Responsiveness of Fruit Acreage and Yield to Climate Change in Pakistan:

A District Level Analysis

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CERTIFICATE

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Abstract

This study investigates the impacts of climate change on productivity and acreage response of citrus and mango fruits using data of 12 major citrus growing districts and 14 mango growing districts of Pakistan for the years 1980-2010. Fixed Effects Model has been employed to estimate the relationship between climatic factors (i.e. temperature, precipitation) and yield of mango and citrus fruits. Dynamic GMM has been executed to investigate acreage responses of aforementioned fruits. The trends of long run norms of temperature and precipitation are indicative that the climatic variables have observed changes during different stages of fruit growth. The findings of the study are indicative that climatic factors have significant impacts on productivity of citrus and mango fruits in Pakistan. Increase in norm of average temperature during different phenological stages of fruit growth affects citrus productivity in non-linear fashion (with negative linear term). However, insignificant impact of increase in temperature was observed in case of mango productivity. The effects of precipitation on fruit productivity during fruit growth in case of citrus and maturity stage in case of mango were also found significant. The results from dynamic GMM suggest that climatic factors affect acreage allocation insignificantly and differently across various phenological stages of the fruits. Moreover, control variables such as tube-wells, lag of cultivated area, infrastructural variables (road length in KM, number of pickups and trucks available in each district)have positive and significant impacts on productivity and acreage responses of both fruits (mango and citrus). Own price was observed to play either a very small or insignificant role in acreage allocation to production of fruits under study.

Key Words: Climate Change, Citrus, Mango, Dynamic GMM, Fixed Effects

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CHAPTER 01

INTRODUCTION

1.1 Introduction

Climate change is burning issue and refers to increase in the average global temperature. The trend is predicted to lead to significant global changes in the future. The global temperature is rising consistently due to increase in concentration of greenhouse gases (GHGs) like Carbon Dioxide (CO_2), Chlorofluorocarbon (CFC), Methane (CH_4) and Nitrous Oxide (N_2O) Hydro Fluorocarbon (HFCs), Per fluorocarbons (PFCs) and Sulfur hexafluoride (SF_6) which are sourced from various anthropogenic activities (agricultural activities; burning of waste, carbon, wood fuel, and fossil fuel; and mining (IPCC 2001). It is estimated that average global temperature has increased by 0.74°C over the last century.

It is predicted that temperature of earth would increase by 3^0C by the year 2100. Even if countries resort to adopting emissions mitigation strategies the global temperature will continue to increase (UNFCCC, 2007). It has been reported that global average temperature has risen by 0.6ºC in the last 140 years. Global temperature will increase by 1.8˚C to 4˚C with an overall average increase of 2.8˚C in temperature over the next two decades (IPCC 2007).

Agriculture is an activity which highly dependent on climatic conditions. Changing climate has threatened the productivity of agriculture sector making it vulnerable both economically and physically to climate unevenness and change. Productivity is being affected by change in a number of climatic factors including rainfall pattern, temperature hike, and water availability etc. According to IPCC report (2007) agricultural sector is most sensitive and delicate sector to climate change among other sectors. Climate change will create new risks for natural and human systems; these risks are widespread and disturb the development of countries (IPCC, 2014).

Climate change affects various regions in different ways across the world. Developing countries are at high risk of environment and socioeconomic vulnerability being constrained in their ability to adapt (Stern, 2006 and Gross, 2002).

Yield of crops would be adversely affected due to variation in rainfall pattern, loss in soil nutrients and degradation of water resources (IPCC, 2001). It has been estimated that 2.5°C increase in temperature or more would lead to reduction in crop yields and increase in food prices because of the faster increase in demand for global food relative to global food supply capacity (Parry et al., 1999). The increase in global mean temperature has given rise to new types of blights and pests causing damages to crops. Especially, damages by brown grasshoppers to apples, peaches, grapes, and soybeans are reported to have been increasing since 2006(Kim and Pang,2009).

Agriculture plays a vital role in an economy as agricultural based necessities of life have no substitutes. Agriculture contributed about two percent of GDP in developed countries while it accounts for over one-fourths in developing countries. The changes in climatic factors like precipitation and temperature may have positive or negative effect on crop productivity, depending on magnitude of warming and changes in precipitation, nature of crop, and location. The agriculture sector in Pakistan plays a pivotal role as the income of more than 60 percent of the rural population is dependent on this sector. It contributes about 21.4 percent to GDP provides employment to about 45 percent of labor force, accounts for 60 percent export earnings, and provides raw material for agro based industries (GOP, 2013) .

Agriculture sector of Pakistan is under serious threat from climate change. It is projected that temperature will increase by 3°C by 2040 and 5°C to 6°C by the end of this century. Due to this scenario, Asian countries (Pakistan, Nepal, Bangladesh and Sri Lanka) can lose 50 percent of the wheat production (Lioubimtseva et al., 2009).

It is reported that environmental factors (drought and flooding) has endangered agricultural production and such extreme weather conditions may lead to starvation and would increase undernourishment (FAO, 1990).

Global warming and climate change is among the major concerns of humans in this century. It is resulting in disturbed production of a number of cash crops, food grains and horticultural crops (fruits, vegetables, and flowers).The studies report that in Himalayan regions, melting of ice cap will reduce required chilling effect for the flowering of many horticultural crops like apple, citrus and mango etc. Due to high temperature physiological disorder of horticultural crops will be more pronounced e.g. spongy tissue of mango, fruit cracking of litchi, flower and fruit abscission in fruits and vegetables. Air pollution also significantly reduces the yield of several horticultural crops and increases the intensity of certain physiological disorder like black tip of mango. Addressing problems of climate change is more challenging in horticulture crops compared to food crops. The crop productivity is subjected to number of stresses and potential yields are seldom achieved under stress conditions. An increase in average air temperature of between 1.4C^{o} and 5.8°C, a rise in atmospheric CO_2 concentration, and significant changes in rainfall pattern have been predicted (Houghton et al. 2001).

Pakistan is located in the region where increase in temperature is expected to be higher as a compared to global average. High dependency of its economy on agriculture for income, employment, and foreign exchange earnings makes the country highly vulnerable to climate change. Extreme events like floods and extended droughts are likely to occur more frequently due to higher risk of monsoon rain variability posing serious threats to water and food securities of the nation (Final Report, Task Force on Climate Change, 2010).

The increase in atmospheric temperature and change of rainfall pattern may result in banana cultivation in India suffer from high temperature, soil moisture stress, or flooding / water logging (Data, 2013).

Horticulture is an important sub-sector of Pakistan’s agriculture and makes an important source of human nutrition especially vitamins and mineral that are otherwise deficient in their diet. A large variety of fruits are cultivated throughout Pakistan over an area of 829.6 thousand hectares with a total production of 6.8 million tonnes during 2011-2012. Citrus and mango are the main horticultural crops substantially contributing to national income and foreign exchange earnings. Pakistan is among the top producers of these fruits in the world. Citrus accounts for the largest area under fruits crops in the country followed by mango. Citrus was grown on an area of 194 thousand hectares during 2011- 2012.

Pakistan has several varieties of citrus fruit including mandarin, more popularly known as kinnow, which is of special interest to exporters and consumers in Asia and Europe. It is considered adapted dominant citrus of Pakistan because of its heat tolerance feature temperature exceeds above 45^0C. It is subtropical favorable temperature required during period is 12.78º C-37.78º C. During the year 2012-13 Kinnow exported from Pakistan was 342.4 thousand tonnes worth Rs.15.33 billion (GOP 2011-12). Citrus is grown in all provinces of Pakistan but Sargodha, Sahiwal, Lahore, Sialkot, Jhang, Mianwali, Multan, and Gujranwala districts of Punjab province account for over 95 percent of country’s citrus production. The major varieties of citrus commercially grown in Pakistan include sweet oranges, mandarin, grapefruit, lemon and lime.

Mango is the second most important fruit grown in Pakistan which is commonly termed as king of fruits. It contains 10-20 percent sugar, vitamins A, C, and a little amount of vitamin B (Usman et al., 2003). It is produced on an area of 98.6 thousand hectares with production of 998.4 thousand tonnes. Pakistan produces 6.5 percent of the world's mangoes and is the third largest exporter of the fruit to the Middle East, UK, and other European countries (Shah et al. 2014). For good growth of mango, temperature should range between 15°C and 36°C, temperature exceeding 46^0C is detrimental for vegetative growth.

1.2 Research Gap

In Pakistan, a number of studies have been carried out to explore the impact of climate change on agriculture. The empirical results provide the clear evidences that climate change adversely affects agricultural productivity of major food grains and other field crops. Pakistan annually produces about 12.0 million tonnes of fruits and vegetables. Citrus fruit is leading in term of production followed by mango, dates and guava. Total horticultural exports of Pakistan amount to over one percent of country's total export earnings.

