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Wheat crop responds to climate change in rainfed areas of District Mansehra, Khyber-Pakhtunkhwa- An Econometric analysis

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Abstract

Agriculture in many ways is affected by climate change and has impact for productivity of crops particularly in rainfed areas. Climate change related research remained a poorly investigated area in KP and instant study filled that gap by investigating impacts of change in climate on farm productivity. The secondary data, spread over 30 years from 1984 to 2013 pertaining to temperature, precipitation, area under cultivation and yield of crops was collected. Analytical models used are ARDL Model. The results pertaining to impact of temperature and precipitation on wheat yield suggest long run relationship among the variables. Temperature is positively and significantly related in Mansehra. The precipitation is positively and significantly related. Short run relationship implies that around 100% deviations from long-term equilibrium are adjusted every year in case of Mansehra. The results wheat areas suggest long run relationship among the variables based on F Statistics value. Both temperature and precipitation are positively and significantly related to the area under wheat in the long run in case of Mansehra. Based on objectives of the research study and field findings recommendations offered include; farmers awareness drive, policies to promote adaptation measures, enhancing farmers' adaptive capacity to strengthen local resilience, participation of farming community in formulation of policies, making meteorological information available to farmers, Design research plans to evolve crops varieties addressing changing climatic challenges, construct water harvesting structures for high efficiency irrigation and further research to estimate range of temperature and precipitation within which crops under study perform better.

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Introduction

Agriculture in many ways is affected by climate change and has impact for productivity of crops (Ziervogel 2009; Falco 2011 and Chandrasiri 2013). The negative effects of climate change are considered too high such as recurrent droughts, flooding, heat waves, cold waves and land deterioration (Adger 2003 and Rosenweig and Hillel 1998). In rainfed areas, climate is key to crop productivity, thus droughts, floods or extreme temperatures could devastate agriculture sector. This devastating situation could result into poor and unsustainable livelihood of the communities depending on agriculture in the rainfed areas (Calzadilla 2009 and Ahmad and Zulfiqar 2019). According to Climate Change Synthesis Report (2014), the limit of global surface temperature increases to 1.5 degrees Celsius and continues to rise beyond 2100 in all scenarios except lower emissions scenario. To come out with evidence about adverse effects of climatic changes on agriculture including ecosystem services became a critical challenge for development practitioners around the globe. It is internationally recognized that decreased productivity of agriculture sector means GDP level loss, decrease in income and consumption for the most vulnerable population and deterioration in households' welfare. Thus influence of climate changes continuously poses major threat to rural livelihoods (Kangalawe and Lyimo 2013).

Climatic variations and resultant weather patterns have already marked as negative effects on agricultural resources, food production and food security globally (Diao, 2010). Climate change may alter rainfall patterns, drought cycles and more frequent severe weather patterns and increased diseases and agricultural pests (Yanda P.Z. 2010 and Hewitson B.C. 2010). Moreover, consequent to climatic changes, productivity of farms decreased in general (Makungwa, 2010 and Parry 1999).

Being an agricultural based economy, Pakistan is under immediate risk because of global climatic variability. The country ranked 12th amongst the most vulnerable states expected to have brunt of the climatic changes (Global climate risk index 2015).

The climatic changes have led to increased vulnerabilities to agriculture, forestry and water resources upon which a large part of the economy and livelihood depend. Pakistan being a developing country is likely to face severe challenges on account of economic and social development, environmental sustainability and land degradation. The adverse outcome of climatic changes are already been felt in Pakistan because of recurring droughts, increased intensity of floods and un predictable weather patterns and changes in behavior of agricultural production system. Within the country, regions with arid land will be on the top of affected list. Such arid regions will face a whole brunt of adverse impacts in terms of their socio-economic conditions, physical, environmental as well as biological resources (Khan 2012).

