TRENDS AND VARIABILITY OF TEMPERATURE TIME SERIES OVER THE KANSHI CATCHMENT IN THE POTOHAR REGION OF PUNJAB-PAKISTAN

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ABSTRACT: The variabilities and changing trends of temperature in the Potohar region have been examined in this study for the period of 1950-2018. Monthly data of mean, maximum and minimum temperature were acquired from Pakistan Meteorological Department (PMD) and slope method was opted to calculate the variation rate of temperature for the period under investigation. The results of the study revealed the rising trend of temperature over the Kanshi catchment in northern Punjab, for the period under study. Trends of maximum temperature significantly increased to a rate of 0.0134 °C/ year, while minimum temperature was also found to have increased at the rate of 0.0334 °C / year. Such high rate of temperacture increase can be attributed to settlement expansion an outcome of rapid urbanization, in Jhelum city. In comparison to maximum temperature (Tmax), the rate of increase of minimum temperature was identified to be more rapid. Correspondingly, a sum of 1 to 2°C increase in minimum temperature was observed, in the study area, for the period under study. The identified temperature changes are anticipated to have adverse consequences particularly for the agriculture and livestock sectors and food security in the region.

Key words: Variability, trend, temperature, predicted, Kanshi catchment, Potohar region.

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INTRODUCTION

Climate change continues to leave irreplaceable marks on developing economies. Variations in temperature have negative impacts on health, inflation, fresh water availability and agricultural production. The temperature intensity affects the institutional, political, economic, demographic, technological, social and operational aspects, at diverse scales (Seaman *et al.,* 2014; Zhang *et al.,* 2015; Abbas *et al.,* 2020). It is essential in order to identify the nature of relationship between health issues, food quality, agricultural productivity and climatic changes, in a typical vulnerability of extreme events assessment. It is essential to understand the policy matters about these issues and analyze the links between them and certain climate variables (Bradbear and Friel, 2013; Abid *et al.,* 2015; Abbas *et al.,* 2020b).

The change in land use pattern linked to anthropogenic activities, leads to increased concentration of CO_2 in the atmosphere, which in turn causes the temperature to rise. The land use patterns are badly affected by temperature intensity and rainfall pattern. Copeland *et. al.,* (2010) lists variation in patterns of vegetation cover and deforestation as the main reasons of climate change. Abbas *et al.,* (2018) also exhibited that land use pattern is undergoing a prominent change in the Kanshi catchment of the Potohar region in Pakistan, where the forest area is being converted into settlements and agricultural area. The agriculture being practiced at an extensive scale is also held responsible to be one of the main reasons of soil erosion,running water, wind and tillage also act as erosion agents and play vital role in the erosion of the cultivable land.

The conversion of the forest area into agrarian land was a basic reason of the maximum flow in channels and stream networks that accelerated the soil erosion, in Kanshi catchment. Alternatively, the soil erosion and cultivation processes in the fields, both affect the soil fertility and its properties on micro and macro scale in Punjab, Pakistan (Ali *et al.,* 2017). Nawaz *et al.,* (2018) also exhibited that the temperature of Punjab is increasing from north to south and high temperature trends were observed in the plain areas of the Punjab.

The observed variations of river flow in Pakistan is an outcome of unpredicted precipitation trends. Shakir *et al.,* (2010) has reported that water flows in the rivers of northern regions of Pakistan had decreased by 2.4 %. Increase in temperature has greater effects on human wellbeing around the globe (Afzaal *et al.,* 2009; Khan *et* *al.,* 2019). Water flow in rivers and temperature are the key factors to investigate the spatial and temporal climate variability. Like many regions on planet facing consequences of climate change, Punjab province also lies in a region which is facing the impacts of unprecedented climate change due to its diverse geographical location and climatic features.

