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CLIMATIC VARIABILITY DURING CROPPING SEASONS IN AGROECOLOGICAL ZONES OF PAKISTAN

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ABSTRACT

This study aimed at assessing the climatic temperature and precipitation across agroecological zones during cropping seasons. Moreover, climatic variations in Pakistan for both parameters were gauged across defined Agroecological zones comprising both cropping seasons traditionally known as Rabi (Winter/Wheat growing) and Kharif (Autumn/Rice growing). Targeting comprehensive analysis, each season further disintegrated into the three stages i.e., sowing, flowering and harvesting stages. We incorporated meteorological data from 1961 to 2017, further climatic parameters extracted by employing a 30-years moving average of monthly means. The study revealed that the three zones having rugged topography were highly vulnerable during Rabi (Winter/Wheat growing) Season having +0.5°C variation in climatic temperature, whereas more than 20mm steep rise in climatic precipitation, it may cause increased or frequent flooding in lower plains. While the zones having smooth and plane topography are much more susceptible during Kharif (Autumn/Rice growing) Season having + 0.75oC variation in climatic temperature, whereas more than 10mm decline in climatic precipitation may lead to drought conditions. Vulnerability in climatic parameters becomes uncertain and intense which leads to extreme events. However, variation of climatic parameters elevated from +1°C to +1.75°C and from + 25mm to + 40mm respectively during last five decades. It indicates severe threats for agriculture production particularly and sustainability in general. There is a dire need of promoting adaptation strategies to mitigate the risk for the growing population of Pakistan.

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INTRODUCTION

Climate change is an antediluvian phenomenon but after the inception of the 20th century, a significant rise was observed in greenhouse gases due to the upsurging of anthropogenic activities, which caused an increase in average global temperature and disrupts the hydrological cycle by intensifying the evaporation process and by escalating water withholding capacity of atmosphere (Chambers, 2020). A high rate of evaporation results in severe droughts whereas some regions get superfluous precipitation, therefore resulting in intense floods (UCAR, 2021). From the beginning of the 21st century, climate change has become the top priority concern for humans because it has influenced and affected both the natural and human systems by disrupting food supplies (agriculture), creating health hazards and increasing vulnerability to exposed eco-systems (IPCC, 2014). Human activities, especially the burning of fossil fuels, are the major factor responsible for the rise in the rate of change in climatic variables i.e., temperature and precipitation. On the other hand, variation in such extreme events is natural but the effects of climate change exacerbate the natural climatic variability (Anwar *et al.*, 2015). However, the effect of these changes is not the same and varies according to geography/topography (Dickinson *et al.*, 2015) and level of economic development across the world (IPCC, 2014; Myers-Smith *et al.*, 2015). Furthermore, the sea level is also rising continuously and coastal areas are facing future extinction (IPCC, 2007). Climatic factors are like ingredients or drivers of human life because variability in these factors leads to fluctuation in the harmony of life. Extreme events and variability in climatic factors have become more intensive and frequent since 1950 (IPCC, 2014), which accentuates the vulnerability of poor communities. Similarly, developing and the least developed countries (LDCs') face greater challenges due to climate change as compared to the developed countries (IPCC, 2014). It is due to their weak economy coupled with poor infrastructure. The fourth Assessment Report of IPCC notified that variability in climatic factors will further exacerbate the flood and drought in Asia. In 2015, the UNDP report revealed that Pakistan figures in a dominant position in the climate risk index, despite very little share in global greenhouse gases emission (Khan, 2014). While Pakistan has witnessed such events including a series of floods (Wang *et al.*, 2011), droughts (Gadiwala and Burke, 2019) and heat waves (Masood *et al.*, 2015). Pakistan has a variety of ecologies including high mountains followed by fertile Indus plain (Naheed and Rasul, 2010), where a large proportion of the population is reliant on climate-sensitive economic sectors i.e. agriculture and energy (Salik *et al.*, 2015). Such catastrophic events have their negative economic impact besides loss of life and infrastructure.

Pakistan is geographically located between 24 -34oN latitude and 62 -75^{o}E longitude, the western zone of South Asia (Salma *et al.*, 2012). Such diversified topography contributes to the extent of variability in climatic conditions along different regions across the country (McSweeney *et al.*, 2010). The total area of Pakistan is 79.6 million hectares, out of which almost 34.5 million hectares are arable (Kazmi and Rasul, 2012). Being an agrarian economy, agriculture contributes 19.3% to Pakistan's GDP, while providing livelihood to 43.5 percent of the labour force (Government of Pakistan, 2020). There are two cropping seasons which Rabi season includes normally the months from November to April, whereas Kharif (Autumn/Rice growing) season comprises the months from May to October (Siddiqui *et al.*, 2012). Pakistan has an increasing demand for agriculture due to significant population growth, as agriculture provides food and fibre to mankind. Unfortunately, growth in agriculture particularly in the crop subsector has been declining for the last couple of decades due to climate change and other factors. Due to variability in climatic factors, both the food and livelihood of Pakistan residents are under threat (Salik *et al.*, 2015). Water and level of temperature significantly affect the productivity and production at different stages of crop development i.e. sowing, flowering and harvesting (Ashfaq *et al.*, 2011), which demand favourable policies for developing a comprehensive model for adaptations vis-à-vis climatic variations.

