INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 15, No. 6, p. 64-72, 2020
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Climate change - impact on maize crop in the rainfed areas of District Mansehra of Khyber Pakhtunkhwa, Pakistan

Rizwan Ahmad[1], Muhammad Zulfiqar*[1], Muhammad Hanif[2], Jawad Ali[3], Arjumand Nizami[3]

[1] *Institute of Development Studies, The University of Agriculture, Peshawar, Pakistan*

[2] *National Forecasting Centre, Pakistan Meteorological Department, Islamabad, Pakistan*

[3] *Helvetas Swiss Intercooperation, Pakistan*

Article published on December 30, 2020

Key words: Climate change, Mansehra, Rainfed, Maize, Livelihood

Abstract

In rainfed areas, climate is key to crop productivity and thus livelihood of rural poor. Thus influence of climate change continuously poses major threat to rural livelihoods with more intensity for arid regions. The instant research piece tried to assess the effect of climate change on area and productivity of maize crop in the rainfed areas of district Mansehra. The result showed association amongst variables using ARDL econometric model (1, 1, 1) with AIC. The long run estimation results show that temperature is positively but insignificantly while precipitation is positively and significantly related to maize yield in the long run. Coefficient of ECT shows that at short run relationship between maize yield and temperature and precipitation, around 64% deviances from long-term equilibrium adjusted each year. Regarding relationship between maize area and precipitation, the result shows long run association amongst the model's variables. The value of F Statistics is higher than upper boundary showing long run relationship among the variables. AIC test shows that temperature is positively and significantly associated while precipitation is positively but insignificantly related to maize area under cultivation in the long run. For the short run relationship between maize area and temperature and precipitation the coefficient of ECT shows that around 82% deviations from the long-term equilibrium are adjusted every year. The study recommends 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 and construction of water harvesting facilities.

***Corresponding Author:** Muhammad Zulfiqar ✉ Zulfiqar@aup.edu.pk

Introduction

The negative effects of climate change are considered too high for food security and poverty reduction at global level. Agriculture is affected by climatic changes in a number of ways and has influence for crops' productivity (Ziervogel, G., F. Zermoglio, 2009; Ahmad, R., M. Zulfiqar, 2019). Recurrent droughts, flooding, fluctuating temperatures and land deterioration are some of the important outcomes of climate change (Adger *et al.*, 2007; Rosenzweig, C., D. Hillel, 1998). In rainfed areas, climate is key to crop productivity, therefore droughts, extreme temperatures and/or floods could destroy agriculture sector and thus livelihood of rural poor (Calzadilla, A. *et al.*, 2009). IPCC's declares that global temperature has increased by 1.5 degree celsius and the increasing trend in temperature will continue even after the year 2100 (IPCC's, 2007). Similar arguments are articulated in Climate Change Synthesis Report (CCSR, 2014). Thus influence of climate changes continuously poses major threat to rural livelihoods.

Pakistan being an agricultural country is under immediate risk because of global climatic variability with potential of increased vulnerabilities to agriculture, forestry and water resources (Zulfiqar *et al.,* 2018). The arid regions/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. Additionally, the biomass of the arid land may also increase along with shift in crop production cycle because of changes in climatic conditions (Khan, S. *et al.*, 2012). In case of Khyber Pakhtunkhwa (KP) province of Pakistan, some of the districts such as Mansehra is mostly rainfed and vulnerable to climate change. Realizing the potential threats of climate change to arid/rainfed areas of KP, this study tried to determine the impact of 25 years based temperature and precipitation on the area and productivity of maize crop in the rainfed areas of district Mansehra.

District Mansehra is located in the North Eastern part of Khyber Pakhtunkhwa with 4,579 sq km of area (ERRA, 2007). The district is mainly mountainous, with an altitude ranging from 200 meters in the south up to more than 4,500 meters in the north. The winter climate is cold and the summer climate is pleasant. The average temperature remains from 21°C to 35°C in summer, while 2°C to 14°C in winter.

