Impact of Climate Change on Vegetables Production:

The case of Potato, Onion and Chilies in Pakistan

Submitted By

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TABLE OF CONTENTS

ACKNOWLEDGEMENT iii

LIST OF TABLES vii

LIST OF ABBREVIATIONS ix

ABSTRACT x

CHAPTER 1 1

INTRODUCTION 1

1.1 Objective of the Stud 8

1.2 Hypothesis 9

1.3Brief description of Crops 9

1.3.1Potato 9

1.3.2Onion 11

1.3.3Chilies 11

1.4Organization of the Study 12

CHAPTER 2 13

REVIEW OF LITERATURE 13

2.1The Structural Approach 13

2.2The Spatial Analogue Approach 19

CHAPTER 3 27

DATA AND METHODOLOGY 27

3.1Background 27

3.2Climatic Data and its Sources 28

3.3Economic Data 29

3.4Phenological Stages of each Crop 29

3.5The Empirical Model 32
3.5.1Fixed Effects Model (FEM)..34
3.5.2Random Effect Model (REM) 35
CHAPTER 4 37
RESULTS and DISCUSSION...37
4.1Potato in Punjab 37
4.2Onion in Punjab 42
4.3Onion in Sindh and Baluchistan 47
4.4Chilies in Punjab 53
4.5Chilies in Sindh...56
CHAPTER 5 61
CONCLUSION AND POLICY RECOMMENDATIONS 61
5.1Conclusion: 61
5.2Policy recommendations..62
REFERENCES 63
Appendix 72

LIST OF TABLES

Title	**Page No.**
Table 3.1: Detail of selected districts for each crop	27
Table 3.2: Details of variables used in the model	28
Table 3.3: Province wise croping calander of potato	30
Table 3.4: Season wise croping calander and production share of potato	30
Table 3.5 Province wise croping calander of onion	30
Table 3.6 Province wise croping calander of chilies	31
Table 4.1 Trends of temperature and precipitation normal for potato	37
Table 4.2 Hausman test results for Potato	38
Table 4.3 Specification tests for potato	39
Table 4.4: REM Estimates for Potato (Dependent Variable: LN yield)	41
Table 4.5 Trends of temperature and precipitation normal for onions	42
Table 4.6 Result of Hausman test for onion in Punjab	43
Table 4.7 specification tests for onion in Punjab	43
Table 4.8 REM Estimates for Onion in Punjab (Dependent Variable: LNyield)	46
Table 4.9 Marginal Effects for Onion in Punjab	47

Table 4.10 Trends of temperature and precipitation normal for onions in Sindh 48

Tabl 4.11 Trends of temperature and precipitation for onions in Baluchistan 48

Table 4.12 Result of Hausman test for Onion in Sindh and Baluchistan 48

Table 4.13 Specification tests for onion in Sindh and Baluchistan 49

Table 4.14 FEM Estimates for Onion in Sindh and Baluchistan 51

Table 4.15 Marginal effects of onion in Sindh and Baluchistan 52

Table 4.16 Trends of temperature and precipitation normal for chilies in Punjab 53

Table 4.17 Result of Hausman Test for chilies in Punjab 54

Table 4.18 Specification tests for chilies in Punjab 54

Table 4.19Random Effect Estimates for Chilies in Punjab 55

Table 4.20 climatic variables time trend in Sindh 56

Table 4.21 Result of Hausman test for chilies in Sindh 57

Table 4.22 Specification tests for Chilies in Sindh 57

Table 4.23 Random Effect Estimates for Chilies in Sindh 59

LIST OF ABBREVIATIONS

IPCC:	Intergovernmental Panel on Climate Change
CO_2 :	Carbon dioxide
CFCs :	Chlorofluorocarbons
GHGs :	Green House Gasses
^oC :	Degree Centigrade
TFCC :	Task Force on Climate Change
GCMs :	Global Circulation Models
GDP :	Gross Domestic Product
GOP :	Government of Pakistan
WHO :	World Health Organization
CGE :	Computable General Equilibrium
KPK :	Khyber Pakhtunkhwa
PMD :	Pakistan Meteorological Department
PBS :	Pakistan Bureau of Statistics
NARC :	National Agricultural Research Centre
FEM :	Fixed Effect Model
REM :	Random Effect Model
G2S :	General to Specific
R&D :	Research and Development
SBI :	Sindh Board of Investment

ABSTRACT

This study has been conducted to examine the impact of climate change and weather shocks on potato, onion and chilies productivity in Pakistan by employing the production function approach using the districts level data for the period of 1981-2010. Employing fixed effects model (FEM) and random effects model (REM) estimations on panel data, this study finds evidence for significant impact of climate variables on vegetable production. The impact differs across various phenological stages of the crops in magnitude as well as in direction. Extreme events like flood and drought cause significant reduction in selected vegetables productivity. The area under cultivation have significant role to increase the productivity except in chilies field in Sindh where it cause decreasing returns to scale. Additionally, technological innovations captured by time trend also play a significant role in enhancing the yield of crops except in Punjab in the field of onion where it has negative sign.

Key words: agriculture, climate change, phonological stages, yield, districts level panel data.

CHAPTER 1

INTRODUCTION

Climate change is likely to be one of the most significant and controversial debate in the world. The climate is a complex system containing of the atmosphere, land surface, snow and ice, oceans and other bodies of the water and living things. Climate change explains as “change in climate due to natural or anthropogenic activities and this change remain for a long period of time” (IPCC, 2007).[1] The natural factors that are external to climate system include solar radiation and change in ocean (IPCC, 2001).On the other hand the increase of greenhouse gases and aerosol emission from human actions such as the use of fossil fuel, transport, deforestation, and land use changes are known as anthropogenic activities which affect climate.

The most looming climate change in current times is the rise in the atmospheric temperature due to increased level of greenhouse gases such as Carbon dioxide (CO_2), Methane (CH_4), Ozone (O_3), Nitrous oxide (N_2O) and Chlorofluorocarbons (CFCs). These gases are produced by a number of anthropogenic activities (IPCC, 2007). Among the GHG_S,CO_2 is responsible for 70 percent of the global climate change followed by CH_4 (18 percent), N_2O (9 percent) and others (1percent)(IPCC, 2007). Climate change is not a phenomenon of a few years. Since the industrial revolution in 1750s people have been burned a large amount of coal, natural gas and oil to power their homes, factories and automobiles. Today most of the world depends on these fossil fuels to meet there energy needs. The CO_2 is mostly

[1] Intergovernmental panel on climate change, Climate Change Synthesis report 2007 (IPCC 2007)

produced during the burning of wastes, carbon, weed and fossil fuels. Methane is produced during the mining of coal, oil and gas. While, nitrous oxide is produced during manufacturing and agricultural activities. During the last several decades increases in temperature has been reported and the related effects on climate have been discussed worldwide. There is now strong indication for an observed rise in worldwide average temperature and changes in precipitation rates and patterns during the 20th century around the world (IPCC, 2001).

Global climate change is a reality now. The result of GHG_s is that the worldwide average temperature has risen by 0.74 ^{o}C during the last century from 1906 to 2005.It is expected to rise further by 1.1 ^{o}C to 6.4^{o}C by the end of present century (IPCC 2007). Global warming also caused changes in the patterns and level of precipitation due to higher water vapor in the atmosphere. Like other regions, the whole Asia is expected to have warmed up by at least of the same magnitude during the last 100 years. The temperature is expected to be above the mean in South Asia. In addition, intense precipitation and winds, increased flood risks, prolonged droughts and other extreme events are increasing in South Asia (Regional climate report of IPCC, 2007; Lal*et al*, 2011).

Pakistan is mostly vulnerable to climate change because it has generally a warm climate. Geographically, Pakistan lies in South Asia between 24-37N latitude and 61-75E longitude with arid to semiarid climate. However, Pakistan has huge environmental diversity in its 796,096 KM area, stretching 1600 kilometer north to south and 885 kilometer east to west. The annual rainfall ranges from 125 mm in the southern parts to maximum 900 mm in the north during the heavy rains period in the months of July to September.

During the previous century, average yearly temperature over Pakistan increased by 0.6 ^{0}C with global trend. Increase in temperature over Northern Pakistan was higher than the Southern part[2]. Precipitation has also increased over Pakistan on the average by 25 percent (TFCC. 2010[3]; Farooqi *et al.* 2005; Malik *et al.* 2012). It has been projected that average temperature will further increase[4], precipitation will increase in summer and decrease in winter. Climate change will increase rainy season and boost the occurrence and harshness of extreme events such as floods and droughts (TFCC, 2010).

The gradual changes in climatic factors on global basis threatened the elementary elements of life for the people round the world such as access to water, food production, health, use of land and the environment. Realizing the potential impacts of climate change the professionals have started to estimate the impacts on important sectors such as agriculture, ecology, fisheries, forestry, water resources and seaside zones. Although several sectors have been studied, none have gained more attention than the agriculture.

Agriculture is the most susceptible sector to climate change. Plant systems, and hence crop yields, are being affected by a number of factors of climate change including temperature, precipitation pattern, water availability, land suitability and changes in sowing and harvesting dates. All these issues can change yield and

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[2] In northern Pakistan temperature rise 0.8 degree centigrade compare to 0.5 degree centigrade in southern Pakistan.

[3] Planning Commission Government of Pakistan, Task Force on climate change, (final report 2010)

[4] Global circulation Models (GCM_S) Studies projected that average temperature will increase in the range 1.3 – 1.5 ^{o}C by 2020s, 2.5 – 2.8 ^{o}C by 2050s and 3.9 – 4.4 ^{o}C by 2080s.

agricultural productivity (Malik *et al.* 2012). The effects of climate change on agricultural crops differ by area and by crop. In Pakistan, fourteen crops (eight field crops, three vegetable crops and three fruits) have exposed certain degree of weakness to heat stress under a climate change situation of a rise in temperature of 0.3 degree per decade (Spijkers, 2011).

The agriculture sector plays an imperative role in the growth progress of the Pakistan's economy. Pakistan is pre-dominantly an agricultural country. It currently contributes 21 percent to the country's Gross Domestic Product (GDP), employs about 44 percent of the entire labor force and approximately 60 percent of rural population depends on this sector for their livelihood (GOP[5], 2013-14). At the same time the industrial sector of Pakistan heavily depends on agriculture for raw material.

Agriculture segment of Pakistan includes four sectors comprises, livestock, crop, forest and fisheries. Livestock contributes 56 percent in agriculture production, crops adds 38 percent while fisheries and forestry contributes 2 percent each. Out of crops sector, horticulture occupies fairly significant position in terms of area, production and share in GDP and employment. A viable and profitable horticulture sector can provide a sustainable livelihood to the agricultural community. Pakistan has a great potential for horticulture due to variety in land and climate which provide opportunities for the production of a wide range of horticultural crops.

A large number of indigenous fruits, vegetables and floriculture commodities are produced in the country while there is scope for cultivation of exotic crops. There

[5] GOP, Economic Survey of Pakistan (2013-14)

is a layman perception that a warming trend may be favorable for fruits and vegetables but simplifications are difficult given the wide range of plant types and traditional practices to be considered (Rosenzweig et al. 1994)Vegetables are normally sensitive to ecological extremes and therefore high temperatures, imperfect soil moisture, heavy rains, salinity and droughts are the major causes of low yields (Pena and Hughes, 2007). As the above factors greatly affect numerous physiological and biological procedures like reduced photo synthetic action, changed absorption and enzymatic motion, thermal injury to the tissues, reduced pollination and fruit set etc (Saibo*et al*. 2009). These adverse impacts on crops phenology may intense further by climate change.

The climate change shall badly hit the vegetable production (Ayyogari*et al*. 2014). Under changing climatic circumstances crop failures, shortage of yields, decrease in quality and cumulative pest and disease problems are common and it reduce the vegetable farming unprofitable. South Asian rainy seasons will be delayed and become less convinced and that temperature increases will be most penetrating during the winter season (Lal*et al.*2001). The failure of the rainy season results in water shortages and accordingly below-average crop yields. This is predominantly true for major drought-prone areas. High temperatures and in sufficientra in at the time of sowing and hefty rainfall at the time harvesting cause severe crop losses (Gadge and Lawande. 2012). This ultimately questions the availability of nutrient source in human diet.

Vegetables are so common in human diet that a meal without vegetable is hypothetical to be imperfect worldwide. The importance of vegetable in human life cannot be denied because vegetable are very significant due to their higher yield potential, higher return and higher nutritious value and sustainability for some small land holdings. At the same time vegetables are important because it provides minerals, proteins and vitamins required for human nutrition and are the best source for overcoming micronutrient deficiencies. WHO estimates that low fruit and vegetable consumption adds to about 16 million disabilities and 1.7 million deaths globally are attributable to low fruit and vegetable intake. In Pakistan, due to lack of awareness and ignorance on the research of vegetable the everyday per capita consumption is low, being about 100 grams (g) compared to the suggested consumption of approximately285 g (Khokhar, 2014).

