



## **Climate Change and Agricultural Production in Pakistan**

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### **ABSTRACT**

Agriculture sector holds great value for Pakistan. Climate change is a major determinant of agricultural productivity all over the world. This sector is the most vulnerable sector to weather change. The productivity of this sector is being affected by several factors of climate change like temperature and rainfall patterns. The core objective of the study is to determine the impact of climate change on agricultural production (wheat, rice, and sugarcane) in Pakistan. Time series data from 1985–2018 is taken from the Pakistan Economic Survey, Metrology department of Pakistan, and the World Bank for the current analysis. Autoregressive Distributed Lag model is used to analyze the impact of climate change on agricultural production in Pakistan. The results show that climate change has an influential impact on agricultural production in Pakistan. The increase in mean temperature reduces agricultural production while the rain positively affects agricultural production. It is suggested that the government should give subsidies on agrarian tools, seeds, and fertilizers.



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## **1. Introduction**

Climate change has a vulnerable effect on the socio-economic and agriculture sectors (Adejuwon, 2004; Boutabba, 2014; Farooq, Bramley, Palta, & Siddique, 2011). Agricultural growth is highly affected by climatic factors like temperature hikes, water availability, rainfall patterns, evaporation, and land stability. All of the variables mentioned above have the potential to influence production growth (Sonal Mathur & Jajoo, 2014; S Mathur, Jajoo, Mehta, & Bharti, 2011; Teskey et al., 2015). Climate change has a multifaceted impact on agriculture, including reduced production potential and a shorter growth period (Iqbal & Arif, 2010). For example, courtiers in tropical regions face adverse conditions, whereas those in temperate zone regions may benefit from high temperatures (Estrada, Botzen, & Tol, 2017; Janjua, Samad, Khan, & Nasir, 2010).

The agriculture sector is playing a double role in Pakistan's economy by providing food and supporting economic growth by decreasing food imports. Agricultural sector is a significant source of raw materials for industry; cotton is an essential export of Pakistan, and the textile industry also depends on this sector for raw materials. To maintain the effectiveness of the population, the agriculture sector also provides a dose to those animals that provide milk, butter, cheese, and meat. All the other sectors of the economy are engaged with the agriculture sector for raw materials. The major crops include wheat, rice, sugarcane, maize, barley, corn, sorghum, pulses, cotton, etc.

Pakistan has diverse geographical structures due to particular climatic characteristics (S Mathur et al., 2011; Quadir, Hussain, Hossain, & Prasad, 2002). Inland areas have high temperatures, whereas mountain areas contain temperature below the freezing point. Despite specific climatic conditions, the climatic pattern has changed at a global level, influencing the crop productivity pattern. Besides a weakening in precipitation, a temperature rise is likely to stress the availability of water supply in Pakistan. Pakistan's agriculture is seriously dependent on water. The problems of the agriculture sector are technological, economic problems, natural problems, socio-economic problems, and financial issues.

Crop productivity is affected not only by climate change but also by a variety of other factors such as crop prices, fertilizer use, technology, water supply, agriculture credit, seed distribution, farmer education, land fertility, and so on (Ashfaq, Zulfiqar, Sarwar, Quddus, & Baig, 2011; Shakoor, Saboor, Ali, & Mohsin, 2011). The most important factor is water supply, which affects productivity. If the water supply is available at the required time, then the productivity of crops will increase. With global warming, the demand for water for crops will grow. Rainfall patterns are influenced by climate change.

Basic objective of the current study is to explore the impact of climate change in terms of temperature and rainfall on three major crops in Pakistan. Furthermore, to examine the effects of climatic or non-climatic variables on crop productivity. The study's organization is as follows: Section 2 describes the literature review. Section 3 explains the methodology and data. Section 4 describes the results and interpretation. Likewise, Section 5 concludes the study findings and provides suggestions based on empirical results.

## **2. Literature Review**

It is evident from the literature that overall food production has been reduced due to global warming (Ashfaq et al., 2011; Kaiser, Riha, Wilks, Rossiter, & Sampath, 1993; Shakoor et al., 2011). Such a climatic threat is a severe issue regarding rising average temperatures (Cline, 2008). Rising temperatures may cause flash floods, destroying crop fertility.

