CLIMATE CHANGE IMPACT ON AGRICULTURE AND PREVALENCE OF FOOD SECURITY IN PUNJAB, PAKISTAN

S. A. Shirazi[1], M.S. Hussain[2], S. Abbas[3] and S. Lee[3*]

[1]Department of Geography, University of the Punjab, Lahore-Pakistan.
[2]Climate Research Institute, Konkuk University, Seoul, Korea
[3]Department of Geography, Konkuk University, Seoul, Korea
[*]Corresponding author: leesh@konkuk.ac.kr

ABSTRACT: The purpose of the present study was to investigate the impact of temperature and rainfall variability in wheat and rice production for the period from 1981 to 2015 in Punjab, Pakistan. The datasets of climate and crops of 28 weather stations were analyzed using statistical methods. Findings revealed that the variability of the climate on wheat (*Rabi*) and rice (*Kharif*) crops observed (r^2 = 903 and 938) in Punjab, respectively. The outcome showed that temperature during Kharif season is negatively influencing the rice. Similarly, a negative effect of temperature was also documented on wheat crop during Rabi season. A significant negative effect of rainfall was revealed which decreases the wheat production. Furthermore, variation in per capita availability of the rice and wheat crops indicated a negative impact of temperature on wheat and rice production.

Keywords: climate impact, productivity, food scarcity, green revolution.

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INTRODUCTION

Food security is a major concern for humanity of the world. It is, therefore, remained an important issue among food scientists, planners, and policymakers all over the world. Food security as an issue, which has been largely under discussion to explore ways and means for finding solutions to ensure food for millions of inhabitants living on the earth (Tripathy *et al*., 2011). The availability of food should be ensured and people are ready to accept as part of the culture without fear to lose food access in their near vicinity (Mishra *et al*., 2008). Climate plays a vital role in the daily life of a human and in agriculture production. The changing climates are causing the earth temperature to rise slowly because of anthropogenic activities. The recorded data over the past 100 years have revealed an increase in global mean temperature by 1.5 °C.

There are evidences that the rate of warming is accelerating (IPCC, 2014). The rise in average global temperature is seemingly inevitable in the upcoming years, which will lead to a change in global weather (IPCC, 2014). The climate projections also show that earth's climate and seasons will continue to change at an unprecedented rate, at least until the end of the 21st century (Abbas *et al*., 2018b; Thornton *et al*., 2008). Elbehri *et al*. (2011) has suggested that in the developing world issues of food security and nutritional density are now very much significant. It is supposed to prevail over mass population groups during most of the time as long as they didn't have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life.

The earth recorded with an average increase in surface temperatures by 1.22ºC during 1955-2005. In this context, 1998 was the hottest year and making 1990s the warmest decade (World Bank, 2009). This is alarming. It is believed that temperature will continue to rise by 0.2ºC per decade for the next two decades (IPCC, 2007). All these predicted changes in weather patterns will ultimately affects millions of poor people and their means of element around the world. The vast majority (98%) of the world's hungry population lives in less developed countries with a 16% rate of under-nourishment. The proportion of undernourished population in the region is about 30% (FAO, 2010). Climate change may cause the agriculture and food security problems in developing countries such as Pakistan, India, and Indonesia in the next few decades (Hertel *et al*., 2010; Ali et al., 2017).

Food safety has continued the notable factual by Pakistan Government. Consequently, the representatives pass considerable time on planning food policy boost-up towards food security issues (Mahmood *et al*., 2012; Janjua *et al*. 2010). Hanjra and Qureshi (2010) has also investigated links of serious issues like food security and world level water source, which demonstrates that water accessibility is declining for the future food security. The extreme climatic pattern generally brings negative impacts on crops especially wheat, which usually leads to a high risk of food shortages in Punjab province of Pakistan (Janjua *et al*., 2010). Due to harsh weather pattern, production of the green sector specifically crops have been extremely affected. Throughout, it would be a vulnerable condition in the coming era as well in Punjab, Pakistan (Unit, 2012; Abbas *et al*., 2020a,b).

However, climate factors like temperature and rainfall are very vital in wheat production and its efficiency and risk measurement (Mitra and Bhatia, 2008; Semenov, 2009). Thus, investigation have to be emphasis on agriculture crop e.g. wheat (Ahmad *et al*., 2012) and rice (Mahmood *et al*., 2012). Disregard by means of irrigation methods, it has to utilized in the wheat production. The climatic variations, directly and indirectly, affects crop production which creates basic hurdles of food security (Spash, 2007; Kirby *et al*., 2016; Hussain and lee, 2016). Additionally, if temperature is 1°C increases with decrease in radiation of 5%, wheat grain yield may decline by 9% from normal (Hundal and Kaur, 2007). Rice cultivated under well-irrigated conditions. The sufficient rainfall is ideal for its proper growth (Cline, 2007; Parry *et al*., 2005) also competing for food security issues and barriers, especially for poor community becomes the serious threat due to climate change (Gregory *et al*., 1999; Rosegrant and Cline, 2003; Hussain and lee, 2016).

The reconciling to climate variations can decrease the undesirable influence on agrarian production (Falco and Chavas, 2009). Climate change's impact on agriculture productivity is the latest buzz-worthy result in this trinity of problems. It is a tactic to build up technical, policy and investment circumstances to accomplish a sustainable agricultural expansion of the food sanctuary under climate change (Birkholz *et al*., 2014; Hussain and lee, 2014). Farmers are more vulnerable to climate change in non- irrigated areas compared to the irrigated areas since production totally depends on the climatic factors like temperature and rain. Thus, it is important to analyze the climatic elements effect on agriculture sectors.

