International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

Analysis of the Precipitation Pattern under Changing Climate in the Lower Kabul River Basin Nangrahar, Afghanistan

Gulab Jan Shinwari[1], Mohammad Yasir Amin[2], Shah Masoud Mokhlis[3]

[1]Lecturer, Department of Civil Engineering, Faculty of Engineering, Alfalah University, Jalalabad, Afghanistan

[2]Lecturer, Department of Civil Engineering, Faculty of Engineering, Alfalah University, Jalalabad, Afghanistan

[3]Lecturer, Department of Civil Engineering, Faculty of Engineering, Alfalah University, Jalalabad, Afghanistan

Email: gulab.shinwari20@gmail.com

Abstract

Precipitation and temperature are two factors utilized to assess the climate conditions in the area. The moderation and variability of the climate, particularly the annual discussion of temperature and precipitation, have garnered significant attention globally. In this regard, the current study investigates the changes in temperature and monsoonal rainfall over the long and short terms in the Lower Kabul Basin, Nangrahar province. Rainfall data from 1981 to 2021 were examined in this research. Statistical trend analysis methods, including Excel with various formulas, the Mann-Kendall test, and Sen's slope estimator, were employed to scrutinize and interpret the data. Nangrahar, characterized by its low-lying terrain and intersecting river systems, is part of the inactive delta of the large Hindu Kash Rivers and is situated in the lower Kabul basin. The study aimed to uncover the monthly trends and seasonal and annual variations in rainfall. The trend analysis revealed a negative trend line for December's monthly rainfall, while all other months exhibited a positive slope in the trend line. Analysis of historical precipitation data also indicated a clear regular variation, with dry months becoming drier and monsoon periods experiencing increased rainfall, making them more susceptible to floods. The annual mean rainfall highlighted that the Nangrahar region is one of the driest areas in the country.

Keywords

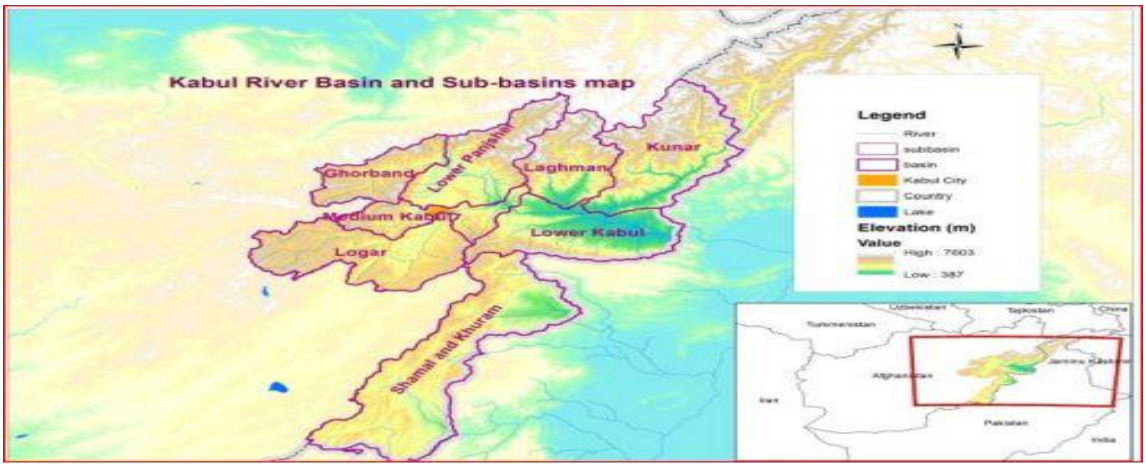
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

Monthly Rainfall, Statistical analysis, Mann Kendall test, Lower Kabul Basin Nangrahar Region, Climate Change.

1. Introduction

1.1. Background

Mainly, variations in precipitation patterns and temperature are regarded as indicators of climate change in specific regions. According to the Global Panel on Changes in the Climate, throughout the late 19th century, the average global surface temperature increased by 0.74%., signifying a shift in the current climate. Rapid changes have been observed recently, with nearly every part of the world experiencing adverse effects (Dore, 2005). Climate changes significantly impact people, their behavior, agricultural resources, and water availability, especially in regions reliant on agriculture for economic activity. Countries like Afghanistan are particularly affected by floods, cyclones, droughts, landslides, and other natural disasters associated with precipitation due to climate change. The alteration in precipitation patterns, influenced by global warming on both global and regional scales, is a crucial parameter for understanding climate change (Jonathan and Raju, 2017). The KRB holds importance due to its location and trans boundary nature, contributing around 50% of the basin's overall outflow. It is one of the Afghanistan have five main river basins, with three primary the sub-basins based on flow generation: the upper Kabul, Punjsher, and lower Kabul (Iqbal et al., 2018). The lower Kabul basin includes Laghman, Kunar, Nuristan, and Nangrahar provinces. (Bromand, 2015). The Kabul River Basin (KRB) includes five main catchment areas, totaling 76,908 km2. It consists of 14,000 km2 of upstream sub-catchments in Pakistan and 62,908 km2 in Afghanistan. The basin covers a diverse range of elevations, from the central highlands at 6000 m above mean sea level (M, S, L) to the eastern valleys at 400 m above (M, S, L) (Akhtar et al., 2022a).in Figure1.1



International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

Figure 1.1. Kabul River Basin and sub-basins map

Afghanistan is an arid, hilly nation with four distinct seasons: summer, fall, winter, and spring. The climate of the Kabul River Basin (KRB) is semi-arid, continental, and characterized by dramatic day-and-night variations in temperature. The majority of the nation has scorching summers and chilly winters due to a dry continental environment. (Mihran, 2011) Over the past 50 years, rising temperatures and diminishing precipitation have resulted in a variety of meteorological anomalies that have caused droughts, floods, unseasonal precipitation, declining groundwater tables, desertification, and biodiversity loss. Afghanistan has experienced intermittent droughts in all or portions of the nation since the 1990s. Lately, particularly in Northern Afghanistan and the regions in the western section of Figure 1.2

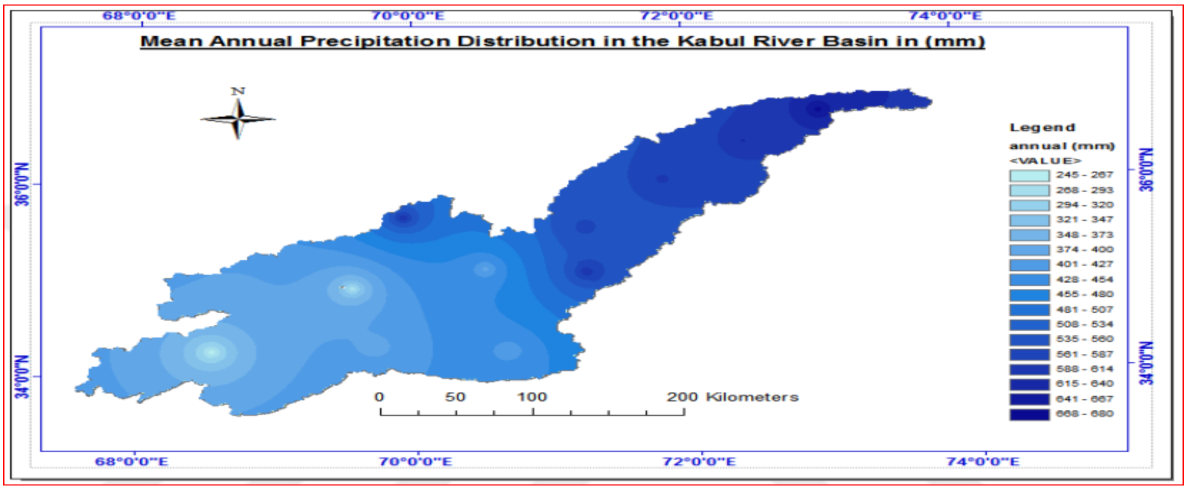
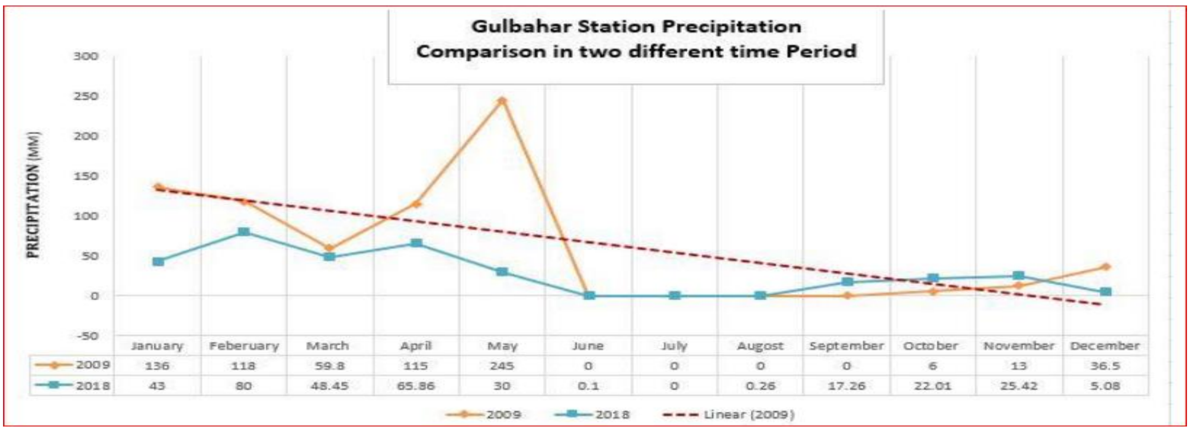


Figure 1.2. Mean annual precipitation distribution KRB

In 2013, the Central Highlands have experienced frequent droughts. The Indian monsoon, which originates in the South Asian Himalayas, typically brings about 327 mm of yearly precipitation to the downstream regions of the Kabul River Basin. Approximately 418 mm of precipitation falls annually in upstream areas (F. Akhtar et al. 2018) figure1.3



https://www.shimej.com/ijsesr/index

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

Figure 1.3. Gulbahar Station Precipitation Comparison in two different time period

The highest amount of rainfall typically happens in the winter months, specifically December, January, and February. Conversely, the lowest levels of precipitation are forecasted for the summer season, particularly June, July, and August. The temperature within the Kabul River Basin varies across different watersheds, with these climatic factors being influenced by elevation. The highest recorded temperature (48°C) in the Kabul River Basin was in the Nangrahar region, situated in a flat area during the summer season, while the lowest temperature (-28°C) was registered in the Chatral valley at high elevation.