Out of 80,747 hectares cultivated area of the district, 79.43% is rainfed (GoKP, 2017). Maize is the dominant summer crop of the district occupying 57,956 hectares. However, 89.4% of the maize area is rainfed (GoKP, 2017) making a strong case for selection of crop for instant study. There is hardly any research study available on climate change impact on maize area and productivity in the rainfed areas in this region. However, some research has been conducted elsewhere to study impact of climate change on crops at higher altitude. Xiao investigated wheat yield at high altitude using data from 1981 to 2005 and found out that yield increased during this period bearing positive change in temperature and precipitation (Xiao, *et al.*, 2005). Increase in temperature would create positive impact on crops yield in higher altitudes such as Chitral in KP (Hussain, S. S., M. Mudasser, 2007). Thus the adverse effects of climatic changes in some of the regions of the world will be balanced in the world markets through increased agricultural productivity in some of the other regions of the world those will have affirmative bearing of the global warming induced climate change. It has also been reported that various scenarios under climatic changes winter wheat is to benefit out of interaction of double CO_2 concentration and increased temperature (Cuculeanu, V. *et al.*, 1999). Thus this study is to fill research gap to some extent pertaining to impact of climatic changes on area and productivity of maize crop at higher altitude.

Methods and material

The selection of the district is based on its rainfed nature. The cultivated area of district Mansehra is 80,747 hectares out of which 79.43% is rainfed (GoKP, 2016). The crop selected is maize grown on almost 90% of rainfed cultivated area of the district and thus possessing direct impact on the livelihoods of the people. 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 selected crop for this research study.

The data related to temperature and precipitation was collected from Meteorological Department, Government of Pakistan (GoP, 2016), while data pertaining to area and yield was collected from the Crop Reporting Wing of the Agriculture Department, Government of Khyber Pakhtunkhwa.

The data pertaining to precipitation and temperature was analyzed against area and productivity of maize. The data was then subjected to an analysis using Auto Regressive Distributed Lag (ARDL), Co-Integration Technique (Grander, 1981 and Engle, Grander 1987) and Bound Test of Co Integration (Johansen, S., K. Juselius 1990; Pesaran, Shin, Smith, 2001; Pesaran, Shin, 1999). The ARDL econometric model also called bound testing cointegration model. The rationale behind use of ARDL model is that the combination of variables in the data 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. The ARDL suitability is regardless of the fact as whether the variables included are purely I(1), purely I(0) or whether mutually cointegrated (Frimpong, Oteng, 2006) but the same is not true if there is any variable having 2^{nd} order difference. The common formula of ARDL model stands as given below:

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

While general format of the ARDL ECM runs as below:

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

The afore 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 cointegration 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

In order to satisfy various assumptions of the analytical model and to ensure that the results of the analytical model are without any bias some diagnostic tests such as ADF Unit Root Test (Kwiatkowski, Phillips, Schmidt, Shinn, 1992; Maddala, 1998; Phillips, Xiao, 1998). Autocorrelation checked through Brush Godfrey LM Test (Breusch, T.S., 1978; Godfrey, L. G, 1978); Heteroscedasticity check (Breusch, Pagan, 1979) and Stability check using CUSUM Test & CUSUMSQ Test (Brown, R.L., J. Durbin, J.M. Evans, 1975).

Results and discussions

Maize Yield

In order to check whether the data which the model to use for this piece of research is stationery or otherwise, the data was transformed to logarithm and then Augmented D. and Fuller test was applied. The test checked the order of integration. Augmented D. and Fuller tests include the extra lagged length (ELL) of variable (dependent) to assess statistical problems in the applied model. The ARDL model which has been used, is accepted on the basis of ADF for the stationarity of the data. The result of ADF unit root test is given in the table 1.

Table 1. ADF Unit Root Test Results.

Variable	ADF Unit Root Test		Order
	T-statistics	Prob. Values	
Log of Maize yield	-9.259	0.000	I(1)
Log of Mean Temperature	-3.597	0.012	I(0)
Mean precipitation	-6.946	0.000	I(0)

The results show that variable maize yield remained stationary at first difference while temperature and precipitation are stationary at the level. Log of Maize yield is stationary at first difference. The value of t-statistics is -9.259 and Probability value is 0.000. So the p value is below 5, so at 5% accepted that data of maize yield is stationary. Log of Mean temperature is stationary at level. At 5% of t value is -3.597 and p value is 0.012 which shows that temperature data is stationary. Similarly Log of Mean precipitation is stationary at level. The p value is 0.000 and t Statistics value is -6.946 so we accept that precipitation data is stationary.