The nature has blessed Pakistan with diverse types of climate conditions and fertile land. Vegetable constitute a significant segment of the cropping pattern but the increasing burden on cash crops have limited the area under vegetable to about 0.62 million ha which is 3.1 percent of the total harvested area (Khokhar, 2014). More than 63 vegetable kinds are grown in numerous parts of the country as summer and winter vegetable.

Total area and production of vegetables including potatoes and condiments, averaged about 588 thousand ha and 7612.4 thousand tones in the former ten years (2002-12). Potato, onion, chili, tomato, turnip, okra, cucurbit and peas are main vegetables grown in the country and covering 81 percent of the entire vegetable production. The chief share in area and production is of potato which is 30.2 percent and 40 percent respectively (Khokhar,2014).

In case of province-wise sharing of area and production of vegetable, Punjab remains key contributor with 60 percent trailed by Sindh 17 percent, Baluchistan 13 percent and Khyber Pakhtunkhwa 10 percent (Khokhar, 2014).

After growing at a stable rate in the past, Pakistan's vegetables exports have hurt volumetric year-on-year reduction of 40.4 percent in 2011-12. This drop is a concern of natural tragedies, one-sided exploiting by middle-men and a change in supply and demand dynamics in the external market places. The momentous drop in exports is largely because the onion crop which has large share in exports was demolished by floods (Memon, 2013).

The overall horticulture sector of Pakistan pays 11 percent to the total value addition in farming subdivision which provides 60 percent exports. The existing country wide horticulture exports are around 400 million US$ (2011-12). Major exporting countries are Afghanistan, Malaysia, Russia, Bahrain, UAE, Saudi Arabia and Sri Lanka. The common exportable vegetables are Potato, onion, chilies, and peas (Khokhar, 2014).

The earlier vegetable research studies can be classified into background research and economic research. The objective of background research was to develop varieties of high yielding and resistant to disease and pest attacks. These studies include Haq*et al*. (2009), Ali *et al*. (2007), Naz and Amjad. (2004),Shah *et al*. (2011), Naz*et al*. (2006), Irfan-ud-din *et al*. (2012), Saleem *et al*. (1998), Khan *et al*. (2009), and Khan *et al*. (2012). Economic research was concerned with institutional adjustment to increase efficiency in production, distribution and marketing. Economic studies conducted in Pakistan have concentrated on cost of production and profitability. These studies include Jehan *et al*. (2014), Saeed *et al*. (2001), Ahmad *et al*. (2008) and Rana and Rehman(1993).The contribution of such studies towards increased production fails to present clear picture. Never the less, the gap between potential yield and actual yield is wide. Worsening climatic conditions are one of the major reasons for this. However, there is paucity of the literature in this regard. This calls for more applied research to bridge up this gap.

Some studies are found that measured the effects of climate change on Pakistan's agriculture covering the major crops such as rice, wheat, cotton and maize. The vegetable sector has been neglected in spite of its significant employment, income and contribution in micronutrients intake. No special attention has been paid to study the impact of climate change on vegetable production in Pakistan. Therefore, the study underhand makes a real contribution towards literature in analyzing the impact of climate change on production of vegetable crops.

1.1 Objective of the Study

The broad objective of this thesis is to investigate the impact of climate variables on three major vegetable crops namely potato, onion and chilies in Pakistan. The specific objective of this thesis considers;

1. To investigate the impacts of temperature variations on yield of selected vegetables (potatoes, onions and chilies);
2. To find the impacts of precipitation variations on yield of selected vegetables;
3. To explore the combined impacts of temperature and precipitation variations on yield of concerned vegetables; and

4. To examine the impacts of increase or decrease in area under cultivation on yield of vegetables.

1.2 Hypothesis

This study empirically estimated the impact of climatic variables (temperature and precipitation) on the yield of vegetable crops. The hypothesis of the study are as follows:-

H_0: overtime variations in temperature have no effect on yield of vegetable crops (Potato, Onion and Chilies).

H_1: overtime variations in temperature have an effect on yield of vegetable crops (Potato, Onion and Chilies).

H_0: overtime variations in precipitation have no effect on yield of vegetable crops (Potato, Onion and Chilies).

H_1: overtime variations in precipitation would have an effect on yield of vegetable crops (Potato, Onion and Chilies).

1.3Brief description of Crops

In this study potato, onion and chilies are selected. The criteria for selection were relative economic importance and land under cultivation in the country.

1.3.1Potato

(*Solan umtuberosum L.*) Botanical name used for potato belonging to So lanaceae family occupies a noticeable position among vegetable crops grown in Pakistan.

Potato is an imperative commercial cash crop of the world. By volume of production it is the fourth most important crop. In Pakistan potato has become the most important crop both for farmers and consumers. Pakistan is self-reliant in potatoes and depend smostly on locally produced seed for household consumption but yield is still low as compared to other producing countries (khan and Akhtar. 2006). Climate change has affected potato crop in Pakistan. Temperature in plain areas of Punjab has started rising in the middle of month of February, resulting into reduced period of spring season of potato crop. Aphid[6] population becomes high due to high temperature during the growth of potato crop which causes spread of viral diseases. Autumn season which contribute 70-75 percent towards total potato production has also shortened due to rise in temperature at the time of planting in the month of September resulting into delayed planting to the month of October. Uncertain climate conditions and heavy rainfall cause late blight which sometimes totally damaged the potato crop.

Potatoes are highly sensitive to temperature and frost. Potato is cooler season crop. The growth of a potato plant occurs in several stages, sprout development, vegetative growth, tuber set, tuber bulking and maturation. Optimum soil temperature for normal tuber growing is 15 to 18°C, and tuber growth is sharply inhibited when temperature is below 10°C and above 30°C. Temperature drops below 0^0C could damage the plant growth seriously. Optimum yields are attained where mean daily temperatures are between 18 to 20 ^{0}C while a night temperature lower than15°C is required for better tuber growth initiation. High temperatures extend the period of leaf

[6] Aphids are the most destructive small sap-sucking insect pests on cultivated plants in temperate regions.

growth, accelerate leaf senescence and reduce the photosynthetic capacity. The effects of these changes vary from region to regions depending upon the time.

1.3.2Onion

(*Allium cepa L.*) Botanical name used for onion is one of the main cash crops for the farmers. It is widely used by all households in Pakistan throughout the year. Onions may be eaten as raw, fried and pickled. Onions are used mostly in soups, sauces and for seasoning diets. Onion bulbs are rich in phosphorus, calcium, and carbohydrates so it plays significant part in preventing cardiac disease and other ailments. The total world production was about 86.34 million tons and Pakistan stands at 8th position with 2.25 percent share in production (Khokhar, 2014). China and India contribute almost half of world onion cultivation. In Pakistan It is annually cultivated over an area of 129.7 thousand hectares with production of 1817.4 thousand tonnes having an average yield of 14.01 tons per hectare.

The suitable temperature for onion cultivation is from 13 to 20^{0}C but temperature required during onion bulb initiation varies from 16 to 25 ^{0}C and also requires long days light (PARC, 2012)

1.3.3Chilies

(*Capsicum annuum*L.) Botanical name used for chilies is the third most key crop of family sloanaceae after potato and tomato. Both green and dry chilies are produced all over the world. It is both vegetable and spice crop of noteworthy economic valve in Pakistan. Pakistan is the sixth largest exporter of chilies in the world (Iqbal*et al*. 2010a) It contributes 1.5 percent in country's GDP and cultivated over an area of 73.8 thousand hectares with production of 187.7 thousand tones and average yield of 2.5 tons/ha (Irfan*et al*. 2012).

Chilies are warm-climate crops most Chilies are cultivate well in areas where the average temperature is 30°C for at least four to five months over the year. The ideal temperature is between 24°C and 32°C. At lower temperatures development becomes gradually poorer and in spite of being a warm season crop, at temperatures above 35°C joined with dry winds, undue flower drop may become a problematic (SBI, 2010).

1.4Organization of the Study

The remaining parts of the study proceed as follow. Second chapter includes the review of literature about the modeling of climate change for crop production and about the climate-vegetable (potato, onion and chilies) relationship. Third chapter includes the description of data and methodology used for analysis in methodological part the empirical model discuss in detail. Fourth chapter includes the results and discussion of analysis. Fifth and last chapter of thesis includes the conclusion and policy recommendation.

CHAPTER 2

REVIEW OF LITERATURE

In the literature review, it was considered mainly the studies focusing on the impacts of climate change on agriculture in general and vegetable in Pakistan in particular. This chapter includes review of different models and approaches which have been applied to investigate the impacts of climate change on agricultural production. These models and approaches can be categorized in two main groups: the structural models and the spatial analogue models. The structural modeling combines the agronomic response of plants with farmer’s management decisions. The second approach uses the observed spatial differences in agricultural production and climate among regions.

2.1The Structural Approach

The structural approach is interdisciplinary which uses numerous disciplines to measure economic costs of climate change. These models use crop growth simulation models to determine the response of specific crop varieties to different climatic and other conditions. Farm management practices can be included in structural models. Economic impacts are then estimated by incorporating yield estimation results obtained from crop simulation models into economic models. A good volume of literature use simulation models to look into the future changes in climate and their impacts on agriculture.

Tobey *et al*. (1992) investigated the global climate change effects on world agriculture. They used Statistical World Policy Simulation (SWOPSIM) constructed on General Circulation Model (GCM). The model used 20 agricultural commodities.

The result shows that negative impacts in some area would not damage the world agriculture market because these adverse impacts would be balanced by higher agricultural yields in some other are where climate change impacts are positive.

Rana and Rehman (1993) analyzed the stabilization of production and price swings of potato and onion crops in Pakistan. The data from 1971-1991 was analyzed using descriptive statistics, graphical presentation and growth rates were attained through regression techniques. They found that increase in production was mainly due to expansion of area under cultivation. The support price policy by the government has not helped the poorer and smaller farmers. It has no impact on prices because of prices being too low and coming into effects too late. Moreover, inadequate storage capacity and inefficient management add to the lack of impact.

Rosenzweig*et al*. (1996) analyzed the potential impact of climate change on fruit and vegetable yields in United States(US) by using citrus and potato simulation models. Twenty-two sites were simulated for citrus yield and twelve sites for potato using climate data from 1951-1980. Response surface were developed for all combinations of increased temperature and $CO_{2.}$ Induced yield improvement indicates that production may shift slightly northward in the southern states, but yield may decline in Florida and Texas due to extreme heat during the winter. CO_2 effects tended to offset the decline in simulated citrus yield. Reduced potato production in the northern states looks susceptible to a rise in temperature. Increased CO_2 and changes in planting date have negligible paying impacts on simulated potato yield.

Jenkins *et al*. (1997) analyzed the predicted geographic and economic response of UK and Wales cropping system to climate change scenarios to predict farm profitability and general market trends in potato industry. The climate driven crop growth models were used by integrating a climate database 1951-1980 to predict for 2023 and 2065. They investigated that although gross margins for main crop and especially potatoes may rise due to shift in production and to price increase but overall production of potato will fall.

Hijmans (2003) estimate the effect of climate change on global potato production. Average monthly climate data during 1961-1990 for current climate and data from 2010-2039 and 2049-2069 for forecasting were used. The simulation model was used to calculate potential yield. He investigated that increase in global average temperature will be 1.2^{0}C and 1.8 ^{0}C in the 2010-2039 and between 2.1^{0}C and 3.2 ^{0}C in 2040-2069, if no adaptation taken global potato yield will decrease between 10 -19 percent in 2010-2039 and between 18-32 percent in 2049-2069. The effect of these climatic changes will be negative more on lower latitudes as compared to higher latitudes. These effects of global warming can be minimized by using heat-tolerant potato varieties.

Naz and Amjad (2004) investigated the performance of different local and unusual genotypes for early bulb production through onion sets under Faisalabad climatic conditions. Nine onion seeds of three local onion genotypes Dark red, Early Red and Faisal Red and six unusual genotypes Roxa IPA-3, Red Creale, Granex-33, Granex-429, Red Bone and Hybrid yellow Branex were observed to the early onion bulb production through sets. The experiment was laid out in a Randomised Complete Block Design (RCBD) with three replications by the Department of Horticulture University of Agriculture Faisalabad. They experienced that genotypes did not differ significantly for number of green leaves. The significant difference occurred among the genotypes for sets diameter, leaf length, neck diameter, bulb diameter, fresh weight and for bulb yield. Under the climatic conditions of Faisalabad the Hybrid yellow Granex showed supremacy and more adaptability.

