Effect of Climatic Change on Crop Productivity in Agro Ecological Zones in Pakistan

By

Anam Hayat

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Supervisor: Muhammad Aqeel Anwar

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PIDE School of Social Sciences

CERTIFICATE

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Supervisor: Muhammad Aqeel Anwar Signature: M. Aqeel

External Examiner: Dr. Sultan Ali Adil Signature:

Head,
PIDE School of Social Sciences: Dr. Hafsa Hina Signature: Hafsa

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I **Anam Hayat**, hereby states that my MPhil thesis titled **"Effect of Climatic Change on Crop Productivity in Agro Ecological Zones in Pakistan"** is my own work and has not been submitted previously by me for taking any degree from Pakistan Institute of Development Economics or anywhere else in country/world.

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Date: 29-07-2022

Anam Hayat

Dedication

This research is lovingly dedicated to my parents, my siblings, my friends and my senior fellows who have been a constant source of inspiration for me. It is impossible to extend enough thanks to all of them especially my mother Naheed Hayat, who gave me the support and encouragement, I need throughout the process.

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ALLAH Almighty is worthy of all acknowledgements…

I bow my head before **ALLAH Almighty** with gratitude, for letting me through all the ups and downs and given me strength to accomplish this task.

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Anam Hayat

List of Tables

Table of Contents

Abstract

The impression of primary climatic variables (temperature and precipitation) and three others like fertilizer, water and technology on crop output in two Pakistani agro-ecological zones is estimated in this study. Wheat and rice were chosen as the crops. The study employed fixed effect model approaches and panel data from 1991 to 2020. The findings demonstrated that due to changes in climate conditions, the effect of climatic variables on crop output differed among agro climatic zones. Precipitation and temperature were the most important factors of crop productivity across Pakistan's agro-climatic zones. Temperature has a detrimental influence on wheat, while precipitation has an adverse effect on wheat produce in the long run in agro-ecological terms. Rice productivity has been impacted more by precipitation as the results are insignificant but there are alternatives for precipitation which can fulfill by artificial means initially rice in temperature has positive impact but to an optimal level after that further increase in temperature will harm the rice yield. Fertilizer and water is having a positive and significant impact of the yield while technology has a positive but insignificant impact of the yield. Hence, the analysis suggests various possible initiatives and inclusive strategies to mitigate the adverse consequences of climatic fluctuations on productivity of crops, instead, enhance yield across regions of Pakistan.

Keywords: Agro Ecological zones, Climate Change, Temperature, precipitation, fertilizer, water, technology, yield

Chapter 1: Introduction

Climatic variation are the fluctuations in long term global or regional weather patterns triggered by high concentration of harmful gases in atmosphere due to various anthropogenic activities including sweltering of fossil fuels, forest clearance for wood, human settlements and agriculture. More precisely, climate change refers to long run rise in temperature and rainfalls regimes, excessive and rapid melting of glaciers and subsequent changes in our socio-ecological systems (Srivastava, Pasala, Minhas, & Suprasanna, 2016). on average, temperature of earth has raised to 0.6℃ in the last century and it is accepted that there will be further upsurge in global temperature that is projected to be 1.4 – 5.8℃ (IPCC 2001). Climate change is a global distress which disproportionately affects the least developed countries (LCDs) more because of their vulnerability context, limited resources and unemployment, low productivity and rampant poverty and marginalization. Agriculture sector in least developed countries (LDCs) is one of the main contributors to their Gross Domestic Product (GDP). At this stage of their economic development, it is very important to focus on agriculture sector because without improving it or solving its problems there will be no development in the economies of least developed countries (LDCs)(al., 2010).

R. Mendelsohn with his co-worker's study has conducted to estimate the impact of climatic variation on the yield of crops in the agriculture sector of United States of America. In the analysis there were threshold-levels for the temperature for example the temperature for corn and Soybean is 29℃ and 33℃ for the Cotton which means that this temperature will be required temperature for the production of the related crops and if temperature is going to increase from the threshold level then it will harm the crops. This study was conducted on almost three

thousand regions of United States for the analysis. So the results from the study were as the temperature in all seasons reduced the agriculture production except in autumn but high levels of rainfall increased the production in agriculture sector in the United States. Hence we can say that global warming is having very little impact on agriculture sector of countries like America. It was predicted that at the beginning there was a small impact of climate change on the developed countries but with time this impact intensifies and gets more negative and stronger (Mendelsohn, 1994).

1.1 Climatic Scenario of South Asian Countries

In the recent times mostly rise in temperature is observed in Asia and pacific regions. As it is noticed that the 37% of entire world emissions from the agriculture production are accumulated in Asia and pacific it is the reason for the high vulnerability of climate change in Asia and pacific. The countries that are more exposed to climate change include Pakistan, Bhutan, Sri Lanka, Indonesia, Thailand, Vietnam, Uzbekistan, and Papua New Guinea.(Bank, 2009).

For the production in the agriculture sector; season and location matters a lot like African crops are considered as highly sensitive to any minimal fluctuation in temperature in comparison to change in rainfall, means that if there is going to be rise in the temperature this will going to impact the African crops in a positive way but if there will be reduction in the rainfall this will have a undesirable impact on the net returns from the crop production. This study has been done on three hundred districts of South Africa and on seven African field crop like (maize, wheat, sugarcane, sorghum, sunflower, groundnut, and soybean). This study also propose that it is possible to shift the growing season of crops according to the temperature but there are chances that such kind of action will lead to an eradication of certain crops from specific regions.(J. P. Aryal & Sapkota, 2020).

For the south Asian economies and citizenry, change in climate is creating a serious intimidation compounded by tight populations, precarious ecology and geography, ethnic disturbances and a host of other factors? The changes in the climatic variables like temperature, precipitation, humidity and its impact on the crop production and food-security will be worst in the south Asian countries.in south Asian countries excepted rise in temperature is 3.4 – 5.5℃ by the end of 21st century. Studies have noticed these differences by investigating a link between the crop production and availability of soil water in the growing time of crops.(S.Bandara & YiyongCai, 2014). South Asian countries, having large number of population are usually settled near coastal lines, river deltas and precarious mountainous regions are highly vulnerable to have adverse impacts of climate change and these countries have problems of rainfall unpredictability, collapses in Himalaya glaciers.(Muhammad Haseeb Raza, 2019).

The delayed monsoon has already had an impact on wheat sowing and, as a result, yield. It's worth investigating whether this has anything to do with the changing climatic scenario. The majority of the discussion about climate change's impact on wheat production focuses on the area's temperature regime, which shortens the ripening period. Upland farmers, on the other hand, cultivate wheat on unirrigated soil, with yield influenced by both temperature and water availability. Rainfall meets the water needs of unirrigated wheat, hence any change in rainfall time, length, or intensity affects unirrigated wheat yield. As a result, climatic fluctuations have a huge impact on wheat output in states like Nepal, where the majority of the farming system is dependent on the monsoon and its associated climate. On this perspective, it's interesting investigating whether weather volatility has a negative influence in a small geographical area with a extensive range of climatic conditions, such as Nepal (Resham Bahadur Thapa-Parajuli1, 2016).

1.2 Climatic Scenario of Pakistan

Focusing on the situation in Pakistan, being an agrarian country around 39% of people was employed in agriculture sector and its economic contribution was near 18% in year 2018. Though agricultural productivity is generally low and is partly affected by the climatic change.(Saifullah, 2017). As agriculture sector is very sensitive to any change in climatic variables like temperature, precipitation or humidity so it to study about its effect on crops of Pakistan is very important. This all could increase the vulnerabilities in the crop production, forestry livestock and water recourse of the country. Being an agrarian economy, Pakistan's rural sphere has an intense dependency on these factors. Change in the climate conditions such as temperature is altering crop productions, fisheries, livestock and forest like it will impact the growing period of crops, its water requirement, it could also alter soil characteristics and may also increase the disease and pests upsetting the yields of the crops and food markets. Such as in Pakistan, maize production in spring season has been shifted to 4 days earlier than its actual time over the decade while the autumn maize sowing period is delayed by 3 days per decade. It implies that all these changes will impact the livelihood of numerous households who have scarcer resources for adoption and are most vulnerable to climatic fluctuations. The influence of climatic variation on agriculture productivity varies with the geographical location of agro-ecological zones of Pakistan. For instance due to higher temperature in mountainous regions, there will be rapid melting of glaciers. This results in enriched water resource of the country on which agriculture sector is highly dependent (BANGASH, HUSSAIN, & RABIA, 2017).

Agriculture sector is directly dependent on climatic conditions therefore any changes in climate will be a threat to agriculture productivity which signifies that, it will reduce agricultural productivity and this will have a undesirable impression on income growth. Another negative

effect of this situation is on the farmers from Asia who are living in marginal or isolated areas like dry lands, mountains or deserts so these areas are basically already scarce in natural resources. Rise in the temperature in the arid zones of India, northern Pakistan, and western china are expected in near future. Almost 500 million countryside population in the Asia anf huge chunk of them are poor farmers who are surviving and occupying rain fed lands. Rice, wheat and maize production has gone down in the recent decades because of the rising water stress due to rise in temperature (Aryal & Prakash, 2019).