The earth's environment and ecosystems are badly affected by massive man-made modifications (Grimm *et al.,* 2008). Land adaptation strategies employ the mechanism of growth trend in urban areas and resultantly, the transformation from rural to urban areas have created more impact on various sectors such as energy, climate variability, biodiversity and biochemical cycles, at both local and regional scales (Sajjad *et al.*, 2009). In rapidly developing economies, the variations in climate, associated with land use/land cover variations, are a common observance. Consequently, due to persistent socioeconomic development, changes are observed as ecological degradation and substantial disintegration in landscape The related environmental impacts have so far been diverse in areas that were once covered with forests. Besides, agricultural land is massively converted into built up areas, where rapid urbanization is being experienced as an impact of uncontrolled anthropogenic activities. Baig and Amjad, (2014) also reported that vegetation cover is being converted into cultivated land in Pakistan for the last two decades. In this context, it was identified that the trends and variability of temperature over a long period has not been investigated for Potohar region, and this study aims to address this gap in the literature. However, there is a need to assess the trends and variability of temperature over the Kanshi catchment area. The main objective of this study is to find out variability and changing trends of temperature in the Potohar region for the period of 1950-2018.

MATERIALS AND METHODS

Jhelum district is located in the northern part of the Punjab province of Pakistan and is one of the four districts of Rawalpindi division. Originally, it comprised of three tehsils, Jhelum, Chakwal and Pind Dadan Khan. During the year 1992, Chakwal district was created comprising of Chakwal tehsil. The Jhelum district consists of four towns Jhelum city, Dina, Pind Dadan Khan and Sohawa.

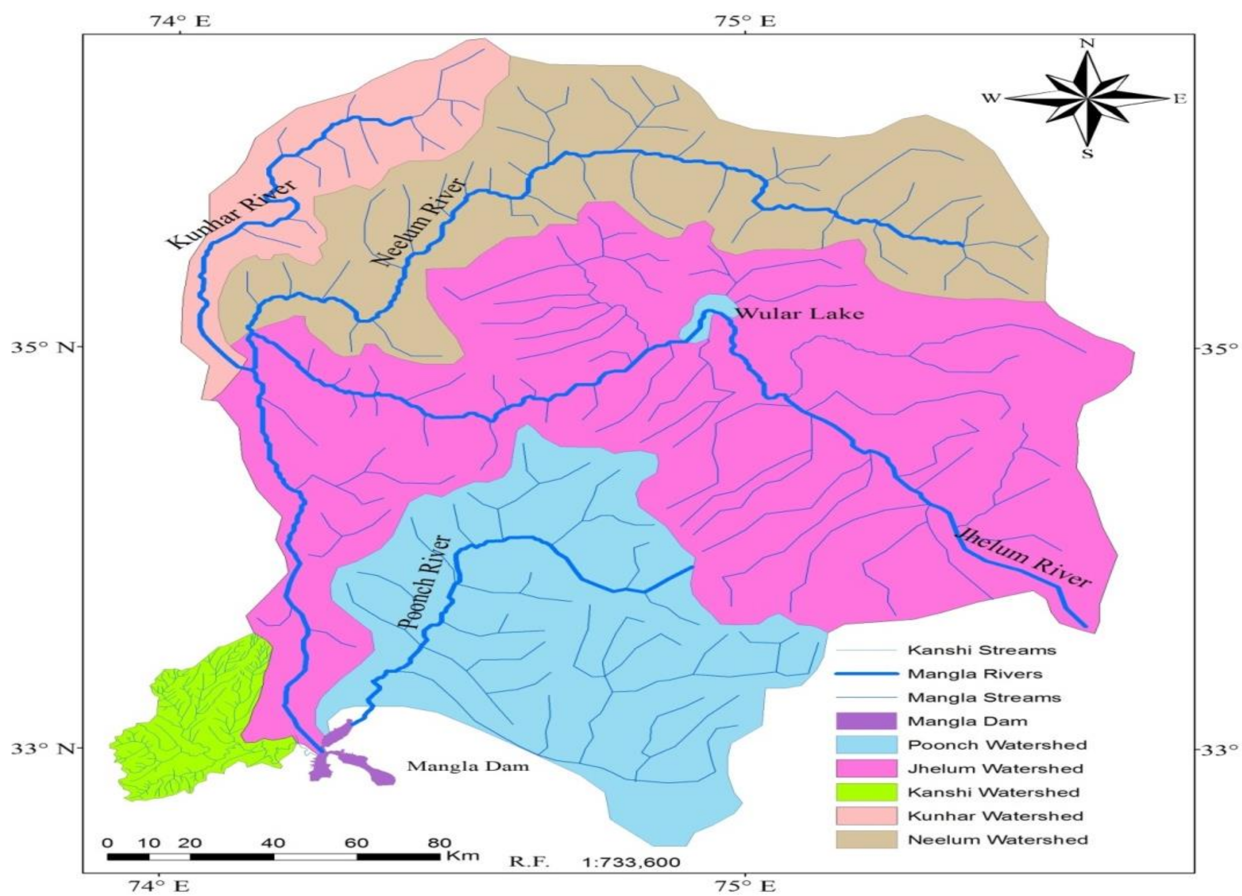

Figure-1. Location map of Mangala watershed with its sub catchment.

