Impact of Climate Change on Maize Yield in Pakistan:
A District Level Analysis

By

Memoona Gul

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Supervisor:

Dr. Muhammad Iqbal

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Department of Environmental Economics
Pakistan Institute of Development Economics
Islamabad, Pakistan

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بسم الله الرحمن الرحيم

Certificate

This is to certify that this dissertation by Memoona Gul is accepted in its present form by the Department of Environmental Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the thesis requirements for the degree of Masters of Philosophy in Environmental Economics.

Supervisor: ________________

Dr. Muhammad Iqbal

Chief of Research
Pakistan Institute of Development
Economics (PIDE), Islamabad

Dedicated to My Beloved Parents

CERTIFICATE OF ORIGINALITY

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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Author Name: Memoona Gul

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ABSTRACT

The current study examines the yield and acreage responsiveness of maize crop to change in climatic condition using fixed effect model (FE) and Arellano Bond GMM estimation technique respectively. The results are suggestive that maize yield is sensitive to precipitation at vegetative stage in spring and at reproductive stage in autumn season in Pakistan. Yield of the crop is found to be more sensitive to temperature as compared to precipitation. The abrupt changes in weather conditions (weather shocks) adversely affect yield of maize in Pakistan. The results show that own-price of maize crop has significant positive impact on acreage allocation of the crop while prices of substituted crops have negative impact on acreage. Fertilizer prices also effect acreage allocation of maize crop. Change in precipitation at vegetative stage of spring maize has significant positive impact on area allocation while change in temperature at reproductive stage of spring maize have negative impact on acreage.

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Memoona Gul

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CHAPTER 01

INTRODUCTION

1.1 Background:

Issue of climate change is becoming more severe due to increase in earth's surface temperature and poses a serious threat to nature and humanity in the 21st century. Report of Intergovernmental Panel on Climate Change indicates that greenhouse gases (GHGs) emissions and resultant atmospheric concentrations have led to changes in the climate conditions including temperature and precipitation (IPCC 2001, IPCC 2007).

It has been reported that global average temperature has risen by 0.6ºC in the last 140 years. Global temperature will increase by 1.8˚C to 4˚C with an overall average increase of 2.8˚C in temperature over the next two decades. (IPCC 2007).

The global warming and the resulting climate change are affecting various sectors of the economy including agriculture and human health. Agricultural production particularly depends heavily on temperature, rainfall and other climatic factors. Climate changes have become threatening to agriculture by reducing its productivity (Long, et al., 2006). Changing rainfall pattern, rise in temperature and water availability affects the economic performance of the sector at the global level. Agricultural sector contribution is important but its share is small in the world economy (2.9 percent for the world as a whole[1]). In developed countries agricultural contributes less than 2 percent of gross domestic

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[1] World Bank data on agricultural value added as a share of GDP in 2008, http://data.worldbank.org.

product, however in developing or low income countries its share is almost one fourth of gross domestic product.

It is widely accepted that the impact of climate change would be unevenly distributed across the regions affecting the agriculture more in low income developing countries as compared to the developed countries (Kurukulasuriya and Mendelsohn, 2008; and Seo et al., 2005). The developing and low latitude countries are expected to suffer more losses from climate change, because they have limited adaptive capacities. In contrast, the regions which have high latitude will generally benefit from climate change. In low-latitude regions, moderate temperature increases (1–2ºC) are likely to have negative yield impacts for major cereals whereas warming of more than 3ºC would have bad impacts on agricultural productivity in all the regions (IPCC 2007).

Agriculture sector plays an essential role in Southeast Asia, contributing more than 10 percent to gross domestic product (GDP) in most regional economies, and providing jobs for over one third of the working population in the region. As is the case in other developing regions of the world, nearly three fourths of the poor in South Asia reside in rural areas, and a large majority of them are dependent on agriculture. Consequently, agricultural development has important implications for the reduction of poverty in South Asia. According to the Economic Survey of Pakistan (2011-12) agriculture sector contributes 21 percent to the national GDP. "Impacts of climate change are more devastating in South Asia and may result 50 percent reduction in wheat productivity by 2050 "(MoE, 2009).

Different factors affect the productivity of food crop like increase in temperature, change in rainfall pattern, soil condition and rising level of CO_2 concentration. The increasing concentration of CO_2 has positive impact on crops yield especially the C4 crops, by increasing photosynthesis process of plant and reducing the water loss. However, rise in temperature shortens growing season length of crops and reduces yields.

Pakistan has mostly arid and semi-arid land area and increases in temperature here resulting from climate change is higher than the global averages. Rainfall level is very low in Pakistan, about 60 percent of area has less than 250mm rainfall annually and 24 percent receives 250-500 mm. Its rivers are mostly fed by the Hindu Kush Karakoram-Himalayan glaciers which are reported to be receding quickly due to global warming posing serious threat to nation's water, food and energy security.

Maize is one of the five major crops of the country and occupies an important place in the current cropping pattern of Pakistan. It positions third among food grains after wheat and rice. Human beings not only consumed it as a food grain but it is also consumed as feed for livestock and poultry besides being a good feed crop. It is also an important source of raw material for industry, where it is being widely used for the preparation of corn starch, corn oil, dextrose, corn syrup, corn flakes, cosmetics, wax, alcohol and tanning material for leather industry. The bulk 97 percent of the whole maize production comes from provinces of Khyber Pakhtunkhwa and Punjab. Khyber Pakhtunkhwa accounts for 57 percent of the total area and 68 percent of total production while contributes of Punjab is 38 percent acreage with 30 percent of total maize grain production. Only 2 to 3 percent of maize is produced in the provinces of Baluchistan and Sindh (PARC, 2013).

Despite linkages of maize with other sectors of the economy and its importance as food, feed and fodder provider, yield and acreage responsiveness of the crop to climate changes is not well explored. Few studies including

Rashid and Rasul (2007) and Shah (2012) estimated the climate change impact on maize crop output in Pakistan. These papers addressed the issues at disaggregate (district or agro-ecological zones) level. Little research has been conducted to examine the impact of climatic variables at important phenological stages of the maize crop. Similarly, response of maize acreage to climate change has not been investigated.

1.2 Research Gap:

In the existing literature, many of the studies have been conducted to analyze the impact of climate change on maize crop productivity in different regions of the world. These studies used the weather variable (temperature and precipitation), measured as seasonal averages (for growing season of crops) or at the most averages over various periods representing different stages of crop growth – the variables often being aggregates at the national level. Although the results of the conducted research are mostly in agreement with agronomic research, however, climate change being a long run phenomenon, the results of these studies do not capture the impact of climate change on crop yields. Moreover, the climate changes may differ in direction and quantum in different areas of a country making it more relevant to conduct the analysis at disaggregated level (zone or district level). Further, responsiveness of the crop acreage to climate change has been rarely examined by the researchers.

Proposed study covers the grey area of research and would use climatic variables at disaggregate level to quantify the impact of climate change on maize crop according to different phenological stages. Twenty years moving average of the climatic factors (temperature and precipitation) will be used to estimate the impact of climate change on yield and acreage of maize crop. The other important control factors shall include variable like land, fertilizer, tractors, input prices, own price of maize, and yields and prices of the substitute crops etc. The climatic conditions in various phenological stages play a very crucial role in determining the crop yield performance. Therefore, for analysis of the yield responsiveness, this study would incorporate the climate variables according to the phenological stages of the maize crop. Production function approach would be employed for empirical analysis using district level panel data regarding major maize producing district of Pakistan over the period 1980-81 to 2009-10.

1.3 Objective of the Study:

The objective of this research is to study the responsiveness of maize yield and acreage to climate changes in Pakistan. The study aims to investigate the effect of climate change (long run averages of temperature and precipitation) as well as weather shocks (deviation of current year values of relevant variables from the corresponding long run averages) on maize yield and allocation of acreage to maize production. This study also suggests policy recommendation for sustained growth of maize production based on empirical findings.

1.4 Hypothesis:

This study would provide empirical estimates of the impact of climatic variable (temperature and precipitation) on area allocation to maize production and its yield. The hypotheses of the study are as follows:-

Hypothesis I

- H_0: overtime variations in temperature have no effect on yield of maize crop.
- H_1: overtime variations in temperature have an effect on yield of maize crop.

Hypothesis II

- H_0: overtime variations in precipitation have no effect on yield of maize crop.
- H_1: overtime variations in precipitation would have an effect on yield of maize crop.

Hypothesis III

- H_0: overtime variations in temperature has no effect on area allocation to maize crop
- H_1: overtime variations in temperature effects area allocation to maize crop

Hypothesis IV

- H_0: overtime variations in precipitation has no effect on area allocation to maize crop
- H_1: overtime variations in precipitation has effects area allocation to maize crop

1.5 Organization of the study:

The present study is composed of six chapters. Chapter 1 presents introduction and objectives of the study. Chapter 2 deals with review of the literature and discusses different methodologies/models used to study the impact of climate change on crop yield and acreage. Theoretical framework of the study is outlined in Chapter 3. Data description, variable construction and methodology are presented in Chapter 4. The empirical estimation and results are discussed in Chapter 5. Finally, Chapter 6 concludes the study and forwards, policy recommendation.

CHAPTER 02

LITREATURE REVIEW

Globally increase in GHGs emission has led to rise in earth surface temperature during the last several decades. Due to climate change world faces consequences like increasing precipitation rate, glaciers melting, floods, cyclones and extreme weather events. Change in climatic pattern, effects the various sectors of the economy especially agricultural and food security are most vulnerable to climate change. Rise in temperature and decrease in precipitation rate affect the crops yield. The overall impacts of climate change on agriculture are expected to be negative, threatening global food security, although there would be gains in some crops in some regions of the world. Populations in the developing world, which are already vulnerable and food insecure, are likely to be the most seriously affected(Nelson, Rosegrant et al. 2009).

Changing climatic pattern will have a considerable impact on agricultural productivity and its productivity have consequences on both food supply and food security at the world wide level but its effects will be seen most in least developed countries (LDCs). LDCs face decrease in agricultural productivity because there is a close link between climate change and agricultural productivity. A greater frequency of extreme events, heat stress, droughts and floods, would increasingly have negative impacts on crop yields. By 2080, the agricultural production in LDCs may reduce by 20 percent due to change in climate condition, while yields could reduce by 15 percent on average(Masters, et al., 2010). This section of the study deals with review of the available literature on impact of climate change as well as acreage response of food crops to different price and non-price factors.