Pakistan has two cropping seasons Kharif and Rabi. Sowing duration of Kharif crop is April-June and is harvested between October-December and Rabi crops are strewed between October-December and harvested in April-May (Ahmad, Ashfaq, & Rasul, 2007). These are two major cropping seasons in Pakistan which contributes a solid share in GDP. Thus climatic fluctuations over the year impact verily the agricultural yield and production. Pakistan was ranked at 28th position among the countries which are more exposed to climate change. Because of the fluctuations in the climate parameters, the country is more vulnerable to natural disasters like floods, droughts, cyclones which affect the agricultural sector adversely.

1.3 Problem Statement

In many of the recent studies, climatic variations and their effect on the agricultural productivity in different districts of Pakistan are being focused (Rihanna Siddique). Districts as an administrative region may not reflect true essence of climatic impacts. Because administrative boundaries may not necessarily follow agro ecological differences. Thus, the effects of climate change may vary considerably on the basis of agro-ecological zones whereas some zones may be experiencing floods while others drought, some extremely cold temperatures while others heat

waves. There is an uncertainty to a great extent based on climatic variations which affects agro production and practices in different seasons. Land management and climatic parameters in agro-ecological zones are more likely to affect agriculture. There are certain problems arising in these agro ecological zones which are affecting agriculture productivity like rapid melting of glacier, hot winters, early summers, shifts in the sowing season of the crops. So this research focus is going to be on agro ecological zones.

1.4 Research Questions

The objectives of research is to investigate the impact of climate change on major crops wheat, rice, in selective agro ecological zones (AEZ) of Pakistan.

- How climatic variables namely long term temperature, precipitations patterns in these agro ecological zones have changed or sided.
- How changes in these climatic variables are impacting the productivity of major crops in these agro ecological zones.
- How climatic variables are impacting the crops and in which cropping stage impacts are more damaging.
- What possible measures and policies should be taken by farmers to avoid damaging impacts of climate change in selected AEZs?

1.5 Objectives of the Study

- To see changing patterns of climatic variables and changes they are bringing in agro ecological zones of Pakistan.

- To pinpoint the impacts of climatic variables on the yield of nominated crops in agro-ecological zones.
- To pinpoint the cropping stage where changes in climatic variables has been most detrimental impact on each major crop.
- To suggest AEZ specific policy measure to help farmers adapt climate changes.

1.6 Significance of the Research

Various studies have been conducted in past based on agricultural productivity of diverse crops in different tropical regions and districts of Pakistan. Different variables were taken as independent variables in research such as temperature, rain patterns etc. This study also includes three new variables like fertilizer, water and technology in order to evaluate the effect of main climatic variables on crops' productivity across different regions.

This study will have uniqueness in the sense that it will be based on agro ecological zones and taken those districts that comes under the boundaries of selected agro ecological zones. As it will give more detailed insight into the productivity patterns and impact of under-observation variables on it. And then relevant and precise actions can be taken in order to restore or enhance the growth level of agriculture. Pakistan being an agrarian economy is highly dependent on it. This research will hopefully generate more discussion on harmful effects of climate change for Pakistan.

1.7 Organization of Study

Chapter 1 of this research includes basic definitions and key terms, problem statement, objectives and significance of the study, chapter 2 describes literature review of the study

including climate condition of world and Pakistan as well as wheat-rice cropping system of Pakistan. Chapter 3 includes data source, descriptive statistics and methodology. Chapter 4 includes discussion and results of and the study and finally chapter 5 describes conclusion and recommendations.

Chapter 2: Literature Review

Climate change is becoming one of the most serious environmental issues confronting the modern world. Changes in the global climate are caused by increased emissions of greenhouse gases (GHG), such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Due to rising temperatures, climate change will cause changes such as sea level rise, changes in rainfall sequences, and the shifting of climatic areas. Droughts, hurricanes, and floods are projected to become more intense as climate trends change. The global temperature will rise by 1.80 degrees Celsius to 4 degrees Celsius, with an overall temperature increase of 2.8 degrees Celsius. Humans are to blame for the newly discovered CO2 Because of deforestation, massive usage of fossil fuels, and other factors, CO2 concentration has increased from 280 ppm to 380 ppm since pre-industrial times (A.G Awan & Yaseen, 2017).

Agriculture is a climate-sensitive industry. Agriculture's production has been endangered by climate change, rendering it economically and physically vulnerable to climate inequity and change. Rainfall patterns, temperature increases, changes in sowing and harvesting dates, water availability, and soil suitability are all influenced by climate change. Climate change may not have far-reaching global consequences, but it does have regional consequences. Climate change will help certain locations while it will have a negative impact on others. Climate change will affect more than just agricultural productivity (Quiggin & Horowitz, 1999).

In the area of climate change there are mainly two key issues which are more in focus. First is globally climate change is happening and at a very fast rate it is being noticed that earth's average temperature has risen to 0.8*C since the start of the 20th century approximately. All this global warming has been due to increase in the number of natural disaster related to the climate

change like floods, cyclones, droughts which are effecting human societies and economies of courtiers. Now it is predicted that in the absence of carbon mitigation global temperature is likely to rise to 2.4-6.5*c in the end of the 21st century. The second thing which is being focused in climate change is that agriculture is much dependent on climate and weather conditions so all the happenings of extreme events like floods, droughts, heat wave will effect crop growth and reduce yield.(Jemma Gornall, 2010). This means that climate change is going to impact food production, price of the food and can also threaten food security among the people it is expected that demand of food will increase up to 300% by 2080 due to higher population growth. This high demand will create an imbalance between supply and demand due to the outcomes of climate change (Cline, 2008). Increase in temperature can impact the agriculture sector as cropping season will be effected and on crops the high level of heat stress. All these factors affect the food security and can prevail poverty in the world (A. Ali & Erenstein, 2017).

Climate change is posing a threat to global agricultural productivity. Different crops and locations are affected differently by climate change, but agricultural productivity is anticipated to fall. In fact, some signs of deterioration can already be detected. Climate change, according to one estimate, reduced world maize yield by 3.8 percent between 1980 and 2010. Farmers were not equally threatened by climate change as crops, but they were the most susceptible category. Extreme weather-related economic losses are becoming more common as a result of climate change. The average temperature is expected to rise, while rainfall patterns are expected to shift (Knox, Hess, Daccache, & Wheeler, 2012).

The government is finding it difficult to cover the costs of the losses. Climate change has an impact on crop productivity, which has major consequences for food security. Although it has been predicted that global warming will increase crops by acting as a fertilizer, the effects will

most likely be negative for poor countries. Food output will be reduced in countries near the equator, for example, as a result of global warming. Droughts and food shortages will persist in African countries. Because Pacific Islands and Indonesia are more reliant on imports, there will be increased poverty and other social problems (S.Bandaraa & YiyongCaib, 2014).

2.1 Climate Changes and Risks Associated to it

Agriculture is extremely dependent on changes in climatic conditions, making it a risky business. Climate change poses a significant threat to agriculture and food systems. Agriculture has been severely harmed by the rising severity and frequency of extreme weather. Natural disasters, erratic rainfall, and pests are all common occurrences for farmers. Farmers, for example, face extreme rains, floods, pests and illnesses, droughts, and market price fluctuations. Financial, marketing, legal, environmental, and human resources, according to a report on production, are key sources of risk factors in agriculture. Production risks due to fluctuations in crop yields and livestock from a variety of sources are among the five key risk variables (i.e., unpredictable weather conditions, disease incidence, and pests). Second, there are financial hazards, such as a farmer's ability to pay his or her bills in order to keep his or her farm afloat and prevent liquidation. Finally, there are marketing hazards, which include price fluctuations in agricultural products. Finally, there are legal and environmental concerns, as well as a scarcity of human resources (i.e., a lack of family members to play the role of labor and farm management). As a result, there is a detrimental influence on output, resulting in significant losses (Sivakumar & Stefanski, 2010).

It was also discovered that farmers with a higher risk perception had more risk aversion than those with a lower risk perception. In the disaster literature, risk perception is a critical indicator.

Individual and community responses to natural catastrophes are depicted, and a favorable correlation between public response and natural hazard adaptation is discovered. This suggests that when farmers' risk perceptions are linked to their risk aversion, they will pursue risk-reduction techniques. Farmers that perceive floods as a high risk prefer to plant off-land and practice diversification as agricultural flood-risk management methods, for example. Farmers can utilize income diversification, precautionary savings, crop diversity, and a variety of other farm risk management methods in both pre- and post-disaster situations to save themselves (M. Monirul Qader Mirza, Warrick, & Ericksen, 2003).

