NUST JOURNAL OF SOCIAL SCIENCES AND HUMANITIES
Vol.4 No.2 (July-December 2018) pp. 240-262

Climate Change Impact on Wheat Yield in Pakistan (An Application of ARDL Approach)

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Abstract:

Wheat is an important food crop of Pakistan and used in variety of ways to produce other by-products. Pakistan falls under top ten major countries of the world producing wheat. The objectives of the study are to investigate whether hasty changes in climate exerting impacts on wheat yield in Pakistan or not. The data spanning over a time period of 1991 to 2015 were used. The variables namely area under cultivation of wheat, water availability, amount of precipitation, mean temperature, and mean relative humidity are used for the purpose of estimation. The Auto Regressive Distributed Lag Model is applied for inference of results. The results of the study indicate that both in short and long run humidity rate, water usages, and area play a significant role in increasing the wheat yield whereas, precipitation shows the negative effect on wheat yield. Also, temperature does not show any significant impact in short run, while it plays a vital role in enhancing wheat yield in the long run.

Keywords: Climate Change, Wheat Production, Impact Assessment

1. INTRODUCTION

Climate change refers to significant change in measures of climate (such as temperature or precipitation) lasting for an extended period (decades or longer).

> *"A change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere, and that is in addition to natural climate variability over comparable time periods"* (UN, 1992).

This definition thus introduces the concept of difference between the climate and the effect of human induced increase in the concentration

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of greenhouse gases (GHGs) and that would be realized without such human interference. The earth's climate has seen much variability over the millennia, but the last two centuries have witnessed development of the phenomenon of GHGs, which threatens to change climate in an unprecedented manner.

The Greenhouse gasses are responsible of global warming comprising Carbon Dioxide (CO_2), Nitrous Oxide (N_2O), Methane (CH_4) and water vapours. These gases are produced by a number of anthropogenic activities. CO_2 is produced during the burning of wastes, fossil fuels, carbon, and wood. Methane is mainly produced during gas and oil process, mining of coal and during their transportation and N_2O is produced during agricultural and industrial activities (USDE, 1999).

Climate change may result from: i) Natural factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun; ii) Natural processes within the climate system (e.g., changes in ocean circulation); and iii) Human activities that change the atmosphere's composition (e.g., through burning fossil fuels) and the land surface (e.g., deforestation, reforestation, urbanization, desertification).

Different studies concluded impacts of climate change on major crops of agriculture sector like wheat, cotton, sugarcane, and rice differently. Schlenker, *et al.* (2006) identified that the temperature above threshold level may harm the crops yield. Rise in temperature reduces the yield in all seasons except autumn but increase in level of precipitation exerts positive impacts on productivity [Mendelsohn (1994)]. Temperature is a more important factor in wheat at higher latitudes [PARC (1982)].

Climate change is playing havoc with agriculture sector, and looking at the other way round agriculture sector is also harmful for climate as identified by Paul, *et al.* (2009) who observed that 14 percent of methane and nitric oxide in climate and 18 percent of due to deforestation comes from agriculture sector. Rise in temperature causes to delay the process of vernalization of wheat [Chouard (1960)].

Temperature hike due to climate change is catastrophic which reduces wheat yield as higher temperature accelerates the process of evapo-transpiration that creates moisture stress for the crop [Warrick (1988)].

Pakistan is highly vulnerable to climate change as its economy is heavily reliant on climate-sensitive sectors like agriculture and forestry, and its low-lying densely populated deltas are threatened by a potential risk of flooding. Pakistan is highly affected by climate change due to number of various factors including temperature hike, rainfall pattern, water availability, different sowing and harvesting timings, land suitability, and evapo-transpiration. These factors can contribute to change productivity of agriculture sector [Harry, *et al.* (1993)].

1.1 Global and National Perspective of Global Change: An Overview

The continuous increase in emission of greenhouse gasses has resulted in global warming, and substantial changes in the future climate are expected by the end of the current century. Global average temperatures have been rising, and human activities have changed the composition of the atmosphere significantly enough that we can now confidently say that the climate will continue to change. Alongwith the projected future increase in temperature by 1.5-4.6^{o}C (IPCC, AR5) by the end of year 2100, there will be changes in atmospheric and oceanic circulation, and in the hydrologic cycle, leading to large increases in frequency and intensity of extreme climate events such as floods, droughts and cyclones; rapid melting of world's glaciers and ice sheets including the polar ice; rise in average sea level causing submersion of small islands and other low lying coastal areas, etc. [IPCC (2015)].

