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ASSESSMENT OF THE IMPACT OF CLIMATE CHANGE ON THE PRODUCTIVITY OF COTTON: EMPIRICAL EVIDENCE FROM COTTON ZONE, SOUTHERN PUNJAB, PAKISTAN

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ABSTRACT

Climate change is one of the venerable factors of the environment. The climate of Punjab is changing over time due to global warming, increasing temperature, melting of glaciers, and changes in the rainfall pattern. Cotton crop is very sensitive and risky to climate change and intensive inputs and huge investment is required for the production of cotton. The research aims to investigate the impact of climate change on the productivity of cotton. The Secondary data was collected from meteorological departments. The general production function that will be used for the analysis where Y is cotton production per hectare, Cl is the vector of climatic indicators including temperature, humidity, and precipitation while NCI is the vector of non-climatic indicators such as fertilizer area under cotton and technological change. An autoregressive distributed lag (ARDL) approach to co-integration was applied for the estimation of long-run relationships and a short-run relationship error correction model was used. For the stability of model CUSUM and CUSUM Q test was applied. ARIMA model was used for forecasting whereas regression analysis was used for impact analysis. Evolving and disseminating cotton varieties having adaptation to climate change should be the focus of future research and development. Improving the practices of farm management, developing awareness among the farmers about climate change, and strengthening the extension department are some measures to be taken for the adaptation to climate change in the cotton zone.

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INTRODUCTION

The productivity of cotton is influenced by two kinds of factors i.e., climatic, and non-climatic factors. Climatic factors include temperature, rainfall, and humidity. Temperature is a measure of the intensity of heat energy produced by solar radiation. Temperature influences plant growth as it affects physiological processes such as photosynthesis, transpiration, respiration, germination, and flowering. Air temperature is more important for crop growth than soil temperature (World Bank, 2010). Rainfall is an important factor which affects the acreage and yields of crop. The rain-fed barani zone has the highest quantity of rainfall, followed by the rice zone, mixed zone, and cotton zone, respectively. Rainfall fluctuated between 697 to 1401 millimeters, 491 to 1403 millimeters 219.5 to 718 millimeters, and 72.8 to 462.5 millimeters in Barani, rice, mixed, and cotton zones respectively over the period 1970-2001 (World Bank, 2010).

Savant a Swedish physical chemist (1859-1927) was the first to suggest the theory of global warming. He argued that doubling mixing ratios due to the increased burning of coal in the UK would increase the temperature by 5°C. (Jacob and Lefgren, 2002). Environmental threats are increasing tremendously. Climate change and global warming are linked with these environmentally degrading scenarios. Global warming and climate change are used synonymously but climate change gives a wider sense of the meaning. Being a global phenomenon, the impact of climate change has become critical for the world.

Underdeveloped or developing countries like Pakistan would have to face additional damages because of their unstable situation. Some pollutants produced by different human activities are increasing the percentage of greenhouse gasses (GHG) emission in the atmosphere. The most important of these are CO_2, CH_4, N_2O, CFCs, water vapour, and other industrial gases. Solar radiation reaches the outer limits of the atmosphere without loss. But afterward, reduction starts by reflection, depletion, and absorption in different parts of the atmosphere. The Earth radiates long wave or infrared radiation back to space in relevant proportion. But GHG acts as a cover for outgoing weak longwave radiation. This radiation is trapped by clouds and GHG, and enhances the warming of the atmosphere, causing global warming. Global warming is no more just a theory: it is affecting millions of people around the world in terms of harsh weather, droughts, flood, heat waves, cyclones, and anti-cyclones (Mustafa, 2007). In 2006 it was measured that the average surface temperature of the earth had increased warmed by 0.7oC in the last 125 years due to CO2 and other greenhouse gasses (GHG). It is obvious that this global warming is man induced.

Many impacts of climate change are observed over the entire globe. The warming of the globe causes snow and ice melting rises in the sea level and changes in weather systems. Fluctuations in the pattern of climate especially rise in temperature and also decrease in rainfall pattern would have a negative impact on the future values of major crop produced in Pakistan. It is usually said that the north is the driving force of carbon emissions, but the south is facing the effects of it. Climate changes especially increase in temperature and also decrease in rainfall would have a negative impact on the future projections of major crop production in Pakistan. It is said that the north is the driver for the carbon emissions, but the south is the victim. In Pakistan, inadequate monitoring systems, assessment of the likely changes in the weather patterns, and its impacts on the agricultural sector make it difficult to have an effective national agro-climate policy (Roohi, 2004).

In developing countries like Pakistan, the impact of climate change is expected to affect severely because of a lack of resources and infrastructure. Further, no significant development and less implementation on new adaptation strategies and policies to tackle climate change are being exploited. Development activities lack proper measures and stress the importance of considering climate change in the planning, designing, and implementation stages (Farooqi *et al.*, 2005). Agriculture is more vulnerable to climate change as a little effect of climate leads to greater change in agriculture production (Gregory *et al.*, 2005; Ahmad *et al.*, 2021).

The impact of climate change on agriculture production is an empirical issue, and the extant literature, in general, concludes that climatic changes are affecting agricultural production negatively (Adams *et al.*, 1988; Cline, 1996; Parry *et al.*, 2004; Lobell and Field, 2007; Cabas *et al.*, 2009; Ahmad *et al.*, 2021). Nonetheless, a handful of studies find evidence for the positive association between increased temperature and agricultural output (Gbetibouo and Hassan, 2005).

Pakistan is a disaster-prone country that is vulnerable to climate change. So, the yield of major crops (Wheat, Rice, Cotton, and Sugarcane) will be directly affected by climate change (Ahmad *et al.*, 2021). It will also cause food and fibre security challenges. Cotton is a major contributor to GDP and value addition. However, very little research work has been done on estimating the impact of climate change on wheat and which are available they merely focused on wheat (Ahmad *et al.*, 2012) and rice (Mahmood *et al.*, 2012). The present study aims at determining the extent of the impact of climate change on the productivity of cotton in the cotton zone and forecasting the productivity of cotton.

METHODOLOGY

The present study was conducted in the cotton zone of Punjab province, Pakistan where the cotton fibre is produced to fulfil the domestic use and export to the other countries of the world. Cotton zone includes all those areas of province of Punjab in which cotton is cultivated in their regular cropping patterns. Cotton zone includes 16 districts. Basically, cotton zone starts from Multan and end at Bahawalpur. 16 districts include in cotton zone are Multan, Lodhran, Khanewal, Muzaffargarh, Dera Ghazi Khan, Rajanpur, Layyah, Vehari, Sahiwal, Toba Tek Singh, Faisalabad, Jhang, Mianwali, Bhakkar, Rahim Yar Khan and Bahawalpur. The picture given below with white arrow indicates the districts of cotton zone.

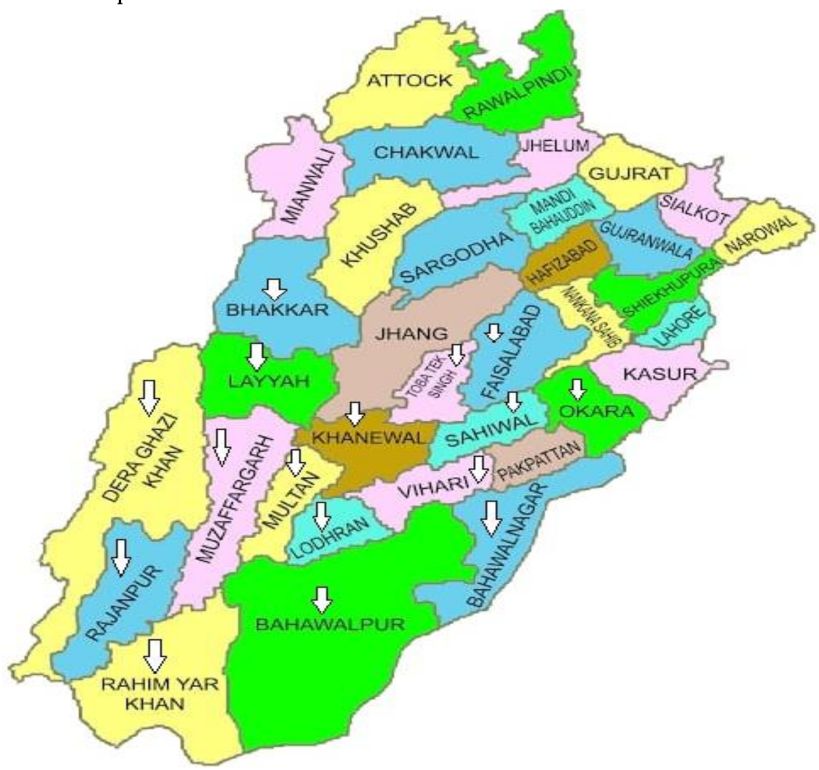


Figure 1. Cotton Zone of Punjab Province.