Naz*et al*. (2006) imagined to assess the best age of transplants of chili F_1 Hybrid Sky Line-2 under Punjab plain conditions especially in Multan, Pakistan. The experiment was conducted at the Bhau din Zakria University (BZU) Multan agriculture farm during 2004-2005. They observed that ages of transplants had no important effects on mortality percentage and root dry weight per plant. They also concluded that 50 days old seedlings exhibited best growth in terms of plant height, number of branches, number of leaves, and foliage fresh and dry weight per plant. Temperature is major variable which causes significant effects in all the process.

Haverkort and Verhagen (2008) examined climate change and its repercussions for the potato supply chain. They concluded that climate change with higher temperature, increased CO_2, higher sea level and higher evaporation demand is a fact now. This affects the yield and quality of potato. The temperature increases cause diseases and erratic rainfall will make control more difficult and potato yield will decrease and quality will also be affected. CO_2 concentration on the other hand has positive effect on potato. They also observed that economic factors such as inadequate farm size and remoteness of markets also affected the potato supply chain.

Saue and Kadaja (2011) generated and analyzed values of meteorologically possible yields of potato for the middle and the end of the 21st century at (Kurassa are, Tallinn and Tartu) three Estonian locations. GCM was applied to evaluate the future climate change and resultant changes were introduced into a dynamical potato growth model (POMOD). They found that increase in temperature has negative impact on early potato growth in all the three studied areas of Estonia and concluded that potato yield could decline. Moderate climate warming has positive effects on the growth of the late potato varieties through prolonging the growing period. The stronger changes will cause the decline of a grometeoro logical resources. For northern Estonia less negative effects of climate change were detected.

Daccache*et al*. (2011) assessed the impacts of climate change on the irrigation water requirements and yields of potatoes in England. The SUBSTOR-POTATO model was used to simulate the baseline and future irrigation needs and yield for selected emission scenario for the 2050s includingCO_2fertilization effects. They analyzed that for the 2050s the impact of climate change on potato yield will be relatively minor 3 to 6 percent. However under conditions of optimal irrigation and fertilizer management potential yield could increase by 13-16 percent on average. With climate change future seasonal irrigation needs for potatoes would increase by 14-30 percent.

Singh*et al*. (2013) evaluated the impact of climate change on potato production in India. The results of INFOCROP-POTATO MODEL have shown that moderately high temperature drastically reduced tuber yield without affecting the photosynthesis and total biomass production but it affected the tuber quality. Model result showed that at elevated CO_2 to 550 ppm and $1^{o}C$ rise in temperature cause 11.12 percent increase in tuber production and further rise in temperature by $3^{o}C$will cause 13.72 percent decline in year 2050. At the same time they discussed that global warming will have serious repercussions on outbreak of viral diseases.

Guoju*et al*. (2013) analyzed the response to climate change for potato water use efficiency (WUE) in Guyuan which is a typical semi-arid rain-fed agriculture region of China using simulation testing. They estimated that increase in temperature and decrease in precipitation remarkably improved potato water use efficiency in Guyuan, when temperature was greater than1.5 ^{o}C and precipitation was less than 310.0 mm water use efficiency showed a declining trend.

Waals *et al*. (2013) calculated past and future trends in potato cropping system at three distinct sites (The Sandvelb, the Eastern Free State and Limpopo) in South Africa by using daily weather data for the period, 1961-2050. They concluded that diseases and pests will increase over the 90 year period in the area under study. The early blight and brown spot will increase in the wet winter and wet summer crop of the Sandveld and Eastern Free State but remain unchanged in the dry summer and dry winter crops of the Sandveld and Limpopo, respectively. The late blight in all of the cropping system under climate change will decrease except in the wet winter crop of the Sandveld.

Sparks *et al*. (2014) examined the effects of climate change on potato late blight, the disease that caused the Irish potato famine and still a common disease around the world. Five regions (Andean highlands, Indo-Gangetic plain and Himalayan highlands, Southeast Asian highlands, Ethiopian highlands and Lake Kicu highlands in Sub-Saharan Africa) which are important potato cropping areas were selected. The Metamodel used and considered three global climate models for the greenhouse gas emission scenario for more three 20 year time slices (2000-2019, 2040-2059, 2080-2099). They found that average global risk of potato late blight disease attack increase initially and then declines as planting dates shifted to cooler seasons.

The review of above studies indicates the impact analyses of climate change by monitoring certain scenarios for temperature, precipitation and CO_2 changes in coming years. The crop simulation approach is an important technique to look into the future changes in climate and their impacts on agriculture. However, it is costly and difficult to implement in developing countries. The negative impacts of climate change predicted using these methods are often overstated and totally neglect the scientific dynamics. Since these approaches do not accommodate the crops substitutions and growers adaptations to climate changes. The approach can be criticized on the bases that it is a crop specific analysis (Salvo *et al.* 2014).

2.2The Spatial Analogue Approach

To overcome the limitations of the structural approach, spatial analogue approaches were proposed. These approaches are based on statistical and econometric methods. These have been used to estimate the impacts of climate change on agricultural production in different regions by taking account of changes in farmer management practices and decisions in response to changing climatic conditions. The factors which can affect crop production such as soil type and quality are also integrated in the models estimated (Adams *et al*. 1998a). The two main spatial analogue methods are the Ricardian approach (Mendelsohn *et al*. 1994) and Computable General Equilibrium (CGE) model combined with a Geographic Information System (GIS) developed by (Darwin *et al*. 1995). The various studies used these models are reviewed in this section.

Mendelsohn*et al*. (1994) measured the economic impact of climate change on US agriculture. A Recardian analysis was applied by using cross sectional data on climate, farmland prices and other economic and geophysical data for 3,000 counties. They estimated that higher temperature in all seasons except autumn reduced average farm values whereas more precipitation outside of autumn increase farm values and also estimated a significantly lower impact of global warming on US agriculture.

Winters*et al.* (1996) used Computable General Equilibrium (CGE) model to analyze the impact of global warming on the less developed countries. They concluded that Africa, Asia and Latin American regions will face severe agricultural loses in cereals and export crops. The most severe affects would be on Africa because its economy heavily depends upon agricultural outputs.

Saleem *et al.* (1998) examined the effect of physical parameters (temperature, flooding duration and soil type) on the incidence of root and collar root disease of chilies. They investigated that temperature had a direct influence on disease development, the disease incidence increased from 0-100 percent with rise in temperature from 15-30 percent producing maximum canker length (4.5 cm) and girdling index (4cm). The gradual increase in flooding duration from 0-48 hours have showed that incidence in non-flooded soil was 25 percent which increased to 100 percent after 48 hours with maximum canker length (3.66cm) and girdling index at 48 hours flooding period. Heavy soils showed 83.3 percent disease as compared to light medium soil which showed 50 and 66.7 percent incidence of disease respectively.

Seo*et al*. (2005) measured the impact of climate change on Sri Lankan paddy, coconut, rubber and tea crops by using the Ricardian method. They studied the limited and greater range impact of temperature as well as precipitation. The result of Atmosphere-Ocean General Circulation Models (AOGCM) scenarios showed that the increased impacts of rainfall were predicted to be beneficial to country as a whole, nevertheless temperature increases were predictedto be harmful. The result suggested that depending on the actual climate change scenario, the climate change damages could be large in tropical developing countries.

Pareira*et al*. (2008) analyzed that how potential potato yield based on climatic elements and cultivar characteristics. The data from four different regions in the state of Sao Pauto, Brazil was used for estimations. An agrometeorological model based on CO_2 assimilation maximum rate for C_3 plants, fraction of photo synthetically active radiation, photoperiod duration, air temperature and crop parameter under tropical climatic conditions were used for estimation. The findings showed excellent performance of the model, with an underestimation of irrigated potato productivity less than 10 percent.

Haq *et al*. (2009) study the effects of farmer's circumstances on onion yield. The study was conducted during July 2005 in four villages (Akhankalay, Daga, Sharifabad and Kotlay) in Swat district of KPK, Pakistan. The data was collected through interview technique from 90 respondents. The results of statistical technique using SPSS packages showed that farmers having small land holdings, high education level, more farming experience, onion transplanted during first half of the December and having information about new technology received higher yields of onion.

Zhai and Zhuang (2009) assessed the economic effects of climate change on Southeast Asian countries through 2080 by using CGE model. They concluded that Southeast Asian region would suffer more than other regions. The result show that up to 2080 this region would face 1.4 percent decline in GDP, 17.3 percent in crop productivity, 16.5 percent in productivity of paddy rice and wheat up to 36.3 percent. The impact of these product decline would result into more losses and the terms of trade for this region would deteriorate.

Moretti*et al*. (2010) investigated the potential impacts of climate change on postharvest quality of fruit and vegetable crops. They found that temperature increase affected photosynthesis directly, causing alterations in sugars, organic acids, and flavonoids contents, firmness and antioxidant activity. Carbon dioxide has directly affected postharvest quality causing tuber malformation, occurrence of common scab, and changes in reducing sugars contents on potatoes. . High concentrations of atmospheric ozone can potentially cause reduction in the photosynthetic process, growth and biomass accumulation.

Aurbacher *et al*. (2010) assessed the impact of climate change on agriculture in German districts. The data of land rental prices and climate variables (temperature and precipitation) were used. The Ricardian analysis results showed a significant correlation between land rents and increase in mean temperature as well as decline in spring precipitation. Net climate data used to calculate local land rent changes under different time horizon between 2011 and 2040. The overall result is an increase in land rents.

Shaker *et al*. (2011) studied how changes in climate variables affected the net farm revenue in arid region of Pakistan. Climate variable data was used from 1999-2010 and socio economic variables data was collected through interview. The estimates of Ricardian approach showed that temperature have negative and precipitation have positive impact. Socio economic variables such as age as an experience have positive whereas education have no significant effects on net revenue per acre of wheat farmers.

Shah *et al.* (2011) analyzed the onion production potential, limitations and the prospects for improvement in the farming system of Punjab, Pakistan. Overall, 25 farmers were selected from 7 districts (Sheikhupura, Okara, Khaniwal, Multan, Bhawalpur, Vehari and Kusur). The primary and secondary data was employed. They observed that area under cultivation has increased as compared to last year but the productivity has decreased due to number of threats including pest and diseases attack, lack of quality and improved varieties high costs of inputs, water stress and ineffective markets. Very small percentage of the onion growers were cultivating hybrid and improved varieties because dasi Varity has a good return. All these reasons have adverse impacts on the quality and profitability which exploit full export potential.

Gadge and Lawande (2012) analyzed how onion crop damage due to climatic changes in two districts Ahmed nagar and Pune, India. The data was collected from 100 farmers through administering questionnaire and data was analyzed using statistical techniques. The findings showed that inconsistent rainfall at the time of harvesting of kharif onion and nursery preparation of rabi onion was the major constraint faced by majority, 73 percent farmers. They also observed that untimely rain fallca used, anthracnose disease due to water stagnation, soil borne diseases like bulb root and colletotrichum were the major constraints in the onion production.

Gregory and Marshall (2012) conducted a study with the objective that either changing climate contributed in the increased potato yield in Scotland since 1960 or not. Daily weather data from 1960-2006 were used for five locations covering the zones of potato growing to determine trends in temperature, rainfall and solar radiation. A physiologically based potato yield model was applied. They observed significant increase in air and soil temperature but no significant increase changes in annual rainfall and timing of frost in spring and autumn. The potential yield increased with time mainly due to increased duration of the green canopy. They measured that warming of weather could contribute potential yield increase of potato in Scotland.

Lee et al. (2012) investigated the impact of climate change on net agricultural production in thirteen Asian countries including Pakistan. Panel data used during the 1998 to 2007 and fixed effect model was applied. The results showed that increase in temperature and precipitation during summer season has positive impacts. Whereas this increase in temperature and precipitation during fall season has negative impacts on tropical Asian countries. The annual temperature increase have negative whereas annual precipitation increase have positive impacts on net agricultural production in Asia.

Irfan *et al.* (2012) conducted a study in two divisions (Peshawar and Malakand) of Khyber Pakhtunkhwa, Pakistan in 2007 to assess the prevalence of root and crown root diseases of pepper. The data was collected from 33 selected sites and recorded according to a disease rating scale of 1-12 based on symptomatology. They examined that pepper crown and root was highly destructive diseases of pepper in different locations of studied areas. However, the area with long history of pepper production affected more which in some locations resulted in failure of the entire crop. They also discussed that it may be attributed to high rainfall during peal monsoon, high humidity and low temperature which are favour able for rapid growth and development of the pathogen resulting in severe pepper production losses.