Particularly large will be the adverse impacts of climate change on developing countries like Pakistan whose water and food security could be threatened by the climate change. In the past few decades, global climate change has had a significant impact on the high mountain environment: snow, glaciers, and permafrost are especially sensitive to changes in atmospheric conditions because of their proximity to melting conditions. In fact, changes in ice occurrences and corresponding impacts on physical conditions high-mountain system could be one of the most directly visible phenomena of temperature increase. This is also one of the primary reasons why glacier observations have been used for climate system monitoring for many years [Haberli (1990)].

The warming observed over the past several decades is consistently associated with changes in the hydrological cycle such as: increasing atmospheric water vapour; changing precipitation patterns, intensity and extreme events; widespread melting of snow and ice; and changes in soil moisture and runoff. Projected Global temperatures will also likely to alter the hydrologic cycle in ways that may cause substantial impacts on water resource availability and changes in water quality. For example, the amount, intensity, and temporal distribution of precipitation are likely to change. Warmer temperatures will affect the proportion of winter precipitation falling as rain or snow. Long term climatic trends could also bring changes in vegetation cover that would alter a region's water balance.

Global temperature has increased by 0.3–0.6°C since the late 19th century and by 0.2–0.3°C over last 40 years. In the last 140 years, the 1990s was the warmest period [Jones and Briffa (1992)]. Kothawale and Rupa (2002) reported a rise of 0.5°C in mean annual temperature over last century. However, no systematic change in mean minimum temperature was observed.

In Pakistan, annual mean surface temperature had a consistent rising trend since the beginning of 20^{th} century. Rise in mean temp. of 0.6-1.0°C in arid coastal areas, arid mountains and hyper arid plains, 10-15% decrease in both winter and summer rainfall in coastal belt and hyper arid plains, 18-32% increase in rainfall in monsoon zone especially the sub-humid and humid areas is observed. There is 5% decrease in relative humidity in Baluchistan, 0.5-0.7% increases in solar radiation over southern half of country [Farooqi (2005)].

According to the reports and studies, Pakistan is one of the most affected countries to climate change impact. It is ranked 7^{th} in the Global Climate Risk Index during period of 1997 to 2016. Pakistan's economy is an agriculture based economy where agriculture contributes 21% share into GDP. 45 percent of the total labour force employs in agriculture sector and it is a source of livelihood about 62% of the rural population. Therefore, in order to examine the climate change impact on agriculture productivity, it is necessary to adapt the essential and effective measures to reduce the climate vulnerability and its impact on socio-economic and demographic characters to avoid the damages to the households' level in Pakistan.

The present study contributes to the literature by examining the climate change impact on wheat yield in Pakistan in the line of previous studies by using three variables of climate change namely temperature, CO2, and precipitation [Janjua, *et al.* (2011)]. This study is different in nature from others in its estimation of climate change impact by employing the updated data spanning over the period of 1991-2015 by using the three climatic variables of humidity, precipitation, and temperature to capture disaggregated impact. The main objective of the study is to assess whether changes in climate exerting effects on wheat yield in Pakistan. More specifically, what has been the impact of humidity, precipitation, temperature, area under cultivation of wheat, on the wheat yield of Pakistan?

2. LITERATURE REVIEW

Gbetibouo and Hassan (2004) have identified impact of climate change on major crops of South African regions by using Ricardian Model. The crops namely wheat, sugarcane, sorghum, maize, soybean, ground nut, and sunflower are used for analysis. They identified that rise in temperature has a positive impact on the production of maize, soybean, sorghum, and sunflower while it showed negative impact on wheat and sugarcane productivity. They viewed that selected regions are already facing high temperature may considerably fluctuate the wheat productivity. Replacement of wheat by sorghum may resolve the issue due to high temperature as suggested by authors.

Lobell, *et al*. (2005) investigated the climate change trends on production of wheat in the regions of Mexico by using simulation model using time series data. They have found wheat yield increased by 25 percent due to climate change during the selected two decades, which gives positive impact on wheat production in the selected regions.

Hussain and Mudassar (2006) have assessed the future impact of change in climate on wheat production in mountainous regions of Chitral and Swat regions of Pakistan by setting average latitude of 950m and

1500m above the sea level respectively. The study has investigated whether rise in temperature up to 3^{o}C would cut the length of growing season of the wheat yield. The results indicated that rise in temperature exerted positive impact on Chitral district because of its location based on high altitude and posted negative impact on Swat district due to its position based on low altitude. It has revealed that rise up to 1.5^{o}C in temperature will boost wheat yield by 14 percent in Chitral and decrease by 7 percent in Swat. Furthermore, an increase in temperature up to 3^{o}C might increase yield by 23 percent in Chitral district and decrease yield by 24 percent in Swat district.