Agriculture is an important source of livelihood for the rural communities of rainfed areas. The majority of the 35.50 million masses living in Khyber Pakhtunkhwa are relying on rain-fed agriculture system. The food availability for such areas is dependent on agricultural productivity. The crop productivity/yield is dependent on timely rainfall specially in rainfed areas. District Mansehra selected for instant research study is one of the 34 districts of Khyber Pakhtunkhwa with almost 80% rainfed area out of its total 80,747 ha of cultivated area (GoKP 2017). In view of the fact that a change in climatic patterns has been occurring and will continue even in future, underlines the importance of understanding as how farmers perceive these changes and how they adapt to these variations. The perceptions of climate change play a vital role in farmers' decisions of adopting protective measures against climate extremes and therefore, are important factors which need to be considered. Minimize the negative impacts of change in climate needs awareness of the farmers and policy makers. Therefore, through instant study, the impact of climate change in terms of precipitation and temperature on area and yield of wheat crop is investigated using time series data. The outcome and recommendation of the research study will have important implications for future policies addressing climate change within the country and farmers behavior towards crop husbandry.

trict Mansehra is located in the North Eastern part of Khyber Pakhtunkhwa with 4,579 sq km of area. The district is mainly mountainous, with an altitude ranging from 200 meters in the south upto more than 4,500 meters in the north. The well-known Babosar pass is located on the northeastern border of the district. The winter climate is cold and the summer climate is pleasant. In the Kaghan Valley which is situated in the northern, the conditions in summer are cool whereas in the season of winter extremely cold and during this period there is snow fall of heavy magnitude. Summer and winter are dominant seasons of the district. The summer season spread over April to September, while that of winter from October to March.

There are two farming seasons. The one is summer locally called as Kharif season and it starts from May and ends in September. Seasonal vegetables, rice and maize are the main crops of this season. The other is winter season locally called as Rabi season. The winter growing season starts from October and ends in March. Important winter season crops are wheat, seasonal vegetables and peas.

Material and methods

Selection of Study Area

The study has been planned and carried out in district Mansehra of Khyber Pakhtunkhwa. The selection is based on rainfed nature of the district. The cultivated area of district Mansehra is 80,747 hectares out of which 77% is rainfed (GoKP 2015-16). Mansehra is situated at 34.33° North latitude, 73.2° East longitude and 1067 meters (https://www.maps-streetview.com/Pakistan/) dated 2.11.2017. Monthly average annual minimum temperature in Mansehra ranges from 2.6 to 21.3 ^{o}C, while monthly average annual maximum temperature in Mansehra ranges from 13.4 to 34.8 ^{o}C. Average annual precipitation in Mansehra ranges from 34-302 mm (https://en. climate- data.org/location/1299/).

Selection of Crop

The crop selected for the study is wheat. The crop selected is grown on vast areas of the rainfed district and have direct impact on the livelihoods of the people.

The total cultivated area of district Mansehra is 80,747 hectares. The area brought under cultivation during winter season is 40,029 hectares out of which 37,374 hectares is under wheat i.e. 93.37%.

Data Collection

The secondary data, time series data, spread over 30 years from 1984 to 2013 was collected. The time series data included temperature, precipitation, area under cultivation and yield of wheat. The data related to temperature and precipitation was collected from Meteorological Department, Government of Pakistan, while data pertaining to area and yield was collected from the Crop Reporting Wing of the Agriculture Department, Government of Khyber Pakhtunkhwa.

Analytical Modeling

A 30 years meteorological data pertaining to precipitation and temperature was analyzed against area and productivity. The data was then subjected to an analysis using Auto Regressive Distributed Lag (ARDL), Co-Integration Technique (Engle 1987) and Bound Test of Co Integration (Pesaran and Shin 1999 and Pesaran *et al.* 2001 and Johnsen and Juselius 1990). The Autoregressive Distributed Lag (ARDL) model also called bound testing cointegration model was advanced by M.H. Pesaran and Y. Shin (1999). The rationale behind use of ARDL model is that the combination of time series variables in the study is stationary at level and integration at order 1. Thus in such a situation ARDL approach is most suitable econometric tool compared to some of the other econometric models. Additionally, it was also aimed to determine impact of diverse independent variables on the dependent variable both, for the short-run and for the long-run for which ARDL model is best suited. The ARDL produces the short run and long run coefficient concurrently along with followings OLS process for cointegration amid the involved variables. Another advantage of ARDL is that it offers flexibility about order of the integration pertaining to variables used. Further, it possesses the suitability regardless of the fact as whether the variables included are purely I(1), purely I(0) or whether mutually cointegrated but the same is not true if there is any variable having 2nd order difference.

