CHANGING CLIMATE IN THE POTOHAR REGION- PUNJAB AND ITS EFFECT ON STREAMFLOW: A CASE STUDY OF KANSHI RIVER

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ABSTRACT: The current study is to identify and examine the impacts of climate change on the water runoff in the Kanshi catchment of the Potohar Plateau region for 50 years from 1961-2010. Simple linear regression and Pearson correlation were used to assess the correlation coefficient, trend magnitude, and variability of temperature, rainfall, and stream. The results revealed that mean and maximum annual temperature steady and significant increase at the rate of 0.06 °C and 0.053/year during the last two decades. The rainfall pattern was also declined at the rate of -6.821, -0.018, -1.458 and -4.409 mm/year in winter, summer, autumn and spring steadily. Similarly, in August and September, the total water discharge had a significant and negative trend with p values 0.08 and 0.03 during 1991-2010. This substantial and significant change resulted from climate change or increased intercession of anthropogenic activities on the earth's surface.

Keywords: Climate change, runoff, magnitude and variability, anthropogenic activities, Salt range**.**

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INTRODUCTION

Climate change is mainly attributed to the continuous rise of greenhouse gases, highlighting fluctuation in rainfall pattern, temperature, and negatively affecting the water resources and land cover. Climate change is measured as a global phenomenon; therefore, its effects are commonly felt due to their larger vulnerabilities and the lesser ability to minimize climate change (Cao *et al.*, 2020). The increase in temperature negatively affects water resource management and hydrological practices during the last century (Abbas *et al.*, 2018a). Such variation in climate parameters is not limited to disaster consequences but also has a direct relation to the variability of the vegetation and land cover.

Globally, the mean temperature of the earth has been increased by 0.85°C from 1880 to 2012, If such trends are continuously increased, then the mean temperature projected to 4°C until 2100 under the RCP 8.5 scenario. The ranking of Pakistan concerning climate change vulnerability is currently 5th number by the Global Climate Change Vulnerability Index. The vulnerability to climate change is increasing in Pakistan due to the geographical features and prevailing arid climate. Furthermore, the human variations that have been characterized as extraordinary have forcefully affected the earth's environment and ecosystems (Lambin *et al.*, 2001). Eckstein *et al.*, (2019) confirmed that Pakistan frequently affected by climate extreme events of 152 from 1999 to 2018, resulting in an economic loss of $ 3.8 billion.

Very few studies have been conducted about regional climate change affected by the land-use change in Pakistan (Shakir *et al.*, 2016; Ali *et al.*, 2011; Babur *et al.*, 2016; Mahmood *et al.*, 2016; Shahid *et al.*, 2018; Shaukat *et al.*, 2020; Shahid *et al.*, 2020). Shakir *et al.*, (2010) indicated that variation in temperature and rainfall has a strong impact on the river flows. Trends of the previous decades in the river flow pattern are entirely different due to climate change. The recharge within watershed downstream catchment areas is vital for the development of landscape and seascape (Midgley *et al.*, 2002). Babur *et al.*, (2016) indicated that a projected increase in annual flow was observed in the RCP 4.5 and RCP 8.5 scenarios. From the detailed investigation, it is stated that the winter and spring seasons exhibited a remarkable increase in discharge of water flow. In contrast, the summer and autumn seasons showed a decline in the streamflow. The watershed catchment process is mostly affected by the change in land-use patterns and climate change (McDonnell *et al.*, 1996). The water discharge was found to be increased by 21.36 mm due to change in rainfall and temperature patterns and 17.44 mm owed to change in land use pattern in the Margalla Hills watershed (Shahid *et al.*, 2020). Shaukat *et al.,* (2020) exhibited the decreasing trend of the rainfall and streamflow in the Tarbela catchment. The contribution of the land-use change pattern was 60.7% observed from the analysis. Furthermore, 39.3% contribution of climate change was found. Presently, there is no detailed investigation found concerning climate change and land-use patterns in the Kanshi catchment and its impact on streamflow.

Mangla sub-watershed lies within the Punjab boundary of Pakistan that falling in a rainfed area that highly dependent on summer monsoon rainfall. Kanshi watershed is the sub-watershed of the Mangala. Punjab shares 52.95 % of the total population and 26 % total area of Pakistan. The sharing of major crops of Punjab was 75.5 % in wheat, 70.2 % in Rice, 68.5% in cotton and 67.8 % in sugar cane and the share of fruits was 79.6 % in mango, 5.8 % in Banana, 96.5 % in Citrus, 76.8 % in Guava, and 8.1 % in dates (Abid *et al.,* 2015; Abbas *et al.,* 2016). Climate change in Pakistan strongly affecting the flow of a river, resultant in reduced agricultural land use area. Mangala watershed is also suffering from large fluctuations in rainfall patterns and temperature. Therefore, looking into the current expected changes in climate, the main objective of the current investigation is to be identified and examined the impacts of climate change on the water runoff in the Kanshi catchment of the Potohar Plateau region.

