CLIMATE CHANGE AND ITS IMPACT ON AGRICULTURE IN PAKISTAN: A Case Study of Khyber Pakhtunkhwa (1980-2010)

By

Samreen Babar

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Supervised By: Dr. Naeem-ur-Rehman Khattak

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ABSTRACT

The world is facing climate challenges in the form of flash floods or harsh droughts, intense thunder storms or occasional rains, swamped plains or barren land, water assimilation or water scarcity. The aim of this research is to study the impact of climate changing events on Pakistan in general and its agriculture sector in particular. It will help in better copping against the future climate changing incidents. The intense rains of 2010, which resulted in a sever flood, is one of the climate change event in Pakistan.

Khyber Pakhtunkhwa was among the provinces affected by the flood event of 2010. Khyber Pakhtunkhwa by ecological landscape can be divided into three zones or regions i.e. the Northern, the Central and the Southern regions. This study is an attempt to measure the climate variations in the three climate zones of the province, over the thirty year period (1980-2010). The environmental trend analysis results of the study shows that Khyber Pakhtunkhwa as a whole has experienced the climate change impacts in terms of rise in mean temperature from 0.3°C to 1.2°C and average rainfall from11mm to 15mm over the thirty years span.

The climate intense event of 2010 impact was observed in terms of decreased agricultural production of Kharif and rabi crop. Khyber Pakhtunkhwa agricultural statistics showed a decline of Kharif (maize) crop from 1880 kg/hector in 2008-09 to 1783 kg/hector in 2009-10 and Rabi (wheat) production of 1565 Kg/hector in 2008-09 was reduced to 1520 Kg/hector in 2009-10.

The climate changing impacts on agricultural sector is accessed by analyzing the two seasoned crops i.e. Rabi and Kharif of the province. The economic regression analysis is performed in this respect. The findings of the study shows that climate factors does effects crop production. Climate impacts on rabi crop of the province are more distinct than the kharif crop. The regional regression results depicts a positive impact of climate change on the northern part of the province whereas a negative impact on crop production is seen due to the elevated temperatures and untimely rainfalls.

CHAPTER 1

INTRODUCTION

1.1 THE CONCEPT

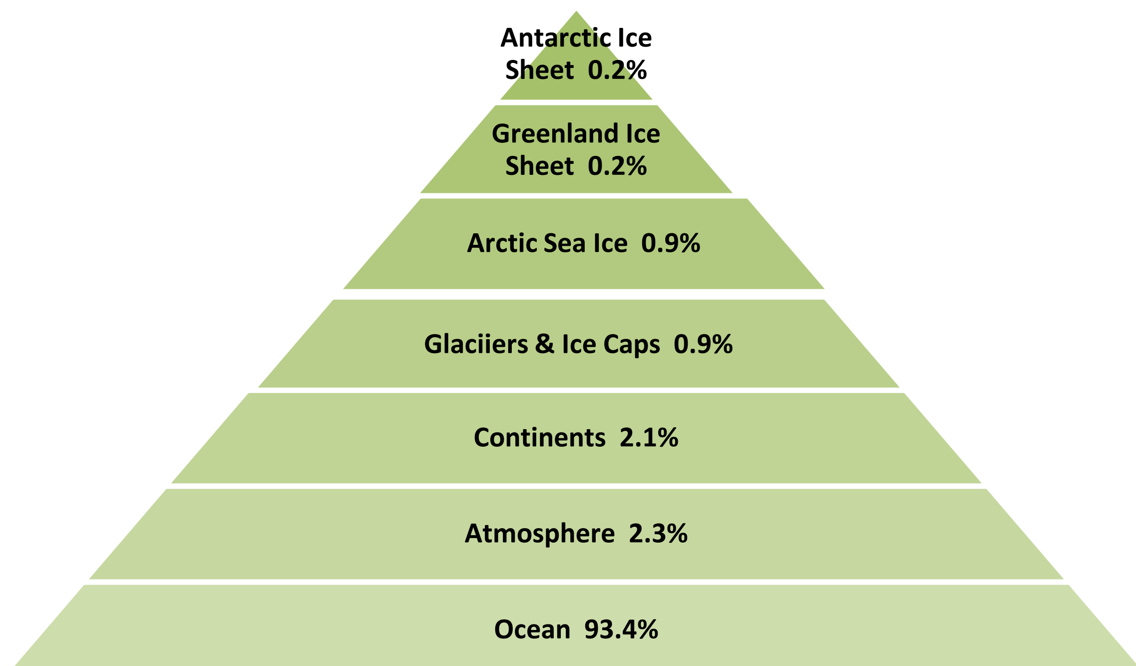
"Climate change is a phenomenon that arises due to emissions of greenhouse gases from fuel combustion, deforestation, urbanization and industrialization, resulting variations in solar energy, temperature and precipitation", (Upreti, 1999). It is a real threat to life which largely affects water resources, agriculture, coastal regions, freshwater habitats, vegetation, forests, snow cover, and geological processes such as melting, land sliding, desertification and floods all of which have long-term effects on food security and human health. (Malla, 2008).

Climate change can be better understood with the help of a simple analogy, consider the amount of salt in the food. Salt is the most important component of food and life, food without salt is tasteless and flavorless, too much salt makes the food bitter and tangy. In the same way, sunlight is an essential component of life i.e. life on earth is possible due to sunlight, it helps in the plant photosynthesis, life under the ocean and maintains the earth`s temperature to moderate level. Just like salt, excess of sunlight is harmful to life on earth. The abundance of sunlight increases the earth`s temperature than usual, causing the greenhouse effect. The greenhouse effect is further intensified by the increase in atmospheric gases such as carbon dioxide, methane, nitrous oxides and fluorinated compounds. The abundance of greenhouse gases leads to the warming up of earth`s temperature, causing the earth freezers to melt its ice than normal. The white ice caps on the earth poles act as a repellent to sunlight, melting of ice means more sunlight will be absorbed by the deep blue ocean underneath it thus raising its temperature further. Warming not only affects the oceanic ecosystem but also energies the additional melting of oceanic ice sheet. The National Snow and Ice Data Center, (2010) shows in its report that the arctic ice caps has been declined from 8 million kilometers to roughly 5.5 million kilometer from 1980 to 2009. All the above discussion does not mean that sunlight is the main culprit. God has made the earth perfect and the proportion of sunlight coming to earth balanced. The problem lies in humans, competing for sustainability and development.

The race of achieving economic development, progress and advancement in the world has forced nations to engage advance gaseous emission technologies. The dream of industrialization has tempted the countries to exploit nature in a number of ways. This exploitation has led to ruthless use of fuel, high carbon emissions, methane and nitrous oxides waste deposition in ocean waters and high level of pollution in atmosphere. This increased proportion of the gases as carbon dioxides, nitrogen oxides and fluorinated compounds in atmosphere are the prime felons of climate change. This exploitation and consumption of natural resources are caused by a number of ways as ; the massive cutting of forests for increased agriculture; the immense usage of herbicides, pesticides and insecticides ; the manufacturing of synthetic compounds; the deposition of industrial , agricultural as well as domestic wastes in oceans. The more polluted the air, the additional the trapping of sunlight, the immense will be the greenhouse effect and eventually adverse impacts of climate change. Global carbon dioxide gas emission has increased from zero to approximately 8000 million metric tons from 1751 to 2007 as reported by Carbon Dioxide Information Analysis Center United States of America. Moreover the atmospheric Carbon dioxide when dissolved in the ocean waters forms weak Carbonic acid. The increased acidification of the ocean is also affecting the aquatic life of small sand grain sized planktons. Those small planktons are helpful in the absorption of 25-50% of the ocean carbon dioxide. This results in changing the chemistry of the ocean, effecting marine ecosystems and oceanic biodiversity. (Jean.et.al, 2009)

Global warming has been observed by various components of the world as the arctic and Antarctic ice sheets, the continents, atmosphere and the ocean. The percentage of the global absorption by different components of the world is shown by the following pyramid.

Figure 1



Sources: Components of Global Warming for the Period 1993 to 2003 calculated from Intergovernmental Panel on Climate Change.(Lenny et.al.2009)

This pyramid shows that it is the ocean that is trapping 93.4 % of the overall earth`s heat. The clear white ice reflects sunlight back into space whereas the dark sea is the major source of heat absorption. A study by Balmaseda et al., (2013) on climate change effects shows that oceanic temperature has also increased five to ten degree centigrade in the past fifty years. This has also led to a 20% decrease in Arctic ice sheets.

Nineteen century is called the era of industrialization and resource utilization. The increased level of greenhouse gases keeps on warming up the earth`s atmosphere. The atmospheric temperature rise due to fuel consumptions are more pronounced in this era. Global atmospheric temperature has risen by 0.6 °C in this era i.e. from 1917 to 2011. (Goddard Institute of Space Studies, 2012)

Global warming and greenhouse effects has also set a speedy transformation in the weather patterns of the earth termed as the El Nino Southern Oscillation (ENSO) and El Nina. These are the regularly occurring natural climatic patterns of the earth thus keeping the earth temperature at moderate level. Normally El Nino comes back after every second or third year and sometimes followed by El Nina. El Nino is characterized by the warm temperature at the equatorial pacific whereas El Nina is opposite of it, characterized by the colder temperature at the equatorial pacific. During the warm El Nino year, ocean heat up the wind above it and warm wind currents are formed. Warm wind is usually lighter in weight, it starts blowing toward the low pressure, colder regions of the earth. These warm air currents raise the overall earth`s temperature and intensification of rains. The warm years of 1997 and 1998 are designated as Al Nino years.

La Nina is a Spanish word meaning little girl. It is opposite of El Nino, as the ocean becomes unusually cold. Normally the wind blows from the eastern pacific to the warm western pacific. The air above it becomes significantly cold and shuffle the ocean westward, causing the atmosphere of the earth cooler and dry. This shuffled cold sea water above also brings important nutrients from the deeper oceans, which is helpful for the fishing industry. (Trenberth et. al. 2010)

Climate change impacts vary with diverse climatic regions of the earth. The polar icecaps, the mountainous peaks, the barren dry lands, the tropical regions and the coastal seas experiences miscellaneous climate induced changes. Lin et. al, (2011) in their research paper highlights the ecological differences of climate change by estimating output elasticity for different grain crops in different regions, under different emission scenarios. The paper investigate the impacts of climate change on China's (PRC) grain output using rural household survey data. It proves that effects of climate change in northern and southern china were positive whereas it showed a negative impact on the rest of the country.

1.2 CLIMATIC CHANGE IMPACTS ON PAKISTAN

Climatic conditions of the world are changing ever since the creation of universe. Now a day, people with the onset of heavy industrialization and huge population are facing the climate change impact more rapidly. More heavy rains, high temperature thresholds, strong winds and heavy snowfalls are observed. The IPPC (2007) fourth assessment report (AR4) criticizes man as the main cause of climate change.

Pakistan is also among the countries at the receiving end of climate change impacts. The average temperature of Pakistan as projected by various environmentalists is increased in range of 1-3 °C in various regions of the country. Moreover dearth of fresh water, excess of Greenhouse Gases (GHG), deforestation for agricultural land use and lastly substantial mechanization and industrialization has intensified the climate situation. The frequency of extreme climatic conditions as heavy rainfalls and extreme weather were seen in the form of severe drought of 2001 and violent floods of 2010 in the country. Furthermore, such types of events with the increased intensity are forecasted in the upcoming years. Scientific evidences shows that the world will face huge Climate disasters in the coming future. It's better to spend some money on the environmental health now and save our future tomorrow.

The climate change impacts as seen in form of extreme climate events. It occurs as dry winters, storms, intense rains, extremely high or low temperature. World Health Organization (WHO) Collaborating Centre for Research on the Epidemiology of Disasters (CRED) has recorded the natural disasters events in the different countries of the world. The natural disaster extreme climate events in Pakistan are given in the following table-1.

Table 1: Natural Disasters & the Economic damage Costs in Pakistan (1980 to 2011)

Disaster	Date	Damage (000 US$)
Flood	8-Sep-1992	1,000,000
Drought	Nov-1999	247,000
Flood	22-Jul-2001	246,000
Flood	10-Aug-2007	327,118
Storm	26-Jun-2007	1,620,000
Flood	28-Jul-2010	9,500,000
Flood	12-Aug-2011	2,500,000

Sources: "EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be - Université Catholique de Louvain - Brussels - Belgium"

The table above shows the extreme climate events of floods and droughts and the damage done in Pakistan during 1980-2010. For all the disasters occurred and damage done, the event of July 2010 flood was the harsh one, giving loss of 9.5 billion dollars, affected 20 million people, demolished thousands of houses and affected an area of 2.4 billion hectares (Mustafa, 2011). Major loss was reported and documented in the agricultural land and property of Pakistan.

Climate change is a global issue; debated on at all fronts whether it's biotic, scientific or economic. Climate must be prevented from further damage before the end arrives. There is a need on all levels of society to understand climate, the factors behind change and its impact on our economy in general and agriculture sector in particular. It is one of the most serious problem; sever than terrorism threat, faced by humanity (King, 2004)

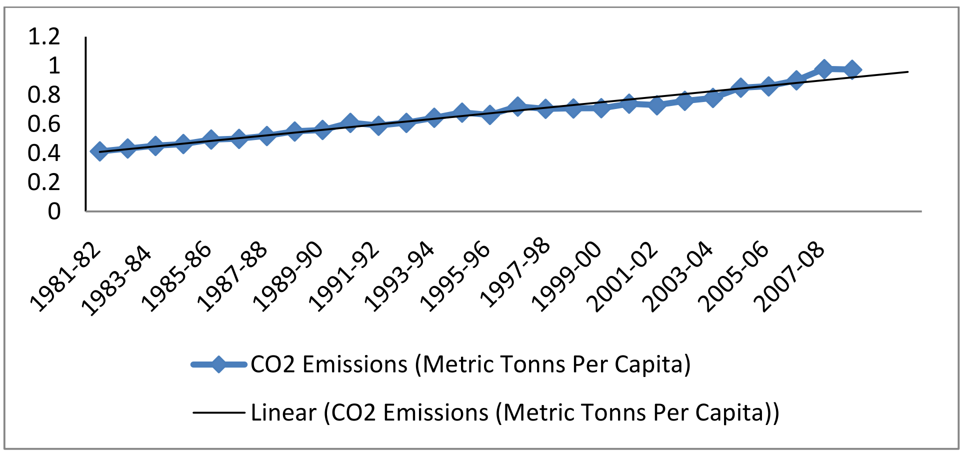
1.3 CLIMATE CHANGE AND AGRICULTURE OF PAKISTAN

Pakistan prosperity, success, affluence and opulence are embedded in its agriculture sector. It is the soul of Pakistan. The agriculture sector is extremely vulnerable to climate change impacts. This sector is the cause as well as the victim of climate change. The greenhouse gaseous emissions as carbon dioxide, methane and nitrous compounds are related to increased agricultural land use. Agricultural processes as the rice cultivation and the enteric fermentation in cattle contributes 54% of methane emissions. Fertilizers and pesticides release 80% of the nitrous compounds. Moreover, the major carbon dioxide gaseous emissions are linked to deforestation and extensive land utilization for agricultural purposes. (IPCC, 2007).

The impacts of climate change are vast and long lasting on agriculture industry. Global warming and change in participation patterns are the main concerns of climate change. Higher temperatures ultimately reduce yields of desirable crops while encouraging weed and pest production. Changes in precipitation patterns elevate the short-run crop malfunction and declines long-run productions. Although there will be an increase in some crops production in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative, intimidating global food security (International food Policy Research Institute,2009)

Pakistan being an agrigarian country is heavily dependent on climate. All the developemntal factors are in one way or the other effected by the climate change impacts.One of the imperative element contributing to climate change is the Carbondioxide (CO_2) gaseous emmissions, resulting greenhouse phenomenon. Figure-2 below is showing the thirty year (1980-2010) trend of CO_2 gaseous emmissions:

Figure 2: CO_2 Emissions (Metric Tonns Per Capita)



Sources: World Bank Data (2012)

This figure is showing an increasing trend of carbon dioxide concentrations in atmosphere. The data sources are from the World Bank. The figure shows as increase of 0.5 metric tons per capita of carbon dioxide since the last thirty years. This is one of the hidden enemy slowly increasing the green house impact in atmosphere and ultimately reducing agricultural yields.

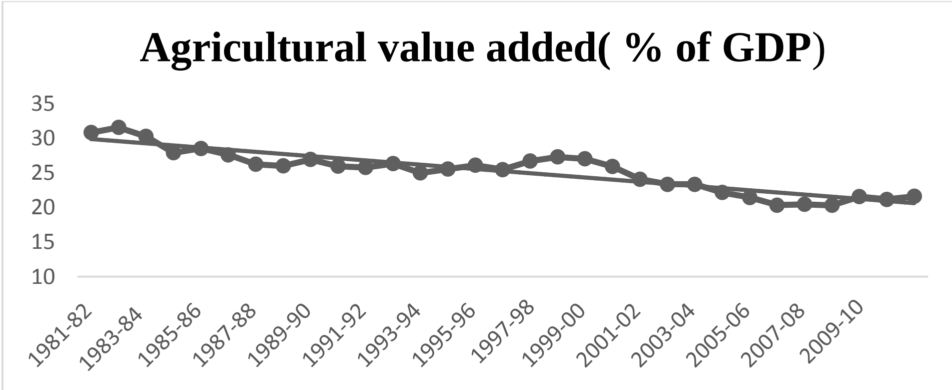
Carbon dioxide (CO_2) is a significant compound in the plant photosynthesis. The increases levels of CO_2 have positive as well as negative impacts on plant growth. It has positive impact in terms of plant physiology by increasing the process of photosynthesis. It encourages plant and crops development in wheat and maize varieties. The shortcoming of increased CO_2 is the decreased number of stomata development in the plant leaves. Stomata are small pores in the leaves for the gaseous exchange and water storage. The decreased number of stomata means decreased usage of water. (Woodward and Kelly, 1995) Moreover, greater concentration of CO_2 in crops leads to the decrease amount of nitrogenous compounds. Nitrous compounds are the prime component of protein, thus reducing the concentration of proteins and important nutrients in food. This ultimately activates a chain process of malnutrition i.e. low calorized grains, under nourished cattle and mal-nutrition population. People will require more quantity of grains to make up the quantity of protein in their food. (Glenn, 2005) The long lasting impacts of low productivity, under nourished population, rural urban migration and insecurity are more distinct in under developed and poor nations of the world.

Climate change impact on agricultural sector is a serious issue that demands immediate attention. Keeping in mind the importance of agricultural sector for the economy and food requirements of Pakistan, a need arises to measure the impact of climate change on the country's economy. Although climate is an immeasurable entity but it is a fact that it has been affected by various elements i.e. Carbon dioxide, temperature variations, precipitation rates, water level, soil erosion, salinity etc.

Pakistan`s agriculture has an extensive versatility in its vegetation due to its variable climate in different parts of the country. Its land is enriched to bear various kinds of fruits as oranges, mangoes, apples, pears and plums etc. It can grow maize, gram, rice, sugarcane, barley, tobacco and various kinds of pulses.

Major crops, such as wheat, rice, cotton and sugarcane contributes 32.2 percent of the value added in overall agriculture whereas 11.7 percent of the value added is contributed by minor crops as gram, lentil and barley etc. (Agricultural Saticticts.2010-11) Pakistan's agricultural performance along with the other economic factors , is also dependent upon the well-timed availability of irrigation water. It is one of the basic inputs of agriculture which is the factor affected by the changing climatic conditions of the country. The untimely harsh rains or no rains have aggravated the current water availability statistics. This leaded to a decreasing agricultural value added percentage of the country. The figure 3 below shows the agricultural value added percentage to GDP. Agricultural value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. (World Bank.2013).