Chen et al., (2013) discussed the crop yield condition in China through the unique country level panel and daily weather dataset. They found a nonlinear and asymmetric relationship between the crops yield and climate variable (temperature, precipitation). The results depicted that extreme high temperature has harmful impact on crop yield. China’s corn and soybean sectors face an economic loss of $220 million.

Cai et al., (2012) studied relationship between corn yield and weather condition in United Stated using panel data regarding the period 2002-2006. They conducted a geographically weighted panel regression (GWPR) analysis to demonstrate the spatial variability of climate-crop yields relationship for the continental U.S. counties. The results showed that, temperature have marginal negative effect on corn yield in warmer region and cooler region have positive effect on corn yield.

Siddiqui et al., (2012) analyzed the climate change impact on four main crops (rice, wheat, cotton and sugarcane) of Pakistan. This study used panel data of seven districts for the period 1980-2008 to estimate the fixed effect model. Results of the study showed that effect of climate change varies on every growth stage of crop, and this impact also varies from crop to crop. The estimated results of the study showed effect of temperature on wheat was positive but the effect of precipitation is negative. Rise in temperature is harmful for rice production and precipitation does not affect rice productivity. Results of the study showed that increasing level of temperature and precipitation have negative impact on production of cotton and sugarcane.

Ashfaq et al., (2011)analyzed the impact of climatic variable on productivity of wheat in mixed zone of Punjab using data for the period 1980-2009. Wheat productivity was affected by climate change (change in temperature and precipitation) differently at different stages of wheat crop growth. An increase in temperature by one degree centigrade at sowing stage enhances productivity of wheat crop about 146 kg ha^{-1}. Productivity of wheat was reduced with increase in mean minimum temperature at vegetative growth stage. At maturity stage the productivity gain of nearly 137 kg ha^{-1} was observed as a result of 1°C rise in mean maximum temperature. Precipitation increased wheat productivity by about 276 kg ha^{-1}.

Shakoor et al., (2011) examined the impact of climate change on net farm revenues in Rawalpindi division using survey data. Result of the study shows that net revenue reduces due to increase in temperature. Increase in temperature by one percent would lead to Rs 4180 loss to the net revenue per year. However, precipitation has significant beneficial effect for crop production in the arid region. In the overall, the negative impact of temperature exceeded the positive effect of rainfall in the region under study.

Ahmed and Schmitz, (2011) studied the climate change impact on the productivity of crops (wheat, maize, rice) using province level panel data for the period 1987-2004. The fixed effect estimation results showed that a relatively small negative effect of climate change on the food crop sector, as it is dominated by wheat production, under irrigated conditions in Pakistan. The use of fertilizers had a significant positive effect on crop yields. An increase of 1˚C in mean temperature reduces crop yields per hectare by 44 kg.

Attavanich and McCarl, (2011)analyzed the effects of climatic variables, crop production technology, and atmospheric CO_2 on yields of five major crops (corn, sorghum, soybeans, wheat and cotton) using US data for the period 1950-2009. The results showed that C3 crops positively responding to the elevated level of CO_2, whereas C4 crops responded negatively to the elevated level of CO_2. The effect of crop technological progress on mean yields was non-linear (with inverted-U shape) in case of all crops, except cotton.

Rowhani et al., (2011)examined relationship between climate and yields of maize, sorghum and rice crops for Tanzania. The study concluded that a temperature increase of 2˚C by 2050 would reduce the average maize, sorghum and rice yields by 13, 8.8, and 7.6percent respectively. In Tanzania, both inter- and intra-seasonal changes in precipitation and temperature were associated with negative changes in maize, sorghum, and rice yields.

Hanif et al., (2010)quantified the climate change impact on agricultural sector using regional and country level panel data regarding the period 1970-2009. The results of the study showed that mean minimum Kharif temperature (April-September) had a significant positive relationship with land prices whereas mean maximum temperature had an insignificant effect. The mean minimum Rabi temperature (October-March) affected land prices significantly but negatively whereas mean maximum Rabi temperature had a significant and positive relationship with land prices. Increase in Kharif season precipitation lead to higher land prices whereas Rabi season precipitation was negatively related to land prices.

Deressa and Hassan, (2009) applied Ricardian approach to examine the impact of climate change on net farm revenue in Ethiopia using household survey data collected from different agro-ecological zones of the country. Results of the study indicate that the impact of climate change is not uniformly distributed across the different agro-ecological zones of Ethiopia. Increase in temperature during winter and summer reduce crop production per hectare, and increase in precipitation during spring season increase crop production per hectare.

You et al., (2009) used crop simulation models to examine the impact of climatic variables on wheat yield in China. The results based on crop specific panel data for the period 1979-2000 showed that wheat yield reduced by 3-10percent because of 1.8 ˚C increase in temperature. Wheat yield in China has declined by 4.5percent over the past two decades because of rise in temperature.

Kucharik and Serbin, (2008) discussed the climate change impact on corn and soybean yield in Wisconsin region of U.S. They found spatial variability in climate trends at the county level has contributed to variable trends of soybean and corn yields. Results showed that if only temperature increase occurs during summer, then corn and soybean yields would reduce by 13percent and 16percent respectively, but if precipitation occurs in summer yield would be boosted by 5-10percent due to interaction impact.

Schlenker and Roberts, (2008) examined the impact of climate change on corn, soybean and cotton yield in US. The study identified non-linear and asymmetric relationships between crops yields and temperature.

Rashid and Rasul, (2007)discussed the impact of climate variability on maize production in the area of Potohar plateau (Chakwal, Rawalpindi, Kamra and Jhelum) of Pakistan for the period 1991-2008. They found that rainfall plays an important role during the reproductive and vegetative growth stages of maize. An increase in rainfall increases, maize yield up to a certain limit, beyond which yield declines with increase in rainfall. Thus both excess and shortage of rainfall effect maize production in potohar region.

Tao et al., (2006)studied the impact of temperature changes on maize productivity and water use in China. Process-based crop model was used against a global mean temperature (GMT) to deal with the uncertainties in maize productivity. The study used data for the period 1961-1990 regarding five stations (Harbin, Shenyang, Jinan, Zhengzhou, and Chengdu) that account for major food production in China. The results of the study showed that increase in temperature reduced yield of irrigated maize.

Bosello and Zhang, (2005)estimated the climate change impact on world-wide economy and agricultural sector by 2050. Estimation about future climate condition is done by using a static computable General Equilibrium Model and Crop Growth Model on cereal productivity. Result of the study shows that influence of climate change on world food supply and welfare had limited effect, but according to distributional consequences, it had stronger negative effect on developing countries as compare to develop countries all over the world.

Seo et al., (2005) used Ricardian model to examine the impact of climate change on four most important crops of Sri Lanka. The study measures the both temperature and precipitation effects on country’s agricultural economy. Rise in temperature is harmful whereas, increase in rainfall has beneficial effect. Applying the estimated regression results to five climate scenarios, they calculated an array of effects ranging from a loss of 20 percent to a gain of 72 percent. The scenarios with losses had overall harmful temperature impacts, with offsetting precipitation benefits. The scenarios with gains had harmful temperature effects, which were dominated by beneficial changes in rainfall.

Gbetibouo and Hassan, (2005) used Ricardian model for measuring the impact of climate change on crops in South Africa including maize, wheat, sugarcane, sunflower, groundnut and soybean. This study used crop revenue data of 300 districts of South Africa for the period 1970-2000. The results showed that, there was a quadratic relationship between climate variables and net revenue per hectare. Furthermore, the climatic variables have a hill-shaped relationship with net revenue in winter whereas in summer climatic variables have a U shaped relationship. The found that crops were more sensitive to change in temperature as compare to that in precipitation. Change in temperature affected net revenue positively, whereas change in precipitation affected negatively.

Liu et al., (2004) examined the climate change net revenue using Ricardian model. Findings of the study showed that increase in temperature and more precipitation have overall progressive impact on China's agricultural economy. It was also found that autumn effect was the most positive, but spring effect was the most negative on China's agricultural economy.

Kapetanaki and Rosenzweig, (1997) used CERES-Maize model, embedded in the Decision Support System for Agro technology Transfer (DSSAT) to examine the impact of climate change on maize in Greece. Results of the study showed maize yields reduction in Central and Northern Greece up to 20 percent. Physiological effect of CO_2

on yield and crop growth was simulated. Production level of maize crop decreased due to reduced duration of growing period.

Makadho, (1996) used the Dynamic Crop Growth Model and Global Circulation Models (GCMs) to analyzed the climatic impact on maize productivity in Zimbabwe. The results suggested that global climate change may influence the future maize yield in Zimbabwe. The maize growing season would become shortened. Because of hydrological uncertainties in the GCMs, future water supply for irrigation remains unknown. The suggested adaptation plans included changes in the management practices of the corn cultivation (irrigation and planting date); and shifting to cultivars that might withstand the effects of climate change.

Huang and Khanna, (2010) used the dynamic panel GMM estimation technique to examine the effect of climate variables on crops (corn, soybeans and wheat) yield and acreage. Result of the study showed that crops response positively to its own prices but the prices of competing crops and fertilizer have negative impact on crop yield and acreage. They found that change in temperature effect positively on crop yield whereas more precipitation enhances the corn and soybean yield but its impact on wheat yield is inconclusive.

Kaufmann and Snell, (1997) used the surveys data to measure the effect of economic environment, site characteristics and climate change on corn yield for U.S.A. The study used the climatic variable (temperature and precipitation) both in linear and quadratic form. The result of study showed that the every variable is in linear form has a positive effect on crop yield but the quadratic form has a negative effect on the crop yield.

Haim et al., (2008) used the production function approach to study the impact of climate change on the output of wheat and cotton crop for Israel. The research found that rise in temperature level and reduced in rainfall will effect cotton yield negatively and use of nitrogenous fertilizers and changing the sowing date could be the best adaption to climate change.