Janjua et al. (2010) examined the impact of climate change on wheat production in a case study of Pakistan. The data spans from 1960-to-2009. Based on data analysis, the trend of wheat production was examined from 2010 to 2060. The Vector Auto Regression model was used for the study. Findings indicate that higher temperature levels reduced wheat productivity, while average precipitation positively impacted wheat productivity. Based on data, researchers' were considering three simulation scenarios for 2060. In the first scenario, researchers assumed both precipitation and temperature increased. In that scenario, wheat production increased by taking increasing temperature and precipitation. That means global warming had a positive impact on the output of crops. In the second scenario, wheat output could increase if the temperature rose while precipitation remained constant. In the last scenario, if temperatures increased and rainfall was reduced, it would also harm wheat productivity. Therefore, it was recommended to cover the negative impact of climate change on wheat productivity through the better irrigation system, new techniques, better seeds, and utilization of drought-resistant seeds.

Mahmood, Ahmad, Hassan, and Bakhsh (2012) analyzed the impact of temperature and precipitation on rice productivity in the rice-wheat cropping system of Punjab. The study covered Punjab's rice and wheat cropping areas where the world's famous rice 'Basmati' is planted. The study focused on rice because rice was the dominant crop during the Kharif season. Time series data has been used for the rice crop from 1978 to 2007. The climatic data was taken from the Pakistan metrological department, Pakistan Economics survey, Agriculture statistics of Pakistan, and Punjab development statistics. Cobb Douglas production function was used for the analysis. The results show that increasing temperature would increase rice yields at the harvesting stage. A 1.5 degree centigrade to 3-degree centigrade increase in temperature would raise rice yield by 2.09% and 4.33%. Precipitation during September and October could negatively affect rice productivity. In the harvesting season, rainfall hurts rice productivity. Agriculture productivity is under threat in various parts of the world due to changes in rainfall patterns, floods, and droughts (Sushila, 2001).

Haris, Biswas, Chhabra, Elanchezhian, and Bhatt (2013) explored the impact of climate change on wheat and winter maize in a sub-humid climatic environment in Bihar,

India. In Bihar, wheat and rice were cereal crops during the winter season. Secondary data was used from 1961 to 1990. Metrological crop and soil data were gathered from Rajendra Agriculture University in Pusa and Bihar Agriculture Colleges in Madhepura and Patna. The Info crop model was used for the analysis. The results showed that changes in minimum temperature lead to an increased respiration rate, and a decrease in minimum temperature increases the crop duration and yield. When carbon di-oxide was increased by 682ppm, the productivity of wheat increased by 10%. The quality of wheat grain could decline when there was a higher atmospheric carbon dioxide concentration. The rise in production of winter maize showed the suitable change in climate for its growth. Bihar's unfavorable cultivation regions for wheat replacement by winter maize crop.

Khan, Anwar, and Khan (1988) explained the relationship between rainfall, acreage, and wheat production in the Northern Punjab. That study aimed to examine the patterns of rainfall distribution during the pre-sowing, sowing, and growing periods of wheat to determine their relationship with wheat acreage and production. The secondary data was used from 1960–84 to obtain the objective of the study. The rainfall data was taken from the metrological department of Pakistan. To establish some empirical relationship between wheat production and acreage rainfall in three districts (Rawalpindi, Jhelum, and Attock), a multiple regression line was run. All the estimated regression coefficients expected for Rawalpindi regarding sowing period rains were positive but statistically non-significant. The regression coefficient for the growing period rainfall suggested that for Rawalpindi and Attock districts, every additional 1mm of rain would increase 0.29 and 0.17kg of wheat in these districts.

In the previous literature, researchers used a single crop as the determinant of agriculture production, while current research has used wheat, rice, and sugarcane. Furthermore, this study contributes to the existing literature.

### 3. Methodology and Data

Climate change affects agricultural economies as its dependence on impulses of nature. Productivity is the output that depends on many input variables. Here, input is categorized into climatic and non-climatic factors.

$$\text{Productivity} = f(\text{Climatic factors, Non-Climatic factors}) \quad (1)$$

This study's dependent variable is agriculture production (wheat, rice, and sugarcane). At the same time, the independent variable (climatic) is climate change measured through temperature and rainfall. Other control variables (non-climatic) are import fertilizer and water availability. Functional form of equation (1) can be written as:

$$\text{Productivity (wheat)} = f(\text{Average Temperature, Average Rainfall, Import fertilizer, Water availability}) \quad (2)$$

$$\text{Productivity (rice)} = f(\text{Average Temperature, Average Rainfall, Import fertilizer, Water availability}) \quad (3)$$

$$\text{Productivity (sugarcane)} = f(\text{Average Temperature, Average Rainfall, Import fertilizer, Water availability}) \quad (4)$$