Figure 3: Agricultural value added (% of GDP)



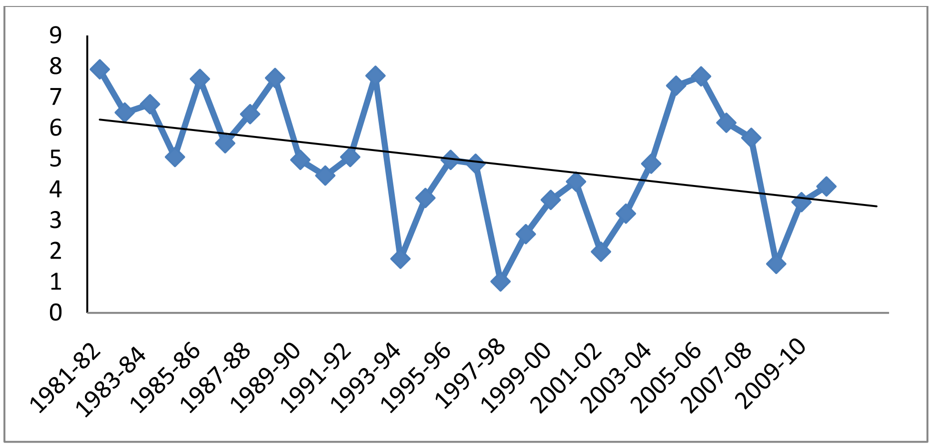
Sources: World Bank Data (2012)

The figure above shows a sharp decline in the agricultural value added percentage. The graphs dipicts a significant decresing trend. This decresed agriculture value added leads to slow growth rate and decreacing economies of scales . There are number of other factors responsible for this decling trend, such as the insecurity situation, the international sanctions, hiking gasoline prices, energy short fall, instable economy etc. Among all those factore there is one more factor slowly, steadly and unnoticibly effecting the growth rate i.e. the factor of climate on agricutural sector.

1.4 CLIMATE CHANGE AND ECONOMY OF PAKISTAN

Pakistan is a rich natural resource state. It has high mountainous peaks, forests, glaciers, precious stones and variety of wild life. It has lush green agricultural lands on one hand and dry barren desert on the other. It has a long sea shore which is opening the way forward toward the sea arenas. These natural resources needs to be explored for the development of the country`s economy. Pakistan due to the lack of capital resources, proper guidance, insecurity and commitment by the higher officials is still fighting for its sustainability. Pakistan Gross domestic product is increasing at a decreasing rate. The figure-4 below shows the annual GDP growth percentage for the last thirty years.

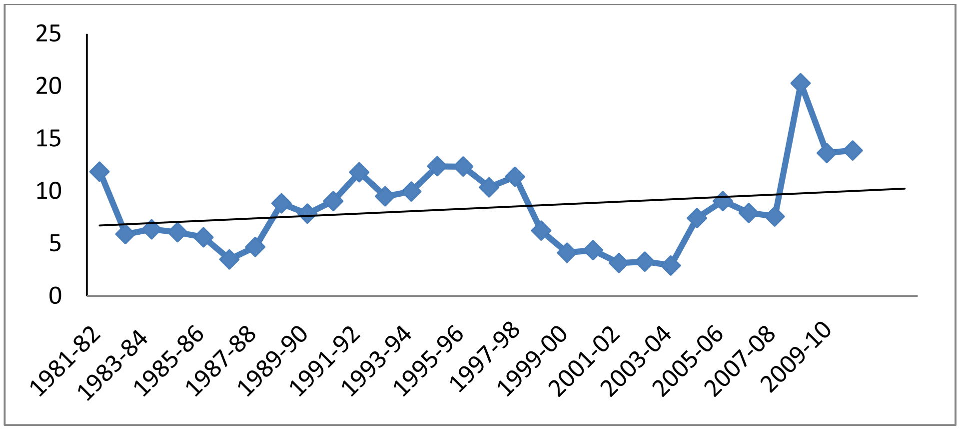
Figure 4: Pakistan GDP Growth (Annual %)



Sources: World Bank Data (2012)

The overall trend of GDP is displaying a decresing tendency. Pakistan GDP is effected by a number of factors as terriorisum, the changing goventment, unstaibility in economy, lack of public security, energy shortfalls, natural desaters, climate change factors and low industrial and agricultural productions. The decrese in GDP percentage is also leading to an increase in the consumer price inflation rates. The following figure-5 of Pakistan`s inflation rates over the last thirty years clearly depicts the pakistan economic situation.

Figure 5: Inflation (Annual % Consumer Prices)



Sources: World Bank Data (2012)

The important economic factors effecting pakistan`s economy are showing a significant decreasing trend that demands serious consideration. The grass root cause of the economic downtun must be pointed out for the prosperity of a country.One of the impartant grass root factor, is the agricultiural sector of Pakistan. Pakistan`s downward moving agricultural value added percentages and GDP and the hiking inflation rates clearly indicates unstable economic situation of the country. It is a fact that climate change along with the other political and socioeconomic factors are contributing towards unsustainable economy. Its impacts yet not realized systematically but effecting economy certainly and silently.

1.5 RESEARCH SIGNIFICANCE

Pakistan's economy and prosperity is closely linked to its agriculture. Pakistan's economic activities relate directly or indirectly to agricultural sector. Agriculture and agri-related activities form 80% of the country's economy. Agricultural sector in turn is dependent on nature. The uncertain changes in nature i.e. changing in precipitation pattern, extremely high and low temperatures, cyclones, thunderstorms, variation in water level, impurification of air, water and soil, have made agriculture and agri-production a challenging issue. Unusual heavy rain storms in 2010, which resulted in floods and distortion of agriculture and property, are an example of climate change. An estimated 14% i.e. 3.4 million hector area of cultivable land has been destroyed. A loss of 1764 people, human injures of 2697 and houses damage of 1.85 million has been reported. The reconstruction & rehabilitation of the flood affectee costed approximately 8-9 billion dollars (Mustafa, 2011). The greatest hit among all the provinces of the country was Khyber Pakhtunkhwa (KP).Out of the 2349 KP flood affecties, 1156 lost their lives and 0.2 million houses damaged or destroyed (Mustafa, 2011). The country's social as well as economic setup suffered and resulted in an economic set back. The loss to the economy and the people sufferings are still remembered and unforgettable. It is the need of the day to carefully observe climate change, the causes and impacts of extreme weather events in terms of agricultural productivity and find the necessary solutions to it. Issues regarding susceptibility to extreme climate conditions should be addressed with seriousness to save Pakistan's agricultural sector and consequently the national economy.

Climate change impact is a known fact and cannot be ignored for an agrarian country like Pakistan. A number of studies has identified the link between climate change, its impact on agriculture and economy of Pakistan. Climate change impact on wheat crop production in Punjab (Pakistan), has been identified by Pervez et.al, (2010), Shakoor et.al (2011), Ashfaq et.al (2011), and Rehana et.al, (2012). Climate change has not only effected agricultural productivity of crops but also added to the situation of water scarcity as explained by Zeb et.al, (2013) in a study on district Karak of Khyber Pakhtunkhwa. Climate change is also one of the factor in effecting the agricultural land prices in various districts of Pakistan. (Uzma et.al 2010 & Ahmad, 2013). The worked done in this field is remarkable and initial stepping stone towards a much advanced and innovative future of Pakistan. The short comings of the Pervez, Shakoor and Ashfaq studies are that most of the work is done on a single crop and the study area under consideration are the districts of Punjab ignoring the rest of Pakistan. The study by Uzam has find the link between agricultural land prices and climate variability on Punjab districts over passing the direct impact of climate change. Zeb et al. (2013) is a new addition to the climate change literature, by assessing the climate impact on a district in Khyber Pakhtunkhwa. The short coming of this study is that it is based on farmer's opinion, neglecting the scientific facts and figures of climate change. Besides, it has considered a single district i.e. Karak of Khyber Pakhtunkhwa.

The present literature shows that Khyber Pakhtunkhwa is one of the provinces ignored by the agricultural economists, biologists and environmental scientists in terms of climate change assessment. In fact, Khyber Pakhtunkhwa's agricultural contribution towards Pakistan`s GDP is 8 %. (Wikipedia, 2013). Looking behind the gaps in the present literature, this study is a unique attempt in identifying the climate change trends in the different ecological zones of Khyber Pakhtunkhwa. It is exclusively focusing on the evaluation of climate change impacts in the three climatic regions of the province. The region-wise analysis is further elaborated to the two cropping seasons i.e. Rabi and Kharif, of the province. Reliable estimates obtained for the three different climatic regions of the province as well as the overall Khyber Pakhtunkhwa will help in region-wise future predictions, mandatory adaptation and comprehensive policy making purposes. Prevention and adaptation are the only approaches to safeguard the interest of a poor farmer and the economy of the country. This research study can be used as a baseline for the other similar zones of the country and then retrieving its impacts on Pakistan's agriculture sector as a whole.

1.6 RESEARCH OBJECTIVES

The aim of this research study is to achieve the following objectives:

1. To investigate the damage caused by climate change events to Pakistan`s economy as a whole and agricultural sector in particular;

2. To observe the climate trend of the last three decades i.e. from 1981 to 2010, in various regions of Khyber Pakhtunkhwa;

3. To analyze temperature and rainfall, as the key factors affecting Rabi and Kharif crops production in Khyber Pakhtunkhwa;

4. To scrutinize different adaptive strategies in coping with the catastrophic conditions of environment and improving the total crops yield;

1.7 ORGANIZATION OF THE STUDY

The research study is organized by giving the introduction of the topic and the significance of the issue in the first chapter. The second chapter of this study comprises the literature review on the climate change issue in the country and the world. The third chapter of the study explains the research methodology adopted, the statistical and econometric techniques used and the variables incorporated. The fourth chapter is portraying the information of the area selected, the seasonal crops, the environmental variability and the data collection issues i.e. its weaknesses and shortcomings.

The results and discussion of the study i.e. the variation in climate behavior of Khyber Pakhtunkhwa and its probable impacts are observed in the fifth chapter. It is done by analyzing the climate change factors of temperature and rainfall rate with crop production over the period of thirty years. The last but not least is the chapter of conclusions and recommendations. It is highlighting the important facts about the regional climate variations, its impact on crops output, the government measures and the future recommendations over the issue of climate change.

CHAPTER 2

LITERATURE REVIEW

Climate change is a topic that is subject to wide, universal debate, with proponents on both sides. There are primarily two camps in this debate, those that believe climate change is a man-made crisis, and the other that either deny climate change is actually happening, or alternatively claim that climate change is a natural phenomenon that cannot be attributed to human actions.

The truth is, the climate is changing slowly and steadily. In the recent past, scholars have begun to vigorously monitor both the changes in global climate trends, and the impact of climate change on global ecosystems. It is a huge issue that demands strong and concrete actions by governments. The issue of climate change has been debated at various international and national forums. Various studies exist that links the impact of climate change on various segments of society. A range of literature exists, that assesses the cause of climate change, effects on agriculture and world economy and how to mitigate against its impacts. In addition, literature review of several studies related to the climate change impacts on Pakistan`s agricultural sector in particular is also highlighted below:

2.1 INTERNATIONAL LITERATURE

The international literature review is further divided as the cause, effects and mitigation against climate change. It is discussed briefly.

2.1.1 Cause of Climate change

Pierre (1997) explains that "heat trapping" gases such as Carbon dioxide are increasing in the atmosphere, resulting in the Greenhouse effect, which has contributed to an increase in global temperature by an average of 1 to 3.5 degree Celsius. He further explains that a warmer atmosphere holds more water than normal, which results in an increase in the precipitation rate by 10 to 15 percent. The author has supported his argument by the use of Global Circulation Models (GCMs). His paper explains the potential impact of climate change on agriculture, in terms of decreased agricultural produce in United States as well as on global scale.

In an article written by Lead (2008), the author contends that changes in climatic conditions are not only natural, but are also attributed to human intervention such as deforestation and burning of fuel. This article further explained that development of heavy industries, cars and the production of electronic goods, such as televisions, air-conditioners, and computers, contribute directly towards a warmer and concentrated Greenhouse Gases (GHG) in environment.

The Fourth Assessment Report (AR4) issued by the Intergovernmental Panel on Climate Change (IPCC) (2007) admits that the climate has changed due to human-induced anthropogenic activities such as fossil fuel burning, livestock wastes and deforestation etc. The assessment report concludes that if anthropogenic activities continue with the same pace, it is expected to raise the global average temperature from 1.1 degree centigrade to

5.5 degree Celsius by 2100. Climate change has already altered the United States agricultural production. This study has benefited agricultural landlords in providing assistance in long term decisions about land use and crop mixes. It has also suggested future adaptation and mitigation ways against climate change and agricultural productivity.

Parry and Carter (1998) explains in their paper that climate change impacts are multi-dimensional and multi-sectorial in nature. They are observed both on natural and human systems. For biophysical systems, it is the change in productivity, quality, population numbers or range. For societal systems, impact are measured as change in value (for example, gain or loss of income) or in morbidity, mortality or other measures of well-being.

Nelson et al. (2009) in its International Food Policy Research Report explains various scientific facts about climate change. The report explains that climate change is primarily caused by the rise in the earth`s temperature. The increased temperature causes the glaciers to melt, and lead to more rains, more floods and more extreme weather conditions. These extreme weather conditions negatively impact crop yields. Low yields in turn lead to high crop prices, which in turn leads to higher meat prices. High meat prices translate into reduced meat consumption, which reduces the level of calories consumed by the general public, increasing the risk of malnutrition and famine. The findings of the report show that not only is climate change a situation that needs to understood, but is also a real threat to the global food supply.

The report recommends that a pro-growth and pro-poor development agenda should be adapted. The report suggests different ways to tackle climate change. First, adaptation to climate change is easier and more worthy than resource management. Secondly, investment should be increased in agriculture sector to meet the world food demand. Lastly, extensive research is required in agriculture field to introduce drought and temperature resistant crop varieties. New Technology and researches should be shared with different countries to overall cope with this unwanted situation.

2.1.2 Climate Change Effects on Agricultural

The Agricultural sector is a cause as well as the victim of Greenhouse Gases. The main issue discussed in the research report by Green Peace (2008) is the effects and impacts of greenhouses gases on agricultural production. They discovered an important fact that greenhouse impact on agricultural production is about 17 to 32 percent. Both Agricultural and non-agricultural sources are the main cause of greenhouse effect. It includes nitrous oxides released by the land used, enteric (extensive) fermentation, Methane from cattle, burning biomass, rice, manure, fertilizers and pesticides production, irrigation and the use of extensive farm machinery. Greenhouse impact can be reduced by sequestrating Carbon, Methane and Nitrogenous compounds.

Another important thing about this report is that it also compared the effectiveness of organic and inorganic products to climate change. They concluded that for food production i.e. wheat, bread, fruits and vegetables the organic products are the better but for animal products as poultry, eggs, milk and meat inorganic or conventional products are the best.

The effects of climate change on agriculture is also debated by Smith, et al (2007). The text explains the importance and the need of agriculture to human life, and additionally points out that 40-50% of world`s land surface is used for agriculture. It employs about 1.3 billion people worldwide, and in return feeds the world. Agriculture sector uses about 87% of extracted water and is responsible of 4% of global gross domestic product. According to the book's estimates, global greenhouse emissions have increased by 17% from 1990 to 2005 that has subsequently reduced the per hector crop yield.

Multiple suggestions are provided for coping with greenhouse gas emissions and increasing the agricultural productivity. These include well equipped agricultural land, livestock and fertilizers management. The recommendations includes gradual elimination of fossil fuel based fertilizers, reduction in inorganic livestock and enhancing the importance of organic feed, with reduced methane gases, for livestock. They also stressed on the need of increased agricultural research and development for agricultural knowledge and technology transfer.

Cline, (2007) beautifully explains, in his book, the global impact of climate change on agriculture. The prime argument of his book is that global warming does not increase the yield of crops as suggested by others. He proved his argument by taking the current verses projected average temperatures of different countries and their precipitation values. He came to the conclusion that global warming might be affirmative for some countries, but for developing countries it is untrue. He explains further that global warming might have minor effect in this century, but if the countries did not take positive measures, such as the use of carbon fertilizers, heat and drought resistant crops, results would ultimately be aggravated.

International Food Policy Research Institute (2009) conducted a study that concentrates on various agricultural sector issues in Asia and the Pacific. It presents indicators of exposure, sensitivity, and productive capacity of the agriculture sector in the region. Those indicators underline the vulnerability of the agriculture sector as a source of livelihood and food security for many people. This study also represents vast heterogeneity in farming systems across Central, East, Southeast, and South Asia and the Pacific Islands. It highlights many other aspects of vulnerability to climate change across the region that includes undernourishment, poverty and slow productivity, all of which are aggravated by the effects of climate change

Aurbacher et.al, (2010) in their paper assess the impact of climate change on German agricultural districts. As per their findings, the world weather is changing, in comparison to historical trends, and that the upcoming years are expected to be harsher with more precipitation in winters and higher temperature in summers. The authors employed a Ricardian analysis for spatial autocorrelation in the data. The variables that were considered were land rental prices, mean temperature and precipitation rates. The cross-sectional analysis showed a significant correlation between land rents and increases in mean temperature except in the case of East Germany. The study concluded that the increase in temperature and precipitation rates accelerated land rental prices. People were moving to areas having more favorable weather conditions. This paper suggested different approaches to compare and consider farm soil qualities at district level. This paper also identified various farmers' adaptation strategies and the rental costs associated to land use.

Rukhsana et.al. (2009), presented a study on the district of Satkhira, a coastal zone in Bangladesh. The study aimed for a statistical analysis of the trends in climate change for the period from 1950 to 2006. The study focused on the impacts of climate change factors such as maximum and minimum temperature and annual total rainfall, on rice production. Using Global Climate Models (GCMs), the authors were able to predict future climate change scenarios. The study concluded that there was a statistically non-significant, increasing trend in rice production due to annual maximum temperature, minimum temperature and annual total rainfall.

Neil and Kulkarni (2007), work is based on a combination of case studies from different regions of the world. These studies have debated climate vulnerability to impacts from climate variation and change. The potential outcomes from exposure to climate hazards and climate change are identified as high-level concern in these studies. The potential hazards includes water scarcity that retards progress towards development goals, losses of entire ecosystems and their species, more frequent and greater loss of life in coastal zones, land degradation, food insecurity, famine, loss of livelihoods and increase in infectious disease epidemics. All of these are possible outcomes of exposure to climate hazards. It is a source of greater information by addressing climate change impacts on all fronts of life whether it is social, economic or political.

2.1.3 Climate Change Effects on World Agricultural Economy

The World Bank (2008) in one of its research papers, explains climate change impact in terms of agricultural GDP. It is estimated that if climate change persists at the current rate, the world agricultural economy fall by 10% of GDP. Countries, greatly affected by climate change are advised in this paper, to increase their involvement in international trade to prepare themselves for rainy days. Other economic measures proposed include climate change mitigation through flexible land use policies, subsidies expansion, and increase access to financial services such as credit and easy loans, improvement in market access, agricultural trainings and improvements in modes of irrigation.

Nyong, (2008) presented a paper for the International Centre for Trade and Sustainable Development (ICTSD). The author argued that climate change is one of the primary drivers behind globalization. It is achieved by affective agriculture yields worldwide, escalating comparative edges for certain markets. Due to climate change, countries with competitive advantages in certain commodities now find it difficult to maintain their position as before. This paper also points out the potential advantages and disadvantages of globalization in agricultural development, as effected by climate change. In order to achieve price stabilization and comparative advantage the paper suggested significant measures regarding climate change mitigation and agricultural practices.

Shand (2008), argues that GHG emissions, in terms of agricultural produce cannot be ignored. He says that instead of reducing agriculture trade, other measures should be taken to reduce greenhouse gas emissions. His paper advocates that, "*the drive to produce and eat local seasonal fruits and vegetables is neither practical nor realistic".* The paper points out the importance of agricultural trade for developing countries such as Kenya, which relies primarily on agricultural export. It is a mean of generating income and employment for most developing nations. He further says that climate change is already reducing agricultural production and trade should be not thwarted more. He argued that climate change copping measures should be shared with the developing nations to ensure the efficient use of worldwide land.

2.1.4 Mitigation and Adaptation Against climate change

Global climate change in not a new phenomenon, but still adaptation is the best strategy to cope with the situation. World Bank (2009) in one of its studies, tries to dig out the costs associated with climate impacts on agriculture. They have adopted a two way strategy to handle the situation i.e. *the Bottom up Approach and the Top down Approach*. The prime purpose of bottom up approach is to better understand the climate change situation at grass root level. According to the bottom-up approach data collection, risk analysis, costs estimates and adapting to the climate change situation at the country level is organized. The Top down approach addresses and handles the problem at the `Global` level. Based on the country level estimates, global climate adaptation costs are estimated.