The main objective of the study was to estimate the effects of climate change on wheat and rice production. Keeping in view the variation in temperature and rainfall and their importance on rice crop, the present study was planned to evaluate the impact of climate on Rice and Wheat, which are the major crops of Pakistan. Moreover, issues of food security are estimated regarding the climate change in the Punjab, Pakistan.

MATERIALS AND METHODS

Study area: The study area-Punjab, lies between 27°-40´ to 34°-01´ N latitudes and 69´-20´ to 75°-20´ E longitudes and derives its names from five snow-fed rivers, which were originated from the Himalayas and associated mountains in the north. It, therefore, derives its name as Punjab; the "land of five rivers" i.e. Jhelum, Chenab, Ravi, Sutlej, and Indus. These rivers pass through the region and the form lifeline of millions of people, who are one way or other, depends upon agriculture in the fertile plains of the Punjab. With respect to areal extent, Punjab is the second largest province in terms of area after Baluchistan with an area of 205,345 Km^2.

The share of Punjab's population in the country's total population is about 56%. Presently Punjab is having 36 districts with 28 weather stations. Physiographical, most parts of this region are comprised of alluvial plains with a plateau named Potwar, which is one of the prominent features of the region. The southeastern part of the province is covered with sand and different desert features. With respect to climatology, this is the area with high rainfall variability (Hussain and lee, 2009). It has a continental type of climate. Rabi and Kharif are two major seasons for crops. Rice is the major Kharif crop and Wheat is the major Rabi crop. Although the scanty amount of rainfall occurs during April-May due to local convective activity while the summer monsoon (June-Sept) and winter depressions (Nov-Jan) are the two major seasons of rainfall.

Data and Analysis: Data regarding annual wheat and rice production, area were collected from Crop Report Service (*CRS*), Government of Punjab, Pakistan for the period from 1981 to 2015. The data set consists of 36 districts of Punjab province. Monthly data sets of climate parameters like temperature and rainfall were also collected from Pakistan Meteorological Department (PMD) for the period from 1981 to 2015. The population data set obtained from the Census Organization of Pakistan during the investigated span. The population data used to observe the per capita availability of the wheat and rice crop. Per capita food availability is calculated by dividing the total production of the crops during a specific time period by the total population. Per capita availability is the Total crop production divided by total population

The Rabi crops are grown normally during the months of November to April and the Kharif crops are grown from May to October. For the data tabulation, climate data (temperature and rainfall data calculated from November to April for wheat crop and May to October for the Rice crop. The wheat and rice datasets were obtained by the total production and the area of Punjab.

The year-to-year variations of crop yield are largely driven by climate (Kukal and Irmak, 2018), but many previous researches indicated that crop management improvement factors like technology, use of fertilizers, agricultural practices, state policy and advanced cropping methods have increased the crop production (Yu *et al*. 2014). To remove the technological errors, the first difference de-trended method is used. Without the de-trended data, impact of climate change on original crop data is difficult to observe.

The previous many studies have used the first difference method to remove the technological errors (Nageswararao *et al*. 2016; Wang *et al*. 2015). Kumar *et al*. (2004) also determined the data series using the first difference values of each year. First, all of the selected time series are detrended by taking the first difference between the present year and the value of the previous year. The detrended datasets were used to investigate the effect of rainfall and mean temperature with wheat and rice over the Punjab province of Pakistan. The obtained datasets were used for further statistical investigation of the impact of climate.

The Multiple Linear Regression (MLR) was used to find out the impact of the climatic parameters on agricultural production. The Rice production variations might be projected by the practice of the regression model (Awal *et al*., 2011). Further investigation, which estimated by the regression indicates impact of climate that harmfully upsets the production of the rice plant (Peng *et al*., 2004; Saseendran *et al*., 2004). This analysis was also used to analyze the significant impact of temperature and rainfall on the scarcity of major crops like wheat and rice. Similar studies have been used to find out the effect on crop production (Stata Corp, 2005; Castelló-Climent, 2008; Dietterich, 2000; Brown *et al*., 2005).

Kanninen *et al*. (2007) also reported that Multiple Linear Regression estimates the impact of the temperature and rainfall on agricultural production. The results contain the input data analysis that highly based on dependent and independent variables (Kaul *et al*. 2005; Bishop, 1995). After analysis of the above mentioned studies about the importance of agricultural production function, there is a need to estimate agricultural crop production function in Punjab, Pakistan.

This function facilitates the correct and accurate estimate of the impact of the area, temperature and rainfall on crops (Wheat and Rice) production function. This function consists of input-output functions. Crop production taken as the dependent variable and area, temperature and rainfall considered independent variables (Abbas *et al*., 2016, 2020b). Multiple Linear regression describes the linear relationship between two variables x and y.

$$\mathbf{Y = a + bx + e} \qquad \text{(i)}$$

Where x = independent or predictor, Y = dependent or Predict and e is the errors. The vertical distance between data points and lines called errors or residule.

$$\mathbf{E_i = y_i - y\,(x_i)} \qquad \text{(ii)}$$

This is the separated residuals for each data pair. For the analytical expression, The least square intercept a and slope b is a straightforward exercise in order to minimize the sum of squared residuals. Whereas the function of the variables are written as

$$\Delta TPRO = \beta_o + \beta_1\, \Delta TAR + b1 \Delta TEP + c1 \Delta RIN\text{-}1\text{-}U\partial t\text{-}1 + €t \qquad \text{(iii)}$$

β= Shows how much change in the dependent variables due to changes in the independent variables, β_1= short run relationship, b1= long run effect relationship, ∂= Error term

Whereas TAR shows the total area in (000 hectares) of crops i.e. wheat and rice, TPRO shows the total production in (000 ton) of wheat and rice, TEP shows the temperature in (0C) and RIN means the rain in (mm). Δ is the difference between the present and the previous year of each data set.