Above mentioned equations can be written in an econometric form as

$$\text{Wheat}_t = \alpha_0 + \alpha_1 AT_t + \alpha_2 AR_t + \alpha_3 IF_t + \alpha_4 WA_t + \alpha_5 NT_t + \varepsilon_{t-1} \quad (5)$$

$$\text{Rice}_t = \beta_0 + \beta_1 AT_t + \beta_2 AR_t + \beta_3 IF_t + \beta_4 WA_t + \beta_5 NT_t + \varepsilon_{t-1} \quad (6)$$

$$\text{Sugarcane}_t = \gamma_0 + \gamma_1 AT_t + \gamma_2 AR_t + \gamma_3 IF_t + \gamma_5 NT_t + \varepsilon_{t-1} \quad (7)$$

Here,  $\alpha_0$ ,  $\beta_0$  and  $\gamma_0$  are intercepts.  $\alpha_1$  to  $\alpha_5$  represents the change in wheat production concerning average temperature (AT), average rainfall (AR), import fertilizer (IF), water availability (WA), and number of tractors (NT), respectively.  $\beta_1 - \beta_5$  ( $\gamma_1 - \gamma_5$ ) indicates the change in the production of rice (sugarcane) w.r.t average temperature, average rainfall,

import fertilizer, water availability, and a number of tractors, respectively.  $\varepsilon_{t-1}$  is error term and Time period (t) consists of time period from 1985-2018. Table 1 shows the sources and definitions of the current analysis's variables. Climate indicators are rainfall and temperature. We collect rain fall data from seven cities of Pakistan Karachi, Lahore, Multan, Jacobabad, Peshawar, Islamabad, and Quetta.

**Table 1**  
**Definition of Variables**

Variables	Sources	Definition of Variable
<b>Dependent Variables</b>		
Production of wheat (PW)	Pakistan Economics Survey	Total yield of wheat per hectare in kilogram
Production of rice (PR)	Pakistan Economics Survey	Total yield of rice per hectare in kilogram
Production of sugarcane (PSC)	Pakistan Economics Survey	Total yield of sugarcane per hectare in kilogram
<b>Independent Variables (Climatic Factors)</b>		
Average temperature (TEMP)	Pakistan Economics Survey	Average annual temperature in centigrade
Average rainfall (RF)	Pakistan Economics Survey	Average annual rainfall in millimeter
<b>Control Variables (Non-Climatic Factors)</b>		
Import fertilizer (IMPF)	Pakistan Economics Survey	Total import of fertilizer in 1000 tones <sup>1</sup>
Water availability (WA)	Pakistan Economic Survey & MDOLP <sup>2</sup>	Water availability Million acre feet
Number of tractors (TC)	World bank & Agriculture census	Total number of tractors

The Autoregressive Distributed Lag (ARDL) is used to analyze the impact of climate changes and other economic variables (import fertilizer, number of tractors, water availability) on agriculture production in Pakistan. Order of integration of mentioned variables is checked through the Augmented Dickey-Fuller (ADF) test.

#### 4. Results and Discussion

This section shows the result of different tests to analyze the relationship between climate change and agriculture productivity. Table 2 indicates the stationarity results at I(0) and I(1) obtained through the Unit Root test. Here ARDL technique is appropriate to use.

**Table 2**  
**Unit Root Test**

Variable	t-Statistics	Level of significance	Decision
Wheat production	-6.596026	1% -4.20, 5% -3.53, 10% -3.19	I(0)
Rice production	-3.369448	1% -4.27, 5% -3.56, 10% -3.21	I(1)
Sugarcane production	-4.677561	1% -4.21, 5% -3.53, 10% -3.19	I(0)
Average Temperature	-3.198384	1% -4.21, 5% -3.53, 10% -3.19	I(0)
Average Rainfall	-5.265493	1% -4.21, 5% -3.53, 10% -3.19	I(0)
Import Fertilizer	-4.645910	1% -4.21, , 5% -3.53, 10% -3.19	I(0)
Water Availability	-6.351695	1% -4.22, 5% -3.53, 10% -3.20	I(1)
Number of Tractor	-5.066027	1% -4.21, 5% -3.53, 10% -3.19	I(1)

In light of the results of the bound test in table 3 indicates the rejection of the null hypothesis as there is no connection between the mentioned variable in the three models (production of wheat, rice, and sugarcane). After finding the co-integration relationship among the variables, then ARDL approach is used to find the long-run association between selected variables.