Jovanovic *et al*. (2012) studied the impacts of climate change on potato in South East European regions. They found that even short period of drought stress can cause significant reduction in tuber yield and quality of potato. CO_2 have positive and temperature have negative impacts on the productivity of potato. They also investigated that using deficit irrigation strategies and introducing the potato genotype resistance to abiotic stress varieties production of potato can be increased.

Levy *et al.* (2013) studied the adaptation of potato to water shortage, irrigation management and enhancement of tolerance to drought and salinity. They investigated that abiotic stress factors such as drought, heat and salinity have adverse effects on growth and yield of potato because potato crop depends on a regular water supply to secure high quality yields. To cope with water stress different approaches are presented including altering morphological, physiological and genetic characteristics of potato by employing biotechnology.

Ami *et al.* (2013) conducted an experiment at the Horticultural Farm, Bangladesh Agricultural University (BAU), My mensingh during the period from October 2010 to April 2011. The objective of study was to defining the effects of vernalisation on the yield of onion seed. The experiment contained three levels of

Vernalisation (vernalisation of mother bulbs at 5 ^{o}C ± 1 and 10 ^{0}C ± 1 and no vernalisation). Bulbs of 20±1g size of local cultivar Taherpuri were used as planting material and were vernalized at the duration of 14 days in freezing. Bulbs were vernalized in a refrigerator at a calibrated temperature of 5 ± 1 ^{0}C and 10 ± 1 ^{0}C. Plant produced from the bulbs vernalized at 5±1 ^{o}C temperature prior to planting gave maximum leaves. Early plant emergence was noticed for longer vernalisation treatment. Cold treatment of mother bulbs influenced the plant to produce maximum number of leaves.

Shibabaw*et al.* (2013) conducted exploratory survey with the objective to understand the climate change impacts on the potato value chain process at the place of AWI-Zone Ethiopia. The survey results showed that drought, floods, heat waves, strong winds, night frost and erratic rainfall affects the value chain process of potato. They observed that drought damages the infrastructure, while delayed and erratic rain fall reduced the yield of potato and increased the insect pest pressure and diseases which causes inconsistent supply to the traders and hence to the consumers.

The spatial analogue approach is the most suitable technique to investigate the impact of climate change on agriculture. However, from the beginning this method has produced criticism. The major drawbacks of this approach include unavailability of reliable data for agricultural farm values and the existence of imperfect land markets in developing countries. This approach can be criticized on the assumptions of long run equilibrium costs which ignore the short and medium run adjustment costs, and the farmers will automatically respond to climate changes. The approach also ignores the changes in output and input prices that result from global changes in production and affect farm level adaptation decisions. (Adams *et al*.1998). This method also criticized for its static nature and how to capture future technologies (Salvo *et al*. 2014).

CHAPTER 3

DATA AND METHODOLOGY

3.1Background

For the analysis, cross-sectional time series (panel) data is used in this study. The analysis shall be carried out using data for three major vegetables namely Potato, Onion and Chilies for selected districts of Pakistan for the time period between 1981 and 2010. The data used in this study relates 10 for potato, 17 for onion and 9 for chilies from major producing districts of these crops for the period 1981-2010.

Table 0.1: Detail of Selected Districts for each Crop

Province	Potato	Onion	Chilies
Punjab	Faisalabad	Faisalabad	Kasur
	Jhang	Gujranwala	Okara
	Sialkot	Kasur	Sahiwal
	Gujranwala	Sahiwal	Multan
	Sheikhupura	Multan	
	Lahore	Vehari	
	Kasur	DG. Khan	
	Okara		
	Sahiwal		
	Multan		
Sindh		Sakhar	Sanghar
		Nawabshah	Therparker
		Shikarpur	Hyderabad
		Sanghar	Badin
		Tharparker	Thatta
		Hyderabad	
		Badin	
Baluchistan		Chaghi	
		Khuzdar	
		Kalat	

The selection of each district was based on three considerations: a) presence of meteorological observatory since early 1960s; b) contribution of the district to vegetables production; and c) the year of creation of the district[7](in 1980-81 or earlier). Out of the selected districts, for potato all were selected from Punjab province. For onion 7 from Punjab, 7 from Sindh and 3 from Baluchistan were selected. For chilies 4 from Punjab and 5 from Sindh were selected. All the selected districts are presented in table 3.1. This chapter further discusses the climatic data and economic data used in the study and its sources from where it obtained.

3.2Climatic Data and its Sources

Temperature and precipitation are the most important climatic variables that are used in this study. Districts level data regarding these two variables was obtained from the Pakistan Meteorological Department (PMD), Islamabad. Further description of these variables and its units are described in table 3.2.

Table 0.2: Details of Variables used in the Model

Variables	**Sources**	**Units**
Temperature	PMD**	Monthly means $°_C$
Precipitation		Monthly means mm
Shocks in temperature	own calculation	
Shocks in precipitation		
Yield	PBS*	Thousand tons per (000) hectare
Area	PBS*	000 Ha
Production	PBS*	000 tones

**Pakistan Metrological Department (PMD),* Pakistan Bureau of Statistics (PBS)

[7]Several new districts were created in Pakistan during the period 1981-2010, the statistics regarding these districts for the years prior to their creation were never worked out by the concerned quarters and therefore are not reported. This left us with no choice but to merge the available data in parent districts. In addition, this action also helped in balancing the panel.

3.3Economic Data

The district level data regarding crop yield, area and production were taken from Pakistan Bureau of Statistics and Provincial Development Statistics. The detail of these variables units are also describe in Table 3.2.

3.4Phenological Stages of each Crop

The growing seasons of the selected three crops vary throughout Pakistan.The scientific information of production stages of these crops and their optimal temperature and precipitations were taken from the National Agriculture Research Centre (NARC), Islamabad.

Potato growing seasons are different throughout the year. Table 3.3shows the different growing seasons and timings of sowing and harvesting and Table3.4 shows the share of cropping seasons throughout the Pakistan. More than 90 percent of total production comes from Punjab and the remaining 10 percent comesfrom KPK, Baluchistan and Sindh. Therefore, for potato crop Punjab has been selected for carrying analysis. The autumn crop of potato contributes 70-75 percent towards overall production. Hence, the autumn potato crop was selected for analyses. The autumn growing season extends from September to January in Punjab. The first phonological stage sowing/sprout development covers time span of September-October. The second vegetative stage/tuber initiation covers time span ofNovember-December. The third and last stage of maturity to harvesting covers in January.

Table0.3: Province Wise Croping Calander of Potato

Province	Time of sowing	Time of harvesting	Crop season
Punjab	September	January	Autumn
	January	April/May	Spring
KPK	September	January	Autumn
	February	June	Spring
Baluchistan	March/ June	November	Summer
Sindhh	October	January/February	Autumn

Table 0.4: Season Wise Croping Calander and Production share of Potato

Potato crop seasons	Sow(Month)	Harvest(Month)	Production share (%)
Autumn crop	September/October	January/February	70-75
Spring crop	January/February	April/may	7-10
Summer crop	March –May	August- October	15-20

Onions are grown all over in Pakistan. However, almost 41 percent comes from Sindh of total production followed by 29 percent from Baluchistan and 20 percent from Punjab. Over 60 percent onion is produced during the seasons of June to January in Sindh and Baluchistan. Table 3.5 shows that the first stage sowing/germination/emergence of onion covers during time span from June to July. The second stage transplantation/vegetative growth and bulb formation extends from August to November. The third and last stage maturity to harvesting covers period from December to January. In Punjab, with 29 percent shares in total production, the first stage covers during October to December. The second stage in Punjab extends from January to April and last stage from May to June as also indicated in table 3.5.

Table 0.5Province Wise Croping Calander of Onion

Activities	Punjab	KPK/hilly areas	Sindhh/ Baluchistan
Sowing/Germination/Emergence	Oct-Dec	Oct-Dec	June-July
Transplantation/Vegetative Growth/Crop Mgt/ Bulb formation	Jan-April	Jan-June	Aug-Nov
Maturity/Harvesting	May-June	July-Aug	Dec-Jan

The climatic suitability of the southern zone of the country to the production of chili has raised the share of Sindh to 59.4 percent of total production, followed by

Punjab, Baluchistan and KPK which contributed 21.1 percent, 18.3 percent and 1.2 percent respectively.

Table 3.6 shows that chilies growing seasons in Punjab and Baluchistan extends normally from February to September. In Sindh chilies growing season starts from September and ends in April covering various phonological stages. The first stage covers sowing/germination/emergence and transplanting; the second stage covers vegetative growth, flowering and fruiting; the third stage covers maturity and harvesting. In Sindh first stage covers period from September to November, the second stage extends from December to January and third and last stage extends from February to April. In Punjab and Baluchistan first stage covers February to April the second stage extends from May to June and third stage covers from July to September.

Table 0.6Province Wise Croping Calander of Chilies

Activities	**Punjab**	**Khyber Pakhtunkhwa/ Baluchistan**	**Sindh**
Sowing/Germination/Emergence	Feb-March	Feb-April	Sept-Oct.
Transplantation	April	May-June	Nov.
Vegetative Growth/Crop mgt/ Flowering/Fruiting/Maturity/Harvesting	May-Sept.	June-Oct	Dec-April

3.5The Empirical Model

In the light of above discussion and observations, this study employs the production function approach to investigate the effects of climate change on vegetables production. The researcher is restricted to employ this approach because consistent time series of precipitation and temperature are not found for the relevant commodity produced in Pakistan such as potato, onion and chilies. Therefore, the other competing models such as Simulation models and Ricardian model cannot be applied due to data constraints. In an attempt to identify the effects of climate change, this study controls for agricultural inputs such as agricultural land and machinery.

The general form of the production function can be written as.

$$Y = f(cv, Ncv) \qquad (3.1)$$

Where, Y is production per-hectare (yield), cv is the vector of climatic variables including temperature and precipitation while Ncv is the vector of non-climatic variables such as area under cultivation and technological changes. Following Ahmad and Ahmad (1998), the Cobb-Douglas functional form can be written as.

$$Y_{it} = e^{\beta_0 + \beta_T(TEMP_{it}) + \beta_P(PREC_{it}) + \beta_{VT}(VTEM_{it}) + \beta_{VP}(VPREC_{it})} \times AREA_{it}^{\beta_{au}} \times e^{\beta_g T} \times e^{\mu_{it}} \quad (3.2)$$

Where Y_{it} represents yield per hectare in district i at time t. β_0 is constant and β_T, β_P, β_{VT} and β_{VP} are vector of unknown parameters to be estimated which respectively relate to temperature normal, precipitation normal, variation of temperature from normal and variation of precipitation from normal. Other unknown parameters β_{au} and β_g are associated with area under cultivation and time trend capturing technological changes, respectively. μ_{it} represent error term with zero mean and variance. Following Caba s*et al*. (2010) Temperature and precipitation are 20 years moving averages of temperature and precipitation to capture the long run impacts because climate change is not a phenomenon of few years. By taking the natural logarithm on both sides of Equation 3.2 the function can be written as.

$$\ln Y_{it} = \beta_0 + \beta_T(TEMP_{it}) + \beta_P(PREC_{it}) + \beta_{VT}(VTEM_{it}) + \beta_{VP}(VPREC_{it}) + \beta_{au}\ln AREA_{it} + \beta_g T + \mu_{it}$$

(3.3)

Following Lee *et al.* (2012) and Chang. (2002)[8] the non-linearity and joint impacts of climatic variables are captured by introducing quadratic and interaction terms of these variables. Floods and drought conditions have been very common in districts which are growing onion and chilies. To control the effects of drought and floods dummy variables (DV) have also been introduced in the model. The recent drought periods have clearly resulted in substantial yield reduction in the areas where in, the most vulnerable to drought such as Baluchistan and Sindh.

Following Dixon *et al*. (1994) and Kaufmann and Snell (1997) the data for climatic variables (temperature and precipitation) used for three phonological stages and estimated the full version of Equation 3.3 which can be written as;

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[8] Lee, et al. (2012) analyzed the impact of climate change on agricultural production in Asian countries; Evidence from panel study.