Production of major fruits plays a crucial role in the economy of Pakistan. Citrus and Mango occupies an important position in national economy feeding a sizeable domestic juice industry and providing raw materials. Despite importance and export contribution of citrus and mango only little attention has been paid to technological development for enhancing productivity and quality of these fruits or exploring the impact of climate change on fruit yield and acreage allocation.

In previous research most of studies carried out using climatic variables (temperature and precipitation) on the basis of year, seasons or quarters ignoring the phenological stages of fruit growth. This study would quantify the yield and acreage responsiveness of citrus and mango fruits to climatic factors for various phenological stages. Further, unlike most of studies analyzing impact of climate change on using data aggregated at the country or state/province level our study attempts to estimate the impact of climate change using data disaggregated at the district level.

1.3 Objectives of Study

The main goal of the study is to explore the impact of climate change on yields and acreage of mango and citrus fruits in Pakistan. The more specific objectives of the study are to

- investigate the impacts of climate change on mango and citrus yields;
- quantify the responsiveness of citrus and mango acreage to climate change; and
- Suggest policy recommendation for sustained growth of mango and citrus fruits based on empirical findings.

1.4 Hypotheses

Keeping in view the objectives of the study the following hypotheses have been postulated:

Hypotheses I

H_0: Over time variations in temperature do not affect yields of citrus and mango fruits

H_1: Over time variations in temperature have an effect on yields of citrus and mango fruits

Hypotheses II

H_0: Over time variations in precipitation have no effect on yield of citrus and mango fruits

H_1: Overtime variations in precipitation have an effect on yield of citrus and mango fruits

Hypothesis III

H_0: Over time variations in climatic factors do not affect acreage allocation to citrus and mango production

H_1: Overtime variations in climatic factors affect acreage allocation to citrus and mango production

1.5 Organization of the Study

To achieve above given objectives, the study proceeds in the following fashion. Chapter 2 deals with review of important studies relating response of agricultural productivity and acreage to climatic factors. Chapter 3 gives the methodological framework for examining the impact of climate change on agricultural productivity and acreage allocation; presents the empirical models for yield and acreage response to be estimated; reports different data sources; and explains the construction of the various variables. Chapter 4 deals with discussion of the results of yield and acreage response models for citrus and mango fruits. Chapter 5 concludes the study and suggests some policy recommendations.

CHAPTER 02

REVIEW OF LITERATURE

Climate change would have a significant effect on agricultural commodities including on their production and food supply and food security and many of these effects would be seen most in least developed countries (LDCs) and developing countries. Climate change without any doubts already disturbed the climate variability global temperature which disturbed forest and agriculture developing and less developed countries again these countries are vulnerable because of their geographic location and less income for climate adaptation and strategies. A drastic occurrence of greater extreme events, heat stress, droughts and floods, would increasingly have negative impacts on crop yields. It is quite difficult for rural communities to sustain and obtain adequate global food supply, climate change challenge agricultural production , food supply and security locality of production ,quantity and quality (Masters *et al*., 2009).

Early studies focused primarily on yield effects of precipitation, temperature and technological progress with their findings suggesting a positive relationship between crop yields and precipitation and a negative relationship between yields and temperature (Oury, 1965).

Hartarska *et al.* (2012) investigated impact of climate change on agricultural production using fixed effect country-level panel analysis in 13 Asian countries from 1998 to 2007. The results show that an increase in temperature and precipitation during summer increases agricultural production in tropical Asian countries while increase in temperature during the fall season reduces production.

Tewari(1991) included variable of composite weather index among the explanatory variables to examine the relationship between weather variable and crop yield in four apple producing districts of Himachal Pradesh using data for the period 1931 to 1960. The estimates of multiple regression analysis show that individual weather weighted index performed better as compared to weather variable itself, the weighted index of maximum temperature shows a positive relationship and weighted index of humidity shows negative relationship with apple yield.

Asghar and Yaseen (2012) investigated the effect of climate change on apple production in Kotli, Pakistan by using data for the period 1980-2010. This investigation revealed that all physico-chemical parameters were supporting production but it declined due to climate change aspect unusual rain and extreme summer periods. Results showed a strong correlation with the changing seasonal variations i.e. rainfall and temperature. Abrupt changes in weather pattern resulted in decreased production and top soil capability to sustain vegetation.

Ayinde *et al*. (2010) employed descriptive statistics and granger causality to analyze impact of changes in climatic parameters on agricultural production in Nigeria using 22 years' time series data. The Granger causality approach revealed that changes in rain fall (climatic parameter) positively affects agricultural production, and there is no relationship between temperature and agriculture production.

Dasgupta (2013) investigated impact of variation in temperature and precipitation on crop yield in 66 countries using data for the period 1977-2002. This study found that increase in precipitation and temperature up to certain threshold can harm wheat and rice yield, and variability in climate change has immense negative effect on low rice yield countries.

Lobell *et al.* (2007) investigated the impact of precipitation, minimum temperature and maximum temperature on 12 important fruits (wine grapes, lettuce, almonds, strawberries, table grapes, hay, oranges, cotton, tomatoes, walnuts, avocados, and pistachios) in California for the period of 1980-2006. The regression models based result showed climatic factor had mixed effect on crop yield having positive effect on oranges and walnuts and adverse effect on avocado yield and little impact on most of the crops.

Makinde *et al.* (2010) investigated effect of climate variables on citrus yield in various agro ecological zones of Nigeria using data for the period 1979-2008. The result showed that maximum temperature, rainfall and relative humidity have positive correlations with yield of all the 12 citrus varieties examined while minimum temperature was negatively correlated with the citrus yield.

Baig and Amjad (2014) employed Vector Regression Model to investigate the impact of climate change on fruit (apple, mango, citrus, and banana) production in Pakistan. The estimate based on 44 years data (1966-2009) reveal that temperature has adverse impact on fruit production while rainfall and water availability have positive impact on fruit production in Pakistan. An additional increase in average temperature of 2^{o}C, 4^{o}C and 5^{o}C would reduce fruit production by 10, 20, and 25 percent respectively. An increase of 10 percent in rainfall and water availability would increase fruit crops production by 7 percent.

Bhandari (2013) examined effect of climate change on yield of major cereal crop in Dadeldhura district of Nepal. The results are suggestive that maximum and minimum precipitation have adverse effect on the yield of rice and maize whereas, maximum temperature and rainfall have positive effect on maize and rice yields, Similarly precipitation has significant effect on maize and barely yields.

Sharma *et al*. (2013) investigated effect of variation in climatic parameters on apple production in Kotkhai area of Himachal Pradesh for the period of 2001-2009. A positive and significant relationship was found between minimum average temperature (during different stages of fruit growth and development) and apple production. However a negative but significant relationship was found maximum average temperature and apple production.

Siddiqui *et al* (2012) investigated the impact of climate change on production of four major crops in Pakistan. The results of Fixed Effect Model estimation show that in the short run increase in temperature is expected to affect the wheat productivity but in long run the increase in temperature has positive affect on wheat productivity. Similarly, the increase in precipitation has negative impact in both the short and long run. A rise in temperature is beneficial for rice production initially. However, beyond a certain optimal temperature, further increase in temperature becomes harmful for rice production. The increase in precipitation does not harm the rice productivity. In case of cotton the change in climate variables (temperature, precipitation) have significant and negative impacts on its production. Finally, the increase in temperature also harms the sugarcane productivity in the long run.

Janjua *et al.* (2010) investigated climate change impact on wheat production in Pakistan using VAR model. The results showed that there is no significant negative impact of climate change on wheat production in Pakistan. However, future wheat production will significantly depend on the area under wheat cultivation and the climate change variables. The variance decomposition reveal that wheat acreage and the climate change variables cause 30 percent and 34 percent variation in wheat production respectively.

Haung and Khana (2010) conducted an econometric analysis of the factors influencing crop yields and allocated acreage in the United States. The dynamic panel GMM estimation method was applied using panel data for the period 1977-2007. They found that corn, soybean and wheat yields respond positively to their own prices and that corn and wheat yields respond negatively to fertilizer prices however soybean and wheat acreage showed an insignificant response to fertilizer prices. Moreover, they found that climate variables (temperature and precipitation) have a significant impact on the yields for all three crops and high temperature could lead to reduced crop yields while more precipitation would enhance yield in case of corn and soybean and vice versa.

Results of the study also revealed that increase in temperature increases total crop acreage, wheat acreage and corn acreage but the effect on soybean acreage is not significant The expected increase in precipitation would lead to a decline in wheat and soybean acreage, but positive impact on total crop acreage and an insignificant effect on corn acreage.

