$$

Where;
RE = random effects; FE = fixed effects; k = the degrees of freedom; b = coefficient values; var = variance.

Null (H_0) and alternative(H_1) hypotheses are formulated as:

H_0: The Random effects is fitting model.
H_1: The Fixed effects is fitting model.

If W exceeds the critical $\chi2$ value at suitable degree of freedom and at significance level of 5 percent, then theH_0 presenting uncorrelated individual effects with rest of the regressors used in the model will be rejected and fixed effects model will be used.

Results and Discussion

Descriptive statistics

The major climatic variables which include temperature, precipitation and humidity of KP Province are presented in Table 2. Descriptive statistics of the aforementioned climatic variables is demonstrating range, mean and standard deviation of each variable. The glance of these variables for the period of thirty years (1985-2015) exemplify that mean minimum-temperature observed during the wheat crop season was 7.67 ^{0}C. While maximum average temperature was reported as 18.26 during the crop season. Similarly, descriptive statistics of other variables such as humidity and precipitation was estimated and given in Table 2.

Table 2: *Descriptive statistic of climatic variables during wheat Season (1985-2015).*

Variables	Min	Max	Mean	S.D.
Temperature (Low ^{0}C/ Min)	2.44	8.99	7.67	1.49
Temperature (High ^{0}C/Max)	15.67	20.22	18.26	1.16
Humidity (percent at 8 am)	54.64	75.85	68.77	4.43
Humidity (percent at 5 pm)	38.48	52.32	46.29	3.29
Precipitation (mm)	30.08	102.4	73.10	16.42

Source: *Author's own estimation from available Panel Data (1985-2015.*

Trend of temperature

The line graph on temperature from the year 1985 to 2015 is underscoring the erratic trend between 12 to 18 ^{0}C during wheat crop season over the period of 30 years in Figure 1. The average annual temperature

