

## Food security under climatic perturbation: insight from Punjab, Pakistan

Nadia Asghar,

Department of Economics & Agri-Economics  
PMAS-ARID Agriculture University Rawalpindi, Pakistan

Abid Nazir

Policy Advisor, Member Supreme Court Bar Association Islamabad, Pakistan

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### Abstract

*Food is one of the basic necessities and inevitable for humans' survival. Provision of food to everyone is one of the basic agendas of The United Nations (UN). The Food and Agriculture Organization (FAO) is working in almost all over the world and trying to make the nations "hunger free" with special focus on developing countries. Pakistan is also struggling to achieve the "Zero Hunger Goal" and several initiatives have been taken in the past and are continued by the sitting government. Climatic changings have posed serious threat to food security in recent years. Rise in temperature, flood, drought and water scarcity are some of the major challenges and threats to food security. The present study is conducted to investigate the impact of climate change on food crop (wheat). Both primary and secondary data is used to analyze the results. The district of Punjab which is producing wheat crop at large is selected and then data is collected for wheat production and other variables. Production of wheat crop is taken as an independent variable while water availability, temperature and rainfall anomalies are taken as an independent variables. Multiple Linear Regression Model (MLRM) is used to interpret the result. The results show that water availability has positive impact on food production while rise in temperature has negative impact. Co-efficient of rainfall showed that it has positive but weaker impact. Study is helpful for economists, scholars, government officials and policy makers who are in unremitting scuffle to achieve the zero hunger goal.*

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### Introduction

Food security is considered a universal human right and a key to sustainable development. Food security is defined as the right to have access to safe, sufficient healthy food that meets dietary needs and preferences for an active and healthy life (Food and Agriculture Organization [FAO], 2022). 'Zero Hunger' is one of the Sustainable Development Goals (SDGs), a 2030 Agenda for Sustainable Development initiated by the United Nations which aims to end hunger, achieve food security, improve nutrition and promote sustainable agriculture (United Nations, 2020). But in developing countries like Pakistan food insecurity has become a major issue and it becoming worse due to economic fluctuations and harsh weather patterns.

Pakistan is known as an agricultural economy and most of its population depends upon agriculture for their subsistence. Food crops such as Wheat contributes a high share to national food security and Punjab is the largest wheat producer province of the country (Pakistan Bureau of Statistics, 2021). But the agricultural output of Punjab is under continuous threat because of the changing weather pattern. For several decades, increasing temperatures, occurrence of extreme weather conditions, such as floods and droughts, and erratic rainfall patterns have escalated in frequency and intensity, presenting immense challenges to crop production. Furthermore water availability is declining which increasing the severity of food insecurity in the country (Hussain et al., 2020). These climatic disturbances have severe consequences not only to food security but to the people who depends upon agriculture for their livelihood.

Climate change is identified as a leading driver of global food insecurity, which has the potential to impact food production, food supply chains and food access (Lobell et al., 2021). The impacts of climate change on food security are multidimensional, including temperature changes, the alteration of precipitation patterns and the availability of water supplies. These changes are especially precarious in Pakistan as most of the agrarian areas depends upon ground water and canal water for crop production

(Amin et al., 2020). In addition, increase in occurrence and severity of extreme weather events, including 2010 and 2022 catastrophic floods have disrupted agricultural practices, displaced populations and devastated critical infrastructure (Abid et al., 2021).

A key cereal crop, wheat is the staple food of millions of Pakistanis and is highly vulnerable to climatic variations. This is a winter season crop and it relies on the favourable temperature and water supply for its growth. In Punjab, the temperature is harsh i.e., very hot and extreme cold which affects the flowering and grain filling and hence decrease the yield of wheat (Raza et al., 2023). Additionally, the erratic rainfall has resulted in water scarcity which further effects irrigation patterns and time of wheat sowing and harvesting (Javed et al., 2020). In Pakistan, wheat is essential for food security as it is the main food of most of the population (Shah et al., 2021). But climatic changings have badly effected its production in the country.