Previous literature exposed that Pakistan suffered from an average temperature higher than the global average (Gadiwala and Burke, 2019), while a 3.8^{o}C increase in mean temperature is projected by 2100 for Pakistan (Salik *et al.*, 2015). Precipitation in Pakistan is categorized into two seasons mainly. The first is, the Indian monsoon in summer and the second is the western disturbances in winter (Wang *et al.*, 2011; Ahmad *et al.*, 2015). Numerous studies have been conducted to assess the weather and climatic conditions of Pakistan from several perspectives. Ahmad *et al.* (2015) investigated the variability in winter-spring precipitation and revealed a decreasing trend. In contrast, Wang *et al.* (2011) addressed climate change leads to a two-stage monsoon in Pakistan, a major cause of floods. While Gadiwala and Burke (2019) and Naheed and Rasul (2010) investigated the annual rainfall variability for Pakistan due to climate change. Whereas rainfall trends according to latitudinal zones of Pakistan are investigated by Salma *et al.* (2012). Moving ahead Babar *et al.* (2015) assessed the impact of climate change on Rabi (Winter/Wheat growing) and Kharif (Autumn/Rice growing) crops for KPK Pakistan. However, Rasul and Ahmad (2012) established the facts to assess the variability of the Indus Delta to climate change. While International Union for Conservation of Nature and Natural Resources (IUCN, 2012) conducted a situation analysis of coastal districts of Balochistan province for climate change. Moreover, Sadiq and Qureshi (2010) estimated the climatic variability for five major cities of Pakistan. However, there is no significant study regarding climate change according to the Agroecological zones of Pakistan. Forecast and variability in precipitation serve as important for agriculture growth, where almost 88 percent area of Pakistan is attributed as arid and semi-arid (Mazhar *et al.*, 2020). Changing in climate having several socio-economic dimensions having different mechanisms (Abdullah *et al.*, 2016). Assessment of climate change and the direction of its effects provide information to reduce uncertainty attached with agriculture (Jäger *et al.*, 2014). This study was concocted to achieve objectives. It provides a keen insight to observe the pattern of climate change from which a valid and fruitful adaptation policy could be drawn to cope with climatic effects which are beneficial for farming communities to reduce their crop risk and improve their socio-economic conditions while providing a sustainable life. This study mainly aimed at.

- To assess climatic parameters for each zone from its time-series metrological data.
- To evaluate the variability in climatic parameters (temperature and precipitation) across Agroecological zones during Rabi (Winter/Wheat growing) and Kharif (Autumn/Rice growing) seasons for Pakistan.
- To capture the trend of variability in both climatic variables during both Rabi and Kharif seasons.

METHODOLOGY

Study area and data

Pakistan, the study area, was classified into ten agroecological zones by PARC (1980) and Muhammad (1986) (See Table 1). This was done based on land use, soil type, climate and other physiographic characteristics. For estimating climate variability, one district from each zone/region was selected and district selection was based on the following consideration: (a) Whole district lies in the same zone. (b) Districts have a large share of cultivated areas. This study utilized data from twelve districts as mentioned in Table 1.

Table 1. Agroecological Zones, Characteristics and Selected Districts.

Sr. #	Agroecological Zone	Characteristic of Region	Selected District
I	Indus Delta	Clayey & Silted Soil	Thatta
II	Southern Irrigated Plain	Silted & Sandy Loam Soil	Shikarpur
III-A	Sandy Desert Region	Fine Sandy Loam Soil, Southeastern Region	Bahawalpur
III-B	Sandy Desert Region	Loamy Fine Sandy Soil, Northern Region	Mianwali
IV-A	Northern Irrigated Plain	Sandy & Clay Loam Soil, Eastern Region	Multan
IV-B	Northern Irrigated Plain	Sandy & Clay Loam Soil, Northern Region	Peshawar
V	Barani Areas	Silt Loamy Soil	Gujranwala
VI	Wet Mountains	Silt Loam to Silt Clayey Soil	Mansehra
VII	Northern Dry Mountain	Clayey & Non-Calcareous Soil	Dir
VIII	Western Dry Mountain	Loamy & strongly Calcareous Soil	Quetta
IX	Dry Western Plateau	Silt Loams & Calcareous Soil	Makran
X	Sulaiman Piedmont	Loamy, Clayey & Calcareous Soil	D. G. Khan

Data regarding temperature and precipitation for selected districts was taken from Pakistan Meteorological Department (PMD), Islamabad. This study incorporates monthly mean temperature and monthly total precipitation for the period 1961 to 2017. The obtained Meteorological data were categorized according to cropping season Rabi (Winter/Wheat growing) and Kharif (Autumn/Rice growing), including months November to April and May to October respectively (Siddiqui *et al.*, 2012). Moreover, climatic variables are generated for each district from collected Meteorological data to evaluate the variation in it.

Data Analysis

Climate researchers use different definitions of climatic variables. Some researchers have employed simple annual average temperature and precipitation, e.g. Shakoor *et al.* (2011), while some others use an average of just growing season, e.g. Lobell and Field (2007). Luo *et al.* (2005) incorporated averages of both growing and non-growing seasons, while Tubiello *et al.* (2002) employed 20 years' monthly averages of temperature and precipitation as normal climate. On the other hand, World Meteorological Organization (WMO, 2011, 2007) suggested 30 years average of Meteorological data as climate normal. The same was done by Gbetibouo and Hassan (2005). In the same way, this study has also utilized 30 years moving averages of both monthly mean temperature and total monthly precipitation as normal climatic temperature and normal climatic precipitation respectively. Normal climatic variables are calculated by incorporating data of both monthly total precipitation and mean monthly temperature for the period 1961 to 2017. Finally, 24 years of climatic data of both parameters (Temperature and Precipitation) is estimated. As argued by WMO (2011) normal climate is not only used as a predictor of future climate but also facilitates as a reference value to assess climate anomalies. In addition, weather shocks during each cropping season were assessed by estimating the variation of climatic parameters (temperature and precipitation). Several specifications were used in the literature to evaluate the climate variation variable. Mendelsohn *et al.* (1999); Yang *et al.* (2014) and Wang *et al.* (2014) suggested the difference between highest and lowest temperature and precipitation as a variation. On the other hand, many degree days can be utilized as variations in climate (Schlenker *et al.*, 2005; Deschenes and Kolstad, 2011; Orlandi *et al.*, 2013). While Piao *et al.* (2014) and Pelletier *et al.* (2015) suggested variation as the difference between normal climatic temperature and precipitation from their corresponding values. Similarly, this study estimates the difference between normal monthly climatic variables (30 years moving averages) from their corresponding monthly values. Moreover, for a brief understanding of climate anomalies, whole seasons (Rabbi and Kharif) were further disintegrated into three stages, i.e., sowing, flowering and harvesting stage. The climate of the entire growing season does not have a uniform effect on each growing stage of the crop (Ashfaq *et al.*, 2011; Siddiqui *et al.*, 2012). Firstly, Ashfaq *et al.* (2011) disintegrated wheat (Rabbi) season according to the biological stages of crops. Similarly, Siddiqui *et al.* (2012) defined growth stages for wheat (Rabbi) and cotton (Kharif) crop seasons and assessed the climatic impact on different stages. So, in this study climatic variables for each stage are estimated, by taking an average of monthly climatic variables, as each stage contains two months shown in Table 2.