MATERIALS AND METHODS

Study area characterization: The area of Kanshi river and its watershed lies between latitude 33°14'54.59" N and longitude 73°36' E. Kanshi river covered an area of approximately 1111.104 km^2 located near to the Palote. According to physiography, the Kanshi river consists of three primary portions. The first part covers the Gujar khan tehsil situated in the Potohar Plateau (Figure 1).

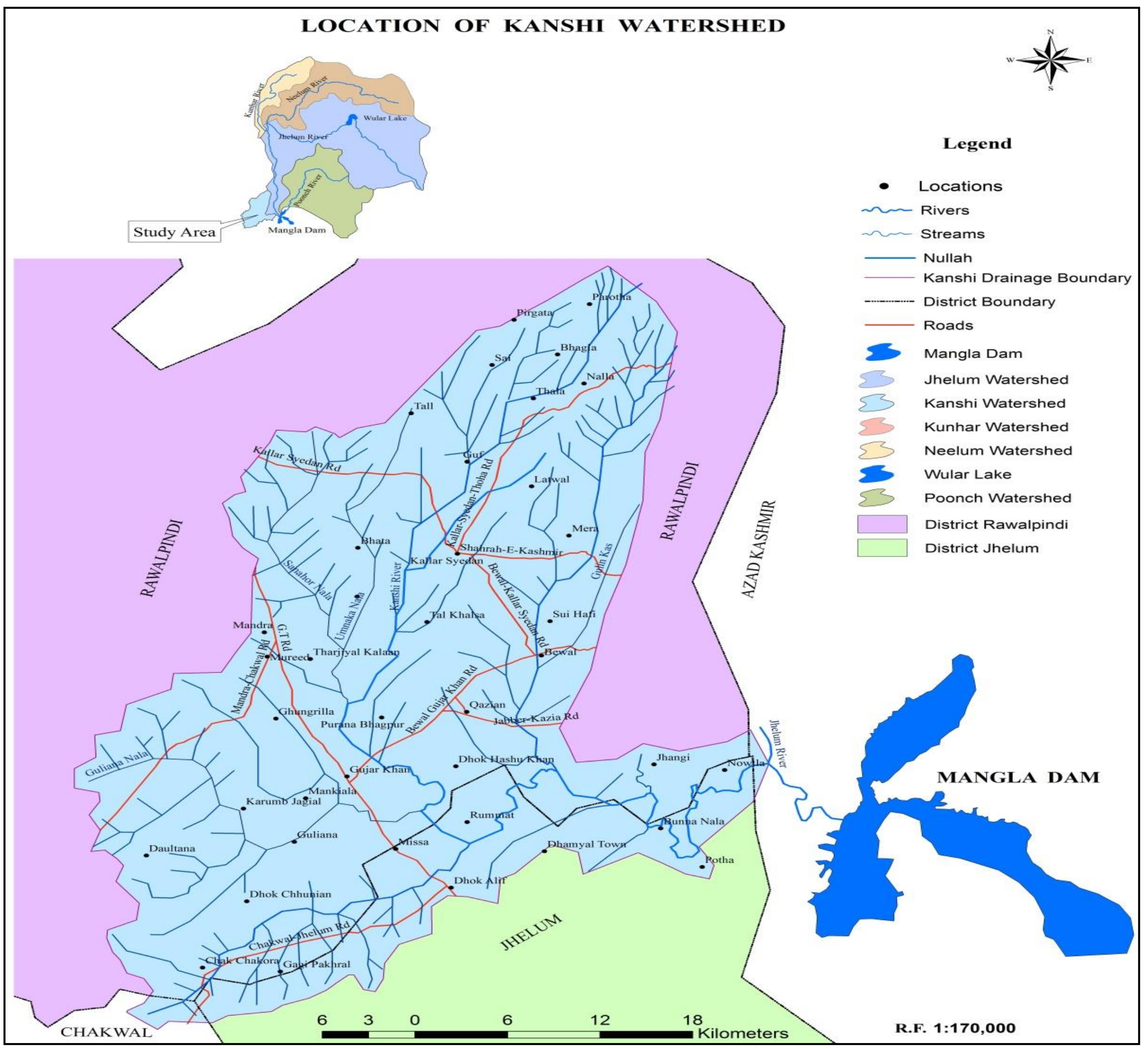

Figure-1. Location map of Kanshi watershed, Pakistan.

The Potohar Plateau has an area of about 18000 km^2 with an elevation of 300-600 west of the Indus river on the north by the Kala Chitta Range and the Margiela hills and on the South by the Salt range. This river is drained by the River Soan. The second part comprises areas of Murree, Kotli-Sattian and some areas of Kahuta tehsil in the north. The third part included the tehsil of Rawalpindi, which start from Kahuta in the west to the Jhelum and down into the Gujar Khan. Gujar Khan and Kahuta tehsil cover the Mangla watershed mainly lies within the district boundary of Rawalpindi. The other sub-watershed of the Mangla watershed that fundamentally links the Kanshi watershed drains into the Jhelum River. The Kanshi river has its headwaters in Kahuta and Gujar Khan.