The twin aims of the study are to identify the overall cost of adaptation. It can be achieved by identifying both micro and macro-level information of the rich and the poor country. Climate adaptation strategies and its implementation cannot be of universal nature, as each country has its own provisions and requirements. It should be region or environmental conditions specific.

World Bank (2010) in one of its books focuses on ecosystem-based approaches, to mitigate climate change impacts. The Bank argues that protecting land, freshwater and marine water ecosystems, for the sake of conserving terrestrial and aquatic life is the key abating issue against climate change. Not only will these ecosystems help in purifying dirty water, they can also act as carbon stores and sinks. Ecosystems such as mangroves, marshes, coral reefs and forests also help in reducing the intensity of extreme weather events such as floods and cyclones. The book strongly emphasizes the importance of natural ecosystems in the fight against climate change. It further strengthens the argument in facilitating, promoting and monitoring investments, and related programs in natural ecosystems to safe guard against future climate change.

Organization of Economic Cooperation and Development, OECD, (2002), explores different ways, in the research paper, by which greenhouse impacts can be moderated. Carbon dioxide and nitrogen sequestration can be reduced by a number of ways i.e. bio-fertilization, organic manure, crop rotation, decreased land tillage and improved irrigation methods. This report also draws attention towards the ruminant impact i.e. livestock (sheep, deer, cattle etc.) on greenhouse emissions. According to OECD estimates, 42% of greenhouse impact is related to the livestock. Mitigation Practices suggested by this paper includes feed diversifying measures for livestock such as increasing feed digestibility and feed efficiency by using diet additives and by diet manipulation. Furthermore the improvement in animal size also aid to animal productivity. Additional measures include the genetic transformation of livestock by giving them anti-methane vaccines to produce less methane. The report also suggested that genetically modified crops should also be produced to reduce greenhouse impact.

Asian Development Bank (2012), in one of its books examines the impact of the change in climatic conditions in Asia and Pacific. Developing countries, especially the Asian countries, are the ones that are hardly affected by climatic conditions. Various adaptive measures in agriculture, natural resources, water management activities and planning tools are suggested in this book to cope with the climate issue successfully. Climate adaptive measure in agriculture and other sectors includes early flood warning systems, soil erosion and deforestation prevention, financial reliefs in form of insurance or aid programs. This is in addition to public awareness campaigns. Various capacity building and risk reductions strategies are also proposed and recommended to countries having different climatic issues.

Santiago (2001) provides an outline of climate change adaptation issues, climate vulnerability literature and climate impact discussions on the agricultural sector. This paper covers assessments of climate vulnerability in various regions of the world and developing countries in particular. The paper discusses some of the existing resources that can be used to conduct climate vulnerability assessments and adaptation work.

The paper highlighted some of the major issues regarding climate change. Global climate change can be better understood by improving the data collection techniques on national level. It also further started, that agriculture adaptation must remain as top priority... Efforts must be done on grass root level to support the local community both technically and financially and help capacity building. The paper suggested that increase funding is the right strategy to all the above measures.

Danish Foreign Office (2008) authored a paper on climate change. The paper provided substantial facts on the main themes of climate change, issues regarding climate impacts and recommendations for a climate policy background process. The paper is dynamic in nature, as it explains outcomes of the climate change issue. This paper briefly highlights the impacts, adaptation and the potential response in agricultural land and water management processes. This paper suggested that climate change impacts on agriculture can be reduced by crop rotation, agroforestry, water harvesting, land conservation and the use of heat and drought resistance seeds. Moreover, climate resilience best practices and knowledge should be shared among countries to better cope with the climate changing situation. This paper also compiled and summarized the views and ideas that have emerged in the activities of Intergovernmental Panel on Climate Change (IPCC) and United Nation Framework Convention on Climate Change (UNFCCC).

2.2 PAKISTAN`S LITERATURE REVIEW

Maplecroft (2010), a British risk assessment consultancy, ranks countries by their expected climate vulnerability over the last next 30 years. Based on their ranking, the firm ranks Pakistan amongst the 20 most climate-vulnerable countries worldwide. Pakistan has seen severe droughts, most notably those in the 1990`s and the extreme floods of 2010, are the outcomes of climate change. Climate impact assessments done by various organizations and agencies to draw the concerned authorities' attention towards the issue. Some of the climate literature relating to Pakistan is briefed below:

International Union for Conservation of Nature (2011) has carried out a project to study the impact of climate change on the mountain areas of Pakistan. They selected Bagrote Valley in Gilgit-Baltistan area of Pakistan. The aim of the study was to carry out an analysis of the various factors including temperature, precipitation rate, fuel wood used, flowering timing, water resources i.e. melting water and glaciers, livestock, agricultural crops production and lifestyle of the people, that are influenced by climatic change. The response from community members clearly indicates that there is a perceived level of change in the climatic conditions in the form of decline in fresh water level, rise in precipitation rate and temperature increase. All these ultimately affect the flower blossoming and cropping patterns which in turn affect the wild life i.e. different species of birds and animals. The essence of this study was to suggest effective and productive ways of mitigation and adoption beside climate change impacts keeping in mind the experiences of local community.

Another case study of the International Union Council of Nature (2008), assesses the climate change impacts and the adaptive strategies on the Shigar valley of Gilgit-Baltistan in Pakistan. This study was a part of the project named, "Improving Livelihood in Shigar through Integrated Planning and Development of the Cultural, Natural and Built Environments". The economy of Shigar is primarily natural resource based and agro-pastoral in nature. It is affected by a range of environmental problems such as inefficient land use, insufficient clean water access, inadequate sanitation facilities and lack of solid waste management. The detailed analysis of the existing situation showed that climate change has impacted numerous factors such as temperature and rainfall, water resources (glaciers and melt water), agriculture(crops and cropping patterns), livestock, biodiversity and livelihood outlines (construction style, clothing, diseases) which are involved in the current socio economic situation of the valley. It was suggested to systematically assess the vulnerability situation, raise their awareness on climate change issues and build the capacity of the community to cope with the situation. Concluding the study the local population proposed three areas which needed adaptation and improvement, including forestation, education and agricultural support through technology and seed provision.

Pakistan Planning Commission (2008), in one of its reports, assessed the impact of climate change on Pakistan's water reservoirs, `Glaciers`, and its impact on agriculture. The main issues discussed in this paper were: climate change trends, water budget of glaciers, Indus river flow trends, and water laws, increasing water storage reservoirs, the use of isotope hydrology, water demand management, mass awareness campaigns, hydro-terrorism, and climate impact on microbiology, sea level and economy. The paper suggested improvements in water resource management, environmental impacts assessment, and last but not least, the formulation of mitigation and adaptation strategies in agriculture and glaciers of Pakistan. The paper also highlighted a few shortcomings on the issue, as the lack of mutual cooperation, relevant data accessibility and networking among the concerned organizations. It also stressed on the need of common data bank for future research and investigations on the current issue in Pakistan.

Pakistan`s economy as an agrarian country, is dependent on the agricultural produce and this sector is at stake by the vagaries of climate issues. International Union for Conversation of Nature (2009) carried out a study on climate change with the cooperation of the Government of Pakistan. This study mainly pointed out the issues and challenges that arise due to climate change on agricultural output. It highlighted that there would be reduced water availability which will in turn reduce the per hector production of crops. It is predicted by regional climate change model that the rise in temperature will decline the crop yield by 15-20% in the southern Pakistan whereas there will be a minor improvement in the yield in the northern area of Pakistan. Plant diseases, weeds and pests attacks will increase, resulting in decreased production. Livestock, forestry and fisheries industries were also predicted to see the downward trend. The overall impact of climate change on Pakistan economy will be negative.

Concluding the study, several coping mechanisms were suggested that can help Pakistan cope with the situation. It was advised that hi-tech meteorological services such as early warning system against floods, droughts, cyclones etc. should be installed. Organic livestock breeding and heat and drought resistant seed varieties must be introduced.

Farmer’s knowledge about the climate issues should be enhanced and the capacity building techniques explained. Green technology that is environmental friendly must be introduced in the farm field. Huge investment is also required in the forestry, agricultural and climate research and development fields.

A climate change impact assessment on Pakistan`s agriculture was carried out by Pervez et.al (2010). The objective of the study was to find out the impact of climate change on wheat crop, as it is one of the primary food crops in Pakistan. The analysis was done by adopting the vector auto regression (VAR) model. The study considered annual data from 1960-2009 and predicted the climate trends of wheat production for the period of 2010-2060.The study founded no significant increase or decrease in the wheat crop production. However, depending upon the changing climate, the crop production situation might get worse in near future. The study has also suggested crop adaptation and mitigation techniques for sustaining future climate variability.

Baig et.al, (2011) conducted a study on impact of climate change on wheat production in Punjab. The objective of the study is to find out the mean maximum temperature, mean minimum temperature and rainfall impact on wheat production. The study founded that adequate rainfall and the relative economic variables have a definite impact on wheat production in the mixed zone of Punjab province. The study results proved that climate change has measurable effects on wheat productivity at sowing, vegetation and maturity stages of wheat growth.

Ashfaq et.al (2011), in his report, points out impact of climate change on wheat crop in the mixed zones of Punjab. The prime objective of the study was to observe temperature and rainfall impact on wheat production at its various growth stages i.e. sowing, vegetation and maturity. A time series data for the period 1980-2009 was incorporated for this purpose. The analysis was done by ordinary least square technique. The study results showed that minimum temperature at sowing stage and maximum temperature at maturity stages have positive impact on wheat production whereas a rise in maximum temperature at vegetation stage put negative impact. Rainfall on the other hand puts positive impact on the wheat crop production i.e. increase in rainfall increase wheat crop production in the mixed zones of Punjab.

Rehana et.al (2012) has estimated the impact of climate change on the major agricultural crops i.e. wheat, cotton, rice and sugarcane in the Punjab region. The study is significant as it has considered the climate effect at four germination stages of crops. Time series data for the period 1980-2008 was used for the study. District-wise panel data analysis was done using fixed effect model. The study results showed that climate variables do put a positive impact on wheat crop production whereas in case of rice, cotton and sugarcane the study results are non-positive.

Shakoor et.al (2011) carried out a study assessing the climate impact on the agricultural farm revenues of Rawalpindi division of Punjab. Cross sectional and time series data was analyzed by the use of Ricardian model (Mendelson et.al. 1992). The crop selected for study was wheat, as it is found abundant in Punjab. The study results showed that climate variables do effect the crop revenues. The rise in temperature showed a negative and rise in rainfall has depicted a non-negative impact on agricultural revenues.

Ahmad, (2013) in his book has pointed out the impacts of climate change on farmer's income in Pakistan. His prime emphasis was modification in the adaptation and mitigation techniques to deal with the changing climate situation. Hedonic price model and reveled preference approach were the basic tools of analysis for the study. The study finding depicts an affirmative climate change impact on Pakistan`s agricultural sector. This study suggested adaptation and mitigation as the first and foremost solution to the inconvenient fact of climate deviation. Secondly, moving away from traditional crops such as wheat, cotton, sugarcane to the non-traditional one as rice, maize and vegetables would be a better option for the income and prosperity of farmers.

A research study assessing the impact of climate change on agriculture, was recently carried by Zeb et.al (2013) in Khyber Pakhtunkhwa (KP). The study was conducted in Nari Panos Bala which is situated in the district Karak of Khyber Pakhtunkhwa. The study adopted primary data collection method through questioners and focus group discussions. The study finding showed that climate change has a negative impact on land efficiency, water scarcity and ultimately agricultural productivity of KP. However, the study recommended the use of modern technological equipment i.e. fertilizers, pesticides, insecticides and machinery could be the solution to the problem. Water scarcity issue can be resolved through the construction of small dams, waterways and tube wells.

2.3 SUMMARY

The review of the above literature shows that a subsistent amount of literature is available on the climate change issue. The question then arises as to why there is a need to conduct another climate impact study. If closely observed, the above studies, in most cases, were contributed by the international community and international experts. There are only a few studies done by Pakistan`s environmental economists i.e. IUCN (2008, 2009, 2011), Pakistan Planning Commission (2008), Beig (2011), Ashfaq (2011), Rehana (2012)), to access the impact of climate change on the economic development and prosperity of the country. Narrowing it down further, the literature available on climate impact assessment of Khyber Pakhtunkhawa is rare. The other short coming of the studies is that most of them have taken the agricultural land price value for assessing the impact by the climate variables, ignoring the direct impact assessment of climate variables on agricultural production. Moreover, most of the analysis has been done on the agricultural sector in Punjab overlooking the climate impact on the other zones of the country. This research work is a unique attempt to address the climate issue and problems faced by Khyber Pakhtunkhwa`s agricultural economy and find necessary solutions to it. A need therefore arises to closely observe the environment, access the climate trends, its impacts on agriculture and recommend necessary mitigation and adaptation measures.

This research work is one of its kinds as it have estimated the impact of climate change on two seasonal crops i.e. Kharif and Rabi production, at different climate varying zones of Khyber Pakhtunkhwa (KP). The climate of KP is versatile in nature, and ranges from the hottest areas in south to the coldest regions in the north. This study may be used as a standard to envisage its findings to the similar climate zones in Pakistan.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

Research Techniques and methods are the instruments employed in the analysis and investigation of various issues. There are four approaches commonly used in assessing the climate impact on agricultural production i.e. Crop simulation models (Pervaiz, 2010), Agro economic zone Models (AEZ) (Pretty, 2006), General regression models (Baig, 2010) and Ricardian models (Uzma, 2010 & Agha, 2010).

Crop simulation models and Agro economic zone models are frequently used to estimate the climate impact on agricultural produce without taking into consideration the economic factors as human capital, employment, GDP etc. (Pervaiz, 2010 & Pretty, 2006). Moreover, these approaches are mostly used by the environmentalists to assess climate impact. The other approach is the Ricardian model, used by Uzma, 2010 and Agha, 2010. The pitfall of Ricardian approach (Mendelson. et.al, 1992) is that it explores the climate relationship with agricultural land value at a specific place and specific time. Additionally, land prices are effected by non-climate variables as agricultural subsidies to specific area, accessibility to market, water availability etc. This approach ignores the direct impact of climate variables as temperature and rainfall on farm yield. Further, it is the technique used in identifying the modes of adaptation and mitigation by farmers in dealing with climate change. The only approach left, is the general linear regression model (Lin et.al, 2011), using linear regression method. The advantage of this approach over the others is that it explores the direct impact of agricultural output with climate variables. This research study is adopting the general linear regression model (Lin et.al, 2011), for the evaluation of the crop productivity. It is estimated by the panel data regression technique. The model developed in this research is used to project climate impacts on crop productivity.

3.2 METHODOLOGY

Various analytical methods, statistical techniques, econometric models, mathematical formulas and investigative procedures are employed in this research study. This section explains in full detail the inspective techniques engaged for achieving the objectives of the study. The climatic variations in KP different ecological regions, is captured by trend analysis technique. For this purpose KP is divided into three ecological regions. In order to evaluate the climate change impact on agricultural produce, the two season crops i.e. Kharif and Rabi, are selected from each ecological region of KP. Panel data regression analysis is performed by shuffling the data in different ways to achieve different research objectives. Region-wise climate impact assessment on crop productivity is performed by paneling the rabi and kharif data sets of each region individually. Furthermore, overall Khyber Pakhtunkhwa crop-wise productivity analysis is also carried out by paneling all the three regions Rabi crop and all the three regions Kharif crop data separately. Following are given the details of the two types of analysis:

i. The Environmental Trend analysis

ii. The Economic Panel Data Regression Analysis

3.2.1 Environmental Trend Analysis

The trend analysis is performed for estimating the climate change trends in the Khyber Pakhtunkhwa province. This is the technique mostly used by meteorologist (Malla.2008) in assessing the impact of climate change. The uniqueness of this research work is the use of trend analysis in the climate change assessment study. The aim of the trend analysis is to compare the climate variables variability over various regions in the two cropping seasons i.e. kharif and Rabi. The environmental trend analysis is worked out with the individual climate variable at specific cropping season. Below is given the detail of the trend analysis:

(i) Rainfall Trend Analysis

The rainfall climate trends for the three regions and the overall Khyber Pakhtunkhwa are estimated and then compared in this analysis. The rainfall trend is further divided according to the cropping season i.e. Kharif rainfall trend and rabi rainfall trend. The trend values are obtained by taking the average rainfall values of the selected cropping season months. Microsoft excel software is used for sketching the trend lines.

(ii). Maximum Temperature Trend Analysis

The maximum temperature trends for the three regions and the overall Khyber Pakhtunkhwa are compared in this analysis. The maximum temperature trend is further divided according to the cropping season i.e. Kharif maximum temperature trend and rabi maximum temperature trend. The trend values are obtained by taking the average maximum temperature values of the selected crop development months. Microsoft excel software is used for sketching the trend lines.

(iii). Minimum Temperature Trend Analysis

The minimum temperature trends for the three regions and the overall Khyber Pakhtunkhwa are compared in this analysis. The minimum temperature trend is further divided according to the cropping season i.e. Kharif minimum temperature trend and rabi minimum temperature trend. The trend values are obtained by taking the average minimum temperature values of the selected crop development months. Microsoft excel software is used for sketching the trend lines.

(iv). Mean Temperature Trend Analysis

The mean temperature trends for the three regions and the overall Khyber Pakhtunkhwa are compared in this analysis. The mean temperature trend is further divided according to the cropping season i.e. Kharif mean temperature trend and rabi mean temperature trend. The mean temperature values are obtained by taking the average of maximum temperature and minimum temperature of the selected crop development months. The purpose of mean temperature trend analysis is to see temperature variation over the selected period. Microsoft excel software is used for sketching the trend lines.

3.2.2 The Economic Regression Analysis

The second type analysis i.e. economic regression analysis is performed in this section. Keeping in mind the research techniques used by various econometricians, the strategy adopted for analysis in this research work is based on the General linear regression model as exercised by Lin et al. (2011). The data is initially checked for stationarity and non-stationarity. The data used in this analysis is stationary in nature. After clearing it with stationarity the selection of climate variables forms in the model is made. Different climate variable options, such as co-integrated, squared, cubic variables, maximum, minimum temperature, there difference, were engaged to check the nature of relationship with agricultural productivity. At last, the variables i.e. mean temperature, rainfall and square of rainfall, are selected in the model. The selection of variables is made by the Ordinary least square technique and then filtering it by Variance Inflation Factor (VIF) method to rule out the existence of multicollinearity. All this analysis is performed by the help of statistical software STATA. Time series panel data is regressed by ordinary least square (OLS) analysis. The data is paneled according to nature of analysis. The selection between fixed effect or random effect model, to get consistent estimates, is done by the Hausman Specification Test. The regression function adopted and the variables used are given below.

The general form of the model used in this research analysis is given by;

Crop`s Productivity = f {Area sown, Climate variables, Climate variables squares}

In equation form;

$$P = f\ (A\ T_m\ N\ N^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation.1}$$

$$P = \beta 0 + \beta 1\ A + \beta 2 Tm + \beta 3\ N + \beta 4\ N^2 + \mu \ldots\ldots\ldots\ldots \text{Equation.2}$$

P = Crop`s productivity in Thousand Tones (Rabi & Kharif Output.

Wheat is taken as Rabi crop and Maize as Kharif Crop)

A = Area sown in thousand Hectors (under Rabi and Kharif crops)

Tm = Mean Temperature on degree Centigrade, of the crop development months

N = Rainfall in millimeters, of the crop development months

N^2 = Square of rainfall in millimeters square, of the crop development months.

μ = Residual or Error term (It engulfs the other factors impact on the model)

β0 = The intercept term

βi`s = The variables respective co-efficient

The above equation shows that crop productivity is a function of area cultivated, mean temperature, rainfall and rainfall square. The crop productivity and area statistics are specific for a specific cropping season. The climate variables including the rainfall and the mean temperature include the averages of the specific crop cropping months climate variables. Mean temperature is obtained by taking the mean of maximum and minimum temperature of the specific cropping season. The square of mean temperature is ruled out due to the presence of high multicollinearity with the mean temperature. The basic model is used to estimate the crop`s productivity due to climate. Two types of analysis is performed in the study i.e. Region-wise analysis and Season-wise analysis.