Table 4 shows the ECM results to capture the short-run association among the mentioned variables. In the case of Model I, average temperature and number of tractors

<sup>1</sup> The domestically supply of the fertilizers are less than the demand so to fulfill the domestic demand import the fertilizers. So we use the import of fertilizer as the proxy of the production of fertilizer.

<sup>2</sup> The Metrology Department of Lahore Pakistan.

have a significant impact on wheat production. Although, another variable effect is not essential in the case of wheat production. The result of co-integration in the long run by 0.74 indicates the significant and strong relation among variables both in the short and long run. In the case of Model II, temperature, imported fertilizer, and water availability significantly impact rice productivity. In the case of Model III, temperature, imported fertilizer, and water availability have a significant impact on sugarcane production. Likewise model I, the result of co-integration in the long run by 0.78 and 0.62 in Model II and III, respectively, indicates the significant and strong relation among variables both in the short and long run.

**Table 3**  
**Bound Test Approach under ARDL**

<b>Model I: Wheat Production</b>				
<b>F-statistics</b>	<b>95% lower bound value</b>	<b>95% upper bound value</b>	<b>90% lower bound value</b>	<b>90% upper bound value</b>
3.6610	2.3784	3.7408	1.9687	3.1726
<b>Model II: Rice Production</b>				
<b>F-statistics</b>	<b>95% lower bound value</b>	<b>95% upper bound value</b>	<b>90% lower bound value</b>	<b>90% upper bound value</b>
6.1584	3.5964	4.9400	3.0278	4.2311
<b>Model III: Sugarcane Production</b>				
<b>F-statistics</b>	<b>95% lower bound value</b>	<b>95% upper bound value</b>	<b>90% lower bound value</b>	<b>90% upper bound value</b>
4.1895	2.3784	3.7408	1.9687	3.1726

**Table 4**  
**Short run Estimates of Error Correction Representation Under**

<b>Dependent Variable: Wheat Production</b>			
<b>Regressors</b>	<b>Coefficients</b>	<b>Standard Errors</b>	<b>t-ratios (prob)</b>
d Average Temperature	-0.66442	0.19082	-3.4820(0.001)
d Average Rainfall	0.034440	0.038616	0.89187 (0.379)
d Import Fertilizer	0.017931	0.025602	0.70038(0.488)
d Water Availability	0.26861	0.31224	0.86025 (0.396)
d Number of Tractor	0.026861	0.014836	1.8377(0.075)
Ecm(-1)	-0.74714	0.18847	-3.9643(0.000)
<b>Dependent Variable: Rice Production</b>			
d Average Temperature	-.53655	.28533	-1.8804 (.069)
d Average Rainfall	.0011605	.031311	.037065 (.971)
d Import Fertilizer	.035814	.020782	1.7233 (.094)
d Water Availability	.59416	.19693	3.0171 (.005)
d Number of Tractor	.007081	.012794	.60249 (.551)
Ecm(-1)	-.77760	.16193	-3.5671 (.001)
<b>Dependent Variable: Sugarcane Production</b>			
d Average Temperature	-.96546	.21335	-4.5252 (.00)
d Average Rainfall	.038734	.031436	1.2322 (.226)
d Import Fertilizer	-.96546	.21335	-4.5252 (.00)
d Water Availability	.21328	.083087	2.5669 (.015)
d Number of Tractor	.010967	.010481	1.0464 (.303)
Ecm(-1)	-.62097	.084909	-4.9579 (.000)

The upper part of Table 5 shows the results of ARDL in wheat production, indicating that temperature, import of fertilizers, number of tractor, and water availability are significant. The average temperature result shows that a one percent increase in average temperature reduces wheat production by 0.89 percent. As climatic changes have raised the average temperature, which is harmful for land and crop production (Ahmed & Schmitz, 2011; Ashfaq et al., 2011; Hanif, Syed, Ahmad, Malik, & Nasir, 2010; Shakoor et al., 2011; Zeb, Khattak, Naveed, & Farid, 2013). Wheat crop is susceptible to the climate a change overall increase in temperature has terrible effects on wheat production (Haris et al., 2013).