Data and analysis: In this study, the monthly data set of mean, minimum, maximum temperature, rainfall, and streamflow were used from 1961 to 2010 for 50 years. The 50 years' time series distributed into four periods; 1961-2010 (50 years); 1971-2010 (40 years);1981-2010 (30 years) and 1991-2010 (20 years). For the *Kharif* and *Rabi* seasons, climate data tabulated from April to October and October to April, respectively. Furthermore, four meteorological seasons like the winter (DJF), Spring (MAM), Summer (JJA) and Autumn (SON) were selected. After tabulation data, an annual time series from each period was plotted to identify any observable trend.

Simple linear regression and Pearson correlation were used to assess the correlation coefficient, trend magnitude and variability of mean, minimum, maximum temperature, rainfall, and streamflow in the Kanshi catchment. The linear regression method is the parametric test that shows the linearity in the data sets in a smooth way. For the analytical expression, least square intercept and slope is a straightforward exercise to reduce the sum of square residuals. Durbin and Watson's statistics are testing statistics used before the regression fit to check the autocorrelation of the data. All the climate variables have no assumption about autocorrelation. The main advantage of linear regression is to define the best fitting line. The slope value used to access climate parameters changes (Chatterjee *et al.,* 2000; Abbas *et al.,* 2018b).

The slope is similar in form to the Pearson correlation coefficient and can be obtained with the single way pass through the data using the computational form given as the second equality (Wilks, 2011; Vannitsem *et al.,* 2018). Pearson correlation coefficient is a test statistic that is used to measure the strength of continuous variables. It is the best method of measuring the strength of variables because it is based on covariance. Pearson correlation's main advantage is to give information about the magnitude of the association and the direction of the observed climate variables (Kumar *et al.,* 2004).

RESULTS AND DISCUSSION

Annual and Seasonal changes in the Temperature and Rainfall: Pakistan is ranked as the 5^{th} top vulnerable country to climatic change; the country faced extreme events like catastrophic climate change events, floods, and drought. Pakistan's economy relies on the agriculture sector. Abid *et al.,* (2015) reported that most of the population depends on the agricultural sector in Pakistan. Shepherd *et al.,* (2013) also declared that till 2030, the huge population of Pakistan will face big multi-hazard risk with a limited capacity level of adaptation (Shepherd *et al.,* 2013). Based on the above facts, it concluded that the total rainfall would be decreased in the future.

The availability of irrigation water in Pakistan mainly depends on rainfall (mostly driven from summer monsoon rainfall) and the melting of big glaciers, which are used for water supply to the rain-fed area and used for irrigated agriculture. The melting of the Karakorum glacier due to temperature rise is predictable (increase at 50%) in century first half and then will be reduced (decrease as 40%) at the century's end (Rees and Collins, 2006). There is a huge variation in spatial surface temperature and rainfall along with tributaries of the Indus River, which is passed from the province of Jhelum river, Punjab. The temporal and spatial precipitation and temperature variation directly affect the hydrological cycles and generate extreme climatic change in the area. However, the change in rainfall and temperature patterns has become a very alarming factor for the crop sector. Bukhari *et al.,* (2017) confirmed the long-term negative impact of climate observed on rice, wheat, sugarcane, and cotton.

The total rainfall changes in the Kanshi river catchment area from 1961 to 2010 was observed at the rate of -1.341mm /year. The highest change was observed from 1991 to 2010, where the trend of rainfall observed decreasing. The mean annual temperature steady and significant increase at the rate of 0.06 °C/year during the last decades from 1991-2010. The annual yearly maximum and mean temperature also increased at the rate of 0.053 and 0.047 °C / year respectively (Figure 2).

The unexpected decreasing trend of rainfall during the last two decades is the main reason for the loss of vegetation cover. The temporal and spatial variations in summer monsoon rainfall have a direct reason for higher losses in agricultural activities. The monsoon rainfall pattern changes in the Kanshi catchment area from 1961 to 2010 was observed at the rate of 0.938 mm /year, whereas from 1971 to 2010, 1981 to 2010 and 1991 to 2010 at the rate of -2.439, 0.0373 and -9.691 mm /year respectively. The biggest change observed from 1991 to 2010 was the highly decreasing rainfall with -193.83 mm. Although summer monsoon minimum temperature indicates a steady and significant increase in the rate of 0.019 °C / year during the last two decades. Similarly, the

