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Climate Change, Rainfall Trends and Variation in Yola, Adamawa State Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study evaluated the effect of climate change on rainfall trends and variation in Yola, Adamawa state Nigeria for the period of 30 years (1992-2021) which represents a climatic period. Rainfall data were collected from the archive of the Nigerian Meteorological Agency (NiMet), Yola station, from 1992-2021. Rainfall variations and trends over the study period were analyzed using Mann Kendal trend test and the Theil Sen slope estimator. The analysis of the inter annual trend of the rainfall shows an overall decreasing trend in Yola within the study period (1992-2021), which implies that rainfall in Yola has decreased during the study period with a magnitude of 7.23 mm year-1. The decadal analysis revealed a positive trend for the three decades. It further show that the first decade has the highest rainfall trend while the second decade is the lowest rainfall decade with values that range from 10.7 to 45.1 mm decade-1. It was also observed that there was a considerable increase in rainfall amount in the third decade compared to the second decade. Finally, the projection of rainfall shows a decreasing trend for the next decade with a decadal trend of -0.057 mm decade -1. It was therefore recommended that farmers should plant species of early maturing crops, drought resistance seeds should be made available to the farmers for planting and government should build earth dams to harvest rain waters for irrigation farming activities in the state.

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Keywords: Climate change; trends; variation; rainfall variability; planting; Adamawa State Nigeria.

1. INTRODUCTION

Rainfall is important physical parameters of climate as it determines the environmental condition of a particular region which affects agricultural productivity [1]. The droplet that forms when atmospheric water vapor condenses fall to the ground as a result of gravity is precipitation. This can come in form of rain, fog, snow etc. Rain plays a crucial role in the water cycle and is responsible for depositing the majority of the fresh water on Earth. It offers water for hydroelectric power plants, irrigation for crops, and favorable environmental conditions for a variety of ecosystems. The amount of rainfall is a climatic factor that influences how people live. However, rainfall has been fluctuating due to climate change. Climate change is a long term change in weather pattern of a region. Rainfall has benefits, but it can also be detrimental in some situations. It was said to create natural calamities like landslides and floods [2]. In Northern Nigeria, excess rainfall primarily affects farming and may cause food insecurity, delay in crop maturity and harvesting of crops while in Southern Nigeria, it results to Flooding [3]. To assess the impact of climate change on rainfall pattern in a region or location, rainfall data for at least 30 years are be used. Based on the distribution of rainfall throughout the year, a region's climate can be described as either markedly seasonal with a long dry season or relatively seasonal with a short dry season [4]. Yola South LGA is one of the vulnerable locations that had resources of flood and drought occurrences over a long climatic period as a result of seasonal unpredictability and rainfall distribution in the areas, which impose a major detrimental influence on agriculture and the environment settings in the area.

The degree to which rainfall levels fluctuate over a region or over time is known as rainfall variability [5]. Rainfall variability can be used to describe a region's climate. In Nigeria, while rainfall variability rises from the north central to the South-East, annual rainfall variability rises from the northwest to the southwest [6]. The rainfall trend on the other hand is a significant change in the spatial and temporal patterns. The duration, severity, frequency, seasonality, variability, trend, and variation of intense rainfall have all been linked to a higher frequency of flooding, according to studies [7]. Through the expansion and development of multiple datasets and more in-depth data analysis conducted globally, the understanding of past and contemporary climate change has attracted great attention [8]. In addition to the risk of more frequent droughts and floods, long-term rainfall patterns may shift due to global climate changes [7].

Low harvests, economic losses, and human famine will result from unfavorable weather conditions for the agriculture sector, such as extended periods of drought and unexpectedly intense periods of rainfall (flood). Therefore, the assessment of past rainfall trends and future trends is necessary to control and manage water resources effectively. Yola's economy is heavily reliant on natural resources that are susceptible to the effects of climate change. The seasonal rainfall pattern in Nigeria has two maximums in the South, one peak in the North, and is typically decreasing throughout Nigeria, especially in the North. The average annual rainfall ranges from 700 mm in the northwest to 1600 mm in the state's far southern region [9]. About 80% of the State's population relies mostly on agriculture for their livelihood [10]. [11] Noticed a small rise in the amount of rainfall experienced in coastal areas, he found that the length of rainy days had significantly decreased, notably in the North. According to the findings, the rate of erosion/desertification, soil erosion, coastal floods, drought, and other extremes in the nation may have been accelerated by the changing rainfall pattern, like elsewhere in the tropics, rainfall makes up most of the precipitation that occurs in Adamawa State.