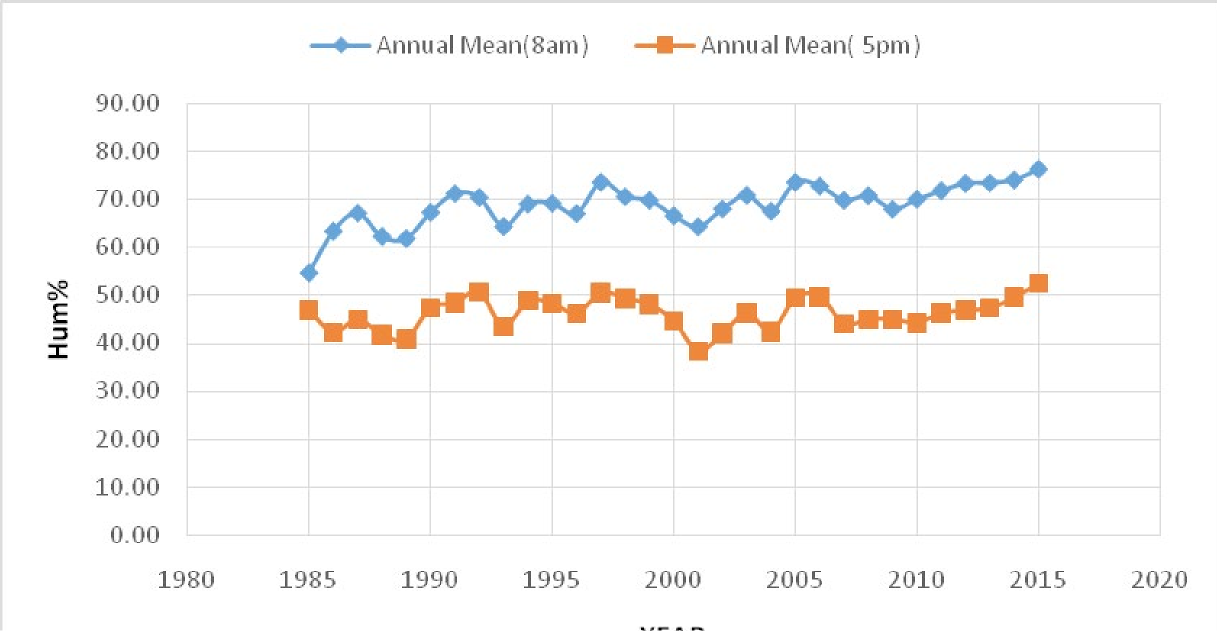

Figure 1: *Volatility trend of Average Annual Temperature (1985-2015).*
Source: *Authors own estimations through panel data (1985-2015), Pakistan meteorological department, Peshawar.*

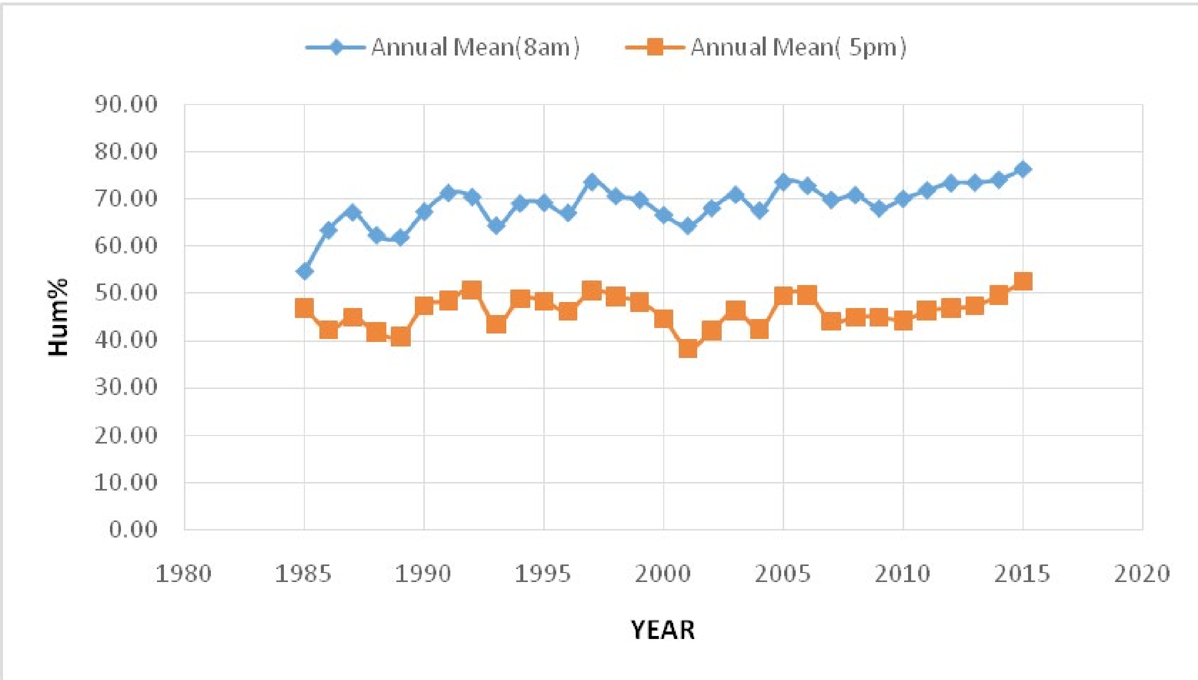

Figure 2: *Erratic trend of Average Annual Humidity (1985-2015).*
Source: *Authors own estimations through panel data, Pakistan meteorological department, Peshawar.*

range was being recorded 12.46 ^{0}C in the year 1995 and 16.10 ^{0}C in the year 1999. According to the Pakistan meteorological department the average annual temperature for the year 2011 revealed higher level as compare to the previous year's average annual temperature. Similar temperature trend was reported from the given figure i.e. in the year 2011 average annual temperature is measured as 14.85 ^{0}C which is higher than the reading 13.83 ^{0}C in the year 2010.