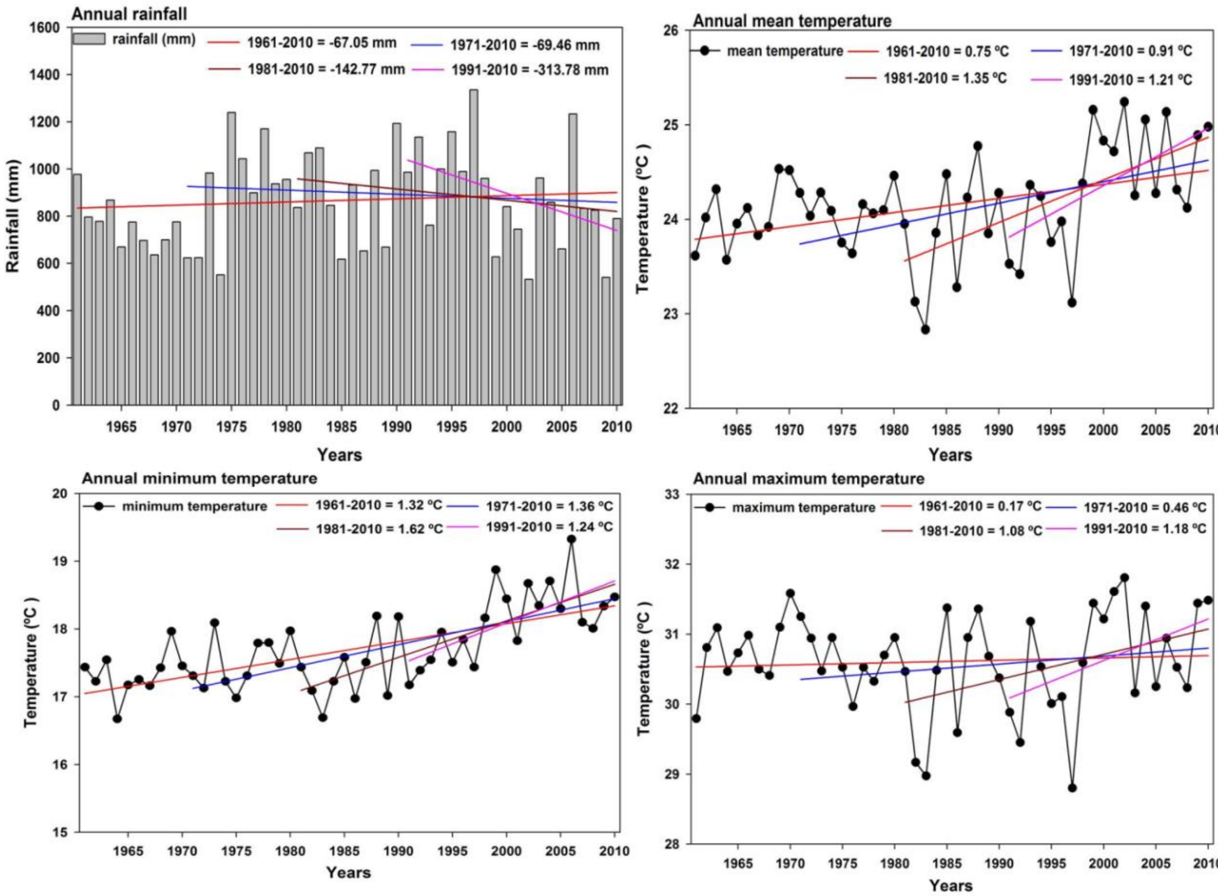

Figure-2. Changes in the rainfall mean temperature, a minimum and maximum temperature of the Kanshi watershed.

cultivated area also observed a decreasing trend for the years 1951, 1995 and 2009 from 0.4, 0.16 and 0.12 ha due to an increase in water stress in Pakistan (World Bank, 2010).

The Kharif rainfall pattern from 1961 to 2010 was observed at the rate of 0.968 mm /year, whereas from 1971 to 2010, 1981 to 2010 and 1991 to 2010 at the rate of -1.809, -1.194 and -11.201 mm /year, respectively. The highest decreasing trend was observed from 1991 to 2010. Where the rainfall was highly decreasing with the -224.20 mm due to increasing the minimum temperature 1.32 °C. The Rabi rainfall pattern from 1961 to 2010 was investigated at the rate of 0.791 mm /year, whereas from 1971 to 2010, 1981 to 2010 and 1991 to 2010 at the rate of 2.05, -2.709 and -5.539 mm /year, respectively. The highest decreasing trend was observed during 1991 to 2010 where the rainfall was highly decreasing with the -110.78 mm due to increasing minimum temperature 1.30 °C during the last two decades from 1991 to 2010 (Figure 3).

Such increase in temperature has negative effects on crop production and builds a negative relationship with the yield (Yasin *et al.*, 2018). This increasing temperature trend brings the change in rainfall patterns, increased variability of Monsoon, and severe water-stressed conditions in arid and semi-arid areas cause a decrease in the yield of about 6 to 18%, such as floods the droughts (Yaseen *et al.*, 2016).

Results revealed that the trend of rainfall in the summer and winter seasons observed increased. In the autumn and spring season, rainfall pattern has decreased for the period 1961to 2010 due to increasing the temperature (Yaseen *et al.*, 2016). The winter and summer rainfall pattern increase in the Kanshi from 1961 to 2010 was observed at the rate of 0.532 and 1.577 mm /year, respectively. While the autumn and spring rainfall patterns declined at the rate of -0.409 and -0.0715 mm /year, respectively. The rainfall pattern is decreased in all seasons; winter, summer, autumn, and spring during the fourth phase. The 1991-2010 rainfall patterns were declined at the rate of -6.821, -0.018, -1.458 and -4.409 mm /year consistently (Figure 4).