In Yola, the effect of climate change on the agricultural field and water resource still lacks significant research and the level of awareness is still low. Thus, in order to make informed decisions and plan effectively in water-sensitive industries like agriculture, energy, and health, accurate and consistent information on future rainfall trends is required. The data is crucial for developing pertinent strategies for mitigating climate change, in addition to aiding in the formulation of effective climate adaption measures.

Therefore, the objective of this study is to reveal the impact of climate change on rainfall trends and variation in Yola, Adamawa State, Nigeria with a view to understand the situation and make appropriate recommendation.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Study area

Yola is a city in Adamawa state, Nigeria, in latitude 09°14'North and longitude 12°28' East. Taraba State, Gombe State, Borno State, and an international border with the Cameroon Republic border Adamawa State to the south and west, the north and northwest, and the eastern side (Fig. 1). Tropical dry and wet weather prevails in the state. Yola has two distinct seasons, the wet season (April to October), and the dry season (November-March). This happens as a result of two main air masses that affect the region's weather and environment. The rain bearing southwestern wind that originates from the Atlantic Ocean and dry northeastern air masses (Harmattan) from the Sahara Desert.

2.1.2 Data collection

Monthly rainfall data for a period of 30 years were collected from Nigerian Meteorological Agency (NiMet), Yola international airport, Adamawa State. The data used spans between the periods of 1992 to 2021.

2.2 Methods

To measure the significance of trends in meteorological time series, the Mann-Kendall statistical test which has been widely used is applied (12). In this work, annual and seasonal rainfall time series data during the 30-years study period were subjected to the Theil-Sen estimator and Mann-Kendal test for trend analysis.

$$S = \sum_{i=1}^{n-1} \sum_{j=1+i}^{n} sign(x_{j-}x_i) \quad (1)$$

Sign (xj - xi) is the sign function, and n denotes the number of data points. xi and xj are the values of the data in the time series i and j, respectively. Mathematically,

$$sign(x_{j-}x_i) = \begin{cases} +1 \; for \; x_i - x_j > 0 \\ 0 \; for \; x_i - x_j = 0 \\ -1 \; for \; x_i - x_j < 0 \end{cases}$$

The variance is calculated by;

$$Var(s) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{p} t_i(t_i-1)(2t_i+5)}{18} \quad (2)$$

$$Zs = \{\frac{S-1}{\sqrt{var(S)}}, for\ S > 0 \; 0,\ for\ S = 0 \; \frac{S+1}{\sqrt{Var(S)}}, for\ S < 0 \quad (3)$$