(i) Region-wise Analysis

In region-wise analysis, three regressions are run on the separate regions i.e. northern, central and southern of KP. Here the data have two panels i.e. one for each cropping season i.e. Kharif and Rabi. Each panel have 30 rows i.e. 60 in total. The results of this analysis shows the dependence of crop productivity on the climate factors of temperature and rainfall in specific region. In other words, to observe climate impact at different climate regions of KP. The general form of the regression models are given below.

i. Crops productivity in the Northern Region of KP

Northern Region Crop productivity = f {Area sown, Climate variables, Climate variables squares}

ii. Crops productivity in the Central Region of KP

Central Region Crop productivity = f {Area sown, Climate variables, Climate variables squares}

iii. Crops productivity output in the Southern Region of KP

Southern Region Crop productivity = f {Area sown, Climate variables, Climate variables squares}

(ii) Season-wise Analysis

In season-wise analysis, two regressions are run representing the two cropping seasons i.e. kharif and rabi of KP. Here the each data set has three panels i.e. northern, central and southern region. Each panel have 30 rows i.e. 90 in total. The purpose of season-wise analysis is to see the climate factors impact on the seasonal crop productivity of KP. The general form of the models used are given below.

i. Rabi (Wheat) productivity at province Level i.e. Khyber Pakhtunkhawa (KP)

Rabi Crop productivity = f {Area sown, Climate variables, Climate variables squares}

ii.Kharif (Maize) productivity at province Level i.e. Khyber Pakhtunkhawa (KP)

Kharif Crop productivity = f {Area sown, Climate variables, Climate variables squares}

3.3 SUMMARY

It is concluded from the above methodology that climate change is a vast phenomenon tricky to measure accurately and challenging to predict precisely. This is the major reason of undertaking two types of analysis i.e. environmental trend as well as economic regression analysis. The purpose of environmental trend analysis at different regions of Khyber Pakhtunkhwa is to get a clear picture of the change in the weather conditions over the thirty years span. Weather analysis gives the way forward to the crop productivity analysis as impacted by the climate variables. The crop productivity analysis as well as the environmental trend analysis helps in accessing the specific climate variable effecting specific crop at specific region of the KP.

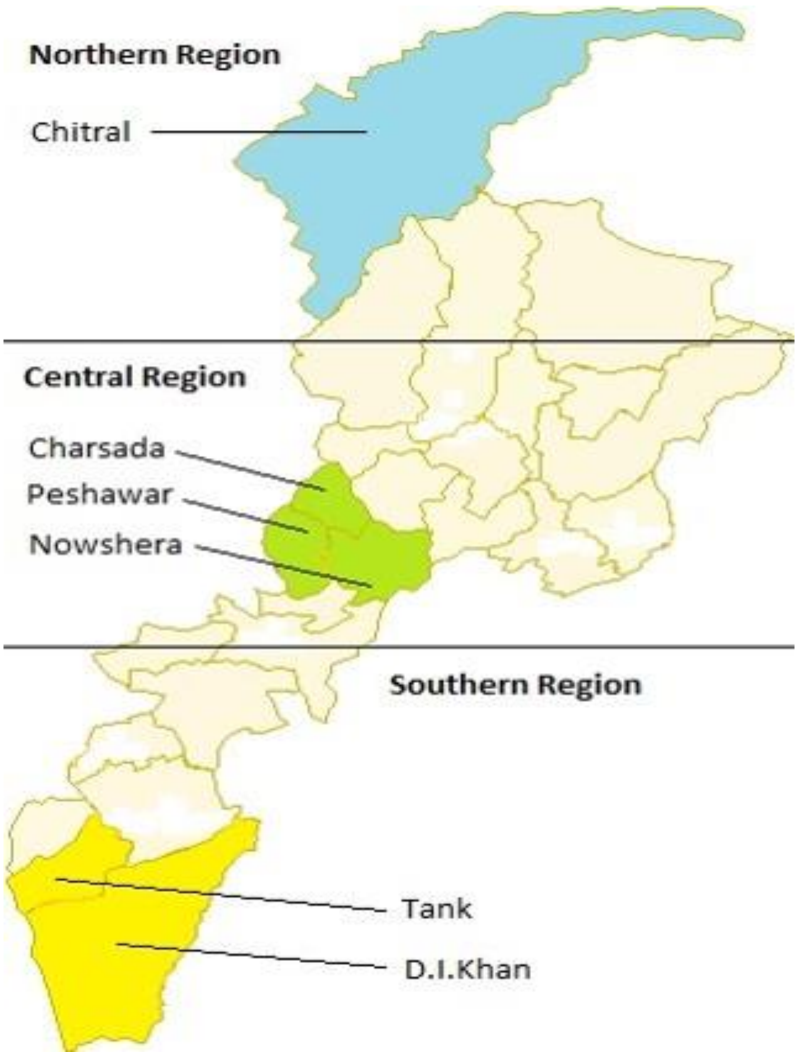
CHAPTER 4

DATA AND VARIABLES

4.1 STUDY AREA

Pakistan`s province, Khyber Pakhtunkhwa (KP), previously called North West Frontier Province (NWFP), is the focal point in this study. It is among the regions in Pakistan effected by the extreme environmental events. The province has an area of 74,521 km^2. Selection of Khyber Pakhtunkhwa (KP) province is subject to versatility in its weather due to the unique topography. Its climate ranges from the hottest and dry rocky areas in south to the colder and lush green forests and plains in the north. Its agriculture is mostly dependent on rain as the province 55% of agricultural land is rain-fed. (Agricultural Statistics. 2010). It has twenty five (25) districts in total. KP can be divided into three regions according to their climatic variability as the southern, the central and the northern regions. The three climate regions i.e. Northern is represented by Chitral district, Central by Nowshera , Charsada and Peshawar districts and Southern region by Dera Ismail Khan and Tank Districts. The following figure-6 will help in getting a clear picture of the three KP regions.

Figure 6: Khyber Pakhtunkhwa Three Climatic Regions



Sources: Pakhtoon.com.

The data used is secondary in nature, mostly obtained from the government departments. The study incorporates two sets of data. One is the climate data set and the other is the agricultural data set. The climate data set includes, maximum temperature, minimum temperature and rainfall data of the selected districts for the last thirty years. The temperature data is measured in °C and rainfall in millimeters. The agricultural data set includes, area in thousand hector and the crop productivity in thousand tones for the thirty year period i.e. 1980-81 to 2009-10. The crop productivity statistics includes two seasoned crop data i.e. kharif and rabi. Kharif crop is represented by maize and rabi crop by wheat production. The crop selection made is due to the availability of crop production statistics along with the area statistics for the specific crop from the thirty year period.

There are a number of other climate variables to be included in the model such as the daily sunshine, carbon dioxide concentration and humidity in atmosphere. Similarly, the agricultural data as the water availability, mode of irrigation, irrigated and unirrigated land, use of fertilizers, pesticides, types of seed any many more can be used. These variables can be incorporated in the model to get effective and efficient estimates. The problem arises in the attainment and the non-existence of thirty years data for these variables.

A brief data description of the three regions included in the analysis is explained below:

4.1.1 The Northern Region

The northern, colder region of Khyber Pakhtunkhwa have various districts. The study includes Chitral district as representative of KP northern region. The selection of chitral district is subject to the availability of secondary data for analysis i.e. climate and agricultural data. Its weather station was established in 1960`s (Director Provincial Meteorology, 2012). The secondary climate data of all the three variables i.e. maximum monthly temperature, minimum monthly temperature and average rainfall for thirty years, i.e. 1980-2010 is obtained from Pakistan meteorological department. Moreover, the data on rabi and kharif crop production and their respective area cultivated is obtained from the Federal bureau of Statistics and the Provincial Agricultural Statistics Department.

4.1.2 The Central Region

The Central, moderate region of Khyber Pakhtunkhwa is represented by Peshawar, Nowshera and Charsada districts. The selection of three districts are based on the change in the district Peshawar boundaries from 1980 till 2010. The previous Peshawar district is divided into these three different districts. The three districts fall in the central region of KP.

Climate and weather is not restricted by man-made boundaries. That is why, the climate data of district Peshawar is taken, as it is the only district having data record for the last 30 years i.e. 1980-2010. Its weather station was established in 1960`s (Director Provincial Meteorology.2012). The climate data of all the three variables i.e. maximum monthly temperature, minimum monthly temperature and average rainfall is obtained from the Pakistan meteorological department. The secondary data of Rabi and Kharif crops production and area of specific crop is obtained from the Federal Bureau of Statistics and the Provincial Agricultural Statistics Department.

4.1.3 The Southern Region

The Southern: Hottest region of Khyber Pakhtunkhwa is represented by Dera Ismail Khan (D.I. Khan) and Tank districts. The selection of these districts is subject to the fact that these are among the hottest regions in South Asia with the temperature as high as 50°C (Agricultural Statistics, 2010). Moreover, D.I .Khan district boundaries have been amended recently. Considering the period of 1980-2010 and constant area assumption of model, district Tank is added along with Dera Ismail Khan (D.I.Khan) district. The two districts fall in the same southern region of KP.

D.I.Khan district weather station is one of the oldest weather stations established in 1960`s (Director Provincial Meteorology.2012). Secondary climate data for all the three variables i.e. maximum monthly temperature, minimum monthly temperature and average rainfall for the period, i.e. 1980-2010 is obtained from the Pakistan meteorological department. The secondary data of Rabi and Kharif crop is also obtained from the Federal bureau of Statistics and the Provincial Agricultural Statistics Department.

4.2 Variables and their Values

The values of the variables selected and estimated in the study analysis are explained in this section. The area and crop productivity variable are specific for specific crop. The climate variables values are in accordance to the two season crop calendar. The details of the crop calendar is given below.

4.2.1 Crop Calendar

Kharif crop is usually sown and harvested in the summer season whereas Rabi crop is the winter season crop. The plant development months of the two season crops are highlighted in the table below. The crop calendar of Kharif Maize and Rabi Wheat is given as:

Table 2: Kharif Maize and Rabi Wheat Calendar

Months	Jan.	Feb.	Mar.	Apr.	May	June	July	Aus.	Sep.	Oct.	Nov.	Dec.
Kharif (Maize)												
Rabi (Wheat)												

Sources: Department of Agricultural Statistics Khyber Pakhtunkhwa

As seen in the above table-2 Kharif (maize) crop production months in Khyber Pakhtunkhwa are in the range of July to September. It means that KP maize crop is mostly cultivated in start of July and harvested in the end September or October start. The plant takes almost three months to grow and produce to its full potency. In order to analyze Kharif crop production, climate variables i.e. maximum temperature, minimum temperature, mean temperature and rainfall, of the displayed months are taken. Mean temperature is obtained by taking the average of maximum and minimum temperatures of the highlighted months.

Rabi (Wheat) crop production in Khyber Pakhtunkhwa is in range of November to April i.e. almost six months. Wheat cultivation generally starts in November and harvested in end April or start of May month. Its cropping cycle is extended over six months i.e. from cultivation to harvesting. The climate variables i.e. maximum temperature, minimum temperature, mean temperature and rainfall, of the Rabi crop months are engaged according to its highlighted calendar.

CHAPTER 5

RESULTS & DISCUSSION

Khyber Pakhtunkhwa (KP) is among the regions, affected adversely by the impacts of climate change. In this chapter attempt is made to analyze the overall impact of climate change over the last thirty years on agricultural crop production. This analysis is divided into two categories i.e.

1. The Environmental Trend Analysis
2. The Economic Regression Analysis

5.1 Environmental Trend Analysis

Trend analysis is a technique mostly employed by the environmentalist to check the weather trends of a specific region. The purpose of this analysis is to check whether over the last 30 decades there is a climate variability in Khyber Pakhtunkhwa. Moreover, this analysis helps in the observation of climate variation at different regions of the province i.e. taking the simple values of KP and investigating the climate analysis will leads to an inaccurate study findings.

The climate change trends of the two cropping seasons of KP is observed by taking the climate variables of rainfall, maximum temperature, minimum temperature and mean temperature. It is then further compared with the three sub-regions i.e. northern, central and southern regions of KP. The subdivisions of the trend analysis are as under;

i. Rainfall Trend

ii. Maximum Temperature Trend

iii. Minimum Temperature Trend

iv. Mean Temperature Trend

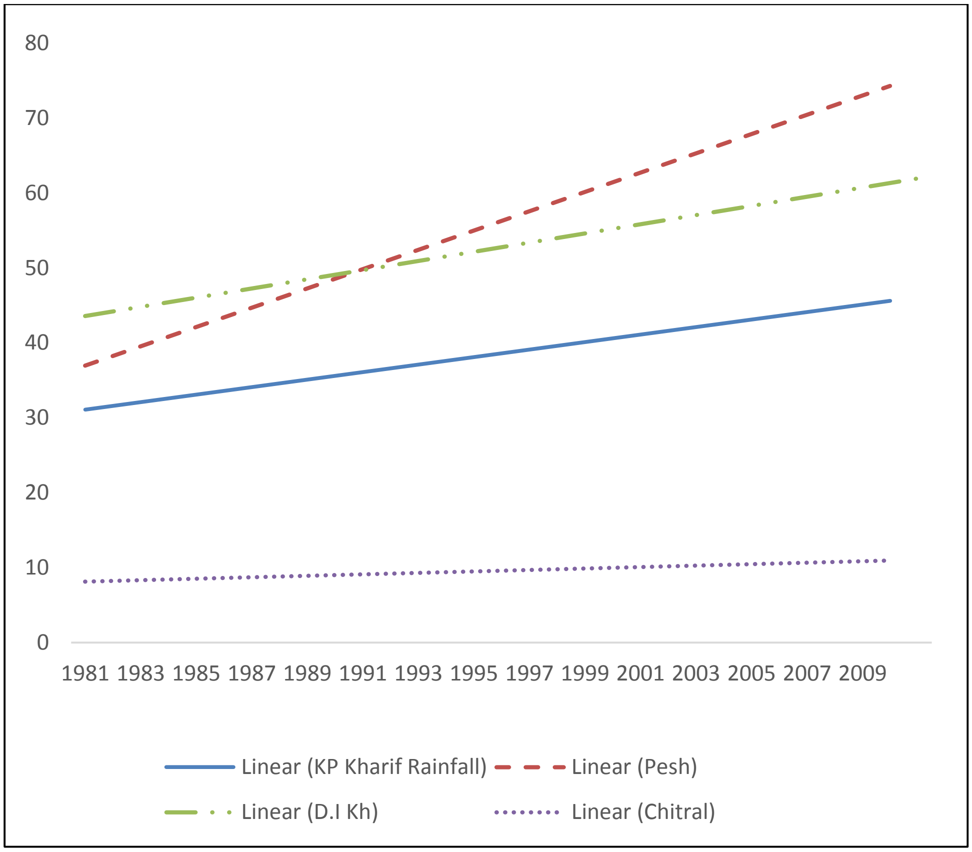
5.1.1. Rainfall Trend Analysis

The first part of the environmental trend analysis is comprised of the rainfall analysis. This analysis has further been divided seasonally as the kharif and rabi rainfall trends of the province. Below is given the detailed analysis of each cropping season trend.

(i) Kharif Rainfall Trend

Kharif Rainfall trend analysis is done by taking the average rainfall values of the kharif season i.e. July, August and September, on Y-axis against the time period on X-axis. Below figure shows four trend lines. The solid line is giving the KP rainfall trend. This shows an increasing trend of rainfall over the thirty year period. The trend analysis shows the increase in overall KP kharif rainfall is up to 11mm. The small dotted line is showing northern zone kharif rainfall trend. There is a slight increase in the rainfall pattern over the thirty year period. This analysis demonstrates an increase in 4mm of rainfall. Similarly, the dashed line in the below figure is depicting the kharif rainfall trend of central region. As seen in the figure 7, a steep rise is observed in the rainfall over the analysis period. This rise is equivalent to 38mm of rain approximately. Similarly, the southern kharif rainfall trend is seen by a dash and dot line. This is also depicting the increased rainfall trend up to 19mm.

Figure 7: Kharif Rainfall Trend

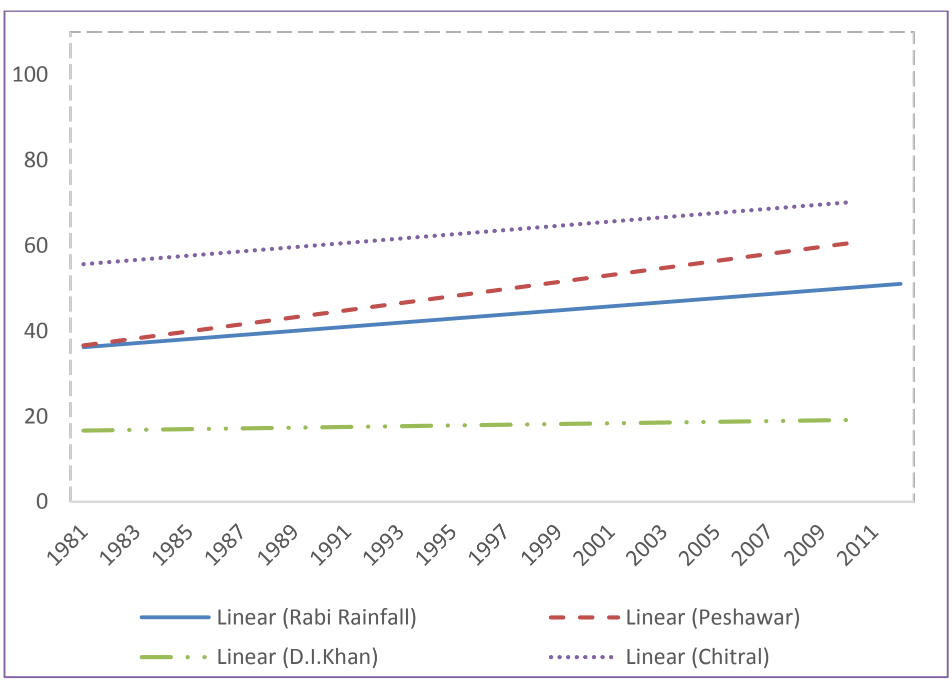


All this analysis shows that kharif rainfall has been increased over the thirty year period and much of this increase is observed in the central KP. This clearly explains the untimely rains and flood events in the central part of the province.

(ii) Rabi Rainfall Trend

Rabi rainfall trend analysis is done by taking the average rainfall of the rabi season i.e. November, December, January, February march and April. It is then plotted against the time values i.e. years. The figure 8 below is showing the four trend lines. Just like the previous graph, KP trend analysis is shown by the solid trend line, the northern region by dotted line, central region by dashed trend line and southern region by dash-dotted line. For instance the figure depicts an increase in rabi rainfall trend over the period in the whole province. A greater increased trend is seen in the central region of the province i.e. approximately equivalent to 25mm. The northern region and overall KP is showing and increase in rainfall trend of 15mm each, whereas the southern trend line is almost constant at 3mm, with no marked increase.

Figure 8: Rabi Rainfall Trend



5.1.2. Maximum Temperature Trends

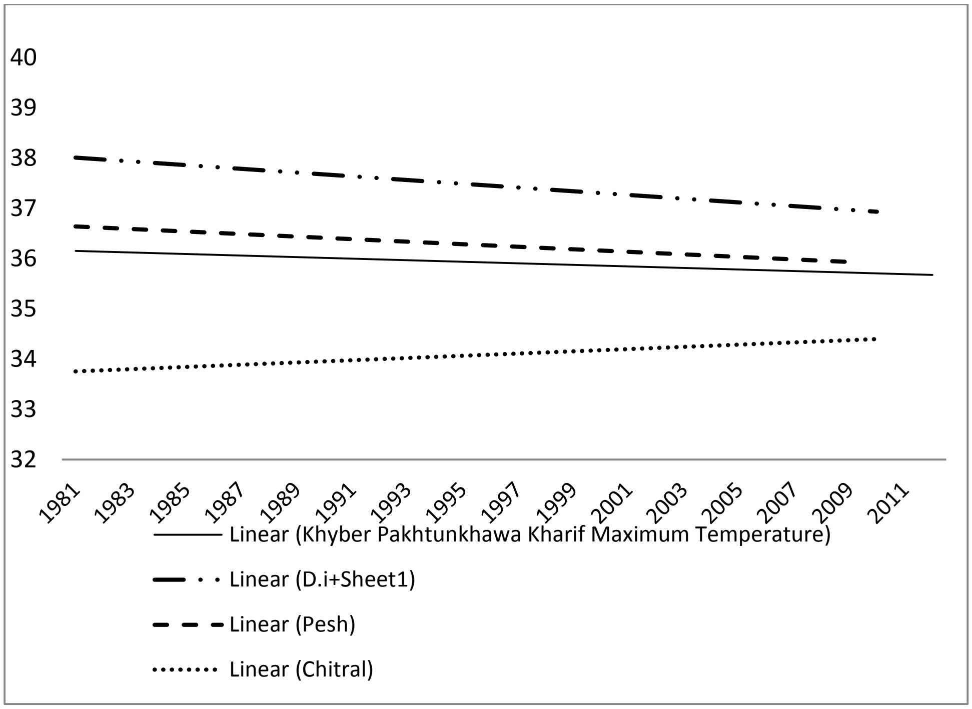
The second part of the trend analysis constitutes the maximum temperature analysis. This analysis has further been divided into the kharif and rabi cropping seasons. Below is the brief explanation of the trend analysis.