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

The table 2 depicts that the p-values related to the test statistics is larger compared to the standard significance level [i.e. 0.2233> 0.05]. Thus, Brush's LM test results reveal that the data is free of autocorrelation problem i.e. there is no autocorrelation.

Table 2. Brush God fray LM Test Result.

F-statistics	1.22167	Prb. F(2,22)	0.314
Obs*R- squared	2.99877	Prb. Chi-Squares (2)	0.223

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 test are presented in the table 3. The diagnostic test given in the table 3 shows at 5%, p-value related to test statistic is larger than the desired level of significance [i.e. 0.4263> 0.05]. The results reveal that the data is homoscedastic and there is no problem of Heteroscedasticity.

Table 3. B-Pagan-Godfrey test's Results.

F-statistics	0.94047	Prb. F(5,24)	0.4729
Observed R-square	4.91497	Prb. Chi-Square (5)	0.4263
Scaled explained SS	5.80040	Prb. Chi-Square (5)	0.3261

For the analysis of stability of the coefficients (long-run) along with short-run dynamics, the CUSUM and CUSUM square test were conducted. As shown in the Fig. 1 & 2, design or plot of the CUSUM and the CUSUMQ residual is contained inside the marked borders. This scenario shows that the parameters pertaining to the stability have remained inside critical bounds of the parameters stability at the level of 5%. Fig.s 1 and 2 clarify that the CUSUM as well as the CUSUMQ tests confirmed the stability of the long-run (coefficients) alongside the short-run dynamics.

Analytical Model - ARDL Bounds Test Results

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

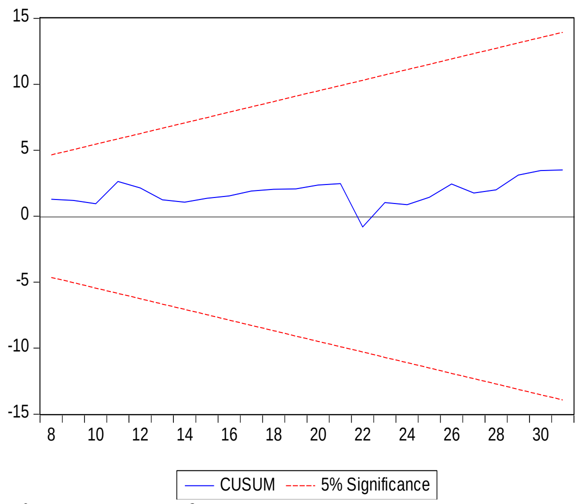

Fig. 1. Out Put of CUSUM.

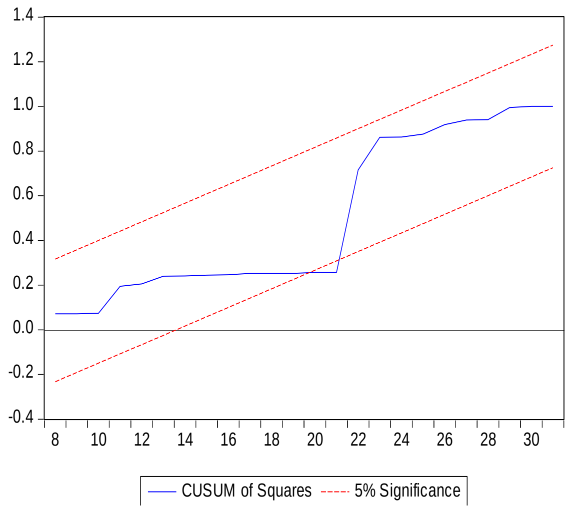

Fig. 2. Out Put of CUSUM Sqr.

The value of F-Statistic given in table 4 is 6.9710 that means higher than upper boundary that shows relationship of long run among the studied variables. We, Therefore used Akike Info Criterion (AIC) in order to choose the lag length at optimal level of variables under study in the model applied. The long-run based relationships depicted in the results derived through ARDL model (1, 1, 1) using AIC is shown in table 5.

Table 4. ARDL Tests Result.