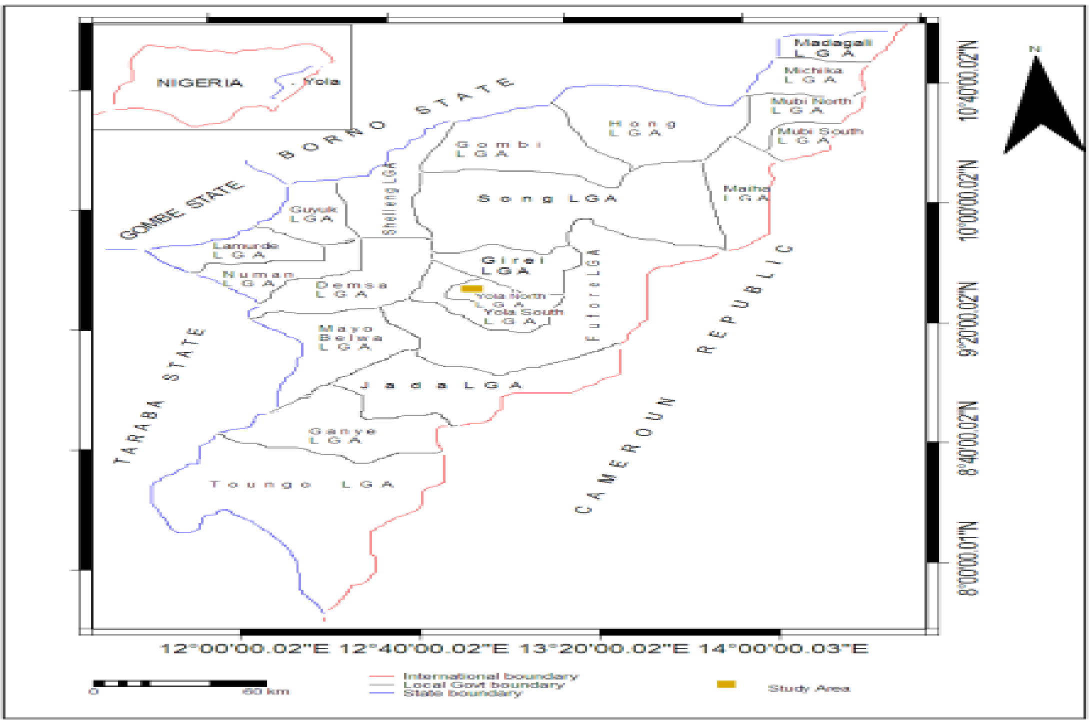

Fig. 1. The Map of the Study area

Where P is the number of linked groups, t_i denotes the number of data values in the Path group, and n denotes the number of data points. The summation sign (Σ) denotes the summing over all tied groups. Positive Zs values show an increase while negative Zs values show a decrease in trend patterns. Trends are tested with a 5% degree of confidence.

3. RESULTS

The following are the results obtained from the statistical tools/software used for the study.

3.1 Annual Variation of Rainfall from 1992 to 2021

Table 1 shows the average rainfall (mm) values across for Yola from 1992-2021. The line plot of the result is presented in Fig 1.

The statistical analysis of the data within the period under review show that rainfall decreased within the period with Kendall's test and Sen's estimate showing negative values though the decrease is not significant since the PVaue of 0.121` is greater than the significant level at 0.05.

3.2 Decadal Rainfall Trend

The study period was divided into three decades in order to analyze the variation of rainfall in each decade. The results obtained are presented in the Tables 3 to 6.

The trend analysis show that rainfall in the decade increased with Kendall's test and Sen Slope having positive values, though the increase is not significant because the PValue of 0.721 is greater than the significant level at 0.05.

The trend analysis show that rainfall increased within the decade, though the increase is not significant because of PValue 0f 0.074 which is greater than the confidence level value of 0.05.

The analysis of rainfall in the decade showed an increasing trend but the increase is not significant because the PValue is greater than the confidence level of 0.05

3.3 Analysis of the Projected Rainfall

Below is the summary of the ARIMA model used for the rainfall projection for the next decade (2022 to 2031) in Yola.

The analysis of projected rainfall showed that a decrease in rainfall is expected in the area in the next decade because the Kendall's test value is negative though the decrease is not expected to be significant as the PValue of 0.6743 is greater the confidence level value of 0.05.

The trend analysis of rainfall between 1992 and 2021 is illustrated in Fig 2. It shows a decreasing trend as stated in Table 2 while the subsequent figures illustrate the trend in various decades. Though, the three decades showed a positive trend, it does not actually mean that rainfall increased progressively within the decades. Rather it showed that rainfall received at the end of each decade is greater than the start of the decade. This is due to non-parametric nature of the Kendall test adopted.

4. DISCUSSION

4.1 Inter Annual Variation of Rainfall

The inter annual variation of rainfall in Yola for the period of 1992 to 2021 is presented in table 1. Table 2 shows the descriptive of the mean rainfall value across the years of study. The annual rainfall is between 566.9 mm to 1635.0 mm with a mean value of 1064.3 mm. The line plot in Fig 2 shows that rainfall has peaked significantly twice within the time of the study in Yola. The first peak was observed in the year 1997 with a value of 1635mm while it dropped in the year 2003 and 2004 with values of 1006.4 mm and 1003. 4 mm. The second peak was in the year 2011 with a value of 1459.95mm and thereafter drops significantly in the year 2012 with a value of 566.9 mm. In recent years, the highest peak observed was in the year 2020 with a value of 1079.9 mm while the least occurred in the year 2019 with value of 732.3 mm. On the account of the variation, it can be observed that the highest rainfall occurred in the year 1997 with a rainfall value of 1635 mm while the lowest rainfall recorded occurred in the year 2012 with a value of 566.9 mm within the study period.

The analysis of the inter annual trend of the rainfall shows an overall decreasing trend in Yola within the study period (1992-2021), with a negative Kendal tau value of -0.203, while -7.23 as the magnitude of the trend change as revealed by the Sen's slope estimator. It implies that rainfall in Yola has decreased during the study period with a magnitude of 7.23 mm $year^{-1}$. This result is consistent with works that revealed decrease in precipitation (rainfall) across arid and semi- arid zones both within and outside the country because of the effect of climate change. Chief of such research is the work of [13] which reported a downward trend in rainfall across some states in the North – East Nigeria, with Yola inclusive, from 1949 to 2014.