2.2 Rising Poverty as a Result of Climate Change

Climate change has challenged agricultural productivity globally as it can be seen that due climate change there is a notable decline in the agricultural production over the time and further decline is expected in near future(Lobell, Schlenker, & Costa-Roberts, 2011). People who live in developing countries and who are unable to meet their necessities in life and are dependent on agriculture sector will be the victims of climate change (Maskrey, A., G., & P.Schaerpf, 2007).

South Asian region is most vulnerable to change in climatic conditions because of its enormous population usually depends on agricultural sector for their earnings higher percentage of population lives under poverty line due to which they have serious challenge to their economic, social and ecological system(M.M.Q. Mirza, 2011).Climate change has worst effects on agriculture in any country. But developing countries are more affected by it. As they are dependent on the agriculture sector people are employed in areas related to agriculture thus climatic impacts will eventually increase number of affected population in developing world (Cervantes-Godoy & D., 2010).

2.3 Research of climate change and its impacts on agriculture around the world

The climatic trend influence on wheat production in the Mexico region was studied using the CERES-Wheat simulation model. They looked at the relationship between climate and wheat yield over the last two decades, from 1988 to 2002. They discovered that the climate had favored them during the last two decades, resulting in a 25% rise in wheat yield. It means that the climate had a good impact on wheat yield in this area. However, when compared to past research that expected a bigger rise in wheat productivity for this location, the 25 percent gain is smaller (Lewis & Warner, 2020).

A study was conducted to determine the impact of climate variability on high altitude crop production and whether climate variability could affect wheat yield at high altitude. Tongue Metrological Station (1798m above sea level) and Peak of Lulu Mountains (2351m above sea level) were chosen for this purpose. They looked at the influence between 1981 and 2005. Their findings revealed that both locations' yields increased throughout this time, despite beneficial changes in temperature and precipitation. Up until 1998, the yield of two heights was high, but after that, the yield of high altitude increased in comparison to loss at low altitude. The simulated results showed that wheat agriculture production for low altitude would increase by 3.1 percent, while wheat agriculture production for high altitude would increase by 4 percent, up to 2030 (Ouda, Zohry, & Tahany, 2018).

The impact of climate change on two Pakistani locations, Swat and Chitral, which are 960m and 1500m above sea level, respectively, was assessed using the Ordinary Least Square (OLS) approach. They looked at whether a 3°C increase in temperature would shorten the growth season length (GSL) of this county's wheat production. Their findings revealed that an increase

in temperature would have a favorable influence on Chitral due to its high altitude location, but a detrimental one on Swat due to its low altitude location. An increase in temperature of 1.5°C would have a favorable influence on Chitral, increasing yield by 14%, but a negative impact on Swat, lowering yield. Increases in temperature of up to 3°C will reduce wheat yields in Swat by 24 percent while increasing yields in Chitral by 23 percent. Because of the predicted increase in temperature in the future, they advised adaption measures such as producing high yielding cultivars for warmer portions of Pakistan's northern region (Vermeulen & J., 2012).

For their research on wheat productivity in Central Oklahoma, this study used the Hardly Centre Model (HadCM3). For the current and future time periods (1950-1999), they chose three scenarios: A2a, B2a, and Gal (2070-2099).Annual future precipitation would decrease by 13.6 percent, 7.2 percent, and 6.2 percent for the three scenarios, respectively, while temperature would rise by 5.7 degrees Celsius, 4 degrees Celsius, and 4.7 degrees Celsius. They came to the conclusion that a lack of rainfall in the summer, but not in the winter, will impact yield, although the effect of increasing temperature will be mitigated by carbon fertilization (Mondal & McDermid, 2014).

In a research for the South African region, they used the Ricardian model on wheat, sorghum, maize, sugarcane, groundnut, sunflower, and soybean. They discovered that increasing the temperature has a good impact on maize, sorghum, sunflower, and soybean agriculture production, but has a negative impact on sugarcane and wheat productivity. They found that the temperature in this location is already high, and that any further rise in temperature in the future owing to climate change would wreak havoc on wheat productivity. They advised replacing wheat with maize, sorghum, or other heat-tolerant crops to offset potential yield losses due to rising temperatures (Janjua, Samad, & Khan, 2010).

Five wheat models built for Europe were examined at varying degrees of agronomic circumstances in a study. 7 They came to the conclusion that practically every model produced the same outcomes. Their findings revealed that rising temperatures would reduce yields, whereas higher precipitation and CO2 fertilization would have a favorable impact on productivity (FlorianSchierhorna, 2014).

For the time period of 2000-2070, a study used the Australian Commonwealth Scientific and Industrial Research Organization's (CSIRO) global atmospheric model under three climate change scenarios: Low, Mid, and High for the South-East Australian area. Their findings revealed that the medium wheat yield decreased by roughly 29% in all three scenarios, but that the favorable effect of CO2 reduced the decline in production from 29% to 25%. Low rain fall and greater temperatures are partially countered by C02 fertilization. They indicated that better agronomic tactics and wheat cultivars could result in increased yield productivity (Barnett, Adam, & Lettenmaier, 2005).

A simulation model was utilized in a research on the Central South region of Brazil up to 2050. They discovered that a 3°C to 5°C increase in temperature and a 1% increase in precipitation would reduce wheat productivity to the level of one million tons of wheat. They discovered that wheat was being grown in Brazil at a temperature threshold, and that any increase in this temperature would cause agricultural productivity, particularly wheat, to fall. They went on to say that most developing countries along the tropical belt that rely on agriculture would suffer agricultural yield losses (M. N. Ahmed & Schmitz, 2011).

In order to investigate the influence of climate change on China's agriculture industry in 2080, a study used a comparable general equilibrium (CGE) model. Their findings revealed a 1.3 percent

decrease in agricultural GDP share. The CGE simulation results showed that agricultural output would decline in 2080, resulting in output losses, with the exception of wheat, which showed an increase in output due to increased global wheat demand. The modelling results also revealed that, compared to the global average, China's agricultural productivity would drop at a slower rate (M. A. Iqbal, Qing Ping, Kazmi, & Rizwan, 2016).

Using the CGE model, a study was conducted on the Southeast Asian region to evaluate the economic impact of climate change on the region. According to them, the impact is not uniform over the world, and developing countries would suffer significant losses. According to their simulation results, Southeast Asia's GDP will decrease by 1.4 percent by 2080. Crop productivity would drop by 17.3 percent, while paddy rice agriculture productivity would drop by 16.5 percent and wheat agricultural productivity would rise by 36.3 percent. The Southeast Asian countries' reliance on agricultural imports will grow in the future, resulting in further welfare losses and hence weakening the term of trade of this region (H Charles J Godfray 1, 2010).

A study was conducted to look into the economic impact of climate change on Kenyan agriculture. The goal of the study was to determine the influence of climate change on Kenya's agricultural crops. For a sample of 816 households, cross-sectional data on climate, soil hydrological data, and household data were employed. The impact of climate on net agricultural revenue per acre was studied using a seasonal Ricardian model. Climate change has been discovered to have an impact on crop productivity. On the one hand, there is a nonlinear relationship between revenue and temperature, while on the other hand, there is a nonlinear relationship between precipitation and revenue. The findings also show that the temperature component of global warming is far more important than rainfall. Checking climate change and

disseminating information to farmers were mentioned as ways to encourage farmers to adapt to climate change (Field, 2007).

A study Attempted to assess the monetary impact of the environment on Kenyan yields. For a sample of 816 families, he uses cross-sectional data on the atmosphere, hydrology, soil, and family unit level information. For measuring the effect of the atmosphere on net yield revenue per slice of land during the infrequent Ricardian exhibition. The findings show that the environment has an impact on the profitability of edits. On the one hand, there is a non-linear relationship between temperature and income, while on the other hand, there is a non-linear relationship between precipitation and income. The estimated minimal effects suggest that an unnatural weather change is detrimental to crop efficiency. Forecasts from global course models show that an unnatural weather shift will have a significant impact on Kenya's net product revenue. The findings also show that the temperature component of a dangerous atmospheric condition is far more important than precipitation. The findings advocate for environmental change to be monitored and data to be disseminated to farmers in order to encourage farmers to make changes in response to the changes (rivas, c.condealvarez, & dorantez, 2010).

A study was conducted to investigate global environmental change, crop yields, and their relationship to late-day warming. Changes in the global generation of actual yields are important drivers of food pricing, food security, and land use decisions. The average global yields for these goods are harvesting in a large number of fields dispersed across a range of administration, soil, and atmospheric administrations is controlled. Despite the complex nature of global food supply, we show that simple measures of developing season temperatures and precipitation spatial midpoints in relation to harvest areas explain at least 30% of year-to-year variations in global normal yields for the world's six most widely grown crops. In the case of wheat, maize, and

grain, there is an unmistakable negative response to rising temperatures around the world. Based on these sensitivity and observed atmospheric patterns, we estimate that warming since 1981 has resulted in annual combined misfortunes of these three products totaling approximately 40 Mt or $5 billion per year, beginning in 2002. While these effects are minor in comparison to mechanical yield gains over the same time period, the results demonstrate that atmospheric patterns are having a detrimental impact on harvest yields on a global basis (Initiative, 2009).