Tests Statistics	Values	K
F-statistics	6.9710	2
Critical Values Bound		
Significances	I0 Bounds	I1 Bounds
10.0%	3.170	4.140
05.0%	3.790	4.850
2.50%	4.410	5.520
1.0%	5.150	6.360

Estimation of Long Run Results

The estimation of long run results in table 5 shows that both temperature and precipitation are positively and significantly associated to the maize yield in the long run. The scenario in table 5 reveals that in the long run temperature is positively but insignificantly related to maize yield but precipitation is found to be affirmatively as well as significantly associated with maize productivity. The equation shows that if 1% change occurs in precipitation wheat yield will increase by 1.422% at 1.7% level of confidence and if temperature changes by 1% the wheat yield will change by 6.580% at 10% level of confidence.

Table 5. Results of ARDL (1, 1, 1) Long Run Estimation.

Coefficients (Long Run)				
Variables	Coefficients	Std. Errors	t-Statistics	Prb.
LMAIZ_TEMP	6.580	4.002476	1.644166	0.1132
LMAIZ_PRECIPIT	1.422	0.555853	2.558002	0.0173
C	-16.387	11.819664	-1.386434	0.1784

LMaizeYield=-16.387+6.580LMAIZ_TEMP+1.422 LMAIZ_PRECIPIT

Estimations for Short Run

The short run relationship between maize yield and temperature and precipitation is given in table 6. The estimation, the sign and value of ECT to be negative as well as significant. The ECT coefficient is (-0.64) gives adjustment speed (-0.64) which means about 64% deviances from the equilibrium (long-term) are adjusted each year. The determination coefficient of 44% reflects that 44% of the dependent variable deviation (maize yield) in the form of explanatory variables is explained by the linear model applied in the instant case.

Table 6. Short Run Estimation Results of Cointegration Form.

Cointegrating Form				
Variables	Coefficients	Std. Errors	t-Statistics	Prb.
D(LMAIZ_TEMP)	1.650	2.044392	0.807137	0.4275
D(LMAIZ_PRECIPIT)	0.675	0.202190	3.335747	0.0028
ECT(-1) CointEq(-1)	-0.64	0.155714	-4.109907	0.0004

Cointeq=Lmaiz_yield - (6.5807*lmaiz_temp + 1.4219 *lmaiz_precipit-16.3872) & R^2=0.44.

Maize Area

The justification for using ARDL model is based on the ADF for the stationarity of data. The table 7 highlights the ADF unit root test results. The result shows that variable maize area is stationary at first difference and temperature and precipitation are stationary at level. For Autocorrelation, table 8 shows the results of Brush God fray LM test.

The result shows that p-value related to test statistics is larger compared to the standard level of significance level [i.e. 0.2516> 0.05] revealing that showing no autocorrelation problem amongst the variables. For Heteroscedasticity, Result of the Test (B-Pagan-Godfrey) is presented in the table 9.

The diagnostic test for Heteroscedasticity given in the table 9 shows that at 5%, p-value related with given test statistic is larger than the standard significance level [i.e. 0.2131> 0.05] revealing that the data is homoscedastic.

Table 7. Results of the ADF Unit Root Test.

Variable	ADF Unit Root Test		Order
	T-statistics	Prob. Values	
Log of Maize yield	-5.249	0.0002	I(1)
Log of Mean Temperature	-3.602	0.012	I(0)
Mean precipitation	-7.010	0.0000	I(0)

Table 8. Brush God fray LM Test Results.

F-statistics	0.771967	Prb. F (2, 13)	0.4822
Obsrd*R-squared	2.760071	Prb. Chi-Square (2)	0.2516

Table 9. Results of Breusch-Pagan-Godfrey test.

F-statistics	1.545116	Prb. F(10,15)	0.2161
Obsrd*R-square	13.19260	Prb. Chi-Squares(10)	0.2131
Scaled explained SS	3.036541	Prb. Chi-Squares(10)	0.9806

For investigating the position of stability of coefficients (long-run) along with the short-run dynamics, the results of CUSUM and CUSUM squares test are given in the Fig.s 3 & 4. The plot of both the CUSUM and the CUSUMQ residual are within the boundaries. Thus, the stability of the parameters has remained within its critical bounds of parameter stability at 5%. Both the Fig. 3 and 4 clarify that the CUSUM as well as the CUSUMQ tests confirm the stability of coefficients (long-run) alongside the short-run dynamics.