The critical issue of determining the impact of climate change on agricultural output attracted the special attention of the researchers after the seminal work of Nordhaus (1977). The production function approach has been widely used to analyse the climate change agriculture nexus. A good volume of literature use simulation models to look into the future changes in climate and their impacts on agriculture (Tubiello *et al.*, 2002; Luo *et al.*, 2003; Luo *et al.*, 2005; Lobell *et al.*, 2005; Magrin *et al.*, 2005; Lobell and Field, 2007; Ludwig *et al.*, 2008). Incapacity of the above-mentioned models to accommodate crops substitutions and adaptations to climate led to the formulation of the Ricardian approach pioneered by Mendelsohn *et al.* (1994) wherein the impact of climate change has been analysed using the value of farmland or net rent as a dependent variable The major advantage of this technique is that it allows crop substitutions and farm-level adaptations—making it most attractive in evaluating the impact of climate change on agriculture. However, the major drawbacks of this approach include the unavailability of reliable data for agricultural farm values and the existence of imperfect land markets in developing countries (Gbetibouo and Hassan, 2005; Guiteras, 2009). This approach has also been criticized on the grounds of its implicit assumptions of constant prices and zero adjustment cost making the welfare calculations biased (Cline, 1996) and provides lower-bound estimates of the costs of climate change (Quiggin and John, 1999).

Following Segerson and Dixon (1999), Chang (2002) and Cabas *et al.* (2009), the above deficiencies can be avoided using a modified production function approach. Some studies including Adams *et al.* (2003) and Felkner *et al.* (2009) introduced quadratic terms of climatic variables to examine whether the impact of climate change on crop production is non-monotonic or not. To account for the joint impact of temperature and precipitation. Hansen (1991), Ludwig and Asseng (2006), Weersink *et al.* (2010) and Cabas *et al.* (2009) further extended the production function by introducing the interaction terms.

To investigate the impact of climate change on the productivity of the cotton zone, secondary data of climatic variables (mean maximum and mean minimum rainfall, humidity, and mean maximum and mean minimum temperature) was collected between 1984 and 2014. There are nine districts (Sahiwal, Bahawalnagar, Bahawalpur, Rahim Yar Khan, Multan, Vehari, Lodhran, Khanewal, and Pakpattan) in the cotton zone of Punjab but only four districts were selected by the random selection method.

Data Sources

The followings were the main sources of data for this research study:

- Regional Metrological Department, Lahore
- Punjab Development Statistics
- National Fertilizer Development Center, Islamabad
- Pakistan Bureau of Statistics
- Economic Survey of Pakistan

Figure 2. Geographical Map of Climate Change.

Analysis of the general trend of variables

Generally speaking, a graph connects the related points of the data under consideration, to give a meaningful picture. Graphs were plotted for each of the climate variables i.e. rainfall, humidity, and temperature by taking them along the Y-axis, and the time-period will be taken along the X-axis. Time interval on X-axis will be taken to feasibly plot the graph for the data of the available years. These graphs conveniently expressed the hidden message of the climatic changes. Moreover, we explained the increase and decrease of data feasibility via the pictorial aid of the graph. After the trend analysis forecasting of cotton was made using ARIMA (Auto-Regressive Integrated Moving Average) Model to have a glimpse of the future.

Model Specification

The general production function used for the analysis was Y = f (Cl, NCl). Where Y is cotton production per hectare (yield), Cl is the vector of climatic variables including temperature, humidity, and precipitation while NCI is the vector of non-climatic variables such as fertilizer area under cotton and technological change. We will use linear function form from the production model (as in (Houck and Gallagher, 1976; Choi and Helmberger, 1993; Kaufmann and Snell, 1997; Deschênes and Greenstone, 2007; McCarl *et al.*, 2008).

$\ln Y = \beta o + \Sigma \beta i \ln Xi + \mu i$……………………

Application of OLS to pooled/panel data provides inconsistent results as it requires the random and/or fixed-effect models (Baltagi, 2005; Asteriou and Hall., 2000; Wooldridge, 2009). This study used the appropriate model. There is the possibility of a correlation between unobserved time invariants and regressors (Stock and Watson, 2003; Baltagi, 2005; Wooldridge, 2009; Sarker, 2012). Furthermore, if needed it will also account for the district-specific effects that are preferred over pooled least square and random-effect methods (McCarl *et al.*, 2008; Kim and Pang, 2009; Barnwal and Kotani, 2010; Cabas *et al.*, 2009; Sarker, 2012). The same Model is used for the Bahawalnagar, Bahawalpur, Rahim Yar Khan, and Multan for the cotton zone of Punjab. Where, S, V, and M (in subscript to s) respectively represent the first stage (sowing), the second stage (vegetative growth), and the third stage (harvesting). Furthermore, it also accounts for the district specific effects that are preferred over pooled least square and random effect methods (McCarl *et al.*, 2008; Kim and Pang, 2009; Barnwal and Kotani, 2010; Cabas *et al.*, 2009; Sarker, 2012). The analytical technique was chosen according to the requirement of the study. An autoregressive distributed lag (ARDL) approach to co-integration was applied for the estimation of long-run relationship and for short-run relationship error correction model was used. Moreover, the stability of the model is very important for its usage in the future. Keeping in view the importance of stability of model CUSUM and CUSUM Q test was applied.

RESULTS AND DISCUSSION

This section is divided into four parts. In the first part, the trend analysis of both climatic and non-climatic variables is described by graphical analysis in the cotton zone of Punjab while in the second part forecasting of climatic and non-climatic variables of cotton zone is explained and in the third part, the results of the fixed effect model are discussed to explain the impact of climate change on the productivity of cotton and in the last part result of short-run and long-run ARDL model for each district is explained.

Trend analysis

The trend analysis is divided into two main parts one is tabular analysis while the other one is graphical analysis. In the first part, tabular and graphical analysis of climatic variable (Mean Maximum temperature, Mean Minimum temperature, Humidity at 0800 am, humidity at 0500 pm, and mean rainfall) of Bahawalnagar, Bahawalpur, Rahim Yar Khan, and Multan was described. While in the second part tabular and graphical analysis of non-climatic variables (Area and fertilizer use) is described. The data of climatic variables were collected from the Regional Meteorological Department, Lahore from the period of 1981 to 2014. Then monthly data of each variable from May to October was collected and find out the mean value of each variable and draw its graphical pictures which show increasing or decreasing trend.

A trend analysis of climatic variables

Trend analysis of climatic variables is explained below;

Trend analysis of mean maximum temperature

The graphical analysis along with the trend line shows that Bahawalnagar and Rahim Yar Khan show an increasing trend of mean maximum temperature with the page of time while Bahawalpur shows a constant trend. The Multan is a great victim of climate change because its maximum temperature is decreasing with the passage of time. All these districts are facing the extent of climate change but its impact on Multan is high while others show mild changes.

Trend analysis of mean minimum temperature

The graphical analysis along with the trend line shows that Bahawalnagar, Multan, and Bahawalpur show an increasing trend of mean minimum temperature with the passage of time. The Rahim Yar Khan is a great victim of climate change because its minimum temperature is decreasing with the passage of time. All these districts are facing the extent of climate change but its impact on Rahim Yar Khan is high while others show mild changes.

Trend analysis of mean humidity at 08:00 am

The graphical analysis along with the trend line shows that Bahawalnagar, Rahim Yar Khan, and Bahawalpur show an increasing trend of Mean Humidity with the passage of time. The City of Multan has no impact on climate change because its Mean Humidity range is almost constant with the passage of time. All these districts excluding Multan are facing the extent of climate change but its impact on Multan is constant while others show mild changes.

Trend analysis of mean humidity at 05:00 pm

The graphical analysis along with the trend line shows that Bahawalnagar, Multan, and Bahawalpur show an increasing trend of mean Humidity with the passage of time. The Rahim Yar Khan is also the victim of climate change keeping in view the humidity of the evening because its mean Humidity is decreasing with the passage of time. All these districts are facing the effects of climate change but its impact on Rahim Yar Khan is high while others show mild changes.

Trend analysis of mean rainfall

The graphical analysis along with the trend line shows that Rahim Yar Khan, Multan, and Bahawalpur show a constant trend of mean rainfall with the passage of time. The Bahawalnagar is a great victim of climate change because its mean rainfall is decreasing with the passage of time. All these districts are facing the extent of climate change but its impact on Bahawalnagar is high while others show mild changes.