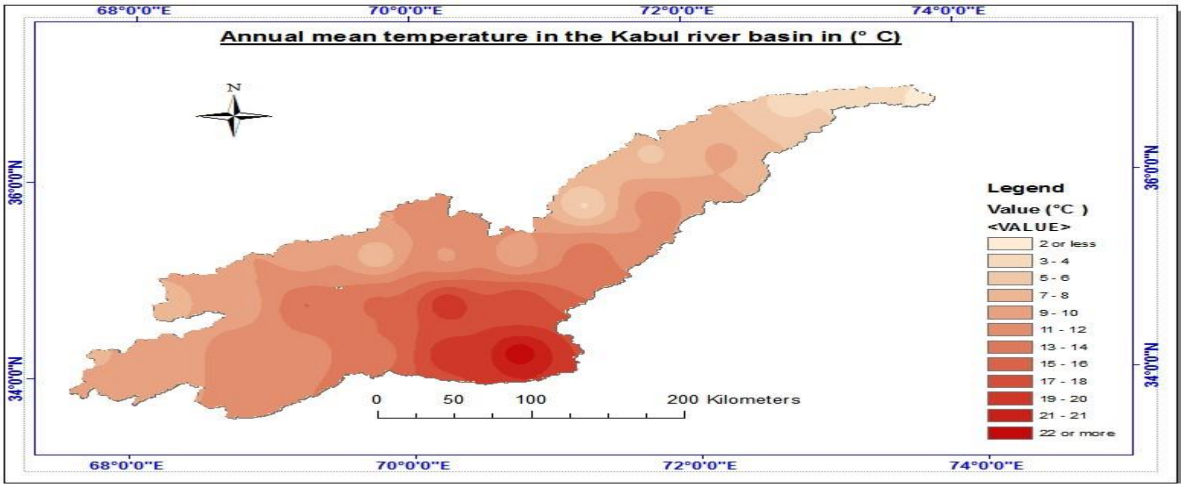


Figure 1.4. Annual average temperature distribution in the KRB

1.2. Agriculture Kabul River Basin

1. Afghanistan has 12% or so of its entire land area cultivable, of which roughly 46% is irrigated and the remaining 54% is fed by rainfall (F. Akhtar 2017).

2. KRB is about 9% of the cropland's total land area. Groundwater wells and karezes (underground water channels) that make use of free-standing aquifers in alluvial fans that are replenished by snowmelt are the primary sources of irrigation for agriculture in the KRB.
3. Grass: Wheat is the crop that is grown and consumed the most in the KRB. It is often grown in rotation with rice, corn, and occasionally vegetables, largely in the downstream

provinces of the KRB (Nangrahar, Laghman, and Kunar). (F. Akhtar, 2017)

4. Fruits: Mostly grown on irrigated ground, fruit orchards (pearls, apples, apricots, etc.) are farmed in the middle KRB as opposed to the downstream areas.(F. Akhtar and others, 2018)
5. Cropping pattern (single crop, double crop): In the upstream and middle upstream regions of the

basin, a single cropping season often wheat is observed annually, but the downstream portion of the basin typically has two cropping seasons.

2. Literature Review

The KRB area and water sources are not sufficiently used to increase the socioeconomic circumstances and quality of life of the residents. Rapidly increasing population, climate change, land Degradation, and deforestation are all hurting the region's current land and water resource systems. The Kabul River Basin's most populous regions, including Kabul and Nangarhar, use a lot of groundwater that is of low quality, which causes the water table to decrease significantly(Bromand, 2015)Worldwide, the increasing use and burning of fossil fuels due to increasing local and global industrialization is affecting the scale of precipitation due to greenhouse gases increasing temperatures and more traffic surface in urbanized environments; therefore, special studies are needed to find the link among surface temperature and precipitation rate to understand the factors that contribute to the management of rainfall patterns in the region.(Jonathan and Raju, 2017) This research has offered a numerical analysis of how climate change affects hydrological patterns (Brekke, 2009). The findings suggest that the changes in water flow are significant enough to warrant explicit consideration in long-term integrated management policies for the Rhine basin (Dore, 2005) The Mediterranean climate is facing irregular rainfall and severe storms, which have caused a lot of damage (Pérez et al., 2021) Many nations experience predominantly arid climates and high temperatures for the majority of the year, with minimal or no precipitation in most regions (Jonathan and Raju, 2017). Research indicates that the Kabul River Basin is particularly vulnerable to the effects of population growth and climate change, as even a slight rise in average temperatures could lead to significant changes in its current hydrological conditions and water resources (Bromand, 2015)The model consistently assumes that the intensity of each precipitation event is increased by approximately a single storm and examines its physical properties (starting location, intensity, spatial extent, duration, and trajectory) to identify this compensation mechanism. makes it possible to identify Also, these predicted changes are less than the bias from model observations, implying that modeling changes in precipitation characteristics and fitting the data accordingly is the best method, especially for summer precipitation (Chang et al., 2016The significant upward trends in soil moisture, with increases of over 1 cm every 10 years, have created favorable conditions for groundwater infiltration. Major aquifers have seen their levels rise by 50-100 cm, leading to a growth in groundwater storage, increased groundwater recharge, and significant low-water runoff. Annual average rainfall is notably low in many arid and semi-arid regions of Asia, with high temporal variability. In some areas, as much as 90% of the annual total rainfall occurs within just 2 months. Certain northern nations in this region have seen an increase in the annual mean rainfall

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

trend over the last fifty years. Nonetheless, from 1894 to 1997, Kazakhstan's annual precipitation trend decreased, despite modest increases in spring, summer, and fall precipitation. Seven out of ten stations in Pakistan have shown a propensity for higher rainfall during the monsoon season. (Chaudhari, 1994)

3. Materials and Methods

3.1. Afghanistan River Basins Overview

Afghanistan is a desert region that covers of approximately 652,000 square kilometers. Afghanistan's borders are adjacent to Iran in the west, China in the northeast, Pakistan in the east, and Turkmenistan, Uzbekistan, and Tajikistan in the north. The country's geography and water resources divide it into five primary river basins: The North River Basin, the Amu River Basin, the Helmand River Basin, the Harrirud-Murghab River Basin, and the Kabul River Basin. A map displays all of these river basins. in the figure 3.1

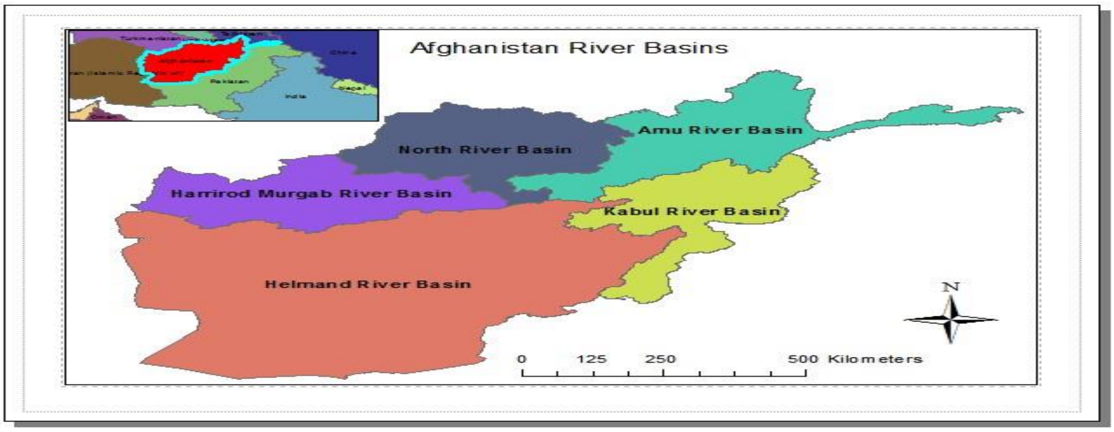


Figure 3.1. Afghanistan River Basins map

3.2. Location

The province of Nangrahar is largely a component of the main KRB and is placed in the lower portions of the Kabul sub-basin, bordering Pakistan. (Akhtar and Iqbal 2017)Nangarhar sub-basin is part of the lower Kabul basin. It lies between 34.25˚ N latitudes and 70.50 ˚ E longitudes as shown in Figure 1.2 with the area of 7727 km2. This province is divided into 22 districts(Lashkar pour and Hussain, 2008). The Hin-Dukush mountain range, which rises more than 7500 meters above sea level, contains steep mountain valleys that make up the upper watershed of the Kabul River basin.(Azizi and Asaoka 2020). The Logar-maidan The Maidan, Paghman, and Qargh rivers are three river branches that emerge upstream from Kabul and are located in the Kabul area. The Ghorband, Salang, and Shatul rivers are three of the tributaries of the Panjshir Ghorband region. (3) The Panjshir and Maidan rivers have an impact on a specific area in Lower Kabul (Aliya and Esmailnejad, 2022).