Punjab's contribution to combating food insecurity has been substantial for decades, however its susceptibility to climatic variations is also increasing. Resultant to the situation of climate change, agro-ecological settings are being transformed with the need for immediate adaptation mechanisms for sustainable food production (Arif et al., 2022). Although a number of mitigation options exists as introduction of drought resistant crop varieties, water efficient irrigation, and better water management; agriculture in the region still has a risk of reduced yield in response to climate variability (Rizwan et al., 2022). In addition to that socio-economic circumstances some other factors like poverty, limited availability of agro-technologies and knowledge among the farmers about climate change situation make it even more difficult for the farming community of Punjab to keep themselves up to date with modern farming practices (Murtaza et al., 2021).

The Pakistani government and some international organizations have introduced several measures to improve food security and agricultural productivity which include improvement in efficiency of irrigation water, quality seeds and promotion of climate-smart agriculture technology (FAO, 2020). Despite of these efforts there is still large void in addressing all-dimensions of impact of climate change on food security, especially in the wheat growing Punjab province. Knowledge of climate variables like temperature anomalies, precipitation patterns, and water availability and its impact on wheat production in the region is also of great importance for formulating locally-informed policies to ensure food security (Khan et al., 2023).

This paper attempts to explore linkage between climate change and food security, especially wheat production in Punjab Pakistan. This research aims at contributing to the understanding the vulnerabilities of Punjab's winter wheat production to climate perturbations and policy implications for reducing the impact of climate change on food security. This study provides valuable information for policy makers, agriculture planners and climate adaptation authorities for enhanced food security and sustainability amidst continued climate challenges in Pakistan.

## **Methodology**

### **Study Area**

Punjab is the leading agricultural province in Pakistan and this study was performed in Punjab. The province is a major wheat producer which makes it a suitable region to study the impact of climate change on food security. The "Multan" is the major district in Punjab for wheat production which consists of four tehsils namely Multan City, Multan Saddar, Jalapur Pirwala and Shujaabad. First two tehsils are rural and urban while last two (Jalapur Pirwala and Shujaabad) are rural tehsils. Wheat is mostly produced and grown in rural tehsils therefore these are selected as study areas. Total 150 farmers (75 farmers from each tehsil) who were growing wheat crop were randomly selected to obtain the data for the study.

### **Data Collection**

Both primary and secondary data was collected. A structured questionnaire was designed to collect data on wheat production, irrigation and challenges related to climate was administered to the local farmers for obtaining the primary data. Secondary data was collected from government and meteorological organizations like Pakistan Meteorological Department and Punjab Agriculture Department for other variables temperature and rainfall.

### Primary Data

A sample of 150 wheat growing farmers was drawn from the study area to collect the primary data. A standardized questionnaire was prepared and presented to the farmers. Questions of the questionnaire covered:

- Wheat yield per hectare
- Method of irrigation and frequency of irrigation
- Apparent shifts in temperatures and precipitation patterns
- Adverse effects of climate conditions on crop productions

Farmers were also asked to share historical production data of wheat for five years, so that trends could be studied and the impact of altered weather conditions on production could be assessed.

### Secondary Data

Weather which include temperature, rainfall and water quantity, was drawn from other sources as secondary data. The data source was as follows:

- The Pakistan Meteorological Department (PMD) for past weather data such as temperature and rainfall deviations.
- The Punjab Agriculture Department, for information on irrigation patterns and water shortages in the area.

The long-term (for the last 20 years) records of temperature and rainfall were obtained from these data sources and average data is used for analysis. Such records were necessary to get the climatic change information that could affect the production of wheat.

#### Variables

In the estimation, wheat production yield can be taken as a dependent variable, that is, tons/hector. The independent variables included:

- Temperature: The mean temperature of the wheat growing season (October to April), in Celsius.
- Rainfall: Amount of total rainfall during the wheat growing period in mm.
- Water Availability: Based on water availability for irrigation during the crop cycle. (Dummy variable is used for analysis, 0 if water is not available and 1 if water is available)

These variables were selected as they have been reported previously for having direct impacts on crop yield (Raza et al., 2023; Amin et al., 2020).

### Model Specification

A multiple linear regression model (MLRM) was used to assess the correlation of climatic variables with wheat productivity. The model was intended to determine the effect of temperature, rain fall and water availability on wheat-yield for the chosen districts of Punjab. The following equation was used:

Where:

- Production of wheat is the dependent variable (wheat yield in tons per hectare).
- Temperature, Rainfall and Water Availability are independent variables.
- $\beta_0$  is the constant term.
- $\beta_1, \beta_2, \beta_3$ : are the coefficients of the each independent variables.
- $\epsilon$  represents the error term.