RESULTS AND DISCUSSION

Multiple Linear Regression (MLR) Model indicates the short-run and long run effects of climate change on the total production (tons) of wheat and rice. The long-run and short-run impact was observed on the basis of dependent and independent variables. Results revealed that dependent variable (crop production) with independent variables TAR (hectares), RIN (mm) and TEP (°C) have positive/negative significant trends. For wheat crop, the beta value shows the multiplier impact on the TPR, whereas the beta value of RIN (mm) and TEP (°C) are -0.225 and 110, respectively which shows the positive and negative impact on wheat production respectively. For rice crop, the beta value of RIN (mm) and TEP (°C) are 0.158 and -0.140 respectively that's had the positive impact of RIN (mm) on rice production. Whereas, the negative impact of TEP (°C) was seen.

Table-1: Description of the Multiple Regression Model (MLR).

MLR (Multiple Linear Regression) Model		
CATREG - Regression for Categorical Data (1981-2015)		
	Wheat Crop (Rabi)	Rice Crop (Kharif)
Multiple R	0.451	0.469
R Square	0.903	0.938
Adjusted R Square	0.886	0.922
Apparent Prediction Error	0.097	0.062
1. ANNOVA		
Sum of Squares	31.600	32.832

Sum of Squares (Residual)	3.400			2.168		
Total	35.000			35.000		
Regression Mean Square	6.320			32.832		
Residual Mean Square	0.117			2.168		
2. Standardized Coefficient	Beta value	Bootstrap (1000) Estimate Std. Error	Sig	Beta value	Bootstrap (1000) Estimate Std. Error	Sig
Wheat Area (hectares)	1.094	0.079	0.007*	0.880	0.108	0.025*
Rain (mm)	-0.225	0.113	0.056**	0.158	0.110	0.145**
Temp (°C)	-0.110	0.089	0.231***	-0.140	0.149	0.425**
3. Correlation and Tolerance	Corre.	Toler before	Toler after	Corr.	Toler Before	Toler after
Wheat Area (hectares)	0.935	0.599	0.567	0.951	0.756	0.674
Rain (mm)	-0.490***	0.642	0.604	0.532*	0.980	0.987
Temp (°C)	-0.315*	0.787	0.877	-0.437**	0.747	0.670

From the above results, there is a long run and short-run effects of the independent variables on rice crop production. TAR, RIN, and TEP have a long run and short-run significant relationship at the first level with TPR (Table-1). TPR of the rice crop has a significant effect on the agricultural development in Punjab, particularly wheat and rice cash crops. According to the results, the RIN is significant at the 0.05 level due to its significant value is less observed from the standard value that rejects the null hypothesis.

Spatial change and crops pattern: According to results, wheat area was found around (6.913 million hectares) 17.085 million acres (irri = 15.335 million acres, un-irri = 1.750 million acres) in 2015 as associated to (6.205 million hectares) 17.247 million acres (irri = 15.511 million acres, un-irri = 1.736 million acres) seeded in the 2014. The results indicate the reduction of wheat production about 0.9 % over the previous year. From the detailed investigation, it is stated that reduction of wheat negatively affected by the temperature. Furthermore, the extreme moisture was observed in 2014. Wheat crop is measured to be around 19.527 million tons (195.27 tons, which consist of irrigated area = 184.76 hundred thousand tons and un-irrigated area = 10.29 tons) in 2013 as associated to 19.281 million tons (192.81 tons, irrigated area = 182.51 tons and un-irrigated area = 10.30 hundred thousand tons) found in the 2012. The production data shows an increase of about 1.3% as compared to the previous years. This is contributed due to crop was seeded at a suitable time and moisture in the Barani area.