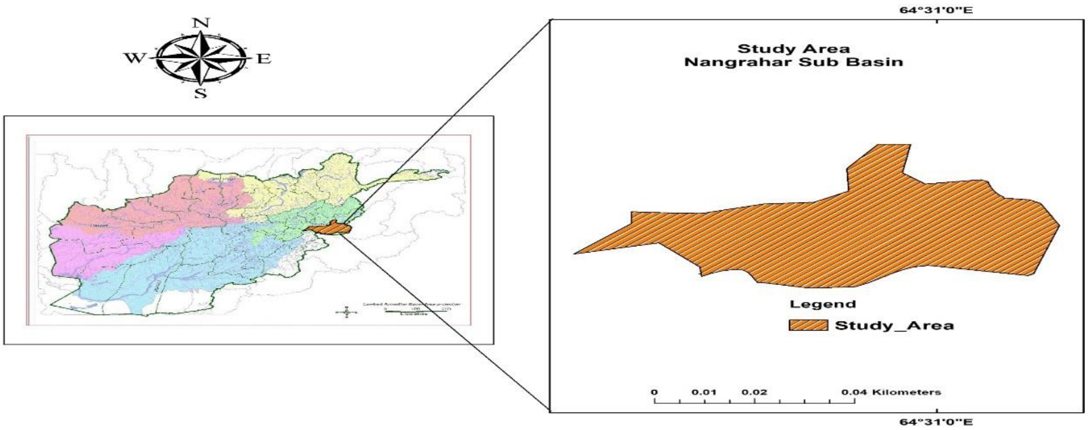


Figure 3.2. Location map of the study area (Nangrahar)

3.3. Population

The latest recorded population of Nangarhar in 2021 was approximately 1,735,531, which accounted for 4.63% of Afghanistan's total population. During that year, Nangarhar had a population density of 220 people per square kilometer. Understanding the precipitation patterns in the river basin catchment is crucial for analyzing population data(Jonathan and Raju 2017).

3.4. Regional Climate

The province of Nangrahar experiences a continental climate that changes with height. In the lowlands and low-lying regions, the temperature is fairly warm. When temperatures are colder at higher altitudes, the air can seriously affect human activity.(Affleck et al. 2011)

3.5. Rainfall-Temperature

The province of Nangrahar experiences hot, semi-arid weather, with average monthly highs and lows of 3°C (the coldest month) and 40°C (the hottest month). February through April are the months with the highest precipitation, with an average of 210 mm of rain falling at Jalalabad, the provincial capital.

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

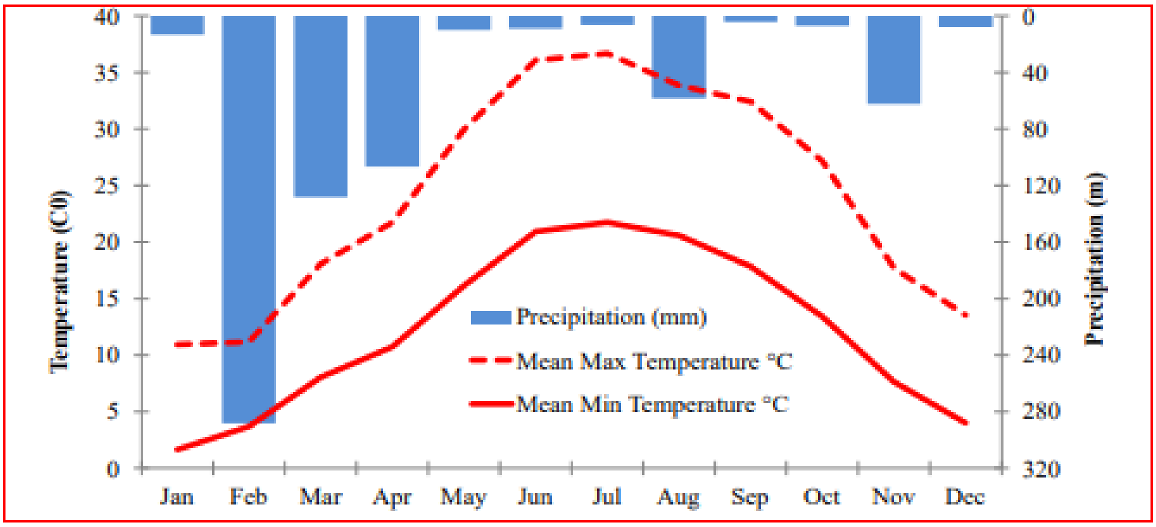


Figure 3.3 Decadal average (2003-2013) temperature-rainfall relationship in Nangrahar province(F. Akhtar et al. 2022b)

3.6. Evapotranspiration

This is a graph of the Evapotranspiration and precipitation in Nangrahar Province. ETO as it is called, is the amount of evaporation that occurs in a region. Evaporation is an important part in the water cycle, and if there is more evaporation than precipitation, a deficit occurs. While there is a precipitation surplus from January to the middle of April, a huge deficit is created for the rest of the year, with the highest amount of Evapotranspiration and lowest precipitation occurring in June.

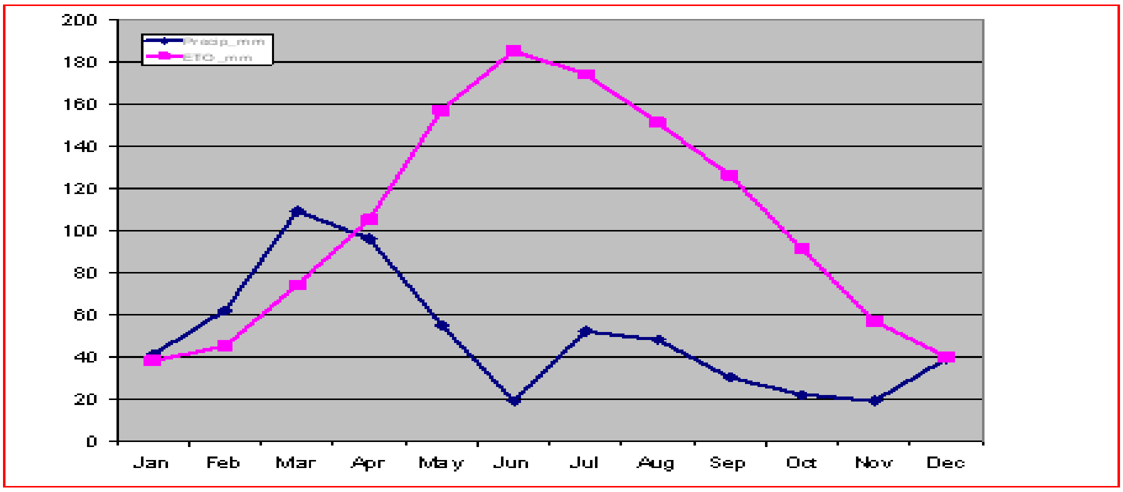


Figure 3.4. Evapotranspiration in the Southeast Nangrahar Province

3.7. Nangrahar River Basin Presidency

Nangrahar river basin is a formal office in the KRB that has meteorological information on the Nangrahar sub-basin got climate data from 1981 to 2021 to analyze model to observed data in the study area.

3.8. Methods

Daily rainfall statistics over the previous 40 years from 1981 to 2021 for the Nangrahar region of Afghanistan were collected from Nangrahar River Basin Deportment (NRBD) from three stations. Analyses data in Manual in Excel and then analyses from Mann-Kendall test.

3.9. Trend analysis (Mann Kendall Test) / two-tailed test

A statistical test called Mann-Kendall is used to examine patterns in data from series of times. It is commonly used in hydrology, climatology, and other fields to determine whether a variable is increasing, decreasing, or showing no trend over time. In this test, the alternative hypothesis H1, which suggests the existence of a trend, is contrasted with the null hypothesis H0, which asserts that there is no trend (the data is independent and ordered randomly). First, the M-K statistic is computed in the following manner

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(xj - xk)$$

The trend test is used on a time series Xk, where k ranges from 1 to n-1, and j ranges from i+1 ton. Each data point xj is considered as a reference point.(Basistha, Arya, and Goel 2009)

$$sgn(xj - xk) = 1 \quad , \quad if\ (xj - xk) > 1$$

$$sgn(xj - xk) = 0 \quad , \quad if\ (xj - xk) = 1$$

$$sgn(xj - xk) = -1 \quad , \quad if\ (xj - xk) < 1$$

This specific trial was conducted using XLSTAT 2023 software. A large positive S value suggests a rising trend, the identification of a statistically significant trend is based on the Z score, with a very small negative value indicating a decreasing trend. Value, with a significance level set at 5%. A continuity correction is applied, and a confidence interval of 95% is used for Sen's slope. In statistics, a two-tailed

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

test involves examining both sides of a distribution to determine if a sample falls within a specified range of values. It is employed in statistical significance testing as well as null hypothesis testing.

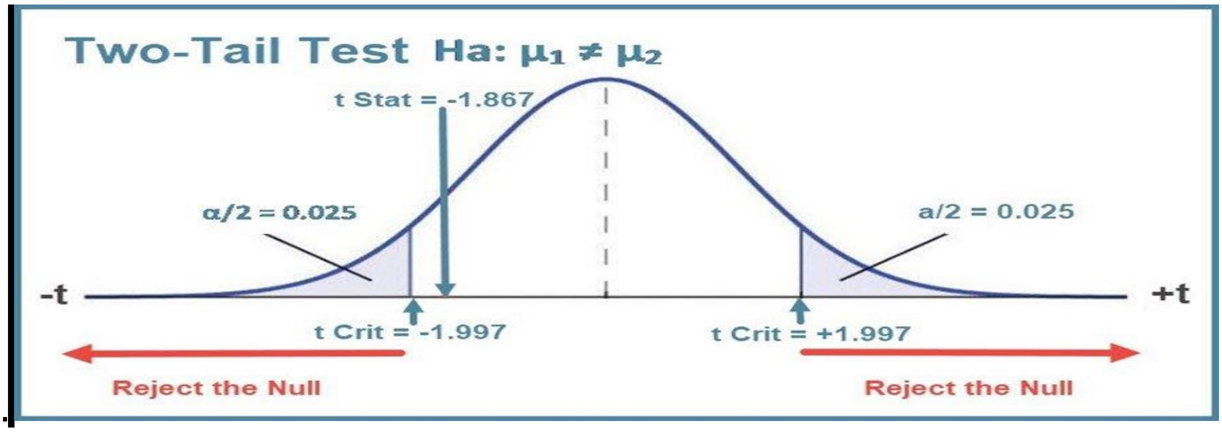


Figure 3.5. Two-tailed test map

3.10. Sen's Slope Estimator Test

Sen's estimator, a nonparametric technique developed by Sen in 1968, is used to determine the trend magnitude in a time series. This method is particularly valuable for estimating the actual slope of trends, such as the annual rate of change. The analysis was carried out using XLSTAT 2023 software. A positive Sen's slope value indicates an upward or increasing trend, while a negative value indicates a downward or decreasing trend within the time series. Nonparametric methods, such as the Mann-Kendall (M-K) test, are commonly used for trend analysis in various studies and are favored by researchers. The statistical analysis involved estimating monthly maximum and minimum rainfall from daily records and evaluating different statistical parameters, including mean and standard deviation, to assess climate behavior changes. The statistical analysis included estimating monthly maximum and minimum rainfall from daily records and examining several statistical parameters, such as mean and standard deviation, to evaluate changes in climate behavior.

a) To verify the pattern of variation, the annual summation of the daily rainfall from 1981 to 2021 is also estimated. Additionally, using the daily rainfall data, the seasonal fluctuation of Nangrahar's four distinct seasons was examined.

b) Compiling the monthly average and creating the trend line: In order to evaluate the variations and patterns in monthly rainfall over many years, the monthly mean of precipitation was calculated using the daily data.