Table 2. Several Stages of Growing Seasons.

Seasons / Stages	Sowing stage	Flowering stage	Harvesting stage
Rabbi Season	November-December	January-February	March-April
Kharif Season	May-June	July-August	September-October

Source: Author's Own

Climatic parameters (temperature and precipitation) and their variations were estimated according to the growth stages of both cropping seasons for the period (1990-2017), for all selected districts. Average variation during the last five years (2009-17) for each cropping stage in both seasons was also discussed to recognize the trend in variability in the next section.

RESULTS AND DISCUSSION

This section comprises two sub-sections, and both seasons are discussed separately. Variation in both climatic parameters (temperature and precipitation) from normal for each zone is considered.

The climate in rabbi season

In this season wheat, maize, gram, pulses, tobacco, carrot, cauliflower and garlic are the major crops cultivated throughout the season, while fruits, guava, citrus and banana are the major fruits grown in several parts of the country in this season. The optimum temperature for the production of each crop or fruit is not the same and each zone has favourable growing conditions for particular crops. The average variation in climatic temperature during Rabbi Season for the period of 1990-2017 is shown in the figure: 2, which reveals the clear trend of positive variation in temperature during the sowing stage, for which Quetta, Makran and

Shikarpur are the leading districts with the variation more than 0.5oC. Whereas almost negative variation in climatic temperature for both flowering and harvesting stages is observed for all districts, though the variation in the harvesting stage is quite larger than in the flowering stage.

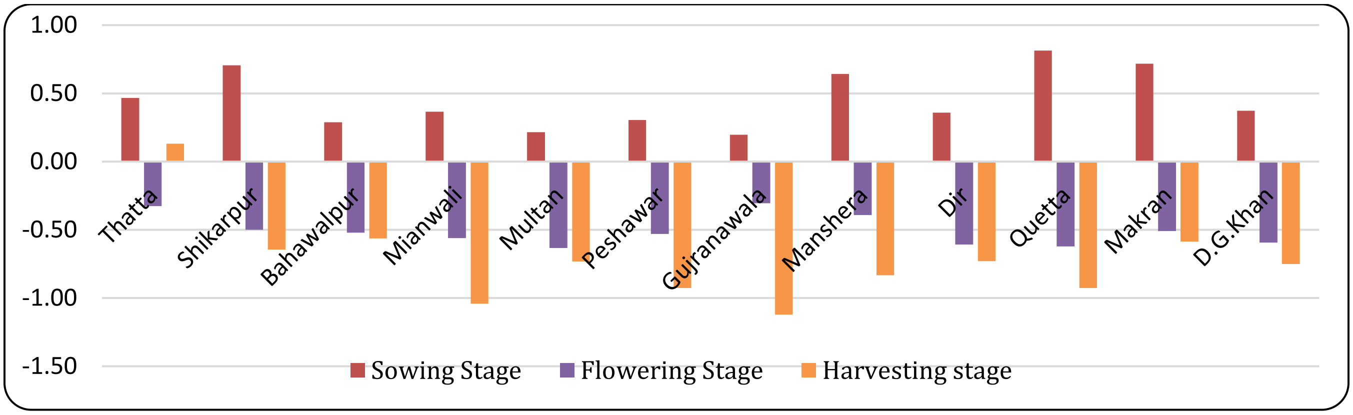

Figure 2. Average Variation in Climatic Temperature (°C) During Rabbi (1990-2017).

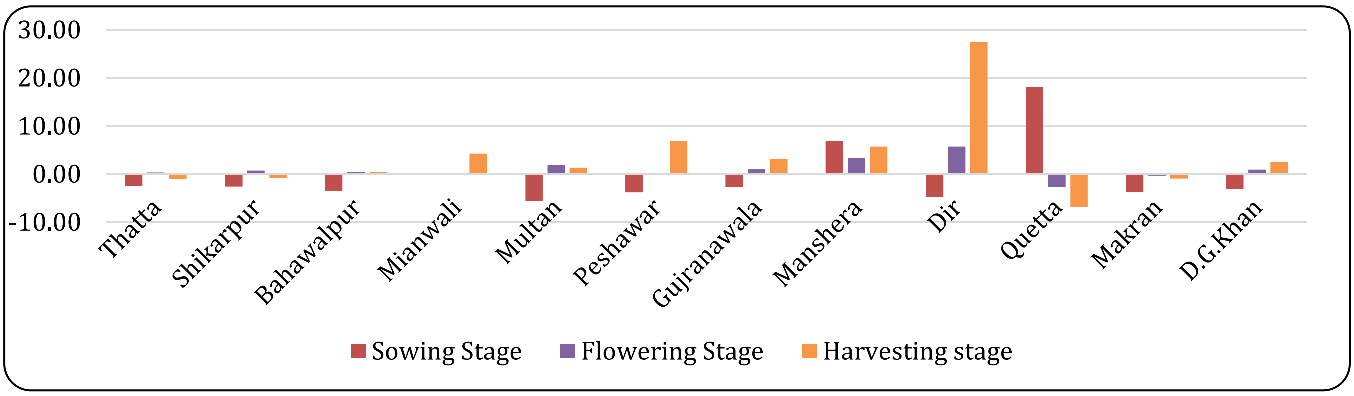

Figure 3. Average Variation in Climatic Precipitation (mm) During Rabbi (1990-17).

