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Abstract

This study aims to analyze trends of three, annual average temperature, annual average T-max, annual average T-mini, and precipitation over the last 30 years 1990-2019 in Kandahar City, the western part of Afghanistan. For the purpose of analysis, available data from Afghanistan Meteorological Department (AMD) and Power Data Access Viewer dataset were used. First, daily average temperature and precipitation data were converted to monthly average data, then converted to annual average data for statistical calculation. The linear regression equation and trend magnitude was applied to identify the trend of temperature and precipitation. Analysis of the data demonstrated an upward trend in average temperature, average T-max, average T-mini, and downward precipitation, the most upward trend obtained in an annual average of T-mini and less upward trend in an annual average of T-max. Simultaneously, by increasing temperature, precipitation decreased which indicates dry and hot temperatures. The ongoing climate change affects various factors, especially agriculture, and socio-economics. On this basis, it is recommended that the result could serve as a key in making plans and policies for those authorities involved in the planning. Further research is needed to identify other climatic parameters for a comprehensive understanding of the current and future climatic situation of the study area.

Keywords: *Air temperature, Precipitation, Climate change, Kandahar city, Trend line*

Introduction

Air temperature and precipitation are the most vital variable for identifying a climatic region and indicate the hotness, coldness and moisture of the air. It regulates several weather parameters such as rate of evaporation, percentage of relative humidity, amount of precipitation and wind speed. According to highly reliable data from IPCC, the period from 1983 to 2012 was the warmest thirty-year period in Northern Hemisphere over the last 800 years [1]. More studies regarding climate in Afghanistan show that the annual average temperature increased since 1950 by 1.8 °C and precipitation decreased, it affected negatively Afghanistan's population which 80% depends on agriculture [2].

Kandahar City, the study area is an urban region, surrounded by the territory of Margo, Jahandum, and Sistan deserts in the south and west, this area indicates a desert area with hot weather and less precipitation. The purpose of this study is to examine the linear trend of air temperature and precipitation from 1990-2019 in Kandahar City, so it is essential to gain a depth understanding of linear air temperature trends. While there has

been much research on climate change and its effects on the country in general, but none has focused specifically on regional and how this trend line determines the climate condition of the region.

The questions are what was the air temperature trend in the last three decades in Kandahar City? Did air temperature increase or decrease during the period of study? What is the relationship between temperature and precipitation? The study aims to analyze air temperature and precipitation trends to determine the amount of change in temperature and precipitation and identify the relationship between air temperature (T-max, T-mini) and precipitation in Kandahar City over the recent three decades. Afghanistan is the most vulnerable country to climate change and its impacts ranked 175th out of 182 countries in the 2020 ND-GAIN Index [3]. It means that Afghanistan is the eighth most vulnerable country to climate change in the world, while has no role in climate change but pays the highest cost.

1.2 Study area

Kandahar province fig (1) is one the largest province located in the south of Afghanistan sharing a border with Pakistan [4]. The research area is located between 31° 35′ 43″ N latitude and 65° 40′ 51″ E longitude with an elevation of 1289 m above sea level, with a population of 2,857,200 and an area of 47676 km² [5]. Kandahar City is including of the first-grade city in Afghanistan and is a financial center in the southern part of Afghanistan. This province is bordered by Oruzgan Province to the North, Durand Line and Baluchistan to the South, Helmand Province to the west, and Zabul Province to the East [5].