Janjua, *et al.* (2011) have investigated that whether the rise in global temperature negatively affects the production of wheat in Pakistan or not. They have used Johensen Co-Integration Techniques and Vector Error Correction Model (VAR) including the variables namely CO_2 emissions, temperature, precipitation, wheat production in thousand tons, agriculture credit, wheat procurement prices and fertilizers off-take. Their main findings did not support their hypothesis and proved insignificant.

Siddiqui, *et al.* (2012) have explored the impact of change in climate on major crops like wheat, rice, sugarcane, and cotton in province of Punjab. The authors have used Fixed Effect Model using panel data including variables wheat, cotton, and sugarcane productivity. The results revealed that rise in temperature in the short run may affect negatively while in long run, it may exert positive impact on productivity of wheat. On other hand, increase in precipitation may affect negatively on productivity of wheat both in the short and long run.

Janjua, *et al.* (2013) have investigated the effects of climatic and other variables on wheat production of Pakistan. The variables namely CO2, temperature, average precipitation, area under cultivation of wheat, fertilizer off-take, technology, and credit disbursement were used. Annual data for a period of 1969 to 2009 were used for the study. Results were inferred by using Auto Regressive Distributed Lag (ARDL) model. The results of the study show that there is no significant impact of global change in climate on what production in Pakistan.

Akram and Asma (2013) have explored the impacts of climate change on growth rate of Pakistan by undertaking analysis at national and provincial level. The data used for the study for a period from 1973-2010.The variables namely Gross Domestic Product (*GDP*), Investment (*K*), Population Growth (*POP*), Temperature (*Tmp*) and Openness (*Op*) have been used for the study. The analysis was made by using Johensen co-integration technique and Vector Error Correction Model (VAR). The results of the study indicated a significant negative relationship of temperature change on GDP, manufacturing sector, services sectors, and agricultural productivity. The results at provincial level revealed that there is significant negative effect of climate change in province of KPK and Balochistan and declared insignificant impacts for the province of Sindh and Punjab.

Amin, *et al.* (2015) explored the impacts of climate change on major food crops of Bangladesh. The variables used for the study were maximum temperature, rainfall, humidity, sunshine, minimum temperature, yield, cropping area, and production of four major crops namely Australian Rice, Boro Rice, Aman Rice, and Wheat. The HAC and FGLS model were used to infer the results of climate change impact on the four food crops of Bangladesh. The results of the study indicated that all climatic variables had significant impact on cropping area and yield of food crops with some variations. Maximum temperature showed significant impact on all crops except Australian Rice and also affected insignificantly to cropping area of all food crops. Minimum temperature showed insignificant effects on Aman's Rice. Rainfall significantly affected cropping area and yield of Australian Rice and Aman Rice. Sunshine significantly benefitted Boro-Rice yield only.

3. METHODOLOGY AND DATA DESCRIPTION

Techniques are also elaborated to capture the effects of the factors affecting on yield of wheat. This section describes the methodology is arranged into four parts: Section 3.1 provides the introduction. Section 3.2 describes the empirical methodology used to measure the factors affecting wheat yield. Section 3.3 deals with the data sources, description of relevant variables, and model specifications. Section 3.4 shows the performance of variables over time.

3.1 The Empirical Methodology

3.1.1 Stationary/Unit Root Test

The first step of the empirical process used involves a test for unit roots. This is necessary because the co-integration tests can be applied only to variables that are non-stationary in levels (contain a unit root) whereas ARDL model approach has been used where some of the variables are stationary at level, while others of them can be integrated at order 1. Unit-root tests have conditioned the standard approaches to analyze time series with strong serial dependence, the focus being placed in the detection of eventual unit roots in an auto-regressive model fitted to the series. Dickey and Fuller (1979) have developed a method to determine whether a variable contains a unit root. The rests are conducted, including a drift term and both with and without a trend. The inclusion of a trend allows testing that determines whether the series is a trend or a difference stationary [Amuedo and Pozo (2001)].

3.1.2 Autoregressive Distributed Lag (ARDL) Model

Autoregressive Distributed Lag (ARDL) or Bound Testing Co-integration technique was originally designed by the Pesaran, *et al.* (2001). The certain reasons behind using this technique is that some of the variables are stationary at level *I(0)* while others are stationary at 1st difference or integrating at order *I(1)*. The ARDL model technique is the best econometric technique instead of using other techniques for the variables having stationary at level and difference of first order. For achieving the objective of this study, this technique is the best and most appropriate as this study focuses on inferring impact of different independent variables on a single dependent variables, i.e., wheat yield in the short run and in the long run as well. This technique is also well suited in that it entertains small set of data sample and generates the coefficient for short and long run simultaneously by following OLS in order to develop the relationship among different variables of the study.