CHAPTER 03

THEORETICAL FRAMEWORK

3.1 Introduction:

It is obvious that many price and non-price factors effects the maize crop response in Pakistan. It is observed that input prices (fertilizer prices), output price (maize crop price), competing crops prices (wheat, rice and sugarcane), climatic factors (temperature. Precipitation), and area under maize crop have effects on the acreage allocation to the maize production.

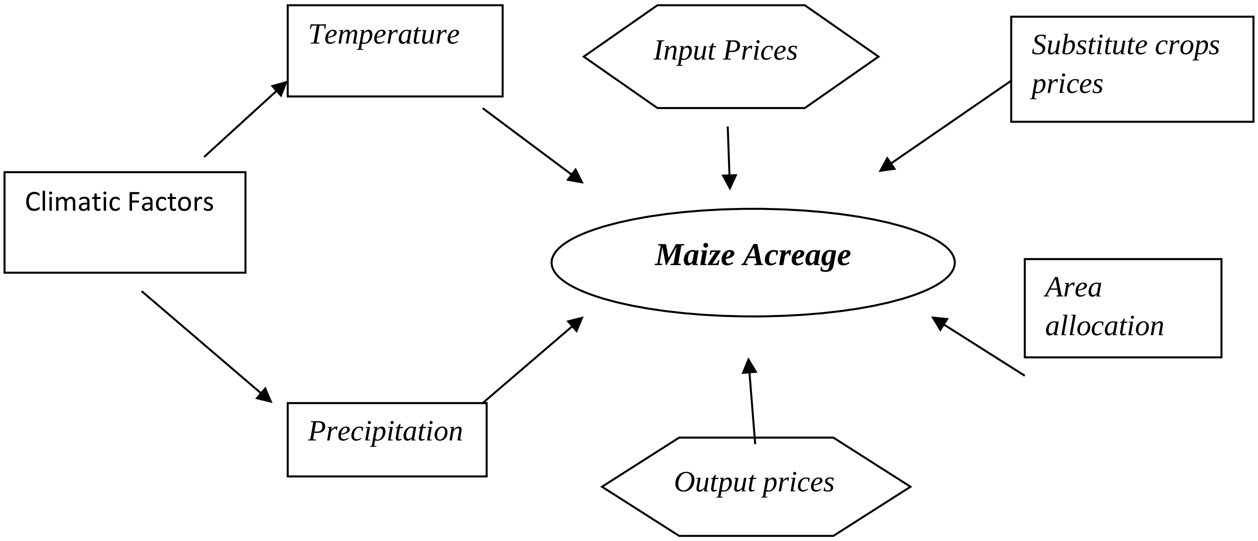

Figure 3 -1: Different Factors Influencing the Maize Acreage

Climate change (temperature, precipitation) is presumably one of the major factors which effect the maize yield. Along with climatic factors different economic factors like fertilizer nutrients, area under maize crop and use of tractors etc. have impact on yield of maize crop.

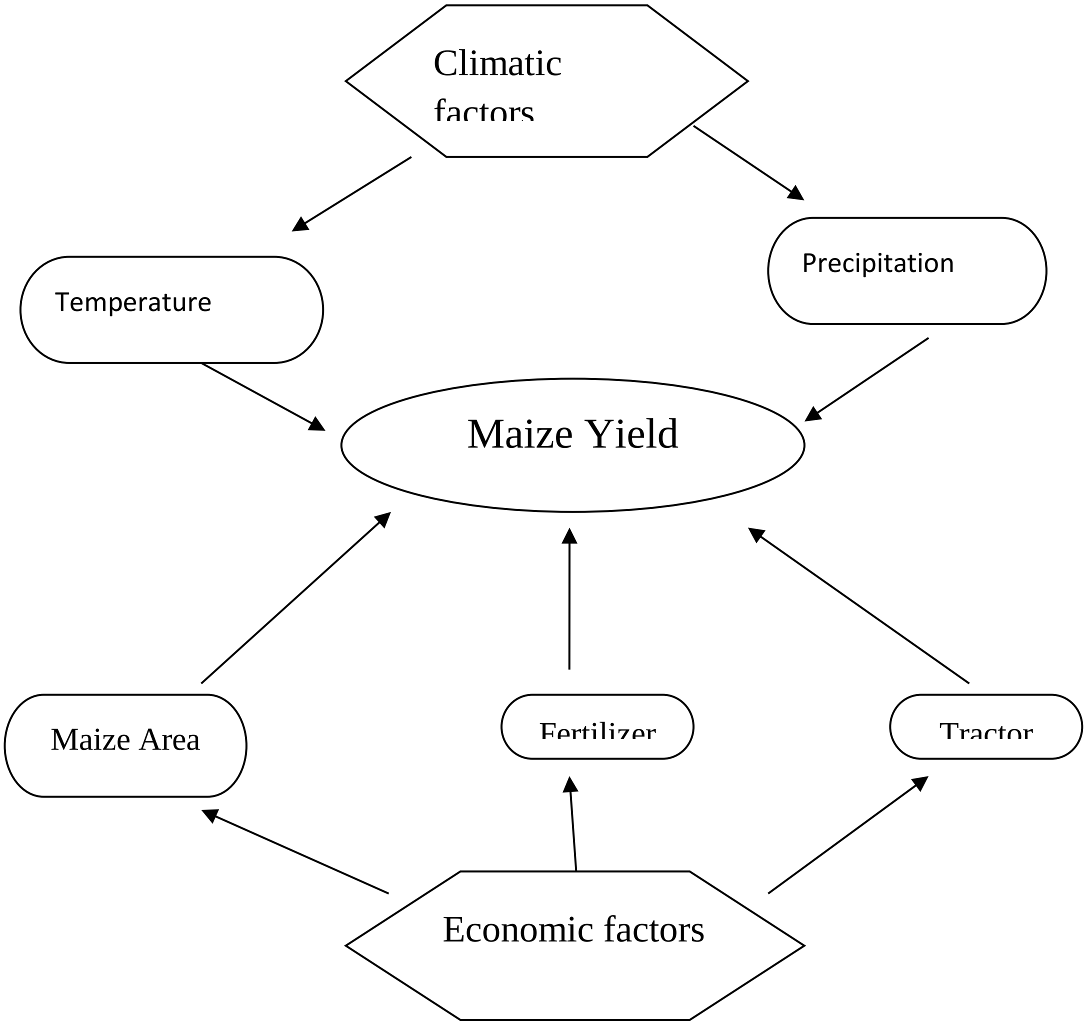

Figure: 3-2 Different Factors Influencing the Maize Yield

3.2) Climate Change and Yield Model:

Climate change is a global phenomenon, adversely impacting the agricultural sector especially in developing countries. Three approaches namely Production function approach, Ricardian approaches and simulation models have been widely used by the researchers to evaluate the impact of climate change on agricultural output. Each of these models is unique in nature and has their own strengths and weaknesses.

Simulation models are used to analyze the change in climate in the future and climate change impact on agricultural yield include-CCSR, AOGCM, PCM, CCCma, CERES, and APSIM[2]models. These models are used to predict future changes in climatic variables and their impact on agriculture. Simulation is a good technique but is costly to be used especially in developing countries. Moreover, this approach does not accommodate the crops substitution and adaptation to climate change.

The Ricardian approach was established by(Mendelsohn et al., 1994) to analyzed the effect of climate change on agricultural land values. This approach analyzed the climate change impact on agricultural sector on the basis of net rent or value of farmland. This approach does not analyzed climate change impact on the basis of yield or total production like traditional approaches. Because land rents are assumed to reflect the value of the activity to which that land is allocated, these models are thought to embody

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[2] The Center for Climate Systems Research (CCSR), *Atmosphere-Ocean General Circulation Model (AOGCM)*, *Parallel Climate Model (PCM)*, Canadian Centre for Climate Modeling and Analysis*(CCCma)*,Crop Estimation through Resource and Environment Synthesis (CERES), Agricultural Production System Simulator (APSIM)

adaptation, thus controlling for the “dumb farmer” scenario that were identified in traditional production function approaches.

The Ricardian approach allows for possibilities of crops substitution and farm level adaptations. This feature makes it more attractive in evaluating the impact of climate change on agriculture. However, the major drawback of this approach is the unavailability of reliable data for agricultural farm values. Developing countries have imperfect land markets, these countries does not have proper documentation of agricultural land. Another criticism of this approach on its implicit assumption of constant prices and zero adjustment cost making the welfare calculations biased (Cline, 1996), and provides lower-bound estimates of the costs of climate change (Quiggin and Horowitz, 1999). This approach assumed that prices are in equilibrium condition, and prices could change for prolonged time period if the huge climate change occurs. So that sometime this approaches over or under estimate the climate change impacts depending on how the prices change.

Production function approach is most commonly used technique to analyze the climate change impact on crops yield. This approach provides detailed understanding of the physical, biological and economics responses and adjustments. This approach generates more accurate yield responses as it relies on relatively more reliable data in terms of the relationship between yield and climatic variables while controlling for the other important physical factors and socioeconomic variables.

Segerson, (1999) and Cabas et al., (2010) used modified production function approach by introducing 20 to 30 years moving averages of temperature and precipitation in estimation of production function to capture the influence of change in climatic condition on crop yields more effectively. The impacts of weather shocks were introduced in the same function by taking the deviations of current weather variables from their respective long-term means. Some authors including Adams et al., (2003) and Felkner et al., (2009)introduced quadratic terms of climatic variables to examine whether the impacts of climate change on crop production are non-monotonic or not. . In order to account for the joint impact of temperature and precipitation Hansen, (1991), Weersink et al., (2010) and Cabas et al., (2010) further extended the production function by introducing the interaction terms. The present study will use the modified production function to assess the impact of climate change on maize yield in Pakistan.

3.3) Climate Change and Acreage Response:

Many price and non-price factors affect the acreage response of maize crop.Menz and Pardey (1983) found that the significant response of corn yield to prices for period 1951-71. Houck and Gallagher (1976) Examined the effect of corn and fertilizer prices on corn yields in the U.S. for the time period 1951-80 and found significant response of corn yield. Choi and Helmberger (1993) investigated the responsiveness of corn, soybean and wheat yields to crop prices and fertilizer application rate using time series for 1964-88 and a two-stage recursive regression model by first estimating the fertilizer use equation and then the crop yield equation.