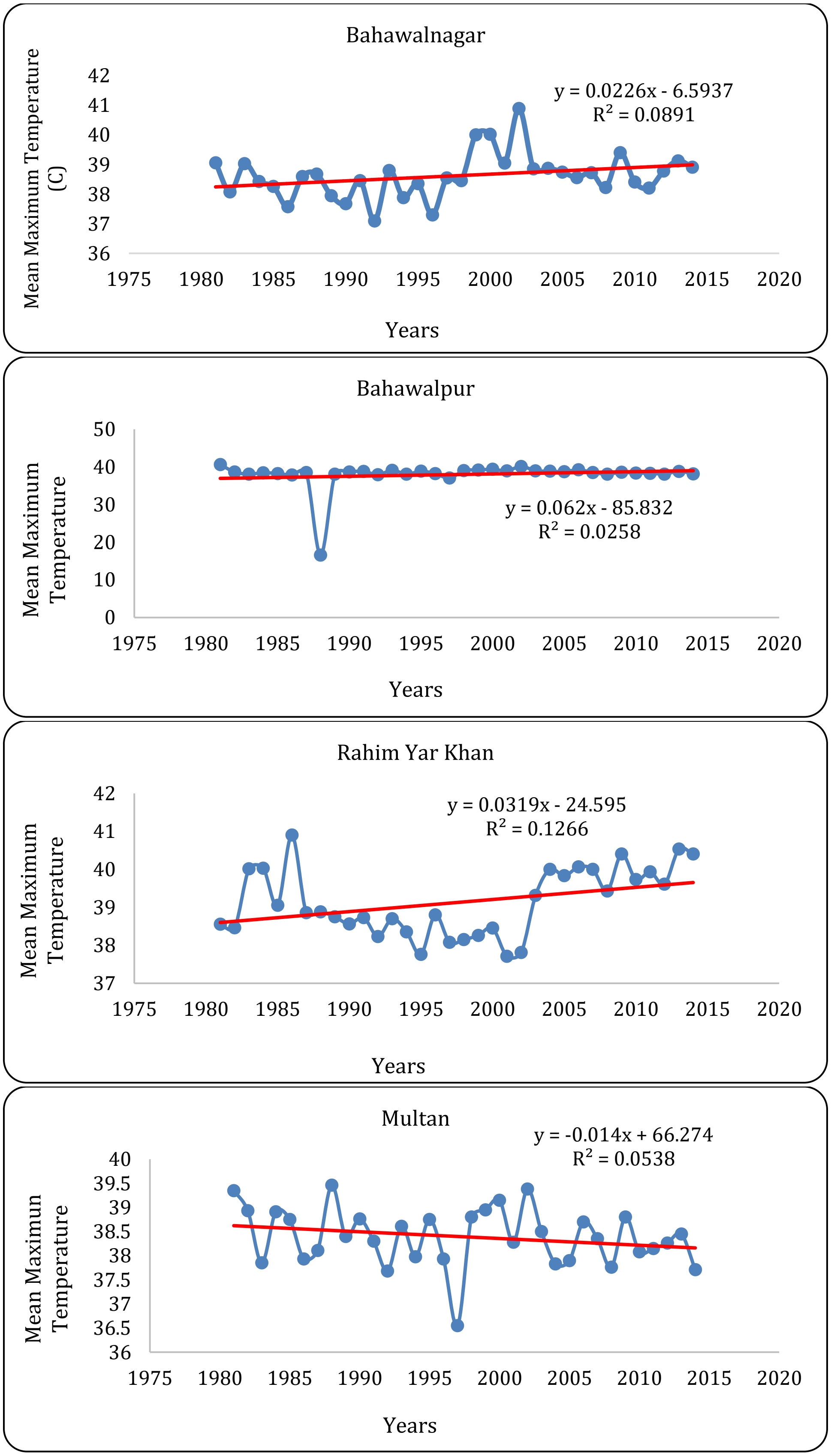


Figure 3 (a-d). Trend Analysis of Mean Maximum Temperature.

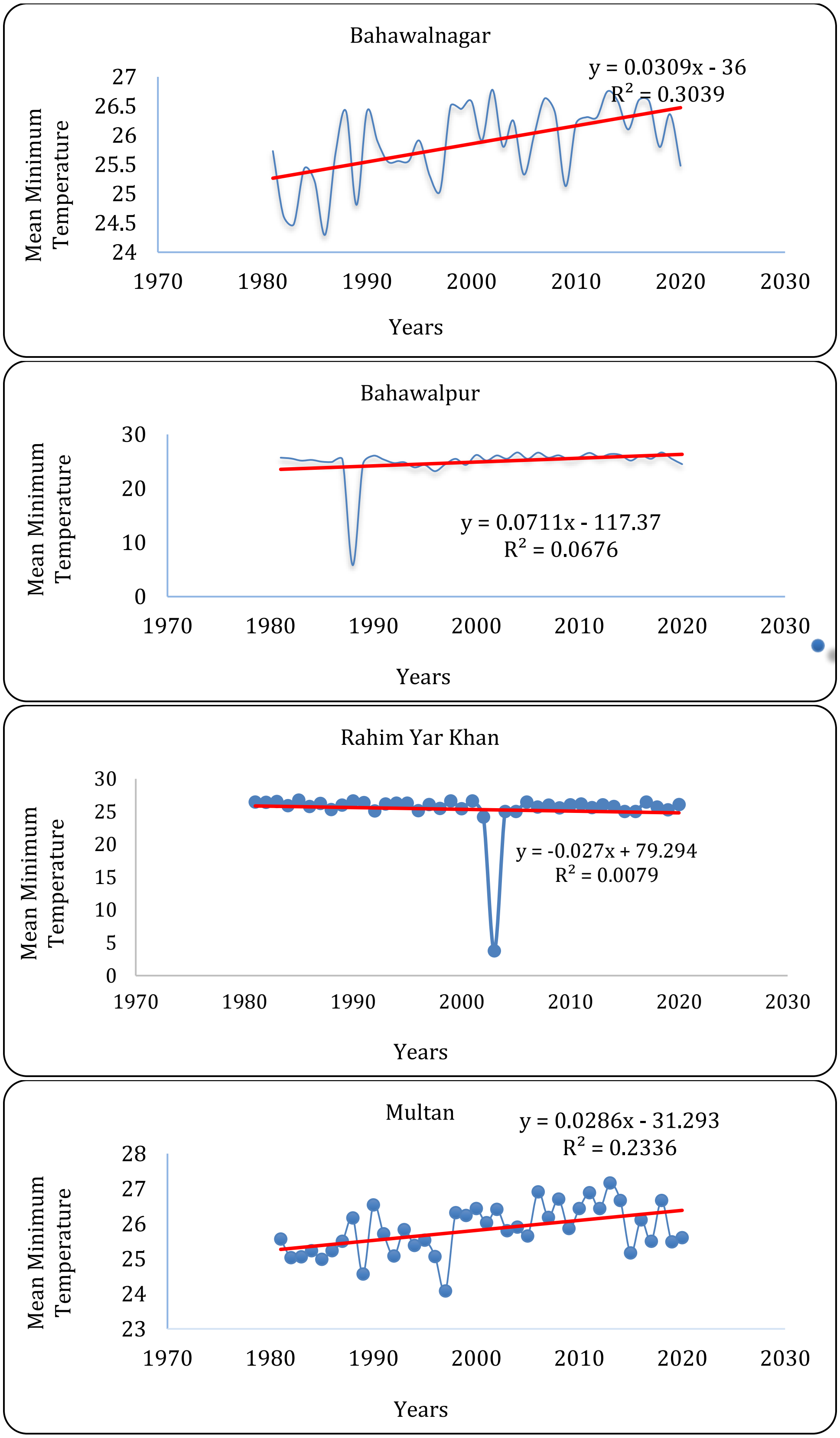


Figure 4 (a-d). Trend analysis of mean minimum temperature.