3.2 Model Specification

The general form of ARDL Model is as under:

$$Y_t = \alpha_0 + \sum_{i=1}^{n} a_i Y_{t-1} + \sum_{i=0}^{m} \beta_i X_{t-i} + \mu_t \qquad \dots (1)$$

The general form of ARDL Error Correction Model is as under:

$$\Delta Y_t = a_0 + \sum ß_j Y_{t-1} + \sum ß_j X_{t-j} + \Psi\, CM_{t-1} + \varepsilon_t \qquad \dots (2)$$

The relationship of dependent variable (wheat yield) with explanatory variables in this study is as under:

$$WY = f\,(MT, AP, AW, WA, MRH) \qquad \dots (3)$$

The above model shows the functional form of wheat yield with a set of explanatory variables that is transformed into log-linear combination for the sake of estimation.

$$LnWY = \lambda_1 + \lambda 2LnMT + \lambda 3LnAP + \lambda_4 LnAW + \lambda_5 LnWA + \lambda_6 LnMRH \qquad \dots (4)$$

where,

WY	Wheat yield (kg/hectare)
MT	Mean Temperature (Maximum+Minimum/2) (^{0}C)
AP	Amount of Precipitation (mm per year)
AW	Area under Wheat Cultivation (000 Hectares)
WA	Water availability at farm gate (Million Acre- feet)
MRH	Mean Relative Humidity[1]at 1200 UCT[2] (%)

3.2.1 Bound Testing Technique

In ARDL Model or Bound Test, the first step is to check long run relationship among variables. In first step of the procedure, null hypothesis of no co-integration among variables, i.e., *Ho:* $\delta 1 = \delta 2 = \delta 3 = \delta 4 = \delta 5 = 0$ may be checked against the alternative hypothesis

[1] Relative humidity is the amount of water vapour present in air (gas) expressed as a percentage of the amount needed for saturation at the same temperature.

[2] Universal cover tape (UCT).

of co-integration, i.e., $H_1: \delta 1 \neq \delta 2 \neq \delta 3 \neq \delta 4 \neq \delta 5 \neq 0$ among the variables may be checked. F-statistic value is the criteria to check the significance of lagged levels of the variables in a conditional unrestricted equilibrium error correction model. F-statistic distribution is non-standard regardless of whether the variables are at *I(0)* or *I(1).* Pesaran, *et al.* (2001) designed two sets of critical values. One set of critical values presumes that all the variables of the study are *I(0)* while other set of values presume that all variables are *I(1)* so these two sets of values form a group that wraps all expected categorization of *I(0), I(1)* or even partially integrated. Afterward, the computed Wald or F-statistics values are compared with critical values which were proposed by Pesaran, *et al.* (2001). If $F_{calculated} > F_{upper\ value}$, then null hypothesis of no-co-integration among variables of the study, i.e., $H_0 : \delta 1 = \delta 2 = \delta 3 = \delta 4 = \delta 5 = 0$ is rejected and it can be assured that a long-run relationship exists among the variables. If computed values fall inside the critical values, then conclusion is indecisive. However, if $F_{\text{Calculated}} > F_{\text{Lower}}$ then we accept null hypothesis of no co-integration among variables, i.e. $H_0 : \delta 1 = \delta 2 = \delta 3 = \delta 4 = \delta 5 = 0$.

3.3 Data and Description of Variables

The key variables used in the analysis are *wheat yield (WY)* as dependent variable, *mean temperature (MT), water availability (WA)* at farm gate, *amount of precipitation (AP), area under cultivation of wheat (AW)* and *mean relative humidity (MRH)* are explanatory variables. Annual Data spanning from the period of 1991 - 2015 are used. Data for area under cultivation of wheat and wheat yield were gathered from different series of Yearly Books of Agriculture Statistics and from Pakistan Economic Survey. Data for Mean Temperature, amount of precipitation and mean relative humidity were obtained from Pakistan Meteorological Department, Islamabad.

The variable of Mean Temperature calculated as an average of maximum and minimum temperature [(Maximum+Minimum)/2] is reported during the periods. The data for Mean Temperature and Mean Relative Humidity is an annual average of 13 big cities called Climatic Zones by Pakistan Meteorological Department and data of amount of precipitation is annual sum of precipitation of all 13 big cities for the six months from November to April. As the wheat crop has its time period from November to April so the study uses average of data from November to April for *MT* and *RH* and uses sum of precipitation for the period of same 6 months from November to April.

3.3.1 Wheat Yield, Area and Production over Time

Wheat is the most popular crop and staple food of Pakistan cultivated on the largest acreages and used in a variety of ways for producing other by-products. Pakistan falls under 10 major countries for producing wheat in the world in terms of total production, yield per hectare, and area under wheat cultivation[3]. Being an essential diet, wheat constitutes 60% of the daily diet of common man and its average per capita consumption is about 125 kg. Wheat accounts for 9.9 percent in the value added agriculture and 2.0 percent of GDP. Area under wheat cultivation has increased from 9.204 million hectares in 2014-15 to 9.260 million hectares during 2015-16 posted an increase of 0.6 percent against last year.