Traboulsi (2013) analyzed yield and acreage response of citrus (oranges and grapefruits) in Florida to overtime changes in temperature and precipitation by using panel data for the period 1980-2010. The result of the study showed that the acreage under fresh oranges and yield of grapefruit respond positively to respective own-prices. Temperature has a positive impact on the acreage response of fresh oranges, whereas it impacted negatively the grapefruits yield and there was no significant impact of precipitation on the supply response.

In Pakistan citrus and mango fruit have great contribution in daily consumption and in national economy. A number of studies carried out in Pakistan to examine the impact of climatic variables (precipitation and temperature) on the basis of yearly, seasonally or quarterly aggregated measures ignoring the phenological stages of fruit growth. On the other hand, this study would estimate the yield and acreage responsiveness of mango and citrus fruits to climatic factors for various phenological stages using district level data. Contrary to previous researches this study would also consider socio economic variable, effect of climate change (long run changes in temperature and precipitation) as well as weather shocks (deviation of temperature and precipitation from long run norms) on citrus and mango yield and acreage allocation using district level data in Pakistan.

CHAPTER 03

DATA SOURCES AND METHODOLOGY

3.1 Introduction

The empirical study would comprise of district level penal data regarding mango and citrus producing districts of Pakistan for the period 1981-2010. The data regarding fruit yield acreage and other economic variables belong to 26 major fruit producing districts of Punjab and Sindh provinces of Pakistan. The variables used in the analysis can be categorized as economic variables and climatic factors.

3.1.1 Economic Variables

The district level data on acreage and production of mango and citrus is reported in Crops Area and Production (by Districts), a publication of Federal Government. The data regarding transport and roads (number of trucks and pickups, and road kilometers) and number of tube-wells in each district are reported in provincial Development Statistics published by Bureau of Statistics of respective provinces. Similarly, input and output prices are reported in Agricultural Statistics of Pakistan published by Pakistan Bureau of Statistics (previously published by Ministry of Food and Agriculture) and ALMA (Agriculture livestock Marketing Advisor). Most of the district level data regarding agricultural input and output are also reported in provincial Development Statistics (publication of Bureau of Statistics of respective provinces). The study used various issues of these publications.

3.1.2 Climatic Factors

The data regarding climatic factors (temperature and precipitation) were collected from Pakistan Meteorological Department.

3.2 Theoretical Framework

3.2.1 Climate Change and Yield Model

The researchers have applied different approaches for analyzing the impact of climate change on crop production. The approaches include production function approach, the Ricardian approach, and simulation models. The Ricardian approach was used by Mendelsohn et al. (1994) to assess the impact of climate change on agriculture. It involves regression of land values, land rents or net profits on climatic factors, soil characteristics, and other socioeconomic variables.

Crop simulation models are the controlled agronomic experiments estimating the impact of different climatic variations on performance of crop grown. Although, Agronomic simulation models are mostly used in analysis of the impact of climate change on crop production but these models also have certain limitations. Firstly, these models use the data of physiological process and most variability is explained by non-linear forms of these variables. It is difficult to interpret the results due to the non-linearity of variables. Secondly, the problem is that model treats all the information about the production function as exogenous so neglect the adaptive response of farmers. Moreover, technique is costly to be used especially in

Production Function Approach of estimating impact of climate change on agriculture productions is most widely used technique in the literature. Empirical production function analysis extends the scope by allowing the direct estimation of the impact of climate changes through incorporation of temperature and precipitation variables while controlling the outcome for physical and biological variables (inputs including technology, fertilizers etc.). Amongst the critique on this approach, its inability to handle the socio-economic characteristics of the farmer affecting, more importantly, his commitment and adaptability stands atop. This deficiency, in turn, may result in overstating the damage (yield reduction).

Given limitations of the available data this study would use Production Function Approach for analysis as the time series data on land rent or land value are not published. Even if made available may not truly represent land returns as the land markets are not well developed in Pakistan.

The study of production function for agriculture has a very long history. Solow (1956) explained the output as function of inputs employed in production. In summation, productivity of output is determined by calculating the productivity of all inputs. The relationship between the output and input is completed by the inclusion of technology factor which is adapted to during production function, so the functional form for any production function could be symbolized as following

$$Y_i = f(X_i) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.1)$$

$$i = 1,2, \ldots \ldots \ldots \ldots, n$$

Where Y_i represents output produced by using X_i (a vector of inputs) under some production technology. For this study we assume that technology of production do not vary across cross-

Section as we are conducting the study for one country. In conclusion, new technology would be available to all the districts once introduced. The efficiency of input use and technology is affected by climatic condition and the soil characteristic of the specific area (Deressa, and Hassan, 2009). Moreover, climate variables in this model are treated as state variables.

For panel data this production function can be written as following

$$Y_{it} = f(X_{it}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

Where "i" denotes districts (1, 2, 3…, n) and "t" represents the year (1, 2, 3…, T). All the variables have panel data representation. Y is the (n*Tx1) vector (representing yield of mango or citrus (40 kg); and X is (n*TxK) matrix consisting of control and state variables including climatic factors. The regression equation of citrus and mango yield can be written as

$$Y_{it} = X_{it}\beta + U_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

Where X_{it} is (n*TxK) matrix of explanatory variables (including physical variable like land, transportation and machinery etc.) and climatic variables (temperature and precipitation) and u_{it} is panel data disturbance term.

Fruit production is very sensitive to climatic factors (precipitation and temperature), and these climatic variables can affect fruit yields differently at each growth stages of fruit. Therefore, this study uses climatic variables according to the phenological stages of citrus and mango production. Four growth stages for citrus and mango were identified during discussion with horticultural scientists working at Pakistan Agriculture Research Council (PARC), Islamabad. The same are outlined in the following.

3.3 Growth Stages of Citrus and Mango Production

The identified growth stages are given in Table 3.1 and the four growth or phenological stages for citrus included: 1) Dormancy Stage —covers the period December to January; 2) Flowering and Fruit Formation Stage –lasts during February to April; 3) Fruit Growth Stage – extends over the period of May – September; and 4) Maturity Stage – comprises the period October to November. Similar to citrus, growth of mango fruit also comprises four stages: 1) Dormancy Stage – this stage for mango lasts during December-January; 2) Flowering Stage – covers the period February to March; 3) Fruit Growth Stage – lasts during April and May; and 4) Maturity Stage – extends from June to July.

Table 3.1: Phenological Stages of Citrus and Mango in Pakistan

Growth Stages	**Citrus**	**Mangoes**
Dormancy Stage	***January-February***	***December-January***
Flowering and Fruit Formation Stage	***March-April***	***February-March***
Fruit Growth Stage	***May- September***	***April-May***
Maturity Stage	***October-November***	***June-July***

Source: Kissan Network Pakistan Agricultural Research Council, Islamabad

3.4: Empirical Model

The main concern of the study is to find out the impacts of climatic factors on yield and responsiveness of acreage allocated to citrus and mango to climate change. The respective empirical models are specified as follows.

3.4.1 Impact of Climatic Factors on Yield of Citrus and Mango

To observe the impacts of climatic factors on the yield of fruits (citrus and mango) the following equation is specified for empirical estimation.

$$lnY_{it} = \beta_o + \beta_1 ln(Area)_{it} + \beta_2 ln(Tubewells)_{it} + \beta_3(Temp_{s1})_{it} + \beta_4(Temp_{s2})_{it} + \beta_5(Temp_{s3})_{it} + \beta_6(Temp_{s4})_{it} + \beta_7(Precp_{s1})_{it} + \beta_8(Precp_{s2})_{it} + \beta_9(Precp_{s3})_{it} + \beta_{10}(Precp_{s4})_{it} + \beta_{11}(Temp_{S1})^2_{it} + \beta_{12}(Temp_{S2})^2_{it} + \beta_{13}(Temp_{S3})^2_{it} + \beta_{14}(Temp_{S4})^2_{it} + \beta_{15}(Precp_{S1})^2_{it} + \beta_{16}(Precp_{S2})^2_{it} + \beta_{17}(Precp_{S3})^2_{it} + \beta_{18}(temp_{S1} * Precp_{S1})_{it} + \beta_{19}(Temp_{S2} * Precp_{S2})_{it} + \beta_{20}(Temp_{S3} * Precp_{S3})_{it} + \beta_{21}(Temp_{S4} * Precp_{S4})_{it} + \beta_{22}(DTemp_{s1})_{it} + \beta_{23}(DTemp_{s2})_{it} + \beta_{24}(DTemp_{s3})_{it} + \beta_{25}(DTemp_{s4})_{it} + \beta_{26}(DPrecp_{s1})_{it} + \beta_{27}(DPrecp_{s2})_{it} + \beta_{28}(DPrecp_{s3})_{it} + \beta_{29}(DPrecp_{s4})_{it} + \varepsilon_{it} \quad (3.4)$$

Where *t* represents year (1, 2, 3…..T) and *i* stands for districts (1, 2….n);

Equation (3.4) will be estimated for citrus and mango yield separately, where *Y* denotes the yield of fruit (citrus or mango) measured in tonnes per hectare, *Area* is the area under fruit 100 hectares, *Tube wells* indicates number of tube wells per 100 hectares of cultivated area, and climatic factors(*Temp* and *Precp*) included to capture effect of 20 year mean monthly temperature and 20 year mean monthly precipitation during various phenological stages[1], $DTemp$ and D$Precp$ respectively denotes deviation of mean temperature and precipitation from long run averages (20 years average) of the climatic factors (to account for the impact of climatic shocks) , and $Precp^2$ denotes square terms of 20 year mean precipitation and $Temp^2$ denotes square term of 20 year mean temperature (to check nonlinearity of the relationship) and $Temp * Precp$ represents the interaction term of mean temperature and mean precipitation for each of phenological stage (to check joint impact of temperature and precipitation on citrus and mango yield), and ϵ_{it} denotes error term.