Geographically, Jhelum is divided into three regions. These regions may be termed as riverine, the upland and the Plateau region, respectively. There is a long stretch of plain level land around Jhelum. This area is elongated into a narrow strip, located along the course of the river, which is overlooked by hills near plateau region.

The Kanshi Catchment area shown in Figure 2, is the sub catchment of the Mangala watershed (Figure 1). The Kanshi catchment is located in tehsil Gujar Khan and Kahuta of Rawalpindi district. There are six sub streams found in Kanshi catchment i.e., Har, Kurri, Missa, Guliana, Phahna and Gulin. These sub streams join the drain of the Kanshi with Jhelum river at 33°15´ north Latitude and 73°36´ east Longitude.

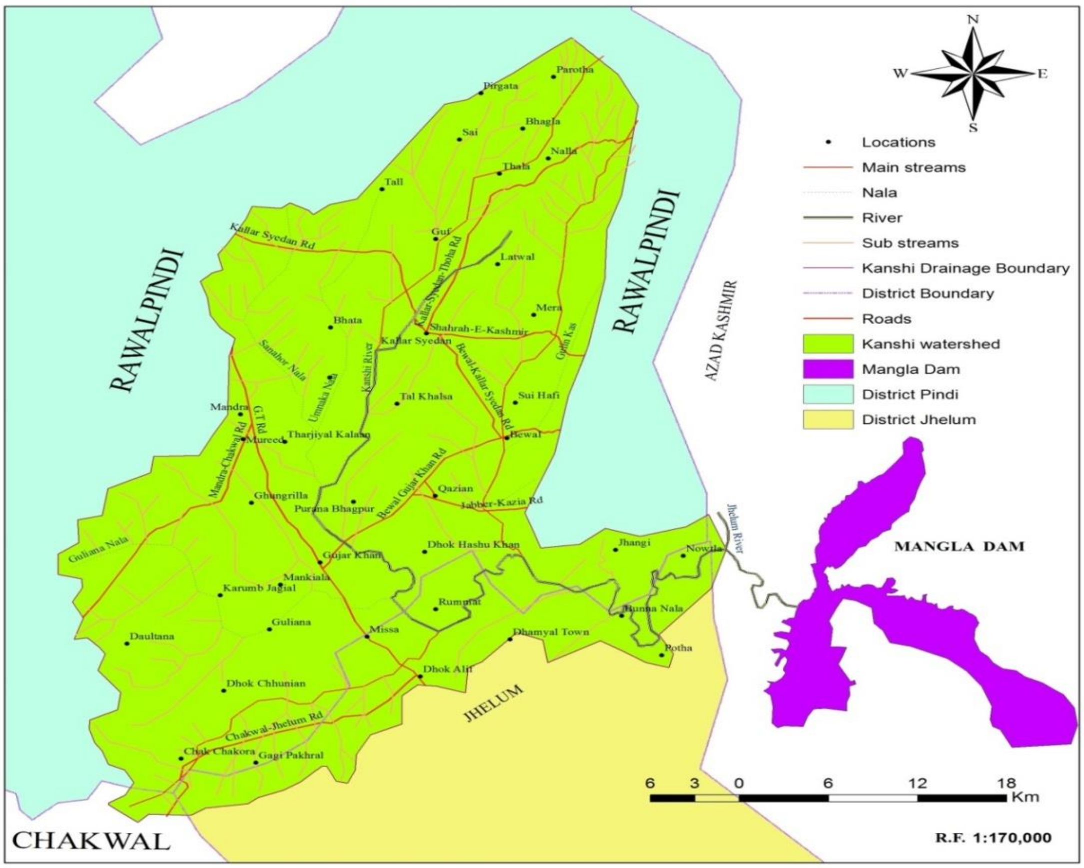

Figure-2. Location map of the Kanshi catchment area.