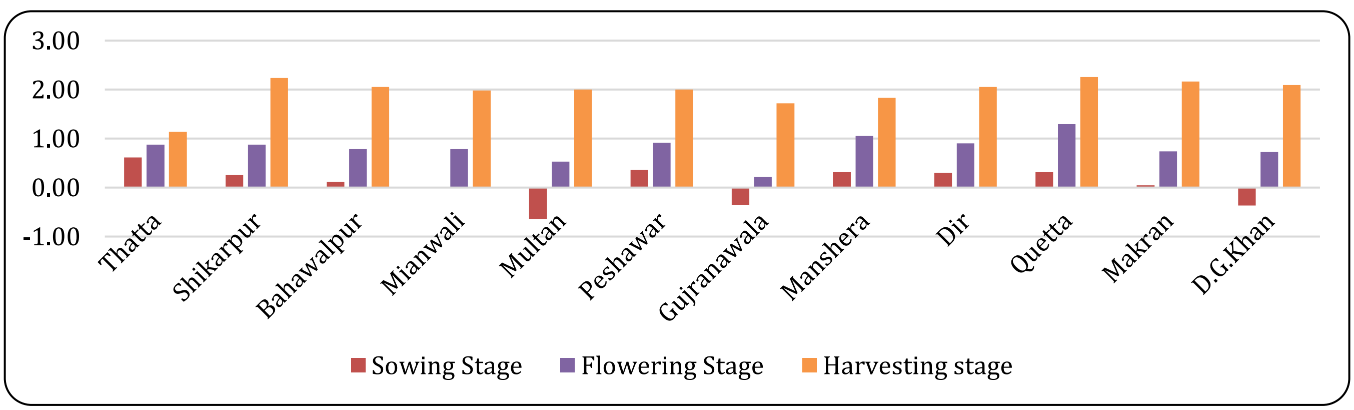

Figure 4. Average Variation in Climatic Temperatture (oC) During Rabbi (2009-17).

Figure 3 shows the average variation in climatic precipitation for the period of 1990-2017 during Rabbi Season. Negative variation for *the* sowing stage is shown for all districts except Quetta and Mansehra Districts. During *the* harvesting stage, slight positive (<5mm) variation can be seen for Mianwali, Gujranwala and D.G. Khan while Mansehra, Peshawar and Dir have quite large positive (>6mm) variation in climatic precipitation.

Similarly, Salma *et al.* (2012) identified the heavy share of precipitation for northern Pakistan during the whole year. However triple pole (KPK-FATA, Southeastern Punjab and Northwestern Baluchistan) spatial precipitation pattern was observed by western disturbances (WDs) in winter-spring by Ahmad et al., (2015). Average normal climatic parameters (temperature and Precipitation) according to growth stage across the districts for the period of 1990-to 2017 are shown in Table 3, which shows that the flowering stage during Rabbi seasons witnesses less temperature in both seasons. As Asmat and Athar (2015) show that December, January and February are the coldest months across the country. Figure: 4 shows the average variation in climatic temperature for five years (2009-17). It shows negative variation during the sowing stage for Multan, Gujranwala and D.G. Khan. However, positive variation can be seen for all remaining districts. During the flowering and harvesting stage, temperature variation is also positive across all districts. Variation during the harvesting stage is quite larger than the variation in any other stage. There is a range of optimum temperatures at which a plant produces seed and fruit, and the optimum temperature for each plant is different (Siddiqui *et al.*, 2012). But the high variation in temperature will cause in loss of crop production (Gornall *et al.*, 2010; Tack *et al.*, 2015), while high positive variation in temperature during the flowering and harvesting stage serves as a serious threat to agriculture. Likewise, Ashfaq *et al.* (2011) found the same for the wheat crop. Moreover, the average positive variation during the harvesting stage is almost 2_{o}C across all the districts. Figure 5 shows the average variation in climatic precipitation for the same period of five years (2009-17). It shows that during the sowing stage of Rabbi Season only Quetta and D. G. Khan have a positive variation of 3.6mm and 0.58mm respectively, whereas all other districts have negative variation. At the flowering stage, Mianwali, Peshawar, Mansehra and Dir districts had significant positive variation in climatic precipitation. Finally, the harvesting stage carries negative variation in climatic precipitation for each district, though the variation in Quetta, Peshawar, Mansehra and Dir have more than 10mm negative variation which shows the decreasing trend of winter rainfall. Similar to Asmat and Athar (2015) and Salma *et al.* (2012) mentioned that northern Pakistan had higher absolute precipitation and higher variability in it. In addition, the negative phase (1990-2006) in winter-spring precipitation was reported by Ahmad *et al.* (2015) Tables 3 and 4 show that normal climatic variables are stated as per growth stages for the period (1990-2017) and (2009-2017) respectively. An increase in climatic temperature during all three stages can be seen in districts Thatta and Bahawalpur, while the increase in normal temperature during the first two stages can be observed in Shikarpur, Mansehra, Quetta and Makran districts. On the other side, an increase in normal climatic precipitation pattern is observed in the flowering and harvesting stage during Rabbi Season for all districts, however, a decrease in normal climatic precipitation is observed in the sowing stage. Such a pattern of precipitation during the whole season is not favourable for crops. Mainly, an upsurge in rainfall during the last stages of crop maturity could lead to a significant loss in production as Ashfaq *et al.* (2011) observed the same findings for the wheat crop. Conclusively, average variation among climatic parameters for both periods (1990-2017) and (2009-17) revealed that the variation is getting stronger and higher in both parameters, which serve as a threat to crop production in particular and agriculture in general. As Ray *et al.* (2015) showed that a third of crop variability is explicated by climate variability. The range of variation in climatic temperature for the period (1990-to 2017) is from 0.81oC to -1.12oC, which increased for the period (2009-17) from 2.26oC to -0.64oC. Climatic temperature variability is positive during the flowering and harvesting stage while it increases significantly for all zones, especially at the harvesting stage. An increasing trend in normal climatic temperature during Rabbi Season is quite vibrant. On the other side, the range of climatic precipitation for both periods (1990-2017) and (2009-17) are from -6.78mm to 27.41mm and -48.88mm to 17.17mm respectively. It can explain the decreasing trend of winter rainfall in Pakistan, which leads to severe drought and water shortage as Gadiwala and Burke (2019) reported. The variation in climatic precipitation during Rabbi Season is negative and quite high for the northern side of Pakistan including northern Punjab as Ahmad et al., (2015) investigated decreasing trend of winter-spring rainfall in Pakistan.