3.4.2 Climate Change and Acreage Response Model

In this study for acreage response analysis Nerlovian adjustment cum expectation model used. This model was adopted by (Nerlove 1958) to farmer output reaction on price expectation and partial adjustment. The model is flexible to include non-price factors, and calculating short run and long run responses and speed of adjustment from actual to desired level of land and other inputs.

The basic Nerlove model can be described through farmer's information, rational price expectation and farmer's crop acreage decision which expressed in form of equations.

$$A_t^{\,D} = a_0 + a_1 P_t^{\,e} + a_2 Z_t + u_t$$
$$P_t^{\,e} = P_{t-1}^{\;\;e} + \beta(P_{t-1} - P_{t-1}^{\;\;e})$$
$$A_t = A_{t-1} + \gamma(A_t^{\,D} - A_{t-1})$$

Where, A_t = actual area under cultivation at time t

$A_t^{\,D}$ = area desired to be under cultivation at time t

P_t = actual price at time t

[1] the numbers 1, 2, 3, 4 in subscript to climatic factors represents various growth stages defined in Table 3.1

u_t = Disturbance term includes those factors not under the control of the farmer.

β, γ = Expectation and adjustment coefficients

Acreage response studies had ignored climate factors and used geographically aggregated time series data to analyze farmer's response (Chavas and Holt, 1990). Nerlove, (1956) developed price adaptive expectation model for estimation of agriculture supply functions, which based on farmers expectations for future prices and crop acreage decisions ,reduced form of acreage in a given year expressed as a function of one year lagged crop price and lagged crop acreage. For acreage response we include lagged acreage, input and output price variables as independent variables in the acreage model. To tackle the endogeneity and autocorrelation problem in a dynamic model a fixed-effect Arellano-Bond difference GMM estimator is used, as well as use robust estimator. Instrumental variables used in the Arellano-Bond GMM estimation include lagged precipitation at different growth stages, procurement price of crop(s) and yield of the competing crop(s) in the district. The competing crop(s) and past weather are included due to their potential influence on price expectations and therefore on crop acreage decisions.

The Responsiveness of Citrus and Mango Acreage to Climatic Factors

Study also is aiming at investigating the responsiveness of citrus and mangoes acreage to climate change and for this purpose the following empirical model is specified.

$$Acr_{it} = \beta_{\circ} + \beta_1 Area_{i,t-1} + \beta_2 Transportation_{i,t-1} + \beta_3 Infrastructure_{i,t-1} + \beta_4 Price_{i,t-1} + \beta_5 Tubewell_{i,t-1} + \beta_6 (Temp_{s1})_{i,t-1} + \beta_7 (Temp_{s2})_{i,t-1} + \beta_8 (Temp_{s3})_{i,t-1} + \beta_9 (Temp_{s4})_{i,t-1} + \beta_{10} (Precp_{s1})_{i,t-1} + \beta_{11} (Precp_{s2})_{i,t-1} + \beta_{12} (Precp_{s3})_{i,t-1} + \beta_{13} (Precp_{s4})_{i,t-1} + \varepsilon_{it} \quad \text{.................(3.5)}$$

Where Acr_{it} denotes area under fruits in current year, $Tubewell_{i,t-1}$ is number of tube wells per 100 hectares of cultivated area in the district during previous year, $Price_{i,t-1}$ is average monthly own prices of fruits during previous year, $Trnsportation_{i,t-1}$ is representing number of vehicles (pickups and trucks) per 100 hectares of cultivated area available in previous years, and $Infrastructure_{i,t-1}$ denotes the total length of roads (kilometer) in previous year and rests of the variables are denoting climatic factors such as lags of mean temperature and precipitation as stated in the case of equation (3.4).

3.4.3 Econometric Techniques to Estimate Models

Equation (3.4) will be estimated by using Fixed Effect or Random Effect models and selection of Fixed or Random Effect model will be made on the basis of Hausman specification test.

Fixed Effects and Random Effect Model*:* in fixed effect models individual specific effects are correlated with independent variables whereas in random effect model individual specific effects are uncorrelated with independent variables. If fixed effect assumption holds then fixed effect model gives more efficient results than random effect model and vice versa.

Dynamic Generalized Method of Moment (GMM): Equation (3.5) is presenting dynamic panel model where lags of dependent variables are used as independent variables where conventional or static Fixed Effect or Random Effect model do not give efficient and consistent results due to persistence of the lag of dependent variables, and these lags brings problem of endogeneity in the model. In the case of dynamic panel, the Arelleno Bond Dynamic Panel GMM estimator has been used. Therefore the study would employ aforementioned dynamic GMM estimator to estimate the acreage response model.

3.5 Definition of Variables

Definitions of the variables which will be used in empirical models are given as follows.

Yield of Citrus and Mango: Yield measured in tonnes per hectare calculated by dividing total output of the fruit with total acreage of that fruit.

Acreage or Area under Mango and Citrus: Acreage is defined as area under respective fruit in hectares.

Tube-wells: To observe impacts of irrigation on yield and responsiveness, this study is using availability of tube-wells in a district per 100 hectares of cultivated area in that district as indicator of control over irrigation water. It is calculated by dividing the total number of tube-wells available in the respective district by total cultivated area measured in 100 hectares.

Transportation Variables: This study will use number of vehicles (trucks and pickups) available per 100 hectares of cultivated area.

Infrastructure Variable

Infrastructure variable represents total length of roads (kilometers) in each selected district.

Climatic Factors: The study would use 20 years averages of monthly temperature and precipitation. Deviations of mean temperature and precipitation from the long run averages shall also be used, and to see joint impact of rainfall and temperature during various phenological stages, study would use interaction terms. Finally to observe non-linearity, square terms of these climatic factors will be included. The symbols and definitions of the variables included in the models are presented in the following table.

Table 3.2: Symbols and Definitions of the Variables

Variables	Definition
Y_{it}	Yield of fruit in year t measured in tonnes per hectare in i^{th} district
Tube well $_{it}$	Number of tube well available per 100 hectares per in t year in i^{th} district in current year t
Transportation $_{it}$	Number of vehicles(pickups and trucks) per 100 hectares of in i^{th} district i in current year
Infrastructure $_{it}$	Total length of road (Km) in i^{th} district during the current year
Price	Average of monthly price of citrus and mango during year t in i^{th} district
$Precip_{it}$	20 year average of Monthly precipitation (mm) during the months representing the respective stages of growth
$Temp_{it}$	20 year average of monthly temperature (^{0}C) during respective stages of growth
$Temp*Precp_{it}$	Interaction term of long run mean temperature and long run mean precipitation
DTemp	Deviation of temperature from 20 years mean for different phenological stages
$Temp^2$	Square of 20 years average precipitation during each phenological stage
$Precp^2$	Square of 20 years average precipitation during each phonological stage
D Precp	Deviation of precipitation from 20 years mean for different phenological stages
t-1	Represent variables is lagged by one year

CHAPTER 04

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and describes the estimated results of the empirical models given in the previous chapter. The empirical models are estimated using fixed effect estimation techniques as described earlier, yield of citrus and mango fruit is regressed on climatic variables (precipitation and temperature) and non-climatic variables. The detail discussion and interpretation of results is preceded by description of the trends of temperature and precipitation for different phenological stages.