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

4. Result and Discussion

4.1. Monthly Average Rainfall

The most productive month for rainfall in Nangrahar is March (69 mm), according to an analysis of daily rainfall data from 1981 to 2021. June, December, and November are the months with the least amount of rain in Nangrahar. The Nangrahar region's monthly rainfall average from 1984 to 2021 was displayed in Figure 4.1. Positive trend lines are shown in January, February, March, April, May, June, July, August, September, October, and November. On trend lines, December exhibits a negative slope. Between June and April, there was a noticeable upward tendency. The trend analysis indicates that there were negative trends over the winter months. It was clear from Figure 4.2 that the dry spell was lengthening. The monsoon season since this was the most vulnerable time of year, there was a concerning trend in the area toward an increase during the monsoon season. The rainfall pattern for frequent floods throughout the months of March and December was seen in Figures 4.3, 4,4 Figure 4.2

June is the minimum rainfall month of all months 16 mm of rainfall, respectively

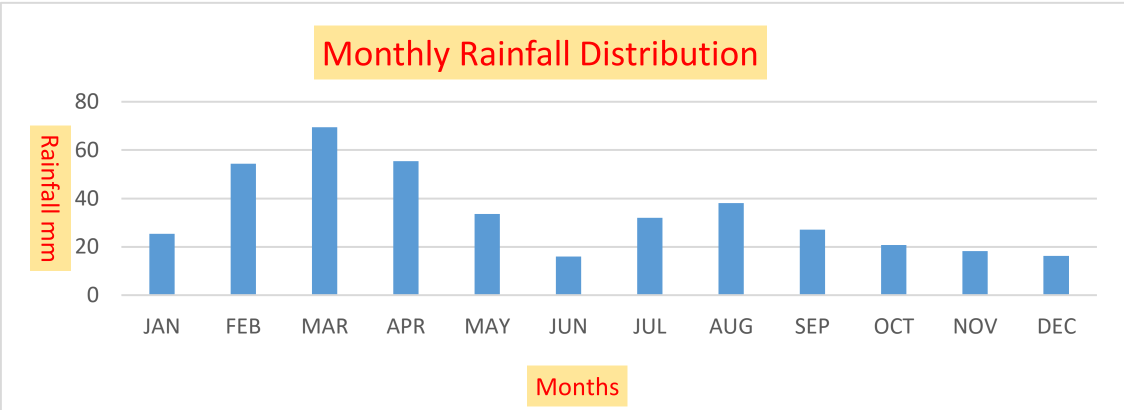


Figure 4.1. Monthly average of rainfall during 1981-2021 in Nangrahar Region

The daily data was used to predict the monthly rainfall, and the trend of each month over the previous 40 years was examined. It was noticed from the trend in the Nangrahar region. March has the largest trend, December has the lowest (negative) trend, and the remaining months have an interval trend.

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

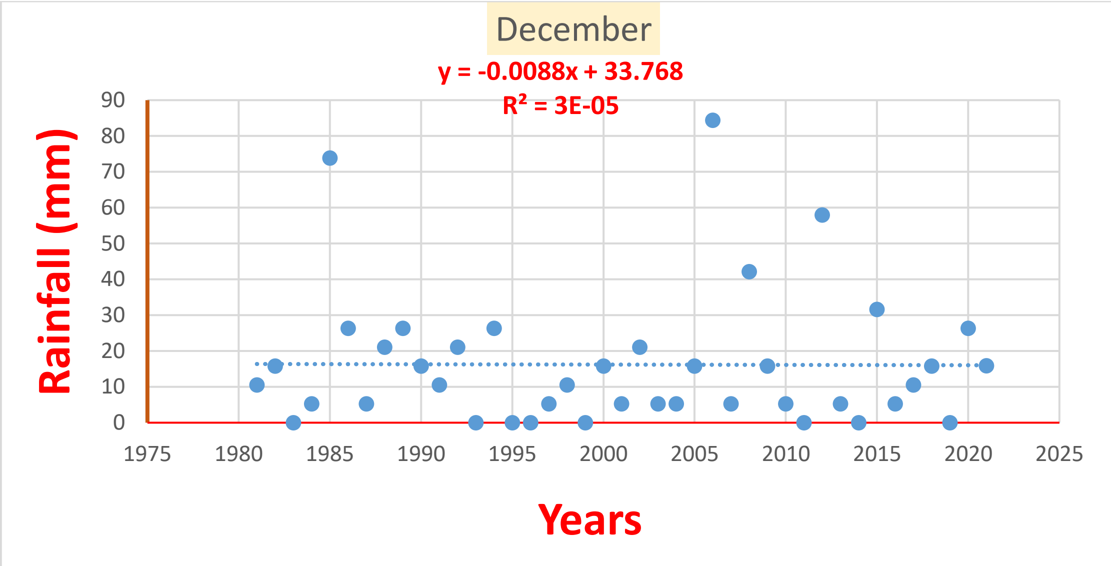


Figure 4.2. Rainfall trend during the month of December

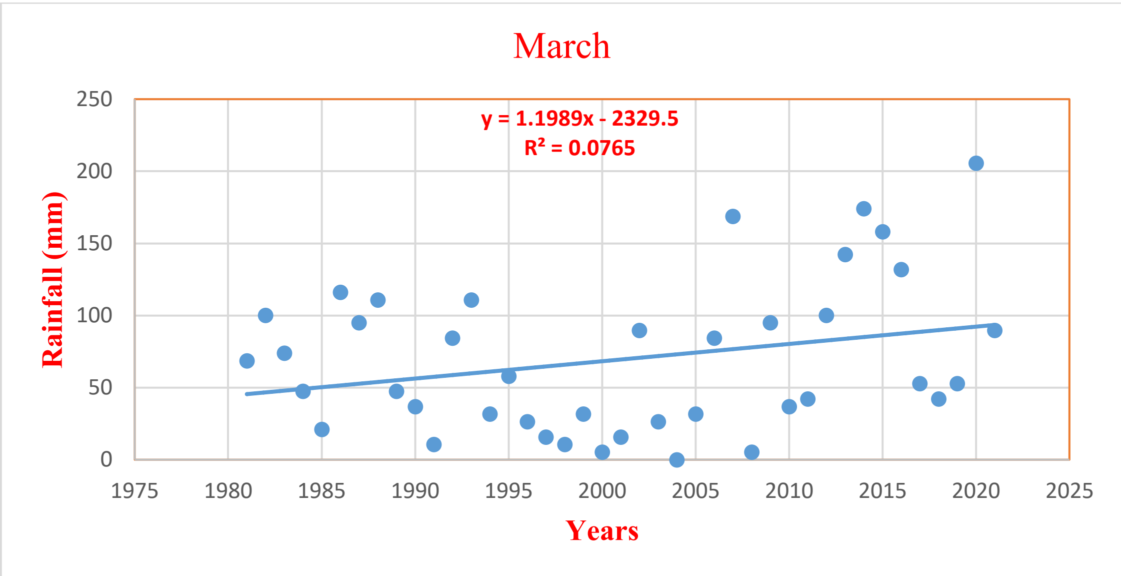


Figure 4.3. Rainfall trend during the month of March

4.2. Variation of Annual Rainfall and Seasonal

Every year, the average yearly rainfall fluctuates. The region with the lowest annual average rainfall in 1991 was 95 mm and the highest annual average rainfall in 2015 was 933.4 mm was depicted in Figure 4.4. The slope decline of the trend line indicates that the average yearly rainfall for the 1981–2021 period is 406 mm, which was less than Afghanistan's standard of 406 to 1000 mm. This shows in Figure 4.4 that the driest area of the nation was the Lower Kabul Basin region. In terms of seasonal rain-

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

fall, the monsoon, post-monsoon, and summer are trending upward, whereas the winter months are trending downward.