The present study includes a log linear functional form of acreage response model. The inclusion of lagged acreage, input and output price variables as independent variables in the model may create an endogeniety problem, similarly in the estimation of the crop yield models. In addition, the presence of lagged dependent variables also gives rise to autocorrelation. To appropriately take care of the issues inherited in such a dynamic panel data model with a relatively short time dimension and a large cross-section dimension, a fixed-effect Arellano-Bond difference GMM estimator is used (Arellano and Bond, 1991). Climatic variables (temperature and precipitation) are included due to their potential influence on price expectations and therefore on crop acreage/yield decisions. Moreover, past weather is included because it is exogenous and varies widely across locations and time and can affect expected prices by affecting inventories (Schlenker and Roberts, 2008)

CHAPTER04

DATA AND METHODOLOGY

4.1 Introduction:

This study would be an empirical analysis based on districts level panel data regarding climatic factors (temperature and precipitation) area allocated to maize production, crop yield and other economic variables related to twelve major maize growing districts[3] of Pakistan for the time period 1981-2010.

4.2 Data Sources and Variables Construction

4.2.1 Economic variables:

The Economic variables used in this study included acreage and yield of maize, fertilizer nutrients applied to crop, and tractors availability for farm use in each district. The construction of these variables is described below. Further description of these variables and data source are given in Appendix A.2

a) Maize yield:

Maize yield will be a dependent variable. Maize yield during a year for each district will be calculated by dividing total maize production (measured in thousand tonnes) by area under maize (measured in thousand hectares) during the same year in the respective districts.

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[3] Sargodha, Faisalabad, T T Singh, Jhang, Okara, Sahiwal, Vehari, Jhelum, Peshawar, Mansehra, Swat and Mardan

b) Fertilizer per Hectare:

The application of fertilizers nutrients like nitrogen, potassium and phosphate to maize crop is quite common in Pakistan. The district level data regarding off-take of nutrient tones by type are available in various publications of National Fertilizer Development Center, federal and provincial Bureaus of Statistics, and provincial departments. The use of fertilizers nutrients for maize crop is calculated on the basis of share of maize in total nutrients based on farm surveys conducted by (NFDC) during different years.

For fertilizer use in maize we multiplied the share of maize crop (in total consumption of fertilizer nutrients) with off-take of total fertilizer nutrients in each district using the following formula.

$$FCC = \%\mathrm{FC} \times \mathrm{TAF}$$

Where FCC is fertilizer application on maize crop at district level, FC is the ratio of the total fertilizer nutrients used in maize production, and TAF is total off-take of fertilizer nutrients in each respective district.

Table 1 Share of Maize in Total Fertilizer

Year	**Share(%)**
1981-1988	0.70
1989-1996	0.40
1997-1998	0.43
1999-2004	2.24
2005-2010	0.15

Source: NFDC

c) Tractors:

Data on total number of tractors in selected districts of Pakistan from 1980 to 2010 is obtained from Punjab development statistics and KPK development statistics. Census of agricultural machinery conducted in the year 1975, 1984, 1994 and 2004 also have district level information on number of tractors. The same were used for exponential interpolation of the data as and when needed.

4.2.2 Climatic variable:

Temperature and precipitation are two important climatic variables. The agricultural sector is sensitive to changes in temperature and precipitation which are expected to affect the maize productivity. In Pakistan maize crop is grown twice a year, spring maize during February/March to May/June and autumn maize during July/August to October/November (Table 2).

Table 2 Duration of Various Phenological Stages of Maize Crop in Pakistan

Stage(s)	Maize	
	Spring	Autumn
Vegetative Stage (V1-VT) About 56 days	February-March	July-August
Reproductive Stage (R1-R6) About 60 days	April-May	September-October

The spring maize crop have two growth stages, vegetative stage of about 56 days duration (February-March) and reproductive stage of about sixty days duration (April-

May). The autumn crop completes vegetative stage during July to August and reproductive stage during September to October.[4]

Twenty year moving averages of mean temperature (˚C) and precipitation (mm) during each phenological stage are calculated to represent the climate change. The weather shocks are estimated as the deviation of current temperature and precipitation from the respective long run norms during each phenological stage.

4.3) Econometric Model:

This study uses a balanced panel data concerning twelve districts and 30 years. Panel data is a combination of time series and cross-sectional data. As defined by (Gujarati and Porter 1999) "this is a special type of pooled data (combination of cross-sectional or time series) in which the same cross-sectional unit (say, a family or firm) is surveyed over time." Panel data are of two types i.e. balanced panel data and unbalanced panel data. If each entity (firms, individual, etc) has same number of observation, it is said to be balanced panel. If each subject has different number of observation it is said to be unbalanced panel.

Panel data are useful for controlling individual heterogeneity. It has more information, efficiency, variability and degree of freedom. It is also best suited to study the dynamics of change and deduction of measurement. Panel data enable to study more complicated behavioral model. Change in technologies can be better handled using panel data than modeling it by pure time series or pure cross-section. It can reduce the bias if we used the

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[4] See Appendix A.3 for Identifying Stages of Development of Maize

aggregate firms or individuals. It is based on number of observation and it can increase the sample size. Panel data models deal with the complicated behavioral models than purely cross section or time-series data.

4.3.1) Fixed Effect Model:

Two models are used in analysis of panel data, fixed effect model (FEM) and random effect model (REM). The term "fixed effect" is due to the fact that, although the intercept may differ across subjects, each entity's intercept does not vary overtime, that is, it is the time invariant. The FEM using dummy variables is known as the least square dummy variable models. FEM is appropriate in situation where the individual specific intercept may be correlated with one or more regressions. Even if it is assumed that the underlying model is pooled or random, the fixed effect estimators are always consistent.

$$Y_{it} = \beta_0 + \beta_i X_{it} + U_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.1)$$

$$U_{it} = \alpha_i D_i + \varepsilon_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (4.2)$$

$$Y_{it} = \beta_0 + \beta_i X_{it} + \alpha_i D_i + \varepsilon_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.3)$$

Where X_{it} vector of explanatory variables (physical variables like land, fertilizer and machinery etc) and climatic variables like temperature and precipitation. α_i is vector effect of X_{it} on conditionalY_{it}, effects are denoted by$\alpha_i D_i$[5], $\alpha_i$is called as individual effect or individual heterogeneity and dummy$D_i$capture the characteristics which are specific to district climatic condition, soil attributes and knowledge of farm practices which makes

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[5] Mundlak, (1978)

the district different from others. Fixed effect model also shows that fixed term in this model is correlated with explanatory variables (cross-section specific characteristics). In agriculture mostly fixed effect model (Lee and Nadolnyak, 2012)are used in the panel data study if the sample is not chosen randomly (Wooldridge, 2005).

4.3.2) Random Effect Model:

Random effect model (REM) is consistent even if the true model is the pooled estimator. However if the true model is fixed effect model, the random effect estimators is inconsistent. If the dummy variables do in fact represent a lack of knowledge about the model, why not express this ignorance through the disturbance term. This is preciously the approach suggested by the proponents of the so called error component model (ECM) or random effect model (REM). Baltagi and Chang (1994) showed that estimating only balanced data extracted from unbalanced data fully loses validity.

$$Y_{it} = \beta_0 + \beta_i X_{it} + U_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.4)$$

$$U_{it} = v_i + \varepsilon_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (4.5)$$

$$Y_{it} = \beta_0 + \beta_i X_{it} + v_i + \varepsilon_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.6)$$

To evaluate the effect of heterogeneity in the data fixed effect or random effect model are used but for this case due to cross-sectional heterogeneity fixed effect model would be preferred as suggested by the literature. However the final decision about which model is most appropriate the (Hausman and Taylor 1981) test would be used.

4.4) Empirical Equation:

The production function approach will be used to quantify the effect of climatic variables on maize yield. Empirical equation will be:

$y_{it=f}(MA_{it}, C_{it}, Mach_{it}, F_{it})$

Where

$\text{t represents year}(1,2,3 \ldots \text{T});$ $\text{i represents district}(1,2,3 \ldots \text{n});$ Y represents the maize yield; MA represents the area under maize, F is the total nutrients of fertilizer used in maize production; and C represents the climatic variable (temperature and precipitation).The mean value of temperature and precipitation are computed according to maize crop development stages. Mach represents the machines like tractors used in agricultural operations.

The empirical production function model that will be estimated in this study is as given below[6]:

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[6] See Appendix A.2 for List of Variables and Data Sources

$$
\begin{aligned}
lnY_{it} = \alpha_\circ &+ \beta_1 ln(MA)_{it} + \beta_2 ln(F)_{it} + \beta_3 ln(tractor)_{it} + \beta_4 (TVSS)_{it} + \beta_5 (TRSS)_{it} \\
&+ \beta_6 (TVSA)_{it} + \beta_7 (TRSA)_{it} + \beta_8 (PVSS)_{it} + \beta_9 (PRSS)_{it} + \beta_{10} (PVSA)_{it} \\
&+ \beta_{11} (PRSA)_{it} + \beta_{12} (PVSS)^2_{it} + \beta_{13} (PRSS)^2_{it} + \beta_{14} (PVSA)^2_{it} + \beta_{15} (PRSA)^2_{it} \\
&+ \beta_{16} (TVSS)^2_{it} + \beta_{17} (TRSS)^2_{it} + \beta_{18} (TVSA)^2_{it} + \beta_{19} (TRSA)^2_{it} \\
&+ + \beta_{20} (PVSS * TVSS)_{it} + \beta_{21} (PRSS * TRSS)_{it} + \beta_{22} (PVSA * TVSA)_{it} \\
&+ \beta_{23} (PRSA * TRSA)_{it} + \beta_{24} (DPVSS)_{it} + \beta_{25} (DPRSS)_{it} + \beta_{26} (DPVSA)_{it} \\
&+ \beta_{27} (DPRSA)_{it} + \beta_{28} (DTVSS)_{it} + \beta_{29} (DTRSS)_{it} + \beta_{30} (DTVSA)_{it} \\
&+ \beta_{31} (DTRSA)_{it} + \beta_{32} (time)_{it} + \varepsilon_{it} \dots\dots\dots\dots\dots\dots\dots\dots (4.7)
\end{aligned}
$$

In this model, quadratic term will be estimated to capture the non-linear relationship between maize yield and climatic variable, interaction term are also used to capture the joint impact of temperature and precipitation on maize yield.