The tractor and water availability are significant and positively impact the wheat production. Results are consistent with that of Ali, Rehman, Nasir, and Ranjha (2011) that the increased number of tractors has a positive impact on wheat production. Similarly, the increase in water supply positively affects crop production. Water supply is vital for crop production (Ahmed & Schmitz, 2011; Janjua et al., 2010).

**Table 5**  
**Estimated Long run Coefficients Using ARDL Approach**

<b>Dependent Variable: Wheat Production</b>			
<b>Regressors</b>	<b>Coefficients</b>	<b>Standard Errors</b>	<b>t-ratios (prob)</b>
Average Temperature	-0.88929	0.16370	-5.4325 (0.000)
Average Rainfall	0.046096	0.51839	0.88922 (0.381)
Import Fertilizer	0.037972	0.042114	0.90166 (0.374)
Water Availability	0.98273	0.13390	7.3395 (.000)
Number of Tractor	0.036491	0.16511	2.2102 (0.034)
<b>Dependent Variable: Rice Production</b>			
Average Temperature	-1.7283	.76906	-2.2473 (.032)
Average Rainfall	.0020092	.054174	.037089 (.971)
Import Fertilizer	.0038974	.045448	.085756 (.932)
Water Availability	1.0287	.33655	3.0565 (.005)
Number of Tractor	.013345	.022961	.58122 (.565)
<b>Dependent Variable: Sugarcane Production</b>			
Average Temperature	-0.4934	.23675	9.6869 (.000)
Average Rainfall	.22389	.092660	2.4163 (.021)
Import Fertilizer	.0068425	.046723	.14645 (.884)
Water Availability	.50663	.15635	3.2404 (.003)
Number of Tractor	.026052	.024530	1.0621 (.296)

Fertilizers have significant effect on crops yield (Ahmed & Schmitz, 2011). Positive impact of the fertilizers shows that due to one percent increase in fertilizers increased the wheat productivity by 0.38 percent.

The middle part of Table 5 show the long run impact of climatic and non-climatic variables on rice production. Average temperature and water availability have a significant impact on rice production. The result of average temperature shows that due to a one percent increase in average temperature, rice production reduced by 1.73 percent. The results of study are consistent with Ahmed and Schmitz (2011); Ashfaq et al. (2011). The result of remaining variables is similar to that of wheat production model.

The lower part of Table 5 indicates long run association in sugarcane production. In the long run, the average temperature result shows that due to one unit increase in average temperature, the production of sugarcane reduced by 0.49 units. Rainfall, imported fertilizers, water availability and a number of tractors positively affect sugarcane production. Rain has positive impact on sugarcane production it increases sugarcane production.

## 5. Conclusion and Policy Recommendation

Wheat, rice, and sugarcane are the main crops of Pakistan, an agriculturist country. The rising trend of climate change in high temperatures may affect agriculture production. The study aims to examine the effects of climate change on agriculture output in Pakistan. To estimate the result of the study, time series data has been used from 1985-2018. Data is taken from the Economic Survey of Pakistan, the Metrological Department of Pakistan and the World Bank. To summarize the relationship among the variables of the study, Auto Distributed Lag Model is used. In existing literature, several efforts have been made to estimate the influence of climate change on agriculture productivity in other developing and developed nations because the agriculture sector is a major source of food supply in the world.

Based on empirical results obtained from ARDL, agriculture productivity is strongly caused by climate change in Pakistan. According to the findings, an increase in average temperature reduces wheat, rice, and sugarcane productivity. In the case of Pakistan, climate changes have adversely affected agriculture productivity because Pakistan is situated in South Asia, making it highly vulnerable to climate change. The agriculture sector of the economy is dependent on the weather changes. The present study results are similar to those of previous research e.g., Hanif et al. (2010); Janjua et al. (2010); Shakoore et al. (2011); Zeb et al. (2013).

As Pakistan is an agricultural country, keeping in mind the climatic issues, policymakers should focus on ways to secure domestic production. Sufficient domestic production can fulfil domestic consumption and provide a way to earn foreign exchange

through exports. To avoid the emerging threat of climate change, policies should be adopted to preserve water conservation. The current study has many limitations. Future studies may expand research by including more cities in Pakistan and include other climatic variables and average temperature and rainfall, like CO<sub>2</sub> concentration. Further crops that are sensitive to climate change and other factors can be incorporated and address those issues in the future.

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