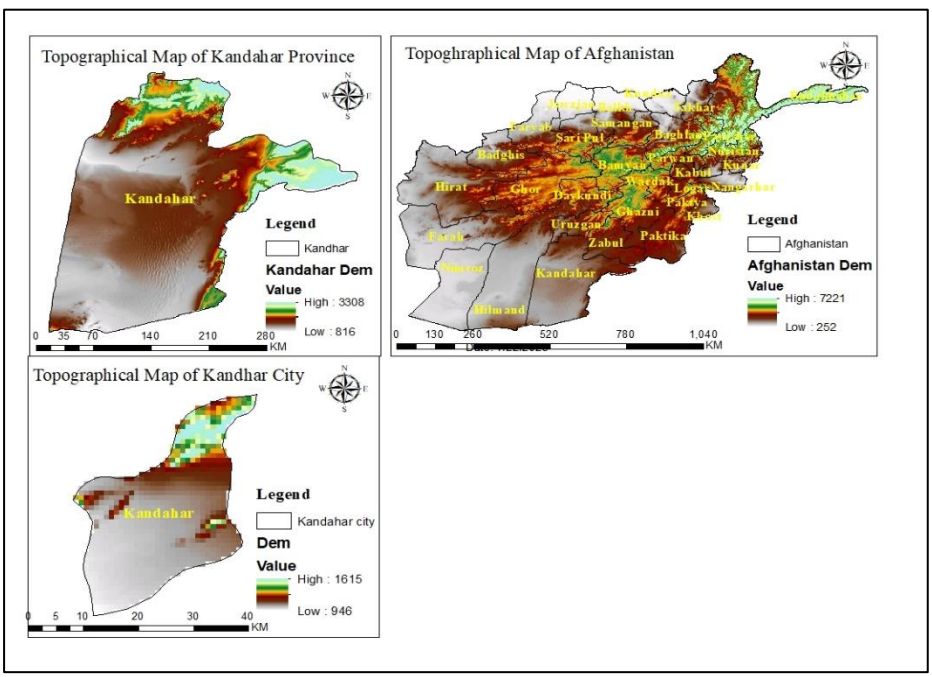


Figure 1: Topographic map of Kandahar (Author)

From a physical geographical aspect, Kandahar City is an urban region, surrounded by the territory of Margo, Jahandum, and Sistan deserts in the south and west of the province. The climate of Kandahar is arid. According to UNESCO (1979) definitions: arid and hyper-arid zones are distinguished by the ratio of mean annual precipitation (P) to

mean annual potential evapotranspiration (PET), arid zones are defined by P/PET as less than 0.20 and greater than 0.03, and hyper-arid zones have less than 0.03 P/PET. While the P/PEP of Kandahar is 0.08 which indicates an arid climate [6].

2. Data and methodology

The paper analyzed air temperature trends (mean temperature, mean T-max, mean T-mini) of the target area for the period of three decades from 1990 to 2019. The data related to mentioned study was collected from the Afghanistan Meteorological Department (AMD) and the Ministry of Energy and Water of Afghanistan. Because of civil war and turmoil conditions in Afghanistan, there were no consecutive records in the weather stations or with some missing in observed data records. In addition, supplementary data for filing the gaps were downloaded from the Power Data Access Viewer dataset which contains meteorological and solar-related parameters formulated for assessing and designing climatic data and renewable energy.

The data was on daily records, daily average temperature converted to monthly and monthly average converted to the annual average for analyzing the trend of temperature for the period of 30 years. In the same way as temperature as precipitation is evaluated to assess the impact of temperature change on precipitation and its relationship.

The Microsoft Office Excel program was used to determine air temperature trends. Linear regression equation analysis is used in order to analyze, evaluate and distribute the range of changes in air temperature. Its general form is:

$$y = ax + b \qquad (1)$$

In which (y) is the air temperature expressed in ^{o}C, (a) is the gradient, (x) is the time series, and (b) is the initial temperature. The air temperature trend value correlates with the gradient. There are three possible scenarios: a) if the gradient is higher than zero – the trend is positive (growing), b) if the gradient is smaller than zero – the trend is negative (declining), c) if the gradient is equal to zero – there is no trend. The trend magnitude is determined by using the linear trend equation [7] as follows:

$$\Delta y = y(1990) - y(2019) \qquad (2)$$

In which Δy is the trend magnitude expressed in ^{o}C, y (1990) is the air temperature at the beginning of the period, and y (2019) is the air temperature at the end of the period. There are three possible scenarios with the trend magnitude: a) if Δy is higher than zero – the trend is negative (declining), b) if Δy is smaller than zero – the trend is positive (growing), and c) if Δy is equal to zero – there is no trend [7].