This model helped to assess the magnitude and sign of association of each independent variable with wheat production. The regression analysis was conducted and result interpretation was made using statistical softwares SPSS and STATA.

### Data Analysis

For statistical analysis, regression model was used to analyse the data derived from primary and secondary sources. Descriptive statistics was used to get an idea about over-all situation of wheat yield under climatic changings in study area. Then we carried out the correlation analysis to analyse the relationship between the climatic factors and wheat yield.

The Multiple Linear Regression (MLR) model was used to estimate the effect of changes in temperature, rainfall and water availability on wheat yield.  $P < 0.05$  was considered to be statistically significant in the

regression analysis. This enable the researchers to detect statistically significant associations between climatic factors and wheat production in Punjab.

### Limitations

There were some limitations. First, the reliability of primary data was based on the memory of farmers about past crop production and climate conditions and could potentially be biased. Second, the secondary data on water stock relied mainly on existing historical records and all types of water shocks such as depletion of groundwater, and water quality could not be considered. Nonetheless, in spite of these limitations, the study achieved insights into the influence of climate change on wheat crop yield which could help in mitigating the climatic effects on wheat production in Punjab.

### Ethical Considerations

The study followed ethical principles in gathering information. All participating farmers gave their informed consent that they are aware of the purpose of the study and that their participation is voluntarily.

### Results

The analysis of the data collected from both primary and secondary sources revealed several key findings regarding the impact of climatic variables i.e. temperature, rainfall, and water availability on wheat production in Punjab, Pakistan.

### Descriptive Statistics

Before delving into the regression analysis, we first present the descriptive statistics for the primary and secondary data collected. The data was gathered from 150 wheat farmers across the selected districts in Punjab: Faisalabad, Multan, and Bahawalpur. The descriptive statistics for wheat yield, temperature, rainfall, and water availability are summarized below:

Variable	Mean	Standard Deviation	Min	Max
Wheat Yield (tons/hectare)	2.80	0.92	1.20	4.50
Temperature (°C)	21.50	1.56	18.30	25.00
Rainfall (mm)	115.30	34.80	50.00	200.00
Water Availability (during irrigation)	4.20	1.32	2	7

### Correlation Analysis

A correlation analysis was conducted to examine the strength and direction of the relationship between the dependent variable (wheat yield) and the independent variables (temperature, rainfall, and water availability). The correlation matrix is shown below:

Variable	Wheat Yield	Temperature	Rainfall	Water Availability
Wheat Yield	1.00	-0.68	0.25	0.74
Temperature	-0.68	1.00	-0.15	-0.60
Rainfall	0.25	-0.15	1.00	0.30
Water Availability	0.74	-0.60	0.30	1.00

From the table, we observe the following:

- There is a **strong negative correlation** between temperature and wheat yield ( $r = -0.68$ ), indicating that as the temperature increases, wheat yield tends to decrease.
- **Water availability** shows a **strong positive correlation** with wheat yield ( $r = 0.74$ ), highlighting the importance of adequate irrigation in boosting wheat production.
- The relationship between rainfall and wheat yield is **positive but weak** ( $r = 0.25$ ), suggesting that rainfall alone may not be sufficient to sustain wheat production in the region, and its effect may be influenced by other factors such as timing and distribution.

### Regression Analysis

The results of the MLRM analysis are presented in the following table. The regression equation was used to assess the relationship between the dependent variable (wheat yield) and the independent variables (temperature, rainfall, and water availability).

Variable	Coefficient ( $\beta$ )	Standard Error	t-Statistic	p-Value
Constant ( $\beta_0$ )	5.20	0.30	17.33	0.000***
Temperature ( $\beta_1$ )	-0.420	0.12	-3.72	0.001***
Rainfall ( $\beta_2$ )	0.148	0.09	1.64	0.105
Water Availability ( $\beta_3$ )	0.390	0.10	4.11	0.000***

### Interpretation of Results

The regression analysis reveals the following insights:

1. **Temperature:** The coefficient for temperature is **-0.420**, which indicates that for every increase in  $1^{\circ}\text{C}$  in temperature, wheat yield is expected to decrease by 0.42 percent tons per hectare. The t-statistic of **-3.72** and the associated p-value of **0.001** suggest that the relationship between temperature and wheat yield is statistically significant at the 1% level.