During this study, the daily datasets of the Jhelum weather station were collected from Pakistan Meteorological Department (PMD) for the period of 68 years from 1950-2018. The mean monthly *T*max, *T*min and *T*mean temperatures were calculated from the daily maximum, daily minimum and daily mean temperatures. The *T*mean were calculated through the arithmetic average of *T*max and *T*min. Temperature datasets for four seasons, winter (December, January and February) (DJF), spring (March, April and May) (MAM)), summer (June, July and August (JJA)) and autumn (September, October and November) (SON), were tabulated by taking the average of the monthly values of the data sets.

Trend of data was shown through trend line which was drawn on the basis of a moving average of every five years from 1950 to 2080. The forecast function is employed to calculate a future value by using the linear regression method (Sajjad *et al.*, 2009; Abbas and Mayo, 2020a). The present study employs linear regression to find out the trends of *T*max, *T*min and *T*mean. Slope value used to evaluate an absolute change of the investigated span has also been calculated in this study. Linear regression describes the linear relationship between two variables x and y (Abbas *et al*., 2016; Abbas *et al*., 2020c).

$X = a + bY$

Y = independent or predictor

X = dependent or Predict

Vertical distance between data points and line is called errors or residuals.

$$E_i = X_i - X(Y_i) \quad (1)$$

This is the separated risiduals for each data pair. Minimized sum of R squares defines the best fitting line.

$$X = X_i + e_i = a + bY_i + e_i \quad (2)$$

True value of predicted is the sum of the predicted value and residual.

For analytical expression, least square intercept a and slope b is a straightforward exercise in order to minimize the sum of squared residuals.

$\sum_{i=1}^{n}(\mathbf{e}_i)\mathbf{2} = \sum_{i=1}^{n}(\mathrm{x}-\mathrm{x}_i)^2 = \sum_{i=1}^{n}(\mathrm{x}_i - [\mathrm{a} + \mathrm{byi}])^2$ (3)

It is only necessary to set the derivatives of equation 4 with respect to the parameters a and b to Zero and solve.

$\partial\sum_{i=1}^{n}(\mathrm{e}_i)^2 = \partial\sum_{i=1}^{n}(\mathrm{y}-\mathrm{a}-\mathrm{bxi})^2/\partial a = -2\sum_{i=1}^{n}(\mathrm{x}_i-\mathrm{a}-\mathrm{byi}])^2 = 0$ (4)

$\partial\sum_{i=1}^{n}(\mathrm{e}_i)^2 = \partial\sum_{i=1}^{n}(\mathrm{x}-\mathrm{a}-\mathrm{byi})^2/\partial b = -2\sum_{i=1}^{n}(\mathrm{x}_i-\mathrm{a}-\mathrm{byi}])^2 = 0$ (5)

Rearranging equations 4 and 5 so called normal equation

$$\sum_{i=1}^{n}(\mathbf{x}_i\mathbf{y}_i) = \mathbf{a}\sum_{i=1}^{n}(\mathbf{x}_i) + \mathbf{b}\sum_{i=1}^{n}(\mathbf{x}_i)^2 \quad (6)$$

Dividing equation 6 a by n leads to the observation that fitted regression line must pass through point located by two sample means of x and y.

RESULTS AND DISCUSSION

Annual temperature trends and variability over Kanshi catchment: Figure 2 depicts the results of trend analysis in Kanshi catchment using the statistical method. The results revealed the increasing trend of *T*max, *T*min and *T*mean with the rate of 0.010°C, 0.015°C and 0.017°C per year respectively for the investigated span. From a detailed analysis , it is deduced that significant trend of maximum and minimum temperature was found positive at the rate of 0.14, and 0.04 °C per year for the period of 1981-2018 (Figure 3).