The common formula of ARDL model with n lags for variable Y and m lag for variable X stands as given below:

$$Yt = \alpha 0 + \sum_{i=1}^{n} \alpha iYt - 1 + \sum_{i=0}^{m} \beta iXt - i + Ut ....1$$

While general format of the ARDL ECM runs as below:

$$\Delta Yt = \alpha 0 + \sum \beta jYt - i + \sum \beta jXt - j + \psi ECMt - 1 + \varepsilon t ....2$$

Therefore given equation reveals the speed with which adjustment of parameter is taking place. It is also pertinent to note that for Error Correction (EC) Model to be significant; its value must be in negative form. The EC term states that any of the divergence occurring in long-run equilibrium amongst the variables is to be corrected in each period as well as the time period that is to be taken to come yet again to the long-run equilibrium point. ECMt-1 shows the residuals which are attained out of estimated co-integration mode.

A regression analysis showed attribution of climatic changes to crop area and productivity. The productivity regression model used is as under:

$P = \beta_0 + \beta_1 R + \beta_2 T + e$

Where

P = productivity per hectare

R = rain/precipitation

T = temperature

βs = coefficients

e = error term

The area under cultivation regression model has been as under;

$A = \beta_0 + \beta_1 R + \beta_2 T + e$

Where

A = Area in hectare

R = rain/precipitation

T = temperature

βs = coefficients

e = error term

Diagnostic Tools Used

The diagnostic tools used to satisfy various assumptions and to ensure that the results of the analytical model are without any bias included; ADF Unit Root Test to decide on analytical model (Kwiatkowski, Phillips, Schmidt and Shinn 1992; Maddala and Kim 1998; and Phillips and Xiao 1998); Autocorrelation Test - Brush Godfrey LM Test (Breusch, T. S. 1978 and Godfrey, L. G. 1978); Heteroscedasticity Test - Breusch-Pagan-Godfrey Test (Breusch, T.S. and A.R. Pagan, 1979) and Stability check Test - CUSUM Test & CUSUMSQ Test (Brown, R.L., J. Durbin and J.M. Evans 1975).

Results and discussions

Wheat Productivity

Before econometric analysis using ARDL Model, certain assumptions were necessary to be satisfied. Therefore, a number of tests were conducted which are detailed below along with their results.

ADF Unit Root

For the econometric analysis of time series data, it is necessary that the data should be stationery. Therefore, the data was transformed to logarithm and then in order to determine stationarity of the data, ADF test was used. The test checked integration order. The test included extra lagged length of variable (dependent) in order to remove the problem of autocorrelation in the model. Justification of using ARDL model is based on ADF test for the stationarity of the data. The results of the ADF unit root test are given in table 1.

Table 1. Results of the ADF Unit Root Test.

Variable	ADF Unit Root Test		Order
	T-Statistics	Prob. Values	
Logarithm of Wheat yield	-6.722	0.0000	I(1)
Logarithm Mean Temperature	-4.339	0.002	I(0)
Logarithm Mean precipitation	-5.824	0.0000	I(0)

The results in table 1 shows that data of variable 'wheat yield' is stationary at first difference while data of variables 'temperature' and 'precipitation' is stationary at level. The value of t-statistics is -6.772 and Probability value is 0.0000. Thus p value is less than 5% which means at 5% mean variable is stationary at level.

Similarly t-statistics and p-values of temperature and precipitation reflect that both variables are stationary at level. The data stationarity was determined using same test by a number of researchers (Peter *et al.*, 1988).