, as shown in Figure 4.6,7,8,9

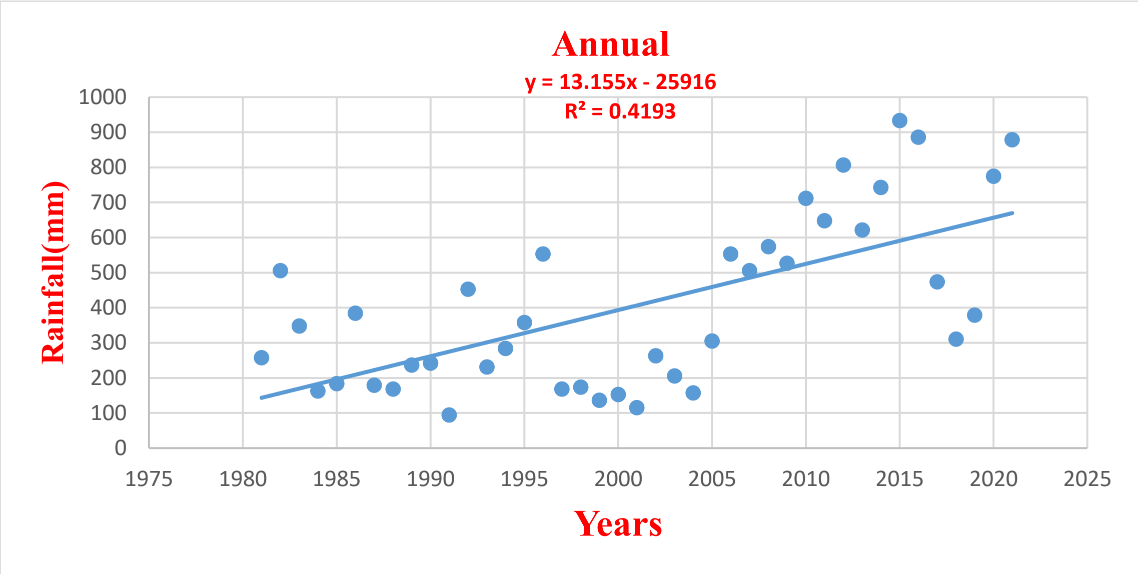


Figure 4.4. Annual rainfall in the LKB Region from 1981-2021

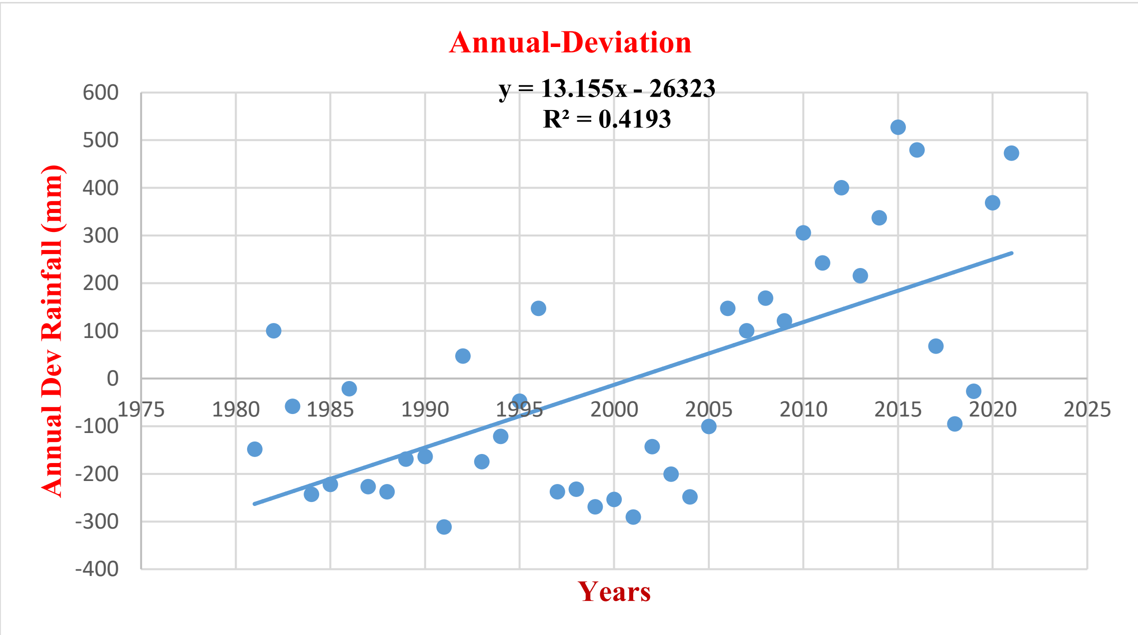


Figure 4.5. Annual rainfall & variation in the LKB Region from 1981-2021

In figure 4.5 shows that higher annual deviation in 526.86 mm in 2015 which indicates greater variability in annual rainfall amounts, with larger deviations representing years with more extreme or unusual precipitation levels compared to the average. And lowest annual deviation was -311.61mm which

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

indicates that particular year, the amount of rainfall recorded was below. Negative deviation can help stakeholders and decisions makers better prepare for changing climate condition and associated challengers related to water resources and environmental sustainability.