Table 1. Yield, Area and Production of Wheat (1991-2015)

Period	Decadal Averages (Yield Kg/Hec)	Decadal Averages Area (000 Hectares)	Decadal Averages Production (000 Tones)
1991-2000	2120.5	8209.6	17426.9
2001-2010	2532.2	8532.1	21661
2011-12	2714	8650	23473
2012-13	2796	8660	24211
2013-14	2824	9199	25979
2014-15	2726	9204	25086
2015-16	2752	9260	25472
1991-2015	2637.81	8816.39	23331.27

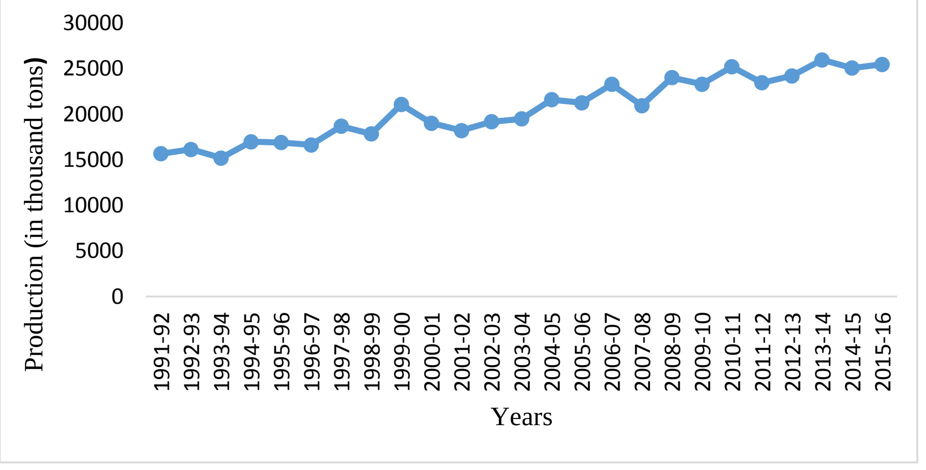
Source: Compiled by authors using GoP (various Issues).

The production reported at 25.472 million tonnes during 2015-16 against production of last year which were 25.086million tonnes

[3] Source: https:// www.worldatlas.com/articles/top-wheat-producing-countries.html (For detail see Appendix A.)

showing increase of 1.54 percent from the last year. The wheat yield per hectare in 2014-15 stood at 2752 (Kg/ha) against 2,726 in the last year showed a positive increase of 0.9 percent as compared to negative 3.5 percent last year. (GoP, various issues). Table 1 shows the decadal averages of the wheat production, area under wheat cultivation, and wheat yield per hectare from 1991-2015.

Figure 1. Trends of Wheat Production over the Time



Source: GoP (Various Issues).

3.3.2 Water Availability at Farm Gate

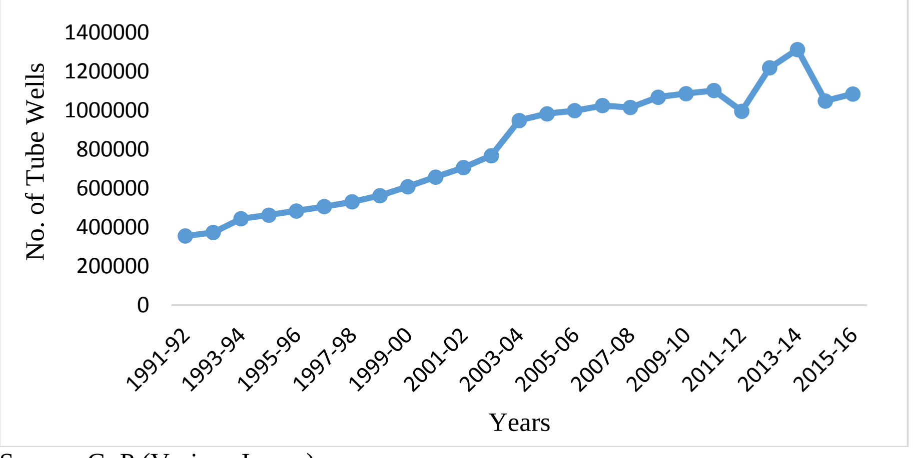
Pakistan has the largest canal irrigation system in the world and depends on canals and tube wells for irrigation as these are two major sources providing water for irrigation purposes to farmers. In 1970s, two large projects, Mangla and Tarbela Dam were commissioned by the Government which resultantly enhanced the availability of irrigation water for agriculture. The importance of irrigation water for farmers cannot be exaggerated as it reduces the effects of vagueness on farmers' investment and production decision along with facilitation about multiple and inter-cropping. Availability of water for irrigation purposes provides the conditions mandatory for the effective use of high yielding variety of seeds and chemical fertilizers.