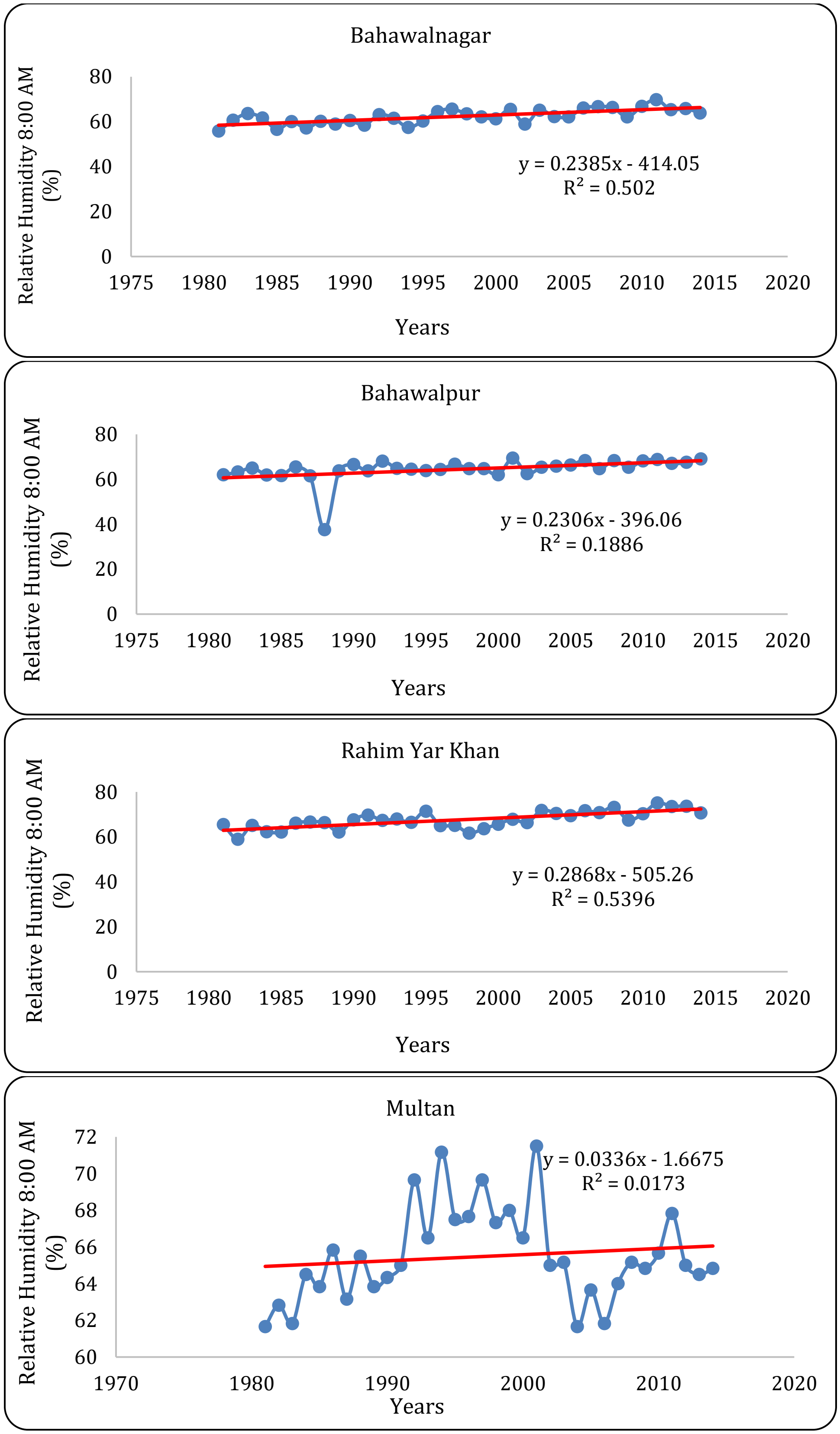


Figure 5 (a-d). Trend Analysis of Humidity at 8:00 AM.

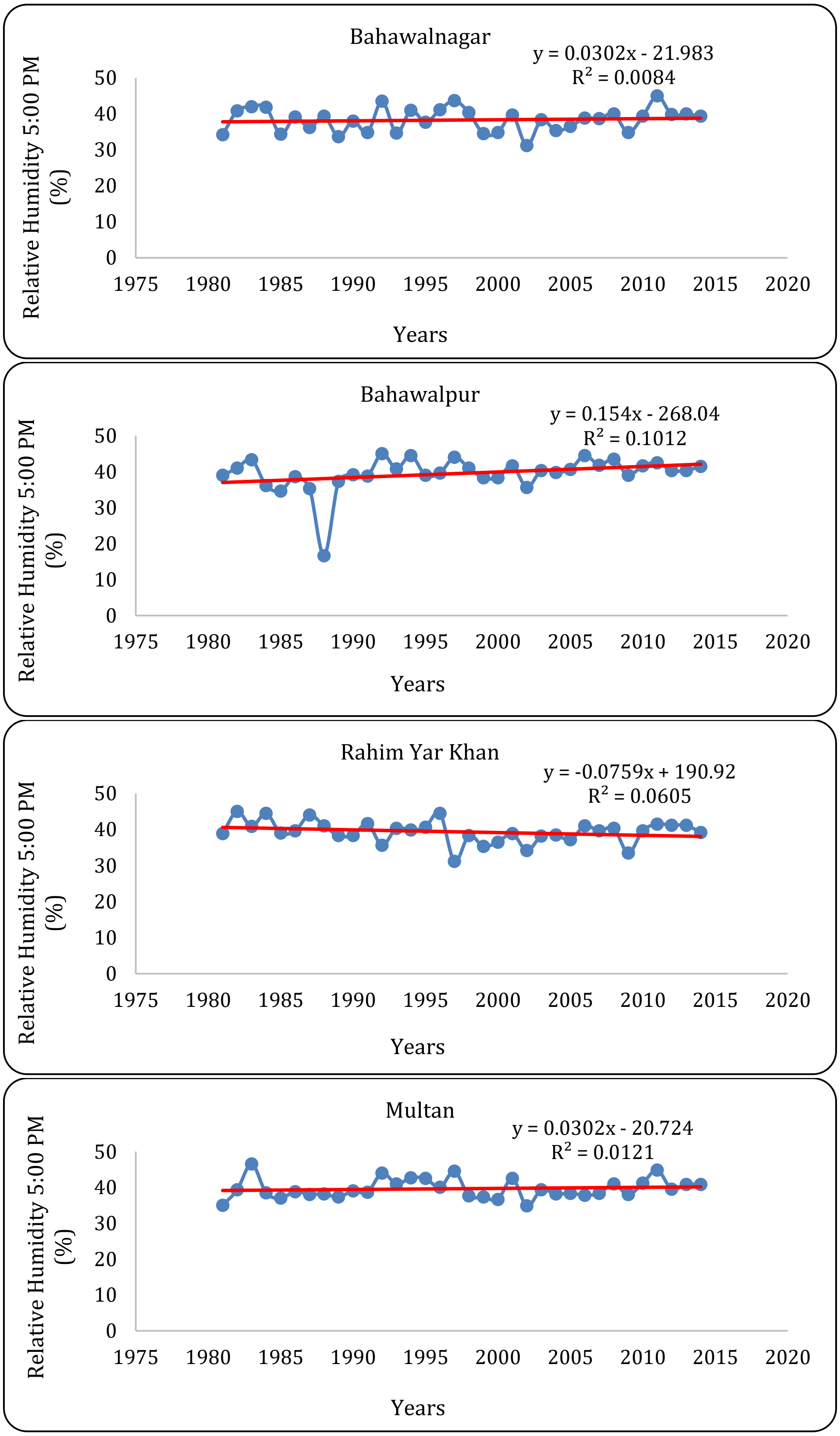


Figure 6 (a-d). Trend Analysis of Humidity at 5:00 PM.