Although fixed effects are introduced on this model but we would use Hausman test[7] given in the following for selection of the final model.

$$H = (\beta^{FE} - \beta^{RE})\ [var - var(\beta^{RE})]^{-1} (\beta^{FE} - \beta^{RE}) \sim X^2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .. (4.8)$$

The Hausman specification test usually checks the existence of fixed or random effect in the model. For test application, first model using the Random effect model is estimated after which we apply the Hausman[8] test based on the assumption of no correlation. It means that both GLS and OLS are consistent while OLS is not efficient and under the alternate OLS is consistent while GLS is not. Usually, this test is operational under the null hypothesis that random effect is reliable and efficient and consistent fixed effect is

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[7] Green, 2012

[8] Hausman, 1978

considered as alternative hypothesis. The test statistics would decide that which estimation technique could be used.

4.5) Panel Unit Root:

Panel unit root tests have been one of the most active research areas for the past several years. This is largely due to the availability of panel data with long time span, and the growing use of cross-country and cross-region data over time to test for many important economic inter-relationships, especially those involving convergences/divergences of various economic variables. Different panel unit root tests are used to check that weather the series are stationary or not when we are dealing with a series that vary over time. Panel unit root would be checked to avoid any spurious regression. In regressing the series of non-stationary with another non-stationary series may lead to what is known as spurious regression. Many tests for panel unit roots have been proposed. Among those, the most common tests in practice are Levin-Lin (LL) and Im-Pesaran-Shin (1997) (IPS). Levin-Lin (LL) dealing with persistence parameters, that is constant across the cross-section and Im-Pesaran-Shin (1997) treat these parameters as cross-section specific. All of these tests have their own merits and demerits.

4.5.1) Im-Pesaran-Shin Test:

Im, Pesaran and Shin (IPS) Test is the best test among the series because this test incorporates the heterogeneity among the cross-sections. This test proceeds with the null hypothesis of non-stationary for every cross-section against the alternative hypothesis of stationary.

The model is:

$$\Delta y_{it} = \rho y_{it-1} + \mu_{it} \dots\dots\dots\dots\dots\dots\dots. (4.9)$$

$$t = 1, 2, \dots, T$$

The null and alternative hypotheses are defined as:

$H_0 : \rho_i = 1, \qquad i = 1, 2, \dots, N$

Alternatives Hypothesis

$H_1 : \rho_i < 1,$

$i = 1, 2, \dots, N_1; \rho i = 1, i = N_1 + 1, N_1 + 2, \dots, N$

4.5.2) Levin, Lin and Chu (LLC) unit root test:

Levin et al., (2002) specify the three alternative models. The first model the panel unit root test is following

$$\Delta y_{it} = \rho y_{it-1} + \mu_{it} \dots\dots\dots\dots\dots\dots\dots (4.10)$$

The null Hypothesis of the model is

$$H_0 : \rho = 0$$

And the alternative is

$$H1: \rho < 0$$

The second model of the panel unit root test is following

$\Delta y_{it} = \alpha_{0i} + \rho y_{it-1} + \mu_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots. (4.11)$

The null hypothesis of the model is that $H_0: \rho = 0$ and the alternative model is$\mathrm{H1}: \rho < 0$. In this model the series y_{it} has cross-section specific mean but no trend.

And the third model of the panel unit root test is following

$\Delta y_{it} = \alpha_{0i} + \alpha_{1i} + \rho y_{it-1} + \mu_{it} \dots\dots\dots\dots\dots\dots\dots (4.12)$

In this model the series y_{it} has cross-section specific mean and time trend. The panel unit root test evaluate the null hypothesis that $H_0: \rho = 0$ and $\alpha_{1i} = 0$ for all i, against the alternative that $\mathrm{H1}: \rho < 0$ and $\alpha_{1i} \in \Re$.

4.6) Acreage Response Methodology:

Nerlovian expectation model has been developed for conducting the supply response analysis. The model facilitates the analysis of both the speed and the level of adjustment of actual acreage toward desired acreage. The supply function approach requires detailed input prices. Nerlovian models are built to examine the farmers' output reaction based on price expectations and partial area adjustment (Nerlove 1956). The nature of Nerlovian models is ad hoc specifications of supply response including partial adjustment and expectation formation. The Nerlovian supply response approach allows us to determine short run and long-run elasticity. It also has the flexibility to introduce non-price production shift variables into the model. Models of the supply response of crops can be formulated in terms of yield, area, or output response. Assuming that farmers have rational price expectations based on their information set, farmers' crop acreage decisions can be described using a typical Nerlovian adaptive price expectations model of three equations (Braulke 1982):

$$A_t^D = \alpha_0 + \alpha_1 P_t^e + \mu_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.13)$$

$$P_t^e = P_{t-1}^e + \beta(P_{t-1} - P_{t-1}^e) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (4.14)$$

$$A_t = A_{t-1} + \gamma(A_t^D - A_{t-1}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots... (4.15)$$

where A_t is actual planted acres, A_t^D is desired planted acres, P_t is actual price, P_t^e is expected price, u_t is a disturbance term representing the effect of weather and other factors affecting cropland supply, the subscript (t) is time period, β and γ are the expectation and adjustment coefficients, respectively. As shown in (Braulke 1982), by removing the unobserved variables A_t^D and P_t^e from the model, the reduced form of the actual planted acreage equation can be written as:

$$A_t^D = b_0 + b_1 A_{t-1} + b_2 A_{t-2} + b_3 A_{t-3} + v_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (4.16)$$

where b_0, b_1, b_2 and b_3 are parameters determined by a_0, a_1, β and γ equations (4.13)-(4.15) and v_t is a disturbance term related to u_t .The yield effect of crop land use change together with other technological effects dominates the influence of other factors in determining the long-term yield trends (Lobell and Asner 2003).

There is a general dearth of empirical research on how crop acreages respond to climate change. Acreage response studies have typically ignored climate factors and used geographically aggregated time series data to represent the behavior of a representative farmer (Chavas and Holt 1990). Nerlove (1956) Showed that farmers' expectations of future prices shape their crop acreage decisions and the Nerlovian adaptive price expectations model has become a useful tool for the estimation of agricultural supply functions[9]. The model leads to a reduced form with acreage in a given year expressed as a function of one-year lagged crop price and lagged crop acreages[10].

In the existing literature, crop acreage response models are usually specified with a log linear functional form for ease of interpretation (Lee and Helmberger, 1985; Orazem and Miranowski, 1994; Miller and Plantinga, 1999). The present study followed the literature and used a log-linear functional form for the acreage models. The inclusion of lagged acreage and input and output price variables as independent variables in the acreage model may create an endogeniety problem. To appropriately take care of the issues inherited in such a dynamic panel data model, a fixed-effect Arellano-Bond difference GMM estimator is used. Instrumental variables used in the Arellano-Bond GMM estimation include lagged temperature and precipitation at different growth stages, procurement price of crop(s), fertilizer price(s) and yield of the competing crop(s) in the district[11]. The competing crop(s) and past weather are included due to their potential influence on price expectations and therefore on crop acreage decisions.

$$Acr_{it} = f(Acr_{i,t-1}, C_{it}, price_{x,i,t}, FP_{y,i,t-1})$$

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[9] see Askari and Cummings, (1977) for a comprehensive review of early applications ofthe Nerlovian model; and Tegene and Kuchler, (1991) for more recent development of the model

[10] Braulke, (1982)

[11] Sargodha, Faisalabad, T T singh, Jhang, Okara, Sahiwal, Vehari, Jhelum, Peshawar, Mansehra, Swat and Mardan

Where t represents year (1,2,3….T); i represent districts (1,2,3….n); x represents (wheat, sugarcane, and rice); and y represents fertilizer types urea, DAP, and SOP

The empirical acreage response model using a district level panel data set can be written as[12]:

$$\begin{aligned} lnAcr_{it} = \alpha_{\circ} &+ \beta_1 ln(Acr)_{i,t-1} + \beta_2 ln(DAP)_{i,t-1} + \beta_3 ln(SOP)_{i,t-1} + \beta_4 ln(urea)_{i,t-1} \\ &+ \beta_5 ln(RP)_{i,t} + \beta_6 ln(WP)_{i,t} + \beta_7 ln(SP)_{i,t} + \beta_8 ln(MP)_{i,t} + \beta_9 (PVSS)_{i,t-1} \\ &+ \beta_{10} (PRSS)_{i,t-1} + \beta_{11} (TVSS)_{i,t-1} + \beta_{12} (TVSS)_{i,t-1} \\ &+ \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (4.22) \end{aligned}$$

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[12] See Appendix A.4 for List of Variables and Data Sources

CHAPTER 5

RESULTS AND DISCUSSION

Maize crop is cultivated twice in a year during Rabi season (commonly referred as Spring maize) and Kharif season (referred as Kharif maize). In each season the crop duration is divided in two growth stages namely vegetative stage and reproductive stage[13]. Table 1 shows the trend of 20 year moving averages of temperature and precipitation during various crop growth stages in major maize growing districts of Pakistan. The evidence is found that temperature is increasing over time during the vegetative stage of Spring maize (February-March) in all the districts except Sargodha, Jhelum Mardan and Peshawar. Reproductive stage in case of Spring maize is completed during the month of April-May. A declining trend of mean temperature was observed in most of the maize growing districts during reproductive stage of the Spring crop (April-May). However, the mean temperature during this crop growth stage has increased overtime in Sargodha, Faisalabad, Jhelum, Mardan and Peshawar districts. Trends in long run mean temperature for vegetative as well as reproductive stages of autumn maize crop were also analyzed. It was observed that mean temperature has declined during vegetative stage of crop growth (July-August) in all the districts whereas the mean temperature during reproductive stage (September-October) has increased overtime all the maize growing districts except Faisalabad, Okara, Jhelum, Mansehra and Mardan.