Trend of humidity

The two sporadic lines in Figure 2 reveal an average annual humidity recorded at 8 am and 5 pm for 30 years. The average annual humidity at 8 am (morning) is observed higher than the readings which were recorded at 5 pm (evening) from 1985-2015. There is a wave like change in the values noted from the year 1985 to 1999 but the pattern of the trend is somehow similar in both the series. After 2000, there is a slight uplift with semi-linear association of humidity with the year.

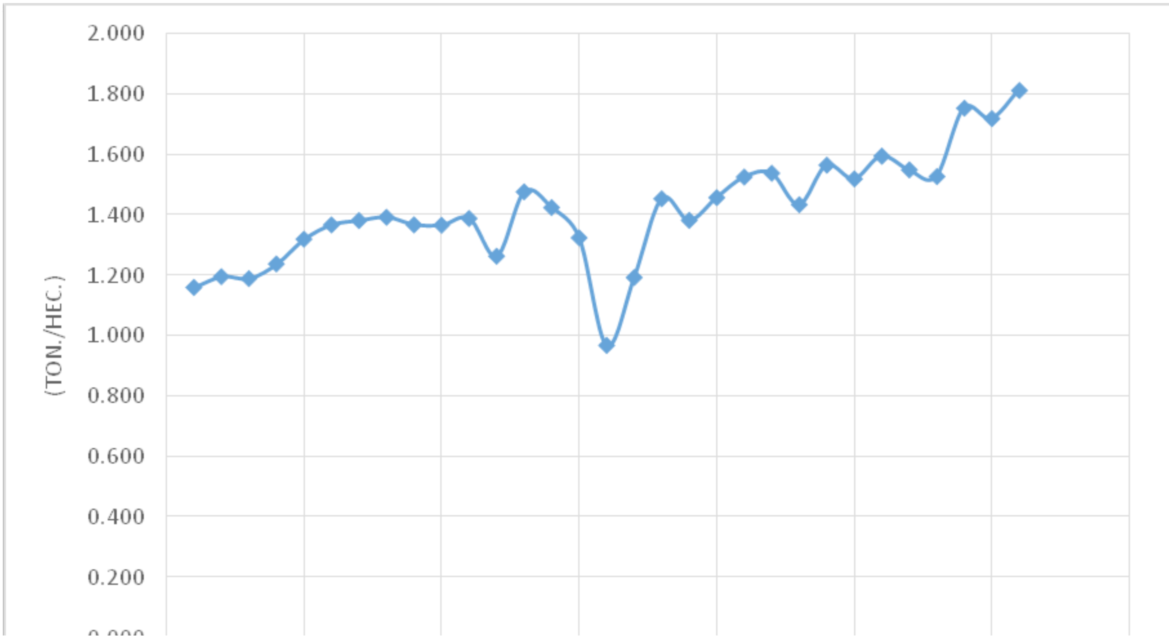

Figure 3: *Irregular trend of average annual precipitation (1985-2015).*
Source: Authors own estimations through panel data, Pakistan meteorological department, Peshawar.