A study has been done on impact of climate change on production off crop based on Ricardian approach this was done in the country of Ethiopia. In that study as country level survey was used various climatic variables temperature and precipitation and some non-climate variables like households and soil were used in that research. The purpose of the study was to analyze the marginal impact of the climate variables like temperature and precipitation on the net revenues from the crops. So the results shows that whenever there is marginal increase in the temperature in summers or winters it will have negative impact on the net revenues from crops per hectare and marginal increase in the rate of participation during spring has a positive impact on the net revenues of crop per hectare (Deressa & Hassan, 2009).

A research have been done in which cress-wheat model have been used to see climate change impacts on production of wheat in Mexico.in this research they have analyzed climate trends and wheat production for the last two decades which means from the 1988 to 2002. So in this research they found out that climate has positive impact of the wheat production for the region of Mexico. It was noticed that they were almost 25% increase in the wheat production which means that climate change has favored wheat production (D. B. Lobel, 2006).

A study has been done to investigate the impact of climatic variables on the cotton production in the district of Marathwada in India. In that study they used time series data of rainfall, maximum and minimum temperature and of maximum and minimum level of humidity from 23 to 52 metrological weeks. They have taken secondary data for the production area of three districts from department of agriculture.in the study some statistical techniques were also used like t test, multiple regression analysis were used. Results of the research shows that crop is more dependent on the level of rainfall followed by maximum and minimum temperature, thus all three districts the area and production has increased over the time but the chances of lesser yield over the years remain same (Abdul Ghafoor Awan, 2013).

The developing world is anticipated to be hit worst by climate change. Quantitative assessment of climate change sensitivity and vulnerability, particularly in terms of agro-economic indicators in poor countries like Pakistan, is one of the top priority for closing gaps between present knowledge and policymaking needs. The most basic criterion for such an assessment is the availability of an accurate forecast of future climatic projections at the regional level. This can be accomplished through the use of various models, as well as the validation of climate models. Climate models are what we use to predict the weather in the future(Awais Jabbar, 2020).

Annual mean temperature over the hilly portions of Pakistan's Upper Indus Basin has showed a non-significant increasing trend. Analyses of temperature data demonstrate significant growing trends in yearly temperature for the North Western Himalayan region based on long-term data sets dating back to the late 19th century. Conclusion: Their research verified that the North Western Himalayan region had 'warmed' at a faster rate than the global average during the last century. The rise in air temperature is mostly due to rapid increases in both maximum and

minimum temperatures, with the maximum temperature increasing at a faster rate, resulting in higher temperatures (Deen, 2011).

According to Pakistan's agro climatic categorization, semi-arid to arid zones cover two-thirds of the country. As a result, the majority of people rely on agro-pastoral activities in arid and semi-arid areas to maintain their lives. More frequent extreme events, such as forest fires, floods, avalanches, and landslides, are predicted to pose the highest and most unpredictable threats in mountain locations. Temperature rises may have a positive impact on agriculture in mountainous places, for example, by decreasing the growth season for winter crops (Hashmi, Siddiqui, & Abdul Razzaq Ghumman, 2012).

Geographical location of a country and season are very important for the suitability of production yields of various crops. Agriculture sector in Pakistan plays an important role in the economy but this sector is under the threat of climate change. It is predicted that temperature is going to increase by 5 to 6 degrees and this will negatively impact wheat production. Estimates shows that approximately there will be 50% reduction in the wheat production in Asian countries (siddiqui, samad, & muhammad nasir, 2012).

In Pakistan the geographical characteristics are different for instance the country is having high mountainous regions in north, northwest and southwest. It also possesses plateaus, plains and a coastline in the south west of the country. All these geographical locations of the country have different climatic condition as some of them are very cold, other are hot, and some remain moderate for the whole year. Pakistan is also having rivers and canal system which is used for irrigation requirement and it has been noticed that the rate of precipitation is less in regions as compared to the adjacent areas (I.Yousufa, 2014).

A research was conducted on four provinces of Pakistan and they considered RABI crops growing season and including drought to capture extreme events due to climate change thus concluded that climatic change in Pakistan has increased and it's still reducing agricultural productivity which is creating a threat to long term food security. So with introduction of different climatic change variable it has been seen that agricultural productivity in arid zones is lower with greater climate pressure and opposing effects on food security due to less agricultural yield (R. Mendelsohn, 1999).

It has already facing every severe conditions in a form of natural disasters in the year 2010 Pakistan had flood which cause loss of crops yields, property and assets of people living in those areas and this country also have droughts in the past years which means due to climate change extreme events are already there like rising temperature, rainfall patters which are causing natural disaster conditions for Pakistan (Asif, 2013).

A research was held on the impact of climate change on four crops in Punjab in which temperature and precipitation were taken as independent variables whereas four crops (wheat, rice cotton and sugarcane) were taken as dependent variables it shows that in short run there is an impact of climate change on wheat productivity which means increase in temperature have impact in short run but it has a positive impact in long run. For rice production increase in temperature in beneficial up to certain level while for cotton and sugarcane rise in temperature harms the long run productivity of crops. Whereas, increase in participation both in long and short runs impacts negatively the wheat production but increase in participation is not harmful for the rice production (siddiqui, samad, et al., 2012).

Average temperatures are rising, rainfall patterns are changing, sea levels are rising, monsoon rains are disrupting, and glaciers are melting as a result of these effects. All of this contributes to extreme happenings throughout the world. Hurricanes, storms, flooding, droughts, and heat waves are all examples of natural disasters. Climate change is, in a nutshell,

Having an impact on every part of the economy, including agriculture, Ecology, biodiversity, infrastructure, forests, human health, and life expectancy are all factors to consider. It is regarded as the most crucial variable in research. Which has a negative impact on agricultural productivity and places a significant financial strain on small farmers in Pakistan has been a long-time friend of mine. Crop production was reduced by 2 percent in 1987 due to a poor monsoon. In Bangladesh, India, and Pakistan, this equates to 216 million tons.

2.4 Agricultural Profile of Asian Region

Agriculture is critical for all Asian and Pacific countries. More than 60% of the economically active population and their dependents—a total of 2.2 billion people—are unemployed. People's livelihoods are dependent on agriculture. Agriculture's contribution to gross domestic product (GDP) is rather small. Although the region's gross domestic product (GDP) is dropping, substantial populations remain. Situated in rural areas and reliant on agricultural production Agriculture provides jobs and revenue, either directly or indirectly. The rural areas continue to have the highest levels of poverty, and the gap between rural and urban areas is expanding. On the other hand, there is a wide range of poverty profiles and growth routes, with some economies growing at a faster rate than others. Furthermore, the contribution of agriculture to the total economy varies greatly between sub regions and countries. The degree of political stability and institutional maturity differs as well. At the country level, the region's profile highlights the need

of providing food security in the region, which is compounded by the difficulties of accomplishing it. Agriculture is not valued in many Asian and Pacific countries because of its contribution to economic growth. Increasing GDP share, but primarily in the context of achieving food security (Stefanski 2010).

With the exception of Turkmenistan, the importance of agriculture to GDP has been dropping across the Central Asia sub region. Similarly, East Asia's agricultural GDP has been falling. Despite accounting for only 12% of overall GDP in the PRC, it accounts for roughly 64% of total employment. Agriculture employs the majority of the country's economically engaged people. Food safety has become a priority. In general, East Asia is improving, although 30% of Mongolia's population still lives in poverty.

The People's Republic of China, Japan, and the Republic of Korea have begun to buy or lease land in other parts of Asia (Indonesia and the Philippines), as well as Africa, Eastern Europe, and Latin America, for food production. Due to severe land constraint, a number of East Asian countries including. Agriculture's contribution to GDP has been dropping throughout Southeast Asia, but it still accounts over 30% in Cambodia and over 40% in the Lao People's Democratic Republic (Lao PDR). Furthermore, while undernourishment in Southeast Asia has decreased since 1995, it still affects 18 percent of the population, with 26 percent of Cambodians suffering from malnutrition. However, reducing the risk of food insecurity in Southeast Asia has resulted in a widespread deterioration of the agricultural resource base, such as land and water resources (Kelkar & Bhadwal, 2008).

Unlike Central, East, and Southeast Asia, South Asia's agricultural value to GDP remains high, declining just marginally between 1995 and 2006. As a result, agriculture employs a large

percentage of the population, with close to half or more working in the industry (with the exception of the Maldives). Finally, the fraction of the population that is undernourished averages above 20%, making South Asia the least food secure sub region in Asia and the Pacific, as well as the world. There is a scarcity of data on irrigated cropland, undernourishment, and the contribution of agriculture to GDP in the Pacific Islands. However, data from Papua New Guinea shows that agriculture's contribution of GDP has been expanding, from 32 percent in 1995 to 42 percent in 2005. Furthermore, agriculture employs about 40% of the population on average.