Table 3. Normal climatic parameters for the period of 1990-2017.

	Rabbi Season						Kharif Season					
	Climatic Temperature			Climatic Precipitation			Climatic Temperature			Climate Precipitation		
Districts	Sowing Stage	Flowering Stage	Harvesting Stage	Sowing Stage	Flowering Stage	Harvesting Stage	Sowing Stage	Flowering Stage	Harvesting Stage	Sowing Stage	Flowering Stage	Harvesting Stage
Thatta	21.09	19.02	26.80	4.92	1.76	2.99	30.83	28.42	28.65	29.36	44.99	22.35
Shikarpur	18.87	17.64	29.92	3.60	1.46	2.72	39.16	36.77	32.87	16.14	32.66	9.58
Bahawalpur	17.05	16.03	28.52	5.83	2.58	3.41	37.68	34.97	30.84	24.62	53.33	19.24
Mianwali	13.22	12.63	25.69	7.44	4.82	8.35	36.68	32.66	24.86	35.44	115.19	54.61
Multan	15.69	14.95	28.08	7.36	3.63	3.89	38.33	35.93	29.86	27.00	61.98	22.42
Peshawar	12.29	11.03	22.45	10.82	7.42	18.86	34.02	30.10	22.58	43.73	116.20	48.17
Gujranawala	12.14	11.98	25.80	17.79	9.63	7.83	35.98	31.29	24.23	57.78	117.46	69.90
Manshera	8.66	6.34	15.94	50.00	44.68	53.55	26.65	23.54	17.65	78.16	140.25	73.41
Dir	7.55	5.16	14.68	62.94	52.98	73.52	26.86	23.74	17.41	67.18	163.03	70.54
Quetta	5.11	2.04	11.44	24.83	36.30	31.05	23.13	24.14	16.63	16.15	27.89	12.74
Makran	17.49	16.31	28.89	4.78	2.59	3.32	38.19	35.65	31.43	20.88	44.94	13.18
D.G. Khan	16.82	15.90	28.68	4.87	2.60	3.34	38.97	36.44	30.36	25.42	70.27	20.91

Table 4. Normal climatic parameters for the period of 2009-2017.

	Rabbi Season						Kharif Season					
	Climatic Temperature			Climatic Precipitation			Climatic Temperature			Climate Precipitation		
Districts	Sowing Stage	Flowering Stage	Harvesting Stage	Sowing Stage	Flowering Stage	Harvesting Stage	Sowing Stage	Flowering Stage	Harvesting Stage	Sowing Stage	Flowering Stage	Harvesting Stage
Thatta	21.18	19.08	26.90	5.75	2.97	5.08	30.95	28.60	28.62	44.42	70.17	19.29
Shikarpur	19.08	17.69	29.84	3.04	2.02	5.20	38.95	36.23	32.68	25.53	43.49	17.03
Bahawalpur	17.07	16.06	28.54	5.13	2.44	5.23	37.50	34.14	30.35	30.62	70.39	26.32
Mianwali	13.31	12.50	25.34	7.31	7.70	16.49	36.42	32.39	24.75	40.31	108.26	55.49
Multan	15.60	14.91	27.97	4.04	4.18	6.63	38.17	35.05	29.28	32.84	76.22	32.81
Peshawar	12.62	10.89	22.18	6.77	12.18	33.70	33.83	30.26	22.84	41.48	103.08	45.59
Gujranawala	12.09	11.79	25.46	14.29	13.55	12.70	35.74	30.86	24.24	65.27	127.69	65.81
Manshera	8.97	6.43	15.71	47.45	53.38	65.82	26.31	23.57	17.96	83.81	141.06	74.29
Dir	7.86	5.06	14.59	54.33	74.49	109.37	26.62	23.73	17.42	68.26	170.97	86.15
Quetta	5.58	2.21	11.29	30.25	38.40	37.40	23.18	24.37	16.95	23.42	36.34	18.64
Makran	17.58	16.35	28.82	3.04	2.31	6.27	37.98	34.91	31.06	29.26	58.98	19.27
D.G. Khan	16.80	15.87	28.53	3.69	3.26	7.09	38.66	35.61	29.82	39.11	87.62	31.28

The climate in the Kharif season

In Pakistan, several crops (rice, cotton, maize), vegetables (chillies, bitter guard, and ladyfinger) and fruits (mango, guava, apple, apricot and peach) are mainly grown during this season in different zones. Their optimum temperature and other environmental characteristics coupled with soil type are the basic factors to support specific crop/fruit production.

The average variation in climatic temperature during the Kharif season for the period 1990-to 2017 is shown in figure: 6. It can be seen that during the sowing stage just Mansehra and Dir have minor negative variations while all other districts have significant positive variations. At the flowering stage, Quetta, Dir, Mansehra, Peshawar and Mianwali districts have positive variation (>0.5oC). Though Peshawar and Mansehra districts show a slight positive variation during the final harvesting stage, however, all other districts suffer from significant negative variation out of which Bahawalpur and Multan districts are in leading positions with high variation (>-1oC). The negative variation in climatic temperature especially at the harvesting stage is due to the trough phase (August) of the monsoon as identified by Wang *et al.* (2011).