Ching-Cheng Chang. (2002) studied the potential impact of climate change on Taiwan's agriculture.

$$\ln Y_{it} = \beta_0 + \beta_{Ts} TEMP_s + \beta_{TV} TEMP_V + \beta_{TM} TEMP_M + \beta_{PS} PREC_S + \beta_{PV} PREC_V + \beta_{PM} PREC_{PM} + \beta_{2Ts}(TEMP_s)^2 + \beta_{2TV}(TEMP_V)^2 + \beta_{2TM}(TEMP_M)^2 + \beta_{2PS}(PREC_S)^2 + \beta_{2PV}(PREC_V)^2 + \beta_{2PM}(PREC_{PM})^2 + \beta_{VTS} VTEMP_S + \beta_{VTV} VTEMP_V + \beta_{VTM} VTEMP_M + \beta_{VPS} VPREC_S + \beta_{VPV} VPREC_V + \beta_{VPM} VPREC_M + \beta_{TPS}(TEMP_S \times PREC_S) + \beta_{TPv}(TEMP_V \times PREC_V) + \beta_{TPM}(TEMP_M \times PREC_M) + \beta_{au} \ln(AREA) + \beta_g T + \beta_{DV} DV + \mu_{it}$$
(3.4)

The literature on panel data basically proposes two different approaches to estimate the country specific effects, the random effects (RE) and the fixed effects (FE). The term “Fixed” and “Random” effects are used frequently in the hierarchical linear modeling literature. The motivation behind these effects is the problem of the omitted variables effects which lead to unobserved effects in the panel data. The model preferred to capture these effects are named accordingly to the nature of the effects which are:

- Fixed effects model
- Random effects model

3.5.1Fixed Effects Model (FEM)

These unobserved effects could be time-wise or cross section wise depending upon the characteristics of the sample and objectives of the study. In agriculture these are usually time invariant because of the agro-ecological characteristics of the specific area in different time horizons. The FEM can be written as;

$Y_{it} = \beta_0 + \beta_i X_{it} + U_{it}$ ....(3.5)

$U_{it} = \alpha_i D_i + \varepsilon_{it}$ ....(3.6)

$Y_{it} = \beta_i + \beta_i X_{it} + \alpha_i D_i + \varepsilon_{it}$ ....(3.7) where X_{it} comprised of explanatory variables like area under cultivation and climatic effects etc., α_i is vector effect of X_{it} on conditional Y_{it}, effects are denoted by $\alpha_i D_i$,α_i is called as individual effect or individual heterogeneity and dummy (D) capture the characteristics which are specific to district climatic conditions, soil qualities and other knowledge of farm practices which distinguish the district from others. FEM implies that fixed terms in this model are correlated with explanatory variables (cross-section specific characteristics). In agriculture mostly FEM is preferred if sample is not chosen randomly(Wooldridge, 2002).

3.5.2Random Effect Model (REM)

The way through which the unobserved effects are viewed help in the selection of fixed or random effects approaches. If unobserved effects are detected as random variables then random effects and if act as parameters then estimated as fixed effects (Hsiao,2003). When unobserved effects, which requires the strong assumption of orthogonality (statistically unrelated) in $v_i$and X_{it} are treated as random variables then random effects model is useful that can be written as;

$$Y_{it} = \beta_0 + \beta_i X_{it} + U_{it} \qquad (3.8)$$

$$U_{it} = v_i + \varepsilon_{it} \qquad (3.9)$$

$$Y_{it} = \beta_0 + \beta_i X_{it} + v_i + \varepsilon_{it} \qquad (3.10)$$

But the random effect model usually requires a strong assumption that the correlation between explanatory variables and random effects must be zero (Wooldrige, 2002).The appropriate model can be chosen using Hausman test (Hsiao, 2006). The Hausman test formulation can be written as

$$H = (\beta^{FE} - \beta^{RE})\ [var(\beta^{FE}) - var(\beta^{RE})]^{-1}(\beta^{FE} - \beta^{RE}) \sim X^2 \qquad (3.11)$$

For test application first the model is estimated using the Random effects model after which apply the Hausman test. Hausman test is based on the idea under the hypothesis of no correlation between OLS and GLS. It means that both OLS and GLS are consistent, however, the OLS is not efficient under the alternative hypothesis; OLS is consistent while the GLS is not. Therefore, under the null hypothesis the random effects is consistent and efficient and under alternative hypothesis the fixed effect is consistent. Which estimation technique is preferred shall be decided on the basis of the Hausman test statistics.

CHAPTER 4

RESULTS and DISCUSSION

4.1Potato in Punjab

To analyze the impact of climate change on potato production, major growing districts of Punjab including Faisalabad, Jang, Sialkot, Gujranwala, Sheikhupura, Lahore, Kasur, Okara, Sahiwal and Multan were selected. To see the trends of climatic variables during the various phonological stages of potato crop, the 20 year moving average of these variables were regressed on time. The estimates of trends presented in table 4.1 show that temperature has generally decreased during the first stage (September – October) except in Faisalabad and Lahore where it show increasing trend. During the second stage (November – December) the mean temperature was observed to have declining trend except Faisalabad, Sialkot, Lahore and Multan. At the time of maturity (January) the mean temperature has been increased in all the selected districts.

Table 0.1Trends of Temperature and Precipitation Normal for Potato (Slope Coefficient of time)

District	Temperature Normals			Precipitation Normals		
	Sep – Oct (Sowing)	Nov – Dec (Vegetative)	January (Maturity)	Sep – Oct (Sowing)	Nov – Dec (Vegetative)	January (Maturity)
Faisalabad	0.010	0.033	0.013	0.399	-0.049	0.100
Jang	-0.020	-0.005^{ns}	0.006^{ns}	0.276	0.051	0.277
Sialkot	-0.001^{ns}	0.025	0.001^{ns}	0.504	0.048^{ns}	0.024^{ns}
Gujranwala	-0.032	-0.018	0.016	0.504	0.048^{ns}	0.024^{ns}
Sheikhupura	-0.017	-0.007^{ns}	0.012	0.327	-0.005^{ns}	-0.043^{ns}
Lahore	0.012	0.049	0.029	0.327	-0.005^{ns}	-0.043^{ns}
Kasur	-0.033	-0.026	0.011^{ns}	0.327	-0.005^{ns}	-0.043^{ns}
Okara	-0.040	-0.024	0.014	0.399	-0.049	0.017^{ns}
Sahiwal	-0.040	-0.017	0.016	0.280	-0.036	0.135
Multan	-0.007	0.028	0.015	0.544	-0.062	-0.039^{ns}

Ns= non-significant

The result further shows that precipitation during first stage September – October has increased in all the selected districts. During the months of November – December it shows declining trend in all the districts except Jhang, Sialkot and Gujranwala. The month of January shows mix trend and generally the estimates were statistically non-significant. The Hausman (1978) test was applied to investigate either random effects or a fixed effect is appropriate.

Table 0.2Hausman test Results for POTATO

Null Hypothesis	Chi-Sq. Statistic	P-Value	Test Summary
Random is appropriate	21.67	0.1542	Not rejected

Table 4.2 shows that null hypothesis not rejected which implies that the Random effect is appropriate. Random effect estimates for potato are reported in table 4.4 by following the General to Specific (G2S) approach. The Wald tests were applied to choose the final model that best suits the data. On the basis of the specification tests Model F[9] has been selected as a final model. The specification tests results are stated in table 4.3.

[9] Six models have been calculated in this Random effects approach. Final Model F selected and results are reported on page 42.

Table 0.3Specification Tests for Potato

Null Hypothesis		χ^2 value (Prob.)	Result
$\beta_{TPS} = \beta_{TPV} = \beta_{TPM} = 0$	Interaction Terms	12.35 (0.0063)	Rejected
$\beta_{VPS} = \beta_{VPV} = \beta_{VPM} = 0$	Precipitation Variations	23.29 (0.0000)	Rejected
$\beta_{VTS} = \beta_{VTV} = \beta_{VTM} = 0$	Temperature Variations	5.39 (0.1453)	Not rejected
$\beta_{2PS} = \beta_{2PV} = \beta_{2PM} = 0$	Precipitation Square	4.89 (0.1803)	Not rejected
$\beta_{2TS} = \beta_{2TV} = \beta_{2TM} = 0$	Temperature Square	4.12 (0.2492)	Not rejected
$B_{PS} = \beta_{PV} = \beta_{PM} = 0$	Precipitation normal	6.04 (0.1099)	Not rejected
$\beta_{TS} = \beta_{TV} = \beta_{TM} = 0$	Temperature normal	4.27 (0.2338)	Not rejected

The first hypothesis tested was that βTPS = βTPV = βTPM = 0 which states that temperature and precipitation combined have no influence on potato productivity. The null hypothesis was rejected which implies that interaction term has significant impact on potato productivity. The second hypothesis tested was thatβVPS = βVPV = βVPM = 0 which states that variation of precipitation is equal to zero. The estimate implies that precipitation shocks have significant influence on potato productivity. By following the results the variation of temperatureβVTS = βVTV = βVTM = 0 was tested which was not rejected. Given the outcome of these tests square terms of both temperature normal β2TS = β2TV = β2TM = 0 and precipitation normal β2PS = β2PV = β2PM = 0 were tested one by one. The null hypotheses of both were not rejected. By following the results of square terms the hypothesis tested was that BPS = βPV = βPM = 0 which states that precipitation normal is equal to zero. The null hypothesis was not rejected. The last hypothesis tested was that βTS = βTV = βTM = 0 which states that potato productivity is not impacted by the temperature normal. The null hypothesis also not rejected.

The results reported in table 4.4 (Model F) show that the variation of precipitation at the time of sowing (September – October) and vegetative (November – December) impacted the yield of potato negatively. However, the results are statistically significant at the time of sowing. While at the time of maturity (January) the coefficient is statistically significant and carries a positive sign. The interaction terms which are temperature normal and precipitation normal have significant influence on potato yield indicating that higher temperature with greater precipitation at the time of sowing is beneficial. However, at the time of vegetative growth and maturity this increase is harmful for the greater productivity. Nevertheless, the results are statistically non-significant.

Among the non-climatic variables the coefficient value of area under cultivation is 0.036 which shows increasing returns to scale though, it is statistically non-significant. The time trend – proxy for technology and infrastructure shows that potato productivity has significantly increased with the improvement of technology in Punjab. These results indicate that the production of potato crops have not been impacted significantly by the changes in climatic normal. However, shocks in precipitation and combine increase in temperature with increase of precipitation have affected the potato productivity negatively.

Table 0.4: REM Estimates for Potato (Dependent Variable: natural logarithm of yield)

		Model A		**Model B**		**Model C**		**Model D**		**Model E**		**Model F**	
Variables		**Coef.**	**Std.**	**Coef.**	**Std.**	**Coef.**	**Std.**	**Coef.**	**Std.**	**Coef.**	**Std.**	**Coef.**	**Std.**
Constant	β_0	22.545**	11.654	22.940**	11.694	22.239**	9.223	1.017	0.787	0.798	0.619	1.876***	0.293
Time	β_g	0.019***	0.002	0.020***	0.002	0.019***	0.002	0.020***	0.002	0.021***	0.002	0.022***	0.002
Temperature (Sep-Oct)	β_{TS}	2.083**	1.066	2.127**	1.069	2.113***	0.814	-0.001	0.040	0.026	0.031		
Temperature (Nov-Dec)	β_{TV}	-0.701	0.489	-0.720	0.490	-0.761**	0.343	0.059***	0.024	0.021	0.019		
Temperature (January)	β_{TM}	0.152	0.228	0.116	0.228	0.080	0.185	-0.030	0.032	-0.010	0.024		
Precipitation (Sep-Oct)	β_{PS}	0.013	0.013	0.019	0.013	0.007	0.010	0.004	0.010				
Precipitation (Nov-Dec)	β_{PV}	0.072*	0.040	0.072*	0.040	0.102***	0.037	0.064**	0.033				
Precipitation (January	β_{PM}	-0.035**	0.015	-0.036**	0.015	0.029***	0.011	-0.023**	0.011				
Temperature (Sep-Oct)2	β_{2TS}	-0.038**	0.020	-0.038**	0.020	0.039***	0.015						
Temperature (Nov-Dec)2	β_{2TV}	0.024	0.016	0.025	0.016	0.027**	0.011						
Temperature (January)2	β_{2TM}	-0.008	0.008	-0.007	0.008	-0.006	0.006						
Precipitation (Sep-Oct)2	β_{2PS}	0.000	0.000	0.000	0.000								
Precipitation (Nov-Dec) 2	β_{2PV}	0.001	0.001	0.001	0.001								
Precipitation (January)2	β_{2PM}	0.000	0.000	0.000	0.000								
V Temperature (Sep-Oct)	B_{VTS}	-0.014	0.010										
V.Temperature (Nov-Dec)	B_{VTV}	0.006	0.011										
V Temperature (January)	B_{VTM}	-0.011	0.008										
V Precipitation (Sep-Oct)	B_{VPS}	0.002***	0.001	0.001***	0.001	0.001***	0.000	0.001***	0.000	0.002***	0.001	-0.002***	0.000
Precipitation (Nov-Dec)	B_{VPV}	-0.001	0.001	-0.001	0.001	-0.001	0.001	-0.001	0.001	-0.001	0.001	-0.001	0.001
V Precipitation (January)	B_{VPM}	0.002***	0.001	0.002***	0.001	0.002***	0.001	0.002***	0.001	0.003***	0.001	0.003***	0.001
Temp x Precip(Sep-Oct)	β_{TPS}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000***	0.000	0.001*	0.001
Temp x Precip(Nov-Dec)	β_{TPV}	0.006***	0.002	0.006***	0.002	0.006***	0.002	-0.004**	0.002	0.000	0.000	-0.001	0.001
Temp x Precip (January)	β_{TPM}	0.001	0.001	0.001*	0.001	0.002*	0.001	0.001	0.001	-0.001*	0.000	-0.001	0.001
N logarithm of Area	β_{Au}	0.057	0.037	0.063*	0.037	0.101***	0.029	0.079***	0.026	0.056**	0.025	0.036	0.035
Note:	***, **,* indicate the 1%, 5% and 10% level of significance.												