While agriculture is critical for the region's food security and provides much of the region's employment, farming agro-ecosystems vary greatly, ranging from the comparatively dry wheat-growing regions of Central Asia to the extremely wet rice-growing regions of Southeast Asia. Similarly, agricultural and agricultural technology support differs greatly amongst countries. Because of the diversity of farming systems, farmers will need customized interventions to help them adapt to and mitigate the effects of climate change.

Even in the absence of climate change, competition for land and water resources is fierce in many Asian and Pacific countries. Climate change will exacerbate the competition for these natural resources, posing new management issues and raising the likelihood of conflict. Conflicts originating from land and water scarcity are particularly common in Central and South Asia.

Finally, the effects of climate change in Asia and the Pacific will have an impact on global food security, not just regionally. In 2000, the region accounted for 43% of global crop production, and it is predicted to account for one-third of total cereal consumption and two-thirds of total meat demand in the coming decades; it also accounts for large net cereal exports, particularly rice (Bandara & Cai, 2014).

2.5 Climatic Scenario of Pakistan

Pakistan is located in a temperate climate zone. The climate is mainly desert, with scorching summers and chilly or cold winters, as well as considerable temperature changes between extremes at different locations. There isn't much rain. However, these generalizations should not mask the significant differences that exist across specific regions. The shoreline along the Arabian Sea, for example, is normally warm, whereas the frozen snow-covered ridges of the Karakoram Range and other far-northern mountains are so frigid all year that world-class climbers can only access them for a few weeks in May and June each year.

There are four seasons in Pakistan: a chilly, dry winter from December to February; a hot, dry spring from March to May; the summer rainy season, also known as the southwest monsoon period, from June to September; and the retreating monsoon period from October to November. The start and duration of these seasons varies depending on where you live (Shakoor, Saboor, & Baig, 2015).

The climate in Islamabad, the capital city, ranges from a daily low of 2° C in January to a daily high of 40° C in June. Half of the annual rainfall falls in July and August, with each month averaging roughly 255 millimeters. The rest of the year sees much less rain, with only approximately fifty millimeters per month. Karachi, Pakistan's largest city and the country's industrial heartland, is hotter than Islamabad but has less rain. In the Karachi area, only July and August average more than twenty-five millimeters of rain; the remaining months are extremely dry. Karachi's weather is also more consistent than Islamabad's, ranging from an average daily low of 13° C in the winter to an average daily high of 34° C in the summer. Although the

summer temperatures are not as hot as they are in Punjab, the heavy humidity causes a lot of suffering to the locals (M. M. Iqbal & Goheer, 2009).

2.6 Impact of Climatic Change on Agriculture Sector of Pakistan

Global climate change has an impact on all economic sectors to some extent, but the agricultural sector is the most sensitive and vulnerable to the negative effects of climate change, as global agriculture, whether in poor or developed countries, is still heavily reliant on climatic resources. Temperature rises, changes in rainfall patterns, changes in sowing and harvesting dates, vapor transpiration, water availability, high CO2 concentrations, and soil suitability are all linked to agriculture productivity as a result of climate change.

Because crops production in these parts of the world is low technology based, current information about agriculture is poor, and domestic economies are heavily dependent on agriculture for their livelihoods, the agriculture sector in poor parts of the world is more vulnerable to the effects of climate change. Climate change has a different impact on the agriculture sector in different parts of the world. Countries in temperate zones would benefit from climate changes, whilst tropical and sub-tropical zones would suffer negative consequences.

Pakistan's status as a developing country is largely dependent on agriculture. Agriculture accounts for 21% of the GDP and employs 44% of the workforce. More over two-thirds of the country's population (62%) lives in rural areas, where they rely on agriculture and agro-based activities for a living. In Pakistan, two types of crops are planted each year: Rabi crops (October to April), which comprise wheat, barley, Gram and Oil seeds, and Kharif crops (May to October), which include rice, maize, sorghum, millets, cotton, and sugarcane. Because the

country is located in an arid and semi-arid environment, it is primarily reliant on irrigated agriculture, and it is dealing with the negative effects of climate change higher glacier melt, longer droughts, harsh winters, and early summers are all contributing factors (Abbas, 2022).

Due to its over-reliance on the environment for basic survival, high population growth rate and density, inadequate capacity to ameliorate the negative consequences of climate change, and poverty, the effects of climate change are more pronounced in Pakistan. Climate change is projected to have long-term consequences for biodiversity (species extinction and habitat loss), water availability, food security, human health, and overall well-being. Despite the fact that agriculture in underdeveloped nations is extremely vulnerable to climate change, little research has been done, and research in this area is quite limited.

It is also evident that climatic effects cannot be attributed to individual districts, and that these effects do not differ significantly within the same district/locality. Their effects vary, mostly throughout the region's natural zones. In this light, this research investigates whether climate variables such as rainfall and temperature have an impact on the productivity of important agricultural crops (wheat and rice) across Pakistan's agro-climatic zones (S. Ali & Ishaq, 2017).

2.7 Cropping System of Wheat and Rice in Pakistan

The rice–wheat cropping method covers 1.1 million hectares of land in the districts of Sialkot, Gujranwala, Sheikhupura, Nankana-sahib, and Hafiz Abad. The majority of the fields are planted in an annual rice–wheat cropping cycle, with only a few exceptions. After rice, wheat is seeded in 72 percent of cases. The rice–wheat system has unique challenges for the two crops, there are conflicts in crop management. Rice necessitates puddled compressed water. During the growth season, soils should be able to store standing water. As a result, when it comes to rice farming,

the for water retention, the puddling procedure to make a hard pan is critical. It gets smaller by mixing soil separately, it significantly changes the porosity distribution to aid in the retention of water and soil. Wheat thrives on well-drained, fertile soils allowing the root system to be penetrated deeply Wheat, on the other hand, may suffer from water-logging issues unless this tough pan is broken. Another problem with rice is wheat the dominance of late-maturing rice types, which allows for better management, is the cause.

There is insufficient time for wheat land preparation, resulting in a delay in wheat cultivation. Water scarcity and management are major concerns in this system. Many Water stress is a concern for farmers during large cultural events, there are labor shortages Planting, harvesting, and threshing processes, in particular, are growing. In some locations, nutrient imbalances and rice and wheat mining have caused problems. In the rice–wheat system, nitrogen and phosphorus are two of the most critical macronutrients that have become scarce. Zinc, boron, and manganese are all minerals. In some locations, there are issues with micronutrients Organic matter levels in the soil may be declining as a result of Addressing issues relating to the rice–wheat system. Wheat sowing season in this region runs from November 20 to December 31. The typical planting rate is 100–125 kg ha1, with two to three cultivations followed by two planking's to prepare the seed-bed (CHANDIO, MAGSI, & OZTURK, 2019).

To save time and avoid delays in wheat sowing, some farmers use remaining moisture from the rice crop to prepare the seed bed. Farmers typically employ the broadcast sowing method, and the fertilizer level most usually used in the areas. Depending on weather circumstances, farmers normally apply four to five irrigations to wheat at important growth stages (crown root initiation, stem elongation, booting and heading, and grain development). By mid-April, it is usually ready for harvest. Progressive farmers, on the other hand, sow with a drill and harvest wheat using a

combine harvester. The average output per hectare is between 3000 and 3500 kg. Sahar-2006, Faisalabad2008, and Lasani-2008 are some of the most common wheat types in the region.

Rice seedlings are transplanted from 30- to 40-day-old seedlings sowed in the rice nursery from 20 May to 20 June. In the nursery, around 5–7 kg of seed is used for transplanting on a one-hectare area. After harvesting wheat two months previous to transplanting, the land is prepped with two cultivations. Four to five cultivations are performed before to transplantation, followed by planking in standing water to puddle the soil and the development of a hardpan to keep water in the crop and generate anaerobic conditions. . Fertilizer is usually applied after one week of transplanting, rather than during land preparation. The average N: P: K fertilizer amounts used are 120:100:0 kg ha1. The total number of irrigation systems varies between 35 and 40. Rice is harvested from October through November, with a peak in November 4000 kg per hectare is the average production. The most common kinds seeded in the area Super Basmati, Basmati-385, and Basmati-2,000 are among of the varieties available (A. Ahmed, Ashfaq , & Rasul, 2017).

Chapter 3: Methodology

This section deals with the theoretical background of this analysis, definitions, data sources and also explain the econometric model used for the analysis.

3.1 Methodology

The central purpose of this study is to measure to what extent temperature and precipitation changes impact crop yields in two agro-ecological zones (AEZ). In this study panel data approach has been employed to measure these impacts over data from a total of nine districts from Punjab and KPK. We setup a cross-sectional panel and after checking for indigeneity determines that the best approach to follow is through a fixed effect model.

