EVALUATION OF THE TRENDS OF CLIMATE VARIABILITY DURING DIFFERENT CROP SEASONS IN DERA GHAZI KHAN

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ABSTRACT: Climate change is profoundly impacting ecosystems and disrupting agricultural systems by altering temperature and precipitation patterns, affecting crop yields and food production. This study evaluates the trends of climate variability during different crop seasons in Dera Ghazi Khan, Pakistan, focusing on temperature and rainfall fluctuations from 1991 to 2020. Climatic data were collected and analyzed, including monthly average temperature and rainfall. The analysis of mean monthly decadal temperature in the study area during the Rabi crop season showed significant fluctuations ranging from 20.04°C, 20.5°C, and 19.73°C in three corresponding decades. The mean monthly seasonal temperature was calculated 20.1°C. Similarly, during the Kharif crop season, notable variations across the mean decadal temperature ranging from 34°C to 34.91°C with mean seasonal temperature 34.6°C. Overall, in both seasons during the past three decades +0.1°C was observed with an annual increase of 0.003°C. All these values were found statistically significant. Mean monthly rainfall also exhibited remarkable variability, with statistically significant differences observed for most months in both Rabi and Kharif seasons, except for November and December in the Rabi season and June and October in the Kharif season. Overall, rain has decreased in the last 30 years to -0.4mm during Rabi and -3.7mm during Kharif seasons. The literature suggests that minor changes in climatic factors remarkably impact crop production. These findings highlight the dynamic nature of climatic conditions in the region and underscore the importance of understanding and adapting to climate change for sustainable agricultural practices.

Keywords: Climate change, precipitation pattern, agricultural system, crop season, sustainable agriculture.

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INTRODUCTION

Climate change, stemming from complex interactions among atmospheric, oceanic, and terrestrial components, manifests in fluctuations of temperature and precipitation, attributed primarily to human-induced alterations such as greenhouse gas emissions and land surface modifications (Ghous *et al.,* 2015; IPCC, 2014). This global challenge presents diverse impacts, from disrupting weather patterns to endangering ecosystems and human welfare, including heightened risks of extreme events like heatwaves, floods, and storms (Nayak et al., 2020; IPCC, 2021). Food security and efforts to reduce poverty are seriously threatened by climate change, which also makes global development more challenging (Malhi *et al.,* 2021; Mubaya *et al.,* 2012). With projections indicating a potential 2^{o}C temperature rise by 2100, there are grave concerns about extensive economic losses. (Watson, 2001).

Climate change poses a significant challenge to agriculture, impacting global food systems by affecting weather patterns, rainfall, and temperature, thereby disrupting crucial elements such as water supply, soil health, and crop growth cycles (Mendelsohn, 2009; Wang, 2022; Zittis *et al.,* 2022). Extreme weather events are increasingly common, leading to harm in crop yields, quality, and planting seasons (Kumar *et al.,* 2022). Cereal crops like maize, rice, and wheat are extremely prone to the effects of climate change. The production of these crops is seriously threatened by rising temperatures, changing precipitation patterns, and extreme weather events (Sharma et al., 2022). These climatic changes can lead to shortened growing seasons, reduced grain quality, and overall yield declines. Changes in precipitation patterns, including droughts and excessive rainfall, directly influence soil moisture, which in turn affects germination, growth, and yield (Dietz et al., 2021).

Dera Ghazi Khan, a district in Punjab, is famous for its cereal and cotton production. The major crops of the district include rice, wheat, sugarcane, sesame, cotton, and gram (Hameed and Salam, 2014). According to 2019-20 statistics, about 56% of the total area of DG Khan is under cultivation (Ahmed *et al.,* 2020). In the present study, the trends of climate variability during different crop seasons, such as Rabi and Kharif have been evaluated in the study area, focusing on temperature and

rainfall fluctuations from 1991 to 2020. Rabi crops are those which are sown between October and December, and harvested around March to May whereas Kharif crops are typically sown at the start of the monsoon season (June and July), and harvesting of these crops are done around September to October (Nageswararao *et al.,* 2018).