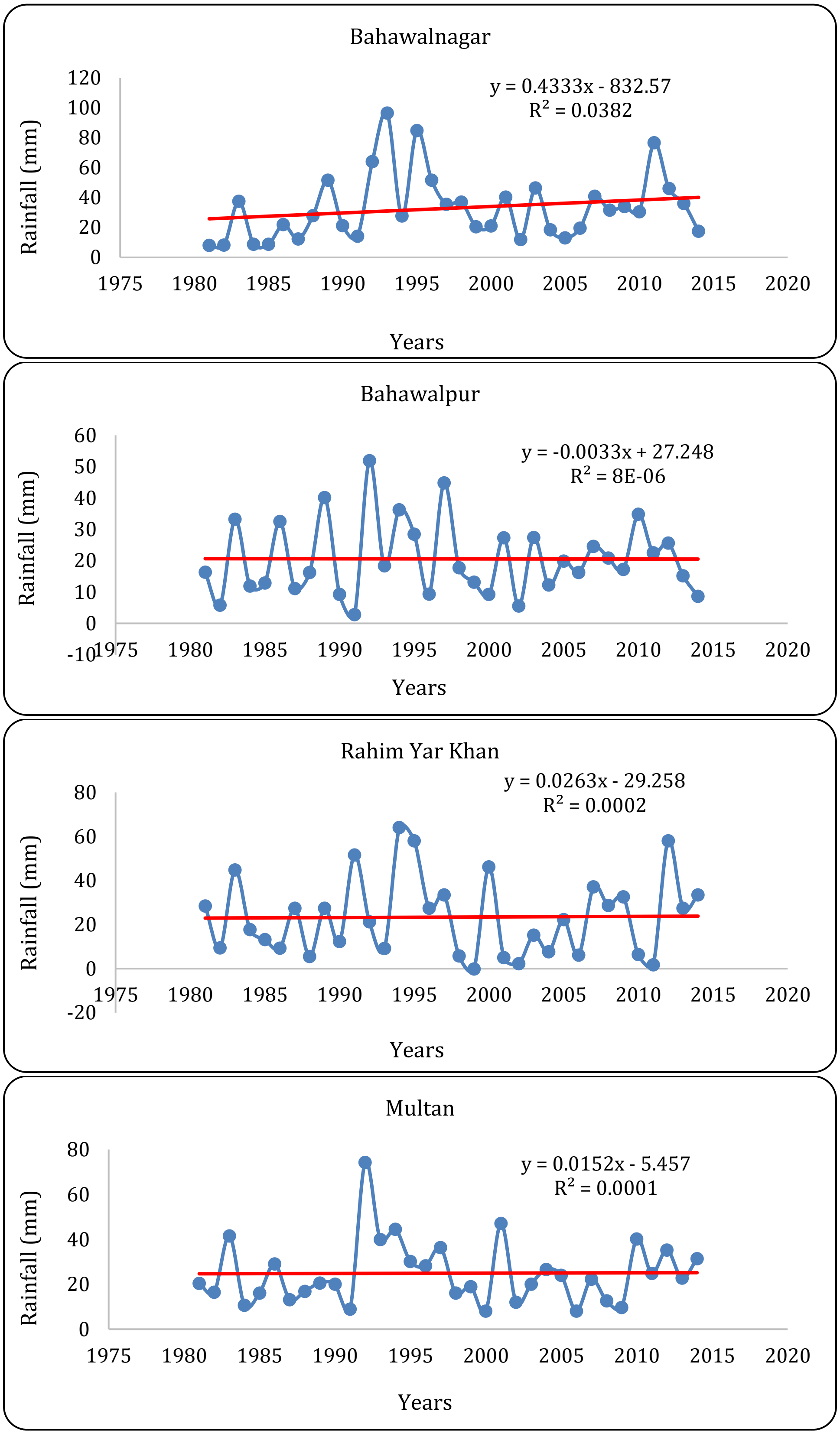


Figure 7. Trend Analysis of Mean Rainfall.

Trend analysis of non-climatic variables

Trend analysis of non-climatic variable is as under;

Trend analysis of productivity of cotton

The graphical analysis along with the trend line shows that Bahawalnagar, Rahim Yar Khan, and Bahawalpur show an increasing trend of mean productivity with the passage of time. The Multan is a great victim of climate change because its Mean productivity is decreasing with the passage of time. All these districts are facing the extent of climate change but its impact on Multan is high while others show mild changes.

Trend analysis of mean fertilizer use in the cotton zone

It showed the Mean Fertilizer use of Bahawalnagar, Bahawalpur, Rahim Yar Khan, and Multan from 1981-2014. It is clear from the graph that all these districts fall in the cotton zone of Punjab therefore it did not show any major fluctuation in the use of fertilizer. The variations exist based on the type of farmer. Small, medium, and large farmers use different proportions of fertilizers. Mean fertilizer use mostly falls in the range of 220-290 Kg.

The Mean fertilizer use of district Bahawalnagar was 220 Kg while the Mean fertilizer use of district Bahawalpur was 250 Kg whereas The Mean fertilizer use of district Rahim Yar Khan was 270 Kg and The Mean fertilizer use of district Multan was 290 Kg.

Trend analysis of cultivated area in the cotton zone

The graph showed the Mean Cultivated Area of Bahawalnagar, Bahawalpur, Rahim Yar Khan, and Multan from 1981-2014. Graph shows that all districts fall in cotton zone and did not show any major fluctuation in Mean Cultivated Area. Mean productivity mostly stood at range of 226 hectares. The Mean Cultivated Area of district Bahawalnagar was 182 hectares while the Mean Cultivated Area of district Bahawalpur was 233 hectares. The Mean Cultivated Area of district Rahim Yar Khan was 278 hectares and Mean Cultivated Area of Multan was 211 hectares.

Forecasting analysis

Due to this outlier type observation, the trend seems exponential. Fluctuations endorse the mean shifting and as the amplitude of variation is also increasing so the presence of unit root is also predictable. So, this time series is looking on stationary, having means changing.

The following figure shows the autocorrelation and partial autocorrelation function of the cotton time series. As both graphs show an indication of a unit root. ACF spikes exponentially decaying, and one large spike is present at one lag so non-stationarity is evident. Results of the ADF test also showing the presence of unit root (Figure 11).

Fixed effect estimates for the cotton crop by using a General to specific approach (G2S) in this research. Keeping in view the specification tests the model being used for Bahawalpur is selected as the final model of this research. It depicts the non-linear impact of temperature and rainfall on the production of cotton. It is clear that rainfall and temperature both make a significant joint impact on the various growth stages of the crop. It is also evident from the results that the impacts of all three climatic variables are not separable (Figure 12).

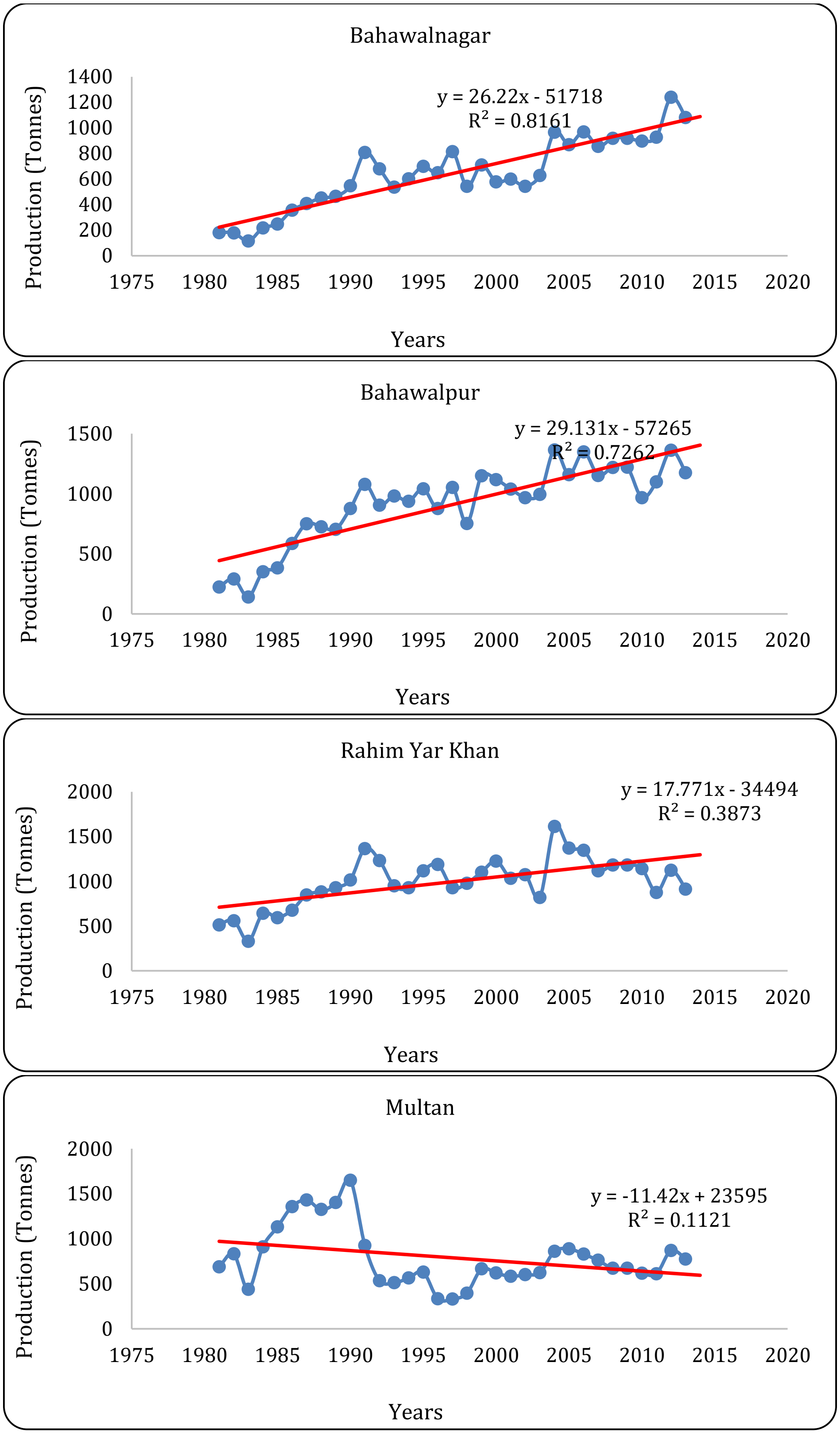


Figure 8 (). Trend Analysis of Cotton Production.