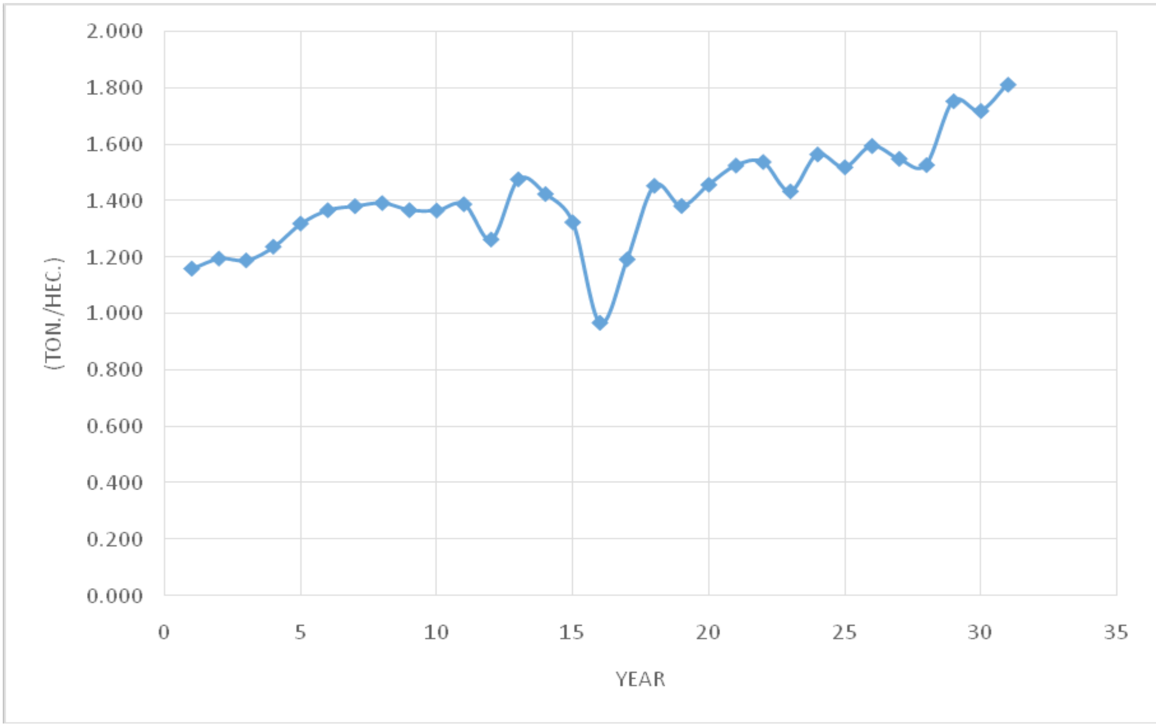

Figure 4: *Average Annual Wheat Yield (Thousand tons/Hectare) in KP for 30 years.*
Source: *Author's own estimation from data set of agriculture statistics of KP, (1985-2015).*

Trend of precipitation

The trend of precipitation during the wheat crop season i.e. Rabi season is shown in Figure 3. It is revealed through the said figure that there are sharp and sudden ups and downs in average annual precipitation since 1985 to 2015 in the KP Province of Pakistan. The minimum amount of precipitation was observed in the year 2001 which was recorded as 30.09 mm while maximum value of 109.48 mm was reported in 1991. After 2012 there is an upward trend line depicting increased amount of precipitation till 2015.

Trend of annual mean yield of wheat from the year 1985-86 to 2015-16

The trend line in Figure 4 indicates sluggish increase in the yield of wheat yield from the year 1985-86 to 1995-96. While sharp decline trend was observed in the wheat yield since year 1997-98 to year 2000-

01 which dropped to 160.967 tons per hectares in year 2000 to 2001. After this year there is a gradual upsurge in wheat yield with minor ups and downs for further fifteen years.

Model diagnostic tests

Hausman and LM test estimates: The estimated value for Hausman Test and Bresusch Godfrey LM is presented in Table 3. Hausman test depicts that Chi2 > p therefore, we reject the null hypothesis and accept that consider Fix Effect model as an appropriate model to be estimated for the panel data. LM test was also computed for three separate regressions and mentioned in same Table which revealed to reject the null hypothesis of no serial correlation for all three regressions. To fix the issue of serial Correlation, the Robust command was executed in STATA software to robust the Standard Error (SE).