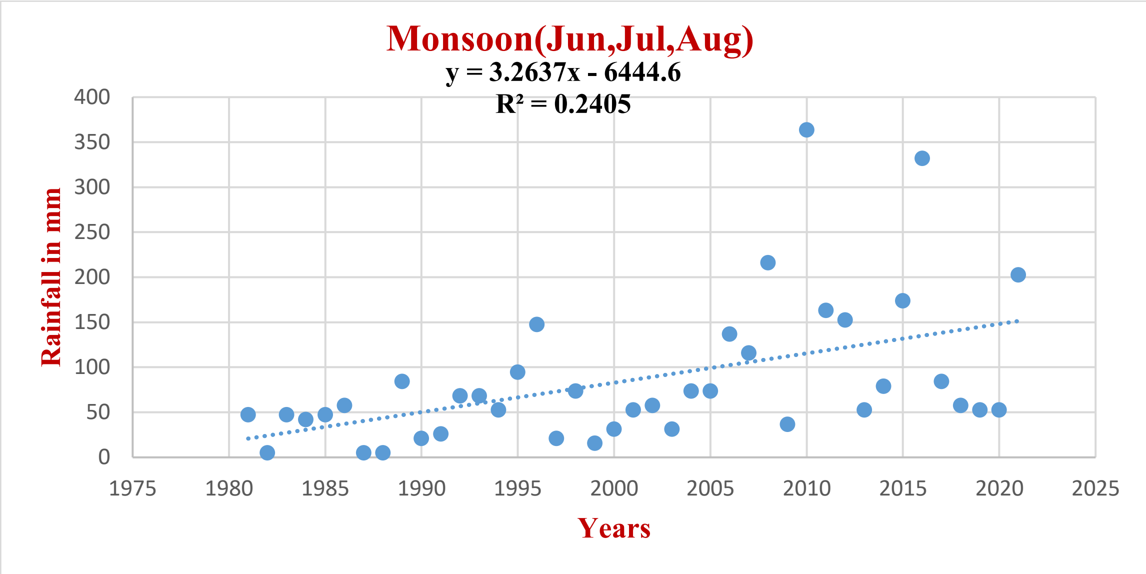


Figure 4.6. monsoon rainfall trend during 1981-2021 in LKB

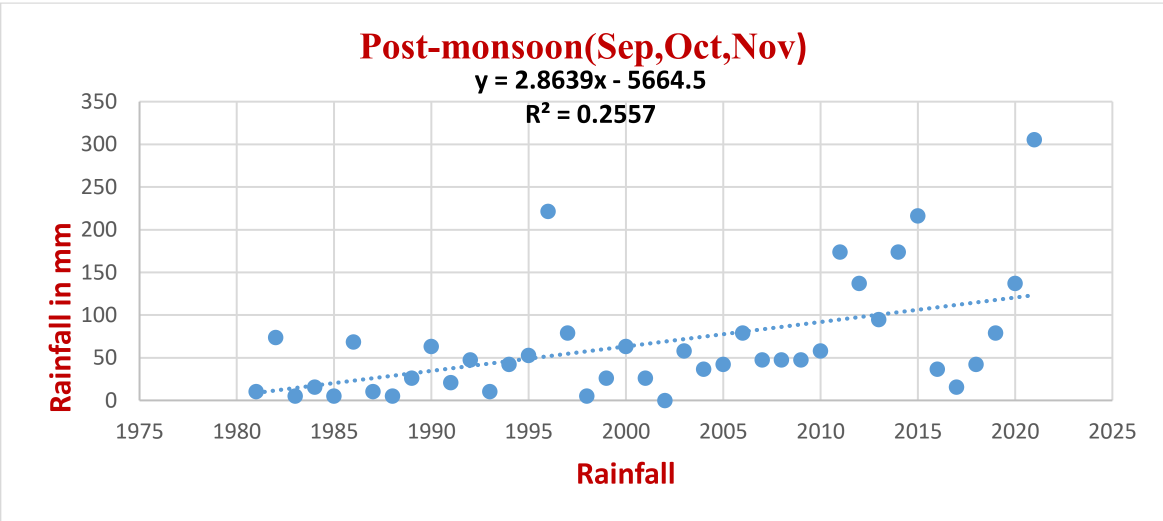


Figure 4.7. post monsoon rainfall trend during 1981-2021 in LKB

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

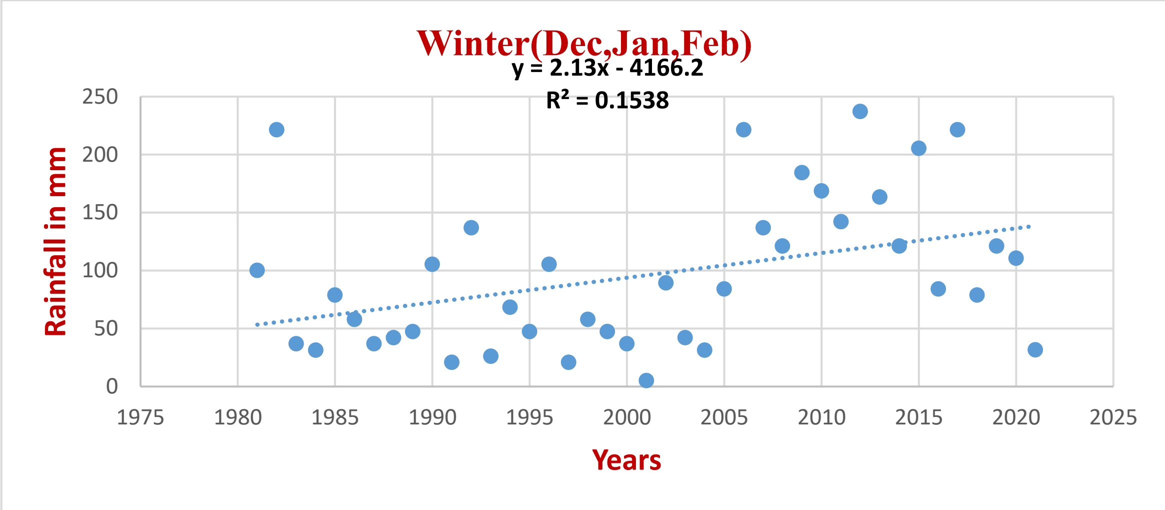


Figure 4.8. winter rainfall trend during 1981-2021 in LKB

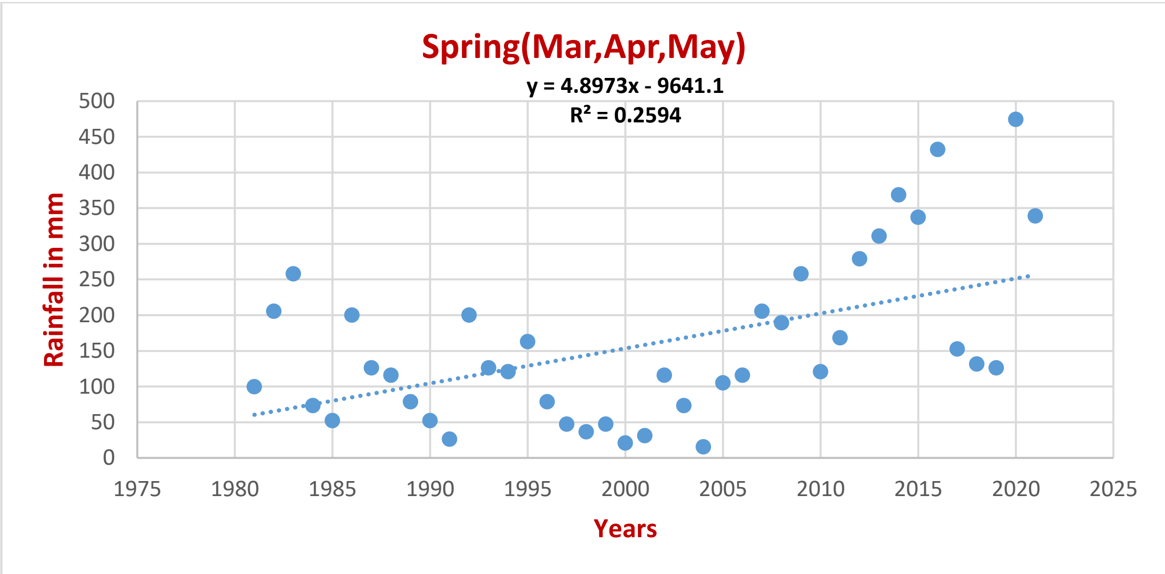


Figure 4.9. Spring rainfall trend during 1981-2021 in LKB

4.3 Statistical Analysis of Monthly Rainfall: The precipitation data's statistical metrics including mean, maximum, minimum, and standard deviation that were gathered were calculated and summarized in Table 4.1. There is zero rainfall in the area. The region experiences maximum rainfall ranging from 84.38 mm to 212 mm. The maximum standard deviation (SD) for the region is 52.23 mm in April. This shows that the region's rainfall totals vary most in the month of April. To assess the parameter of the rainfall, the coefficient of variation, or CV, is computed. Greater variability is indicated by a greater CV value, and vice versa. CV is calculated as $CV=\sigma/\mu\times100$. The highest coefficient of variation (CV) is observed in June at 168.62%, where μ represents the mean precipitation level and standard deviation indicates the fluctuation Table 4.2 discusses the descriptive statistics of rainfall, including the mean,

Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

standard deviation, and coefficient of variation. December had the highest values of the coefficient of kurtosis (19.45), and December also had the highest values of skewness (3. 9373). The monthly rainfall pattern is depicted in Figure 4.23, which indicates that the study area experiences its highest rainfall throughout the spring months of March through May. The overall increasing trend of seasonal rainfall in the examined region is depicted in Figures 4.23, 24, and 25, with a positive slope value of 4.897 (a = 4.897) and an R2 value of around 0.2594 in the linear regression equation. This linear regression model accounts for 25% of the variability in the seasonal rainfall, according to the coefficient of determination (R2). The temperature data was recorded and descriptive statistics such as average, standard deviation, coefficient of variation, and skewness were used.

Months	Monthly Rainfall in (mm)			Average	S_D	CV(%)
	Min	Max	Median			
JAN	0	121.29	10.55	25.33	26.921	106.25
FEB	0	158.2	36.91	54.4	45.737	84.065
MAR	0	205.66	52.73	69.45	51.923	74.757
APR	0	184.57	36.91	55.36	52.239	94..356
MAY	0	199.81	21.09	33.5	39.819	118.67
JUN	0	158.2	5.27	16.003	26.984	168.62
JUL	0	189.84	21.09	32.04	37.233	116.21
AUG	0	121.29	26.37	38.06	31.485	82.72
SEP	0	212	21.09	27.03	36.158	133.74
OCT	0	137.11	10.55	20.8	30.452	146.43
NOV	0	100.2	10.55	18.26	23.199	127
DEC	0	84.38	10.55	16.2	19.066	117.63

Table 4.1. Statistical analysis of the monthly rainfall from 1981-2021

Summary statistics from Mann Kendall							
Months	N	Min	Max	Mean	S-D	Kurtosis	Skewness
JAN	41	0.000	121.290	25.338	26.921	2.611014	1.536678
FEB	41	0.000	158.200	54.406	45.737	-0.65501	0.796669
MAR	41	0.000	205.660	69.455	51.923	-0.04034	0.784177

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

APR	41	0.000	184.570	55.363	52.239	0.41273	1.219019
MAY	41	0.000	199.810	33.555	39.819	19.44891	3.937367
JUN	41	0.000	158.200	16.003	26.984	7.358783	2.379505
JUL	41	0.000	189.840	32.040	37.233	0.57695	1.136224
AUG	41	0.000	121.290	38.062	31.485	17.0718	3.614102
SEP	41	0.000	212.000	27.036	36.158	6.054094	2.409685
OCT	41	0.000	137.110	20.796	30.452	3.232094	1.820846
NOV	41	0.000	100.200	18.267	23.199	3.232094	1.820846
DEC	41	0.000	84.380	16.209	19.066	4.669067	2.080736
ANN	41	94.920	933.400	406.535	243.353	-0.70086	0.66982
WINTER	41	5.270	237.310	95.952	65.069	-0.49848	0.728019
SPRING	41	15.820	474.600	158.374	115.190	0.557216	1.053635
SUMMER	41	5.270	363.860	86.106	79.721	4.293919	1.986836
AUTUMN	41	0.000	305.390	66.098	67.842	3.37369	1.829906

Table 4.2. Mann Kendell Test Statistical analysis of the monthly rainfall from 1981-2021

Summary statistics from Mann Kendall:										
Months	M	Min	Max	Mean	SD	S-Value	p-value	Sig.level	Sen's slop	Result
JAN	41	0.000	121.290	25.338	26.921	192	0.030	P<0.05	0.550	Positive
FEB	41	0.000	158.200	54.406	45.737	179	0.045	P<0.05	1.054	Positive
MAR	41	0.000	205.660	69.455	51.923	98	0.275	P>0.05	0.882	Positive
APR	41	0.000	184.570	55.363	52.239	289	0.002	P<0.05	1.506	Positive
MAY	41	0.000	199.810	33.555	39.819	250	0.005	P<0.05	1.055	Positive
JUN	41	0.000	158.200	16.003	26.984	219	0.012	P<0.05	0.310	Positive
JUL	41	0.000	189.840	32.040	37.233	264	0.003	P<0.05	0.838	Positive
AUG	41	0.000	121.290	38.062	31.485	267	0.003	P<0.05	0.989	Positive
SEP	41	0.000	212.000	27.036	36.158	330	0.000	P<0.05	0.959	Positive
OCT	41	0.000	137.110	20.796	30.452	263	0.003	P<0.05	0.502	Positive
NOV	41	0.00	100.20	18.26	23.19	209	0.018	P<0.05	0.329	Positive

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

		0	0	7	9					
DEC	41	0.00 0	84.380	16.20 9	19.06 6	-5	0.964	P<0.05	-0.0088	Negative

Table 4.3. Shows Mann Kendell Test Sen's Slope

Although not statistically significant, the application of this trend analysis shows an overall increasing and declining trend. Additionally, although not very significant, the Mann-Kendall Test in this study shows both positive and negative trends in the field. Test values indicate a negative trend in January, February, March, April, May, November, June, July, August, September, and October, however, there was evidence of an increasing trend for these months. Additionally, summer showed a maximum declining trend with a substantial value, whereas autumn and summer both exhibited decreasing trends, according to Sen's slope. The total yearly slope was the second largest negative value, with the spring and winter seasons showing negligibly positive values.

The two-tailed test (Jan) or Mann-Kendall trend test:

tau value	0.247
S	192
Variance(S)	7757.333
P-Price	0.030
A	0.05

Clarification of the test:

H0: The series shows no trend

Ha: The series is following a trend.

Given that the p-price determination was smaller than the significance levelα=0.05, this indicates that Ha should be accepted, and H0 should be rejected.

Sen's slope:

	Price	Lower limit	Upper limit
Tendency	0.550	0.000	1.318
Cut Off	1083.653	2615.577	10.550