3. Results and Discussion

The presented work was tested according to the data series of Kandahar Meteorological Station and data from Power Data Access Viewer. A 30 years air temperature and precipitation data series from 1990 to 2019 were used. Accordingly, the data were grouped into four statistical series: annual average, T-max, T-mini air temperatures, and precipitation. First, daily average data in three groups was converted to monthly average and after that converted to annual average. Its charts were drawn, and trend lines were applied to show the rate of change in air temperature and precipitation during the time study. All mentioned steps were implemented and shown in the figures below.

Figure (2) shows a positive linear trend which indicates an increase in air temperature in Kandahar city from 1990 to 2019 with the rate of 0.0377° C/year and 1.131° C/30 years.

$$y = 0.0377x + 17.938$$

In this equation a is equal to 0.0377 °C which is higher than zero and indicates a positive trend (growing) air temperature.

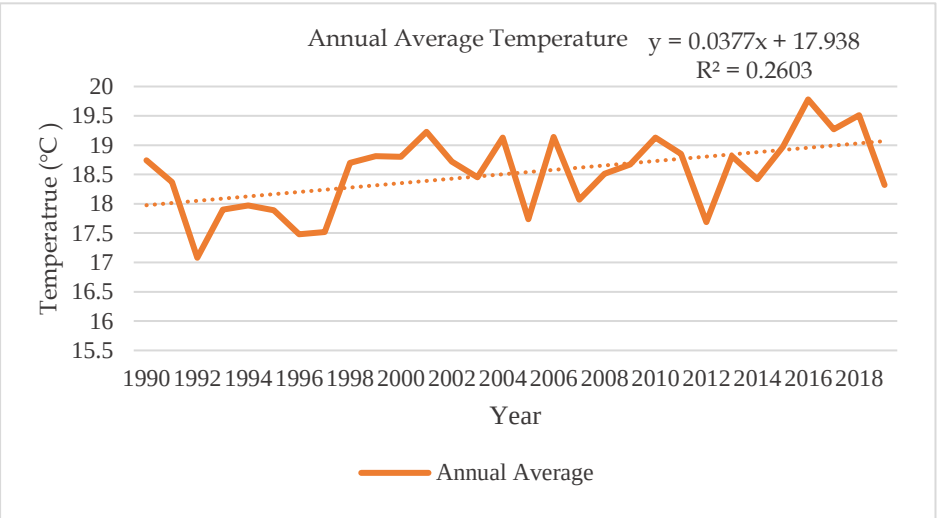


Figure 2: Annual Average Temperature in Kandahar City 1990-2019

Figure (2) air temperature exhibits an increasing trend with the passage of time, this may be attributed to changes in land use patterns, unplanned urbanization, intense population, and use of fossil fuel. In addition, the rise in temperature is also attributed to the gradual increase of atmospheric carbon dioxide and global climate change.