Table 3: *Estimates of Hausman and LM Test.*

Hausman Test	
Chi2	162.31
P-value	0.000
LM Test for Regression 1 (1985-2015)	
Chi2	62.26
P-value	0.000
LM Test for Regression 2: (1985-2000)	
Chi2	35.42
P-value	0.000
LM Test for Regression 3: (2001-2015)	
Chi2	35.42
P-value	0.000

Table 4: *Fixed effect model estimates for wheat production (1985-2015).*

Ln Production	Coefficient	S.E	T-Value	P-Value
Ln Area	0.5229	0.2185	2.39	0.018**
Ln Seed	0.3321	0.732	4.53	0.000***
Ln Fertilizer	0.0674	0.2040	0.33	0.741
Ln Temperature	-0.0740	0.0353	-2.10	0.037**
Ln Precipitation	-0.0332	0.0586	0.57	0.572
Ln Humidity	0.4650	0.1428	3.25	0.001***
Constant	1.81	0.726	2.50	0.013**
Sigma U	0.1994			
Sigma e	0.1664			
R-Square = 0.963				

Source: *Author's own estimation from Panel Data (1985-2015);* **Note:** *Level of Significance; *** p<0.01(1 %); ** p<0.05 (5 %); * p<0.1 (10 %).*

Fixed effect model estimates for panel data (1985-2015)

Estimated results of Fixed Effect model are demonstrated in Table 4. The major findings of the panel data since 1985 to 2015 has illustrated significant and interesting results of majority of the explanatory variables. The explanatory variables encompassed non-climatic variables such as area under wheat cultivation, wheat seed and fertilizer while climatic parameters deemed as input for this model were temperature, precipitation and humidity. The estimation depicts that among non-climatic variables two variables i.e. area under wheat cultivation and seed are contributing significantly to the wheat production. Conversely, fertilizer contribution for wheat crop in KP province was observed insignificant. Area under wheat cultivation is reported significant at 5 percent level of significance ($P < 0.05$), whereas seed of wheat crop was ranked significant at 1 percent level of significance ($P < 0.01$). The corresponding climatic variables temperature and humidity except precipitation were also contributing considerably to the wheat production and are computed as significant at 5 percent and 1 percent level of significance respectively. However, the negative sign with temperature's coefficient is confirming the inverse impact on wheat production that implies by soaring 1^0C temperature there can be 0.074 percent decrease in the wheat production. The present result of this research endeavor is corroborated by previous studies such as Asseng et al. (2015) and Falcucci et al. (2007). Furthermore, humidity is contributing significantly and positively to wheat production. Surprisingly contribution of precipitation was observed insignificant. These estimates also reveal that wheat crop's inputs are contributing more significantly to the wheat yield as compared to climatic variable. This can be due to the reason that Pakistan has an agrarian economy and wheat is one of major crops of this country which always get attention by the policy makers. Such intervention of policy makers also include time to time support price for wheat that has encourage the farmers to grow more.

Fixed effect model estimates for panel data (1985-2000)

The estimates of Chow test have suggested that the panel data of 30 years may be treated through structural breaks as expressed by Gujarati (2003). One of the suggested approaches followed by chow test is to bifurcate the panel data into two equal data sets Gujrati (2003). Therefore, the data set of present study was divided into two equal data sets on the basis of

15 years each. The fixed effect model was run to assess the climate change impact during 1985 to 2000 on wheat crop which are demonstrated in Table 5. Major findings reveal that area and seed are observed as highly significant at 1 percent level of significance. The contribution of fertilizer was figured as significant at 10 percent level of significance ($P < 0.10$). Apart from this the temperature and precipitation were found significant at 10 and 1 percent level of significance respectively but remarkably both have inverse relation with the wheat crop production in KP province. This negative association of precipitation with wheat production reveals that an increase in precipitation beyond certain level can hamper the wheat production by 0.104 percent and similar results of temperature highlighting negative association are figured out by Gbetibouo et al. (2005).