Rabi wheat, gram, and sesame are important Rabi and rice, cotton, and sugarcane are major Kharif crops cultivated in the study area. All these crops are important contributors to the economy of the Punjab as well as Pakistan. So, it is necessary to study the climatic variability during these crop seasons and to further plan sustainable practices considering the changing climatic conditions.

MATERIALS AND METHODS

Study Area: Dera Ghazi Khan District, located in Punjab Province, covers an area of 11977 km^2 and is situated between 29° 34' and 31° 20' N latitudes and 69 53' and 70° 55' E longitudes. It distinctively shares its administrative boundaries with three provinces of Pakistan (Fig. 1). In the north of DG Khan there lies Dera Ismail Khan, Rajanpur in the south, in the east Leiah and Muzaffar Garh are situated, and Baluchistan province is in the west. The district is known for its diverse geographical features, including the Sulaiman Range, piedmont, and river plains. The climate of the district is arid and hot, it profoundly relies on the Indus River and its tributaries for water resources, which significantly affects agricultural activities.

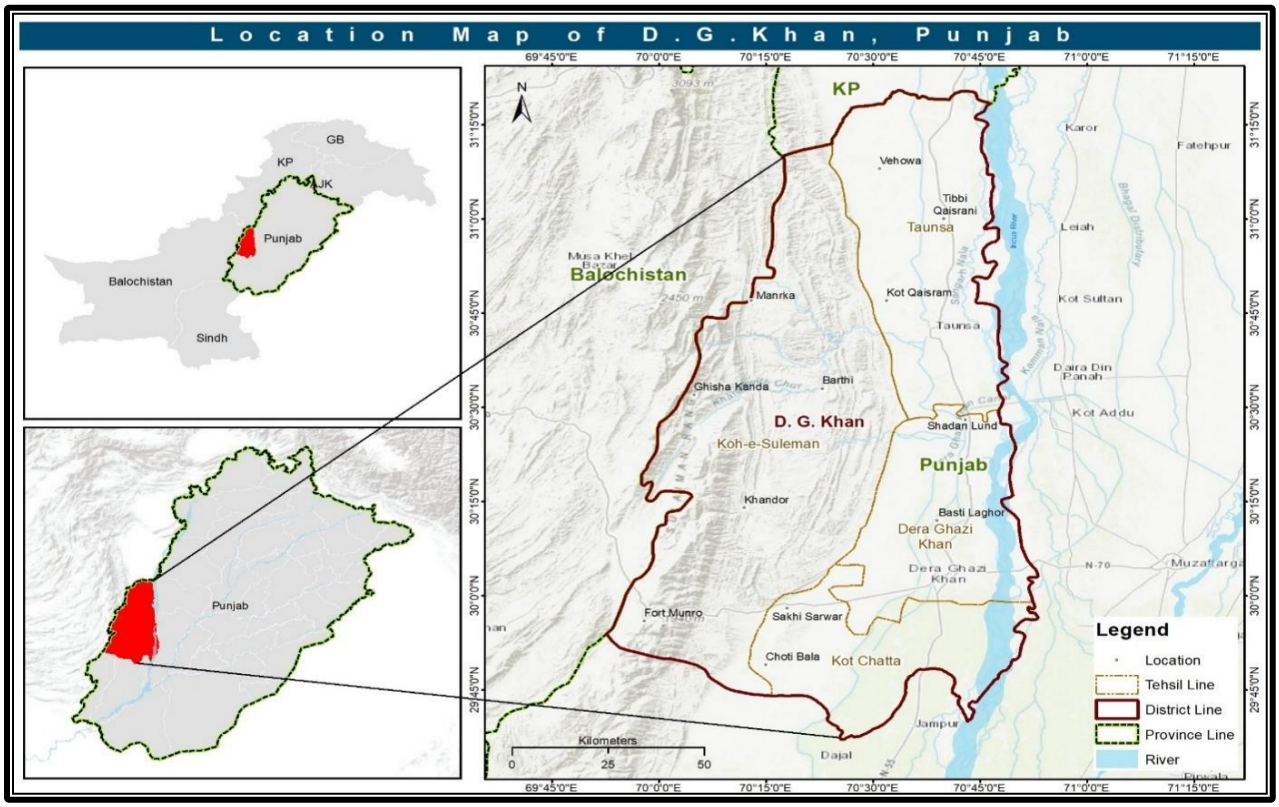

Fig. 1 Location map of the study area (Dera Ghazi Khan District)

Data Sources: To investigate climatic variability in the study area, climate data of thirty years (1991-2020) was obtained from Lahore office of Pakistan Meteorological Department. The data included mean monthly temperature (^{0}C) and mean monthly rainfall.