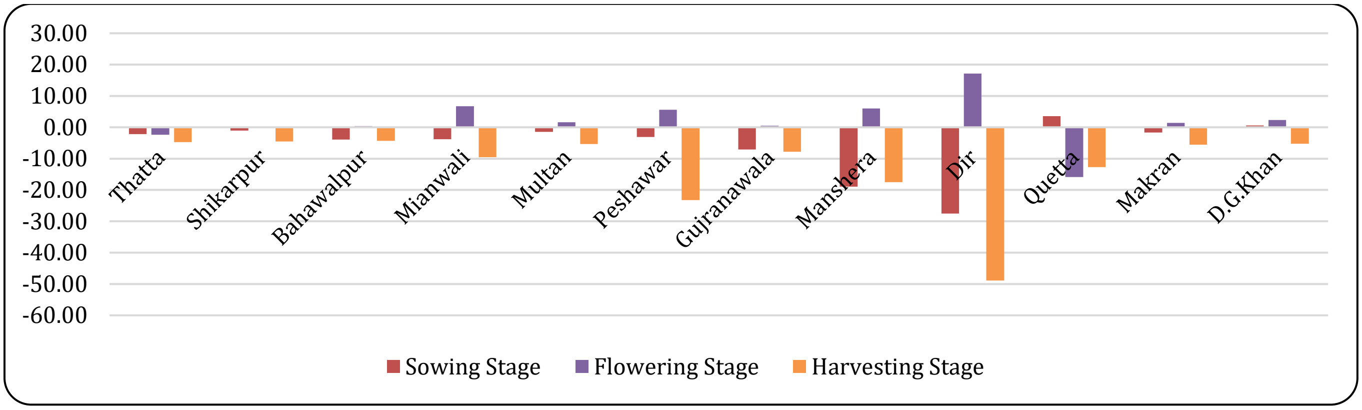

Figure 5. Average Variation in Climatic Precipitation (mm) During Rabbi (2009-17).

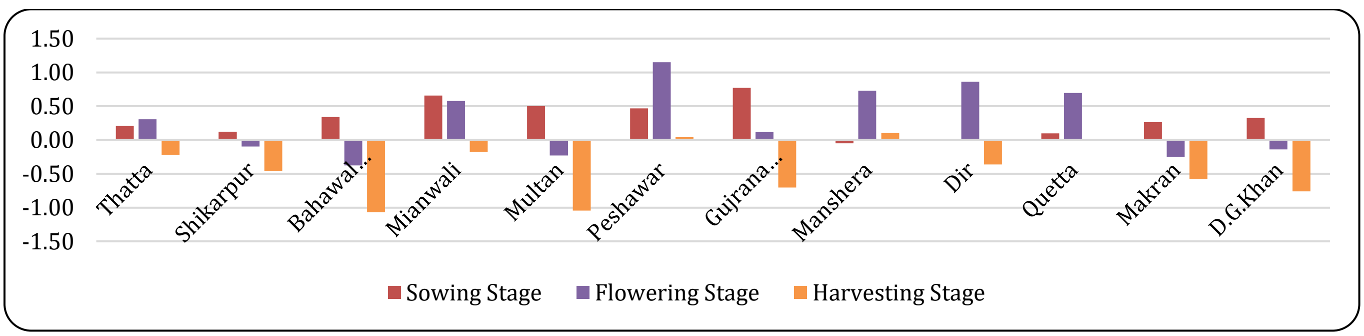

Figure 6. Average Variation in Climatic Temperature (oC) During Kharif (1990-2017).

On the other hand, the average variation in climatic precipitation for the period of 1990-to 2017 is presented in Figure 7, District Thatta and Shikarpur have quite a high variation during the sowing stage as Muslehuddin *et al.* (2005) identified Sindh summer monsoon starts from June. While districts Mianwali, Peshawar, Gujranwala, Dir, Mansehra, Quetta and D.G. Khan showed negative variation during the flowering stage. Whereas Peshawar, Mansehra, Mianwali and Dir have large variations (>-25mm). Peshawar, Mansehra and Mianwali have negative variations in the harvesting stage as well. It is quite relevant to the argument by Ahmad *et al.* (2015) and Salma *et al.* (2012) that the northern side of Pakistan receives a large share of absolute precipitation with large variation throughout the year. Whereas the normal climatic variables for the period of 1990-2017 as per growth stages are stated in Table 3, the large share of climatic precipitation can be seen for districts located in the northern side of Pakistan. Figure 8 shows the average variation in climatic temperature during the Kharif season from 2009-to 2017. Slight positive variation is shown for districts Thatta, Quetta and Mansehra in the sowing stage, while only Peshawar district has positive variation during the flowering stage. For the district Peshawar Ghaffar and Javid (2011) observed the increasing trend in temperature during pre-monsoon. Negative variation in climatic temperature during all three stages can be seen for Shikarpur, Bahawalpur, Multan, Makran and D.G. Khan. It is due to an increase in climatic precipitation as shown in Table 4, which induces a decline in climatic temperature as well. However, Peshawar, Mansehra, Dir, Mianwali and Gujranwala have positive variation in temperature at the harvesting stage due to the small share of monsoon and increase in average temperature. All these districts are located in the northern half of country, whereas Asmat and Athar (2015) publicized the highest variation in temperature for the northern part of Pakistan. Such variations exacerbate the melting of glaciers and increase the water flow from mountains to the Arabian Sea, which causes floods in the downstream areas of the country.