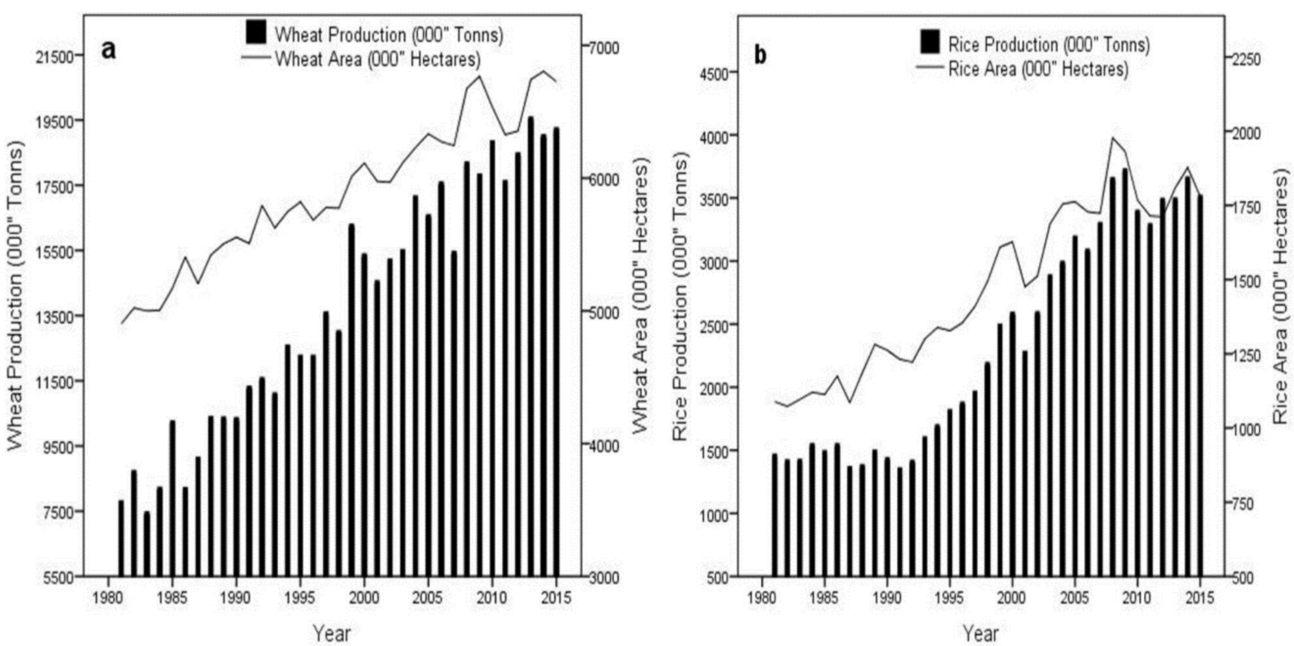

Figure-1: Total production (t) and area (ha) of wheat and rice in Punjab, Pakistan.

Results indicates an area of (1.736 million hectares) 4.291 million acres (Basmati =3.343, Irri = 0.359, Others = 0.589) harvest during Kharif 15 as compared (1.780 million hectares) 4.399 million acres (Basmati = 3.099, Irri = 0.453, Others = 0.847) was cropped in 2014. The decrease of 2.5% rice area was reported in the 2015, which is owed to low market occurrences of the previous year crop, discouraged the growers to bring more the area under the crop. The estimation of rice crop varieties during 2014-15, the total production was estimated to be at 3.475 million tons (Basmati = 2.524, irri = 0.392 and others = 0.559) as compared to 3.502 million tons (Basmati = 2.279, irri = 0.461 and others = 0.762) that makes the previous year (Figure 1).

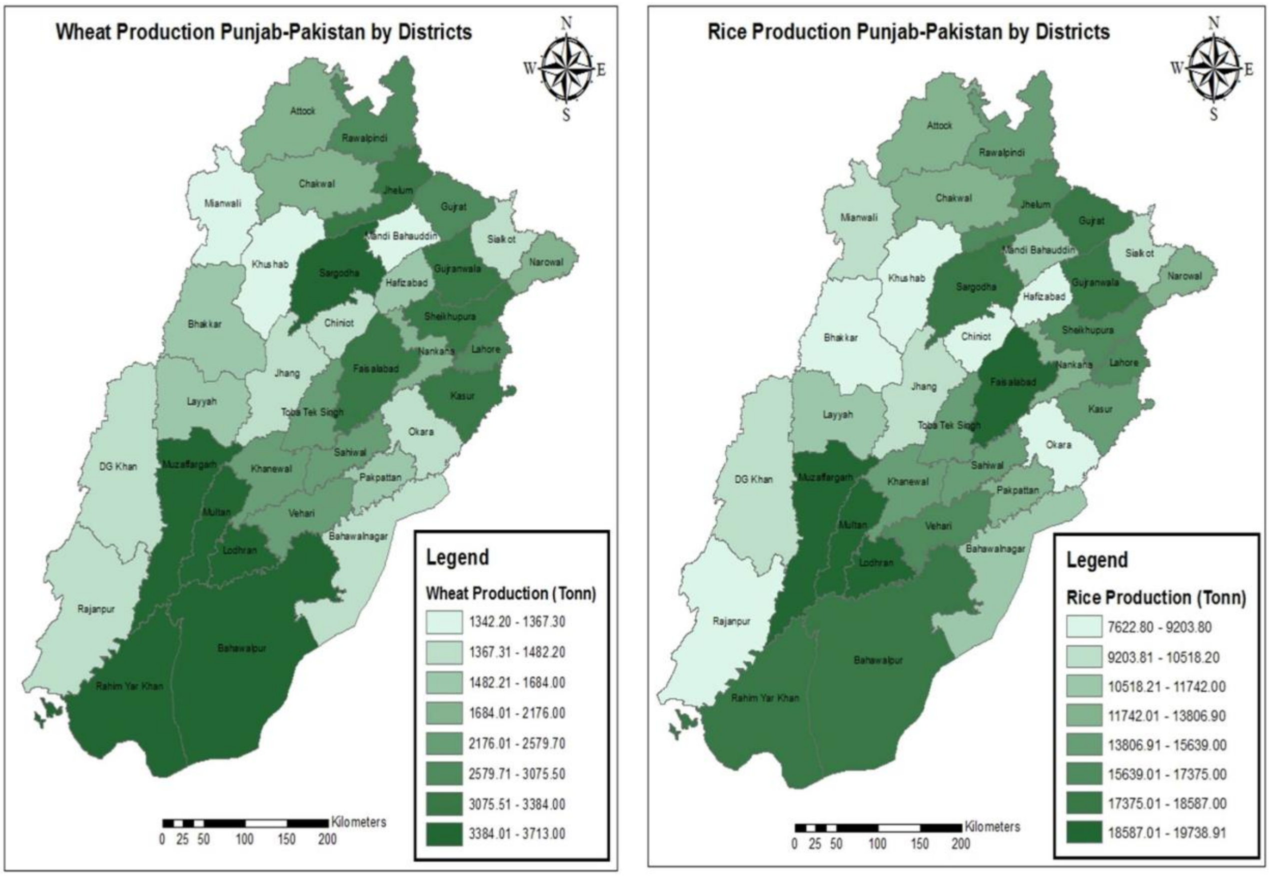

Figure -2: Total production (t) and area (ha) of wheat and rice in Punjab, Pakistan by districts.