Fixed effect model is a panel data estimation technique that let one to compensate for unobserved time-invariant individual traits which can be connected with the observed independent variables. Hence the individual specific effect is correlated with the explanatory variables. Whereas, random effect model is a statistical model in which some of the parameters (effects) that define systematic components of the model exhibit some form of random variation. Thus, the individual unobserved heterogeneity is uncorrelated with the independent variables.

fixed effect model is used in this research as it allows to control invariant omitted variables of all the times. Fixed Effect Model (FEM) is used on the base of the balanced data design, the dependent variable is Crops (Wheat, Rice) yield and explanatory variables are first stage temperature (FT), second stage temperature (SST), third stage temperature (TST), first stage precipitations (FP), second stage precipitation (SSP), third stage precipitation (TSP).

It is argued that crop yield is a function of temperature and precipitation, fertilizer, water and technology therefore the general equation becomes:

$$crops_{w,r} = f(FT, FT^2, SST, SST^2, TST, TST^2, FSP, FSP^2, SSP, SSP^2, TSP, TSP^2, F, W, T)$$

A transformation of this equation in to an econometric model will be:

$$(crops)_{it} = \alpha_i + \beta_1 FT_{it} + \beta_2 FT^2{}_{it} + \cdots + \beta_n (Tem, Pre)_{it} + \Upsilon_1 fertilizer + \Upsilon_2 water + \Upsilon_3 technology + V_{it}$$

Where $i = 1,2, \ldots 9; t = 1,2, \ldots 30$, $(crops)_{it} =$ crop yields and $V_{it} = \mu_i + \Sigma W_{it}$ asV_{it} is the composite error term and μ_i is unobservable individual district specific effects and ΣW_{it} is other disturbances. Moreover, squared variables for temperature and precipitation have been added to the model as the data suggests that movement in these variable is of non-linear nature.

3.2 Data Sources

For the analysis purpose, the data on crop yield, temperature, precipitation, fertilizer uptake, water availability and technology has been collected from nine districts in total belonging to provinces Punjab and KPK namely; D. I. Khan, Jhelum, Bannu, Sialkot, Lahore, Faisalabad, Bahawalnagar, Peshawar and Multan. These districts are further classified in agro-ecological zones (AEZ) where (Agriculture, 2021).

- AEZ-1 (Barani Lands) includes following districts; D. I. Khan, Jhelum, Bannu and Sialkot
- AEZ-2 (Northern Irrigated Plains) includes districts from Punjab and KP that are; Lahore, Faisalabad, Bahawalnagar, Peshawar and Multan

The data on yield, temperature, precipitation, fertilizer uptake, water availability and technology is collected on an annual basis from 1991-2020. Data on crop yield for both rice and yield is obtained from crop reporting survey published by the ministry of agriculture for both Punjab and KPK whereas, the precise data on precipitation and temperature is sourced from the Pakistan Meteorological Department that was officially provided to us for this study upon request. And data on fertilizer, water availability and technology has been collected from ministry of agriculture and agriculture bureau of statistics.

3.3 Variable Construction

variable of interest that is also the designated dependent variable in our analysis is the yield of two major crops; Wheat and Rice. Even though yield of these crops is realized at the end of the crop production process yet it is most important to look deeply and inspect the different stages of its production where it is vulnerable to external variables. Keeping in mind that the crop production process has stages i.e., germination, tillering & flowering and maturity, gives us insight regarding design of corresponding external/explanatory variables that have an impact on these stages to study their impact pattern and intensity on the overall yield of the crop measured as ‘mounds per acre’ (sohail Abbas, 2021).

Temperature is one of the two explanatory variables that possess a direct impact on the yield of crop if it is not in required range. To measure the effect of changes in temperature over the crop production stages and consequently the overall crop yield, so temperature is divided in three sub-variables that corresponds to the crop production stages i.e., first stage temperature (FST), second stage temperature (SST) and third stage temperature (TST). These variables are constructed by calculating the mean-value of ‘average maximum’ and ‘average minimum’

temperatures of the month(s) corresponding to the production stage in ℃. As mentioned before, this study is dealing with two major crops; Wheat and Rice and their respective seasons occupy different months and lengths of the calendar year i.e., Rice is a four-month season that ranges from August to November and Wheat is a five-month season that ranges from December to April. In case of both crops, temperature in the first and last month of the season is considered as FST and TST respectively and average of the months in between is taken as SST.

Precipitation is the other explanatory variables that also have a direct impact on the yield of crop if it is not in required range. As far as the crop yield is concerned, nature of this variable is very similar to that of temperature thus, this variable is constructed in the same manner. Precipitation is divided into three sub-variables i.e., first stage precipitation (FSP), second stage precipitation (SSP) and third stage precipitation (TSP). These variables are constructed by taking the average precipitation of the month(s) corresponding to the production stage in millimeters. Similarly, precipitation in the first and last month of the season, as mentioned in the previous paragraph, is considered as FSP and TSP respectively and average of the months in between is taken as SSP.

Some other variables are also taken in this study like fertilizer uptake for each crop, water availability and technology as these variable also have an impact on the yield of the crops so along with temperature and precipitation these were also important to be included in this research work.

3.4 Theoretical Framework

Economics literature on the relationship among crop productivity and climate change utilizes a host of different techniques such as the Ricardian method, agronomic crop simulation model and the production function approach to name a few (siddiqui, samad, et al., 2012). All these approaches have their pros and cons with limitations but the approach followed in our study is based on our theoretical understanding of the relationship among crop yield and environmental variables coupled with the specific research objective that we plan to pursue.

This study employed a panel data approach to our analysis because of the fact that it could make a distinction among the agro-ecological zones based on environmental variables i.e., 'barani lands' and 'northern irrigated plains'. The districts under these zones have May not have too much variation in some environmental variables but may also have a lot of variation in the other. In our case, we see temperature may not vary too much among two zones but precipitation varies significantly. The need to capture this heterogeneity that exists on the agro-ecological zone level with the help of data available to us on the district level.

The data available to us on a monthly level for environmental variables along with yields on an annual basis makes it possible for us to carry out this analysis and separate the two agro-ecological zones for our analysis with the help of a dummy. .

3.5 Descriptive Statistics

For the purpose of this study the data is arranged in the form of a cross-sectional panel where districts serve as the cross-section variable and a thirty-year period from 1991-2020 serves as the

time variable. Before getting into the econometric analysis here are some of the descriptive statistics of the data separated by crop type.

In case of Wheat crop for the given districts, mean yield stands at 23.91 mounds per acre.

Table 1: Descriptive Statistics for Wheat

	Yield	**FST**	**SST**	**TST**	**FSP**	**SSP**	**TSP**	**fer**	**Wate**	**tech**
Mean	23.91	16.69	18.12	28.68	8.64	32.67	31.34	65.8	164.9	935.3
Median	24.28	15.35	17.03	28.27	2	24.29	19.9			
Maximum	40.3	24.9	25.7	38.1	9	138.2	265	2968	6975	9007
Minimum	0	2.6	3.8	2.25	0	0.43	0	1	184	475
Std.Dev	7.1	3.84	3.05	3.83	15.12	26.42	34.73	185.5	181.6	102.8
Skewness	-0.29	0.41	0.25	-1.16	2.84	1.34	2.27	14.2	1.45	4.50
Kurtosis	2.74	2.43	3.69	12.22	12.26	4.97	11.87	223.5	4.41	35.13
Jarque-Bera	4.72	11.35	8.26	1019.3	1329.3	124.88	1119.5			
Probability	0.09	0.003	0.01	0	0	0	0			

In case of Wheat crop for the given districts, mean yield stands at 23.91 pounds per acre with a standard deviation of a substantial 7.1 that shows that there is movement that can both be due to different cross-sectional units in the data and environmental changes. As for the explanatory variables, mean temperature in all stages of the production process stays within the minimum

and maximum temperature bracket required for the wheat crop with minimal deviations. Mean temperature rises from first consistently from first to the third stage as this crop starts in December and ends in April when temperature is on the higher end of the spectrum. Precipitation however is a completely different story. Precipitation follows a volatile pattern through all stages of the crop production process as is evident from the large values for deviation from mean. It suggests that if alternate means of provision of water to the crops is not available, a larger portion of volatility in crop yield can be attributed to it. From table b, the mean of yield of rice across districts standing at 18.73 mounds per acre with significant standard deviation. Again, the indication that this can be due to cross-sectional differences or environmental changes. Fertilizer and water availability both appear to have lower mean values and higher standard deviation. The possible reason is difference in land composition in two agro-ecological zones as water availability can differ due to rainfall and ground water level as well as some lands would need more fertilizer than others. Technology on the other hand is not dependent on soil or whether thus shows a lower standard deviation and shows a similar pattern of use in areas of wheat cultivation.