4.2 Trends of Temperature and Precipitation at Different Phenological Stages for Citrus

Citrus (Kinnow) is perennial fruit grown in Pakistan and has four growth stages: dormancy (December to January), flowering and fruit formation (February-April), fruit growth (May- September), and fruit maturity stage (October-November). The trend of 20 year moving averages of temperature and precipitation during various phonological stages for major fruit growing districts of Pakistan are estimated and presented in Table 4.1 and Table 4.2 respectively for citrus and mango. The evidence found that temperature is increasing over time during the dormancy stage of (December-January) in all the citrus growing districts except Gujarat, Sheikhupura, Nawabshah and Khairpur districts. While a decreasing trend has been observed during flowering (February-April) and fruit growth stage (May to September) in all the citrus growing districts. A similar trend was also found during fruit maturity stage (October-November) in all cirrus growing districts except in Nawabshah and Khairpur.

In the overall, precipitation has decreasing trend in major citrus growing districts during the dormancy stage in all districts except Lahore, Gujarat, Sheikhupura, and

Nawabshah district for which an increasing trend of precipitation was observed during this phenological stage. An increasing trend of precipitation has been observed in all citrus growing districts except Sargodha during flowering and fruit formation stage. Similarly, an increasing trend of precipitation has been found in citrus growing area during fruit growth stage. However, a declining trend in long run (20 year) average of precipitation was observed in the citrus growing districts during maturity stage except for Lahore, Gujarat, Shiekhupura, and Nawabshah for which an increasing trend was found during the same phonological stage.

Table 4.1: Trends of Temperature and Precipitation at different Phenological Stages of Citrus in Selected Districts of Pakistan

	Temperature				Precipitation			
Districts	Dormancy stage	Flowering stage	Growth stage	Maturity stage	Dormancy stage	Flowering stage	Growth stage	Maturity stage
Sargodha	↑	↓	↓	↓	↓	↓	↑	↓
Faisalabad	↑	↓	↓	↓	↓	↑	↑	↓
Jhang	↑	↓	↓	↓	↓	↑	↑	↓
Sahiwal	↑	↓	↓	↓	↓	↑	↑	↓
Multan	↑	↓	↓	↓	↓	↑	↑	↓
Vehari	↑	↓	↓	↓	↓	↑	↑	↓
Bahawalpur	↑	↓	↓	↓	↓	↑	↑	↓
Bahawalnagar	↑	↓	↓	↓	↓	↑	↑	↓
Lahore	↑	↓	↓	↓	↑	↑	↑	↑
Gujarat	↓	↓	↓	↓	↑	↑	↑	↑
Sheikhupura	↓	↓	↓	↓	↑	↑	↑	↑
Nawabshah	↓	↓	↓	↑	↑	↑	↑	↑
Khairpur	↓	↓	↓	↑	↓	↑	↑	↓

4.3 Trends of Temperature and Precipitation at Different Phenological Stages for Mango

In Pakistan mango fruits once in a year and is a temperature loving plant. It also has four phenological stages: dormancy stage (December-January) flowering stage (February-March), fruit growth stage (April-May) and fruit maturity stage (June-July).The trend of 20 year moving averages of temperature and precipitation during various phenological stages of mango in selected districts of Pakistan are presented in Table 4.2**.** The evidence is found that temperature has increased overtime during the dormancy stage (December-January) in all the mango growing districts whereas it has decreased during flowering stage (February-March). A decreasing trend has been observed during fruit growth stage (April-May) in all of the major mango growing districts except Bahawalpur, Hyderabad, Sanghar, and Badin. Similarly, a decreasing trend of long run mean temperature was found in all of the mango growing districts during fruit maturity stage except in Hyderabad district.

A decreasing trend of precipitation has been observed during dormancy stage (December-January) in all the mango growing districts except Faisalabad, Jhang, Sahiwal, Hyderabad, Sanghar, Nawabshah and Badin. However, an increasing trend of precipitation has been observed in all the mango growing districts during rest of the phenological stages except for Hyderabad district where precipitation has declined during the flowering stage.

Table 4.2: Trends of Temperature and Precipitation at different Phenological Stages of Mango in Selected Districts of Pakistan

	Temperature				Precipitation			
Districts	Dormancy stage	Flowering stage	Growth stage	Maturity stage	Dormancy stage	Flowering stage	Growth stage	Maturity stage
Faisalabad	↑	↓	↓	↓	↑	↑	↑	↑
Jhang	↑	↓	↓	↓	↑	↑	↑	↑
Sahiwal	↑	↓	↓	↓	↑	↑	↑	↑
Muzaffargarh	↑	↓	↓	↓	↓	↑	↑	↑
Multan	↑	↓	↓	↓	↓	↑	↑	↑
Vehari	↑	↓	↓	↓	↓	↑	↑	↑
Bahawalpur	↑	↓	↑	↓	↓	↑	↑	↑
Bahawalnagar	↑	↓	↓	↓	↓	↑	↑	↑
Rahim Yar Khan	↑	↓	↓	↓	↓	↑	↑	↑
Hyderabad	↑	↓	↑	↑	↑	↓	↑	↑
Sanghar	↑	↓	↑	↓	↑	↑	↑	↑
Khairpur	↑	↓	↓	↓	↓	↑	↑	↑
Nawabshah	↑	↓	↓	↓	↑	↑	↑	↑
Badin	↑	↓	↑	↓	↑	↑	↑	↑

The above analysis shows that the temperature and precipitation have changed overtime during various phenological stages in major citrus and mango growing districts of Pakistan. Such changes may have important implications for fruit producers in terms of realized yields and allocation of land to fruit production. The same are studied in the following by using district level panel data. The empirical models proposed in the previous chapter are estimated using fixed effect model and random effect estimation techniques. The final selection of the model was made on the basis of Hausman Test.

4.4 Tests of the Data and Estimation of Empirical Models

This section will discuss results obtained from fixed effect model for yield (of citrus and mango separately) and Dynamic GMM estimation which estimates impacts of climate change on acreage allocation to citrus and mango fruits. Further, some diagnostic tests are performed to check the model specification and test of stationary for panel data because it is important to check the nature of data prior to conducting panel estimation. Moreover, this section provides results obtained from Hausman Model Specification Test which will suggest whether Fixed Effect or Random Effect gives consistent results.

Post regression diagnostic tests are applied for Dynamic GMM where Wald Chi-square test is used to check the goodness of fit for the model and Sargan test of over-identifying restrictions is conducted to check the validity of instruments The test for endogeneity of restrictions or instruments is also conducted along with all the above mentioned tests and the results are explained in the forthcoming sections.

4.5 Panel Unit Root Tests

In order to avoid biased regression and to investigate the stationary of a panel series unit root tests the Levin-Lin and Chu (LLC) and Im-Pesaran-Shin (IPS) panel unit root tests are carried out for variables included in citrus and mango yield models. The Results of the unit root test are given below (Table 4.3and 4.4) respectively.

Table 4.3*: Unit Root Test for Variables included in Citrus Yield Model*

Variables	LLC test	Prob.	IPS Test	Prob.	Conclusion
lnY	-2.0866	0.00	-4.6565	0.00	Stationary
$Precp_{s1}$	-3.3466	0.00	-4.3214	0.00	Stationary
$Precp_{s2}$	-2.9849	0.00	-4.0839	0.00	Stationary
$Precp_{s3}$	-3.5560	0.00	-3.2409	0.00	Stationary
$Precp_{s4}$	-3.2231	0.00	-3.0991	0.00	Stationary
$Temp_{s1}$	-4.0092	0.00	4.0839	0.00	Stationary
$Temps_{2}$	-3.0096	0.00	0.0013	0.00	Stationary
$Temp_{s3}$	-4.4148	0.00	-3.8319	0.00	Stationary
$Temp_{s4}$	4.5428	0.00	-2.8498	0.00	Stationary
$Temp_{s1}^2$	-3.1608	0.00	-2.4740	0.00	Stationary
$Temp_{s2}^2$	-4.2837	0.00	-3.9268	0.00	Stationary
$Temps_3^2$	-5.2542	0.00	-3.7151	0.00	Stationary
$Temps_4^2$	-5.1948	0.00	-3.6438	0.00	Stationary
$Precp_{s1}^2$	-3.2935	0.00	-3.2343	0.00	Stationary
$Precp_{s2}^2$	-3.345	0.00	-3.9268	0.00	Stationary
$Precp_{s3}^2$	-3.5333	0.00	-3.4678	0.00	Stationary
$Precp_{s4}^2$	-3.3414	0.00	-3.5678	0.00	Stationary
$Temp*Precp_{s1}$	-2.3828	0.00	-4.3456	0.00	Stationary
$Temp*Precp_{s2}$	-3.6033	0.00	-5.2345	0.00	Stationary
$Temp*Precp_{3}$	-4.0277	0.00	-3.8319	0.00	Stationary