4.2Onion in Punjab

To check the behavior of climatic variables (temperature and precipitation) in major onion growing areas, 20 years moving average of these climatic variables were regressed against the time. The estimated trends are presented in the table 4.5. This shows that during the months of October – December the temperature have decreasing trend in the selected districts of Punjab except Faisalabad and Multan where it shows increasing trend. The second phonological stage of onion covers in the month of January – April. The temperature trend in these months also shows decreasing trend except Faisalabad and Multan. The trend of May – June is increasing except Gujranwala and DG. Khan with a slightly decreasing trend. Overall the precipitation shows increasing trend during October – December and May – June the first and third phonological stages respectively. During the second stage of crop production precipitation was showing decreasing trend except in the districts of Faisalabad and Sahiwal.

Table 0.5Trends of temperature and precipitation normal for onions (slope coefficient of time) Punjab

District	Temperature Normals			Precipitation Normals		
	Oct – Dec (Sowing)	Jan – April (Vegetative)	May – Jun (Maturity)	Oct – Dec (Sowing)	Jan – April (Vegetative)	May – June(Maturity)
Faisalabad	0.019	0.019	0.018	-0.019^{ns}	0.085	0.477
Gujranwala	-0.021	-0.030	-0.002^{ns}	0.198	-0.074^{ns}	-0.300
Kasur	-0.030	-0.016	0.006	0.051^{ns}	-0.216	0.420
Sahiwal	-0.026	-0.014	0.008	0.076	0.036	0.024^{ns}
Multan	0.016	0.025	0.017	0.054	-0.004^{ns}	0.071
Vehari	-0.037	-0.022	0.002^{ns}	0.054	-0.004^{ns}	0.071
DG. Khan	-0.003^{ns}	-0.021	-0.002^{ns}	0.054	-0.004^{ns}	0.071

Ns= non-significant

Based on the Hausman test Random effects technique was selected. The Wald specification tests were applied to check that either climatic variable have affected the onion yield in selected districts of Punjab or not. The result of specification tests are presented in table 4.7 shows that most of the variables affected the yield of onion except the temperature and precipitation variation. The null hypothesis of temperature variation and precipitation variation not rejected. This implies that variation in the temperature and precipitation has no effect on the onion yield in Punjab.

Table 0.6Result of Hausman test for onion in Punjab

Null Hypothesis	Chi-Sq. Statistic	Prob.	Test Summary
Random is appropriate	21.42	0.4337	Not rejected

Based on the specification tests Model C selected as a final model which suggests a non-linear impact of climatic variables on onion yield in Punjab. It is obvious from the results that temperature and precipitation normal make a significant joint impact across various stages of the crop growth. It shows the fact that the impact of temperature and precipitation is not independent.

Table 0.7Specification tests for onion in Punjab

Null Hypothesis		χ^2 value (Prob.)	Result
βTPS = βTPV = βTPM =0	Interaction Terms	48.81 (0.0000)	Rejected
βVPS = βVPV = βVPM =0	Precipitation Variations	7.18 (0.0665)	Rejected
βVTS = βVTV = βVTM =0	Temperature Variations	2.34 (0.5058)	Not rejected
β2PS = β2PV = β2PM=0	Precipitation Square	14.84 (0.0020)	Rejected
β2TS = β2TV = β2TM = 0	Temperature Square	8.59 (0.0353)	Rejected
BP**S** = βPV = βPM = 0	Precipitation normal	52.23 (0.0000)	Rejected
βT**S** = βTV = βTM = 0	Temperature normal	11.82 (0.0080)	Rejected

The result of specification tests helps that variation term of temperature and precipitation should not incorporated in the final Model C presented in table 4.8. The results of this model purposed that increase in average temperature normal during the sowing stage (October – December) is beneficial for the onion productivity. While during the second stage (January – April) and third stage (May – June) of crop growth harms the productivity. However, these results are statistically non-significant.

The increase in precipitation during the first stage of sowing has statistically significant and positive impact on the productivity. The second stage results show negative but non-significant impact. However, at the time of maturity increase in precipitation has significantly negative impact on the productivity. The temperature normal combined with precipitation normal show statistically significant and negative influence at the time of sowing which shows that higher temperature with greater precipitation at the time of sowing cause low productivity.

The marginal impact of increase in temperature during the sowing stage(October – December) is 0.113 which implies that if there is any increase in temperature assuming the precipitation occurs at the historic mean would prove beneficial for the crop productivity. The higher temperature with greater precipitation at the time vegetative growth and maturity has positive impact. This impact at the time of vegetative stage is statistically non-significant while at the time of maturity it is significant. The marginal impact of temperature at the time of vegetative stage (January – April) is -0.205 which show that increase in temperature at the historic mean of precipitation cause harmful for yield of onion. The marginal impact of rise in temperature during maturity stage (May – June) is 0.092 this implies positive impact on the productivity of onion in Punjab.

The marginal impacts of precipitation for sowing, vegetative and maturity stages are 0.238, -0.020 and -0.141 respectively. This implies that increase in precipitation assuming the temperature at its historic mean would cause beneficial at the time of sowing in October – December but it harms the productivity at the stages of vegetative growth in January – April and maturity in May – June. The low productivity due to increase in precipitation could be due to higher pests and disease infection and uselessness of weed control measures.

Table 0.8 REM Estimates for Onion in Punjab (Dependent Variable: natural logarithm of yield)

		Model A		**Model B**		**Model C**	
Variables	**Parametr**	**Coef.**	**Std.**	**Coef.**	**Std.**	**Coef.**	**Std.**
Constant	β_0	12.421***	5.070	12.013**	5.028	12.971***	5.047
Time	β_g	-0.014***	0.002	0.014***	0.002	-0.014***	0.002
Temperature(Oct-Dec)	β_{TS}	0.120	0.180	0.116	0.179	0.162	0.180
Temperature (Jan -Apr)	β_{TV}	-0.155	0.315	-0.117	0.313	-0.123	0.317
Temperature(May- Jun)	β_{TM}	-0.525	0.382	-0.517	0.380	-0.603	0.381
Precipitation (Oct-Dec)	β_{PS}	0.19***	0.062	0.190***	0.062	0.210***	0.061
Precipitation (Jan-Apr)	β_{PV}	-0.029	0.028	-0.026	0.028	-0.023	0.028
Precipitation (May- Jun)	β_{PM}	-0.118***	0.029	0.120***	0.029	-0.120***	0.029
Temperature(Oct-Dec)2	β_{2TS}	0.000	0.004	0.000	0.004	-0.001	0.004
Temperature (Jan-Apr)2	β_{2TV}	-0.001	0.006	-0.002	0.006	-0.002	0.006
Temperature(May-Jun)2	β_{2TM}	0.008	0.005	0.008	0.005	0.009*	0.005
Precipitation(Oct-Dec)2	β_{2PS}	0.002**	0.001	0.002**	0.001	0.002***	0.001
Precipitation (Jan-Apr)2	β_{2PV}	0.000	0.000	0.000	0.000	0.001	0.001
Precipitation(May-Jun)2	β_{2PM}	-0.001**	0.000	-0.001**	0.000	-0.001**	0.001
V Temp (Oct-Dec)	B_{VTS}	0.008	0.006				
V Temp (Jan-Apr)	B_{VTV}	0.007	0.007				
V Temp(May-Jun)	B_{VTM}	-0.008	0.006				
V Precip (Oct-Dec)	B_{VPS}	-0.001	0.001	-0.001	0.001		
V Precip (Jan-Apr)	B_{VPV}	-0.001	0.001	-0.001	0.001		
V Precipi (May- Jun)	B_{VPM}	0.001**	0.001	0.001**	0.001		
Temp x Precip (Oct-Dec)	β_{TPS}	-0.011***	0.003	0.011***	0.003	-0.012***	0.003
Tempx Precip(Jan-Apr)	β_{TPV}	0.001	0.001	0.001	0.001	0.001	0.001
Temp x Precip (May- Jun)	β_{TPM}	0.004***	0.001	0.004***	0.001	0.004***	0.001
N logarithm of Area	β_{Au}	0.008	0.022	0.006	0.022	0.011	0.021
DF (Extreme Events)	β_{Df}	-0.254**	0.106	-0.250**	0.106	-0.222**	0.106

Note: ***, **,* indicate the 1%, 5% and 10% level of significance, respectively.

The non-linear impact of temperature and precipitation is captured by including the square terms. The temperature square at the time of sowing and vegetative growth harms the productivity while at the time of maturity it causes beneficial and statistically significant impact on productivity. The precipitation square has beneficial impact on the productivity at the time of sowing and vegetative stages. While at the time of maturity it has negative impact on productivity. However, it is statistically significant at the time of sowing and maturity.

Table 0.9Marginal Effects for Onion in Punjab

Temperature sowing	0.113
Temperature vegetative	-0.205
Temperature maturity	0.092
Precipitation sowing	0.238
Precipitation vegetative	-0.020
Precipitation maturity	-0.141

During the last couple of decades the intensity of floods has increased (TFCC, 2010). The country also has major drought history. The impact of these events have captured by introducing the dummy variables. The sign of coefficient of the extreme events is significantly negative which show that these extreme events were major caused to decline in productivity. Among the non-climatic variables, the sign of coefficient of area under cultivation is positive, indicating the increasing returns to scale. However, it is statistically non-significant. The coefficient value of time trend is -0.014 signifying that onion productivity in Punjab has been decreasing significantly due to technological change.

4.3Onion in Sindh and Baluchistan

The behavior of climatic variables trend with the passage of time presented in table 4.10 and in table 4.11 shows that during the months of (June – July) temperature have generally declining trend in selected districts of Sindh and Baluchistan. The trend in the months of (August – November) and (December – January) is showing increase in temperature.

Table 0.10Trends of temperature and precipitation normal for onions in Sindh (slope coefficient of time)

District	Temperature Normals			Precipitation Normals		
	June – July (Sowing)	Aug– Nov (Vegetative)	Dec – Jan (Maturity)	June – July (Sowing)	Aug– Nov (Vegetative)	Dec – Jan (Maturity)
Sakhar	0.013	0.037	0.014	0.562	-0.062	-0.009^{ns}
Nawabshah	0.005	0.018	0.024	0.007^{ns}	0.642	-0.033
Shikarpur	-0.010	0.012	0.011	-0.049^{ns}	0.089	0.099
Sanghar	-0.009	-0.011	0.014	-0.049^{ns}	0.089	0.099
Tharparker	-0.011	-0.022	0.004^{ns}	0.341	-0.063^{ns}	-0.004^{ns}
Hyderabad	-0.017	-0.011	0.004^{ns}	-0.157^{ns}	0.134	0.011^{ns}
Badin	-0.004	0.003^{ns}	0.034	0.341	-0.063^{ns}	-0.004^{ns}

Table 0.11Trends of temperature and precipitation normal for onions in Baluchistan (slope coefficient of time)

District	Temperature Normals			Precipitation Normals		
	June – July (Sowing)	Aug– Nov (Vegetative)	Dec – Jan (Maturity)	June – July (Sowing)	Aug– Nov (Vegetative)	Dec – Jan (Maturity)
Chaghi	0.021	0.037	0.003^{ns}	0.371	0.089	-0.521
Khuzdar	-0.006	0.021	0.013	0.387	-0.072	0.069
Kalat	-0.072	-0.022	0.088	0.568	0.161	1.615

Ns= non-significant

The precipitation trend was positive throughout the crop growth period. The impact of climate change is different in different scenarios in different regions. After investigating the impact of climate change on onion yield in Punjab now this impact is measured separately in selected districts of Sindh and Baluchistan

Table 0.12Result of Hausman test for Onion in Sindh and Baluchistan

Null Haypothesis	Chi-Sq. Statistic	Prob.	Test Summary
Random is appropriate	36.88	0.0082	Rejected