Data Analysis: To comprehensively assess climate variability trends during the Rabi and Kharif crop seasons, a multifaceted analytical approach was employed. This approach integrated descriptive statistics, statistical tests, and data visualization techniques. Descriptive statistics, including mean, difference, and standard deviation, were calculated to summarize the central tendency and dispersion of the data. Statistical software packages, namely GraphPad Prism 5 and SPSS, were utilized for data analysis.

To analyze temperature and rainfall patterns during Kharif (May to October) and Rabi (November to April) cropping seasons, monthly data were aggregated into decadal and seasonal means. Specifically, mean monthly decadal, mean annual decadal, and mean seasonal temperature and rainfall were calculated for

three decades (1991-2020), denoted as D^1, $D^{2,}$ and D^3, respectively. All these means were calculated by applying the specified statistical formula;

$$\bar{x} = \frac{\Sigma x}{n} \qquad (1)$$

Here

$\bar{x}$ is mean of D^1, D^2 and D^3

Σx is sum of D^1, D^2 and D^3

n is number of decades

To assess the statistical significance of changes in calculated mean monthly and mean seasonal temperature and rainfall over the three decades, a one-sample t-test was employed. This test compares the mean of a sample to a specified value. Here mean of a sample is the mean value of three decades (temperature and rainfall) and the specified value is the mean of D^1. The t-test was applied by using the following statistical formula;

$$t = \frac{\bar{x} - \mu O}{\frac{S}{\sqrt{n}}} \qquad (2)$$

Where

$\bar{x}$ is the sample mean

μ0 is the value of the sample parameter to be tested

s is an unbiased standard deviation

n is the sample size

RESULTS

Mean monthly temperature and rainfall variability for both rabi and kharif seasons in the study area have been evaluated and the following results;

Mean Monthly Temperature (^{o}C) during Rabi Crop Season: Table 1 indicates the significant variations that were found in the mean monthly temperature during the Rabi crop season in District Dera Ghazi Khan from 1991 and 2020. Over the three decades, there were distinct variations in temperature across the months of November to April, which are critical for crop growth and development. The mean monthly temperature for each decade ranges from 20.96°C to 21.31°C in November, 15.79°C to 16.64°C in December, 13.65°C to 14.19°C in January, 16.65°C to 17.47°C in February, 22.28°C to 24.04°C in March, and 29.02°C to 30.41°C in April. The overall mean temperature for the Rabi crop season was relatively consistent across the three decades, ranging from 20.1°C to 20.5°C. However, statistical analysis showed significant differences ($p < 0.05$) in mean temperature for all months, with t values ranging from 39.09 to 204.7 and corresponding p values less than 0.001. The results indicated that the observed differences in mean temperature are statistically significant. The standard deviation values further support the variability in temperature within each month across the three decades (Figure 2).

Mean Monthly Temperature (^{o}C) during Kharif Crop Season: The examination of mean monthly temperature during the Kharif crop season showed significant deviations and tendencies as presented in Table 2. Across the three decades, there were noticeable differences in temperature from May to October, a crucial period for the growth and development of Kharif crops. The mean monthly temperature for each decade ranged from 34.81°C to 36.01°C in May, 37.57°C to 38.32°C in June, 37.29°C to 37.79°C in July, 35.79°C to 36.23°C in August, 32.96°C to 33.31°C in September and 27.33°C to 27.95°C in October. The overall mean temperature for the Kharif crop season was relatively consistent across the study period, ranging from 34.34°C to 34.91°C. Statistical analysis revealed significant differences ($p < 0.05$) in mean temperature for all months, with t values ranging from 90.97 to 327.5 and corresponding p values less than 0.001. These results suggested that the observed variations in mean temperature were statistically significant. The standard deviation values further supported the variability in temperature within each month across three decades (Figure 3).