Figure-2 indicates the pattern of wheat and rice production in Punjab, Pakistan district wise. The high pattern of wheat production was examined from 1981-2015 in the districts of Rahim Yar Khan, Bahawalpur, Bahawalnagar, Jhang, Muzaffargarh, and Faisalabad. Similarly, production of rice increased in the districts of the Sahiwal, Sheikhupura and Mandi Bahauddin. It shows that the impact of the climate on the agricultural production and growth varies from region to region. The fact that such climate change practice is being under the scenario of the "green revolution" highlights the dichotomy in agribusiness. The increasing trend of maximum and minimum temperature was reported for 1981-2015.

Figure-3 shows the pattern of temperature and rainfall during summer monsoon and winter in Punjab, Pakistan by district. The maximum temperature showed an increase in winter season in the districts of Mianwali and Gujrat. Whereas, the maximum temperature increased in the districts of Lodhran, D.G khan and Rahim Yar Khan during the summer monsoon season. Average maximum rainfall increased in winter western depression in the districts of Okara, Rajanpur and D.G Khan during the winter. Where as in monsoon, the increasing rainfall trend found in Sahiwal, Gujranwala and Mandi Bahauddin.

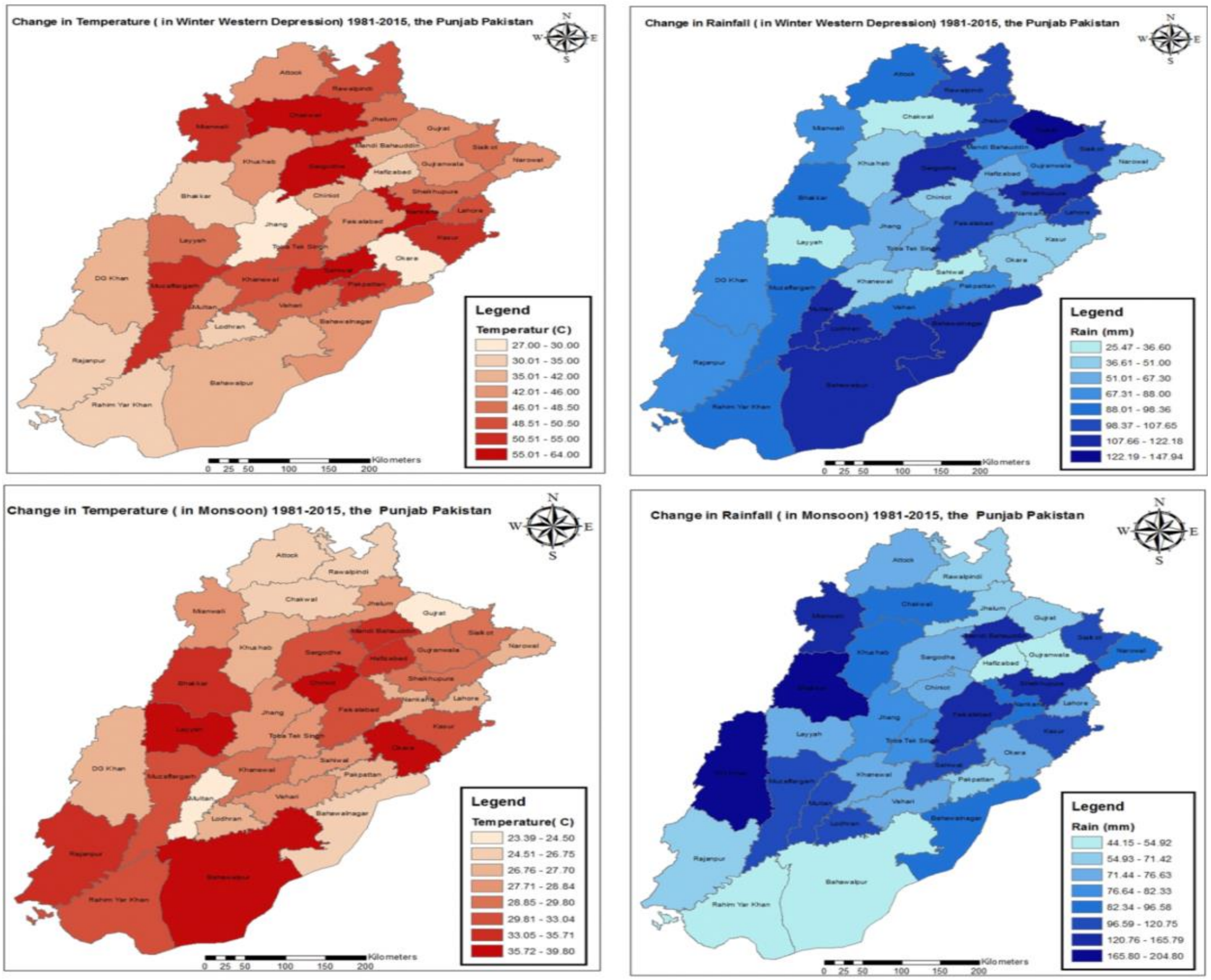

Figure-3: Change in temperature and rainfall during summer monsoon and winter by districts in Punjab.