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Variables	LLC test	Prob.	IPS Test	Prob.	Conclusion
Temp*Precp$_{s4}$	-2.6354	0.00	-3.0376	0.00	Stationary
DPrecp$_{s1}$	-3.9308	0.00	-8.3615	0.00	Stationary
DPrecp$_{s2}$	-4.5900	0.00	-6.9417	0.00	Stationary
DPrecp$_{s3}$	-4.2876	0.00	-2.3577	0.00	Stationary
DPrecp$_{s4}$	-5.2510	0.00	-6.789	0.00	Stationary
DTenps1	-6.2520	0.00	-11.6650	0.00	Stationary
DTemp$_{s2}$	-4.4210	0.00	-8.9245	0.00	Stationary
DTemp$_{s3}$	-5.5161	0.00	-4.8058	0.00	Stationary
DTemp$_{s4}$	-12.0052	0.00	-9.6522	0.00	Stationary
Area	-4.7190	0.00	-3.8941	0.00	Stationary
Tube well	-2.9870	0.00	-2.2912	0.00	Stationary

Table 4.4: Unit Root Test for Mango Yield

Variables	LLC test	Prob.	IPS Test	Prob.	Conclusion
lnY	-1.3458	0.00	-3.1449	0.00	Stationary
Precp$_{s1}$	-1.8364	0.00	-2.3625	0.00	Stationary
Precp$_{s2}$	-1.4567	0.00	-2.3257	0.00	Stationary
Precp$_{s3}$	-8.0938	0.00	-5.0374	0.00	Stationary
Precp$_{s4}$	-6.1399	0.00	-4.5920	0.00	Stationary
Temp$_{s1}$	-4.2979	0.00	-2.4971	0.00	Stationary
Temps$_{2}$	4.5092	0.00	-4.2177	0.00	Stationary
Temp$_{s3}$	0.0002	0.00	-6.6840	0.00	Stationary

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Variables	**LLC test**	**Prob.**	**IPS Test**	**Prob.**	**Conclusion**
$Temp_{s4}$	-6.2150	0.00	-4.0823	0.00	Stationary
$Temp_{s1}^2$	-2.3625	0.00	-4.6461	0.00	Stationary
$Temp_{s2}^2$	-4.5092	0.00	-4.4288	0.00	Stationary
$Temps_3^2$	-6.8818	0.00	-5.0374	0.00	Stationary
$Temps_4^2$	-6.9305	0.00	-11.0123	0.00	Stationary
$Precp_{s1}^2$	-5.321	0.00	-8.673	0.00	Stationary
$Precp_{s2}^2$	-4.4288	0.00	-4.5092	0.00	Stationary
$Precp_{s3}^2$	-3.1817	0.00	-5.4157	0.00	Stationary
$Precp_{s4}^2$	-7.8247	0.00	-5.456	0.00	Stationary
$Temp*Precp_{s1}$	-7.213	0.00	-5.643	0.00	Stationary
$Temp*Precp_{s2}$	-7.543	0.00	-5.432	0.00	Stationary
$Temp*Precp_{33}$	-8.2145	0.00	-5.0879	0.00	Stationary
$Temp*Precp_{s43}$	-5.6679	0.00	-4.3522	0.00	Stationary
$DPrecp_{s1}$	-5.8409	0.00	-11.7314	0.00	Stationary
$DPrecp_{s2}$	-6.0947	0.00	-9.4834	0.00	Stationary
$DPrecp_{s3}$	-4.0647	0.00	-11.3259	0.00	Stationary
$DPrecp_{s4}$	-7.8247	0.00	-9.8183	0.00	Stationary
DTenps1	-6.6173	0.00	-13.8026	0.00	Stationary
$DTemp_{s2}$	-6.0947	0.00	-9.4834	0.00	Stationary
Tube well	-5.567	0.00	-7.523	0.00	Stationary

The results of Levin-Lin and Chu (LLC) and Im-Pesaran-Shin (IPS) panel unit root tests show the stationary of all the variables at level. This indicates that all the variables included in the estimated models are stationary at level.

4.6 Fixed Effects- versus -Random Effects

On the basis of Hausman test we can make selection among the random and fixed effects models. Random effects are consistent whereas the fixed effects are inconsistent when the individual specific effects of explanatory variables are randomly and independently distributed. Therefore the most important factor is to check whether or not individual effects are correlated with explanatory variables.

The Hausman (1978) test is based on the difference among the random and fixed effects estimates. When there is a significant difference between random and fixed effects estimates, it is interpreted to be evidence against the random effect model. The Hausman test null hypothesis states that the coefficients of the estimators of random and fixed effects are insignificantly different.

The estimates of the fixed effect are consistent in both alternative and null hypothesis. The estimators of the random effect under the null hypothesis are more efficient but with the alternative hypothesis they are inconsistent. It can be implied from the rejection of null hypothesis that individual specific effects have correlation with at least some of the explanatory variables. Results of test in model of climate change for citrus yield are given in the following table.

Table 4.5: Result of Hausman Test

Null Hypothesis (H_0)	**Alternative Hypothesis (H_1)**	χ^2	**Probability**	**Conclusion**
Random is appropriate	Fixed is appropriate	11.26	0.9575	H_0 is accepted

It is clear that Hausman test accepts the null hypothesis so we are using the random effect model to estimate the proposed equation for measuring the impact of climate change on citrus yield.

4.7 Climate Change and Citrus Yield Response

The estimated model includes the quadratic terms of precipitation and temperature to capture any non-linear effect of climatic variables on citrus yield. The citrus fruit response to temperature varies across phenological stages of the crop. The sign and significance of the coefficient of quadratic terms reflects the nature of the relationship among climatic variable and the yield. The random effect model estimates of the yield equation are reported in Table 4.6.

Table 4:6: The Coefficient Estimates of Citrus Yield Model

Independent Variable	Coefficient	Probability	Independent Variable	Coefficient	Probability
$Temps_{1}$	-3.316068	0.000	**$Temp*Precp_{s2}$**	0.112576	0.490
$Temp_{s2}$	-0.3522882	0.158	**$Temp*Pecp_{s3}$**	-0.0605063	0.843
$Temp_{s3}$	-0.3891869	0.001	**$Temp*Pecp_{s4}$**	0.0036169	0.154
$Temp_{s4}$	-12.40743	0.000	**$DPrecp_{s1}$**	-0.0038765	0.075
$Precp_{s1}$	-0.083204	0.171	**$Dprecp_{s2}$**	-0.0003791	0.812
$Precp_{s2}$	0.0044363	0.663	**$DPrecp_{s3}$**	-0.024004	0.079
$Precp_{s3}$	-0.3646387	0.000	**$DPrcp_{s4}$**	0.000421	0.688
$Precp_{s4}$	0.2528728	0.246	**$DTemp_{s1}$**	-0.0275525	0.032
$Precp_{s1}^2$	-0.0119479	0.037	**$DTemp_{s2}$**	0.0068393	0.588
$Precp_{s2}^2$	0.0108967	0.548	**$DTemp_{s3}$**	0.0088317	0.826
$Precp_{s3}^2$	-0.0168599	0.321	**$DTemp_{s4}$**	0.0066468	0.357
$Precp_{s4}^2$	-0.1318247	0.172	**Area**	-0.0000138	0.000
$Temp_{s1}^2$	0.0869901	0.000	**Tube-well**	0.00004	0.000
$Temp_{s2}^2$	-0.0050283	0.193	**Constant**	7.847939	-8.251463
$Temp_{s3}^2$	0.0022125	0.000			
$Temp_{s4}^2$	0.1068201	0.084			
$Temp*Precp_{s1}$	0.0003119	0.751			

Dependent variable: Ln(Yield)				
R-Square	within 0.3023		Number of Obs	= 390
	Between 0.2303		Number of groups	= 13
	Overall 0.2310			

The result shows that there is a significant and nonlinear effect of temperature during dormancy, fruit growth stage, and maturity on citrus yield. The result shows that change in long run norm of temperature during these phenological stages has significant and negative impact on citrus yield in Pakistan. However, changes in long run mean temperature during flowering stage has an insignificant effect on citrus yield.

Valiente and Albrigo (2004) found that under climatic conditions of Florida increase in accumulative hours of temperature exceeding 15^0C than prevailing temperature can harm floral intensity of sweet oranges during flowering and fruit setting stages. Rosenzweig et al. (1996) reported that maximum temperature exceeding than 38°C may cause losses in citrus fruit set near the end of bloom. This study further predicted a 50 percent loss in the case if maximum temperature exceeds 48°C.

Moreover, the results are suggestive that precipitation during all the phenological stages have insignificant impact on citrus yield except during fruit growth stage for which long run norm of precipitation is negatively related to citrus yield in a linear fashion.

The results are also suggestive that temperature and precipitation have insignificant joint impact on citrus yield.