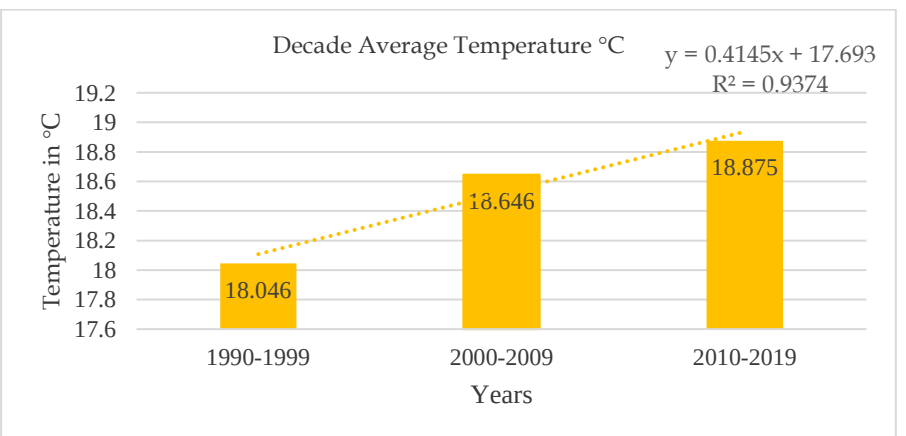


Figure 3: Decade Average Temperature in Kandahar city 1990-2019

The decade average temperature trend line shows that temperature has increased at the rate of 0.4145 ºC per decade, which can be identified from Figure (3). The analysis shows that the first-decade average temperature of the study periods (1990-1999) was 18.046 °C, the second-decade average temperature of the study periods (2000-2009) was 18.646 °C, and the third-decade average temperature of the study periods (2010-2019) was 18.875 °C. From the first decade to the third decade of the study, the average temperature has

increased by 0.829 °C, near to 0.9 °C has increased totally. If we observe three warm and cold years during the study period time, table (1) clearly shows that the three warm years comparatively are 2016, 2018 and 2017 which all are after 2010, and the three cold years are 1992, 1996, and 1997 which is before 2000. It indicates that air temperature increased at a high rate in recent years.

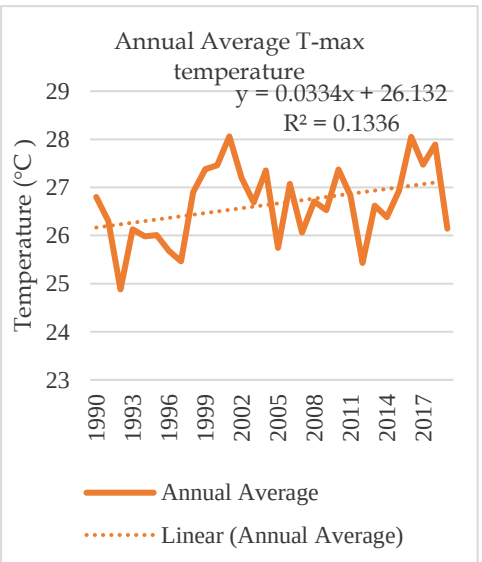
Three warm years in three decades 1990-2019	
Year	**Annual Average temperature in ° C**
2016	19.78
2018	19.51
2017	19.27

Table 1: Three warm years in three decades 1990-2019

Three cold years in three decades 1990-2019	
Year	**Annual average temperature in ° C**
1992	17.08
1996	17.48
1997	17.52

Table 2: Three cold years in three decades 1990-2019

In the same way, data were analyzed to identify the annual average T-max trend and decade average T-max temperature trends. Its trend line shows that T-max increased by the gradient of 0.0334 ºC per year, which can be identified from Figure (4). The analysis shows that the annual average T-max of the first decade of the study (1990-1999) was 26.152 °C, the annual average T-max of the second decade of the study (2000-2009) was 26.887 °C, and the annual average T-max of the third decade of study (2010-2019) was 26.911 °C. From the first decade to the third decade of the study, the annual average of T-max has increased by 0.759 °C.



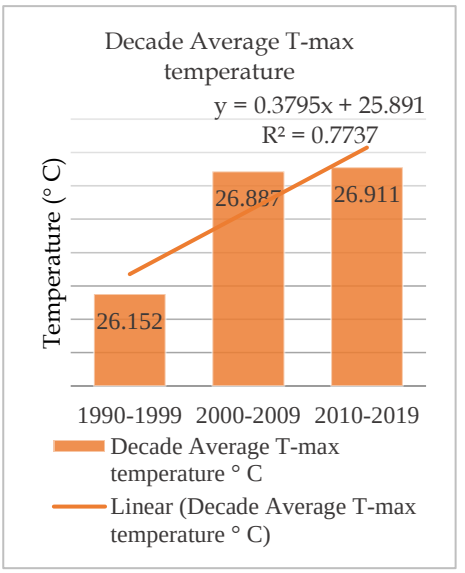
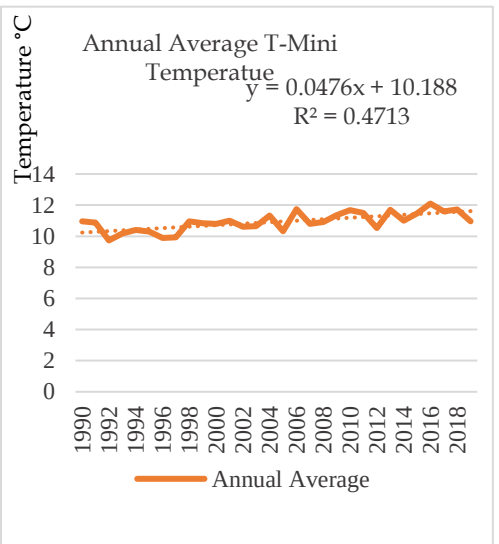