Climate change and rice crop: Results have documented that in the Zone-l, total rice production was 55.9 tons and area 44.1 hectares in the year of 1981. Whereas, production was increased 56.6 tons and area decreased 39.6 hectares in the year of 1999. The decreasing trend of rice production was observed from 56.6 to 53.2 tons from 1999-2015. In the Zone-2, total rice production was 93 tons and area 75.1 hectares in the year of 1981. While, production was increased 202 tons and area 79 hectares in the year of 1999. The increase of rice production was observed from 202 to 279 tons and area decreased 79 to 50 hectares during 1999-2015.

In the Zone-3, total rice production was 587 tons and area 461hectares in the year of 1981. Whereas, production was increased 882 tons and area 588 hectares in the year of 1999. The decrease of rice production was observed from 882 to 560 tons and area 588 to 560 hectares during 1999-2015. In the Zone-4, total rice production was 538 tons and area 376 hectares in the year of 1981. Whereas, production was increased 946 tons and area 590 hectares in the year of 1999. The increase of rice production was observed from 946 to 1382 tons and area 590 to 670 hectares during 1999-2015.

In the Zone-5, total rice production was 38.3 tons and area 30.8 hectares in the year of 1981. Whereas, production was increased 157 tons and area 90.9 hectares in the year of 1999. The increase of rice production was observed from 157 to 312 tons and area 90 to 157 hectares during 1999-2015. In the Zone-6, total rice production was 137 tons and area 99.8 hectares in the year of 1981. Whereas, production was increased 235 tons and area 154 hectares in the year of 1999.

The increase of rice production was observed from 235 to 408 tons and area 154 to 207 hectares during 1999-2015 (Figure 4). Furthermore, the adverse effects of extreme temperature are marked from the last two decades (Sarker *et al*. 2012). It is found that extreme temperature has the negative impact on the growth of rice production. In spite of this, rise in minimum temperature also negatively affects the rice production (Shakoor *et al.*, 2015).

Climate change and wheat crop: The results revealed that in the Zone-1, total wheat production was 866 tons and area 743 hectares in 1981. Whereas, production was increased 929 tons and area 677 hectares in 1999. A similar trend continued with the increase of wheat production 1439 tons and area 1220 hectares during the year of 2015.