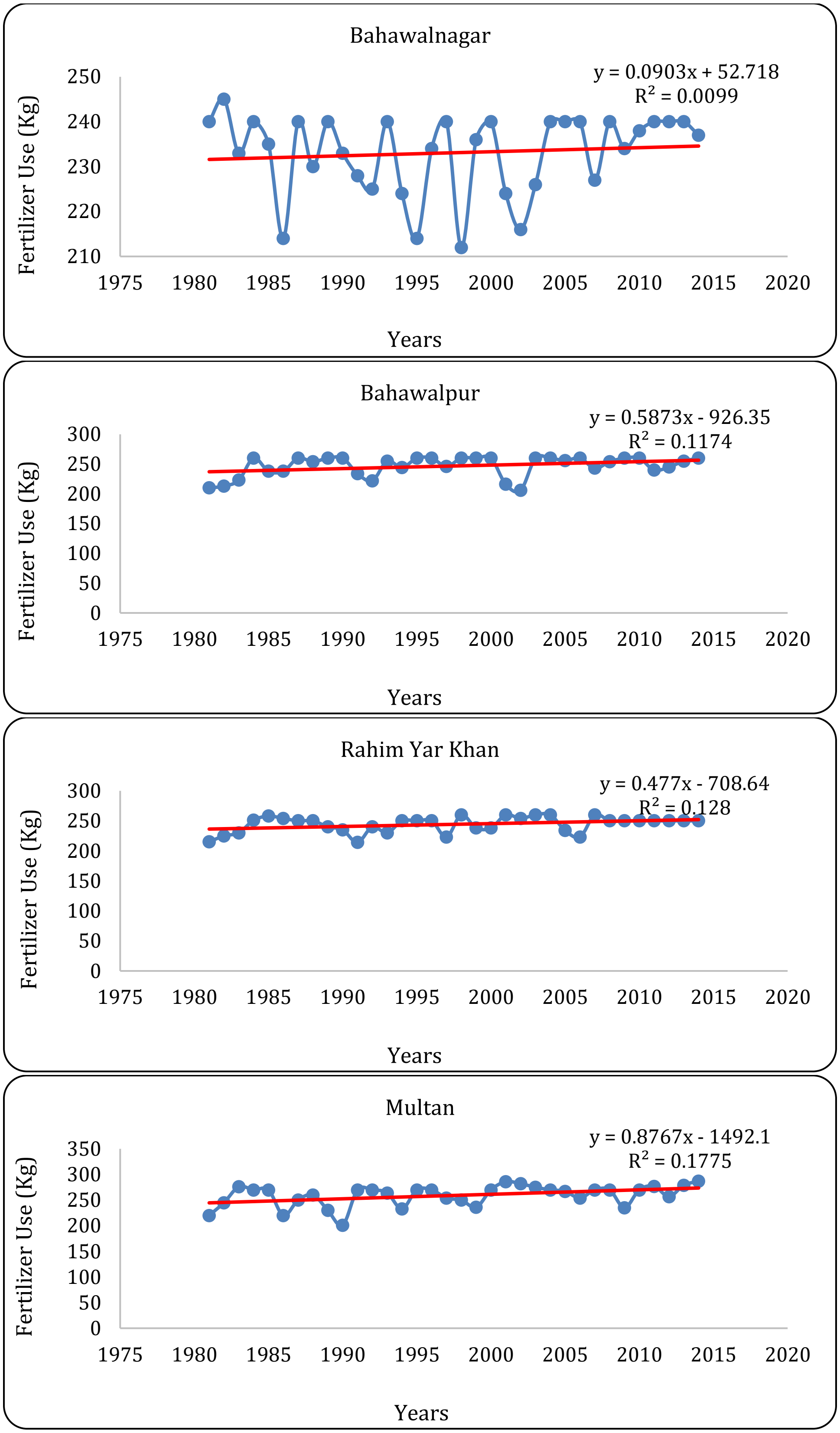
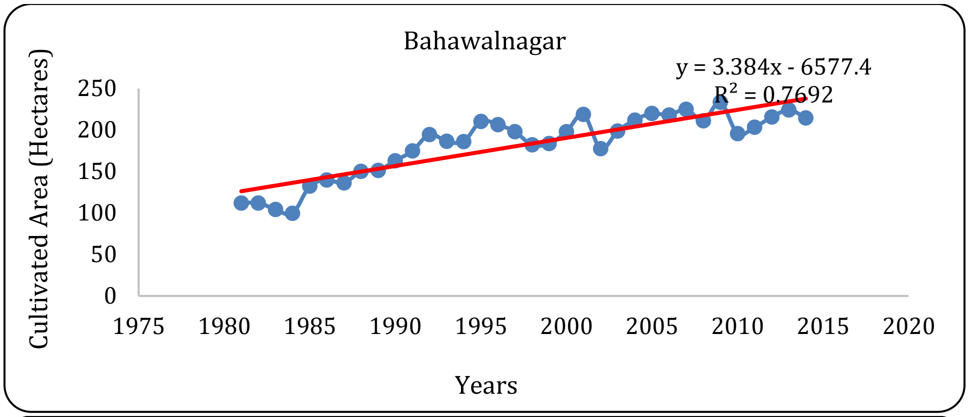
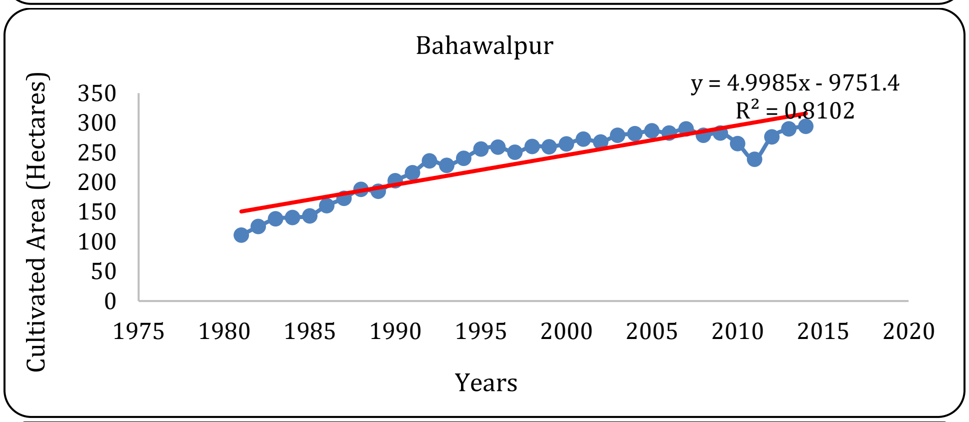
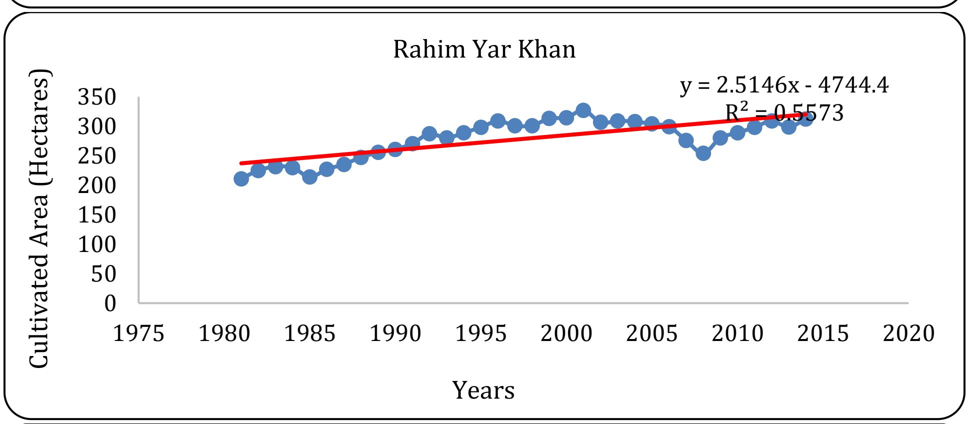


Figure 9 (a-d). Trend Analysis of Mean Fertilizer Use.