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

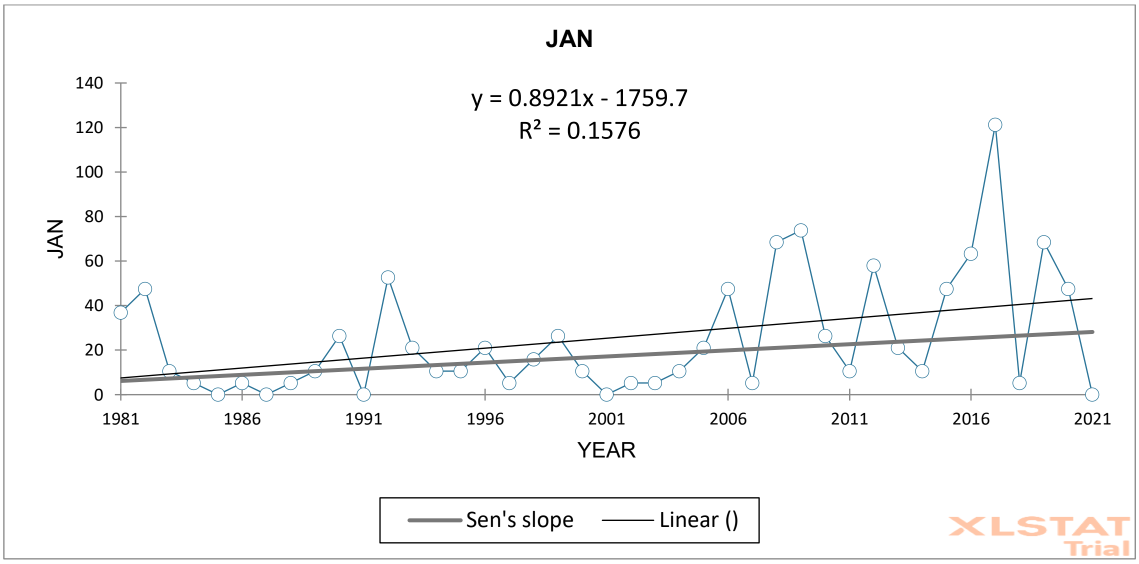


Figure 4.10. Rainfall trend for the month of January

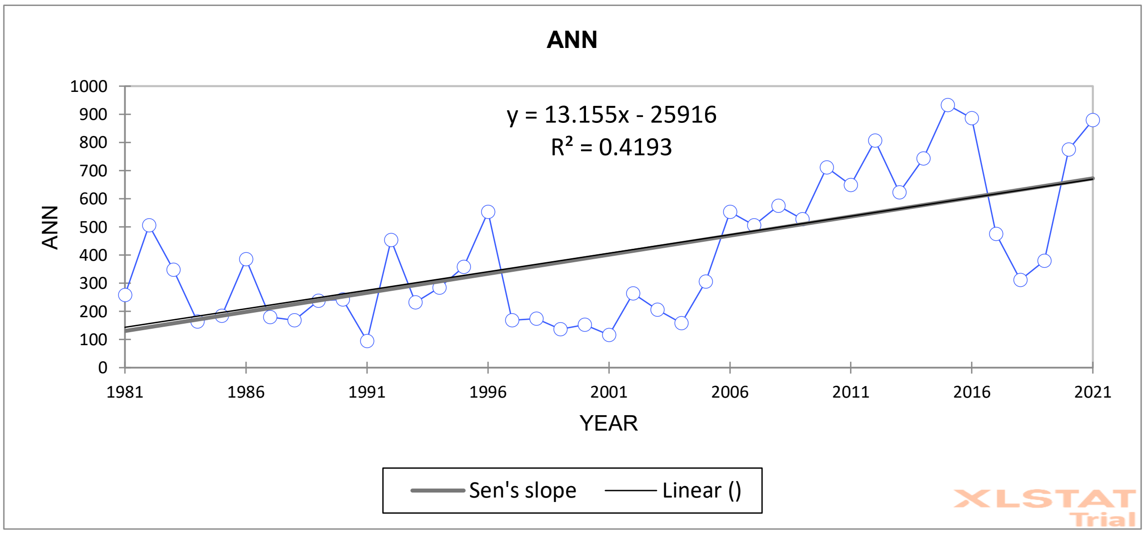


Figure 4.11. Rainfall trend the Annual

The two-tailed test (Winter) or Mann-Kendall trend test:

tau value	0.264
S	215
Variance(S)	7917.667
P-Price	0.016
α	0.05

Clarification of the test:

H0: The series shows no trend

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

Ha: The series is following a trend.

Given that the p-price determination was smaller than the significance levelα=0.05, this indicates that Ha should be accepted, and H0 should be rejected.

Sen's slope:

	Price	Lower limit	Upper limit
Tendency	2.126	0.329	3.766
Cut Off	-4171.215	-7443.956	-576.027

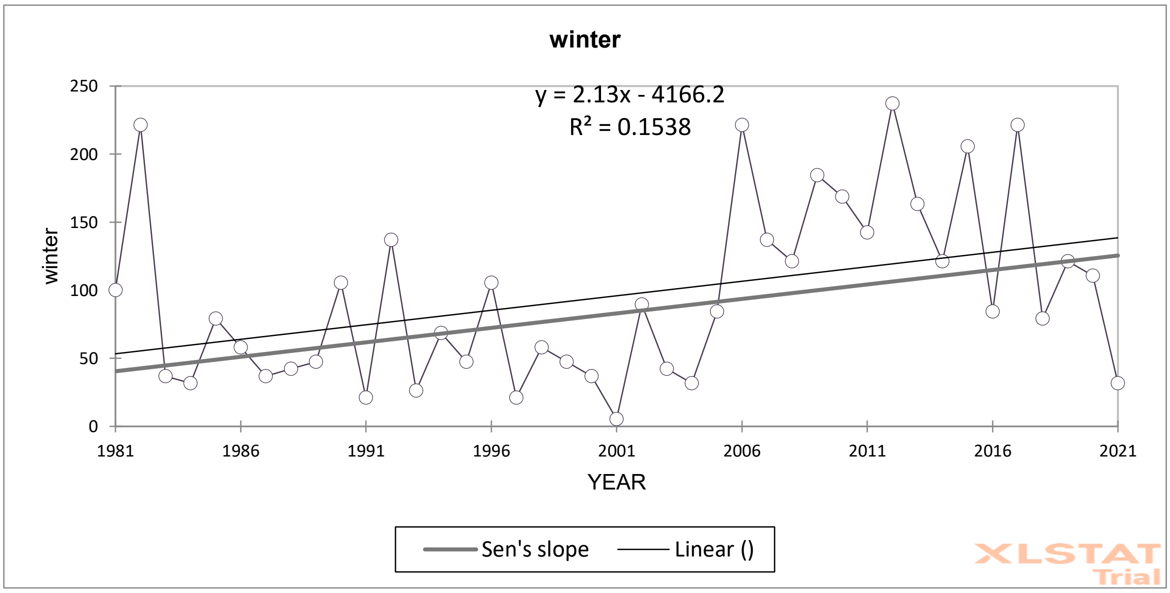


Figure 4.12. Rainfall trend the winter

The two-tailed test (SPRING) or Mann-Kendall trend test:

tau value	0.290
S	237
Variance(S)	7923.667
P-Price	0.008
α	0.05

Clarification of the test:

H0: The series shows no trend

Ha: The series is following a trend.

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

Given that the calculated p-value was less than the significance level alpha=0.05, the Alternative hypothesis Ha should be accepted and the null hypothesis H0 should be rejected.

Sen's slope:

	Price	Lower limit	Upper limit
Tendency	3.955	0.879	7.251
Cut Off	-7772.890	-14343.636	-1631.446

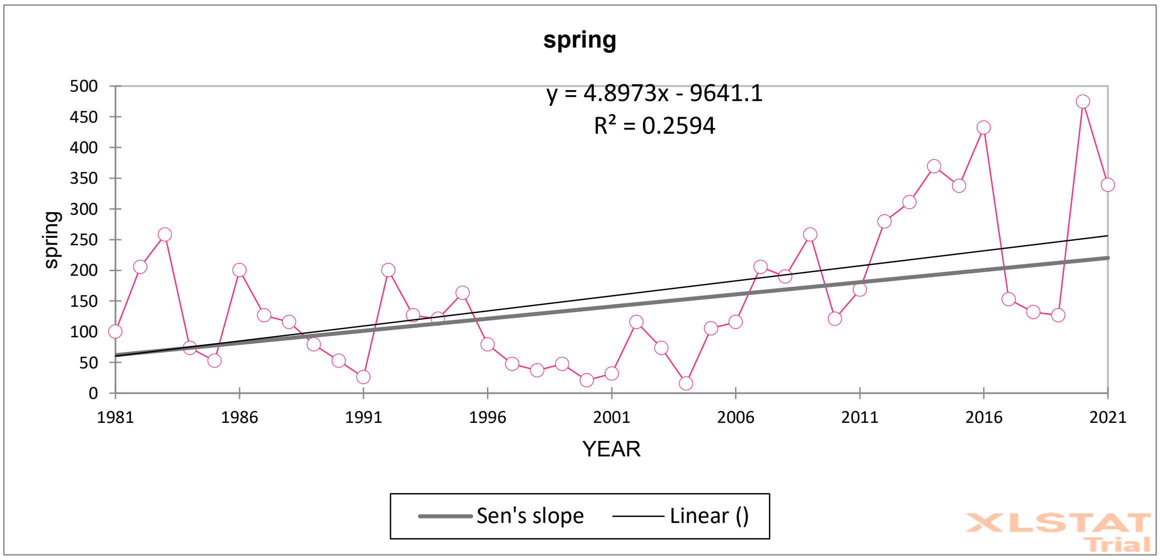


Figure 4.13. Rainfall trend the spring

The two-tailed test (Summer) or Mann-Kendall trend test:

tau value	0.410
S	334
Variance(S)	7916.000
P-Price	0.000
α	0.05

Clarification of the test:

H0: The series shows no trend

Ha: The series is following a trend.

Given that the p-price determination was smaller than the significance levelα=0.05, this indicates that Ha should be accepted, and H0 should be rejected.