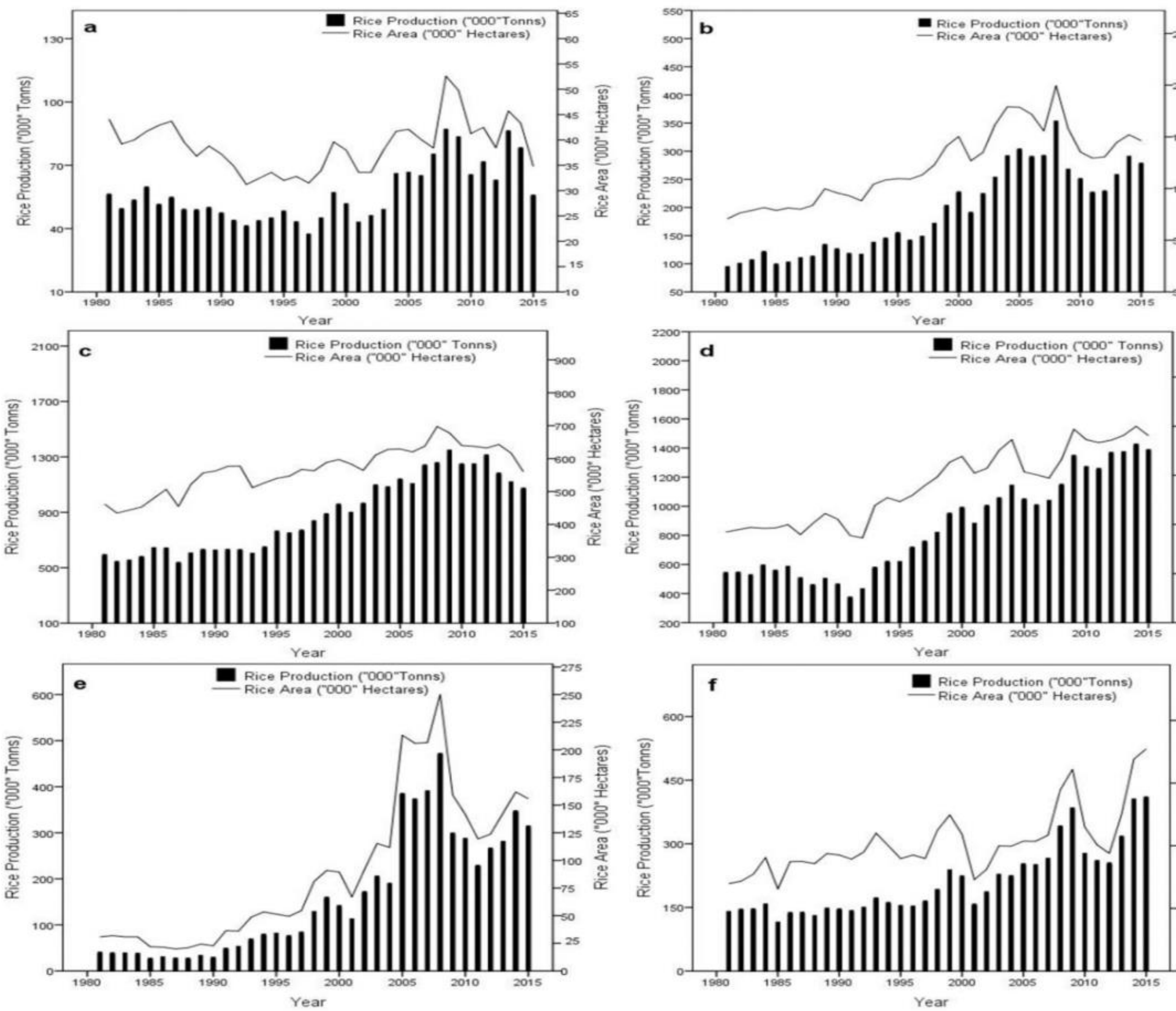

Figure -4: Total annual production and cultivated area of rice in Punjab by identified zones.

In the Zone-2, total wheat production was 1570 tons and area 987 hectares in 1981. Whereas, production was increased 2801 tons and area 1101 hectares in 1999. A similar trend continued with the increase of wheat production 3338 tons and area 1220 hectares during the year of 2015. In the Zone -3, total wheat production was 968 tons and area 778 hectares in 1981. Whereas, production was increased 1979 tons and area 1120 hectares in 1999. A similar trend continued with the increase of wheat production 2434 tons and area 987 hectares during the year of 2015. In the Zone -4, total wheat production was 734 tons and area 649 hectares in 1981. Whereas, production was increased 2591 tons and area 1101 hectares in 1999.

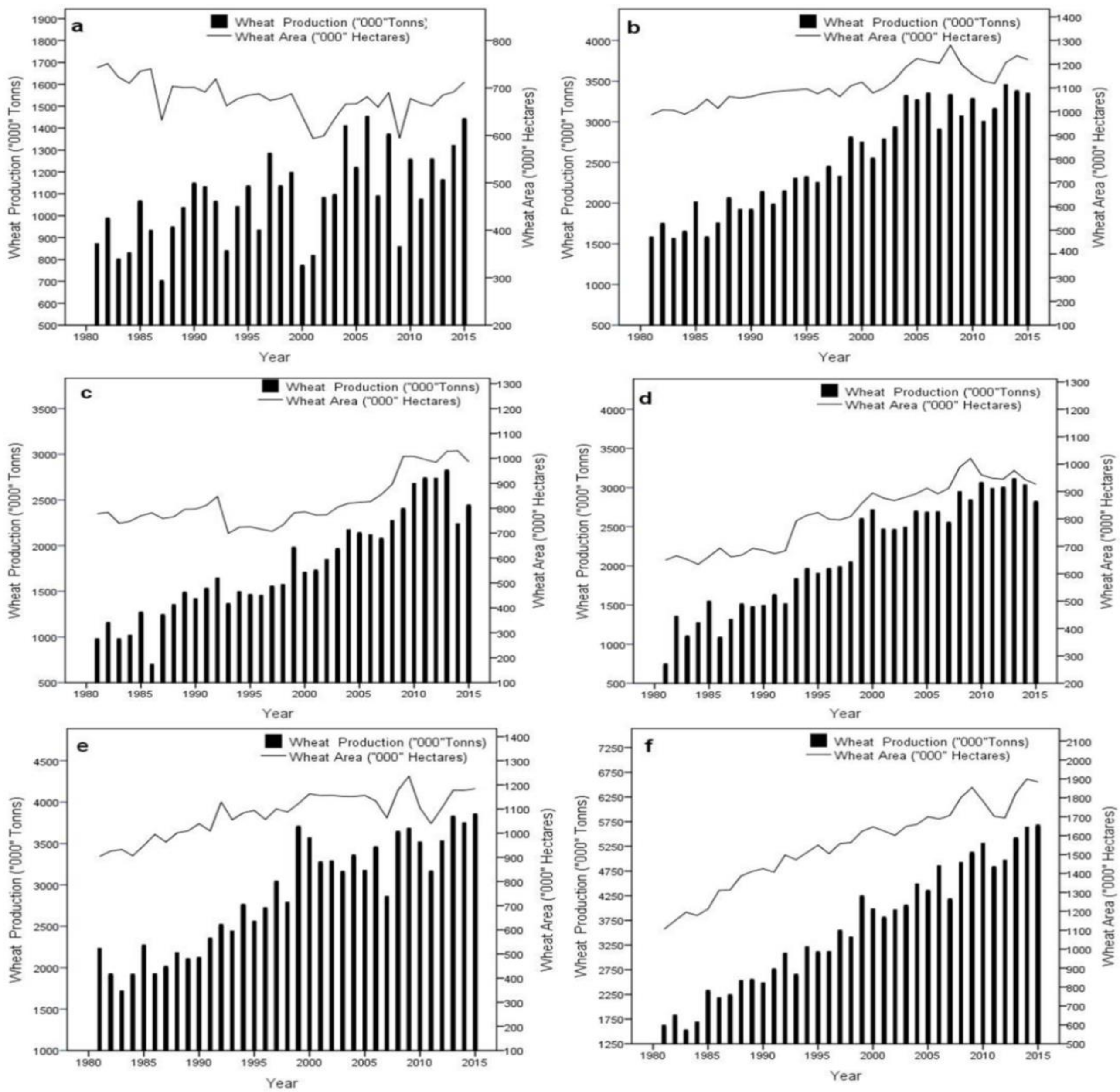

Figure -5: Total annual production and cultivated area of wheat in Punjab by identified zones.