Mean Monthly Rainfall (mm) during Rabi Crop Season: Table 3 shows the analysis of mean monthly rainfall during Rabi crop season, which presented remarkable variations across three decades. The differences in rainfall observed for the months of November to April were critical for Rabi crop cultivation. The ranges of mean monthly rainfall for each decade were from 0 mm to 2.12 mm in November, 2.64 mm to 8.96 mm in December, 4.74 mm to 8.44 mm in January, 8.97 mm to 13.73 mm in February, 9.52 mm to 14.54 mm in March and 4.22 mm to 13.19 mm in April. The overall mean rainfall for the Rabi crop season varied across the decades, ranging from 6.1 mm to 8.8 mm. Statistical analysis displayed significant changes ($p < 0.05$) in mean rainfall for January, February, March and April with corresponding t values ranging from 6.096 to 8.274 and p values less than 0.0259. However, November and December did not show statistically significant differences in mean rainfall. The standard deviation values further illustrated the variability in rainfall within each month across three decades (Figure 4).

Mean Monthly Rainfall (mm) during Kharif Crop Season: Table 4 displays significant variations and noticeable trends in the mean monthly rainfall throughout the Kharif agricultural season in District Dera Ghazi Khan from 1991 to 2020. Across the decades, rainfall fluctuation observed from May to October was precarious for Kharif crop cultivation. The mean monthly rainfall for each decade contrasted from 4.23 mm to 6.34 mm in May, 10.03 mm to 25.34 mm in June, 15.82 mm to 36.39 mm in July, 20.45 mm to 27.42 mm in August, 11.62 mm to 27.96 mm in September and 1.59 mm to 4.75 mm in October. The overall mean rainfall for the Kharif crop

season ranged from 10.6 mm to 19.3 mm across the decades. Statistical analysis revealed significant differences ($p < 0.05$) in mean rainfall for all months except June and October. The t values ranged from 4.790 to 14.02, with corresponding p values less than 0.0173 (Table 4). The standard deviation values further demonstrated variability in rainfall within each month across three decades (Figure 5).

Table 1. Mean Monthly Temperature (C^o) during Rabi Crop Season in the Study Area (1991-2020).

Year	Nov	Dec	Jan	Feb	Mar	Apr	Mean
D^1	21.31	16.64	14.19	16.86	22.29	29.03	**20.04**
D^2	21.2	15.88	14.08	17.47	24.04	30.41	**20.5**
D^3	20.96	15.79	13.65	16.65	22.28	29.02	**19.73**
Mean	**21.2**	**16.1**	**14.0**	**17.0**	**22.9**	**29.5**	**20.1**
Difference	-0.2	-0.5	-0.2	0.1	0.6	0.5	0.1
Std. Deviation	0.1790	0.4669	0.2854	0.4259	1.013	0.7996	0.3874
t value	204.7	59.73	84.81	69.10	39.09	63.87	89.82
P value (two-tailed)	< 0.0001	0.0003	0.0001	0.0002	0.0007	0.0002	0.0001
Significant (alpha=0.05)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 2. Mean Monthly Temperature (C^o) during Kharif Crop Season in the Study Area (1991-2020)

Year	May	Jun	Jul	Aug	Sep	Oct	Mean
D^1	34.89	37.99	37.35	36.23	33.12	27.33	**34.49**
D^2	36.01	38.32	37.79	36.13	33.31	27.95	**34.91**
D^3	34.81	37.57	37.29	35.79	32.96	27.63	**34.34**
Mean	**35.2**	**38.0**	**37.5**	**36.1**	**33.1**	**27.6**	**34.6**
Difference	0.3	0.0	0.1	-0.2	0.0	0.3	0.1
Std. Deviation	0.6709	0.3759	0.2730	0.2307	0.1752	0.3101	0.2955
t value	90.97	174.9	237.8	270.7	327.5	154.4	202.7
P value (two-tailed)	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Significant (alpha=0.05)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 3. Mean Monthly Rainfall (mm) during Rabi Crop Season in the Study Area (1991-2020)