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[13] *See table 4 A.3 for growth stages of maize*

Table 3: Trends of Temperature and Precipitation at Vegetative and Reproductive Stages of Crop Growth in Major Maize Growing Districts of Pakistan [14]

	Precipitation in Spring Season		Precipitation in Autumn Season		Temperature in Spring Season		Temperature in Autumn Season	
Districts	PVSS	PRSS	PVSA	PRSA	TVSS	TRSS	TVSA	TRSA
Sargodha	↑	↓	↑	↑	↓	↑	↓	↑
Faisalabad	–	–	↑	↑	↑	↑	↓	↓
T. T Singh	–	–	↑	↑	↑	–	↓	–
Jhang	↑	↓	↑	↑	↑	–	↓	–
Okara	–	–	↑	↑	↑	–	↓	–
Sahiwal	↑	↑	↑	↑	↑	–	↓	–
Vehari	↑	↓	–	↑	↑	↓	↓	–
Jhelum	↑	↓	↑	↑	↓	↑	↓	–
Mansehra	–	↓	↑	↓	↑	–	–	–
Swat	↑	↑	↑	↑	↑	–	↓	–
Peshawar	↑	↓	↑	↓	↓	↑	↓	↑
Mardan	–	↓	↑	↓	↓	–	↓	↓

Note: Upward arrows shows positive and significant effect, downward arrows shows negative and significant effect while _ indicates insignificant change.

In the overall, precipitation has increasing during the vegetative stage of spring as well as autumn crop. However, a declining trend of precipitation has been found at reproductive stage of spring maize in all the districts except that in Sahiwal and Swat. The precipitation showed a decreasing trend in Mansehra, Peshawar and Mardan during the reproductive stage of autumn

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[14] See Appendix for Table of values of coefficient

season (September and October) whereas in all the other maize growing districts precipitation has increased during reproductive stage of autumn season.

5.1) Panel Unit root test:

The results of the panel unit root tests for yield and acreage models are given below (Table 5.2) Results of the tests indicate that all of the variables are stationary at level. Detailed descriptions of the variables are given in Table A.2 and A.4.

Table 4 Unit Root Test for Maize Yield Model

Variable	LLC Test	Prob.	IPS Test	Prob.	Fisher-ADF Chi-square	Prob.	Conclusion
lnY	-7.7413	0.000	-8.5499	0.000	118.630	0.0000	Stationary
lnF	-2.0717	0.019	-10.5002	0.000	146.496	0.0000	Stationary
Lntractor	-6.9457	0.000	-8.7462	0.000	123.440	0.0000	Stationary
PRSA	-4.0301	0.000	-4.0218	0.000	56.7393	0.0002	Stationary
PVSA	-4.1916	0.000	-4.0487	0.000	55.9206	0.0002	Stationary
PVSS	-4.5686	0.000	-5.2080	0.000	70.9718	0.0000	Stationary
PRSS	-4.0241	0.000	-4.3989	0.000	59.9725	0.0001	Stationary
TVSA	-7.4916	0.000	-6.2108	0.000	83.8528	0.0000	Stationary
TRSA	-5.9424	0.000	-5.4432	0.000	74.0636	0.0000	Stationary
TVSS	-8.0846	0.000	-7.0565	0.000	95.9945	0.0000	Stationary
TRSS	-4.7219	0.000	-5.7422	0.000	76.2417	0.0000	Stationary
lnMA	-7.5935	0.000	-8.6754	0.000	120.067	0.0000	Stationary
$PVSA^2$	-4.0531	0.000	-3.8143	0.000	53.0619	0.0006	Stationary
$PRSA^2$	-3.6839	0.000	-3.9009	0.000	55.0015	0.0003	Stationary
$PVSS^2$	-4.5020	0.000	-5.1671	0.000	70.2733	0.0000	Stationary
$PRSS^2$	-4.1218	0.000	-4.4999	0.000	61.2108	0.0000	Stationary
$TVSA^2$	-7.5735	0.000	-6.2425	0.000	84.4051	0.0000	Stationary

Variable	**LLC Test**	**Prob.**	**IPS Test**	**Prob.**	**Fisher-ADF Chi-square**	**Prob.**	**Conclusion**
TRSA^2	-5.9838	0.000	-5.4575	0.000	74.3154	0.0000	Stationary
TVSS^2	-8.1458	0.000	-7.0995	0.000	96.6744	0.0000	Stationary
TRSS^2	-4.7643	0.000	-5.7371	0.000	76.1859	0.0000	Stationary
PVSA*TVSA	-4.1292	0.000	-3.9005	0.000	54.1254	0.0004	Stationary
PRSA*TRSA	-3.9222	0.000	-4.0177	0.000	56.4797	0.0002	Stationary
PVSS*TVSS	-3.3598	0.000	-4.6891	0.000	63.7250	0.0000	Stationary
PRSS*TRSS	-3.9901	0.000	-4.4065	0.000	60.1937	0.0001	Stationary
DPVSA	-6.5729	0.000	-7.4655	0.000	104.842	0.0000	Stationary
DPRSA	-11.0357	0.000	-10.431	0.000	146.910	0.0000	Stationary
DPVSS	-5.2282	0.000	-8.6885	0.000	120.944	0.0000	Stationary
DPRSS	-9.0723	0.000	-9.2128	0.000	128.206	0.0000	Stationary
DTVSA	-15.5958	0.000	-14.748	0.000	214.983	0.0000	Stationary
DTRSA	-11.9526	0.000	-11.8484	0.000	169.610	0.0000	Stationary
DTVSS	-11.7864	0.000	-11.3179	0.000	161.680	0.0000	Stationary
DTRSS	-11.7876	0.000	-10.7967	0.000	152.027	0.0000	Stationary

Table 5Unit Root Test for Acreage Response Model

Variable	**LLC test**	**Prob.**	**IPS Test**	**Prob.**	**Fisher-ADF Chi-square**	**Prob.**	**Conclusion**
*ln*DAP	-10.9777	0.000	-4.1517	0.000	54.9411	0.0003	Stationary
*ln*Urea	-8.46723	0.000	-7.2389	0.000	96.2095	0.0000	Stationary
*ln*Sop	-5.58719	0.000	-6.4196	0.000	81.5083	0.0000	Stationary
Maize_P	-4.35286	0.000	-6.4926	0.000	89.4213	0.0000	Stationary
Sugarcane_P	-6.20812	0.000	-3.9995	0.000	53.276	0.0005	Stationary
Wheat_P	-8.45087	0.000	-5.5294	0.000	72.4240	0.0000	Stationary
Rice_P	-7.33113	0.000	-5.9327	0.000	77.8484	0.0000	Stationary
PVSS	-4.56868	0.000	-5.2080	0.000	70.9718	0.0000	Stationary
PRSS	-4.02417	0.000	-4.3989	0.000	59.9725	0.0001	Stationary
TVSS	-8.08464	0.000	-7.0565	0.000	95.9943	0.0000	Stationary

Variable	**LLC test**	**Prob.**	**IPS Test**	**Prob.**	**Fisher-ADF Chi-square**	**Prob.**	**Conclusion**
TRSS	-4.72196	0.000	-5.7422	0.000	76.2417	0.0000	Stationary
Maize Area	-7.8339	0.000	-7.9089	0.000	103.143	0.0000	Stationary

5.2) Results of Random Effect Model and Fixed Effect Model Estimation:

Panel data model is used in this study to investigate the nature of effect of climatic variables prevailing during different plant growth stages of maize crop. The estimated regressions include linear, quadratic, and interaction terms of temperature and precipitation to account for the possible non-linear and joint impact of long run changes in climatic variables. The deviations of current year's temperature and precipitations from respective long run norms are also introduced to incorporate the effect of weather shocks.

Result of the random and fixed effect models estimations are given below. The choice of fixed effect model or random effect model shall be made on the basis of Hausman test.

Table 6 Random Effect Model with Log of Yield as Dependent Variable

Explanatory variables	Coefficient	S.E	z-stat	P>|z|
Time trend	0.03119	0.002	11.15	0.000
MA	0.312	0.312	9.73	0.000
F	-0.145	0.045	-3.17	0.002
Tractors	0.169	0.034	0.50	0.617
PVSS	0.034	0.050	-0.70	0.487
PRSS	-0.0371	0.060	-0.62	0.538
PVSA	-0.0180	0.022	-0.79	0.432
PRSA	-0.216	0.142	-1.52	0.129
$PVSS^2$	0.000	0.000	0.41	0.684
$PRSS^2$	0.0002	0.000	1.22	0.222
$PVSA^2$	0.0000	0.000	2.43	0.015
$PRSA^2$	0.0003	0.000	0.78	0.434
TVSS	0.5093	0.494	1.03	0.303
TRSS	-1.4802	0.655	-2.22	0.024
TVSA	1.3246	1.080	1.22	0.223

TRSA	-1.787	0.978	-1.83	0.068
TVSS^2	-0.136	0.013	-1.00	0.317
TRSS^2	0.023	0.010	2.27	0.023
TVSA^2	-0.021	0.015	-1.38	0.169
TRSA^2	0.027	0.016	1.65	0.098
PVSS*TVSS	0.0011	0.000	0.47	0.637
PRSS*TRSS	0.001	0.001	0.56	0.572
PVSA*TVSA	0.0003	0.000	0.56	0.578
PRSA*TRSA	0.0064	0.004	1.48	0.139
DPVSS	0.0004	0.000	2.00	0.045
DPRSS	0.0006	0.000	1.07	0.283
DPVSA	-0.0004	0.000	-0.37	0.712
DPRSA	-0.0000	0.000	-0.08	0.933
DTVSS	-0.0491	0.012	-3.09	0.000
DTRSS	0.227	0.104	2.17	0.030
DTVSA	0.0250	0.012	2.05	0.040
DTRSA	0.445	0.014	2.99	0.003
Constant	26.93	14.81	1.82	0.069

Note

- Area, Tractors and fertilizer are in log form.
- Random effect model is rejected on the basis of Hausman Test.

The results of random effect model reinforce the results of literature. Hausman test was applied in order to decide about suitability of the random effect model. The findings of the Hausman test are shown in the following table.

Table 7 Hausman Test

Test Summary	**Chi-Sq. Statistic**	**Chi-Sq. d.f.**	**Prob.**
Cross-section random	92.58	24	0.000

The value of Chi-square statistics shows that fixed effect model is more appropriate and consistent. Based on Hausman test, a fixed effect model was estimated and the results are presented in the following.