In Pakistan, farmers applied irrigation in numerous forms. Generally irrigation is based on water from ponds, wells and tanks, and by diverting water from perennial streams in those regions of the country where annual rainfall is not meeting the requirements of the farmers. The practice of getting water from wells is continued from immemorial time and placed particularly on those places where water table is not deep.

During the 1950s, the number of installed tube wells was 300, which were increased up to 154,290 in 1974-75 and 10, 86,200 in 2015-16.

The remarkable increase in the installation of number of tube wells in the country is attributable partly to government to participate in the expansion of tube wells.

Figure 2. Pattern of Tube Wells during 1991-2016 (000 Nos.)

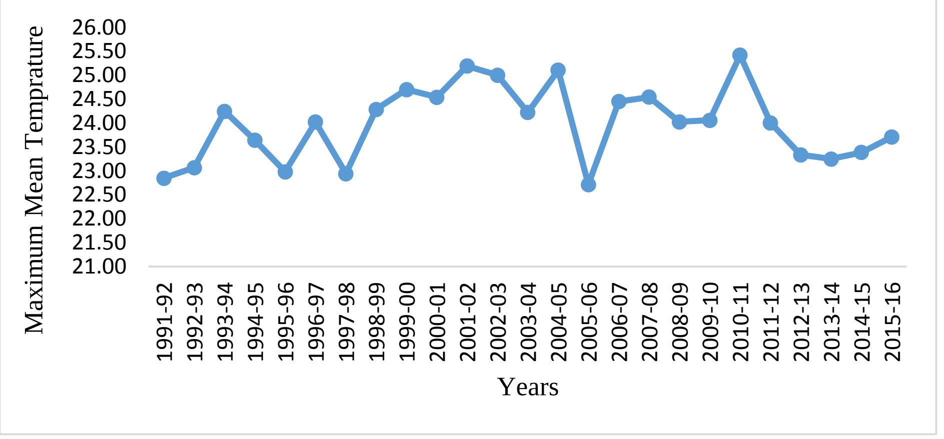


Source: GoP (Various Issues).

3.3.3 Mean Temperature

Pakistan's agriculture sector is considered the largest sector as the majority of the population is attached with this sector for securing livelihood and employment. This sector is facing emergence extortions of climate changes and it was projected that temperature will rise by 3°C till 2040 and increase from 5°C to 6°C at the end of this century. Due to these emerging threats of climatic variations, Asia can lose its wheat production by 50 percent. Agriculture sector is deemed much vulnerable to change in climate due to its geographical location [Janjua, *et al.* (2011)]. Figure 3 shows that Mean Temperature in decades of 2000 and 2010 was 23.729 and 24.475 respectively and Mean Temperature from 1991 to 2015 were remains 23.989 showing an increase of 1.1 percent.

Figure 3. Mean Temperature (C^0)



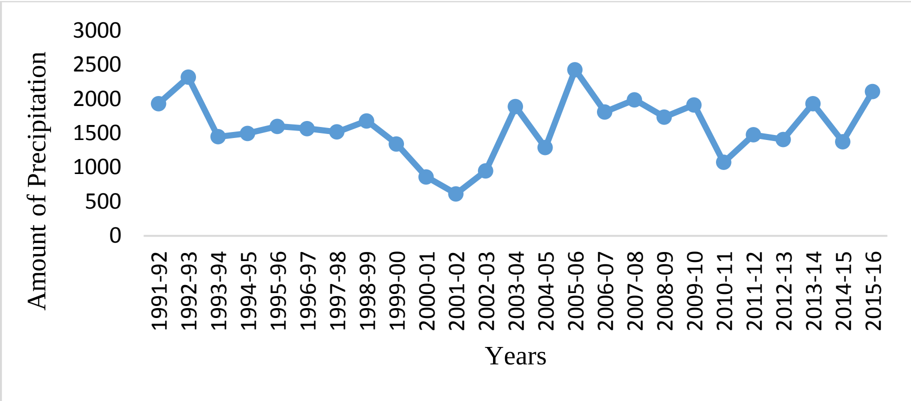
Source: GoP (Various Issues).