This decrease in rainfall was due to an increase in temperature, which fluctuates the agriculture sector and irrigation framework's negative impact. For the last two decades, climate change had a negative impact on the Pakistan's agricultural crop production, supporting the results of Matthews *et al.*, (1994a); Zhang, (1993); Jin *et* *al.*, (1995), and Shakoor *et al.*, (2011). Results showed that climate parameters are the key element for agricultural output, such as the rise of temperature, decline in precipitation and manifestation of extreme events like droughts, floods and windstorms that directly impact the crop yields. The severs climate change creates stress in the period of maturation stage of the crop, increase the pest attacks, increase the period of harvesting, lack of availability of irrigation water, reduced the soil fertility, and increase the soil erosion process (Rahman, 2016).

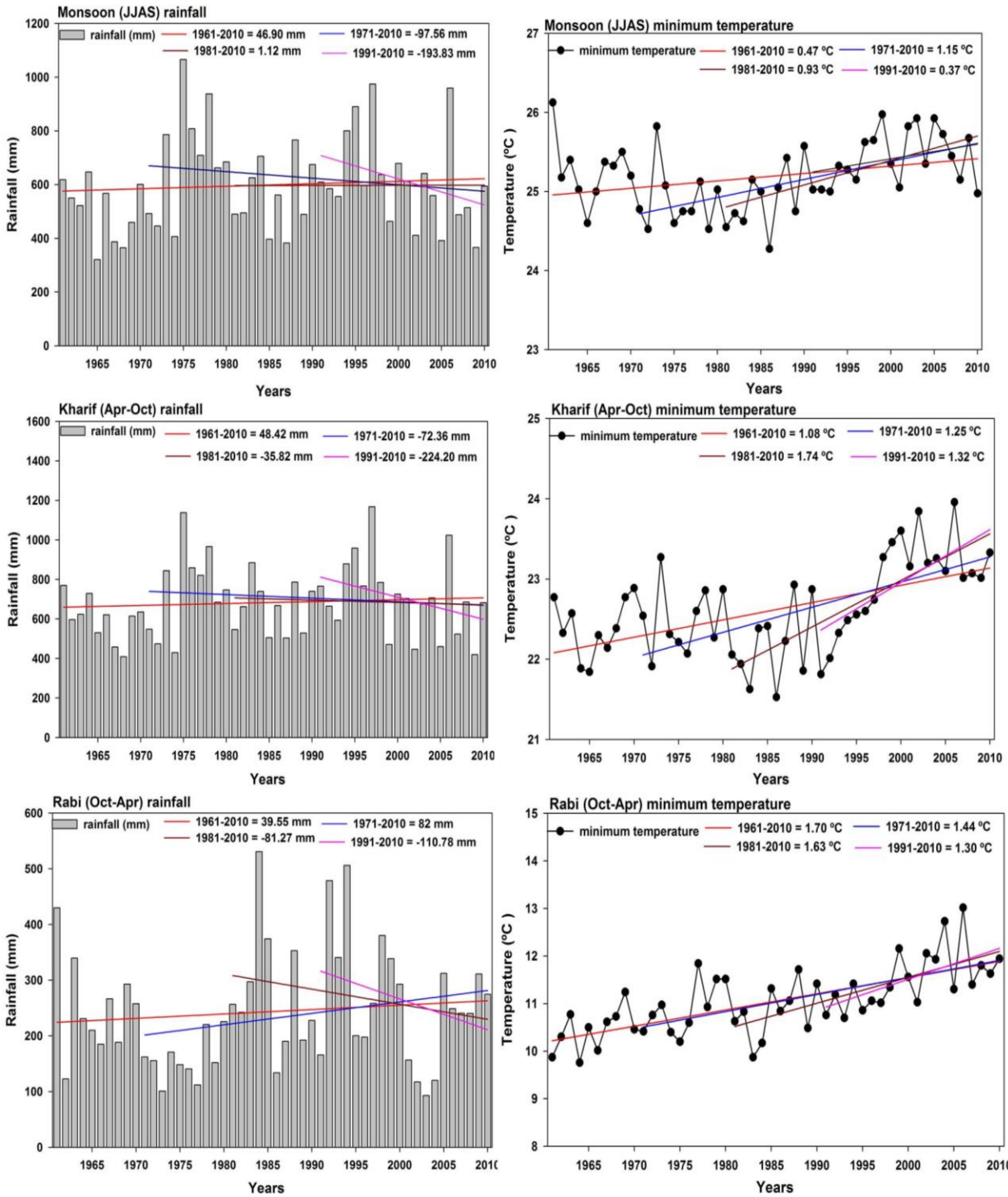

Figure-3. Panel (A) showing Monsoon, *Kharif* and *Rabi* rainfall, Panel (B) showing Monsoon, Kharif and Rabi minimum temperature of the Kanshi watershed.