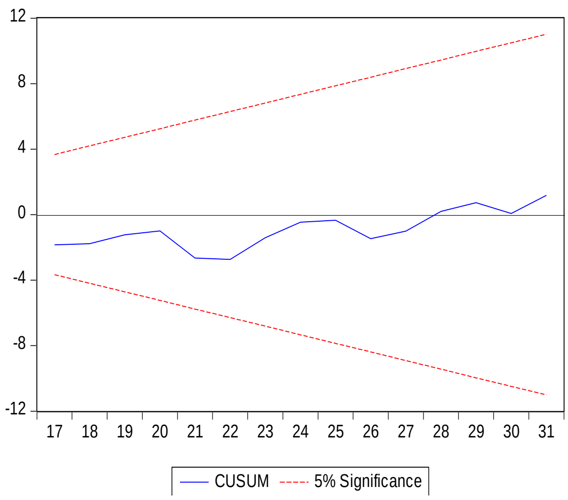

Fig. 3. CUSUM Result.

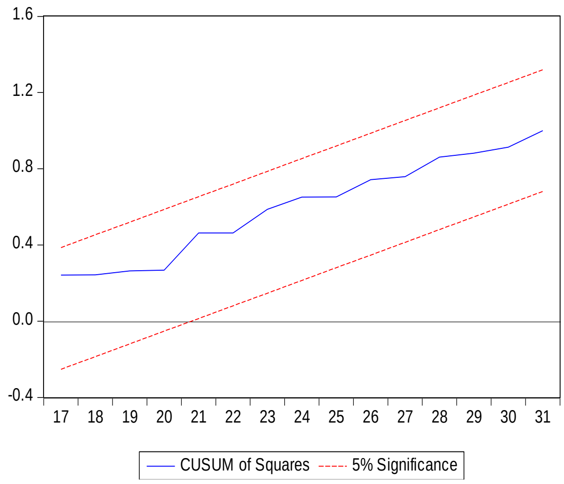

Fig. 4. CUSUM square Result.

ARDL Bound Test

After satisfying all the necessary assumptions, the relationship between maize area as an outcome variable and temperature and precipitation as predictor variables was estimated using ARDL bound test. The result of the test as depicted in table 10 shows long run relationship amongst the variables. The value of F Statistic in the above table is 6.104 which is higher than upper boundary that shows long run relationship among the variables.

Akike info criterion (AIC) is used to determine optimum lag length of variables involved in the ARDL econometric model. Table 11 demonstrates the result of relationship (long-run) of the applied ARDL econometric model (1,0,4) using AIC.

Table 10. ARDL Bound Test Results.

Test Statistics	Values	k
F-statistics	6.104	2
Critical Value Bound		
Significance level	I0 Bound	I1 Bound
10%	4.19	5.06
5%	4.87	5.85
2.5%	5.79	6.59
1%	6.34	7.52

Table 11. Long Run Estimation Results of ARDL (1,0,4).

Variable	Coefficients	Std. Errors	t-Statistics	Prb.
LMean MAIZ_PRECIPIT	87.554	67.326621	1.300450	0.2131
LMean MAIZ_TEMP	24668.555	7172.284091	3.439428	0.0037
C	-294699.217	105586.068998	-2.791080	0.0137

LMaiz_area=-294699.217+ 87.554 Lmean_maiz_precipitation+24668.56Lmean_maiz_trmperature.

The long run estimation results are reflected in table 11 show that both temperature and precipitation are positively and significantly associated with the maize area in the long run. The above scenario reveals that temperature is positively and significantly related to maize area under cultivation in the long run. While precipitation is positively but insignificantly related to maize area under cultivation in the long run. The table 12 indicates the short run relationship between maize area and temperature and precipitation. The table 12 indicates the short run relationship between maize area and temperature and precipitation. In the above estimation, the sign and value of ECT must be negative and significant respectively.

The coefficient of ECT is (-0.82) means the adjustment speed is (-0.82) that means that about 82% deviances from long-term equilibrium are adjusted every year. The coefficient of determination 86% indicates that 86% of the dependent variable variation (Maize area) in the form of explanatory variables is explained by the presented linear model.