From the probability value of Hausman test presented in table 4.12 we can infer that fixed effect is more reliable and suitable than Random estimates. Based on the Wald specification tests Model D, has been selected as final model. For Wald tests statistics see (table 4.13). The results shows that temperature normal, precipitation normal, and square terms of these normal affected the yield and should include in the final Model D, whereas temperature and precipitation variations from mean have no influence on the productivity. The estimates of the Wald tests also lead us that the temperature normal interacts with precipitation normal also have no impact on the onion yield in Sindh and Baluchistan

Table 0.13Specification tests for onion in Sindh and Baluchistan

Null Hypothesis		**χ^2 value (Prob.)**	**Result**
βTPS = βTPV = βTPM = 0	Interaction Terms	5.11 (0.1636)	Not rejected
βVPS = βVPV = βVPM =0	Precipitation Variations	4.76 (0.1906)	Not rejected
βVTS = βVTV = βVTM=0	Temperature Variations	4.32 (0.2286)	Not rejected
β2PS = β2PV = β2PM = 0	Precipitation Square	24.59 (0.0000)	Rejected
β2TS = β2TV = β2TM = 0	Temperature Square	22.57 (0.0000)	Rejected
BP**S** = βPV = βPM = 0	Precipitation normal	13.48 (0.0037)	Rejected
βT**S** = βTV = βTM = 0	Temperature normal	7.67 (0.0532)	Rejected

The results of alternative models estimates for onion yield for Sindh and Baluchistan using fixed effects methods are stated in table 4.14. The estimates show that the temperature normal at the time of sowing in the months of (June – July) and maturity in the months of (December – January) have positive impacts on yield. While at the time of vegetative growth increase in temperature normal has negative impacts on productivity. However, the results are statistically significant at the time of sowing and vegetative growth. It is obvious from the results that precipitation normal at the time of sowing impacts statistically significant and carries positive sign. At the time of vegetative growth coefficient carries positive sign however it is statistically non-significant. The increase in precipitation normal at the time of maturity impacted the onion productivity harmfully. The result of quadratic terms shows that at the time of sowing temperature have significantly harms the productivity. At the time of vegetative growth this increase proves to be significantly beneficial for the yield. While at the time of maturity this increase cause loss of productivity however it is statistically non-significant. Precipitation square at the time of sowing and vegetative growth has negative impact but this increase will be beneficial at the time of maturity. The drought and flood events in Sindh and Baluchistan are captured by including the dummy variables of extreme events. The coefficient of extreme events carries negative sign which implies that these events caused to decrease in the productivity of onion.

The parameter estimates of non-climatic variables including area under onion and time trend proxy for technological innovation are statistically significant and carry positive signs. The important conclusion arise from these findings are that growing of onion crop faces increasing returns to scales and improvement in production technologies has played a substantial role in improving onion yield in Sindh and Baluchistan.

Table 0.14FEM Estimates for Onion in Sindh and Baluchistan (Dependent Variable: LN yield)

		Model A		Model B		Model C		Model D	
Variables	Parameters	Coef.	Std.	Coef.	Std.	Coef.	Std	Coef.	Std.
Constant	β_0	-9.800	13.763	22.750**	11.260	23.499**	11.272	-19.830*	11.020
Time	β_g	0.013***	0.003	0.014***	0.002	0.014***	0.002	0.014***	0.002
Temperature(Jun-July)	β_{TS}	0.800	0.809	1.650***	0.649	1.740***	0.643	1.546**	0.630
Temperature (Aug-Nov)	β_{TV}	-0.446***	0.160	0.502***	0.151	0.532***	0.147	0.546***	0.145
Temperature(Dec - Jan)	β_{TM}	0.297	0.244	0.468**	0.226	0.416*	0.217	0.331	0.212
Precipitation (June-July)	β_{PS}	0.076*	0.042	0.015	0.012	0.018	0.011	0.019*	0.011
Precipitation (Aug-Nov)	β_{PV}	0.094	0.076	0.028**	0.014	0.023	0.014	0.022	0.014
Precipitation (Dec - Jan)	β_{PM}	-0.061***	0.023	-0.022*	0.013	-0.020	0.012	-0.017	0.012
Temperature(June-July)2	β_{2TS}	-0.010	0.012	-0.024**	0.010	0.025***	0.010	-0.022**	0.010
Temperature (Aug-Nov)2	β_{2TV}	0.009***	0.003	0.009***	0.003	0.010***	0.003	0.010***	0.003
Temperature(Dec - Jan)2	β_{2TM}	-0.007	0.008	-0.013*	0.008	-0.011	0.007	-0.008	0.007
Precipitation (June-July)2	β_{2PS}	0.000	0.000	0.000	0.000	0.000	0.000	-0.001*	0.001
Precipitation (Aug-Nov)2	β_{2PV}	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.001
Precipitation (Dec - Jan)2	β_{2PM}	0.000*	0.000	0.000	0.000	0.000	0.000	0.001	0.001
V Temperature (June-July)	B_{VTS}	-0.009	0.008	-0.008	0.008	-0.008	0.008		
V Temperature (Aug-Nov)	B_{VTV}	0.012	0.011	0.013	0.011	0.015	0.011		
V Temperature(Dec - Jan)	B_{VTM}	0.011	0.009	0.010	0.009	0.009	0.009		
V Precipitation (June-July)	B_{VPS}	0.000	0.000	0.000	0.000				
V Precipitation (Aug-Nov)	B_{VPV}	-0.001	0.000	-0.001*	0.000				
V Precipitation (Dec - Jan)	B_{VPM}	0.001	0.001	0.001	0.001				
Temp x Precip (Jun-July)	β_{TPS}	-0.002	0.001						
Temp x Precip (Aug-Nov)	β_{TPV}	-0.002	0.003						
Temp x Precip (Dec - Jan)	β_{TPM}	0.003**	0.002						
Natural logarithm of Area	β_{Au}	0.052**	0.022	0.063***	0.022	0.066***	0.022	0.067***	0.022
DF (Extreme Events)	β_{Df}	-0.191	0.138	-0.185	0.139	-0.175	0.139	-0.162	0.138
Note	***, **,* indicate the 1%, 5% and 10% level of significance, respectively.								

The marginal impact of increase in temperature at the time of sowing and maturity are 0.1382 and 0.0982 respectively. This implies that any increase in temperature at the time of sowing and maturity assuming the precipitation occurs at the historic mean would prove beneficial for the productivity. However, increase in temperature at the time of vegetative growth at constant precipitation productivity of onion will be affected negatively.

Table 0.15Marginal effects of onion in Sindh and Baluchistan

Temperature sowing	0.1383
Temperature vegetative	-0.0449
Temperature maturity	0.0982
Precipitation sowing	0.0076
Precipitation vegetative	0.0128
Precipitation maturity	-0.0142

The marginal effects of increase in precipitation if temperature remains same would be binomial at the time of sowing and vegetative growth. But at the time of maturity increase in precipitation would cause decrease in productivity by –0.0142. This decrease in productivity may be due to increase in diseases due to precipitation.

4.4Chilies in Punjab

In order to observe that how temperature and precipitation behaved over time during the chilies growing season in Punjab. 20 years moving averages of these climatic variables were regressed on the time. The result presented in the table 4.16shows that during (February – April) at the time of sowing temperature have declining trend except Multan where it shows increasing trend. At the time of vegetative growth (May – June) all the districts show significantly increasing trend. This show that hotter month has become hotter. The third stage (July–September) show decrease in temperature significantly.

Table 0.16Trends of temperature and precipitation normal for chilies (slope coefficient of time) Punjab

District	**Temperature Normals**			**Precipitation Normals**		
	Feb – April (Sowing)	May – June (Vegetative)	July – Sep (Maturity)	Feb – April (Sowing)	May – June (Vegetative)	July – Sep (Maturity)
Kasur	-0.025	0.006	-0.026	-0.273	0.420	0.164^{ns}
Okara	-0.023	0.006	-0.032	0.080	0.477	-0.758
Sahiwal	-0.023	0.008	-0.033	0.003^{ns}	0.024^{ns}	-0.330
Multan	0.029	0.017	-0.011	0.008^{ns}	0.071	0.121

ns= non-significant

Precipitation on the other hand has increasing trend except Kasur in the months of (February - April). During the months of (May –June) precipitation has increased in all the selected districts. The months of (July – September) show mix trend in Kasur and Multan it has increasing while in Okara and Sahiwal it has declining trend. The overall trends of climatic and non-climatic variables are captured using random effects techniques. It was selected on the basis of Hausman test reported in table 4.17

Table 0.17Result of Hausman Test for chilies in Punjab

Null Haypothesis	Chi-Sq. Statistic	Prob.	Test Summary
Random is appropriate	6.11	0.9422	Not rejected

Based on the Wald specification tests Model G, selected as final model. Based on the Wald specification tests only hypothesis of temperature variation rejected which shows that only temperature variation has affected the productivity in Punjab.

Table 0.18Specification tests for chilies in Punjab

Null Hypothesis		χ^2 value (Prob.)	Result
βTPS = βTPV = βTPM =0	Interaction Terms	2.42 (0.4897)	Not rejected
βVPS = βVPV = βVPM =0	Precipitation Variations	6.73 (0.0811)	Not rejected
βVTS = βVTV = βVTM =0	Temperature Variations	10.15 (0.0173)	Rejected
β2PS = β2PV = β2PM = 0	Precipitation Square	0.12 (0.9894)	Not rejected
β2TS = β2TV = β2TM = 0	Temperature Square	3.63 (0.3041)	Not rejected
βPS = βPV = βPM = 0	Precipitation normal	2.44 (0.4864)	Not rejected
βTS = βTV = βTM = 0	Temperature normal	3.80 (0.2836)	Not rejected

The random effect estimates reported in Table4.19show that during the first stage (February – April) of plant growth variation in temperature has non-significantly positive impact on the yield. The second stage (May – June) the increase in temperature have negative and statistically significant impact. During the stage of maturity (July –September) variation of temperature have significantly positive impact

Table 0.19Random Effect Estimates for Chilies in Punjab (Dependent Variable: natural logarithm of yield)

Variables		Model A		Model B		Model C		Model D		Model E		Model F		Model G	
		Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.
Constant	β_0	-73.455	66.256	-41.322	35.691	-34.755	35.454	-28.892	28.878	1.327	1.035	-0.747**	0.347	0.457***	0.121
Time	β_g	-0.001	0.002	0.000	0.002	0.001	0.002	0.001	0.002	0.000	0.001	0.001	0.001	0.003**	0.001
Temp (Feb Apr)	β_{TS}	-0.420	0.813	-0.808	0.744	-0.620	0.755	-0.588	0.718	-0.018	0.027	-0.042	0.026		
Temp (May-Jun)	β_{TV}	3.288**	1.693	4.182***	1.343	4.019***	1.374	3.838***	1.273	0.015	0.019	0.026	0.018		
Tempe (July - Sep)	β_{TM}	1.056	3.193	-1.499	1.330	-1.856	1.310	-2.036*	1.102	-0.022	0.035	0.046***	0.011		
Precip (Feb April)	β_{PS}	0.134	0.098	0.004	0.015	0.005	0.015	-0.001	0.003	0.006***	0.002				
Precip (May- June)	β_{PV}	0.061	0.140	-0.003	0.012	-0.003	0.012	0.000	0.003	0.003	0.003				
Precip (July - Sep)	β_{PM}	0.032	0.052	-0.003	0.003	-0.002	0.003	-0.001**	0.001	-0.001	0.001				
Temp (Feb April)^2	β_{2TS}	0.010	0.017	0.016	0.016	0.012	0.016	0.011	0.016						
Temp (May- June)^2	β_{2TV}	-0.045*	0.024	0.057***	0.018	0.055***	0.019	0.052***	0.017						
Temp (July - Sep)^2	β_{2TM}	-0.015	0.047	0.024	0.020	0.029	0.020	0.032*	0.017						
Precip (Feb April)^2	β_{2PS}	0.000	0.000	0.000	0.000	0.000	0.000								
Precip (May- June)^2	β_{2PV}	0.000	0.000	0.000	0.000	0.000	0.000								
Precip (July - Sep ^{2}	β_{2PM}	0.000	0.000	0.000	0.000	0.000	0.000								
V.Temp (Feb April)	B_{VTS}	0.001	0.004	0.001	0.004	0.001	0.004	0.001	0.004	0.001	0.004	0.005	0.004	0.004	0.004
V.Temp (May- June)	B_{VTV}	0.006	0.006	0.005	0.006	0.004	0.006	0.004	0.005	0.002	0.006	-0.005	0.005	-0.003**	0.006
V.Temp (July - Sep)	B_{VTM}	0.005	0.004	0.006	0.004	0.006	0.004	0.006	0.004	0.008	0.004	0.012***	0.004	0.011**	0.005
V.Precip (Feb April)	B_{VPS}	-0.001	0.001	-0.001	0.001										
V.Precip (May- Jun)	B_{VPV}	0.001*	0.000	0.001*	0.000										
V.Precip (July - Sep)	B_{VPM}	0.000*	0.000	0.000**	0.000										
TempxPrecip	β_{TPS}	-0.006	0.004												
Temp x Precip	β_{TPV}	-0.002	0.004												
Temp x Precip	β_{TPM}	-0.001	0.002												
ln Area	β_{Au}	0.052**	0.025	-0.042*	0.024	-0.018	0.023	-0.017	0.022	-0.021	0.020	-0.030*	0.016	0.003**	0.015
Note:	***, **,* indicate the 1%, 5% and 10% level of significance, respectively.														