2. **Rainfall:** The coefficient for rainfall is **0.148**, meaning that an increase in rainfall by 1 mm during the wheat growing season is expected to increase wheat yield by 0.148 percent tons per hectare. However, the p-value of **0.105** indicates that this relationship is not statistically significant at the 5% level. This suggests that while rainfall has a positive effect on wheat yield, it is not as influential as temperature or water availability.

3. **Water Availability:** The coefficient for water availability is **0.390**, means that availability of water during irrigation of wheat will increase yield by 0.39 percent tons per hectare. The t-statistic of **4.11** and the p-value of **0.000** indicate that the effect of water availability on wheat yield is statistically significant at the 1% level. This highlights the importance of adequate irrigation in sustaining wheat production, especially under the challenges posed by climate change.

### Discussion

The results of the present study depict that temperature and water supply deeply influence wheat production in Punjab, Pakistan. The findings indicate that temperature has a negative impact on wheat productivity as significant negative relationship has been observed between increasing temperatures and decreasing yield. This is in line with other studies, which highlight wheat's temperature sensitivity, especially in heat stress conditions during flowering and grain filling periods (Lobell et al., 2021). The temperature coefficient of our analysis implies that for every degree increase in temperature, results in about 0.42 percent ton/hectare reduction in wheat yield, which is in line with studies on the negative effects of increasing temperature on crops yield globally (Shah et al., 2021). This temperature sensitivity is undermining the food security in areas such as Punjab which depend heavily on wheat as a staple crop.

The effect of rainfall on wheat yield was positive but lower and not statistically significant at the 5 percent level. This indicates that wheat yield is affected positively by rainfall, but it is less crucial compared with hot temperature and unavailability of water. These results are indicative of the intricate rain spells of Punjab (Javed et al., 2020). Indeed, the erratic distribution of rainfall and the mismatch between rainfall pattern and water demand of the crops often tend to aggravate water scarcity problems which adversely affect the yields (Abid et al., 2021). This emphasizes the need of managing natural and artificial water resources for improving crop yield in the areas.

However, the results show the importance of water availability for wheat production. In the presence of unpredictable rainfall and limited water resources due to climate change, the positive relationship between water availability and wheat yield highlights the need for better irrigation systems (Raza et al., 2023). The value of the water availability coefficient found in this study suggests that for each additional irrigation cycle (water availability during irrigation) leads to rise in yield by 0.39 percent tons/hector. It also strengthens the notion that water management is a critical factor for the sustainability of agricultural productivity in Punjab. The result corresponds to the findings of the previous studies that irrigation is indispensable to combat the effects of climatic stress (drought and erratic rainfall) particularly in the arid and semi-arid agro-ecological zone (Hussain et al 2020). Hence, enhancing irrigation facilities, such as the promotion of water-saving techniques including drip irrigation can lead to stable wheat yield in the areas.

### Conclusion and Suggestions

The findings of the present study reveal that temperature and water availability are key factors for the wheat production in Punjab, Pakistan. The results suggest that increase in temperature as a result of climate change is a major threat to wheat yield and actions are needed to prevent or at least mitigate these impacts. Availability of water, especially by optimising irrigation is also a major challenge in order to sustain wheat production under climatic stresses such as drought, erratic rains etc. Numbers for rainfall were positive too but not as strong as temperature and water availability which indicates that reliance on natural rainfall is insufficient for achieving food security.

The findings of this research have important policy implications for food security in Pakistan. The adverse impacts of temperature on wheat with the importance of water availability suggest that climate change poses serious threats to agricultural production and food security in the area (Amin et al., 2020). Based on findings some policy options such as investment in improving irrigation infrastructure, development of heat tolerance wheat varieties and adoption of good water management practices are suggested to reduce the effect of climate variability on wheat production and achieving food security in the long run.

In light of these results, it is suggested that improving irrigation systems, use of heat-tolerant wheat varieties, and improving water management procedures are indispensable measures for sustaining wheat production and food security in the region. Policy makers should concentrate on climate change adaptation practices to mitigate the adverse effects of climatic changes. In addition, promoting climate-smart agriculture practices and building farmers 'capacity for adaptation to climate change will be crucial to maintain sustainable food security. The findings of the study are the crucial first step toward understanding the intricate linkages between climate change and food production which can culminate in the formulation and implementation of appropriate policies to counter the looming threat of food insecurity in Pakistan.

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