(i) Kharif Maximum Temperature Trend

Kharif maximum temperature values is obtained by taking the average of the kharif cropping months maximum temperature values. It is plotted year-wisely to plot its trend line for the thirty year period. The figure 10 below explains the situation. There are four trend lines in the figure. Similar to the rainfall analysis the trend line for the overall KP, the northern KP, the Central KP and the southern KP is plotted by a solid, dotted, dashed and dash-dotted lines.

Figure 9 of the kharif maximum temperature analysis shows a mixed result. The two KP regions i.e. the central and the southern region is showing a decreasing trend. Whereas, the northern region of the province is depicting an increasing trend of 0.7 °C in the kharif cropping month. The increased maximum temperature is seen in the form of melting glaciers and increased runoffs on one hand and on the other hand increased the agricultural productivity at the northern part.

Figure 9: Kharif Maximum Temperature Trend

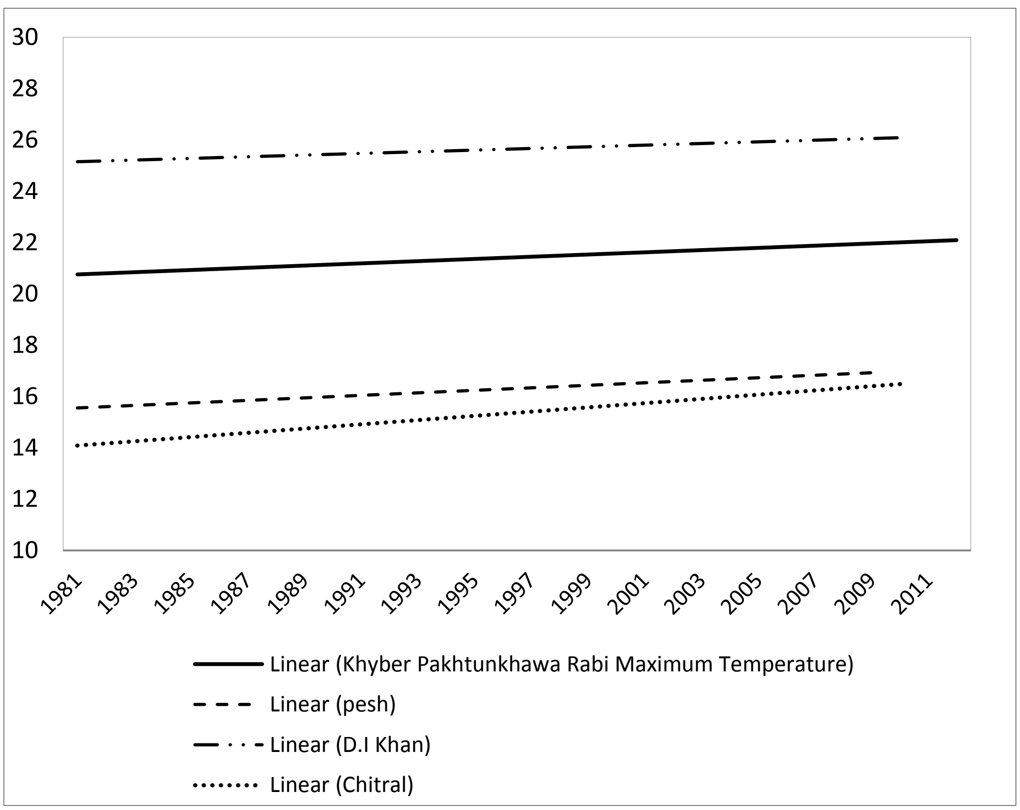


Similarly the decreased maximum temperature trend of 0.6 °C, 1.3 °C and 0.6 °C at the central, southern and in the overall KP is respectively observed. Along with the other factors effecting crop output, this can also be attributed to the low crop productivity i.e. by immature kharif crops. This also explains the shifting in the kharif crop sowing and harvesting timing.

(ii) Rabi Maximum Temperature Trend

Rabi maximum temperature trend is obtained by taking the average maximum temperature of the rabi season of the concerned region. The figure 10 portrays an increased maximum temperature trend in the rabi season in the whole province over the thirty year period. The trend line for the overall KP, the northern KP, the Central KP and the southern KP is plotted by a solid, dotted, dashed and dash-dotted lines.

Figure 10: Rabi Maximum Temperature Trend



The three trend lines of Overall KP, the central region and the southern region shows an almost same degree increase. Moreover in mathematical terms KP increase trend is 1°C, central region as 1.3 °C and southern region shows 0.7°C increase. For instance, the northern region shows and increased maximum temperature of about 2.5 °C. The increased maximum temperature explains the short crop cycle, malnutrition and small sized crop grains in the central and southern part of the province. In case of northern region, it is putting favorable impacts in terms of crop productivity at the northern regions whereas the alarming fact of 2.5 °C increase in rabi maximum temperature is acceleration in the glaciers melting process.

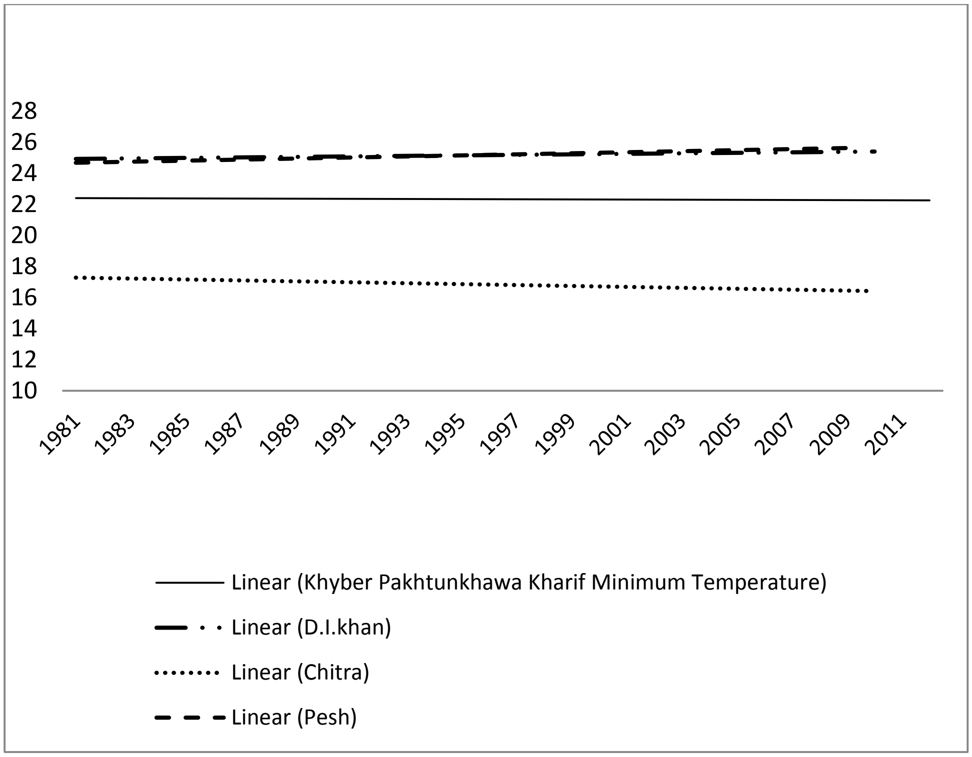
5.1.3. Minimum Temperature Trend

This section constitutes the minimum temperature trends of various Khyber Pakhtunkhwa regions in there kharif and rabi cropping seasons.

(i) Kharif Minimum Temperature Trend

Kharif minimum temperature trend is obtained by taking the average minimum temperature of the kharif cropping months of different regions separately. Figure 11 below shows the minimum temperature trend of different regions and the overall KP. The trend line for the overall KP, the northern KP, the central KP and the southern KP is plotted by a solid, dotted, dashed and dash-dotted lines.

Figure 11: Kharif Minimum Temperature Trend

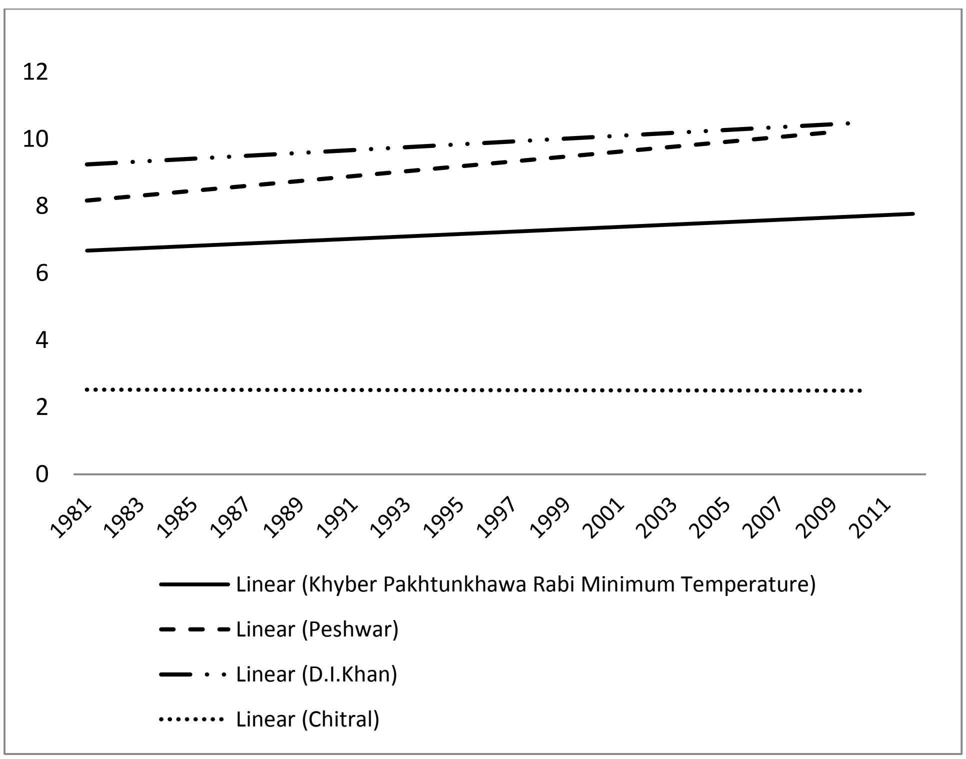


The figure 12 above shows two overlapping lines, these are the central and southern region trends. It is showing an increase of 0.7 and 0.8 degree centigrade in minimum temperature of central and southern region respectively. In case of northern region the minimum temperature has shown a decreasing trend of 1.3 °C. The decreased minimum temperature is a negative sign for crop productivity. The overall KP kharif minimum temperature is showing a slight increase of 0.2 °C.

(ii) Rabi Minimum Temperature Trend

Rabi minimum temperature trend is shown in figure 12. The trend values are obtained by taking the average minimum temperature of the different regions at the rabi cropping months. Below figure shows four trend lines. The dotted line depicts the northern region trend, the dashed line shows the central region, the dash-dotted line explains the southern region and the solid line shows the overall KP rabi minimum temperature trend. The figure show an overall increase in the rabi minimum temperature trend.

Figure 12: Rabi Minimum Temperature Trend



The overall KP kharif minimum temperature is showing a marked increase of 2 °C in minimum temperature. The central and southern minimum temperature is also showing a 1.2 °C and 1.6 °C respective increase. The minimum temperature increase is among the reasons of short crop cycles. In case of northern region no change has been observed in the minimum temperature of rabi cropping season.

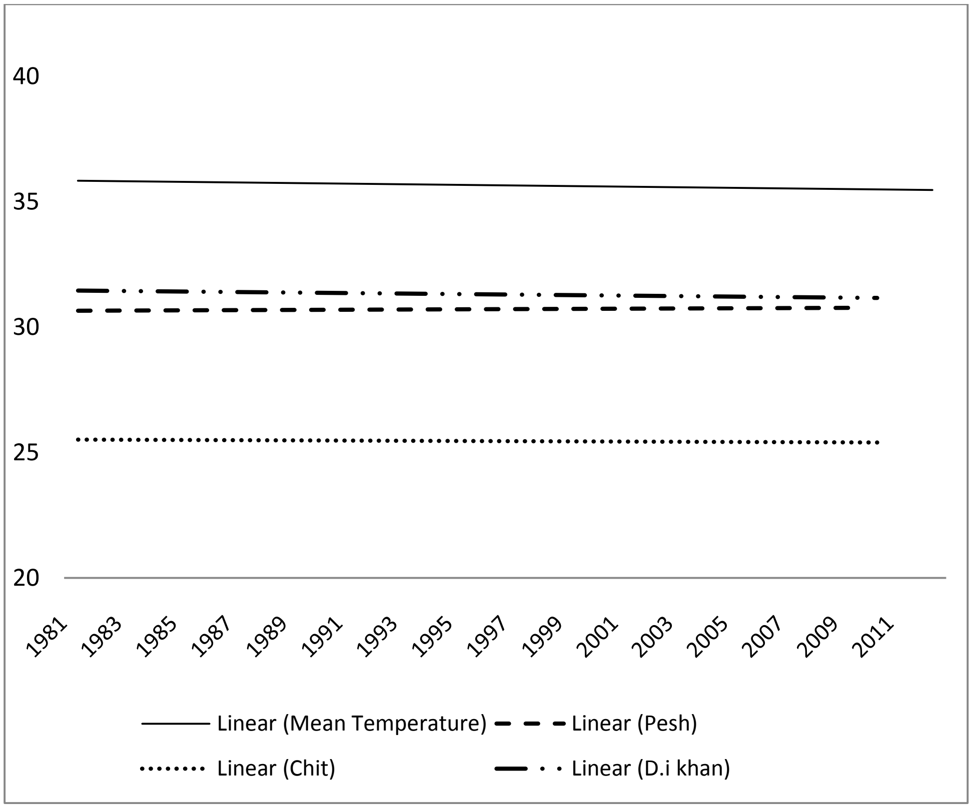
5.1.4 Mean Temperature Trend

The fourth and last part of the analysis comprises of the mean temperature trend. The mean temperature values are obtained by taking the average of the maximum and minimum temperature of different KP regions. It is analyzed according to their respective cropping season. Below is the details of the analysis.

(i) Kharif Mean Temperature Trend

Kharif mean temperature trend values are obtained by taking the average of kharif month's minimum and maximum temperature. Kharif mean temperature trend is shown in figure 13 below. A decreased trend is observed in the overall kharif mean temperature. The northern, southern and overall KP trend line shows a decreasing trend of 0.3 °C. These lines are represented by the dotted, dash-dotted and the solid lines respectively. The dashed line representing central region is depicting no change in the kharif mean temperature.

Figure 13: Kharif Mean Temperature Trend

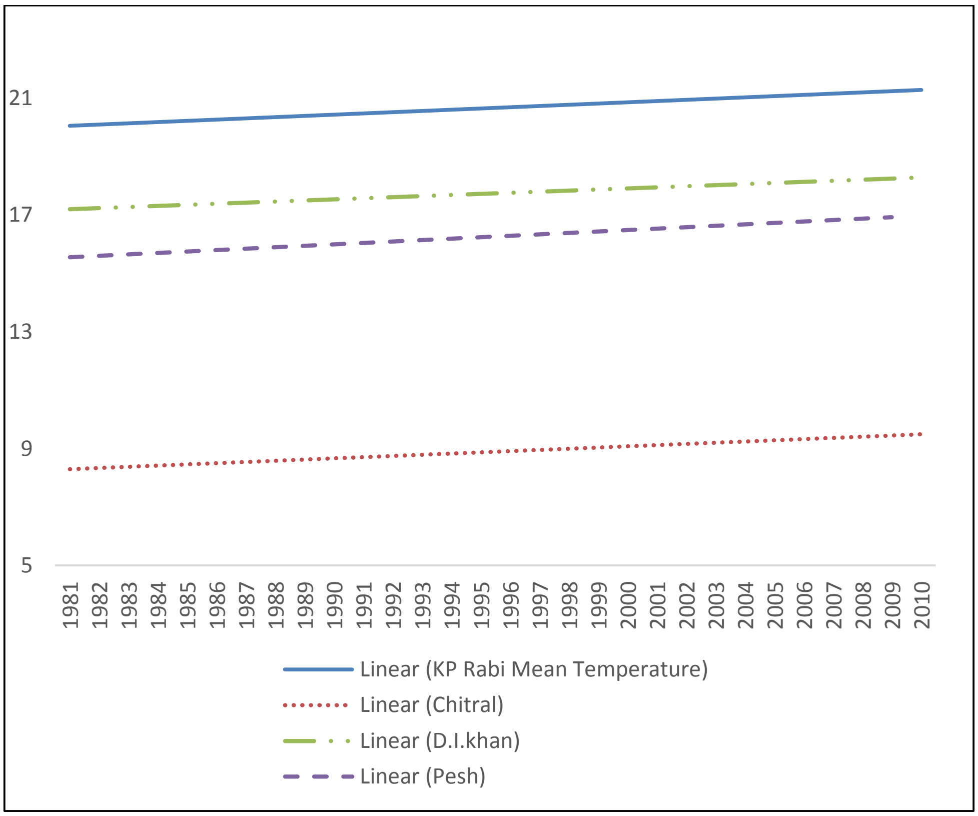


(ii) Rabi Mean Temperature Trend

Rabi mean temperature values are obtained by taking the average of the rabi maximum and minimum temperature. Figure 14 of the trend analysis is portraying the variation in the mean temperature of various KP regions. The increased trend values are obvious from the figure below.

The detailed calculation of the trend analysis shows that the northern region trend line, as seen by dotted line, is showing an increased trend of 1 °C. The central region trend line i.e. the dashed line, is showing and increased trend of 1.2 °C. The southern region trend line i.e. the dash-dotted line, is also showing and increased trend of 1.1 °C. Moreover, the overall trend line of KP, as depicted by solid line, is showing an increase of 1.2 °C.

Figure 14: Rabi Mean Temperature Trend



5.1.5 Summary

Summarizing the whole trend analysis concludes that climate change in KP has been perceived in the form of increased rainfalls and increased mean temperature. The trend analysis results are shown in table 3 below.

Table.3: Tabulated Thirty years Cropping Season Trend Analysis

	Kharif	Season	Trend		Rabi	Season	Trend	
	Rainfall	Maximum Temperature	Minimum Temperature	Mean Temperature	Rainfall	Maximum Temperature	Minimum Temperature	Mean Temperature
Southern Region	19mm↑	1.3°C↓	0.8°C↑	0.3 °C↓	3mm↑	0.7°C↑	1.6°C↑	1.1°C↑
Central Region	38mm↑	0.6°C↓	0.7°C↑	0.3 °C↑	25mm↑	1.3°C↑	1.2°C↑	1.2°C ↑
Northern Region	4mm↑	0.7°C↑	1.3°C↓	No Change	15mm↑	2.5°C↑	No Change	1°C ↑
KP	11mm↑	0.6°C↓	0.2°C↑	0.3 °C↓	15mm↑	1°C↑	2°C↑	1.2°C ↑

Khyber Pakhtunkhwa rainfall trend, for both the kharif and rabi cultivation period, has increased over the last thirty years span. This increased rainfall trend i.e. 3mm-38mm, has physically been seen in the form of flash floods, unproductive agricultural land and human loss.