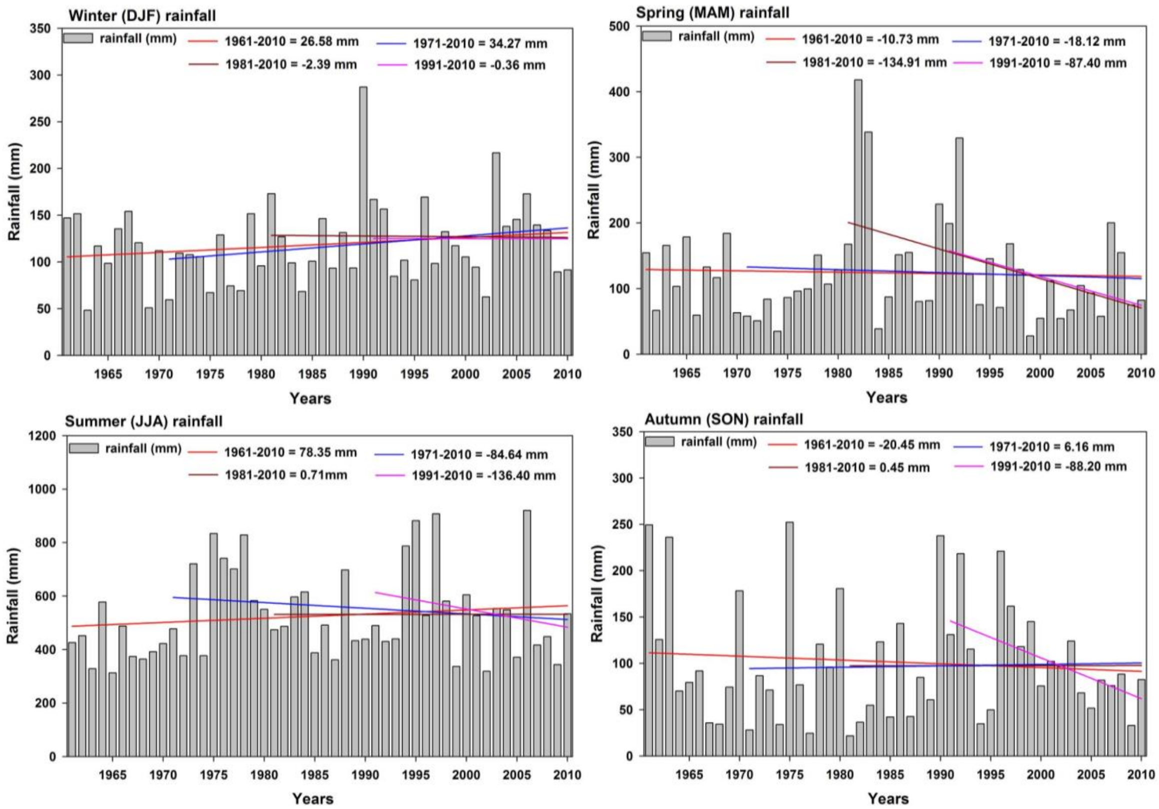

Figure-4. Trends of winter, spring, summer, and autumn rainfall of the Kanshi watershed.

Effects of rainfall and temperature on water discharge: The Kanshi river is the main drainage of the Potohar plateau region. The Kanshi river eroding the material and does not deposit it, like the other rivers of Punjab. The direction of the river's seasonal flow in a southern way and then in an eastern way to connect the Jhelum river. The main six streams included in the Kanshi river, namely Gulin, Guliana, Kurri, Phahna, Har, and Missa, joined each other and form a Kanshi stream network. The variation in temperature and rainfall at spatial and temporal measures distresses and affects the streamflow. Moreover, to investigate the effects of changing climate on streamflow, 50 years of stream flow from 1961-2010 was examined.

From 1961 to 2010, in August and September, the total water discharge had a significant and negative trend with p values 0.08 and 0.03. While, from 1971 to 2010, August had a significant and negative trend with p values 0.02. From 1981 to 2010, the water discharge had a significant and positive trend with a p-value of 0.02. While March, April, August, November, and December had a significant and negative trend with p values 0.00, 0.06, 0.02, 0.06 and 0.08, respectively. Similarly, last 20 years, from 1991- 2010, water release in the months of the January, March, August, September, October, and November had negative and significant trend with p values 0.06, 0.04, 0.00, 0.09, 0.07, and 0.03 respectively (Table 1).

Table 1. Shows the significance (p values) of monthly water discharge at Palote.