3.3.4 Amount of Precipitation (KM)

Precipitation is defined as any kind of water falls from clouds in the form of liquid or solid. Steady increase in temperature and its impacts on rainfall and cryo-sphere are very apparent around the globe and changes in rain fall pattern no doubt exerting impacts on agriculture sector of Pakistan. Fluctuations in rain fall pattern leads to natural disasters including floods, cyclones, intense rainfall, droughts, and earthquake [Task Force: Climate Change (2010)]. It is evident from the last couple of decades that there has been an increasing trend of incidence, intensity, and frequency of extreme climate events. Due to such disastrous events occurrences, about 40 percent of the Pakistani people became victims of multiple disasters due to variations in storms, floods, rain fall pattern, and droughts [Hussain, *et al.* (2010)]. Moreover, rain fall pattern shows an unpredictable and unreliable pattern that makes the effected communities, lives very hard as they do not have sufficient sources to make arrangements for their safety, livestock, and crops. This situations is clearly depicted in super flood faced by the people in July 2010.

Figure 4 shows the precipitation pattern of Pakistan from 1991 - 2015. The line shows that country has faced irregular pattern of rain fall during the last two decades.

Figure 4. Amount of Precipitation (Km)



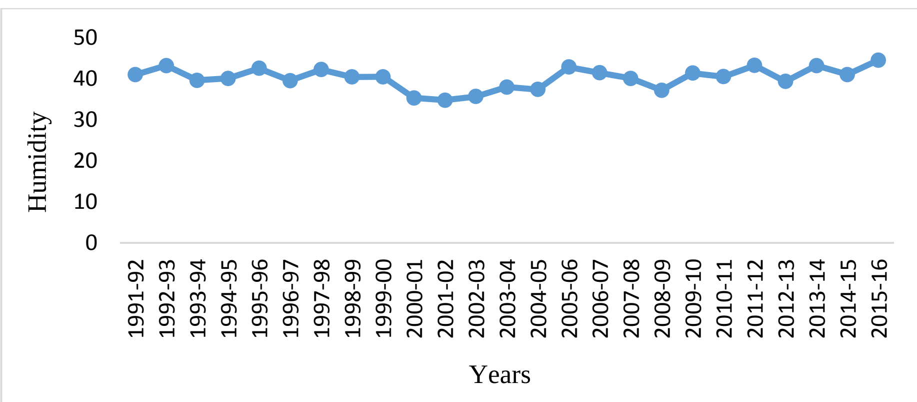
Source: GoP (Various Issues).

3.3.5 Humidity

Humidity is called amount of water vapour present in the air which indicates the likelihood of dew, fog, and precipitation. Humidity can be measured by three ways: absolute, relative, and specific. Humidity is climate-variable and strongly interacts with other climatic variables and affected by rain fall and winds.

Figure 5 shows humidity pattern in Pakistan from 1991-2015. Mean Annual relative humidity pattern in Pakistan does not depicts increasing trend but remains an annual average of 40 percent from 1991-2015.

Figure 5. Humidity Pattern



Source: GoP (Various Issues).

4. RESULTS AND DISCUSSION

4.1 Results of ADF and PP Tests

In empirical investigation, checking stationarity is necessary because during building models for time series, the underlying stochastic process that generated the series must be invariant with respect to time. If the characteristics of the stochastic process change over time, i.e. if the process is non-stationary, it will often be difficult to represent the time series over past and future intervals of time by a simple algebraic model. This leads to misleading results. On the other hand, if the stochastic process is fixed in time, i.e., if it is stationary, then one model with fixed coefficients can be estimated from past data. The table below shows the results of unit root test.

Before the application of ARDL model, the stationarity of the variables of the model needs to be checked. Because bound test is only applicable where the variables to be integrated at *I(0)* and *I(1)* for computation of value of F-Statistic. To check the stationarity of each variable, Augmented Dickey Fuller and Philips Perron unit root test is applied. The results of both tests are presented in Tables 2 and 3.

Table 2. Unit Root Test
(Augmented Dickey Fuller Test)

Variable	Level	Probability	1st Difference	Probability	Order of Integration
LnWY	-2.1083	0.4224	-2.09099	0.0047	I(1)
LnMRH	-2.19867	0.4671	-2.798723	0.0772	I(1)
LnWP	-5.82953	0.0004	-4.074535	0.0228	I(0)
LnWA	0.02365	0.5994	-4.13249	0.0052	I(1)
LnMT	-3.82329	0.0329	-5.525223	0.001	I(0)
LnAP	-2.96786	0.1609	-6.610081	0.0001	I(1)

Results of ADF test shows that humidity is stationary at 10% while all other variables are stationary at 5% whereas PP test results depicts that all variables are stationary at 5% level of significance.

The results of unit root tests reveal that all variables are not stationary at one level. Some variables are stationary at level while others shows stationary at first difference order. No variable is stationary at second order difference. The above results of ADF and PP test lead to test the variables of the model for obtaining relationship by using ARDL bound testing approach. The table below shows the results of ARDL Bound Testing technique.