Similarly, KP mean temperature in rabi season is showing an increased trend of 1-1.2 degree centigrade whereas the kharif mean temperature is showing a decreasing trend of 0.3 degree centigrade. Moreover, majority of the climate change has been observed in the rabi cropping season, which mostly constitutes the KP winter season. It seems that warm winters will be observed in the coming future. Warm winters are the clear indication of intensified greenhouse effect. This has also resulted in variation in crop sowing and harvesting patterns, early crop maturation, low nutritional food, low crop productivity and intensified weed and pest outbreaks. Furthermore, the increased temperature fact is understood and acknowledged by the scientist and general public in the form of melting glaciers and depleting water reservoirs.

5.2 Economic Regression Analysis

The second part of the study comprises the economic regression analysis of the crop output with the climate variables. Although there are a number of factors effecting crop productivity as the amount of fertilizers and pesticides used, irrigation mode, mechanical equipment etc. Similarly the output of crop are also dependent on the daily sunshine value and the carbon dioxide concentration in atmosphere. The problem is attainment of the comprehensive district wise data for thirty years. As such the climate variables are selected in this study based on the climate variable records available for thirty years. The maximum and minimum temperature value are not included in the model because of the multicolinearity occurrence between the variables. Mean temperature value is taken instead to capture the temperature effect on crop production. Rainfall as the second climate variable is taken in its quadratic form to capture the increased rainfall effect on the crop production. Time series panel data regression technique is employed for the model analysis. The investigation is divided into region-wise and crop-wise analysis. Below are the details of each analysis.

5.2.1 Region-wise Analysis.

Regression analysis is performed region-wise in this section of the study. The prime purpose of this analysis is to capture the climate variables impact on the crop productivity. In other words, how much yield is effected by variation in the climate variables?

Region-wise panel data analysis is done separately at the three different regions of the province i.e. the southern, central and northern regions. There are two panels in each region i.e.one of kharif and other of rabi crop. There are five variables at the length of each panel i.e. the crop production statistics, area of the region, mean temperature, rainfall and square of rainfall of the selected cropping months. Crop production is taken as dependent variable over the other four independent variables. Each variable has 60 values in total. The random effect model is used in the analysis. The selection between fixed and random effect model is done by the help of hausman specification test. The region-wise panel data analysis are given in table 4 below.

Table 4: KP Region-wise Crop Estimates

Variables	KP Southern Region Model Estimates	KP Central Region Model Estimates	KP Northern Region Model Estimates
Constant	76.51***	-111.35***	-14.48***
	(16.85)	(35.36)	(8.23)
Area	0.96***	2.926***	2.36***
	(0.1001)	(0.275)	(0.815)
Mean Temperature	-2.39***	1.933***	0.523***
	(0.553)	(0.792)	(0.145)
Rainfall	-0.0089	0.212***	2.51*
	(0.073)	(0.084)	(1.506)
Rainfall Square	-0.0000097	-0.000567	-0.000092
	(0.00086)	(0.00077)	(0.00034)
R-Square	0.967	0.93	0.23
Adjusted R-square	0.96	0.92	0.17

*****significant at 1%; **significant at 5%; *significant at 10%**

The above table 4 presents the coefficient of the variables engaged in the three regional models. The southern region model estimates shows two highly significant variables. The first significant variable is area, showing a positive impact on the crops production. A one million hector increase in the area of cultivated land leads to an increase in 960 tons of crop. The second, climate variable, mean temperature, has a negative impact on the crop`s production. Keeping other factors of the model constant, a degree increase in the mean temperature of the crop will leads to a decrease in the crop production by 2390 tones. This is an alarming fact which leads to the conclusion that harsh impacts of climate are observed in the southern regions of KP. The main reason behind this is the lack of sufficient water and early crop maturation. The crop grain remained small and under developed. The insignificant rainfall co-efficient shows that any increase on rainfall leads to increased crop productivity. The R-square value of the model is 0.967 showing 97% goodness of model fitted. For detailed southern Region regression results see annexure B-1.

The central region random effect model gives R-square value of 0.93, showing the 93% effectiveness of the model. This model gives four significant values i.e. Area, Mean Temperature, Rainfall and the constant. The coefficient of area is 2.926. It shows that one million hector increases in area under cultivation will leads to an increase of 2926 tons of crop. Similarly one degree increase in mean temperature of central region will increase the crop production by 1933 tones. Average rainfall also have a positive impact on the crop production i.e. 1 mm increase in rainfall will peaks till the increase crop productivity of 460 tones. For detailed Central Region regression results see annex-2

The third regression analysis is comprised of the KP northern region. Three variables along with the constant intercept are significant in the model. This result shows a pronounced and prominent impact of climate change. . The coefficient of area 2.36 is highly significant. It is showing that a one unit increase in area will leads to the increased crop productivity by 2360 tones. The highly significant coefficient of mean temperature shows that a 1°C increase in temperature will result in the increased production by 523 tones. The third variable, rainfall is transformed into logarithmic form to rule out the occurrence of multicollinearity. It explains that 1 % increases in rainfall peaks at the crop production of 0.05percent. For detailed northern region regression results see annexure B-3.

5.2.2 Season-wise Analysis

The season-wise analysis is performed in this section of the study. The two cropping seasons i.e. kharif and rabi, of KP are taken in this regard. The aim of this analysis is to check the seasonal crop productivity with respect to the climate variables under consideration. Season-wise panel data analysis is done separately in this regard. There are three panels of the selected crop in each model i.e. the northern, central and southern regions. There are five variables at the length of each panel i.e. the crop production statistics, area of the region, mean temperature, rainfall and square of rainfall of the selected cropping months of the crop. Crop production is taken as dependent variable over the other four independent variables. Each variable has 90 values in total. The fixed effect model is used in the analysis. The selection between fixed and random effect model is done by the help of hausman specification test. The season-wise panel data analysis are given in table 5 below.

Table 5: KP Season-wise Crop Estimates

Variables	KP Kharif Model Estimates	KP Rabi Model Estimates
Constant	-43.098*	-1.85*
	(31.29)	(30.054)
Area	3.37***	1.24***
	(0.42)	(0.124)
Mean Temperature	0.632	4.46**
	(1.04)	(1.89)
Rainfall	-0.01	0.643***
	(0.0390)	(0.135)
Rainfall Square	0.006*	-0.004***
	(0.0002)	(0.0017)
R-Square	0.97	0.94
Adjusted R-square	0.97	0.93

*****significant at 1%; **significant at 5%; *significant at 10%**

Khyber Pakhtunkhwa kharif crop model effectiveness is shown by R-square value of 96%. There are two highly significant variables in the model i.e. Area & Rainfall square. Keeping other factors of the model constant, a one million hector increase in the area of land cultivating the crop will lead to an increase of 3370 tons of kharif crop. Similarly the rainfall coefficient is insignificant shows that as the rainfall increases the productivity of crop also increases. The significant squared rainfall coefficient also portrays a positive relation of crop productivity and rainfall. Here the rainfall relationship is U-shaped with a minimum at N=0. The non-significant coefficient of mean temperature shows that kharif crop productivity decreases with the increase in temperature. For detailed Kharif Crop regression results see annexure B-4.

The second analysis in table 5 is comprised of the rabi crop model estimation. The model shows four significant variables. The highly significant coefficient of area shows that one million hector increases in land area will lead to increase in the production of rabi crop by 1240 Tones Similarly climate variables have greater impact on the production of rabi crop. An increase in 1 °C increase in mean temperature of KP will lead to an increase in rabi production by 4465 tones. Likewise, Rainfall has a positive impact on rabi crop production. Rainfall is followed by its negative square variable to capture the quadratic effect of the factor i.e. ($y = N_1t-N_1^2t$). It shows an inverted U-shaped regression. Its peak point is at 0.80. It shows that an increase in average rainfall of one millimeter will lead to increase wheat production by 80 tones but from that point onwards the law of decreasing returns starts i.e. each mm of rainfall will decrease crop productivity by a factor of 0.004. The model effectiveness indicator R-square is 0.90 showing the 90% goodness of fit to the model. For detailed Rabi crop regression results see annexure B-2.

5.3 Summary

The conclusion from above analysis is that climate variables do have impact on crop production. It has more harsh impact on the southern part of KP, which is already short of water supply and untimely rainfalls has aggravated the situation. Moreover high temperature has further intensified the crop productivity by quick ripening of crops. On the other hand climate variables impact on northern region of KP has positive and favorable. Elevated temperatures escalate the crops ripening processes giving bumper crops but the insufficient land availability is the only hindrances in the agricultural growth. The central regions of the province is also experiencing a positive impact of climate change, but to a certain limit, after that limit it leads to a downturn. The law of decreasing returns to scales applies in terms of rainfall in this situation.

The seasonal crop-wise analysis also concludes that climate change is effecting positively on the kharif crop. A timely sufficient rain leads to more crop yield. Moreover, a sufficient high temperature is the source of high productivity in the province. On the other hand, climate impact on Rabi crop is negative as high temperature leads to decreased crop production due to increased weed and pest proliferation. But if timely sufficient rain occur, it can help increase the crop productivity.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Climate change is aggregation of complex dynamic activities, caused by Nature, human and animal activities. Change in nature is a centuries long process i.e. in the form of change in the tectonic plates of earth, volcanic eruptions and earth`s equatorial axis. Human induced climate change activities refers to the excessive use of organic oil in industries , which results in arsenic and sulfur compounds disposal in sea and fresh water. Lastly animals are also one of the main source of all anthropogenic activities that consequences in the release of nitrogenous gaseous in the atmosphere. The ultimate result is the enhancement in greenhouse effect and the variation in temperature and rainfall patterns of the earth. These climate induced variables have harmful impacts on crop`s output at different climate zones of the world.

Pakistan is also among the countries that are at the receiving end of the climate change impacts. The mega floods of 2010, high temperatures and malnutrition crops are a few of the climate change events. Summarizing the above thesis; the conclusion drawn is that climate variables do have impact on crop production. Rise in temperature and rainfall do have positive impacts in rabi crops production but until a certain limit and at certain places. It is proved in the thesis trend analysis that southern KP has experienced a rise of 1.6°C minimum temperature in the rabi season and an increase of 19mm rainfall during the kharif season. This rise in temperature puts harsh impacts on dry lands and rain fed areas in the southern part of KP, which is already short of water supply. Furthermore, high temperature has aggravated the crop productivity situation, by quick ripened and malnourished grains. In case of central KP rabi season, the increase in mean temperature is 1.2°C accompanied by rise in average rainfall over 25mm. Furthermore, central region kharif season rainfall is also increased upto 38mm. Lastly in the northern part of KP, the rabi season rise in rainfall and temperature is 15mm and 1°C respectively. The overall KP rainfall rate has increased both in kharif and rabi season i.e. upto15mm. Whereas in case of temperature, rabi season is experiencing the increased temperature of upto1.2 °C. All these are the signs of global warming and climate change. The increased temperature and rainfall has a negative impact on rabi crop as seen in terms of fallen crop yield from 1565 Kg/hector in 2008-09 to 1520 Kg/hector in 2009-10. On the other hand kharif crop has also experienced a shrinkage in yield i.e. from 1880 Kg/Hector in 2008-09 to 1783 kg/hector in 2009-10. (Agricultural Statistics of Pakistan. 2010-11).

This research work is an attempt to assist the concerned authorities in solving the climate variation problems faced by Pakistan's agricultural sector. The mathematical and theoretical analysis made in this research will help in the identification of the variation in temperature and rainfall patterns at different regions of the province.

Climate change is a vast phenomenon and needs a multidisciplinary approaches at different levels of society. A few of the recommendations strained from the above research includes farmer edification about climate change. The knowledge regarding the shift in tilling and harvesting timings at different regions of the country must be shared at farm level. Along with farm education, land and water management strategies should also be introduced to cope with water stressed or water abundant regions of the country. Training and skill development should also be provided in coping with the harsh climate impacts as floods and droughts. Moreover, climate region specific crop incentives in the form of crop insurances, relaxed terms of credits and subsidies be introduced to farmers to cope with the varied climate conditions. Metrological information should be made available at the farmer`s door step. Research and development in the areas of agriculture, metrological engineering and green energy resource development should also be high-lightened.

Local government, disaster management authorities, industrialists having direct access to farms can play an effective role in climate knowledge sharing i.e. shift in the weather patterns, use of heat and pest resistant seeds, crop rotation techniques etc. Additionally, long term perspective in dealing with this inevitable situation of climate change can be handled with future mitigation and adaptation measures in enhancing crop productivity. Think green and perceive clean should the prime logo of our government.

6.1. Limitations & Future Prospects

This research study is interesting and innovative in all respects. The basic problem is in the assortment and collection of secondary climate data of the various districts taken.

Some of the agricultural districts as Nowshera, Charsada, Tank didn`t have the weather stations. In case if they have any, the newly established weather stations are lacking the past thirty years data. Similarly the agricultural data i.e. fertilizers, pesticides, water quantity and mode of irrigation at various districts is not available in compact form. It is still in the form of book entries etc. Moreover, data on wind speed, daily sunshine and carbon dioxide concentration in atmosphere are also missing for long periods.

The climate impact and the extent of climate influence in terms of rainfall and temperature have been found out in this research study. This research is opening new dimensions for future researches in the climate impact arenas by considering other environmental factors i.e. CO_2 concentration, wind speed, daily sunshine, fertilizers inputs and many more . Moreover, extensive research in the climate change adaptations and mitigation strategies regarding crop production can also be comprehend to cope with this non-eluded situation.

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ANNEXTURE-A

TABLE -1
Pakistan Statistics

YEAR	CO2 emmissions (metric Tons per capita)	GDP growth (annual %)	Inflation, Consumer prices (annual %)	Agriculture, value added (% of GDP)
1981-82	0.413	7.9	11.87	30.82
1982-83	0.433	6.5	5.9	31.56
1983-84	0.451	6.77	6.36	30.26
1984-85	0.464	5.06	6.08	27.91
1985-86	0.494	7.59	5.61	28.53
1986-87	0.5	5.5	3.5	27.62
1987-88	0.52	6.45	4.68	26.24
1988-89	0.55	7.62	8.83	26.02
1989-90	0.56	4.96	7.84	26.94
1990-91	0.61	4.45	9.05	25.97
1991-92	0.59	5.06	11.79	25.77
1992-93	0.61	7.7	9.5	26.34
1993-94	0.644	1.75	9.97	24.99
1994-95	0.68	3.73	12.36	25.55
1995-96	0.663	4.96	12.34	26.1
1996-97	0.722	4.84	10.37	25.48
1997-98	0.705	1.01	11.37	26.7
1998-99	0.708	2.55	6.23	27.31
1999-00	0.71	3.66	4.14	27.03
2000-01	0.74	4.26	4.36	25.92
2001-02	0.73	1.98	3.14	24.09
2002-03	0.76	3.22	3.29	23.35
2003-04	0.78	4.84	2.91	23.36
2004-05	0.85	7.37	7.44	22.18
2005-06	0.86	7.67	9.06	21.46
2006-07	0.9	6.17	7.92	20.35
2007-08	0.978	5.68	7.59	20.46
2008-09	0.974	1.59	20.28	20.33
2009-10		3.59	13.64	21.56
2010-11		4.1	13.88	21.17

Sources: World Bank 2010 Pakistan Data

TABLE-2
Khyber Pakhtunkhwa Southern Region Kharif (Maize) Crop Statistics

YEAR	Production in (000) Tones	Area in (000) hector	Average Maximum Temperature	Mean of Max_Min Temp	Average Minimum Temperature	Average Rainfall	Square of Rainfall
1981-82	3.3	2	37.1	31	25	90	8064
1982-83	3	2	38.9	32	24.3	38	1421
1983-84	2.6	2	37.3	31	25	92	8458
1984-85	2.5	2	36.6	31	24.4	20	403
1985-86	2.4	2	39.9	31	23	19	347
1986-87	2.5	2	37.2	31	25	47	2228
1987-88	3	2	39.9	33	25.7	6.2	38.4
1988-89	2.6	2	37.3	31	25.5	34	1127
1989-90	2	1	37.2	31	25	69	4697
1990-91	2.4	2	37.4	32	26.5	66	4396
1991-92	2.5	2	37.8	32	26.1	48	2323
1992-93	1.6	1	36.4	31	25	48	2272
1993-94	2	1	37.5	31	25.4	45	2046
1994-95	1.7	1	36.1	31	25.3	84	7078
1995-96	1.9	1	36.8	31	25.6	74	5540
1996-97	2.5	2	37.8	31	24.9	28	807
1997-98	2.5	2	38.1	31	24.1	15	215
1998-99	2.2	1	38.2	31	24.2	35	1216
1999-00	2.3	1	38	32	26.7	41	1711
2000-01	2.3	1	37.5	32	26.1	68	4660
2001-02	2.3	1	37.3	32	26.4	52	2718
2002-03	2.4	1	38.4	32	24.9	9.3	87.1
2003-04	2.7	2	37.3	31	24.6	62	3790
2004-05	2.4	1	37.7	32	25.6	65	4221
2005-06	2	1	36.9	31	24.9	104	####
2006-07	1.9	1	37.5	31	24.2	8.5	71.7
2007-08	2.9	1	37.1	32	26.1	65	4221
2008-09	2.7	1	36	31	25	65	4225
2009-10	2.8	1	37.9	32	25.5	89	7921
2010-11	2.7	1	35.1	30	24.8	53	2809

Source: Pakistan Metrology Department, Agriculture Statistics of Khyber Pakhtunkhawa (2010) Rearranged by the Author

TABLR-3
Khyber Pakhtunkhwa Central Region Kharif (Maize) Crop Statistics

YEAR	Production 000Tinnes	Area 000 hecter	Ave Max Temp	Mean of Max_Min Temp	Ave Min Temp	Ave Rainfall	Square Rainfall
1981-82	87.5	45.6	36.2667	30.367	24.4667	36.6	1337
1982-83	86.1	45.1	36.8	30.683	24.5667	32.2	1039
1983-84	74.3	41.6	36.1667	30.683	25.2	99.4	9887
1984-85	68.4	39.7	34.4667	29.35	24.2333	120	14368
1985-86	71.1	40.5	36.2	30.717	25.2333	41.9	1753
1986-87	71.9	41.2	36.3	30.367	24.4333	29.9	894
1987-88	74.1	40.3	39	32.35	25.7	3.53	12.48
1988-89	71.1	38.1	36.2667	30.733	25.2	29.1	846.8
1989-90	73.5	39.6	36.6333	30.4	24.1667	28.5	812.3
1990-91	76.5	42	36.8667	31.317	25.7667	43	1846
1991-92	79.1	41.5	36.7667	31.017	25.2667	12.7	160.4
1992-93	74.2	43.4	36.1	30.35	24.6	44.5	1983
1993-94	79.4	44	37.1	30.967	24.8333	57.2	3272
1994-95	76.8	41.3	35.0667	29.7	24.3333	85	7219
1995-96	70.3	40.9	36.1667	30.283	24.4	85.5	7310
1996-97	77.5	42.6	37.3333	31.283	25.2333	59.6	3552
1997-98	65.1	36.6	36.9	31.3	25.7	23.5	552.3
1998-99	82.7	44	36.9333	31.15	25.3667	61.2	3741
1999-00	85.2	44.9	37.6333	31.733	25.8333	25.3	641.8
2000-01	83.2	45	35.5333	30.55	25.5667	7.33	53.78
2001-02	88.9	45.9	35.6	30.517	25.4333	35.7	1272
2002-03	71.5	39.7	35.6667	30.5	25.3333	53.5	2862
2003-04	80.8	43.5	35.2667	30.35	25.4333	127	16129
2004-05	83.9	45.4	36.3333	30.833	25.3333	35.3	1248
2005-06	92.3	45.1	35.9333	30.883	25.8333	37.7	1419
2006-07	93.9	45.1	35.2	30.433	25.6667	53	2809
2007-08	94.3	44.9	35.6667	30.65	25.6333	62	3844
2008-09	117.3	44	35.2	29.933	24.6667	116	13533
2009-10	115	44	36.9	31.383	25.8667	43	1849
2010-11	114	45	36	30.9	25.8	179	32159

Source: Pakistan Metrology Department, Agriculture Statistics of Khyber Pakhtunkhawa (2010) Rearranged by the Author