Year	Nov	Dec	Jan	Feb	Mar	Apr	Mean
D^1	1.06	2.64	8.44	13.73	10.56	12.15	**8.1**
D^2	0	8.96	4.74	8.97	9.52	4.22	**6.1**
D^3	2.12	4.23	6.39	12.3	14.54	13.19	**8.8**
Mean	**1.060**	**5.277**	**6.523**	**11.67**	**11.54**	**9.853**	**7.7**
Difference	0.00	2.64	-1.92	-2.06	0.98	-2.30	**-0.4**
Std. Deviation	1.060	3.287	1.854	2.442	2.650	4.906	1.401
t value	1.732	2.780	6.096	8.274	7.544	3.479	9.477
P value (two-tailed)	0.2254	0.1087	0.0259	0.0143	0.0171	0.0736	0.0110
Significant (alpha=0.05)?	No	No	Yes	Yes	Yes	No	Yes

Table 4. Mean Monthly Rainfall (mm) during Kharif Crop Season in the Study Area (1991-2020).

Year	May	Jun	Jul	Aug	Sep	Oct	Mean
D^1	6.34	12.66	36.39	27.42	27.96	4.75	**19.3**
D^2	4.23	10.03	15.82	20.58	11.62	1.59	**10.6**
D^3	4.83	25.34	29.85	20.45	16.89	3.7	**16.8**
Mean	**5.133**	**16.01**	**27.35**	**22.82**	**18.82**	**3.347**	**15.6**
Difference	-1.21	3.35	-9.04	-4.60	-9.14	-1.40	**-3.7**
Std. Deviation	0.8877	6.684	8.581	3.255	6.809	1.314	**3.657**
t value	11.57	4.790	6.375	14.02	5.528	5.094	**8.517**
P value (two-tailed)	0.0014	0.0173	0.0078	0.0008	0.0117	0.0146	**0.0034**
Significant (alpha=0.05)?	Yes	Yes	Yes	Yes	Yes	Yes	**Yes**

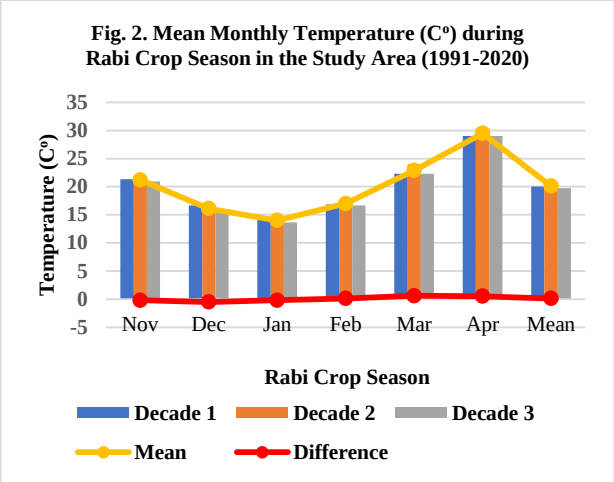

Fig. 2. Mean Monthly Temperature (Cº) during Rabi Crop Season in the Study Area (1991-2020)

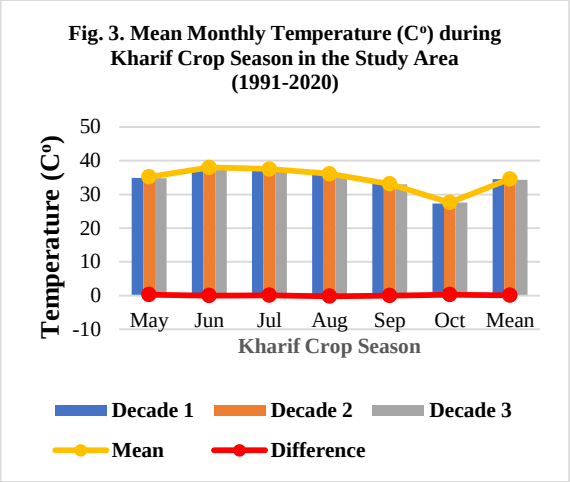

Fig. 3. Mean Monthly Temperature (Cº) during Kharif Crop Season in the Study Area (1991-2020)