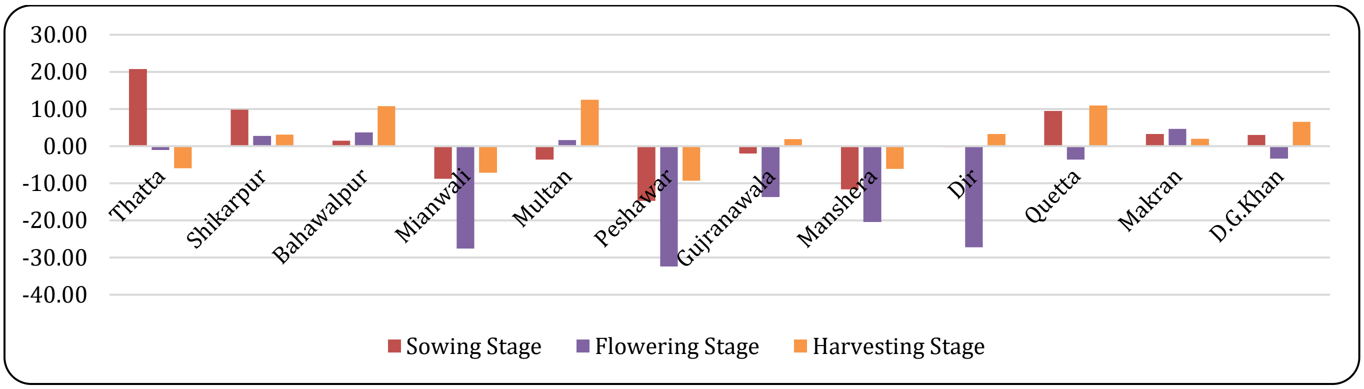

Figure 7. Average Variation in Climatic Precipitation (mm) During Kharif (1990-17).

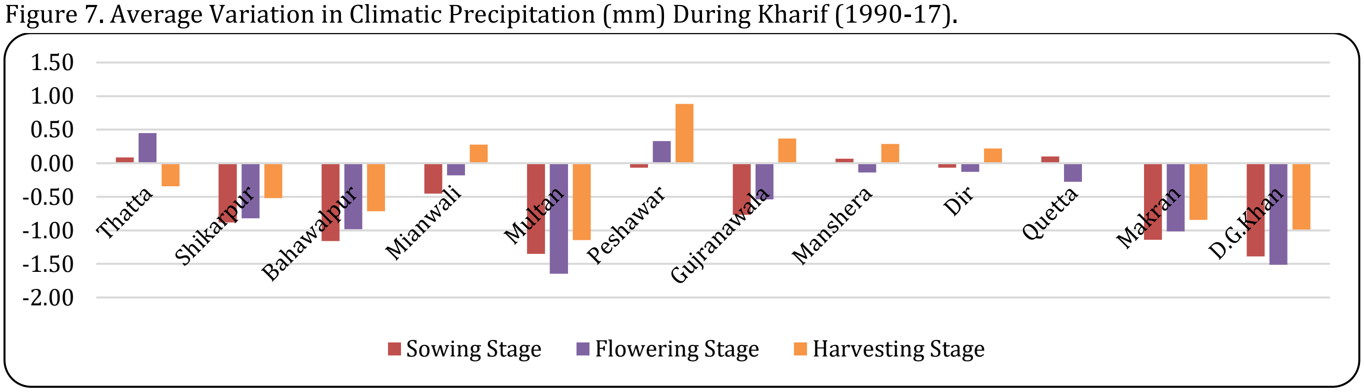

Figure 8. Average Variation in Climatic Temperature (oC) During Kharif (2009-17).

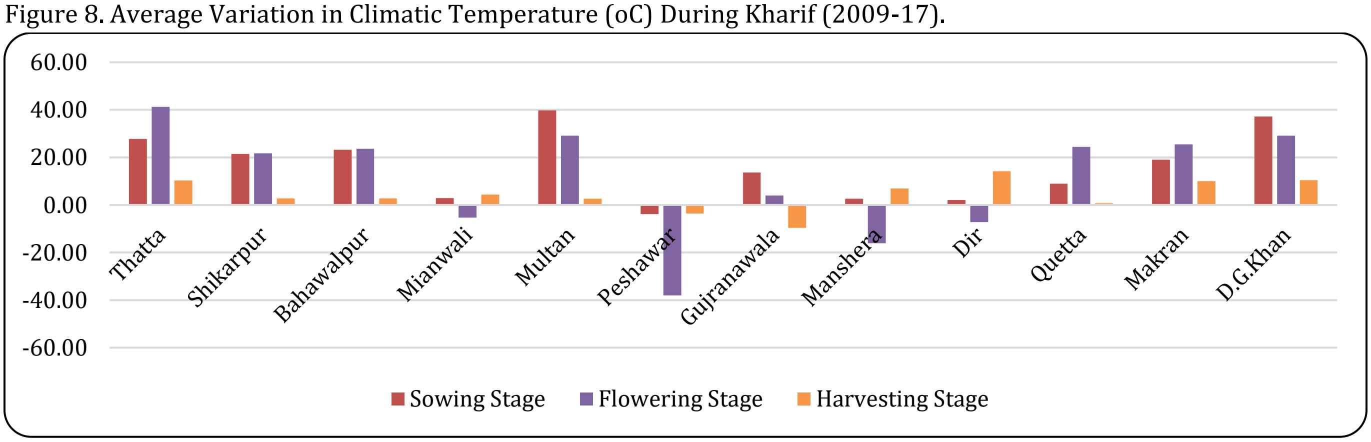

Figure 9. Average Variation in Climatic Precipitation (mm) During Kharif (2009-17).

On the other side of Figure 9, the average variation in climatic precipitation for 2009-17 is shown, only district

Peshawar has negative variation during the sowing stage of the season, whereas districts Thatta, Multan and D.G. Khan have high positive variation (>25mm) at the same stage. Muslehuddin *et al.* (2005) revealed the early start of the monsoon in June for southeastern parts of the country. At the flowering stage, Dir, Mansehra, Peshawar and Mianwali have negative variation, while Peshawar is the leading one with the most variation (>-35mm). Similarly, Ghaffar and Javid, (2011) found decreasing trend in monsoon rainfall for Peshawar and Wang et al., (2011) as he explored those western parts of Pakistan observed a weak monsoon. However, only Peshawar and Gujranwala showed negative variation during the harvesting stage, while all other districts have positive variation in climatic precipitation due to post-monsoon. But the variation in the harvesting stage is less than the flowering stage across the districts located in the southern parts of the country, Wang *et al.* (2011) found large and episodic rainfall during August (flowering stage).