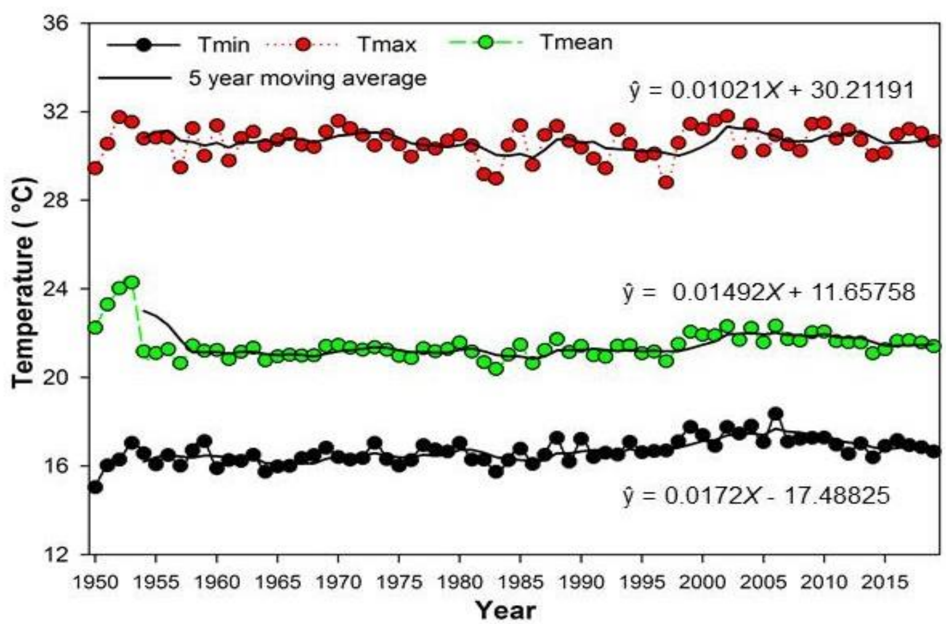

Figure- 3. Trends and variability of annual temperature in Kanshi.

In Kanshi catchment area, the substantial decreasing trend of annual temperature was observed at the rate of 0.010°C and 0.012°C per year, whereas the maximum temperature was found to be increasing at the rate of 0.021°C per year from 1950-1980. These results declare that intensity of temperature is increasing with perceived warming trends of *T*max over the catchment of the Kanshi watershed. Similar results were reported by the recent researches (Nawaz *et al.,* 2019; Abbas *et al.,* 2018a, b; Afzaal *et al.,* 2009). Recent literature helps conclude that Maximum temperature of Punjab is increasing with the rate of 0.10°C per year since the last century. Similarly, a decreasing trend of the minimum temperature has also been reported from 1981-2018, at the rate of the 0.04°C per year (Nawaz *et al.,* 2019; Yaseen *et al.,* 2014). From the monthly analysis of temperature datasets, the results indicate that high maximum temperature was measured in the month of June which was 42.90 °C in 1995, whereas, the maximum temperature in the month of December was 20.2 °C recorded in 2011. The minimum temperature of 9.60 °C was observed in 2008, in the Jhelum district of the Potohar region, for the period under study.

Seasonal Maximum temperature trends and variability over Kanshi: Results revealed that a significant correlation coefficient was noticed during the investigated span. The detailed examination of the Seasonal Maximum temperature depicts variation in temperature over the Kanshi catchment area (Figure 4). The winter and spring seasons have opposite trends as compared to summer and autumn seasons.