Figure 4: Annual Average T-max in Kandahar City 1990-2019
Figure 5: Decade Average T-max in Kandahar City 1990-2019

Simultaneously, data were analyzed to identify the annual average T-mini trend. Its trend line shows that T-mini has increased by the gradient of 0.0476 °C per year, which can be identified from figure (6) and $y = 0.0476x + 10.188$ equation. The analysis shows that the annual average T-mini of the first decade of the study (1990-1999) was 10.62 °C, the annual average T-mini of the second decade of the study (2000-2009) was 10.95 °C, and the annual average T-mini of the third decade of the study (2010-2019) was 11.426 °C. From the first decade to the third decade of study, the annual average of T-max has increased 0.806 °C.



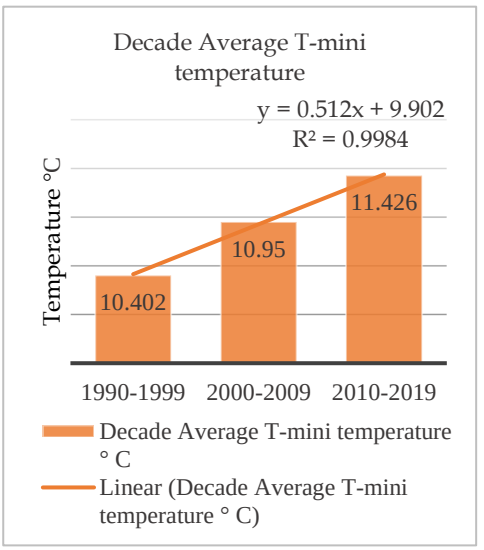
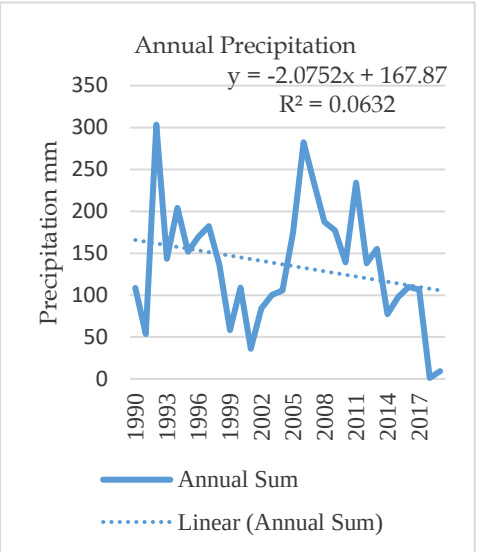


Figure 6: Annual Average T-mini in Kandahar city 1990-2019
Figure 7: Decade Average T-mini in Kandahar city 1990-2019

The research shows that temperature in all three types has increased in the last 30 years in Kandahar city. Temperatures in the cities could soar as a result of the urban heat island effect [8]. This may negatively influence various sectors of society such as health, population, economics, and particularly the agriculture sector. These changes may develop more arid land and hot waves in the study area.