TABLE -4
Khyber Pakhtunkhwa Northern Region Kharif (Maize) Crop Statistics

YEAR	Production in (000) Tonnes	Area in (000) Hecter	Average Maximum Temperature	Mean of Max_Min Temp	Average Minimum Temperature	Average Rainfall	Square of Rainfall
1981-82	11.1	6.7	33.53333333	25.06666667	16.6	5.533333333	30.61777778
1982-83	11.1	6.7	33.16666667	24.83333333	16.5	5.033333333	25.33444444
1983-84	11.5	6.9	34.6	26.48333333	18.36666667	4.033333333	16.26777778
1984-85	11.6	7	33.5	25.63333333	17.76666667	1.7	2.89
1985-86	11.7	7	34.7	26.21666667	17.73333333	7.266666667	52.80444444
1986-87	18.3	7	32.1	24.36666667	16.63333333	14.33333333	205.4444444
1987-88	24.4	7	33.96666667	25.1	16.23333333	2.433333333	5.921111111
1988-89	22.3	6.7	34.03333333	25.78333333	17.53333333	11.1	123.21
1989-90	19	6.4	32.8	24.2	15.6	10.43333333	108.8544444
1990-91	17.2	6.3	35.16666667	26.66666667	18.16666667	3.15	9.9225
1991-92	17.4	6.3	33.66666667	25.36666667	17.06666667	44.86666667	2013.017778
1992-93	15.3	6.3	33.43333333	25.03333333	16.63333333	9.766666667	95.38777778
1993-94	16.4	6.3	34.16666667	24.98333333	15.8	5	25
1994-95	16.5	6.3	33.96666667	25.86666667	17.76666667	13.83333333	191.3611111
1995-96	16.9	6.3	34.36666667	25.71666667	17.06666667	18.4	338.56
1996-97	17.1	6.3	34.33333333	25.51666667	16.7	6.266666667	39.27111111
1997-98	16.3	6.3	35.1	26.31666667	17.53333333	2.433333333	5.921111111
1998-99	16.4	6.3	34.6	25.86666667	17.13333333	5.3	28.09
1999-00	17.7	6.3	34.56666667	26.08333333	17.6	12.36666667	152.9344444
2000-01	16.7	6	34.6	25.91666667	17.23333333	14.7	216.09
2001-02	17.6	5.9	34.4	25.75	17.1	10.2	104.04
2002-03	17.7	5.9	34.26666667	25.41666667	16.56666667	6.3	39.69
2003-04	17.1	6.1	34.33333333	25.8	17.26666667	8.733333333	76.27111111
2004-05	12.4	5.9	34.4	23.21666667	12.03333333	9.466666667	89.61777778
2005-06	12.8	6.1	34.7	25.86666667	17.03333333	0.9	0.81
2006-07	12.2	5.7	34.5	26.21666667	17.93333333	6.15	37.8225
2007-08	13.1	5.7	34.66666667	26.11666667	17.56666667	2.2	4.84
2008-09	13.1	5.7	33.7	25.08333333	16.46666667	0.333333333	0.111111111
2009-10	13	5.7	35.03333333	25.48333333	15.93333333	3	9
2010-11	13	5.6	31.96666667	24	16.03333333	41.46666667	1719.484444

Source: Pakistan Metrology Department, Agriculture Statistics of Khyber Pakhtunkhawa (2010) Rearranged by the Author

TABLE -5

Khyber Pakhtunkhwa Southern Region
Rabi (Wheat) Crop Statistics

YEAR	Production in(000) Tonnes	Area in 000) Hecter	Average Maximum Temperature	Mean of Max_Min Temp	Average Minimum Temperature	Average Rainfall	Square of Rainfall
1981-82	148.7	111.4	25.58333333	17.79166667	10	17.95	322.2025
1982-83	149.4	102.6	23.93333333	16.51666667	9.1	29.06666667	844.8711111
1983-84	104.2	99	24.56666667	16.58333333	8.6	23.56666667	555.3877778
1984-85	116.4	109.1	25.53333333	17.11666667	8.7	9.1	82.81
1985-86	96.4	76.4	26.61666667	17.30833333	8	11.76666667	138.4544444
1986-87	97	86.6	24.88333333	16.35833333	7.833333333	19.36666667	375.0677778
1987-88	109.7	64.4	26.38333333	18.58333333	10.78333333	20.26666667	410.7377778
1988-89	130.2	85.2	26.71666667	18.9	11.08333333	13.3	176.89
1989-90	136.2	88.9	24.66666667	17.36666667	10.06666667	17.35166667	301.0803361
1990-91	127.5	83.5	25.1	18.08333333	11.06666667	17.78333333	316.2469444
1991-92	115.3	68.1	24.55	17.60833333	10.66666667	20.26833333	410.8053361
1992-93	115.8	72.3	24.4	15.35	6.3	19.9	396.01
1993-94	93.9	65.5	26.18333333	18.35	10.51666667	17.26833333	298.1953361
1994-95	110.3	85.8	25.48333333	18.125	10.76666667	17.93333333	321.6044444
1995-96	111.2	85.3	24.98333333	17.53333333	10.08333333	18.85166667	355.3853361
1996-97	93.5	69.1	26.43333333	18.21666667	10	13.86833333	192.3306694
1997-98	125.7	83.9	24.26666667	16.70833333	9.15	18.41666667	339.1736111
1998-99	96.8	58.5	25.75	17.425	9.1	16.98333333	288.4336111
1999-00	68.5	51.4	26.21666667	18.45	10.68333333	7.918333333	62.70000278
2000-01	83.4	55.4	26.61666667	18.73333333	10.85	3.751666667	14.07500278
2001-02	77.1	52.8	26.55	18.91666667	11.28333333	11.90333333	141.6893444
2002-03	101.2	53.2	26.68333333	18.68333333	10.68333333	12.53333333	157.0844444
2003-04	72.4	51.3	25.35	17.23333333	9.116666667	10.41833333	108.5416694
2004-05	82.6	52.3	27.45	19.23333333	11.01666667	12.035	144.841225
2005-06	78.7	49.8	24.23333333	16.95833333	9.683333333	29.36833333	862.4990028
2006-07	66.9	48	25.7	17.96666667	10.23333333	18.91666667	357.8402778
2007-08	65.4	48.1	25.23333333	17.55	9.866666667	33.05	1092.3025
2008-09	101.9	52.6	26.03333333	18.20833333	10.38333333	24	576
2009-10	84.6	49.6	25.9	17.525	9.15	14	196
2010-11	94	48.6	26.46666667	18.8	11.13333333	27	729

Source: Pakistan Metrology Department, Agriculture Statistics of Khyber Pakhtunkhawa (2010) Rearranged by the Author

TABLE -6

Khyber Pakhtunkhawa Central Region
Rabi (Wheat) Crop Statistics

YEAR	Production in (000) Tonnes	Area in (000) Hecter	Average Maximum Temperature	Mean of Max_Min Temp	Average Minimum Temperature	Average Rainfall	Square of Rainfall
1981-82	147.6	79.1	23.61666667	16.16666667	8.716666667	23.61666667	557.7469
1982-83	152.2	82.4	21.63333333	15.06666667	8.5	21.63333333	468.0011
1983-84	127.8	67.1	21.63333333	14.56666667	7.5	21.63333333	468.0011
1984-85	126.5	65.4	23.13333333	15.675	8.216666667	23.13333333	535.1511
1985-86	149.8	79.8	24.61666667	17.025	9.433333333	24.61666667	605.9803
1986-87	143.3	80.7	22.66666667	15.50833333	8.35	22.66666667	513.7778
1987-88	121.5	67.9	24.2	16.575	8.95	24.2	585.64
1988-89	135.9	74.9	24.05	17.00833333	9.966666667	24.05	578.4025
1989-90	159.6	78.5	22.73333333	15.65833333	8.583333333	22.73333333	516.8044
1990-91	162.2	80.6	22.73333333	15.94166667	9.15	22.73333333	516.8044
1991-92	164.9	80.7	22.15	15.275	8.4	22.15	490.6225
1992-93	172.2	85.8	22.43333333	15.66666667	8.9	22.43333333	503.2544
1993-94	173.5	81.9	24.13333333	16.40833333	8.683333333	24.13333333	582.4178
1994-95	183.3	85.9	23.2	15.93333333	8.666666667	23.2	538.24
1995-96	191.6	87.3	22.98333333	15.23333333	7.483333333	22.98333333	528.2336
1996-97	169	96.9	24.3	16.425	8.55	24.3	590.49
1997-98	225.1	96.7	22.46666667	15.36666667	8.266666667	22.46666667	504.7511
1998-99	208	89.5	23.46666667	16.05	8.633333333	23.46666667	550.6844
1999-00	197.9	89.7	24.46666667	17.13333333	9.8	24.46666667	598.6178
2000-01	144.8	89.9	23.66666667	16.65833333	9.65	23.66666667	560.1111
2001-02	124.6	66.5	24.15	17.175	10.2	24.15	583.2225
2002-03	175.9	81.6	23.21666667	16.925	10.63333333	23.21666667	539.0136
2003-04	175.9	82.2	22.93333333	16.38333333	9.833333333	22.93333333	525.9378
2004-05	171.8	85.1	24.78333333	17.96666667	11.15	24.78333333	614.2136
2005-06	184.1	85	22.01666667	15.56666667	9.116666667	22.01666667	484.7336
2006-07	194.1	85.1	23.48333333	17.2	10.91666667	23.48333333	551.4669
2007-08	191.1	85.1	23.6	16.85	10.1	23.6	556.96
2008-09	226.8	91.7	23.76666667	16.825	9.883333333	23.76666667	564.8544
2009-10	217.6	92.4	23.21666667	16.65833333	10.1	23.21666667	539.0136
2010-11	209.9	86.6	25	18.5	12	37	1369

Source: Pakistan Metrology Department, Agriculture Statistics of Khyber Pakhtunkhawa (2010) Rearranged by the Author

TABLE -7

Khyber Pakhtunkhawa Northern Region
Rabi (Wheat) Crop Statistics

YEAR	Production in (000) Tonnes	Area in(000) Hecter	Average Maximum Temperature	Mean of Max_Min Temp	Average Minimum Temperature	Average Rainfall	Square of Rainfall
1981-82	8.8	7.3	14.35	8.741666667	3.133333333	64.65	4179.623
1982-83	9.4	7.8	13.38333333	8.158333333	2.933333333	45.18333	2041.534
1983-84	9.4	7.8	14.1	8.216666667	2.333333333	41.06667	1686.471
1984-85	9.5	7.9	13.63333333	7.758333333	1.883333333	56.96667	3245.201
1985-86	9.7	7.9	15.51666667	9.575	3.633333333	35.63333	1269.734
1986-87	11.2	8	13.38333333	7.716666667	2.05	75.95	5768.403
1987-88	10.1	7.9	16.11666667	9.683333333	3.25	53.26667	2837.338
1988-89	10.9	8.5	15.58333333	9.333333333	3.083333333	80.48333	6477.567
1989-90	10.9	8.5	13.8	7.983333333	2.166666667	54.23333	2941.254
1990-91	11.2	8.5	14.95	8.691666667	2.433333333	57.56667	3313.921
1991-92	11.2	8.6	13.73333333	7.833333333	1.933333333	74.26667	5515.538
1992-93	11.2	8.6	13.75	7.358333333	0.966666667	92.28333	8516.214
1993-94	12	8.6	15.35	9.058333333	2.766666667	66.63333	4440.001
1994-95	13.1	8.6	14.63333333	8.433333333	2.233333333	63.56667	4040.721
1995-96	13.1	8.6	14.86666667	8.391666667	1.916666667	48.51667	2353.867
1996-97	13.3	8.7	15.33333333	8.875	2.416666667	61.76667	3815.121
1997-98	13.7	8.7	15.73333333	8.558333333	1.383333333	62.81667	3945.934
1998-99	21.2	9.1	17.05	9.591666667	2.133333333	59.85	3582.023
1999-00	17.2	9.1	15.93333333	9.558333333	3.183333333	72.35	5234.523
2000-01	12.2	9.2	16.15	9.508333333	2.866666667	84.06667	7067.204
2001-02	18.8	9	17.76666667	10.29166667	2.816666667	30.13333	908.0178
2002-03	24.4	9.2	16.45	9.641666667	2.833333333	60.1	3612.01
2003-04	21.7	9.2	15.91666667	9.25	2.583333333	59.63333	3556.134
2004-05	14.3	6.3	17.05	10.06666667	3.083333333	43.28333	1873.447
2005-06	18.4	7.9	14.53333333	8.633333333	2.733333333	63.88333	4081.08
2006-07	18.6	8	15.88333333	9.666666667	3.45	71.9	5169.61
2007-08	16.1	7.8	16.53333333	9.508333333	2.483333333	71.2	5069.44
2008-09	16.2	8	15.51666667	8.875	2.233333333	73.7	5431.69
2009-10	15.7	8	13.76666667	8.15	2.533333333	98.16667	9636.694
2010-11	15	8	17.63333333	9.766666667	1.9	62.05	3850.203

Source: Pakistan Metrology Department, Agriculture Statistics of Khyber Pakhtunkhawa (2010) Rearranged by the Author

TABLE -8

Khyber Pakhtunkhawa Kharif (Maize) Crop Statistics

YEAR	Kharif Average Rainfall	Kharif Maximum Temperature	Kharif Minimum Temperature	Kharif Mean Temperature
1981-82	43.96667	35.63333	35.14444	35.38889
1982-83	24.98889	36.27778	35.41481	35.8463
1983-84	65.14444	36.03333	35.6	35.81667
1984-85	47.21111	34.85556	34.27407	34.56481
1985-86	22.58889	36.93333	35.94444	36.43889
1986-87	30.47778	35.2	34.53333	34.86667
1987-88	4.055556	37.61111	36.85926	37.23519
1988-89	24.58889	35.86667	35.38889	35.62778
1989-90	35.82222	35.54444	34.99259	35.26852
1990-91	37.47222	36.48889	36.17407	36.33148
1991-92	35.24444	36.07778	35.5037	35.79074
1992-93	33.98889	35.31111	34.94815	35.12963
1993-94	35.81111	36.26667	35.84444	36.05556
1994-95	60.97778	35.04444	34.69259	34.86852
1995-96	59.44444	35.76667	35.43333	35.6
1996-97	31.42222	36.5	36.05556	36.27778
1997-98	13.53333	36.7	36.23333	36.46667
1998-99	33.77778	36.57778	36.03704	36.30741
1999-00	26.35556	36.73333	36.31111	36.52222
2000-01	30.1	35.86667	35.33333	35.6
2001-02	32.66667	35.75556	35.25185	35.5037
2002-03	23.04444	36.11111	35.34815	35.72963
2003-04	65.76667	35.62222	35.07407	35.34815
2004-05	36.58889	36.14444	35.62593	35.88519
2005-06	47.6	35.84444	35.49259	35.66852
2006-07	22.53889	35.72222	35.14074	35.43148
2007-08	43.05556	35.82222	35.38519	35.6037
2008-09	78.11111	34.97778	34.62593	34.80185
2009-10	18.88889	36.61111	36.18148	36.3963
2010-11	85.06667	34.01111	33.65926	33.83519

Source: Pakistan Metrology Department, Agriculture Statistics of Khyber Pakhtunkhawa (2010) Rearranged by the Author

TABLE -9

Khyber Pakhtunkhawa Rabi (Crop) Statistics

YEAR	Rabi Average Rainfall	Rabi Maximum Temperature	Rabi Minimum Temperature	sRabi Mean Temperature
1981-82	40.88889	21.18333	19.71667	20.45
1982-83	37.12222	19.65	18.22222	18.93611
1983-84	40.91667	20.1	18.61111	19.35556
1984-85	30.63333	20.76667	19.17778	19.97222
1985-86	26.57222	22.25	20.79444	21.52222
1986-87	48.18333	20.31111	18.78704	19.54907
1987-88	38.15556	22.23333	20.85	21.54167
1988-89	45.57222	22.11667	20.58333	21.35
1989-90	32.05611	20.4	18.97778	19.68889
1990-91	39.18889	20.92778	19.53704	20.23241
1991-92	46.61722	20.14444	18.67593	19.41019
1992-93	61.84778	20.19444	18.79259	19.49352
1993-94	43.15056	21.88889	20.45741	21.17315
1994-95	43.4	21.10556	19.6463	20.37593
1995-96	40.35611	20.94444	19.59815	20.2713
1996-97	42.465	22.02222	20.55185	21.28704
1997-98	40.53889	20.82222	19.67407	20.24815
1998-99	47.25111	22.08889	20.86852	21.4787
1999-00	42.66167	22.20556	20.86852	21.53704
2000-01	31.27278	22.14444	20.6537	21.39907
2001-02	22.39556	22.82222	21.57963	22.20093
2002-03	36.32222	22.11667	20.59444	21.35556
2003-04	46.71167	21.4	20.08333	20.74167
2004-05	38.63944	23.09444	21.64259	22.36852
2005-06	56.41722	20.26111	18.93704	19.59907
2006-07	46.07778	21.68889	20.35185	21.02037
2007-08	61.35	21.78889	20.64074	21.21481
2008-09	67.22222	21.77222	20.35185	21.06204
2009-10	60.16667	20.96111	19.31481	20.13796
2010-11	39.525	22.05	19.84167	20.94583

Source: Pakistan Metrology Department, Agriculture Statistics of Khyber Pakhtunkhawa (2010) Rearranged by the Author

ANNEXTURE-B

Annex-1

Khyber Pakhtunkhawa Southern Region Regression Analysis (STATA) Results

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
  Production |        60      52.125    52.67096        1.6      149.4
        Area |        60    35.90167    37.37288        1.1      111.4
       MeanT |        60    24.52833    6.887379      15.35   32.76667
 AveRainfall |        60    35.46283    29.60508   3.751667        129
Squarerain~l |        60    1857.282    2518.973     14.075   10864.59

. regress Production Area MeanT  AveRainfall Squarerainfall

      Source |       SS       df       MS              Number of obs =      60
------------+------------------------------           F(  4,    55) =  392.82
       Model |  158144.052     4  39536.0129           Prob > F      =  0.0000
    Residual |  5535.50085    55   100.64547           R-squared     =  0.9662
-------------+------------------------------           Adj R-squared =  0.9637
       Total |  163679.553    59   2774.2297           Root MSE      =  10.032

--------------------------------------------------------------------------------
    Production |      Coef.   Std. Err.      t    P>|t|     [95% Conf.Interval]
---------------+----------------------------------------------------------------
          Area |   .9603828   .1001919     9.59   0.000     .7595936   1.161172
         MeanT |   -2.38649   .5532365    -4.31   0.000    -3.495201   -1.27778
   AveRainfall |  -.0088043   .0731549    -0.12   0.905      -.15541   .1378013
Squarerainfall |  -9.76e-06    .000864    -0.01   0.991    -.0017413   .0017217
         _cons |   76.51264   16.85374     4.54   0.000     42.73699   110.2883

    Variable |       VIF       1/VIF
-------------+----------------------
       MeanT |      8.51    0.117493
```

```
       Area |      8.22    0.121664
Squarerain~l |      2.78    0.360135
 AveRainfall |      2.75    0.363683
-------------+----------------------
    Mean VIF |      5.56
. xtset CropGroup YEAR
       panel variable:  CropGroup (strongly balanced)
        time variable:  YEAR, 1981 to 2010
                delta:  1 unit

. xtreg Production Area MeanT AveRainfall Squarerainfall, fe
Fixed-effects (within) regression               Number of obs      =        60
Group variable: CropGroup                       Number of groups   =         2

R-sq:  within  = 0.6788                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.8517                                        max =        30
                                                F(4,54)            =     28.53
corr(u_i, Xb)  = 0.8161                         Prob > F           =    0.0000
------------------------------------------------------------------------------
    Production |      Coef.   Std. Err.      t    P>|t|     [95% Conf.Interval]
---------------+--------------------------------------------------------------
          Area |   .9913245   .0965235    10.27   0.000     .7978067   1.184842
         MeanT |   2.167678   1.896717     1.14   0.258     -1.63501   5.970366
   AveRainfall |   .0572762   .0747252     0.77   0.447    -.0925388   .2070912
Squarerainfall |  -.0002021   .0008291    -0.24   0.808    -.0018643   .0014601
         _cons |  -38.29049   48.66049    -0.79   0.435    -135.8489   59.26792
---------------+---------------------------------------------------------------
       sigma_u |   43.89585
       sigma_e |  9.5851224
           rho |   .9544887   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(1, 54) =     6.25              Prob > F = 0.0155
. xtreg Production Area MeanT AveRainfall Squarerainfall, re
Random-effects GLS regression                   Number of obs      =        60
Group variable: CropGroup                       Number of groups   =         2
```