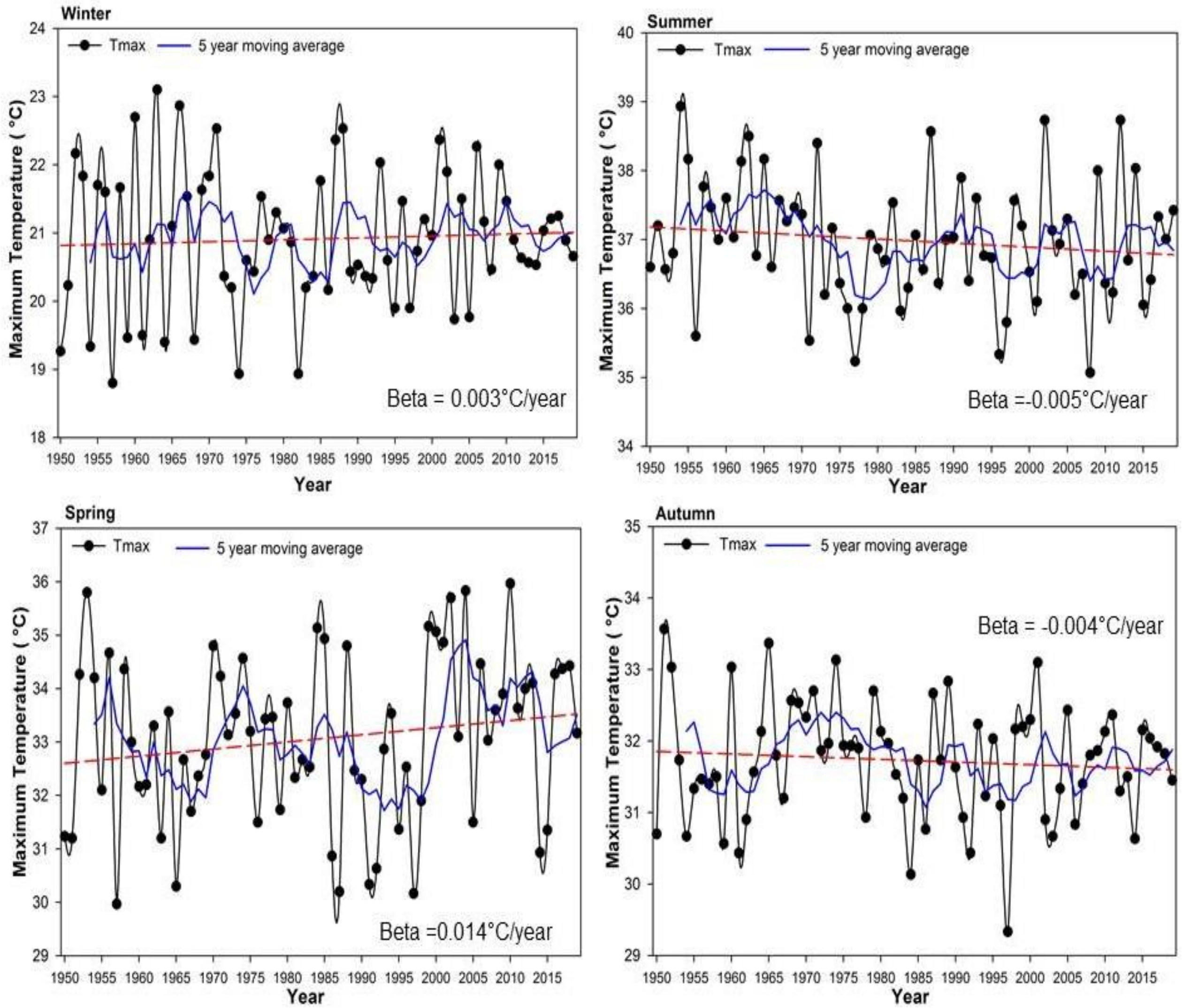

Figure-4. **Trends and variability of maximum temperature in Kanshi.**

Trend analysis indicated that Maximum temperature observed increased during the winter and spring season at the rate of 0.003°C and 0.014°C per year. Maximum temperature during the summer and autumn season observed non-significant decreasing trend, with the rate of -0.005°C and 0.004°C per year respectively. Khattak *et al.,* (2011) also reported that Tmax is increasing in the winter season in the Kanshi catchment area of the Indus basin, Pakistan. The findings of UNFCCC (2007) also support the results of this examination that shifting pattern of temperature over the Punjab province was observed in Pakistan. Our results are also in line with the previous studies (Abbas *et al.,* 2018; Yaseen *et al.,* 2014, 2015)

Seasonal Minimum temperature trends and variability over Kanshi: The seasonal trends in *T*min over Kanshi catchment are presented in Figure 4. The beta value of the annual *T*min showed an increasing trend over Kanshi catchment basin, which showed a significant increasing at the magnitude of −0. 015 ◦C / year. For the winter season, the *T*min exposed the increasingly significant affinity over the entire period but was found to be decreasing from 1981-2018 at the rate of -0.012 ◦C / year (Ahmed *et al.*, 2014). The highest increase in minimum temperature was observed at the rate of 0.070 ◦C/year over the Kanshi watershed area. This beta value confirmed the highest magnitude in autumn season. Similarly, Beta value of *T*min in spring season also revealed a significant positive trend at the rate of 0.070

◦C / year over the Kanshi watershed area. The inclinations in minimum temperature during the winter and summer season presented an insignificant increasing trend at the rate of 0.005 and 0.002 ◦C / year (Figure 5). Analogous findings have been reported in the previous studies (Khan et al., 2018; Qasim et al., 2014).