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961-2010	0.38	0.50	0.33	0.64	0.80	0.13	0.65	**0.08***	**0.03***	0.19	0.95	0.85
1971-2010	0.97	1.00	0.22	0.97	0.48	0.31	0.52	**0.02***	0.17	0.92	0.68	0.51
1981-2010	0.12	0.48	**0.00***	**0.06***	0.37	**0.02***	0.69	**0.02***	0.34	0.32	**0.06***	**0.08***
1991-2010	**0.06***	0.23	**0.04***	0.13	0.21	0.31	0.87	**0.01***	**0.09***	**0.07***	**0.03***	0.13

Correlation is significant at 0.001** and 0.05*

The significant and maximum discharge occurs in the Kanshi River in August due to the result of heavy rainfall in the winter season (Table 2, 3). The ground surface water table is the primary source for domestic use; however, the range of the Kanshi water table from 80-300 feet is very low-slung. This Kanshi watershed is divided into four zones. Each zone has a specific range. Due to the low depth of the water table, its drilling cost is very high, therefore, could not be used in the agriculture sector. In the Qazian zone, the water table approximately from 151-200 feet was measured. The water table in the Dongi zone, Missa-Keswal zone, and Guliana zone was observed ranges from 100-120 feet, 251-300 feet, and 121-130 feet, respectively.

Table-2. Shows the trend of monthly water discharge at Palote.

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961-2010	N	N	N	N	P	P	N	**N**	**N**	P	N	N
1971-2010	P	P	N	N	P	P	N	**N**	N	P	N	N
1981-2010	N	N	**N**	**N**	N	**P**	N	**N**	N	N	**N**	**N**
1991-2010	**N**	**N**	**N**	**N**	**N**	**P**	**N**	**N**	**N**	**N**	**N**	**N**

P = positive trend, N= negative trend

Table-3. Shows the significance (p values) and trend of seasonal Water discharge at Palote.

Years	Winter (DJF)		Spring (MAM)		Summer (JJA)		Autumn (SON)	
	P value	Trend	P value	Trend	P value	Trend	P value	Trend
1961-2010	0.32	P	0.38	N	0.19	N	**0.04***	**N**
1971-2010	0.90	P	0.63	N	**0.07***	**N**	0.13	N
1981-2010	0.19	N	**0.01***	**N**	0.12	N	0.21	N
1991-2010	**0.04***	**N**	**0.06***	**N**	**0.05***	**N**	**0.02***	**N**

Correlation is significant at 0.001** and 0.05*, P = positive trend, N= negative trend

According to Water and Power Development Authority (2010), the total discharge of Kanshi river from 1961 to 2010 was 289.72 (m^3/s) and discharge from 1971 to 2010, 1981 to 2010 and 1991 to 2010 was 232.40 (m^3/s), 170.40 (m^3/s) and 106.30 (m^3/s) respectively. Figure 4 shows that the average water discharge decreased from 1991 to 2010 was -5.76 (m^3/s). The reduced trend was observed in Water discharge (m^3/s) from 1995 to 2000 and followed in the next decade from 2000 to 2010.

The last 20 years from 1991 to 2010 found a significant and negative trend. Therefore, the highest flow of water discharge was found in 1992 in the Kanshi River catchment due to heavy rainfall. The average water release from 1991 to 2010 was declined, but the 2010 flow was at its peak value. Similarly, in 2010, heavy rainfall showed that had caused flooding in Pakistan (Abid *et al*. 2015). However, it might be estimated that the average Water discharge from 2011 to 2020 would be 63.130 (m^3/sec). If it is reduced by 43.11 % in the usual water discharge of 53.1045 (m^3/sec), then the total water discharge of the Kanshi river in the next decade from 2011 to 2020 would be 34.685 (m^3/s) and if there is a 43.11 % increase in average water discharge of 62.1045 (m^3/sec) then the total water discharge might be 89.514 (m^3/sec).

From 1961 to 2010, during the autumn season, the total water discharge had a significant and negative trend with p values 0.04. While during 1971 to 2010, the summer season had a substantial and negative trend with p values 0.07. The water discharge from 1981 to 2010, spring season had a significant and negative trend with a p-value of 0.01. So, last 20 years from 1991 to 2010, the water discharge in all seasons like winter, spring, summer, and autumn had a negative and significant trend with p values 0.04, 0.06, 0.05, and 0.02, respectively (Table 3). The water discharge trend declined in the winter; spring, summer, and autumn seasons at the rate of -0.206, -0.123, -0.520, and -0.209 m^3/sec / year during the last two decades from 1991 to 2010. The highest change observed in the summer season was due to the decline in the trend of rainfall and the rise in the mean temperature in the Kanshi watershed area (Fig. 5 A-D).

Fig. 5E revealed that annual water discharge decreased from 1961 to 2010 at the rate of -0.0685 m^3/sec / year due to the decline in the trend of rainfall. Similarly, during the periods of 1971-2010, 1981-2010, and 1991-2010 decrease trend at the rate of -0.0327, -0.1070, and -0.2899 m^3/sec / year. The mean temperature in annual and spring, winter and autumn seasons had risen for the period 1961-2010. The outcomes of annual and seasonal rainfall show that the trends were not steady and consistent. The annual streamflow's in the Kanshi river and watershed to reduce up to 41 % with a rise of 1°C annual mean temperature for the period of 50 years from 1961-2010 (Yaseen *et al.*, 2016). The water discharge of the Kanshi river has reduced by 44.15 % during the last two decades from 1991-2010. This substantial and significant change resulted from climate change or increased intercession of anthropogenic activities on the earth's surface. Furthermore, such variations in streamflow of the Kanshi river due to changes in rainfall pattern and temperature intensity have negative effects on the land use pattern and vegetation cover (Shakir *et al.*, 2010).