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

Sen's slope:

	Price	Lower limit	Upper limit
Tendency	2.068	0.959	3.958
Cut Off	-4070.914	-7838.495	-1852.509

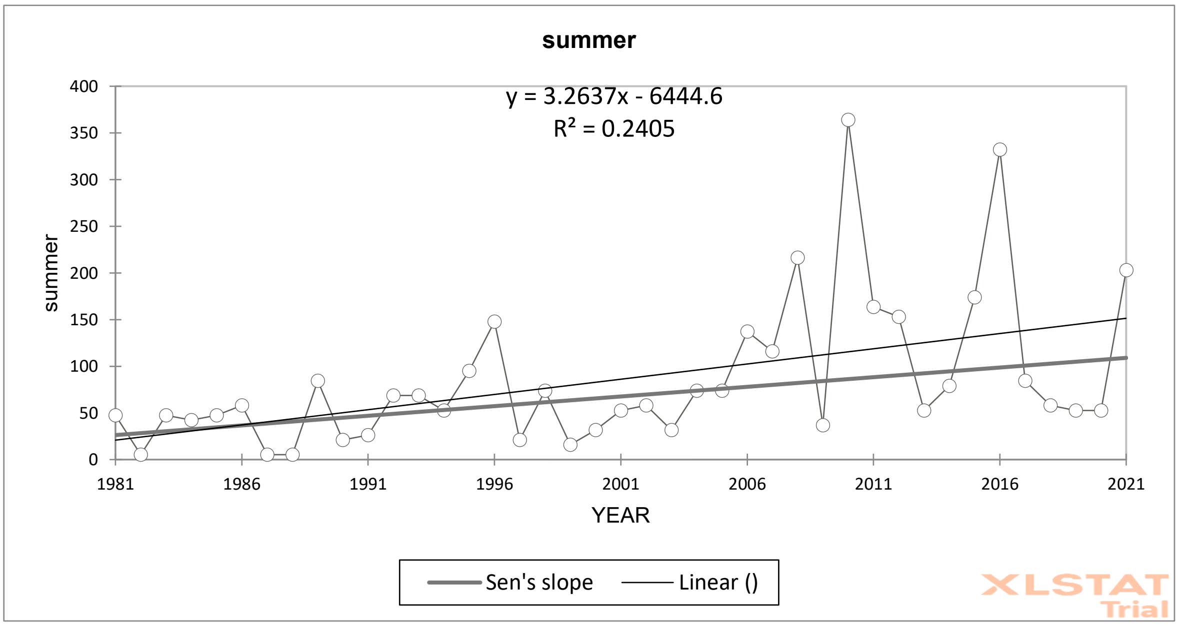


Figure 4.14. Rainfall trend the summer

Mann-Kendall trend test / Two-tailed test (Autumn):

tau value	0.377
S	306
Variance(S)	7907.333
P-Price	0.001
α	0.05

Clarification of the test:

H0: The series shows no trend

Ha: The series is following a trend.

Given that the p-price determination was smaller than the significance levelα=0.05, this indicates that Ha should be accepted, and H0 should be rejected.

Sen's slope:

International Journal of Science and Engineering Science Research
Volume 2 | Issue 1 | January-March 2026 | ISSN 3049-2793
Peer Reviewed (Referred Journal)
DOI: https://doi.org/10.63671/ijsesr.v2i1.88

	Price	Lower limit	Upper limit
Tendency	2.108	0.989	3.356
Cut Off	-4166.452	-6657.112	-1936.961

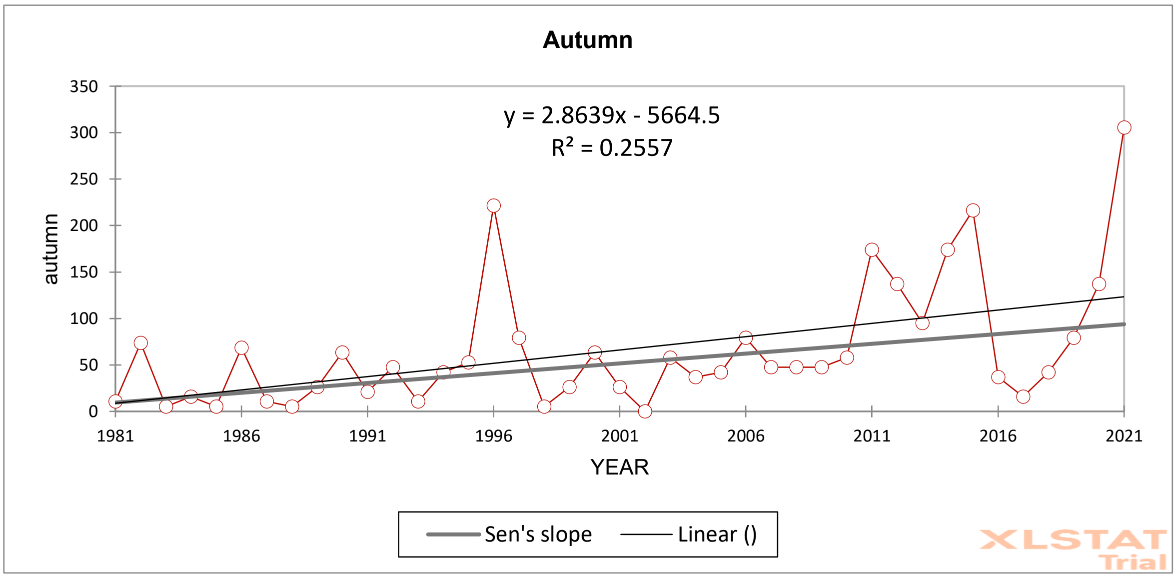


Figure 4.15. Rainfall Trends in the Autumn

Summary of Sen's slope

Series\Test	Kendall's tau	p-value	Sen's slope
JAN	0.247	0.030	0.550
FEB	0.223	0.045	1.054
MAR	0.121	0.275	0.822
APR	0.360	0.001	1.506
MAY	0.317	0.005	1.055
JUN	0.291	0.012	0.310
JUL	0.333	0.003	0.838
AUG	0.336	0.003	0.989
SEP	0.420	0.000	0.959
OCT	0.343	0.003	0.502
NOV	0.271	0.018	0.329
DEC	-0.007	0.964	0.000
ANN	0.417	0.000	13.550
winter	0.264	0.016	2.126
spring	0.290	0.008	3.955
summer	0.410	0.000	2.068
autumn	0.377	0.001	2.108

Table 4.3. Mann Kendell Test Kendall's tau, p-value, Sen's slope of the monthly rainfall from 1981-2021

5. Conclusions

5.1. Conclusions

This was specific to the discussion that the trend analysis of annual rainfall shows a statistically significant positive trend. Because the computed P-price was smaller than the alpha (significance hypothesis), the alternate hypothesis should be accepted and the null hypothesis should be rejected. The yearly rainfall trend study for Nangrahar indicates an increasing tendency, albeit not one that was statistically significant. The study found that there was a tendency for rainfall to rise in the examined area, as indicated by the outcomes of the supplementary Mann-Kendall trend test and Sen's Slope estimator. However, one cannot rule out the null hypothesis, H0 (0.05), because the estimated p-value was less than the significant level of alpha Thus, harsh weather may befall Nangrahar City's capital due to the increasing tendency in rainfall caused by climate change as well as other factors. According to this study, the incidence of rainfall patterns in recent decades has been significantly impacted by climate change as a result of global warming. In the previous 40 years, the Nangrahar region of Afghanistan had seen an increase in the wet monsoon's wetness and a decrease in the dry winter's dryness, which has led to detrimental effects from flood and drought, respectively. December has a negative trend line for monthly rainfall, whereas the trend line slopes positively in all other months. Every year, the amount of precipitation fluctuates; the lowest amount is 0 mm, the highest is 212 mm, and the highest the average yearly precipitation from 1981 to 2021 was 406 mm. The standard deviation (SD) was highest in April. June has the largest coefficient of variance (CV). For the lower Kabul basin in Nangrahar region. The Mann-Kendall test was also analyzed and gave a similar conclusion. The regularity and intensity of severe weather occurrences, such as years with strong rainfall and drought, have risen in the basin due to climate change. In addition to adding to our understanding of Nangrahar's rainfall patterns, this study offers stakeholders, local people, and politician's helpful advice on how to improve the region's water security and sustainability.

References

1. Affleck, Rosa T, Shad M Sargand, Andrew L Russ, Farid Momand, and Michelle C Perez Canals. 2011. "Designing Roads and Retaining Structures for Nangarhar Province, Afghanistan."
2. Akhtar, Fazlullah. 2017. "Water Availability and Demand Analysis in the Kabul River Basin, Afghanistan."

3. Akhtar, Fazlullah, Usman Khalid Awan, Bernhard Tischbein, and Umar Waqas Liaqat. 2018. "Assessment of Irrigation Performance in Large River Basins under Data Scarce Environment—A Case of Kabul River Basin, Afghanistan." *Remote Sensing* 10 (6): 972.
4. Akhtar, Fazlullah, Rana Ali Nawaz, Mohsin Hafeez, Usman Khalid Awan, Christian Borgemeister, and Bernhard Tischbein. 2022a. "Evaluation of GRACE Derived Groundwater Storage Changes in Different Agro-Ecological Zones of the Indus Basin." *Journal of Hydrology* 605: 127369.
5. 2022b. "Evaluation of GRACE Derived Groundwater Storage Changes in Different Agro-Ecological Zones of the Indus Basin." *Journal of Hydrology* 605: 127369.
6. Akhtar, Fazlullah, and Usman Shah. 2020. "Emerging Water Scarcity Issues and Challenges in Afghanistan." *Water Issues in Himalayan South Asia*, 1–28.
7. Akhtar, Shahid Mehmood, and Javed Iqbal. 2017. "Assessment of Emerging Hydrological, Water Quality Issues and Policy Discussion on Water Sharing of Transboundary Kabul River." *Water Policy* 19 (4): 650–72.
8. 8.Aliyar, Qurban, and Morteza Esmailnejad. 2022. "Assessment of the Change of Trend in Precipitation over Afghanistan in 1979–2019." *IDŐJÁRÁS/QUARTERLY JOURNAL OF THE HUNGARIAN METEOROLOGICAL SERVICE* 126 (2): 185–201.
9. Azizi, Abdul Haseeb, and Yoshihiro Asaoka. 2020. "Assessment of the Impact of Climate Change on Snow Distribution and River Flows in a Snow-Dominated Mountainous Watershed in the Western Hindukush–Himalaya, Afghanistan." *Hydrology* 7 (4): 74.
10. Basistha, Ashoke, Dhyan Singh Arya, and Narendra Kumar Goel. 2009. "Analysis of Historical Changes in Rainfall in the Indian Himalayas." *International Journal of Climatology: A Journal of the Royal Meteorological Society* 29 (4): 555–72.
11. Bromand, Mohammad Tayib. 2015. "Impact Assessment of Climate Change on Water Resources in the Kabul River Basin, Afghanistan."
12. Jonathan, KH, and PS Raju. 2017. "Analysis of Rainfall Pattern and Temperature Variations in Three Regions of Sultanate of Oman." *International Journal of Civil Engineering and Technology* 8 (2): 173–81.
13. Lashkaripour, Gholam Reza, and SA Hussaini. 2008. "Water Resource Management in Kabul River Basin, Eastern Afghanistan." *The Environmentalist* 28 (3): 253–60.