Table 12. Short Run Estimation Results of Co-integration Form.

Cointegrating Form				
Variables	Coefficients	Std. Errors	t-Statistics	Prb.
D(Lmaiz_area(-1))	0.671737	0.221183	3.037021	0.0083
D(Lmaiz_precipit)	72.172688	54.923612	1.314056	0.2086
D(Lmaiz_temp)	5567.037984	2643.052399	2.106291	0.0524
D(Lmaiz_temp(-1))	-3018.107933	2411.484179	-1.251556	0.2299
D(Lmaiz_temp(-2))	-4018.215047	2501.488838	-1.606329	0.1290
D(Lmaiz_temp(-3))	1992.076048	2523.345846	0.789458	0.4421
D(Lmaiz_temp(-4))	-9214.580774	2549.140209	-3.614780	0.0025
D(@trend())	-939.848326	239.750899	-3.920103	0.0014
ect(-1).cointeq(-1)	-0.824314	0.183378	-4.495152	0.0004

Cointeq = MAIZ_AREA - (87.5549*MAIZ_PRECIPIT + 24668.5547 *MAIZ_TEMP -294699.2165 -1140.1587*@TREND) & R^2=0.86.

The results of this study are in line with many other studies conducted on climate change impact on crops at high altitudes (Xiao, *et al*., 2005; Hussain, S. S., M. Mudasser, 2007; Cuculeanu, V. *et al*., 1999). The study recommends that the 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, construction of water harvesting facilities. Further research is required to estimate range of temperature and precipitation within which crops under study perform better.

Conclusion and recommendations

Climate change affects agriculture in a number of ways and has implications for yield of crops. In rainfed areas, climate is key to crop productivity, therefore droughts, extreme temperatures and/or floods could destroy agriculture sector and thus livelihood of rural poor. The global temperature has increased by 1.5 degree celsius and the increasing trend in temperature will continue even after the year 2100. Thus influence of climate changes continuously poses major threat to rural livelihoods. Pakistan being an agricultural country is under immediate risk because of global climatic variability with potential of increased vulnerabilities to agriculture. The arid regions/land will be on the top of affected list. In case of Khyber Pakhtunkhwa (KP) province of Pakistan, some of the districts such as Mansehra is mostly rainfed and vulnerable to climate change. Realizing the potential threats of climate change to arid/rainfed areas of KP, this study tried to determine the impact of 30 years based temperature and precipitation on the area and productivity of maize crop in the rainfed areas of district Mansehra. The Autoregressive Distributed Lag (ARDL) model also called bound testing cointegration model is used for analytical purpose. The ARDL approach is most suitable econometric tool for such type of analysis. A umber of diagnostic tools were applied for determining suitability of the model used and to satisfy other necessary assumptions. After satisfying all the necessary assumptions, the relationship between maize yield as an outcome variable and precipitation and temperature as predictor variables were estimated using ARDL (bounds) test. The value of F Statistics is 6.971 is larger than upper boundary that shows long run relationship among the variables. Therefore, Akike Info Criterion (AIC) was used to select the optimal lag length of variables included in the ARDL model that showed long-run relationship of the selected ARDL model (1, 1, 1) using AIC. The long run estimation results show that temperature is positively but insignificantly related to maize yield in the long run but precipitation is positively and significantly related to maize yield in the long run. The coefficient of ECT is (-0.64) which shows that in the short run relationship between maize yield and temperature and precipitation, around 64% deviations from long-term equilibrium are adjusted every year. The determination coefficient indicates that 44% of the dependent variable variation (maize yield) in the form of explanatory variables is explained by the linear model applied in the instant case.

The relationship between maize area as a dependent variable and temperature and precipitation as independent variables was estimated using ARDL bound test. The result of the test shows long run relationship amongst the variables. The value of F Statistics in the above table is 6.104 which is higher than upper boundary showing long run relationship among the variables. Akike info criterion (AIC) used to select the optimal lag length of variables included in the ARDL model. The results show that temperature is positively and significantly while precipitation is positively but insignificantly related to maize area under cultivation in the long run. For the short run relationship between maize area and temperature and precipitation the coefficient of ECT is (-0.82) means the speed of adjustment is (-0.82) which implies that around 82% deviations from long-term equilibrium are adjusted every year. The coefficient of determination indicates that 86% of the dependent variable variation (Maize area) in the form of explanatory variables is explained by the presented linear model. The study recommends that the 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, construction of water harvesting facilities. Further research is required to estimate range of temperature and precipitation within which crops under study perform better.