```
R-sq:  within  = 0.6466                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.9662                                        max =        30
                                                Wald chi2(4)       =   1571.30
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
------------------------------------------------------------------------------
    Production |      Coef.   Std. Err.      z    P>|z|     [95% Conf.Interval]
---------------+----------------------------------------------------------------
          Area |   .9603828   .1001919     9.59   0.000     .7640102   1.156755
         MeanT |   -2.38649   .5532365    -4.31   0.000    -3.470814  -1.302167
   AveRainfall |  -.0088043   .0731549    -0.12   0.904    -.1521853   .1345766
Squarerainfall |  -9.76e-06    .000864    -0.01   0.991    -.0017032   .0016836
         _cons |   76.51264   16.85374     4.54   0.000     43.47992   109.5454
---------------+--------------------------------------------------------------
       sigma_u |          0
       sigma_e |  9.5851224
           rho |          0   (fraction of variance due to u_i)
```

```
. hausman fixed .                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed          .          Difference          S.E.
-------------+----------------------------------------------------------------
        Area |    .9913245     .9603828        .0309418               .
       MeanT |    2.167678     -2.38649        4.554168        1.814239
 AveRainfall |    .0572762    -.0088043        .0660805        .0152386
Squarerain~l |   -.0002021    -9.76e-06       -.0001924               .
------------------------------------------------------------------------------
           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg
    Test:  Ho:  difference in coefficients not systematic
                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        6.26
                Prob>chi2 =      0.1808
                (V_b-V_B is not positive definite)
```

Annex-2

Khyber Pukhtunkhawa Central Region Regression Analysis (STATA) Results

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
  Production |        60    126.8067    50.16466       65.1      226.8
        Area |        60    62.70833    21.06315       36.6       96.9
       MeanT |        60    23.47792    7.324759   14.56667      32.35
 AveRainfall |        60    52.06567    30.77312   3.533333   179.3333
Squarerain~l |        60    3106.028    3390.799          0      16129

. regress Production Area MeanT  AveRainfall Squarerainfall

      Source |       SS       df       MS              Number of obs =      60
-------------+------------------------------           F(  4,    55) =  188.06
       Model |  138356.962     4  34589.2406           Prob > F      =  0.0000
    Residual |  10116.1549    55  183.930089           R-squared     =  0.9319
-------------+------------------------------           Adj R-squared =  0.9269
       Total |  148473.117    59  2516.49351           Root MSE      =  13.562

--------------------------------------------------------------------------------
    Production |      Coef.   Std. Err.      t    P>|t|     [95% Conf. nterval]
---------------+----------------------------------------------------------------
          Area |   2.926285   .2752559    10.63   0.000      2.37466    3.47791
         MeanT |   1.933302   .7923568     2.44   0.018     .3453835    3.52122
   AveRainfall |   .2117699   .0844554     2.51   0.015     .0425176   .3810222
Squarerainfall |  -.0005659    .000766    -0.74   0.463     -.002101   .0009692
         _cons |  -111.3539   35.35599    -3.15   0.003    -182.2089   -40.4989
-------------------------------------------------------------------------------
. estat vif
```

```
    Variable |       VIF       1/VIF
-------------+----------------------
       MeanT |     10.81    0.092549
        Area |     10.78    0.092743
 AveRainfall |      2.17    0.461533
Squarerain~l |      2.16    0.462108
-------------+----------------------
    Mean VIF |      6.48
. xtset CropGroup YEAR
       panel variable:  CropGroup (strongly balanced)
        time variable:  YEAR, 1981 to 2010
                delta:  1 unit
. xtreg Production Area MeanT AveRainfall Squarerainfall, fe
Fixed-effects (within) regression               Number of obs      =        60
Group variable: CropGroup                       Number of groups   =         2

R-sq:  within  = 0.6797                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.9302                                        max =        30
                                                F(4,54)            =     28.65
corr(u_i, Xb)  = 0.9012                         Prob > F           =    0.0000

--------------------------------------------------------------------------------
    Production |      Coef.   Std. Err.      t    P>|t|     [95% Conf.Interval]
---------------+----------------------------------------------------------------
          Area |   2.898767   .3044763     9.52   0.000     2.288329   3.509205
         MeanT |   2.516493   2.765539     0.91   0.367    -3.028079   8.061064
   AveRainfall |   .2147792   .0862839     2.49   0.016     .0417905   .3877679
Squarerainfall |  -.0005436   .0007793    -0.70   0.488    -.0021061   .0010189
         _cons |  -123.5464   65.84632    -1.88   0.066    -255.5604   8.467487
---------------+----------------------------------------------------------------
       sigma_u |   6.816854
       sigma_e |  13.680936
           rho |   .1988957   (fraction of variance due to u_i)
--------------------------------------------------------------------------------F test that
all u_i=0:     F(1, 54) =     0.05               Prob > F = 0.8265
```

```
. estimates store fixed

. xtreg Production Area MeanT AveRainfall Squarerainfall, re

Random-effects GLS regression                   Number of obs      =        60

Group variable: CropGroup                       Number of groups   =         2

R-sq:  within  = 0.6794                         Obs per group: min =        30

       between = 1.0000                                        avg =      30.0

       overall = 0.9319                                        max =        30

                                                Wald chi2(4)       =    752.23

corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------

    Production |      Coef.   Std. Err.      z    P>|z|     [95% Conf.Interval]

---------------+--------------------------------------------------------------

Area |   2.926285   .2752559    10.63   0.000     2.386794   3.465777

         MeanT |   1.933302   .7923568     2.44   0.015     .3803112   3.486293

   AveRainfall |   .2117699   .0844554     2.51   0.012     .046240    .3772994

Squarerainfall |  -.0005659    .000766    -0.74   0.460    -.0020672   .0009354

         _cons |  -111.3539   35.35599    -3.15   0.002    -180.6503  -42.05742

---------------+--------------------------------------------------------------

       sigma_u |          0

       sigma_e |  13.680936

           rho |          0   (fraction of variance due to u_i)

------------------------------------------------------------------------------

. hausman fixed .             ---- Coefficients ----

             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))

             |     fixed          .          Difference          S.E.

-------------+----------------------------------------------------------------

        Area |    2.898767     2.926285       -.0275183         .130154

       MeanT |    2.516493     1.933302        .5831906        2.649599

 AveRainfall |    .2147792     .2117699        .0030093        .0176691

Squarerain~l |   -.0005436    -.0005659        .0000223        .0001436

------------------------------------------------------------------------------

            b = consistent under Ho and Ha; obtained from xtreg

            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)

                          =        0.05               Prob>chi2 =      0.9972
```

Annex-3

Khyber Pukhtunkhawa Northern Region Regression Analysis (STATA) Results

Variable	Obs	Mean	Std. Dev.	Min	Max
Production	60	14.75667	3.779129	8.8	24.4
Area	60	7.3	1.153624	5.6	9.2
MeanT	60	17.18069	8.390315	7.358333	26.66667
lograin	60	1.285296	.598302	-.4771213	1.991964
Squarerain~l	60	2187.152	2473.583	.1111111	9636.694

```
. regress Production Area MeanT lograin Squarerainfall
```

Source	SS	df	MS
Model	186.834486	4	46.7086216
Residual	655.792847	55	11.9235063
Total	842.627333	59	14.2818192

Number of obs =	60
F(4, 55) =	3.92
Prob > F =	0.0072
R-squared =	0.2217
Adj R-squared =	0.1651
Root MSE =	3.453

Production	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Area	2.359523	.8148315	2.90	0.005	.7265643	3.992482
MeanT	.522497	.1450955	3.60	0.001	.2317191	.8132749
lograin	2.516785	1.506343	1.67	0.100	-.5019951	5.535564
Squarerainfall	-.0000918	.0003412	-0.27	0.789	-.0007757	.000592
_cons	-14.47869	8.234167	-1.76	0.084	-30.98033	2.02295

```
    Variable |       VIF       1/VIF
-------------+----------------------
       MeanT |      7.33    0.136360
        Area |      4.37    0.228712
     lograin |      4.02    0.248807
Squarerain~l |      3.53    0.283671
-------------+----------------------
    Mean VIF |      4.81
```

```
. xtset CropGroup YEAR
       panel variable:  CropGroup (strongly balanced)
        time variable:  YEAR, 1981 to 2010
                delta:  1 unit
```

```
. xtreg Production Area MeanT lograin Squarerainfall, fe
Fixed-effects (within) regression               Number of obs      =        60
Group variable: CropGroup                       Number of groups   =         2
R-sq:  within  = 0.2260                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.0882                                        max =        30
                                                F(4,54)            =      3.94
corr(u_i, Xb)  = -0.9829                        Prob > F           =    0.0070
-------------------------------------------------------------------------------
    Production |      Coef.   Std. Err.      t    P>|t|     [95% Conf.Interval]
---------------+---------------------------------------------------------------
          Area |   2.022378   .8247224     2.45   0.017     .3689094   3.675847
         MeanT |   1.524098   .6019978     2.53   0.014     .3171649   2.731031
       lograin |   2.637137    1.48222     1.78   0.081    -.3345363   5.608809
Squarerainfall |  -.0000128   .0003385    -0.04   0.970    -.0006915    .000666
         _cons |  -29.55328   11.95755    -2.47   0.017    -53.52673  -5.579831
---------------+----------------------------------------------------------------
sigma_u |  12.002791
       sigma_e |  3.3939236
           rho |  .92596545   (fraction of variance due to u_i)
--------------------------------------------------------------------------------
F test that all u_i=0:     F(1, 54) =     2.93              Prob > F = 0.0925
```

```
. estimates store fixed
```

```
. xtreg Production Area MeanT lograin Squarerainfall, re

Random-effects GLS regression                   Number of obs      =        60
Group variable: CropGroup                       Number of groups   =         2

R-sq:  within  = 0.1844                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.2217                                        max =        30

                                                Wald chi2(4)       =     15.67
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0035
------------------------------------------------------------------------------
    Production |      Coef.   Std. Err.      z    P>|z|     [95% Conf.Interval]
---------------+----------------------------------------------------------------
          Area |   2.359523   .8148315     2.90   0.004     .7624827   3.956564
         MeanT |    .522497   .1450955     3.60   0.000     .2381151    .806879
       lograin |   2.516785   1.506343     1.67   0.095    -.4355943   5.469164
Squarerainfall |  -.0000918   .0003412    -0.27   0.788    -.0007606    .000577
         _cons |  -14.47869   8.234167    -1.76   0.079    -30.61736   1.659982
---------------+--------------------------------------------------------------
       sigma_u |          0
       sigma_e |  3.3939236
           rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
. hausman fixed .
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed          .          Difference          S.E.
-------------+----------------------------------------------------------------
        Area |    2.022378     2.359523       -.3371449        .1273447
       MeanT |    1.524098      .522497        1.001601        .5842505
     lograin |    2.637137     2.516785        .1203519               .
Squarerain~l |   -.0000128    -.0000918         .000079               .
------------------------------------------------------------------------------
```

```
          b = consistent under Ho and Ha; obtained from xtreg
          B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        2.93
                Prob>chi2 =      0.5690
                (V_b-V_B is not positive definite)
```

Annex-4

Khyber Pakhtunkhawa Kharif Crop Regression Analysis (STATA) Results

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
  Production |        90    33.54889    36.21435        1.6      117.3
        Area |        90    16.82889    18.54543        1.1       45.9
       MeanT |        90    29.16407    2.719945   23.21667   32.76667
 AveRainfall |        90    39.40148    36.74218   .3333333      179.3
Squarerain~l |        90    2712.676    4617.266   .1111111   32148.49

. regress Production Area MeanT AveRainfall Squarerainfall
      Source |       SS       df       MS              Number of obs =      90
-------------+------------------------------           F(  4,    85) =  756.67
       Model |  113533.222     4  28383.3055           Prob > F      =  0.0000
    Residual |   3188.4027    85    37.51062           R-squared     =  0.9727
-------------+------------------------------           Adj R-squared =  0.9714
       Total |  116721.625    89  1311.47893           Root MSE      =  6.1246

------------------------------------------------------------------------------
  Production |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        Area |   1.921465   .0374909    51.25   0.000     1.846923    1.996008
       MeanT |  -.7560049   .2858609    -2.64   0.010    -1.324373   -.1876368
```

```
 AveRainfall |  -.0403974   .0370654    -1.09   0.279    -.1140934    .0332986
Squarerain~l |   .0007963   .0002749     2.90   0.005     .0002497    .0013429
       _cons |    22.6926   7.821987     2.90   0.005     7.140394    38.24481
------------------------------------------------------------------------------


    Variable |       VIF       1/VIF
-------------+----------------------
 AveRainfall |      4.40    0.227246
Squarerain~l |      3.82    0.261590
       MeanT |      1.43    0.697163
        Area |      1.15    0.871842
-------------+----------------------
    Mean VIF |      2.70
. xtset RegionGroup YEAR
       panel variable:  RegionGroup (strongly balanced)
        time variable:  YEAR, 1981 to 2010
                delta:  1 unit
. xtreg Production Area MeanT AveRainfall Squarerainfall, fe
Fixed-effects (within) regression               Number of obs      =        90
Group variable: RegionGroup                     Number of groups   =         3

R-sq:  within  = 0.5128                         Obs per group: min =        30
       between = 0.9930                                        avg =      30.0
       overall = 0.9652                                        max =        30
                                                F(4,83)            =     21.84
corr(u_i, Xb)  = -0.9908                        Prob > F           =    0.0000
------------------------------------------------------------------------------
  Production |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        Area |   3.376532   .4200066     8.04   0.000     2.541155    4.211908
       MeanT |   .6328957   1.038413     0.61   0.544    -1.432466    2.698258
 AveRainfall |  -.0101579   .0393571    -0.26   0.797    -.0884375    .0681217
Squarerain~l |    .000651   .0002647     2.46   0.016     .0001244    .0011776
       _cons |   -43.0979   31.29049    -1.38   0.172    -105.3334    19.13763
-------------+----------------------------------------------------------------
```

```
     sigma_u |  34.863391
     sigma_e |   5.723296
         rho |  .97375757   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(2, 83) =     7.17               Prob > F = 0.0013

. estimates store modelfixed
. xtreg Production Area MeanT AveRainfall Squarerainfall, re
Random-effects GLS regression                   Number of obs      =        90
Group variable: RegionGroup                     Number of groups   =         3
R-sq:  within  = 0.4630                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.9727                                        max =        30
                                                Wald chi2(4)       =   3026.70
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
------------------------------------------------------------------------------
  Production |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        Area |   1.921465   .0374909    51.25   0.000     1.847985    1.994946
       MeanT |  -.7560049   .2858609    -2.64   0.008    -1.316282   -.1957278
 AveRainfall |  -.0403974   .0370654    -1.09   0.276    -.1130443    .0322495
Squarerain~l |   .0007963   .0002749     2.90   0.004     .0002575    .0013351
       _cons |    22.6926   7.821987     2.90   0.004     7.361787    38.02341
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |   5.723296
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
. hausman modelfixed .
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |   modelfixed       .          Difference          S.E.
-------------+----------------------------------------------------------------
        Area |    3.376532     1.921465        1.455066          .41833
       MeanT |    .6328957    -.7560049        1.388901        .9982913
 AveRainfall |   -.0101579    -.0403974        .0302395        .0132338
```

```
Squarerain~l |     .000651     .0007963       -.0001453               .
------------------------------------------------------------------------------
            b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic
                  chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       14.36
                Prob>chi2 =      0.0025
                (V_b-V_B is not positive definite)
```

Annex-5

Khyber Pakhtunkhawa Rabi Crop Regression Analysis (STATA) Results

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
  Production |        90    95.57667       68.18        8.8      226.8
        Area |        90    53.77778    34.95603        6.3      111.4
       MeanT |        90    14.29389    3.971282   7.358333   19.23333
 AveRainfall |        90    43.08233    23.69932   3.751667   98.16667
Squarerain~l |        90    1711.599    2109.521     14.075   9636.694

. regress Production Area MeanT AveRainfall Squarerainfall

      Source |       SS       df       MS              Number of obs =      90
-------------+------------------------------           F(  4,    85) =  308.03
       Model |  387018.092     4  96754.5231           Prob > F      =  0.0000
    Residual |  26699.4686    85  314.111395           R-squared     =  0.9355
-------------+------------------------------           Adj R-squared =  0.9324
       Total |  413717.561    89  4648.51192           Root MSE      =  17.723

------------------------------------------------------------------------------
```

```
  Production |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        Area |   1.494946   .1192587    12.54   0.000     1.257827    1.732064
       MeanT |   2.658532   1.195597     2.22   0.029     .2813643    5.035699
 AveRainfall |   1.284764   .1328636     9.67   0.000     1.020595    1.548932
Squarerain~l |  -.0096687   .0018965    -5.10   0.000    -.0134394    -.005898
       _cons |  -61.62059   17.25433    -3.57   0.001    -95.92682   -27.31435
------------------------------------------------------------------------------

    Variable |       VIF       1/VIF
-------------+----------------------
       MeanT |      6.39    0.156553
        Area |      4.92    0.203081
Squarerain~l |      4.53    0.220511
 AveRainfall |      2.81    0.355967
-------------+----------------------
    Mean VIF |      4.66
. xtset RegionGroup YEAR
       panel variable:  RegionGroup (strongly balanced)
        time variable:  YEAR, 1981 to 2010
                delta:  1 unit
. xtreg Production Area MeanT AveRainfall Squarerainfall, fe
Fixed-effects (within) regression               Number of obs      =        90
Group variable: RegionGroup                     Number of groups   =         3

R-sq:  within  = 0.6209                         Obs per group: min =        30
       between = 0.9379                                        avg =      30.0
       overall = 0.9049                                        max =        30
                                                F(4,83)            =     33.99
corr(u_i, Xb)  = 0.3414                         Prob > F           =    0.0000
------------------------------------------------------------------------------
  Production |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        Area |   1.239728   .1240811     9.99   0.000     .9929359    1.486521
       MeanT |   4.464845   1.889858     2.36   0.020     .7059928    8.223698
 AveRainfall |   .6430401   .1352911     4.75   0.000     .3739515    .9121286
```

```
Squarerain~l |  -.0040285   .0016686    -2.41   0.018    -.0073473   -.0007097
       _cons |  -55.72163   30.05476    -1.85   0.067    -115.4993    4.056081
-------------+----------------------------------------------------------------
     sigma_u |  20.991703
     sigma_e |  13.886779
         rho |  .69558899   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(2, 83) =    27.73              Prob > F = 0.0000

. estimates store modelfixed
. xtreg Production Area MeanT AveRainfall Squarerainfall, re
Random-effects GLS regression                   Number of obs      =        90
Group variable: RegionGroup                     Number of groups   =         3
R-sq:  within  = 0.5896                         Obs per group: min =        30
       between = 0.9904                                        avg =      30.0
       overall = 0.9355                                        max =        30
                                                Wald chi2(4)       =   1232.10
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
------------------------------------------------------------------------------
  Production |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        Area |   1.494946   .1192587    12.54   0.000     1.261203    1.728688
       MeanT |   2.658532   1.195597     2.22   0.026     .3152044    5.001859
 AveRainfall |   1.284764   .1328636     9.67   0.000     1.024356    1.545171
Squarerain~l |  -.0096687   .0018965    -5.10   0.000    -.0133858   -.0059517
       _cons |  -61.62059   17.25433    -3.57   0.000    -95.43846   -27.80271
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  13.886779
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
. hausman modelfixed .  ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |   modelfixed       .          Difference          S.E.
-------------+----------------------------------------------------------------
        Area |    1.239728     1.494946       -.2552173        .0342562
```

```
      MeanT |    4.464845     2.658532        1.806313        1.463596
 AveRainfall |    .6430401     1.284764       -.6417235        .0255137
Squarerain~l |   -.0040285    -.0096687        .0056402               .
------------------------------------------------------------------------------
            b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg
    Test:  Ho:  difference in coefficients not systematic

    chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       97.62
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```