Table 8 Fixed Effect Model with Log of Yield as Dependent Variable

Explanatory variables	Coefficient	S.E	t-stat	P (t)
Time	0.0421	0.0029	14.51	0.000
*ln*MA	0.3540	0.0301	11.75	0.000
*ln*F	0.0749	0.0504	1.49	0.138
*ln*Tractors	0.0978	0.0304	2.89	0.004
PVSS	-0.0338	0.0630	-0.54	0.059
PRSS	0.0027	0.1086	0.03	0.980
PVSA	-0.0140	0.0370	-0.38	0.706
PRSA	-0.2771	0.1513	-1.83	0.068
$PVSS^2$	0.0001	0.0006	1.03	0.305
$PRSS^2$	-0.0002	0.0002	-0.10	0.924
$PVSA^2$	0.0000	0.0000	2.06	0.045
$PRSA^2$	0.0018	0.0005	2.08	0.035
TVSS	-0.3294	0.6650	-0.95	0.034
TRSS	0.5775	1.1560	0.50	0.618
TVSA	-0.1465	1.3300	-0.71	0.047
TRSA	-0.2942	1.0920	-1.55	0.012
$TVSS^2$	-0.1546	0.0182	-0.85	0.398
$TRSS^2$	-0.0095	0.0194	-0.49	0.624
$TVSA^2$	-0.0145	0.0192	-0.75	0.451
$TRSA^2$	0.0243	0.0183	1.33	0.185
PVSS*TVSS	-0.0025	0.0030	-0.82	0.414
PRSS*TRSS	0.0007	0.0033	0.21	0.832
PVSA*TVSA	-0.0002	0.0009	-0.24	0.080
PRSA*TRSA	0.0064	0.0064	1.39	0.010
DPVSS	0.0002	0.0002	0.93	0.354
DPRSS	0.0012	0.0005	2.27	0.024
DPVSA	-0.0001	0.0001	-1.14	0.257
DPRSA	0.0003	0.0004	0.07	0.944
DTVSS	-0.0290	0.0122	-2.83	0.018
DTRSS	0.0177	0.0096	1.83	0.068

DTVSA	0.0049	0.0116	0.42	0.671
DTRSA	0.0329	0.0141	2.33	0.021
Constant	1.8090	23.889	0.05	0.964

The value of R^2 is 0.7743 which shows that the log-linear function gave the best statistical fit for the data in the regression analysis.

5.3) Climate Change and Maize Yield:

The results of the study show that increase in precipitation during February-March (vegetative growth of spring maize) has a significant and negative linear effect on crop yield. However, precipitation increase during April-May (reproductive stage of spring maize) has an insignificant positive effect on crop yield. The results are suggestive that a 1mm increase in precipitation at vegetative stage in spring season reduces maize yield by about 3 percent. The precipitation at reproductive stage of autumn maize (September-October) and maize yield depict a non-linear relationship with a negative linear term significant at 10 percent and positive square term significant and 5 percent level of significance. The precipitation and temperature during reproductive stage of autumn maize has a significant positive joint impact on yield of the maize.

The results show that temperature during vegetative stage of spring maize has a significant and negative effect on overall yield of maize crop while at reproductive stage it has an insignificant effect. If there is a 1°C increase in long run temperature norm at vegetative stage then the maize crop yield would decrease 3.2 percent. Effect of temperature during both stages of crop growth of autumn maize shows a linear relationship with crop yield. If there is a 1°C increase in long run norm of the temperature in each stage of crop growth then the maize yield declined by 17 and 30 percent respectively. Kucharik and Serbin, (2008) and Lobell and Asner, (2003) findings showed that 1˚C increase in temperature during the month of July_August reduced corn yield 13 percent and 17 percent respectively. The effect of temperature in reducing the length of the growth cycle, especially the grain filling phase, is the most important factor in explaining reduced yields at warmer temperatures (White & Reynolds, 2003).

Other variables like fertilizer, tractors and area also have effect on yield of maize crop. Fertilizer (NPK nutrients) has positive but insignificant effect on maize crop yield. The availability of tractors has a significant and positive impact on maize yield as availability of tractors ensures timely operations of tillage, ridge making, and shelling etc. The results of the maize cropped area showed increasing returns to scale.

Chen and Chang, (2005) used variation in precipitation and temperature to know the impact of weathers shock on crop yield. Similarly, this study also used weather fluctuations (shocks) in precipitation and temperature but disaggregated at different crop growth stages. The weather shocks observed in precipitation at vegetative stages (of spring as well as autumn crop) have insignificant impact on crop yield. However, precipitation fluctuation at reproductive stage of the spring maize has significant positive effect on maize crop yield. Results also indicate that temperature fluctuation about long run norm during vegetative growth stage of spring maize has significant negative impact on crop yield whereas temperature fluctuations during reproductive stages of the crop (in both seasons) have positive significant impact on crop yield.

Marginal Impacts of Climate:

To compare the differences in coefficient estimates of climate models, the following study use linear coefficients of climate variables (Temperature, Precipitation) to find out the marginal effect ($\frac{\partial ln y_{it}}{\partial x_{it}}$), at the sample mean on maize yield. The results are reported in the following table.

Table 9 Marginal Effect of Climate Variables

Precipitation	**Coefficient**	**Temperature**	**Coefficient**
PVSS	-0.0368 (0.059)	**TVSS**	-0.143 (0.03)
PRSS	0.0012 (0.980)	**TRSS**	0.345 (0.514)
PVSA	-0.012 (0.706)	**TVSA**	-0.143 (0.047)
PRSA	-0.213 (0.012)	**TRSA**	-0.264 (0.012)

The above table shows the marginal effect of climate variable, which shows that change in percentage yield of maize crop due to one unit change of climatic variables (Temperature and Precipitation). The above table shows that Precipitation at vegetative stage of spring season and reproductive stage of autumn season effect the maize crop yield is significant, while at reproductive stage of spring season and vegetative stage of autumn season the effect is insignificant. The estimated results indicate that 1mm increase in precipitation at vegetative stage of spring season and reproductive stage of autumn season decrease maize yield to 3 percent and 21 percent.

The effect of temperature on vegetative stage of spring maize and vegetative and reproductive stage of autumn maize is significant while at reproductive stage of spring maize is insignificant. The marginal impact analysis of temperature reveals that the 1°C increase in temperature at vegetative stage of spring maize decreases the maize yield 14 percent.

5.4) Acreage Response of maize Crop:

Fixed effect Arellano-Bond GMM estimates are used to estimate the acreage response of maize crop in Pakistan at district level. Empirical results of the estimation are given in table 9. The adjustment coefficient of the area is 1-0.24(=0.76) which is larger than the adjustment coefficient of cereal crop 0.18 calculated byMythili (2012).

Table 10 GMM Model with Lag of maize area as Dependent Variable

Explanatory variables	Coefficient	S.E	t-stat	P (t)
(Maize area)$_{-1}$	0.24	0.034	7.17	0.000
(Pvss)$_{-1}$	0.008	0.005	1.508	0.013
(Prss) $_{-1}$	-0.006	0.019	-0.305	0.76
(Tvss) $_{-1}$	-0.06	0.09	-0.66	0.504
(Trss) $_{-1}$	-0.046	0.629	-1.66	0.09
(DAP Fertilizer Price)$_{-1}$	0.66	0.18	3.54	0.0005
(SOP Fertilizer Price)$_{-1}$	-0.17	0.07	-2.21	0.027
(UREA Fertilizer Price)$_{-1}$	-0.26	0.075	-3.46	0.0006
Price of rice	-0.12	0.060	-2.053	0.04
Price of wheat	-0.18	0.09	-2.06	0.03
Price of sugarcane	0.05	0.136	0.38	0.702
Price of maize	0.122	0.07	1.708	0.08
Observation	336		Prob>chi2	0.000

According to the study of Surekha (2005) farmers are reluctant to make larger adjustments in the cereal crop while in this study farmers are readily make larger adjustment because maize crop has overtime turned into more of a cash crop and farmers make quick area adjustments for maize crop.

Changes in climatic pattern (temperature, precipitation) have significant impact on crop growth, yield level and acreage allocated. Result of supply analysis shows that precipitation at vegetative stage of spring maize has significant positive impact on area allocation to maize crop. 1 mm increase in precipitation at vegetative stage of maize crop will increase the maize crop acreage by 0. 8percent. The temperature at reproductive stage of spring maize is related to area allocation to the crop negatively and significantly. A 1˚C increase in long run temperature norm would reduce area under maize crop by 4.6 percent.

Different factors affect the metabolic process of plant output of the crops are affected by a whole range of environments in which the plant is grown, that include rainfall, precipitation, temperature, radiation, type of soil, soil moisture, growth stage and pests and diseases. If all the essential elements are not provided at the accurate time, it will badly affect the production level. Allocation of land to maize crop will reduce gradually after utilizing the marginal land. Improved agricultural farm management practices and technological improvements reduces the area allocated to maize crop and increase the farm productivity in major maize producing districts of Pakistan.

Among the non-climatic factors, prices of inputs, own price, and prices of competing crops also affect the acreage allocation to maize crop. Result of the study shows that rice and wheat prices affect maize acreage adversely and significantly. The results are suggestive that a one percent increase in procurement price of rice and wheat shall decrease the maize acreage by 12 and 18 percent, respectively. The price of maize crop affects maize crop acreage positively and significantly.

Huang and Khanna, (2010)) find that the effect of price of fertilizer on the yield and area of the crop is significantly negative. Prices of three types of fertilizer (Urea, DAP, and SOP) are used to analyze the acreage response of maize crop, these three fertilizer are used as the main source of N, P and K nutrients respectively. The result of the study shows that prices of urea and SOP fertilizers affect the acreage of maize crop negatively.

CHAPTER 6:

Summary and Conclusion and Policy Recommendations

This study explores the responsiveness of maize acreage and yield to climatic variables in Pakistan using a district panel data for the period 1981-2010. Change in climatic condition (Temperature, precipitation) affect the yield of maize crop differently on both phenological stages of spring and autumn season.