Autocorrelation

In order to know the existence of autocorrelation problem or otherwise, Brush God fray LM test was applied. The results of the test are presented in table 2.

Table 2. Results of Brush God fray LM Test.

F-statistic	0.920149	Prob. F(2,11)	0.4271
Obs*R-squared	3.869696	Prob. Chi-Square(2)	0.1444

Table 2 shows that the p-values associated with test statistic is greater than the standard significant level [i.*e. 0.144> 0.05*]. Thus, Brush's LM test results reveal that the data is free of autocorrelation problem i.e. there is no autocorrelation. The same test to check autocorrelation was used Pervez *et al.*, 2010.

Heteroscedasticity

The presence of Heteroscedasticity in the data could result in biased results. Therefore, it was important to check its presence or otherwise. For this purpose, Breusch-Pagan-Godfrey test was used. The results of the Breusch-Pagan-Godfrey (BPG) test are presented in the table 3.

Table 3. Results of BPG test.

F-statistic	0.994834	Prob. F(13,13)	0.5037
Obs*R-squared	13.46504	Prob. Chi-Square(13)	0.4126
Scaled explained SS	2.741691	Prob. Chi-Square(13)	0.9987

The diagnostic test for Heteroscedasticity using Breusch-Pagan-Godfrey test given in the table 3 shows at 5%, p-value associated with the test statistics is greater than the standard significance level [i.e. 0.4126> 0.05]. The results reveal that the data is homoscedastic and there is no problem of Heteroscedasticity.

Stability Check

For analyzing the stability of the long-run coefficients together with the short-run dynamics, the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUM) test were applied. As shown in fig.s 1 and 2, both the CUSUM and the CUSUMQ plot residual are found inside the boundaries. That is to say that the stability of the parameters has remained within its critical bounds of parameter stability at 5%.

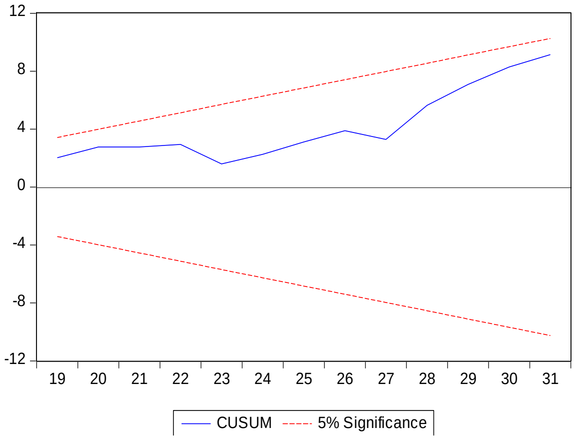

Fig. 1. CUSUM Result.

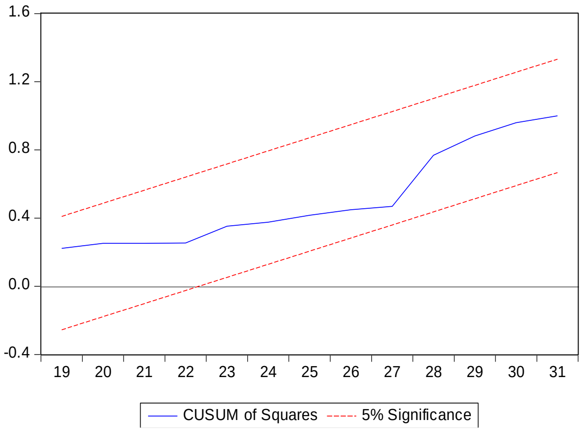

Fig. 2. CUSUM of Square Result.

Both the figures clarify that the CUSUM as well as the CUSUMQ tests confirm the stability of the long-run coefficients along with the short-run dynamics. These tests are in line with the many other researchers work such as Sahbi F. (2012) and Stephen E. M. (1982).

Analytical model-ARDL Bounds Test Results

After satisfying all the necessary assumptions, the relationship between wheat yield as a dependent variable and temperature and precipitation as independent variables was estimated using ARDL (bounds) test. The result of the test as depicted in table 4 shows long run relationship amongst the variables.