Table 3. Unit Root Test
(Philips –Perron)

Variable	Level	Probability	First Difference	Probability	Order of Integration
LnWY	-2.792651	0.213	-7.415746	0	I(1)
LnMRH	-2.8138	0.2061	-7.541133	0	I(1)
LnWP	-5.82953	0.0004	-16.64356	0	I(0)
LnWA	-0.454785	0.8783	-4.12144	0.0144	I(1)
LnMT	-3.787469	0.0353	-20.33201	0	I(0)
LnAP	-2.897279	0.1805	-6.610081	0.0001	I(1)

4.2 Results of ARDL Bound Test

ARDL bound testing technique has been used to check the long-run relationship between the variables. For testing the null hypothesis of no co-integration against alternative of having co-integration, lag length of one as suggested by Schwarz Bayesian (SBC) and Akike Information Criterion (AIC) has been used and results of bound test is presented in Table 4.

Table 4. ARDL Bound Test

	Critical Value Bounds (at 5 % significance level)	
F-statistic	$I_{(0)}$ Bounds	$I_{(1)}$ Bounds
4.45	2.62	3.79

The results of the bound test in table 4 indicate that the calculated value of F-stat is greater than upper bound (Pessaran et al (2003) values at 5% level which confirm the presence of long run association and relationship among the variables of the model.

4.2.1 ARDL Co-integration and Long Run Form
(Short Run and Long Run Elasticities for Wheat Yield)

The results of elasticities for short and long run are presented below in the Tables 5 and 6. The results show that the value of co-integration equation is negative and less than 1 which shows the existence of long-run relationship. The short-run coefficients of area under wheat cultivation and number of tube wells are statistically significant. In the short run number of tube wells and area under wheat cultivation are important factors for increasing wheat production. A 1% increase in area under cultivation of wheat will lead to increase wheat production by 2.1% whereas 1% increase in number of tube wells will enhance wheat production by 0.30. The short run coefficient of amount of precipitation is negative and significant which shows that an increase in 1% in precipitation will decline wheat production by 0.13% whereas humidity has positive and significant relationship with wheat production in short run. The variable of Mean Temperature is insignificant, which shows that temperature does not affect wheat production in short run. The results of insignificant temperature have consistency with Janjua, *et al.* (2013) and Amin, *et al.* (2015).

Table 5. Results of Short Run Coefficients Estimates of Co-integration Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LnWA)	0.204	0.031	6.022	0.000
D(LnAP)	-0.133	0.039	-3.423	0.004
D(LnMT)	0.516	0.340	1.515	0.153
D(LnMHU)	0.568	0.203	2.794	0.015
D(LnAW)	2.079	0.383	5.420	0.000
CointEq(-1)	-0.981	0.172	-5.857	0.000

Table 6. Results of Long Run Coefficients Estimates of Co-integration Form

Regressor	Coefficient	Std. Error	t-Statistic	Prob.
C	-17.931	3.127	-5.733	0.000
LnTW	0.301	0.037	8.063	0.000
LnAP	-0.132	0.042	-3.114	0.008
LnMT	1.126	0.545	2.063	0.059
LnMHU	1.042	0.303	3.428	0.004
LnAW	0.947	0.359	2.632	0.020

The results of long run coefficients of the model show that all variables are statistically significant in the long run including Mean Temperature. Temperature is not playing any role in the short run for affecting wheat yield; while in the long run change in temperature will effect wheat yield. The study explores how anthropogenic activities global temperature is increasing which may exert negative effects on wheat yield. By using "Vector Auto Regressive" (VAR) model it is confirmed that climate change does not exert any significant impact on wheat yield in Pakistan.

5. CONCLUSION

The current study has been designed to compute the impact of change in climate on wheat yield in Pakistan. The analysis was made by using ARDL Model approach for checking the impact of climatic variables on wheat yield. The data for a period from 1991 to 2015 were used to compute the results. The results of the study indicated that both in short run and long run, water availability and area under wheat cultivation play an important role in enhancement of wheat yield whereas change in temperature does not exert impact on wheat yield in short run but change in temperature may affect the wheat of Pakistan in the long run. Moreover, amount of precipitation is negative and significant both in short and long run whereas humidity is significant and positively related with wheat yield both in short and long run.

Appendix Table

Top 10 wheat producing countries in the world

Sr.	Country	Million Metric Tons
1	Ukraine	24
2	Australia	25
3	Pakistan	26
4	Germany	28
5	Canada	29
6	France	39
7	USA	55
8	Russia	60
9	India	95
10	China	126

Source: https://www.worldatlas.com/articles/top-wheat-producing-countries.html.

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