References

Adger. 2007. Assessment of Adaptation Practices, Options, Constraints. Cambridge University Press.

Ahmad R, Zulfiqar M. 2019. Climate change-farmers' perception, adaptation and impact on agriculture in the Lakki Marwat district of Khyber Pakhtunkhwa. Sarhad Journal of Agriculture **35(3),** 880-889.

Breusch TS. 1978. Testing for Autocorrelation in Dynamic Linear Models. Australian National University. https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-8454.1978.tb00635.x

Breusch, Pagan. 1979. A Simple Test for Heteroscedasticity and Random Coefficient Variation. Econometric **47 (5),** 1287-1294.

Brown RL, Durbin J, Evans JM. 1975. Techniques for Testing the Constancy of Regression Relationships over Time. Journal of the Royal Statistical Society. Series B (Methodological) **37(2),** 149-192.

Calzadilla A. 2009. Economy-wide impacts of climate change on agriculture in sub-Saharan Africa. Working Paper FNU-170. Hamburg: Hamburg University and Centre for Marine and Atmospheric Science.

Cuculeanu V. 1999. Climate change impact on agricultural crops and adaptation options in Romania. Climate Research **12(2-3),**153-160.

Engle F, Granger WJ. 1987. Co-Integration and Error Correction: Representation, Estimation and Testing. Econometrica **55(2),** 251-276.

ERRA. 2007. Emergency Response and Rehabilitation Authority. Government of Pakistan, Islamabad.

Godfrey LG. 1978. Testing for higher order serial correlation in regression equations when the regressors include lagged dependent variables. Econometrica **46,** 1303-1310.

GoKP. 2016. Crops Statistics of Khyber Pakhyunkhwa, Crop Reporting Services. Agriculture, Livestock and Cooperation Department, Government of Khyber Pakhtunkhwa.

GoP. 2017. Economic Survey of Pakistan 2016-17. Finance Division, Government of Pakistan, Islamabad.

Hussain SS, Mudasser M. 2007. Prospects for Wheat Production under Changing Climate in Mountain Areas of Pakistan—An Econometric Analysis. Agricultural Systems **94(2),** 494-501.

IPCC. 2007. Climate Change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

IPCC. 2014. Climate Change Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland.

Johansen S, Juselius K. 1990. Maximum Likelihood Estimation and Inference on Cointegration with Applications to Demand for Money. Oxford Bulletin of Economics and Statistics **52.**

Khan S. 2012. People Perception about Climate Change and Adaptation in the Arid Region of Pakistan.

Kwiatkowski, Phillips, Schmidt, Shinn. 1992. Testing the null hypothesis of stationarity against the alternative of a unit root. Journal of Econometrics **54,** 159-178.

Maddala. 1998. Unit Roots Co-integration and Structural Change. Cambridge University Press. ISBN 978-0-521-58257-5.

Pesaran, Shin, Smith. 2001. Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics **16,** 289-326.

Pesaran, Shin. 1999. An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis. Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium. Cambridge University Press.

Phillips, Xiao. 1998. A Primer on Unit Root Testing. Journal of Economic Surveys **12(5).**

Rosenzweig C, Hillel D. 1998. Climate Change and the Global Harvest: Potential Impacts of the Greenhouse Effect on Agriculture. Oxford University Press.

Xiao. 2005. Impact of Recent Climatic Change on the Yield of Winter Wheat at Low and High Altitudes in Semi-Arid Northwestern China. Agriculture, Ecosystems and Environment **127,** 37-42.

Ziervogel G, Zermoglio F. 2009. Climate change scenarios and the development of adaptation strategies in Africa: challenges and opportunities. Climate Research **40,** 133-146. doi: 10.3354/cr00804

Zulfiqar M. 2018. Threats of global warming for Pakistan's Agriculture: An evidence from Shigari Kalan watershed, Skardu. Sarhad Journal of Agriculture **34(3),** 569-574.