It is also observed that weather shocks (deviation of current years' precipitation and temperature) from the respective long run norms during dormancy stage have a negative and significant effect on citrus yield. Similarly, deviation of precipitation during fruit maturity also has an adverse and significant effect on citrus yield.

This study also found that there is area under citrus in a district has very small adverse but statistically significant effect on citrus yield. The number of tube-wells in a district were found to have a positive and significant effect on citrus yield.

4.8 Climate Change and Mango Yield Response

The result of Hausman Test for mango yield model rejects the null hypothesis suggesting that individual specific effects have correlation with at least some of the explanatory variables. The estimates of the fixed effect are consistent in both alternative and null hypothesis. The estimators of the random effect under the null hypothesis are more efficient but with the null hypothesis they are inconsistent. On the basis of Hausman Test (Table 4.7) we selected the fixed effect estimation technique for the mango yield response model.

Table 4.7: Result of Hausman Test

Null Hypothesis (H_0)	**Alternative Hypothesis (H_1)**	**χ^2**	**Probability**	**Conclusion**
Random is in appropriate	Fixed is appropriate	160.58	0.0000	H_1 is accepted

The estimated model involve the quadratic terms of precipitation and temperature to capture any non-linear effect of climatic variables on mango yield. For each phenological stage mango yield has a different response to changes in climatic factors (temperature and precipitation). The sign of coefficient of quadratic terms reflects the nature of the relationship among climatic variable and mango yield (Table 4.8). The result shows that changes in long run norm of the temperature has negative and insignificant impact on mango yield for all phenological stages of mango defined in previously.

Table 4.8: The Coefficient Estimates of Mango Yield Model

Independent Variable	Coefficient	Probability	Independent Variable	Coefficient	Probability
$Temps_1$	-0.1213275	0.787	**$Temp*Precp_{s2}$**	-0.0017607	0.753
$Temp_{s2}$	-0.6240448	0.417	**$Temp*Pecp_{s3}$**	0.0002215	0.976
$Temp_{s3}$	-0.2770676	0.892	**$Temp*Pecp_{s4}$**	0.0019443	0.021
$Temp_{s4}$	-0.624803	0.549	**$DPrecp_{s1}$**	0.0001751	0.922
$Precp_{s1}$	-0.1161151	0.384	**$Dprecp_{s2}$**	-0.0002888	0.841
$Precp_{s2}$	0.0243144	0.829	**$DPrecp_{s3}$**	-0.0006237	0.437
$Precp_{s3}$	0.0196143	0.938	**$DPrcp_{s4}$**	-0.0003901	0.618
$Precp_{s4}$	-0.0606449	0.022	**$DTemp_{s1}$**	-0.0030189	0.726
$Precp_{s1}^2$	-0.0031768	0.082	**$DTemp_{s2}$**	0.0256738	0.004
$Precp_{s2}^2$	-0.0058796	0.186	**$DTemp_{s3}$**	-0.019025	0.038
$Precp_{s3}^2$	0.0002875	0.859	**$DTemp_{s4}$**	-0.0122692	0.098
$Precp_{s4}^2$	6.78e-07	0.817	**Area**	-6.90e-06	0.001
$Temp_{s1}^2$	-0.0031768	0.832	**Tube-well**	9.60e-06	0.000
$Temp_{s2}^2$	0.0138085	0.422	**Constant**	26.72089	0.506
$Temp_{s3}^2$	0.0055777	0.852			
$Temp_{s4}^2$	0.0077927	0.595			
$Temp*Precp_{s1}$	0.0006231	0.938			

Dependent variable: Ln(Yield)
R-Square within 0.1864
Between 0.1602
Overall 0.1181

Number of Obs = 416
Number of groups = 14

The results shows that changes in long run norm of precipitation during dormancy stage and mango yield are related negatively in a non-linear fashion However, precipitation has linear and significant impact on mango yield during fruit maturity stages affecting mango yield negatively and significantly. The changes in temperature have an insignificant effect on mango yield during all phenological stages. However, temperature and precipitation have a joint positive and significant effect on mango yield during fruit maturity stage. Liang et al (1996) in case study of Yaching Area revealed that increase in cumulative temperature before flowering and 30 days after flowering was related positively with mango yield but during flowering period is detrimental for mango yield.

The results of this study are suggestive that the weather shocks (temperature) during flowering, fruit growth and maturity stage have significant effect on mango yield, positive impact during flowering and negative during the latter phenological stages. Similarly, weather fluctuations (shocks) in precipitation during all the stages have insignificant impact on mango yield.

This study also found a statistically significant but a small positive relationship between tube-well and mango yield, similarly area under fruit has significant but a small negative effect on mango yield.

4.9: Climate Change and Citrus Acreage Response

Fixed effect Arellano-Bond GMM technique is used to estimate the acreage response of citrus fruit to changes in climatic factors in Pakistan. The results are presented in Table 4.7. The dependent variable acreage and all the non-climatic variables included in the model as dependent variables (price, area, infrastructure, transportation, and tube-wells) are in logarithmic form whereas all the climatic factors are not in logarithmic form. The estimated results are suggestive that Wald Chi-square has been found statistically significant which implies that model is good fitted (see table 4.9.1).

The results obtained suggest that lagged area (previous year's area under citrus) has positive and statistically significant impacts on current year's area allocated to citrus production. It is showing that these impacts are although positive and significant but however are less elastic.

The price of citrus and area allocation to citrus production are related positively and statistically significantly but interestingly the acreage allocation is found to be inelastic. The results suggest that one percent change in price of citrus will bring 0.16 percent change in area under citrus production during the current year. Clearly it shows supply response of citrus are almost inelastic, which means change in prices bring minor changes in cultivated area of citrus. The results are in agreement with Traboulsi (2013).

Similarly, number of tube-wells per hundred cultivated hectares available in a district has statistically significant and a small positive effect on an area allocated to citrus production in that district. For the development of road infrastructure (road kilometer) in a district is found to be an important determinant of citrus acreage. The results depict a highly significant and positive relationship between infrastructure availability and citrus acreage. Moreover, transportation (number trucks and pickups) is found to play an insignificant role in determination of acreage under citrus.

The results are indicative of the fact that climatic factors (long run averages of temperature and precipitation) are crucial determinant of citrus acreage in Pakistan. However, the results differ in terms of level of significance of the coefficients as well as in magnitude and direction.

It is observed that increase in precipitation during dormancy stage of growth of citrus (December-January) has positive and statistically significant impacts on area allocation to citrus production. However, any increase in long run norm of temperature during dormancy stage has a negative and significant effect on acreage allocation to citrus production. The results suggest that other things remaining the same one degree centigrade increase in long run norm of average temperature during dormancy stage would result in decline of area allocation to citrus production. Results are suggestive that normal of precipitation for all other stages (flowering/fruit formation, fruit growth, and maturity) has insignificant effect on area allocation to citrus production. However the temperature normal during flowering/fruit formation and fruit growth stages are found to have a positive and significant effect on area allocation to citrus production in Pakistan.

Table 4.9: Coefficient Estimates of Citrus Acreage Response Model

No Of Obs:325					
Independent Variables		**Probability**	**Independent Variables**	**Coefficients**	**Probability**
$(Precp_{s1})_{-1}$	0.000645	0.044	$(lnCitrusArea)_{-1}$	0.7393928	0.000
$(Precp_{s2})_{-1}$	-0.0000253	0.254	$(Infrastructure)_{-5}$	0.000066	0.006
$(Precp_{s3})_{-1}$	0.0024261	0.402	$(lnTransportation)_{-1}$	8.83e-07	0.123
$(Precp_{s4})_{-1}$	-0.0090139	0.119	$(lnPriceCitrus)_{-1}$	0.1626566	0.000
$(Temp_{s1})_{-1}$	-0.002823	0.000	$(lnTube\text{-}well)_{-1}$	0.0000551	0.000
$(Temp_{s2})_{-1}$	0.0344604	0.011	Constant	1.620455	0.001
$(Temp_{s3})_{-1}$	0.0080032	0.014			
$(Temp_{s4})_{-1}$	0.0003037	0.973			

4.9.1: Diagnostic Test for (Acreage Response) Regression of Citrus

The study has used certain post estimation diagnostic tests where Wald chi-square test has been applied to check goodness of fit for the model and the results suggested that the model is a good fit. Moreover, Alleno-Bond test for AR (1) is found statistically significant which suggested auto-correlation is not present at first difference. Sargan test of over identifying restrictions test (Table 4.9.1) is suggestive that all instruments are valid. Similarly, Sargan Exogeneity test is statistically insignificant suggesting that all included instruments are exogenous.