A similar trend continued with the increase of wheat production 2811 tons and area 926 hectares during 2015. In the Zone -5, total wheat production was 2219 tons and area 903 hectares in 1981. Whereas, production was increased 3695 tons and area 1122 hectares in 1999. A similar trend continued with the increase of wheat production 3843 tons and area 1184 hectares during the year of 2015. From the detailed investigation, it is stated that temperature positively affects the wheat production during the year of the 2015. The other studies also confirmed that 30 % of the wheat yield is manipulated by the temperature variation (Janjua *et al*., 2014; Tariq *et al*., 2014).

In the Zone -6, total wheat production was 1609 tons and area 906 hectares in 1981. Whereas, production was increased 4227 tons and area 1337 hectares in 1999. A similar trend continued with the increase of wheat production 4743 tons and area 1484 hectares during the year of 2015 (Figure 5). Moreover, on the detailed examination, it is stated that irregular pattern of rainfall during the winter season negatively affects the wheat production in Punjab Pakistan in 2011 (GOP, 2015).

Per capita total production (wheat and rice) availability: We estimated the per capita availability of total production of wheat and rice crops on the basis of different periods. The impact of climate on the total production is found to be significant in both crops. The result indicated that in 2015 the per capita availability of rice and wheat was 80 and 200 kg, respectively, whereas 108 and 160 kg, respectively in the year of 2008. The comparison between 2008 and 2015 shows decreasing trend of per capita availability of rice, but increasing the wheat (Figure 6). For the rainfall scenarios, we find that the production of crops increased with increasing rainfall.

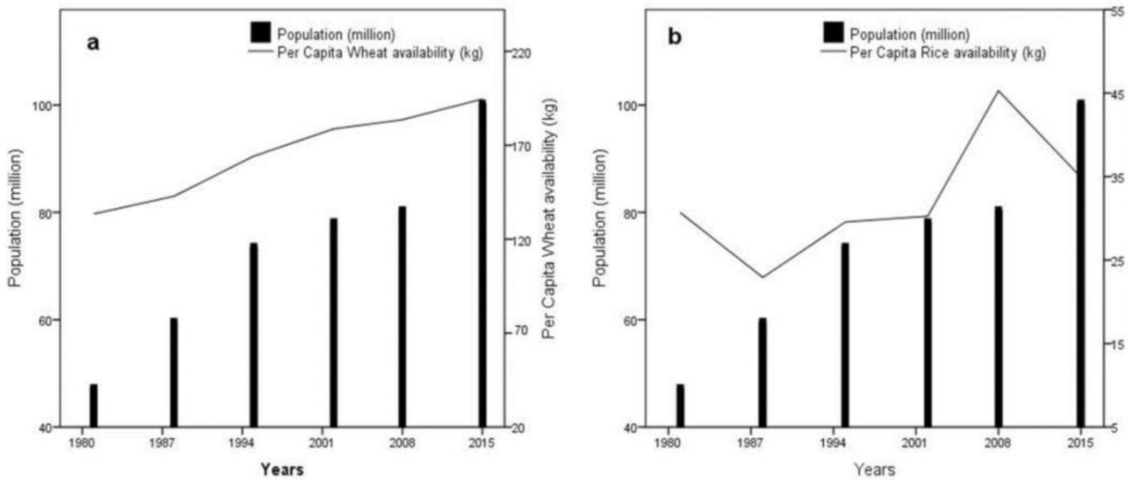

Figure-6: Per capita availability of wheat and rice crops in Punjab, Pakistan.

Increasing trend of rainfall indicated the positive relationship with per capita availability of crops in Punjab. However, it is observed from the analysis that the decrease in rainfall negatively affects the crop production. Consequently, per capita availability would also be decreased. The results are exhibited that an increase in population and a decrease in the production have a negative impact of climate variability.

According to statistical analysis, rice and wheat negatively affected by the variation of temperature and rainfall patterns. The positive impact of Kharif rainfall founded on rice production, whereas, the negative effect of temperature was observed during the Kharif season. On the other hand, increasing trend of wheat production is observed in irrigated districts. Temperature shows the negative effects on the wheat production during the Rabi season. Results documented that decreasing and increasing trend of per capita availability of rice and wheat was concerned to climate variability.

The substantial trend of temperature and rainfall has been seen towards sustainable agricultural development through crop production and growth in the Punjab-Pakistan. Consequently, it is evident from the current study that wheat and rice crop response to the impact of rainfall and temperature has certainty and predictability. However, the sustainable agricultural practices must be adopted by the farmers such as ensure food supply, counter the carbon emissions, growth of green product markets and organic foods.

Conclusion: In the present study, the climate variability and its impact on crop production have been analyzed using rainfall and temperature data sets for the period of 1981-2015. The positive impact of Kharif rainfall founded on rice production. While, temperature shows the negative influence on wheat production during the Rabi season. Consequently, it is evident from the current study that wheat and rice crop response to the impact of rainfall and temperature has certainty and predictability.

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