Table 2: Descriptive Statistics for Rice

	Yield	**FST**	**SST**	**TST**	**FSP**	**SSP**	**TSP**	**ferti**	**wat**	**tech**
Mean	18.73	33.01	29.74	21.94	121.56	34.91	6.88	65.5	154.6	876.9
Median	18.72	32.52	28.9	20.65	81.8	24.92	0.8			
Maximum	35.29	40.2	36	29.8	839.6	298	77.9	3432	6437	7689
Minimum	0	16	17.7	16.2	0	0	0	0	1	345

	Yield	FST	SST	TST	FSP	SSP	TSP	ferti	wat	tech
Std.Dev	6.35	3073	3055	3.53	132.89	35.32	12.21	145.9	187.8	130.1
Skewness	-0.18	-1.54	-0.38	0.54	2.2	2.81	2067	16.2	2.9	3.45
Kurtosis	3.74	8.82	4.09	1.9	9.93	16.89	11.32	245.1	3.6	23.5
Jarque-Bera	7.67	488.66	20.06	26.74	655.8	2526.4	1101.3			
Probability	0.02	0	0.04	0.02	0	0	0			

For a general idea, the mean values of temperature and precipitation. Statistics on temperature shows that mean temperature at different stages of rice production doesn't have much volatility and stays within the parameters of the appropriate minimum and maximum temperature required for rice production. Precipitation shows a similar pattern as it does in the wheat production with much volatility again suggesting that in absence of alternate irrigation plans, volatility in rice yield can be attributed in greater part to the volatility in rainfall. Rice crop season starts in summer and continues all the way through to the start of winter season therefore, a decline can be seen which in temperature which is not linear and at times drops abruptly. Similarly, a drop in precipitation can be seen because at the FSP for rice we have the end of rainfall season in most districts of Punjab and KPK. In areas of rice cultivation, we have the same observations regarding fertilizer, water availability and technology as it is noted previously.

Chapter 4: Discussion and Results

Wheat crop requires an optimal level of temperature and precipitation throughout its life cycle in order to give an optimal yield. Wheat is a seasonal crop and its production takes place from December to April. The first stage is for the month of December that is the germination stage of the crop when seeds are disseminated; the time span for second stage is the months of January to March which includes the time period of growing crop, stemming outside and flowering. The third stage of wheat production is maturing of the crops and harvesting which is carried out all in April. Throughout the life cycle of wheat production, the temperature is required to stay mainly between 4 degrees centigrade to 37 degrees centigrade that is why divided production in different stages. Similar conditions apply for the precipitation as well (Daubenmire, 1972).

Annual rainfall in plain regions of Punjab ranges from about 300-500 mm in the south west to 200-300 mm in the east, which is insignificant when compared to the actual water requirements of key crop wheat (Hussain & Bangash, 2017). Irrigation is therefore essential for agricultural crops in areas where there is slight or no rainfall at all during the growing season thus, artificial irrigation systems such as tube wells and canals can be used to compensate for the lack of rainfall in the regions. As a result, an increase in rainfall benefits crop productivity in these locations. Therefore, we argue that rainfall or precipitation have an insignificant impact on crop productivity is plausible here because of the presence of robust artificial irrigation channels i.e., when the average rainfall is less than required amount, it is compensated through artificial means. Table 1 displays us the outcomes of both models that are used in estimating the effect of precipitation and temperature on wheat produce in two agro ecological zones of Pakistan.

From the results in table 1, let's take a look at model. It is clear that first stage temperature and second stage temperature are crucial for wheat production and any variations in the temperature are going to have a substantial impression on the wheat yield. The effect of first stage and second stage temperature however differ with each other in the direction of their effect on wheat yield i.e., for every one-degree increase in temperature in the first stage will negatively impact the wheat germination process (first stage) whereas, every one-degree increase in the flowering process (second stage) will have a positive impact on the crop yield

Table 3: Estimation Results for Wheat Production

Variables	Model 1
Constant	30.73694***
First stage temperature	-3.053404***
First stage temperature²	0.0787843***
Second stage temperature	1.838631
Second stage temperature²	-0.04404
Third stage temperature	-0.0658117
Third stage temperature²	0.0068056**
First stage precipitation	0.0078399
First stage precipitation²	-0.0004796**
Second stage precipitation	0.1130844***
Second stage precipitation²	-0.000982***
Third stage precipitation	-0.0063031
Third stage precipitation²	-0.000294

Fertilizer	0.0001121**
Water availability	0.0001669***
Technology	7.4506
AEZ-1	-9.365824***
R^2	0.6542

Note: ***, ** and * represent significance at 1 percent, 5 percent & 10 percent level of significance respectively

As far as precipitation is concerned, it is another vital element for the wheat yield and its requirement is different at different stages of wheat production process. Looking at the results, precipitation in the first and third stage the variations in precipitation are having insignificant results on the wheat yield whereas in the second stage any variation in precipitation is going to impact wheat yield significantly but the magnitude is almost negligible.

Based off of the argument regarding alternate irrigation channels and volatility in precipitation as an insignificant impact variable over crop yield, the precipitation variables were removed from the model. It is seen from the results that temperature changes at all stages hold significant impacts, however, their direction is different. For the first and third stage, increase in one-degree temperature negatively impacts the wheat yield whereas the increase in temperature for the second stage where the crop is in the flowering stages benefit from it so these results are in line with the study of (Siddiqui, Ghulam , Muhammad, & Jalil, 2012).

Next variables are fertilizer and water availability both of them are having positive impact on the wheat yield which means that if farmers are going to use fertilizers and water availability is going to be proper according to the need of then this will increase crop yield so it is easy to say

that impact of climate change on the crop yield can be mitigated with the use of proper fertilizer and water availability. These results are in line with the studies of (Abbas, 2022; Chandio, Jiang, Joyo, & Rehman, 2016). In the above table the impact of technology is positive but is in significant it is because farming techniques in Pakistan are old and acceptance of technology is very basic and not up to scale so that is why results are insignificant.

As for the agro-ecological zone, our analysis concludes that variations in temperature and precipitation in model has negative impact on the crop yield but with use of fertilizer and fulfilling the requirement of water the yield of crop can be increased.

Table 2 holds the outcomes of the effect of climatic variations on the rice produce in different agro-ecological zones in Pakistan. It is evident from the result of model that only second stage temperature holds any meaningful impact for the production process of rice. Means that for each 1° C rise in temperature in the second stage significantly impacts the rice yield negatively. Precipitation holds absolutely no value in the production process of rice for the same reason as it is being argued in the previous section in the case of wheat production results of precipitation are in line with the study of (Siddiqui, Ghulam , et al., 2012). In this study is has been argued that there exist robust alternate channels of irrigation for rice crop that can fulfil any shortfall in rainfall and consequently the demand of water for the rice crop as well as the wheat crop.

Next variable are fertilizer and water availability from the results it is shown that the impact of fertilizer and water availability is positive and significant this result is in line with the study of (Chandio et al., 2016; Hussain, 2010). which means that if farmers are going to use appropriate amount of it for crops then the yield can be increased which means that in whatever way climate change is impacting crops yield use of fertilizer and water availability as it also has a positive

and significant impact on the yield so these two variables can recuse the situation and we can increase the yield of crops.

Then there is variable of technology as results are showing positive but insignificant impact on the yield which can be due to old farming techniques in Pakistan and inability of farmers to deal with new technology because of which they are still using rational ways of farming.

Table 4: Estimation Results for Rice Production

Variables	**Model 1**
Constant	104.8***
First stage temperature	0.1611
First stage temperature²	-0.0074
Second stage temperature	-6.3118***
Second stage temperature²	0.1440*
Third stage temperature	-1.3365
Third stage temperature²	0.0064
First stage precipitation	0.0113
First stage precipitation²	-0.0056***
Second stage precipitation	0.0351**

Second stage precipitation²	-0.001
Third stage precipitation	0.3006
Third stage precipitation²	-0.00835
Fertilizer	0.0096**
Water availability	0.0073**
Technology	5.9200
AEZ-1	-4.2494*
R^2	0.3505

Note: ***, ** and * represent significance at 1 percent, 5 percent & 10 percent level of significance respectively.

In many of the recent studies, climatic changes and their effects on the agricultural productivity in different districts of Pakistan are being focused. Districts as an administrative region may not reflect true essence of climatic impacts. Because administrative boundaries may not necessarily follow agro ecological differences. Thus, the effects of climatic change may vary considerably on the basis of agro-ecological zones whereas some zones may be experiencing floods while others drought, some extremely cold temperatures while others heat waves. There is an uncertainty to a great extent based on climatic variations which affects agro production and

practices in different seasons so in this study agro ecological zones are main focus so that is why in estimations we have generated two dummy variables like for each zone AEZ-1 and AEZ-2 so from which the study is going to see amount of reduction or increment in the average yield of specific zone so here if the sign with coefficient is negative that means there is a reduction in the average yield of wheat that is due to unfavorable climatic conditions too high or too low situations of temperature and rainfall can have reduction in the wheat yield. From the results in table 1 and table 2, it is evident that for each 1℃ upsurge in temperature or a rise in precipitation, whether looking at model the over impact on the wheat crop yield is negative. similar pattern can be seen emerging for the rice crop yield.