Table 4. ARDL Bound Test Results.

Test Statistic	Value	K
F-statistic	8.460	2
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10.0%	3.17	4.14
05.0%	3.79	4.85
02.5%	4.41	5.52
01.0%	5.15	6.36

The value of F Statistics in table 4 is 8.46 which is higher than upper boundary that shows long run relationship among the variables. Akike Info Criterion (AIC) is used to select the optimal lag length of variables included in the ARDL model. Table 6 presents the results of long-run relationship of the selected ARDL model (3,4,4) using SBC. The long run estimation results reflected in table 6 shows that both temperature and precipitation are positively and significantly related to the wheat yield in the long run.

Table 5. Long Run Estimation Results of ARDL (3,4,4) Model.

Variables	Coefficients	Std. Error	t-Statistic	Prob.
Lwheat_temp	3.714	0.782195	4.748261	0.0004
Lwheat_precip	1.583	0.586459	2.698739	0.0182
C	-6.39	2.913093	-2.194763	0.0469

Lwheat_yield=-6.39+3.714lwheat_temperature+1.583lwheat_precipitation

The scenario reveals that temperature and precipitation are positively and significantly related to wheat yield in the long run. The equation reflects that if 1% change occur in precipitation wheat yield will increase by 1.583% and if temperature increases by 1% the wheat yield will increase by 3.714% in the long run.

Short Run Estimation

The table 6 indicates the short run relationship between wheat yield and temperature and precipitation.

Table 6. Short Run Estimation Results of Cointegration Form of ARDL (3,4,4) Model.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LWHEAT_YIELD(-1))	-0.025488	0.196943	-0.129416	0.8990
D(LWHEAT_YIELD(-2))	-0.216262	0.160628	-1.346355	0.2012
D(LWHEAT_TEMP)	0.378930	0.463448	0.817631	0.4283
D(LWHEAT_TEMP(-1))	-0.320502	0.496660	-0.645315	0.5299
D(LWHEAT_TEMP(-2))	-1.538222	0.534321	-2.878836	0.0129
D(LWHEAT_TEMP(-3))	-1.648004	0.582195	-2.830671	0.0142
D(LWHEAT_PRECIP)	0.341336	0.212161	1.608857	0.1317
D(LWHEAT_PRECIP(-1))	-0.295750	0.235570	-1.255463	0.2314
D(LWHEAT_PRECIP(-2))	-0.139246	0.202482	-0.687699	0.5037
D(LWHEAT_PRECIP(-3))	-0.452239	0.194169	-2.329105	0.0366
ECT(-1)	-1.001	0.224848	-4.454906	0.0006

Cointeq = LWHEAT_YIELD - (3.7141*LWHEAT_TEMP + 1.5827 *LWHEAT_PRECIP -6.3935)

In the estimation shown in table 6 indicate for model to be fit, the sign and value of ECT must be negative and significant. The coefficient of ECT is (-1.00) means the speed of adjustment is (-1.00) which implies that around 100% deviations from long-term equilibrium are adjusted every year. The coefficient of determination (R^2) is 84, indicating that 84% of the dependent variable's variation i.e. wheat yield is explained by the explanatory variables presented in the linear model.

Wheat area

After satisfying all the necessary assumptions, the relationship between wheat area as a dependent variable and temperature and precipitation as independent variables was estimated using ARDL (bounds) test. The result of the test as depicted in table 7 shows long run relationship amongst the variables.

Table 7. ARDL Bound Test Results.

Test Statistic	Value	K
F-statistic	3.83	2
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	3.17	4.14
5%	3.79	4.85
2.5%	4.41	5.52
1%	5.15	6.36

The ARDL (Bound test) shows long-run relationship among the variables. F Statistics value is 3.83 which lies between lower and upper boundaries. It shows long-run relationship since we take decision from ECT. ECT must be negative and significant for the model to be fit. When Error correction term is negative and significant it shows long run relationship. Akike Info Criterion (AIC) was used to select the optimal lag length of variables included in the ARDL model. Table 4.11 presents the results of long-run relationship of the selected ARDL model (1,0,0) using AIC.