Among the non-climatic variables area under cultivation have significantly positive impact. This implies that with the increase in area productivity have increased.It shows increasing returns to scale. The technological impact obtained through time trend show that innovation in technology cause increase in productivity.

4.5Chilies in Sindh

The results reported in table4.20 shows the time trend of temperature and precipitation normal for chilies in Sindh. At the time of sowing (September – November) temperature have decrease in Sanghar, Therparker and Hyderabad whereas in Badin and Thatta it has increased. Second stage of growing (December – January) temperature has increased in all the selected districts of Sindh. At the time of maturity (February – April) again normal temperature has decreased in all the selected districts except Badin where it shows increasing trend.

Table 0.20climatic variables time trend in Sindh

District	**Temperature Normals**			**Precipitation Normals**		
	Sep – Nov (Sowing)	Dec – Jan (Vegetative)	Feb – April (Maturity)	Sep – Nov (Sowing)	Dec – JJan (Vegetative)	Feb – April (Maturity)
Sanghar	-0.008^{ns}	0.014	-0.014	-0.163	0.099	0.030
Therparker	-0.023	0.004^{ns}	-0.012	0.192^{ns}	-0.004	0.067
Hayderabad	-0.006	0.004^{ns}	-0.004	0.081^{ns}	0.011	0.065
Badin	0.007	0.034	0.017	0.192^{ns}	-0.004	0.067
Thatta	0.007^{ns}	0.008	-0.009^{ns}	-0.005	0.105	-0.247

ns= non-significant

Precipitation trend show that in Sanghar and Thatta in the months of September – November precipitation has decreased whereas in Therparker, Hyderabad and Badin trend was positive. At the time of vegetative stage it shows positive trend except in Therparker and Badin. Whereas at the time of maturity all the selected districts shows increasing trend except in Thatta.

The Hausaman's specification test estimates reported in table 4.21lead us to select random effects techniques. The Wald specification tests estimates were followed to select the final Model F. The specifications results presented in table 4.22 show that temperature normal and precipitation square have affected the productivity and included in the final model.

Table 0.21Result of Hausman test for chilies in Sindh

Null Haypothesis	Chi-Sq. Statistic	Prob.	Test Summary
Random is appropriate	12.99	0.9662	Not rejected

Table 0.22Specification tests for Chilies in Sindh

Null Hypothesis		**χ^2 value (Prob.)**	**Result**
βTPS = βTPV = βTPM =0	Interaction Terms	4.21 (0.2398)	Not rejected
βVPS = βVPV = βVPM =0	Precipitation Variations	4.24 (0.2371)	Not rejected
βVTS = βVTV = βVTM =0	Temperature Variations	0.75 (0.8625)	Not rejected
β2PS = β2PV = β2PM = 0	Precipitation Square	8.49 (0.0369)	Rejected
β2TS = β2TV = β2TM = 0	Temperature Square	2.49 (0.4779)	Not rejected
βPS = βPV = βPM = 0	Precipitation normal	2.92 (0.4044)	Not rejected
βTS = βTV = βTM = 0	Temperature normal	8.07 (0.0446)	Rejected

The random effect estimates presented in table 4.23 for chilies in Sindh show that rise in temperature during first stage (September – November) have significantly negative impact on productivity. The second stage (December – January) affected by rise in temperature positively however, it is statistically non-significant. At the time of maturity (February – April) rise in temperature is beneficial for chilies in Sindh. The non-linear impact of precipitation captured by precipitation square terms show that it has overall negative impact on productivity. However, coefficient of sowing only has statistically non-significant impact. Extreme events coefficient carries negative sign and have statistically significant impacts on productivity.

Table 0.23Random Effect Estimates for Chilies in Sindh (Dependent Variable: natural logarithm of yield)

Chilies Sindh		**Model A**		**Model B**		**Model C**		**Model D**		**Model E**		**Model F**	
Variables		Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.
Constant	β_0	-9.113	7.868	5.724***	2.210	4.868**	2.181	4.856**	2.152	3.553*	1.864	1.237	1.804
Time	β_g	0.003	0.005	0.001	0.005	0.001	0.005	0.001	0.005	-0.001	0.003	0.008***	0.003
Temp (Sep -Nov)	β_{TS}	0.112	0.228	0.287***	0.102	-0.231**	0.099	-0.224**	0.096	0.238***	0.082	-0.176**	0.084
Temp (Dec - Jan)	β_{TV}	-0.041	0.176	-0.103	0.116	-0.083	0.115	-0.095	0.112	0.020	0.047	0.012	0.052
Temp (Feb - Apr)	β_{TM}	0.421**	0.209	0.357***	0.124	0.280**	0.119	0.284**	0.117	0.199***	0.064	0.177***	0.072
Precip (Sep -Nov)	β_{PS}	0.746	0.554	0.173***	0.040	0.178***	0.040	0.178***	0.040	0.168***	0.032		
Precip (Dec - Jan)	β_{PV}	0.711	0.660	0.241***	0.055	0.235***	0.054	0.234***	0.054	0.272***	0.048		
Precip (Feb - April)	β_{PM}	1.076	1.124	0.035	0.066	0.033	0.066	0.032	0.065	0.048	0.064		
Temp (Sep -Nov)2	β_{2TS}	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001				
Temp (Dec - Jan)2	β_{2TV}	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002				
Temp(Feb - April)2	β_{2TM}	-0.005	0.004	-0.006*	0.004	-0.005	0.004	-0.006	0.003				
Precip (Sep -Nov)2	β_{2PS}	0.005**	0.002	0.007***	0.002	0.008***	0.002	0.008***	0.002	0.007***	0.002	-0.001	0.001
Precip (Dec - Jan)2	β_{2PV}	0.015***	0.006	0.020***	0.005	0.021***	0.005	0.021***	0.005	0.023***	0.005	-0.002*	0.002
Precip(Feb - April)2	β_{2PM}	-0.004	0.005	-0.005	0.005	-0.005	0.005	-0.005	0.005	-0.005	0.005	-0.003***	0.001
V Temperature	B_{VTS}	-0.005	0.015	0.004	0.014	-0.001	0.014						
V Temperature	B_{VTV}	-0.007	0.019	-0.011	0.019	-0.009	0.019						
V Temperature	B_{VTM}	-0.013	0.021	-0.012	0.021	-0.009	0.021						
V Precipitation	B_{VPS}	0.002	0.001	0.002*	0.001								
V Precipitation	B_{VPV}	0.003	0.003	0.003	0.003								
V Precipitation	B_{VPM}	0.002	0.003	0.003	0.003								
Temp x Precip	β_{TPS}	-0.031*	0.019										
Temp x Precip	β_{TPV}	-0.050	0.035										
Temp x Precip	β_{TPM}	-0.041	0.043										
Area	β_{Au}	0.109***	0.033	0.105***	0.033	0.110***	0.033	0.109***	0.032	0.087***	0.027	-0.066**	0.028
(Extreme Events)	β_{Df}	0.232***	0.073	0.213***	0.072	0.225***	0.072	0.225***	0.067	0.214***	0.064	- 0.249***	0.072
Note:	***, **,* indicate the 1%, 5% and 10% level of significance, respectively.												

Among the non-climatic variables the area under cultivation has negative coefficient sign. This implies that increase in area under cultivation in Sindh caused to decline in productivity. It indicates negative economies of scale. This decrease in productivity is due to increase in marginal lands under cultivation. The coefficient of time trend to capture the impacts of technology and infrastructure carries positive sign. It shows that innovation of technology causes increase in productivity.

CHAPTER 5

CONCLUSION AND POLICY RECOMMENDATIONS

5.1Conclusion:

Pakistan is vulnerable to climate change. Climate variables (temperature and precipitation) along with other non-climatic factors (area and technology) have influenced the different crops differently in different regions. Extreme events such as flood and drought are major environmental hurdles on the way forward to higher productivity of vegetable crops along with temperature and precipitation. The important factors that affect productivity are crop area and technology. The area under cultivation have significant role to increase the productivity except in chilies field in Sindh where it cause decreasing returns to scale. The technological innovations captured by time trend also play a significant role in enhancing the yield of crops except in Punjab in the field of onion where it has negative sign.

This study also confirms that the effects of temperature and precipitation are not uniform on phonological stages of each crop. The Wald tests results suggests that linear relationship exists between climatic normal (temperature and precipitation) and yield for onion in Punjab, Sindh and Baluchistan. For chilies this relationship exists only for temperature normal. The non-linearity relationship captured by square terms of the climatic normal result shows that relationship exists for onion as a whole and for Chilies this relationship exists only in the case of precipitation square. The shocks of temperature and precipitation captured by introducing the variation terms from mean normal shows that for temperature shock only relationship exists for chilies in Punjab. The result shows that variation in precipitation only affects the potato in

Punjab. The combine effects of temperature and precipitation normal have affected the potato and onion in Punjab differently at different growth stages of the crops in magnitude as well as in direction.

5.2Policy recommendations

In order to make Pakistan's food production system more resilient to climate change (normal and variations) due attention shall be given in policy making. The results of this study have brings forth some important policy recommendation.

1. In order to reduce the adverse impacts of climate change there is urgent need to scale up the adaptation strategies. Therefore, instead of one common national level adaptation framework there should be more localized framework because climate change is not uniformly affecting all parts of the Pakistan.
2. There should be consistence allocation of the agricultural research and development (R&D) funds for improving varieties of vegetables crops which should be resilient to climate change (drought resistant verities, tolerant to heat and water stress and less prone to viral attack) and for enhancing the physical availability and economic access to promoting technologies.
3. There is need for extension in agriculture advisory services to work with vegetables growers to enhance labor management skills through improving the knowledge of farmers and remodeling the required support services.

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Appendix 1:

Table A.1: Details of the variables

Sr.No	Variables	Detail
1	$\ln Y_{it}$	Log of yield of i^{th}crop at t time period i.e. (potato, oniom and chillies)
2	$TEMP_S$	Monthly mean temperature at the time of sowing growth stage
3	$TEMP_V$	Monthly mean temperature at the time of vegetative growth stage
4	$TEMP_M$	Monthly mean temperature at the time of maturity growth stage
5	$PREC_S$	Monthly mean precipitation at the time of sowing growth stage
6	$PREC_V$	Monthly mean precipitation at the time of vegetative growth stage
7	$PREC_M$	Monthly mean precipitation at the time of maturity growth stage
8	$(TEMP_S)^2$	Temperature square at the time of sowing stage
9	$(TEMP_V)^2$	Temperature square at the time of vegetative stage
10	$(TEMP_M)^2$	Temperature square at the time of maturity stage
11	$(PREC_S)^2$	Precipitation square at the time of sowing stage
12	$(PREC_V)^2$	Precipitation square at the time of vegetative stage
13	$(PREC_M)^2$	Precipitation square at the time of maturity stage
14	$VTEMP_S$	Variation of temperature form normal at the time of sowing stage
15	$VTEMP_V$	Variation of temperature from normal at the time of vegetative stage
16	$VTEMP_M$	Variation of temperature from normal at the time of maturity stage
17	$VPREC_S$	Variation of precipitation from normal at the time of sowing stage
18	$VPREC_V$	Variation of precipitation from normal at the time of vegetative stage
19	$VPREC_M$	Variation of precipitation from normal at the time of maturity stage
20	$(TEMP_S \times PREC_S)$	Temperature × precipitation at the time of sowing stage
21	$(TEMP_V \times PREC_V)$	Temperature × precipitation at the time of vegetative stage
22	$(TEMP_M \times PREC_{M)}$	Temperature × precipitation at the time of maturity stage

23	LN(AREA)	Log of cropped area
24	T	Time trend to capture the technological impacts
25	DV	Dummy variable for flood and drought