Trend analysis was performed to identify significant changes in precipitation variables over a long period. Daily precipitation data was summed to monthly and similarly summed to calculate annual precipitation and statistically analyzed. The results from the regression method for the trend analysis of the precipitation data are shown in Figures (8) and (9). The results indicate that precipitation has decreased over the last three decades. The gradient of this change is -2.1361 mm per year which obtained from this $y = -2.1361x + 168.5$ equation. Hence, the trend line of decade average precipitation in Figure (9) indicates that precipitation decreased from decade to decade, the first decade of the study (1990-1999) average decade precipitation was 151.106 mm, the second decade of the study (2000-2009) was 149.125 mm, and the third decade of the study (2010-2019) was 105.937 mm, which decreased significantly. From the first decade to the third decade

of the study about 45.169 mm precipitation has been decreased. This may be attributed to increase of air temperature, evaporation and less humidity.



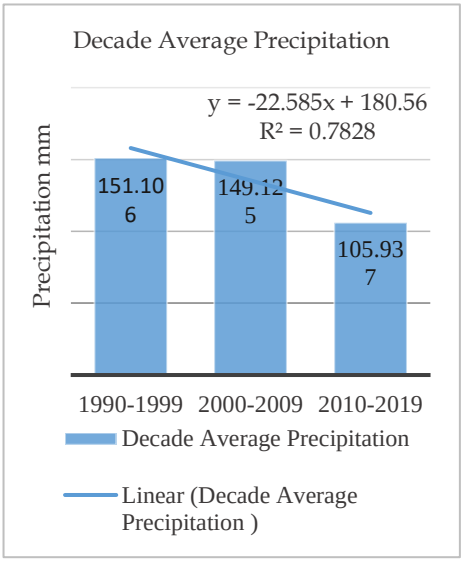


Figure 8: Annual Precipitation of Kandahar City, 1990-2019
Figure 9: Decade Average of Kandahar City, 1990-2019

The trend magnitude of precipitation identified from this $\Delta y = y(1990) - y(2019)$ equation. Which Δy is the trend magnitude expressed in mm, y (1990) is the amount of precipitation at the beginning of the period, and y (2019) is the amount of precipitation at the end of the period.

Trend magnitude equation $\Delta y = 108.61mm - 9.2mm, \Delta y = 99.41$

The trend magnitude shows a huge difference which indicates drought, hot air, and lack of precipitation than normal, meanwhile shows a negative trend magnitude. This negative change in temperature and precipitation posed Afghanistan the most vulnerable country ranked 175th out of 182 in the world. The lowest precipitation was found in the southwest province like Helmand, Kandahar, and Farah, these provinces are mostly dependent on rain-fed agriculture which affect the crop yield [9].

4. Conclusion

This study aimed to identify the temperature and precipitation trend line from 1990-2019 in Kandahar City and investigate the relationship between temperature and precipitation over time passage. Based on linear regression equation and trend magnitude analysis, it can be concluded that temperature in three, average temperature, average T-max, and average T-mini demonstrated positive trends and increases. T-max showed small changes at 0.0334 °C/y, 0.3795 °C/decade, and 1.002 °C/30 y over three decades, the average temperature changed moderately by the rate of 0.0377 °C/y, 00.4145 °C/decade, and 1.131 °C/30 y over three decades and T-mini changed significantly by rate of 0.0476 °C/y, 0.512 °C/decade and 1.428 °C/30 y over three decades. Simultaneously past precipitation data depicted a negative trend, the change was $-2.0752mm/y$, and$-22.584mm/10y$.

The research revealed that temperature increased, and precipitation decreased in the last 30 years, which means that temperature and precipitation have a negative relationship

with each other, while temperature increase, precipitation decrease, and vice-versa. This may negatively influence various sectors of society, health, population, and economy, particularly the agriculture sector. These changes may develop more arid land and hot waves in the study area.

Afghanistan is the most vulnerable country to climate change impacts in the world ranked 175th out of 182 countries in the 2019 ND-GAIN Index, and these changes in climate parameters such as temperature and precipitation must be taken into consideration during the decision and policy making for socioeconomic development projects such water resources management, agriculture, food production and environmental challenges incorporation projects.

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