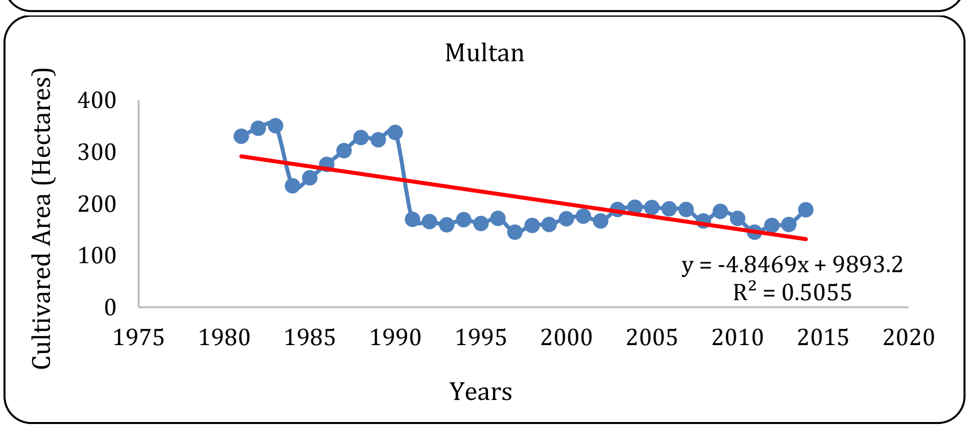


Figure 10 (a-d). Trend Analysis of Mean Cultivated Area.

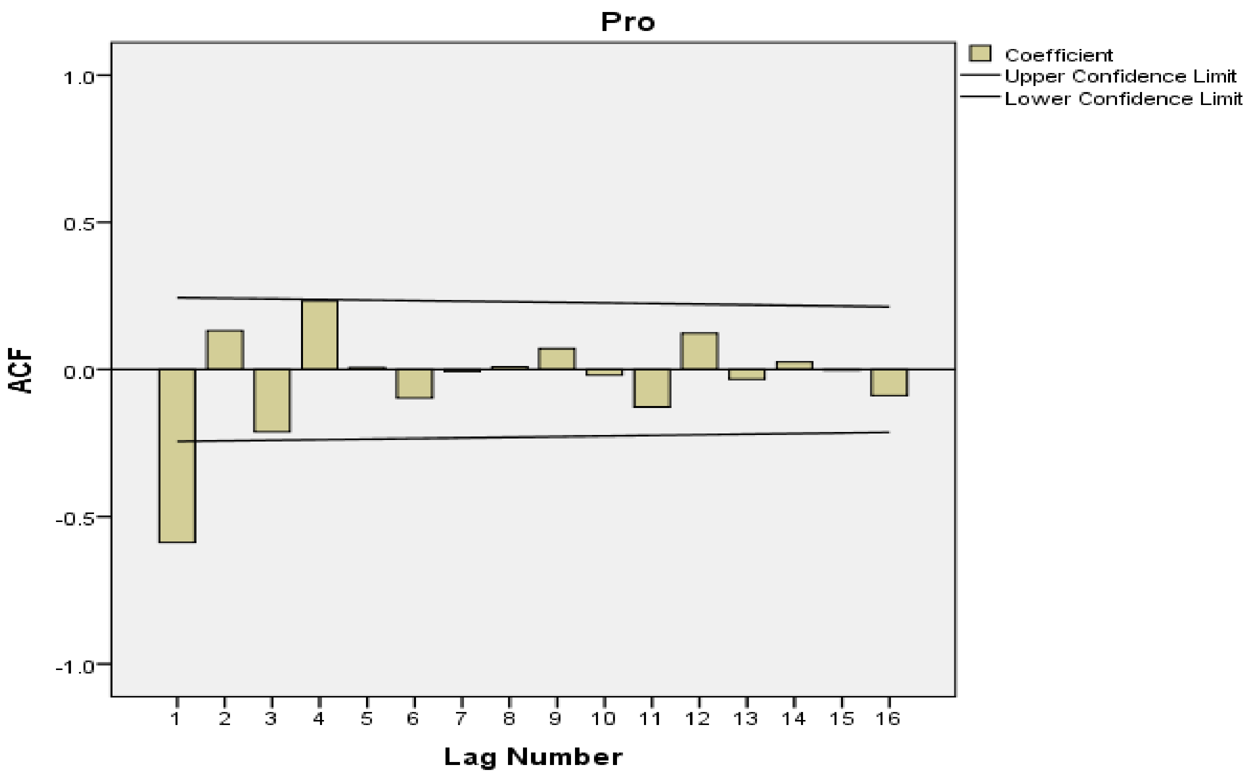


Figure 11.

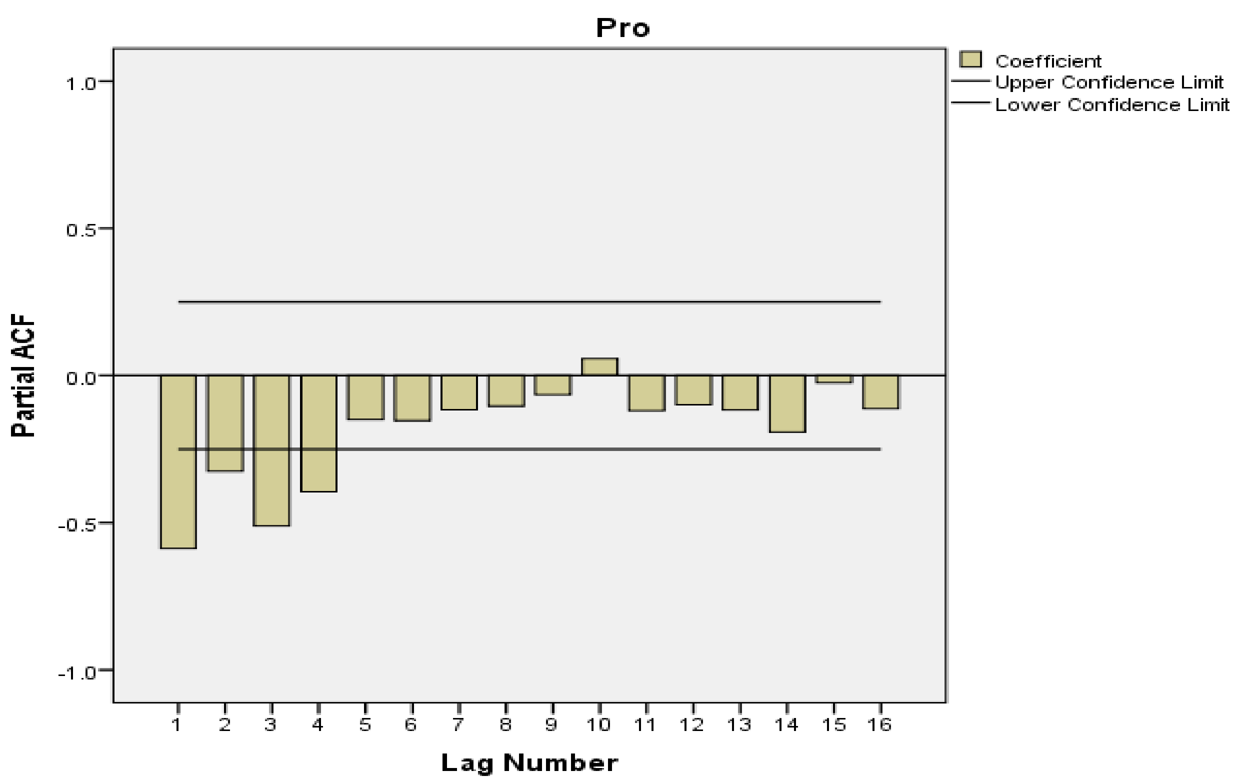


Figure 12.

Table 1. Comparison of results of fixed effect model estimates.

Variables	Parameters	Coefficient				Standard error			
		Bahawalpur	Rahim Yar Khan	Multan	Bahawalnagar	Bahawalpur	Rahim Yar Khan	Multan	Bahawalnagar
Constants	0	6.179	4.813	12.930	10.965	6.418	6.997	8.669	5.572
Tem (May-June)	TS	0.053	-0.134	0.247	0.083	0.164	0.131	0.203	0.081
Tem (July-August)	TV	-0.001	0.249	-0.097	0.218	0.225	0.261	0.387	0.192
Tem (September-October)	TM	-0.043	-0.101	-0.316	-0.255	0.075	0.133	0.318	0.166
Humidity (May-June)	HS	0.025	0.031	0.058	-0.014	0.047	0.025	0.043	0.023
Humidity (July-August)	HV	-0.087	-0.036	-0.102	-0.010	0.068	0.049	0.078	0.034
Humidity (September-October)	HM	0.044	-0.002	0.008	0.019	0.059	0.030	0.071	0.038
Rainfall (May-June)	RS	0.000	-0.003	-0.008	-0.009	0.005	0.002	0.005	0.004
Rainfall (July-August)	RV	0.002	0.002	0.001	0.001	0.003	0.001	0.002	0.002
Rainfall (September-October)	RM	-0.002	-0.002	-0.002	-0.002	0.004	0.002	0.004	0.004
Natural Logarithm of Fertilizer	F	0.737	-0.942	-0.616	1.473	0.781	0.894	0.750	0.852
Natural Log of Cotton Area	Ac	1.843	1.212	1.070	1.752	0.405	0.576	0.376	0.291
Time Trend	T	-0.002	0.004	0.009	0.014	0.013	0.010	0.010	0.008
Adjusted R-Square		0-86	0.71	0.68	0.94				

Results of fixed effect estimates

The results of this model also guide us that decrease in mean minimum and mean maximum temperature during the first growth stage (May-June) and second-growth stage (July-August) harms the productivity of cotton crop because cotton is a crop of hot temperature and decrease in temperature cause its partly and completely damage. The joint impacts of rainfall, humidity, and temperature have a significant influence on cotton. Higher temperature with greater intensity of rainfall and temperate humid climate is very beneficial for the productive stages of cotton.