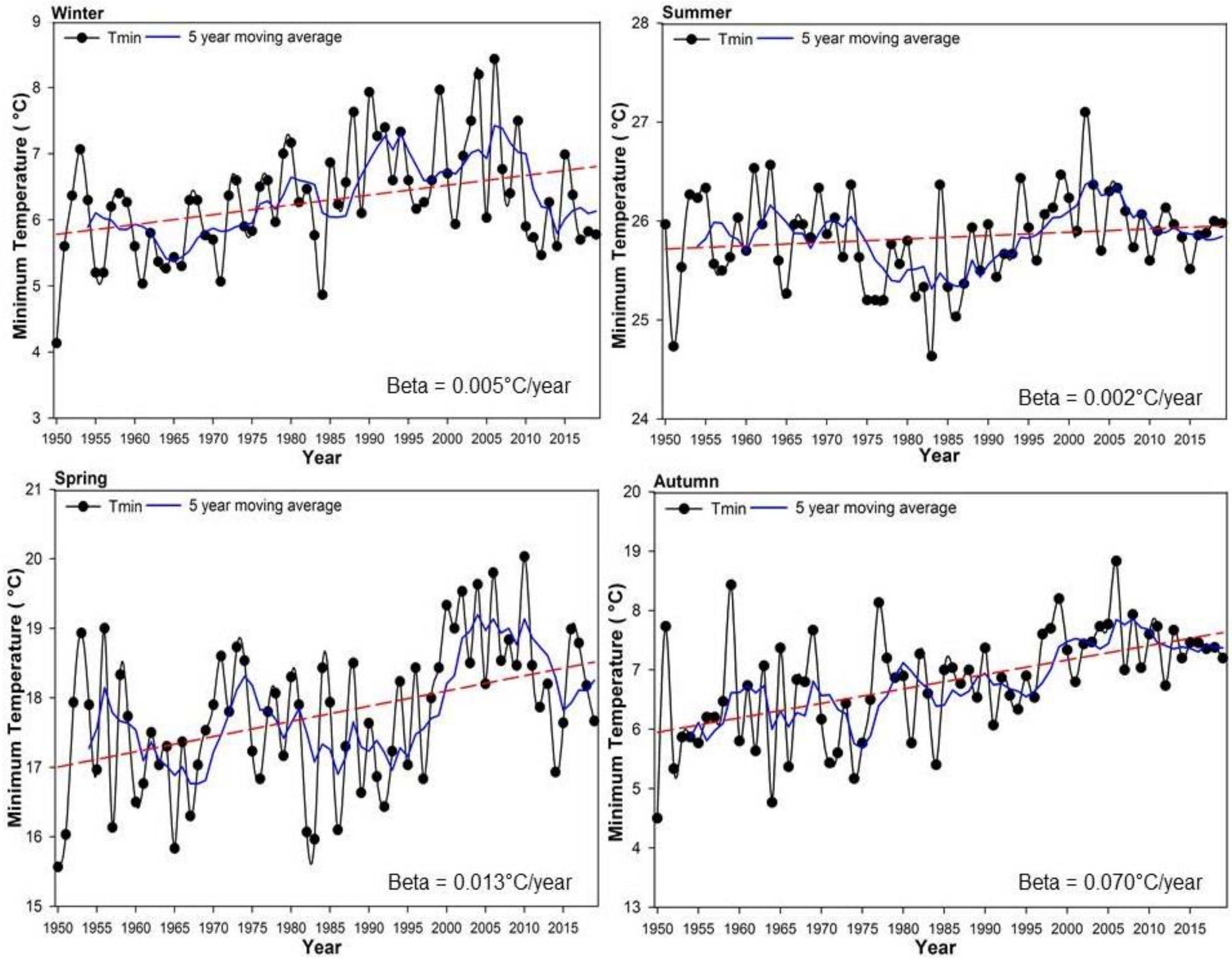

Figure-5. Trends and Variability of Minimum Temperature over Kanshi.

Minimum and Maximum temperature future scenario trends over Kanshi: The rate of change of minimum temperature observed during 1950-2080, is 0.0169 ◦C/ year. The value of R^2 shows that 79.2 % of the variability in the minimum temperature of the Kanshi catchment can be explained by the given regression.