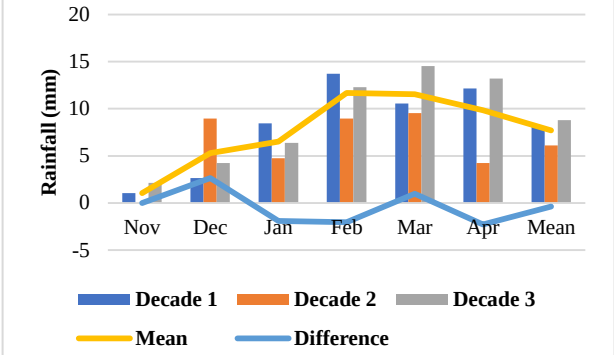

Fig. 4. Mean Monthly Rainfall (mm) during Rabi Crop Season in the Study Area (1991-2020)

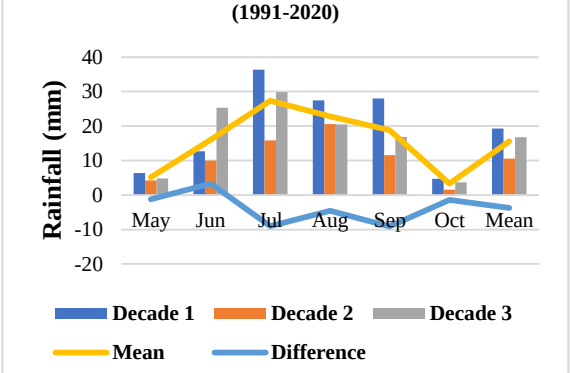

Fig. 5. Mean Monthly Rainfall (mm) during Kharif Crop Season in the Study Area (1991-2020)

DISCUSSION

It is evident from the results that the mean annual decadal temperature in both rabi and kharif seasons has increased by +0.1°C with an annual increase of 0.003 °C in the study area. Overall, temperature is increasing throughout Punjab Province as concluded by Abbas and Mayo, 2021; Nawaz *et al.*, 2019; Bokhari *et al.*, 2017; Khattak and Ali, 2015 and Siddiqui *et al.*, 2012. The increasing temperature due to climate change has significant impacts on global crop production that can lead to shortened growing seasons, reduced crop yields and quality and increased exposure to pests and diseases which resultantly poses a considerable risk to global food security (Kogo *et al.*, 2021; Malhi *et al.*, 2021; Guntukula, 2020; Leisner, 2020; Basit *et al.*, 2015; Mahato, 2014; Hatfield *et al.*, 2011). So far as rainfall is concerned, the amount of rainfall is decreasing as it dropped -0.4mm during Rabi and -3.7mm during Kharif crop seasons since 1991 as evaluated by Abbas *et al., 2022;* Ahmed *et al.*, 2022; Syed *et al.*, 2021; Akhtar and Athar, 2020. Decreasing rainfall like temperature variability, has also significant adverse impacts on crop production, particularly in regions reliant on rain-fed agriculture. Insufficient moisture can hinder germination, reduce crop growth, and limit yields (Kogo *et al.*, 2022; Klutse *et al.*, 2021; Msongaleli, 2021; Amir *et al.*, 2020). The increasing temperature and decreasing rainfall in the study area are posing threats to the agricultural productivity of the area which needs to be addressed by the concerned stakeholders.

Conclusion: The analysis of mean monthly temperature and rainfall patterns during both Rabi and Kharif crop seasons in District Dera Ghazi Khan from 1991 to 2020 indicates significant fluctuations and trends. For the Rabi crop season, there were notable variations in temperature and rainfall across the months of November to April, crucial for crop growth and development. Similarly, during the Kharif crop season, significant fluctuations in temperature and rainfall were observed from May to October, critical periods for Kharif crop cultivation. Statistical analysis revealed significant differences in mean temperature and rainfall for most months, highlighting the impact of climate variability on agricultural practices. These findings highlight the importance of adapting agricultural strategies to cope with changing climate patterns and implementing

measures to enhance resilience in crop production systems in Dera Ghazi Khan.

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