4.1 Qualitative research

Qualitative research involves collecting and analyzing non-numerical data (e.g., text, video, or audio) to understand concepts, opinions, or experiences. It can be used to gather in-depth insights into a problem or generate new ideas for research. Qualitative research is the opposite of quantitative research, which involves collecting and analyzing numerical data for statistical analysis. In various respects, qualitative research differs from quantitative research. Qualitative research, for the most part, is concerned with language rather than numbers, there are three more characteristics to consider especially noteworthy an interpretivist epistemological position, which emphasizes understanding of the social world through an examination of its participants interpretations, rather than using a natural scientific model in quantitative research. An ontological position known as constructionist, in which social qualities are results of individual interactions rather than phenomena 'out there' and unrelated to those involved in their construction.

The phrase "qualitative research" is occasionally misused to refer to a method of conducting business research in which no quantitative data is collected or generated. Many qualitative researchers are skeptical of such a representation of qualitative research, because (as we will see) qualitative research's distinctiveness is not only based on the absence of numbers. Qualitative research is sometimes considered in terms of how it varies from quantitative research. One possible drawback of this strategy is that it forces qualitative research to be defined in terms of what quantitative research is not (Alan Bryman, 2011).

In the qualitative part of the analysis, I have conducted online interviews from agricultural experts on effect of climate change on agriculture sector of Pakistan to see their point of view on my topic of research to make more clarity of the topic. In the table below I have mentioned the names of agriculture experts along with their occupations and regions. As climate change is a global problem every country in the world is facing this issue but some countries has worst impact including Pakistan because of unavailability of resources. Pakistan is the country whose 76% of the population is dependent on this agriculture sector but severe implications of climate change is impacting this sector adversely which means that people who are engaged with this sector their income and living standard will be impacted so thinking of new strategies and methods to mitigate the impact of climatic variation is very important to save Pakistan from future consequences of this disaster.

Table 5: List of interviewees

Agriculture experts	Occupation	Region
Muhammad Musaab	Reginal Head Pesticides	Layyah
Muhammad Amir Bashir Malik	FMC United (Pvt.) limited	Faisalabad
Muhammad Asif Sharif	Founder Chairman at Pedaver Pvt. Ltd.	Karachi
Dr Zakir Hussain Dahri	National coordinator (PARC)	Islamabad

4.2 Interview questions

- How would you define climate change in current scenario?
- Is there any impact of it on agriculture productivity in broader perspective?
- According to my analysis, production of crop has increased over time but the productivity isn't up to the mark. To what extent climatic changes could be the reason for this downfall?
- At what stage of crop production, does changes in climate impact adversely affect the overall yield?
- As the population of Pakistan has been exploded immensely in last two decades, reduction of agriculture yield could lead it to a serious task of food-insecurity for the government in future. What is your opinion on this?

- Also what further challenges do you think it could create?
- What possible strategies and measures can we adopt to mitigate the effect of climatic variations on agricultural productivity?
- Major crops of Pakistan face excessive decline in their productivity and yet it is hard to satisfy domestic demand. How this fall in yield of these crops have an impact on GDP?
- With policy point of view, what would you suggest to increase or maintain substantial amount of yields to meet its demand?

4.3 Outcome of the interviews

Climate change is having an impact on the crop productivity and is having significant impact on agriculture sector in all over the world but, its impact is getting worse in certain countries including Pakistan due to certain reasons like farmers who are dealing with agriculture sector are not well educated and well aware because of that they don't know what technology or adoptive measure they should adopt in order to mitigate climate change.

In opinion of experts, there are a lot of factors that have an impact on climate change if we talk about the condition of Pakistan the hap hazard towards industrialization means we haven't planned anything for industrialization but we jumped to it from agriculture sector because of which we have destroyed our trees, farms and now one tree is providing oxygen to 20 people which in an alarming situation. In opinion of experts climatic conditions are directly related to the environment of any place and we cannot control it artificially except using different fertilizers to improve the quality of crops and use different technology to enhance the yield productivity. Many countries in west have adopted new technology in order to deal with climate change BT technology is an example which was adopted by the west countries.

According to experts the major problem in agriculture sector of Pakistan is that farmer is unaware about the climatic conditions and how to tackle the new problems we are facing with the change in environment. So, to improve the quality of crops we should give skills and knowledge to the farmers as because of this change new pests are generating and we have no appropriate pesticides to protect the crops and our farmer don't know how to use the new technology either that is why Pakistan has not adopted the new technology which means that they were unable to cope with the problem like universe did.

One of our experts suggested that as good environment has an impact on human mood if their environment and surroundings are going to be appropriate they will be productive and active same is the case with crops if the climatic conditions in which they are growing is going to be appropriate then they will grow and their production will increase over the time.

In the opinion of experts, specific climatic temperature is important at every stage of production to get the better quality of crops and increase the yield productivity. As there are some stages of production like germination and vegetation are the initial ones so according to experts if we are facing problems in these stages we can tackle with them somehow by doing germination again or by using different techniques like animals and pesticides to solve the problem but the worst impact of climate change is on the stage of reproduction as we cannot do anything in that stage so experts say we should be aware about the future severity of climate and go for the crops which can give productivity in severe climatic conditions.

One of the expert suggested that back in 1980 there were severe climatic conditions which impacted our crops badly. Pakistan is the country which is producing 27 million tons of wheat and it is having population of 22 crore and considered as 6^{th} biggest country in the world in terms

of population. Agriculture is extremely vulnerable to climate change, particularly in Pakistan, due to the country's arid and semi-arid climate. A rise in temperature could have a greater impact on arid and semi-arid areas than on humid places. A number of climate variables, including rainfall patterns, rising temperatures, and higher CO2, are affecting productivity in Pakistan.

The agricultural industry provided 53 percent of Pakistan's GDP in 1949-50, but this plummeted to 31 percent in 1980-81 and 21.4 percent in 2012-13. The floods of 2010 flooded 20% of the land area, resulting in a total loss of 13.3 million tons of sugar cane, paddy, and cotton production. A total of two million hectares of standing crops were destroyed or damaged. Households reported losing more than half of their key crops, including rice, vegetables, cotton, sugar, and fodder, in 60 to 88 percent of cases. Due to a severe drought in 2000-2001, agricultural growth experienced a significant setback. The primary crops experienced a nearly 10% drop in growth, while total growth fell by 2.6 percent. According to experts, Pakistan loses $5.2 billion every year as a result of environmental degradation.

Chapter 5: Conclusion and Policy Recommendation

5.1 Conclusion

This analysis focuses on the influence of main climate variables (precipitation and temperature) and fertilizer, water and technology on major crop yields (wheat, rice) across two agro-climatic zones of Pakistan to examine the effect of climatic variations on agriculture crops. The study's empirical findings reveal that two primary climatic variables and three other have a considerable influence on major crop productivity in the chosen regions.

The study determined that an increase in a major climatic variable, such as temperature (average temperatures) has a negative impact in short run and long run has and precipitation has negative impact both in short and long on wheat crop. Initially, a rise in temperature is advantageous to rice production. However, once a specific ideal temperature is reached, any further rise in temperature is detrimental to rice production. Surprisingly, more precipitation has no negative impact on rice yield.

First, the influence of variations in temperature and precipitation varies greatly dependent on the timing and stage of agricultural production. Second, the influence differs from one crop to the next. Finally, crop productivity varies significantly across agro ecological zones.

Fertilizer and water availability has a positive and significant impact on the crop yield in long and short run while technology is having a positive but in significant impact on the yield because of the old farming techniques used by farmers.

From the qualitative research it is evident that Climate change is having an impact on the crop productivity and is having significant impact on agriculture sector in all over the world but, its

impact is getting worse in certain countries including Pakistan due to certain reasons like farmers who are dealing with agriculture sector are not well educated and well aware because of that they don't know what technology or adoptive measure they should adopt in order to mitigate climate change.

5.2 Policy Recommendations

As Pakistan is one the country who has worst impacts of climate change and in future if we will neglect them further consequences will be more critical so following are the policy recommendations in order to mitigate the impact of climate change.

1. According to the findings, adaption options in such areas include the farming of heat and drought tolerant agricultural varieties and the planting of early maturing crop varieties. Agricultural research groups should also produce crop types that are suitable for mountainous regions in changing climate circumstances.
2. We should focus on crop zoning which means that there should be proper research on the crops first then on the land and climatic condition of specific region then crops should be cultivated in the regions where the land and climatic condition is suitable for them
3. Punjab as possess high temperature in summers ranging from 40 degrees to 45 degrees. The climate is from arid to semi-arid. Thus it is recommended that, in these regions where there is high temperature, crops that can withstand high temperature should be

cultivated in order to get high yield of the crop that can add up to higher shares in the economic growth of the country as well.

4. As fertilizer and water availability can mitigate the impact of climate change so government should focus on providing good quality of fertilizer and water availability for each crop for the better yield.

Limitations of the study

The limitations are:

(1) The analysis is limited to the two agro ecological zones of Pakistan and only those districts are included from each agro ecological zones whose data is available.

(2) The study considers two important climate change variables namely temperature and precipitation and non-climatic variables such as fertilizer, water availability and technology. other inputs variables like sowing date, seed varieties are not considered due to non-availability of districts wise data.

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