The second-degree polynomial regression models showed to be more strong and fit (R^2=79%) in estimating the trend of *T* min during 1950-2080 (Figure 6a). The trend of maximum temperature during 1950-2080 is found to be increasing at the rate of 0.0017 ◦C/ year. The value of R^2 shows 24.5 % of the variability in the maximum temperature of the Kanshi catchment. The second-degree polynomial regression models proved low and fit (R^2 = 24.5 %) in estimating the trend of *T*max during 1950-2080 (Figure 6b).

Abbas et al., (2018) also stated that 70% of residents of Kanshi catchment are associated with agriculture, while the remaining 30% adopts livestock herding as their main source of income generation. Thus, *T*min is significant as its rise makes the economy more vulnerable in the Kanshi catchment area. An important reason behind it, is that this region is densely populated and increasing number of individuals living here would lead to an escalation in removing the vegetative cover to build more housing schemes to accommodate such large number of people, industries and factories to meet their needs and employment, roads for transportation and large areas ending up being cleared for infrastructural development These clearings are inversely proportional to the area covered with vegetation. The more land is cleared up, lesser would be the area left for growing vegetation (Abbas *et al.,* 2018a), and the greater the rise in mean, maximum and minimum temperatures.

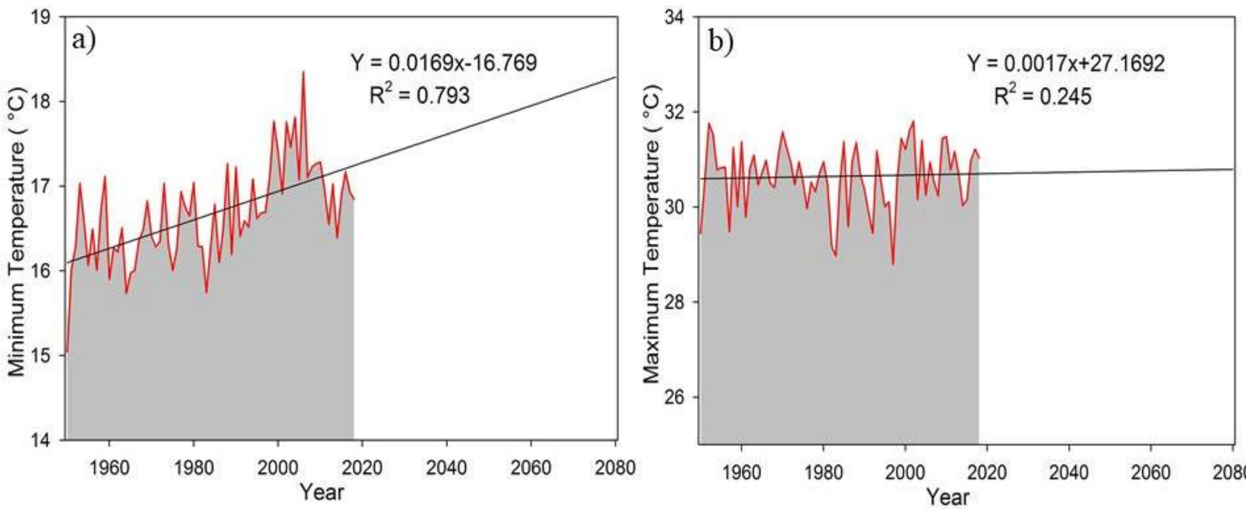

Figure-6. Trend line showing the future prediction of *T*max and *T*min of Kanshi catchment until 2080.

Conclusion: Trends and variability of annual and seasonal maximum, minimum and mean temperature are investigated for a period of 1950-2018, for the Kanshi catchment area. The identified temperature changes are anticipated to have consequences for the agricultural activities and food security in the study area. The anthropogenic activities linked to rapid urbanization was found to be associated with variations of temperature both annually and seasonally in the study area. Annual *T*max, *T*min and *T*mean for Kanshi watershed have the warming trend rate of 0.010 °C, 0.015 °C and 0.017 °C/ year respectively and indicated that annual maximum and minimum temperature has significantly increased up to 2.9% and 1.6% respectively. The trends for winter temperatures reveal that maximum and minimum observed temperature in Kanshi area has shown an increasing trend at the rate of 0.003°C and 0.005°C/ year respectively. Nevertheless, further study is required to estimate the effects of local climatic conditions on the stream flow and precipitation in the Kanshi catchment.

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