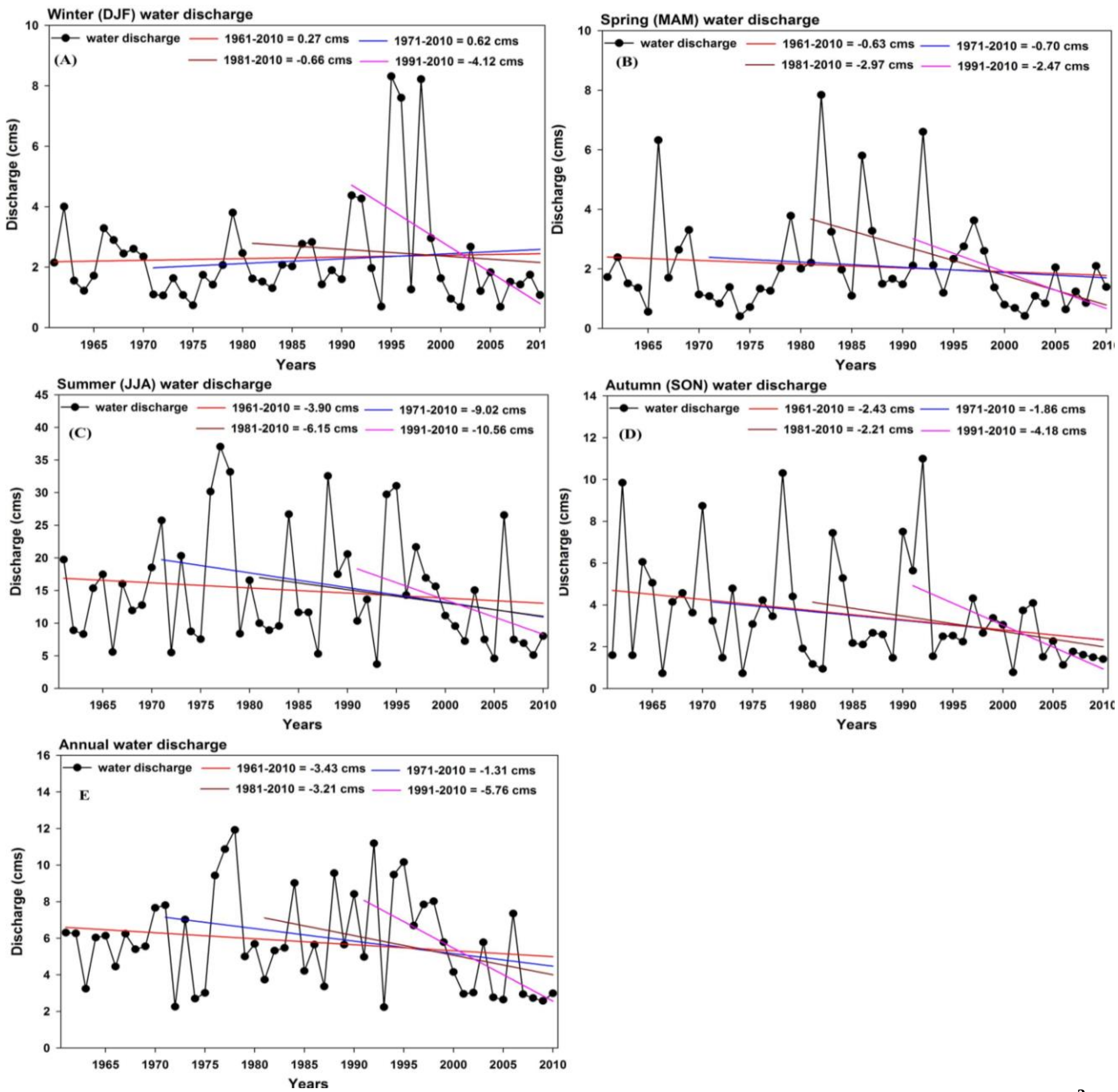

Figure-5. Shows winter (A), spring (B), summer (C) autumn (D) and annual (E) water discharge (m^3/s) of the Kanshi river at Palote.

Conclusion: In this study, statistical methods were applied to investigate the effects of climate change on the streamflow in the Potohar Plateau region of the Kanshi watershed. The unexpected decreasing trend of rainfall during the last two decades is to observe. The water discharge was also decreased by 44.15 % during the last two decades. This substantial and significant change resultant due to climate change or increased intercession of anthropogenic activities on the earth's surface. The current study recommended that a water harvesting structure be constructed for the water resource management to reduce the impact of climate on the vegetative cover of Agro-zones of the Kanshi watershed.

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