The normal climatic temperature and precipitation during the Kharif season for both periods (1990-2017) and (2009-17) are shown in Tables 3 and 4 respectively. Only Quetta's climatic temperature increased in all stages, while the climatic temperature of Mansehra and Peshawar increased during the flowering and harvesting stage. However, the hottest stage during the whole season is the sowing stage (May-June). Asmat and Athar (2015) mentioned that June, July and August are the hottest months in southern Pakistan. On the other hand, climatic precipitation during the Kharif season substantially increased in all districts except Peshawar. This increase in episodic monsoon rainfall resulted in floods, owing to the scarcity of dams and reservoirs in Pakistan. At the inception of this century, Pakistan suffered from a series of floods, as reported by Paulikas and Rahman (2013). Besides this, climatic precipitation was highest during the flowering stage as it includes the trough of monsoon (August) as declared by Wang *et al.* (2011).

Finally, average variation among climatic parameters for both periods (1990-2017) and (2009-17) revealed that the variation is getting stronger and higher in both parameters, which serve as a growing risk for agricultural activities. According to Torquebiau *et al.* (2015), climatic variation affects the risk in agriculture by adding other risks to its production. The general range of variation in climatic temperature during the Kharif season for the period (1990-to 2017) is from 1.15oC to -1.07oC, which increased for the period (2009-17) from 0.88oC to -1.65oC. A decreasing trend in climatic temperature is quite evident in this season. On the other hand, the range of climatic precipitation for both periods (1990-2017) and (2009-17) are from 20.81mm to -32.36mm and 41.19mm to -38.05mm respectively. It can explain the increasing trend of summer monsoon in Pakistan, which lead to the severe situation of the flood as Wang *et al.* (2011) and Gadiwala and Burke (2019) reported. Variation in climatic precipitation during the Kharif season was positive and quite high for the southern parts of the country, which has also been endorsed by Asmat and Athar (2015) who revealed high variation of monsoon for southern Pakistan.

CONCLUSIONS AND RECOMMENDATIONS

Climate change has become a widespread phenomenon and is bullying not only water availability, food security and energy sector, but also has a bearing on agriculture, forests and livestock which are the sectors vital for Pakistan's economy. Melting glaciers, persistent rise in sea level and ocean temperature are other side effects. The agroecological study revealed an increasing trend in climatic temperature throughout the country during the Rabbi season. Barani areas and the eastern portion of the northern Irrigated Plane have little negative variation in climatic temperature during the sowing stage, while all other zones witnessed positive variation in climatic temperature for the sowing and flowering stages. Whereas the variation in the harvesting stage is quite larger than in the flowering stage. Due to variation in climatic temperature, western dry mountains ranked at the top and Indus Delta ranked at rearmost during Rabi (Winter/Wheat growing) season. On the other side variation in climatic precipitation exhibits an almost negative trend across all zones during Rabbi Season. It can lead to an extreme situation of drought because more than two-thirds of the country is categorized as arid and semi-arid. By the way, Western Dry Mountains, Northern Dry Mountains, Wet Mountains and the western region of Northern Irrigated Plain have witnessed large climatic precipitation variation during the whole season. In addition to it, the flowering stage of Rabbi Season includes months with the least temperature, so it is the coldest stage in both cropping seasons. On the contrary, during the Kharif season

Southern Irrigated Plain, Dry Western Plateau, Sulaiman Piedmont, the eastern portion of Sandy Desert Region and the eastern region of Northern Irrigated Plain witnessed negative variation in climatic temperature during all growth stages. While the northern portion of Sandy Desert Region, the western portion of Northern Irrigated plains, Barani Areas, Wet Mountains and Northern Dry Mountains witnessed positive variation in climatic temperature during the harvesting stage. As far as variation in climatic precipitation is concerned, the only western region of Northern Irrigated Plain suffers negative variation during all three stages. Indus Delta, Southern Irrigated Plain, the eastern region of Sandy Desert, Western Dry Mountains, Dry Western Plateau and Sulaiman Piedmont suffered positive variation in precipitation for all growth stages. Such high positive variation in climatic precipitation serves as a flood warning for downstream areas of the country. Moreover, the sowing stage of the Kharif season has the highest temperature of the whole year. In the context of the objectives of the study, conclusions are discussed below in bullets.

1. During Rabi (Winter/Wheat growing) season all the agroecological have positive variation in climatic temperature during the sowing stage while having negative variation is observed in the flowering and harvesting stage, On the other hand, Western Dry Mountains revealed high positive variation in climatic precipitation particularly in sowing stage while the region of Wet Mountains has positive variation in climatic precipitation during all three growth stages.
2. During Kharif (Autumn/Rice growing) season Northern Irrigated Plain, Northern Dry Mountain and Sandy Desert Region have positive variation in climatic temperature whereas all these regions suffered negative variation in climatic precipitation in the observed period of data.
3. It is factual to say that the rugged/rough topography areas in Rabbi and plane or smooth topography areas during Kharif were extremely uncertain with high variation in both climatic parameters (temperature and precipitation). But both cropping seasons Rabbi and Kharif come along with the threat of severe drought and flood respectively.
4. The complex and stouter variation in climatic parameters for the diversified topography of Pakistan aligned the country to severe events, which causes harm to the economic, social and environmental conditions of the residents.

It is generally perceived that the poor get more affected due to their high vulnerability and limited adapting capacity, unfortunately, more than one-third portion of the population lives below the poverty line in Pakistan. Additionally, the poor governance and underprivileged farming community add insult to injury. To cope with climate change micro-level adaptive measures are obligatory, commencing extension services and training programs are recommended to educate, encourage and involve locals for better results. Moreover, there is a dire need to develop small and large dams to deal with life-threatening variations in precipitation. As the climate is a global/regional phenomenon, Pakistan alone cannot do much in controlling climate change. Joint action and policy for climate should be formulated at the global as well as regional levels. Policymakers should consider these directions, and devise measures to develop climate policy and adapt approaches to mitigate risk.

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