The marginal impacts, assessed at the mean of temperature normal, are 0.0014 and 0.0012 for the first and second stages of crop growth, respectively. This result could be due to the increasingly erratic rains that may cause submergence of the newly grown cotton crop and overflow of fertilizer nutrients which are crucial for vegetative growth. Also, increase precipitation results in high humidity that can cause high pests and disease infestation of the crop and ineffectiveness of weed control measures. The marginal impact of precipitation normal during the maturity stage, evaluated at the mean levels of precipitation and temperature normal, turned out to be positive (0.0006) implying that better precipitation helps the crop productivity if the temperature stays at the historical mean.

Deviations of temperature and precipitation from their respective long-run means (variations) are incorporated to gauge the impact of weather shocks on cotton yield. Temperature variation at the first stage enters statistically insignificant showing that heat Marginal impacts can be computed by taking the partial derivative of the estimated version of the Equation concerning the targeted variable and then be evaluated at the mean of the other variable(s) involved. Waves during June-July had not significantly affected the yield in the case of Cotton. Statistically significant coefficients for the deviations of temperature from historic mean during the second and third stages imply that the temperature variations from their respective normals would influence yield adversely when the crop is in vegetative growth, flowering, and milking stages and positively during the maturity and harvesting stages.

Deviation of precipitation from its long-run mean during June-July yields a statistically significant positive effect indicating that a cool wave or positive precipitation shock would affect cotton yield positively. The cotton crop requires water at the initial stage which is evident from the sign and significance of the precipitation term at the first stage. The precipitation shocks may decrease cotton yield which is evident from the floods and drought that prevailed in Pakistan. During the third stage (maturing/ripening and harvesting) precipitation variation is found to affect cotton yield positively and significantly.

Fertilizer use has a significant positive impact on Cotton yield. The response coefficient for fertilizer is low—may be due to unbalanced use of fertilizer. The coefficient of the area under Cotton is negative and statistically significant supporting the evidence of decreasing returns to scale. The plausible explanation of decreasing return may be that major proportions of the farmlands are under cotton cultivation during Kharif season in cotton-growing districts of Pakistan with little opportunity for fallowing the land and/or crop rotation. Allocation of additional farm area to cotton production thus amounts to the intensification of mono-cropping agriculture that in turn results in land degradation and pest/insect build-up reducing productivity. The technological improvement, captured through time trends, contributes positively to the yield of cotton.

Long-run and short-run results of ARDL

Before elaborating the results of long-run and short-run analysis from ARDL, F-bound testing was applied to investigate the long-run relationship.

Results of F-Bound test

This test for the existence of a long-run relationship is only applied if the variables are stationary at level, at first difference or combination of both which means variables should I (0) or I (1) or combination of both. The reason behind this is that the upper bound assumes that all of the variables are I (1) i.e., stationary at the first difference and the lower bound assumes that all the variables are I (0) i.e., stationary at level. It is clear from the results of ACF and PACF that no variable is stationary at the second difference that is why the bound f-testing can be applied to check the long-run relationship among variables. The null hypothesis and alternative hypothesis for the F-bound test is given as under;

Ho: $\eta1 = \eta2 = \eta3 = \eta4 = \eta5 = \eta6 = \eta7 = \eta8 = \eta9 = \eta10 = 0$

H1: $\eta1 \neq \eta2 \neq \eta3 \neq \eta4 \neq \eta5 \neq \eta6 \neq \eta7 \neq \eta8 \neq \eta9 \neq \eta10 \neq 0$

After applying F-bound test, results obtained are given as under;

Table 2. Bound F-test result.

Critical Value at 90% level of Significance		F-Calculated
Lower Bound I (0)	Upper Bound I (1)	
1.859	3.058	3.7623

Table 2 Given above shows that the lower bound is 1.859 and the upper bound is 3.058 at 90% level of significance. The calculated value of the F-test is 3.7623 to compare with the bounds. It is clear from the above table that the F-calculated is more than the upper bound of the F-test, therefore the null hypothesis is rejected, and the alternative hypothesis is accepted. Therefore, it is concluded from the results given in the table above that there is a significant long-run relationship between the dependent and independent variables.

Stability of the model

The stability of the model is a very important issue as the unstable model does not remain valid in changing circumstances i.e., changing climatic and non-climatic conditions and Govt policies etc. to check the stability CUSUM and CUSUM Q test was applied (Brown et al. 1975). These tests use the cumulative sums and sums square of residuals and plotted against the time. The following hypothesis are tested.

H_0: All coefficients in the model are stable

H_1: Unstable Model

If the plot of CUSUM and CUSUM Q are within the boundaries, we accept the null hypothesis that the model is stable but if the plot line crosses the boundaries at any level, reject the null hypothesis. Both the plots show that the line remains within the boundary at 5 percent level of significance. Therefore, we accept the null hypothesis and conclude that the model is significant.

CONCLUSION AND RECOMMENDATIONS

The evidence suggests that temperature has a significant impact on the yield of cotton. The impact, however, varies in magnitude and direction across the growth stages. The precipitation normal plays a significant role in enhancing cotton yield. The extreme events (shocks) of temperature, as well as precipitation during second stage (covering phonological stages of vegetative growth), reduce the yield of cotton but during the other two stages, these shocks exert a positive effect on Cotton yield. We find evidence for the existence of a hill-shaped relationship between precipitation normal and Cotton productivity. However, the specification tests indicate the non-existence of a hill-shaped relationship between temperature normal and cotton productivity. The combined effect of climatic variables was found significant in the cotton yield model. Despite that, sensitivity analysis checks the robustness of the coefficients for both types of Cotton with the application of general to specific criteria.

There is a need to identify, test, and scale up the adaptation strategies to reduce the adverse impact of climate change. Some special measures should also be undertaken to enhance the adaptive capacities of farmers through developing innovations/ technologies that can withstand the adverse impact of climate change which may include the following:

- Enhancing physical availability and economic access to promising technologies.
- Improving knowledge of farmers.
- Remodeling of the required support services.

The development of high-yielding verities (HVYs) tolerant of biotic and abiotic stresses as well as adapting crop production practices to climate change (especially sowing dates, sowing methods, and irrigation practices) are crucial to improving Cotton yields in Pakistan. Therefore, reprioritizing of the agricultural research agenda is required giving higher attention to address the issues of climate change. Promotion of balanced use of NPK (macronutrients) and application of micronutrients in Cotton fields can be effective for Cotton yields in Pakistan. Although Pakistan is not self-sufficient in the production of cotton therefore it does not fall in top producers and exporters of cotton. It has been observed from past studies that the yield level of Pakistani cotton is very low as compared to the international level. Despite input constraints and limitations faced by farmers which can be eliminated, there are some other factors like climatic variables, which cause to decline in yield per hectare. The followings are some suggestions through which we can take a better yield of the cotton crop. Temperature variation has a negative effect on the productivity of the cotton crop. This problem can easily be solved by developing and adopting such hybrid varieties of cotton that have strong resistance to temperature fluctuations.

As concluded from the analysis that rainfall, temperature, and humidity have positive as well as a negative effect on the productivity of cotton in the four districts of the cotton zone. As all these districts are lie under the same zone but their climatic factors show fluctuation in the climatic and non-climatic variable.

The acreage response of the cotton crop is negatively related to the price risk and positively to the expected cotton prices. So, it is suggested that variation in prices should be minimized and made stable for a specific period. Farmer organizations may perform this helpful task. Lack of proper farm management and technological awareness affect the yield of the crop. Productivity can be increased by the proper utilization of inputs. Less and unbalanced use of inputs might be due to lack of awareness or non-availability of the inputs in time or higher prices of inputs. So, the farmers should be provided timely inputs at reasonable prices. To create awareness training programs should be conducted for the farmers. There is a need to identify, test, and scale up the adaptation strategies to reduce the adverse impact of climate change. Some special measures should also be undertaken to enhance the adaptive capacities of farmers through developing innovations/ technologies that can withstand the adverse impact of climate change which may include the following:

- Enhancing physical availability and economic access to promising technologies.
- Improving knowledge of farmers.
- Remodeling of the required support services.

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