Agricultural sector have importance in the production of food crops, and agricultural sector and climatic variable (temperature and precipitation) have strong relationship. In the literature, some of the studies use only climatic variable and yield to analyze the impact of climate change on crop yield. Only climatic variable (temperature, precipitation) are not involved to effect the crop production, some non-climatic variable are also involved in it. This study analyzed the effect of climate change on maize yield under some control variable like fertilizer uptake (NPK nutrients), tractors, area under maize crop etc. Maize crop is important cereal crop and it gives staple food for population.

This study also used the climatic variables (temperature, precipitation) along with prices and non-price factors detrimental for the maize acreage in major maize producing districts of Pakistan. This study used fixed effect model, to statistically analyze the effect of temperature and precipitation on the yield of Maize crop. Result of the study shows statistically positive effect of linear temperature expects the reproductive stage (September-October) of autumn season. The effect of linear precipitation is negative except the month of vegetative stage (April-May) of spring season. This study also analyzed the effect of quadratic form of variable, capturing the non-linear effect of climatic variable (temperature, precipitation). The quadratic effect of temperature is negative except the month of September-October. The effect of quadratic form of precipitation is positive except the vegetative stage of spring season. This study also analyzed the non-climatic variable, the impact of these variables is positive for crop production.

Results of acreage response model shows that the effect of previous year area, relative price of substitute crops (rice sugarcane and wheat), precipitation at vegetative and reproductive stage of spring season, temperature at reproductive stage of spring season and the price of fertilizers (urea, DAP and SOP) are significant. Post green revolution era brings lot of technological improvements i.e. better seed varieties, improved farm management practices and research and development to get rid of insect pest infiltration. Therefore, the result of acreage response may imply that farmers are responsive to price incentive but it takes time due to infrastructural problems. Agriculture support price policy will be effective if farmers believe that these prices are permanent. Thus it can be concluded that maize market price policies and market interventions are on their own inadequate to influence land allocation in the case of maize.

In order to enhance maize productivity and production, government should enhance agricultural R&D funds to develop technologies aiming at solutions to climate change issues. The research institutions should develop improved heat resistant crop varieties including maize varieties suitable for growing in different seasons (spring and autumn season). Finally there is a need for closely linking the farmers, agricultural extension and research with Pakistan Meteorological Department. Research should be conducted to identify promising adaptation strategies in turn to be up scaled for wider adoption. There is a dire need to enhance awareness of the treats of climate change among various stakeholders and their capacity building.

6.1) Limitation of the Study:

This district level study faces some type of data limitations. These limitations are

- The data related to soil fertility at district level in Pakistan are not available.
- The district level data of labor which are engaged in agricultural crop sector is not available so that, present study capture the effect of labor comes under the error term.
- In the production of maize, there is a huge share of pesticides and chemicals but present study faces availability of data at district level.

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APPENDICES:

Appendix 1:

A.1: List of Districts

Serial No	**Districts**	**Province**
1	Sargodha	Punjab
2	Faisalabad	Punjab
3	Toba tak Singh	Punjab
4	Jhang	Punjab
5	Okara	Punjab
6	Vehari	Punjab
7	Jhelum	Punjab
8	Sahiwal	Punjab
9	Peshawar	KPK
10	Mansehra	KPK
11	Swat	KPK
12	Mardan	KPK

Appendix 2:

A.2: List of Variables and Data Sources

Variable	Definition	Data Source
Dependent Variable		
Y_{it}	Yield of maize in district i during the year t.	Punjab Development Statistics, KPK Development Statistics
Independent Variables		
MA	Total area under maize in every district.	Punjab Development Statistics, KPK development statistics
F	Fertilizer consumption	National Fertilizer Development Centre, Islamabad (NFDC).
Tractors	Total number of tractors	Punjab Development Statistics, KPK development statistics
TVSS	Spring season Vegetative stage Temperature	Pakistan Meteorological Department (PMD)
TRSS	Spring season Reproductive stage Temperature	
TVSA	Autumn season Vegetative stage Temperature	
TRSA	Autumn season Reproductive stage Temperature	

TVSS^2	Square of Vegetative stage Temperature in spring season	Pakistan Meteorological Department (PMD)
TRSS^2	Square of Reproductive stage Temperature in spring season	
TVSA^2	Square of Vegetative stage Temperature in Autumn season	
TRSA^2	Square of Reproductive stage Temperature in Autumn season	
PVSS	Vegetative stage Precipitation in spring season	Pakistan Meteorological Department (PMD)
PRSS	Reproductive stage precipitation in spring season	
PVSA	Vegetative stage Precipitation in Autumn season	
PRSA	Reproductive stage precipitation in Autumn season	
PVSS*TVSS	Joint impact of Temperature and precipitation in Vegetative stage in spring season	Pakistan Meteorological Department (PMD)
PRSS*TRSS	Joint impact of Temperature and precipitation in Vegetative stage in spring season	

PVSA*TVSA	Joint impact of Temperature and precipitation in Vegetative stage in autumn season	
PRSA*TRSA	Joint impact of Temperature and precipitation in Vegetative stage in autumn season	
PVSS^2	Square of Vegetative stage Precipitation in spring season	Pakistan Meteorological Department (PMD)
PRSS^2	Square of Reproductive stage Precipitation in spring season	
PVSA	Square of Vegetative stage Precipitation in Autumn season	
PRSA^2	Square of Reproductive stage Precipitation in Autumn season	
DTVSS	Deviation of Temp from long run mean average of Vegetative stage in spring season	Pakistan Meteorological Department (PMD)
DTRSS	Deviation of Temp from long run mean average of Reproductive stage in spring season	

DTVSA	Deviation of Temp from long run mean average of Vegetative stage in autumn season	
DTRSA	Deviation of Temp from long run mean average of Reproductive stage in autumn season	
DPVSS	Deviation of prec. from long run mean average of vegetative stage in spring season	Pakistan Meteorological Department (PMD)
DPRSS	Deviation of prec. from long run mean average of Reproductive stage in spring season	
DPVSA	Deviation of prec. from long run mean average of vegetative stage in autumn season	
DPRSA	Deviation of prec. from long run mean average of Reproductive stage in autumn season	

Appendix 3:

A.3 Stages of Development of Maize

Vegetative Stage		Reproductive Stage	
VE-Emergence	Approx. 7-10 days	R1 silking	Approx. 69-75 days
V1_V6	Approx. 24-30 days	R2	
V6_V12	Approx. 42-46 days	R3	
V12_V18	Approx. 56 days	R4	
VT-Tesseling	Approx. 56-58 days	R5	
		R6 Physiology Maturity	Approx. 130 days

Appendix 4:

A.4 Description of the variables for acreage response model

Variable	Definition	Units	Source
			Pakistan Bureau of Statistics
$(Acr)_{it}$	Maize crop acreage in ith district in t time period	000 hectares	
$(Acr)_{i,t-1}$	Maize crop acreage in ith district in t-1 time period		
$(\Pr e)_{i,t-1}$	Monthly mean precipitation at different phonological stages of maize in ith district in t-1 time period	Mm	Pakistan Metrological Department
(temp)$_{I,t-1}$	Monthly mean precipitation at different phonological stages of maize in ith district in t-1 time period	˚C	Pakistan Metrological Department
$(\Pr ice)_{x,i,t}$	Procurement price of xth crop in ith district in t time period i.e. sugarcane, cotton, and wheat	Rs./40kg	Pakistan Bureau of Statistics
$\text{Ferti\_Price}_{y,i,t-1}$	Real price of yth fertilizer in ith district in t-1 time period i.e. Urea, DAP and SOP	Rs./50Kg	

Appendix 5:

A.5 Coefficient values of Time Trend

	Precipitation in Spring Season		Precipitation in Autumn Season		Temperature in Spring Season		Temperature in Autumn Season	
Districts	PVSS	PRSS	PVSA	PRSA	TVSS	TRSS	TVSA	TRSA
Sargodha	0.034 (0.04)	-0.052 (0.03)	0.318 (0.002	0.102 (0.00)	-0.001 (0.06)	0.012 (0.00)	-0.003 (0.001	0.003 (0.000
Faisalabad	0.0120 (0.26	-0.023 (0.138	0.446 (0.000	0.055 (0.000	0.024 (0.07	0.008 (0.000	-0.004 (0.002	-0.002 (0.02
T. T Singh	0.012 (0.26)	-0.023 (0.138	0.446 (0.00)	0.055 (0.000	0.004 (0.004	-0.001 (0.155	-0.006 (0.02	0.001 (0.68)
Jhang	0.034 (0.04	-0.052 (0.03)	0.318 (0.002	0.102 (0.000	0.003 (0.008	-0.001 (0.13	-0.006 (0.03	0.000 (0.70
Okara	0.012 (0.26	-0.023 (0.138	0.446 (0.000	0.055 (0.000	0.006 (0.004	-0.001 (0.21	-0.005 (0.05	-0.000 (0.86
Sahiwal	0.053 (0.002	0.011 (0.02	0.146 (0.07	0.043 (0.019	0.005 (0.002	-0.001 (0.21	-0.006 (0.02	0.000 (0.82
Vehari	0.051 (0.002	-0.035 (0.000	0.024 (0.393	0.045 (0.03	0.004 (0.005	-0.001 (0.09	-0.007 (0.00	0.000 (0.89
Jhelum	0.054 (0.006	-0.104 (0.001	0.570 (0.001	0.061 (0.06	-0.004 (0.000	0.008 (0.001	-0.003 (0.001	-0.000 (0.655
Mansehra	0.012 (0.67	-0.117 (0.03	0.276(0 .006	-0.065 (0.01	0.004 (0.00	-0.001 (0.18	-0.002 (0.11	-0.000 (0.737
Swat	0.704 (0.00	0.436 (0.002	0.747 (0.000	0.320 (0.000	0.003 (0.02	-0.000 (0.85	-0.002 (0.08	0.000 (0.48
Peshawar	0.075 (0.011	-0.158 (0.00	0.243 (0.001	-0.030 (0.01	-0.002 (0.001	0.012 (0.000	-0.003 (0.000	0.003 (0.001
Mardan	0.057 (0.21)	-0.319 (0.000	0.297 (0.005	-0.071 (0.002	-0.013 (0.000	0.000 (0.64	-0.025 (0.000	-0.012 (0.000