Long Run Estimation

The long run estimation results are reflected in table 8 shows that both temperature and precipitation are positively and significantly related to the area under wheat in the long run.

Table 8. Long Run Estimation Results ARDL (1,0,0).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Wheat_precip	104.962	93.003323	1.128584	0.2694
Wheat_temp	317.849	1627.611914	0.195286	0.8467
C	25345.874	14685.665593	1.725892	0.0962

Wheat_Area=25345.874+104.962whet_Mean_Precipitation+317.849wheat_Mean_Temperature

The table 8 reveals that temperature and precipitation is positively and significantly related to area under wheat cultivation in the long run. The equation shows that if 1 percent increase in precipitation will increase by 104.962 unit and if temperature increases by 1 unit, wheat area under cultivation will increase by 317.849 unit in the long run.

Short Run Estimation

The table 9 indicates the short run relationship between wheat area and temperature and precipitation.

Table 9. Short Run Estimation Results of Cointegration Form.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(wheat_precip)	51.936661	35.977296	1.443595	0.1608
D(wheat_temp)	157.276433	798.399548	0.196990	0.8454
Ect(-1).cointeq(-1)	-0.494814	0.181729	-2.722803	0.0114

Cointeq = wheat_area - (104.9621*wheat_precip + 317.8499 *Wheat_temp + 25345.8738)

In the estimation, the sign and value of ECT must be negative and significant respectively. The coefficient of ECT is -0.49 means the speed of adjustment is -0.49 which implies that around 49% deviations from long-term equilibrium are adjusted every year. The coefficient of determination (R^2) is 24 indicating that 24% of the dependent variable's variation i.e. wheat area is explained by the explanatory variables presented in the model applied.

Conclusion and recommendations

Agriculture is an important source of livelihood for the rural communities of rainfed areas. More than 80% of the 35.6 million people of Khyber Pakhtunkhwa are living in rural areas and depend on agriculture. Out of 1.621 million hectares cultivated area of KP, 47% is rain-fed. The food availability for such areas is mainly dependent on agricultural productivity which is further dependent on timely rainfall and temperature that has now been affected by climate change.

Keeping in view the importance of the issue and to fill research gap current study has been designed to assess the potential impacts of change in climate on farm productivity. The result of the research shows long run relationship among the variables. The Akike Info Criterion (AIC) was used to select the optimal lag length of variables and showed that both temperature and precipitation are positively and significantly related to the wheat yield in the long run. The results reveal that if 1% change occur in precipitation wheat yield will increase by 1.583% and if temperature increases by 1% the wheat yield will increase by 3.714% in the long run. For the short run relationship, the coefficient of ECT is (-1.00) which implies that around 100% deviations from long-term equilibrium are adjusted every year. The R^2 is 84, indicating that 84% of the dependent variable's variation i.e. wheat yield is explained by the explanatory variables.

The ARDL (Bound test) shows long-run relationship among the area related variables based on F Statistics value. The ECT is negative and significant showing long run relationship. AIC result shows that both temperature and precipitation are positively and significantly related to the area under wheat in the long run. The result shows that 1 percent increase in precipitation will increase 104.962% increase in area and if temperature increases by 1%, wheat area under cultivation will increase by 317.849% in the long run. The short run relationship between wheat area and temperature and precipitation shows that ECT is (-0.49) which implies that around 49% deviations from long-term equilibrium are adjusted every year. The R^2 is 24 indicating that 24% of the dependent variable's variation i.e. wheat area is explained by the explanatory variables.

The study recommends that Government should workout with public and private research organizations to design research plans for rainfed areas aiming at evolving crops varieties which offer high yields along with suitability to changing climatic scenarios such as heat and cold resistance, short duration maturity, needing less water, etc.

Further research is required to estimate range of temperature and precipitation within which wheat productivity is optimum.

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