Table 5: *Fixed Effect Model estimates for wheat production (1985-2000).*

Ln Production	Coefficient	S.E	T-value	P-value
Ln Area (000 Hectares)	1.1206	0.2866	3.91	0.000***
Ln Seed	0.2714	0.1001	2.71	0.008***
Ln Fertilizer	0.4409	0.2480	1.78	0.070*
Ln Temperature	-0.210	0.1214	-1.73	0.086*
Ln Precipitation	-0.1047	0.0424	-2.47	0.015***
Ln Humidity	0.30098	0.2157	1.40	0.166
Constant	0.9080	1.0616	0.86	0.394
Sigma U	0.1867			
Sigma e	0.1522			
R-Squared = 0.91				

Source: *Author's own estimation from panel data (1985-2000);* **Note:** *Level of Significance; *** $p<0.01$ (1 %); ** $p<0.05$ (5 %); * $p<0.1$ (10 %).*

Fixed effect model estimates for panel data (2001-2015)

Another fixed effect model was estimated to compute the second panel data set for the year 2001-2015. The results highlighted in Table 6 portrays that the non-climatic determinants such as area, seed and fertilizer are significant to the wheat production during the said span of time. Computed results also reveal that temperature and precipitation are significantly affecting the wheat production but has negative association with wheat production. This infers that one percent increase in temperature and precipitation can adversely affect wheat production in KP Province. Previous research study undertaken by Ahmad et al. (2014) illustrate that surge in temperature can curtail the phonological phases of wheat crop. The negative association of increase in temperature with wheat production is also evident and underscored by the research endeavor carried out by Blanc (2012). Ahmed and Schmitz (2011) have mentioned that in all the four provinces of Pakistan increase in temperature cascade negative significant impact on the yields of food crops. Correspondingly, they have also underscored inverse relationship between agricultural productivity and precipitation throughout the country.

Table 6: *Fixed effect model estimates for wheat production (2001-2015).*

Ln Production	Coefficient	S.E	T-value	P-value
Ln Area (000 Hectares)	0.8483	0.3693	2.30	0.024**
Ln Seed	0.3477	0.0933	3.73	0.000***
Ln Fertilizer	0.4033	0.1685	2.39	0.018**
Ln Temperature	-0.1177	0.0555	-2.12	0.036**
Ln Precipitation	-0.0733	0.0512	-1.43	0.100*
Ln Humidity	0.0605	0.1767	0.34	0.733
Constant	4.288	1.793	2.39	0.019
Sigma U	0.4059			
Sigma e	0.181			
R-Square = 0.932				

Source: *Author's own estimation from panel data (1985-2000);* **Note:** *Level of Significance; *** $p<0.01$ (1 %); ** $p<0.05$ (5 %); * $p<0.1$ (10 %).*

Conclusions and Recommendations

This research study concludes that non-climatic variables which include area under wheat cultivation and seed have contribution significantly to the wheat production. Whereas, contribution of fertilizer for wheat crop in KP province was observed insignificant. The estimation of Panel Data of climatic variables since 1985 to 2015 underscores that temperature and humidity except precipitation are contributing considerably to the wheat production and are computed as significant at 5 percent and 1 percent level of significance respectively. However, the negative sign with temperature's coefficient is confirming the inverse impact on wheat production.

1. The major results underscore that increase in temperature and precipitation has negative association with wheat production. Therefore, the government may provide heat resistant wheat varieties to farming community.
2. The plant breeders may also introduce high yielding wheat varieties which are suitable to the changing climate.

3. Concerned policy-makers may give due attention to construct the climate change policy for climate change adaptation strategies.

Author's Contribution

Sonia: Undertaken the research. Develpoed the reseach proposal, collected and analysed data and executed the results.
Khuram Nawaz Sadozai: Presented the main idea of the research. Designed the analytical framwork, assisted in econometric analysis and interpreted the results.
Noor Paio Khan: Guided in model selection and sample design.
Abbas Ullah Jan: Provided technical assistance at every step of the study.
Gulnaz Hameed: Reviewed the literature and helped in writing the manuscript.

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