Table 4.9.1: Diagnostic Tests

Test Name	**Statistic**	**Significance Level**	**Conclusion**
Wald Chi-square Test	Wald Chi-square=3802.59	Significant	Model is Good Fitted
Alleno Bond Test	AR (1)—Z-stat= --11.83	Significant	No Autocorrelation
Sargan Overidentification Restriction Test	Chi-square (211) = 244.12	Insignificant	Valid Restrictions
Sargan exogenous Restriction test (GMM)	Chi-square (135) = 137.27	Insignificant	Exogenous Restriction
Sargan exogenous Restriction test (IV)	Chi-square (5)=40.50	Insignificant	Exogenous Restriction

4.10: Climate Change and Mango Acreage Response

Fixed effect Arellano-Bond GMM estimates of the acreage response model for mango are presented in Table 4.10.

The dependent variable is log of area under mango cultivation whereas among the independent variables the non-climatic variables are in logarithmic form and climatic factors are not in logarithmic form.

The results are suggestive that current year's area under mango production is positively related to lagged acreage and statistically significant impacts on current year cultivated area The (lagged) price of mango has positive and statistically insignificant effect on area allocation to mango production.

The number of tube-wells affects mango acreage positively and statistically significantly. The results are suggestive that transportation facility (number of trucks and pickups) and area under mango cultivation are related positively and statistically significantly.

It is observed that climatic factors (long run averages of temperature and precipitation) during most of phenological stages have negative but insignificant impacts. It is important to note that precipitation during maturity stage and temperature during fruit growth stage have respectively negative and positive but significant impact of acreage allocation to mango production. The results show that increase in temperature during April-May would enhance area under mango cultivation. However, increase in precipitation during maturity stage would reduce area allocation to mango production in Pakistan.

Table 4.10: Coefficient Estimates of Mango Acreage Response Model

No Of Obs:350					
Independent Variables	**Coefficients**	**Probability**	**Independent Variables**	**Coefficients**	**Probability**
$(Precp_{s1})_{-1}$	-0.0115586	0.475	$(\text{lnmango Area})_{-1}$	0.8138762	0.000
$(Precp_{s2})_{-1}$	-0.0236088	0.276	$(\text{Infrastructure})_{-1}$	-0.0000157	0.301

No Of Obs:350					
Independent Variables	**Coefficients**	**Probability**	**Independent Variables**	**Coefficients**	**Probability**
$(Precp_{s3})_{-1}$	-0.0239301	0.207	$(\ln Transportation)_{-1}$	0.0000463	0.000
$(Precp_{s4})_{-1}$	-0.0065238	0.023	$(\ln Mango\ price)_{-1}$	0.000041	0.762
$(Temp_{s1})_{-1}$	-0.0468514	0.570	$(\ln Tube\ well)_{-1}$	0.0000533	0.004
$(Temp_{s2})_{-1}$	0.0619595	0.421	Constant	-48.55659	0.081
$(Temp_{s3})_{-1}$	3.016698	0.069			
$(Temp_{s4})_{-1}$	-0.0164237	0.706			

4.10.1: Diagnostic Test for (Acreage Response) Regression of Mango

Various post estimation regression diagnostic have been conducted and the results are resented in Table 4.10.1. The diagnostic tests are suggestive that there is no nuisance in regression estimation.

Table 4.10.1: Diagnostic Tests for Mango Regression			
Test Name	**Statistic**	**Significance Level**	**Conclusion**
Wald Chi-square Test	Wald Chi-square= 2786.34	Significant	Model is Good Fitted
Alleno Bond Test	AR (1)—Z-stat= -11.13	Significant	No Autocorrelation
Sargan Overidentifying Restriction Test	Chi-square(135) = 131.58	Insignificant	Valid Restrictions
Sargan Exogenous Restriction Test(GMM)	Chi-square(254) = 242.62	Insignificant	Exogenous Restriction
Sargan Exogenous Restriction Test(IV)	Chi-square(13) = 10.69	Insignificant	Exogenous Restriction

CHAPTER 05

CONCLUSION AND POLICY RECOMMENDATION

This chapter presents conclusion of the study, suggests some policy recommendations on basis of the results obtained and gives limitations of the study

5.1 Conclusion

Pakistan is exposed and vulnerable to harsh weather conditions, the production of fruit crops depends on area and yield response of the fruits to various climatic factors and non-climatic factors. The effect of temperature varies during different phenological stages of fruit growth. The acreage response to fruit prices is though positive and significant but is quite inelastic. The study supports that area and yield of citrus and mango fruits in Pakistan are quite responsive to climatic factors (temperature and precipitation).

The result shows that change in long run norm of temperature during various phenological stages (except during flowering/fruit formation stage) has significant and negative impact on citrus yield in Pakistan. The change in long run mean temperature during flowering and fruit formation stage has an insignificant effect on citrus yield.

Precipitation during all the phenological stages have insignificant impact on citrus yield except during fruit growth stage for which long run norm of precipitation is negatively related to citrus yield in a linear fashion. The empirical results reveal that temperature and precipitation have no joint impact on citrus yield.

The weather shocks (deviation of current years' precipitation and temperature from the respective long run norms) during dormancy stage have a negative and significant effect on citrus yield. Similarly, deviation of precipitation during fruit maturity stage also has an adverse and significant effect on citrus yield. This study also found that there is significant and positive relationship between tube-wells and citrus yield.

In case of citrus acreage response model, precipitation during all growth stages is found to have no significant effect on acreage allocation to citrus production except during dormancy stage for which a positive and significant effect has been observed. The temperature during dormancy, flowering/fruit formation, and fruit growth stages has significant effect on acreage allocation to citrus production. The temperature affects acreage allocation adversely during the dormancy stage but positively and significantly during the latter two stages

The own price is positively related to citrus acreage. Similarly, other non-climatic variables (infrastructure, area, and tube-wells) also have a positive and significant effect on citrus acreage allocation.

Similarly, changes in long run norm of precipitation during dormancy stage and fruit maturity stages and mango yield are related negatively and significantly. However, precipitation has linear and significant impact on mango yield during maturity stage and a non-linear negative impact during the dormancy stage. A positive and insignificant acreage response of mango to own price and negative response to infrastructure and precipitation during all phenological stages was observed except for fruit maturity stage for with it was negative and significant. A positive and significant effect on acreage response of mango to non-climatic variables like tube-well, area, and transportation was also observed.

5.2 Policy recommendation

The climate factors in Pakistan during certain phenological stages have been observed to have adverse impacts on fruit yield and acreage allocation to citrus and mango fruits. The following recommendations are suggested in order to avoid the negative effects.

The research on fruit crops in Pakistan has been a neglected and low priority area and need to be strengthened in order to realize the unachieved potential and in order to achieve increased fruit productivity. The national agricultural research system should focus on development of adaptation strategies to face the challenge of climate change. Undertaking the following measures can increase quality and quantity of fruit in Pakistan.

1) Developing fruit varieties tolerant to stresses like heat, moisture, and salinity; resistant to pest, diseases, and viruses; and cultivars fit for early or late fruiting.
2) Establishing a weather information system ensuring close linkages between agricultural research, extension, and education; Pakistan Meteorological Department; and fruit growers.
3) Identification and promotion of adaptation strategies adopted successfully by fruit growers in Pakistan and elsewhere in the world.
4) Initiation of crop insurance policy for fruit growers. .

5.3: Limitations of Study

The study at hand has the following limitations that are worth mentioning here for the readers.

The wind speed has significant effect on citrus and mango productivity however it could not be incorporated because of the non-availability of district level data. Similarly, incidence of frost also significantly effects productivity of fruits but could not be analyzed due to non-availability of data. Further, effects of fertilizer use on fruits and soil fertility could not be controlled for due to lack of the required information regarding these variables.

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Appendices:

Appendix 01: List of Major Citrus Growing Districts in Pakistan

Serial No.	Districts	Serial No	Districts
1	Sargodha	7	Bahawalpur
2	Sahiwal (including Okara and Pakpattan	8	Shiekhupura
3	Jhang including Chiniot	9	Bahawalnagar
4	Faisalabad including Toba Tek Singh	10	Lahore including Kasur
5	Multan	11	Nawabshah including Nowshero Feroze
6	Vehari	12	Khairpur

Appendix 02: Lists of Major Mango Growing Districts in Pakistan

Serial No	Districts	Serial No	Districts
1	Faisalabad including Toba Tek Singh	8	Jhang including Chiniot
2	Multan	9	Rahim Yar Khan
3	Muzaffargarh	10	Sanghar
4	Vehari	11	Hyderabad
5	Sahiwal including Okara and Pakpattan	12	Badin
6	Bahawalpur	13	Khairpur
7	Bahawalnagar	14	Nawabshah including Nowshero Feroze