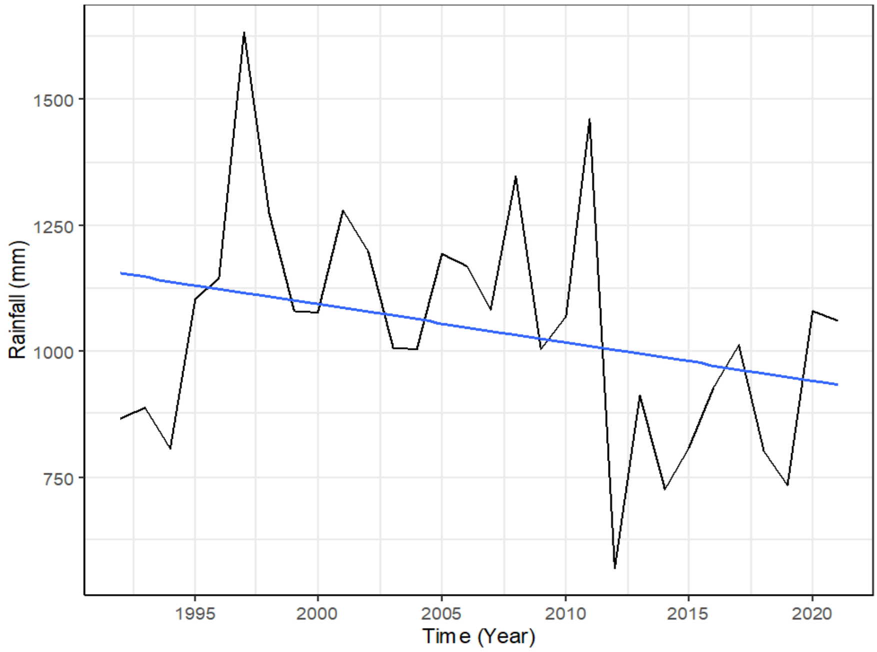

Fig. 2. Inter annual rainfall trend in Yola from 1992 to 2021

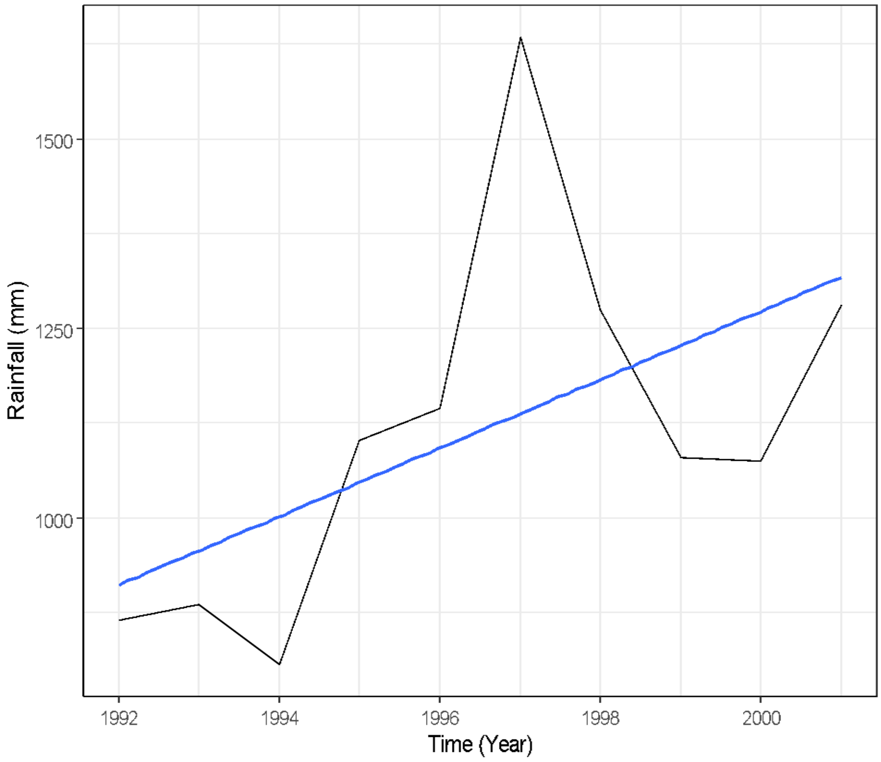

Fig. 3. Decadal rainfall trend in Yola from 1992 to 2001

Table 1. Annual rainfall for Yola from 1992-2021

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1992	0	0	0	40.5	48.6	93.5	61.9	407.3	182	31	0	0	**864.8**
1993	0	0	0	83.2	98.2	226.8	93.7	161.6	125.5	97.4	0	0	**886.4**
1994	0	0	0	52.8	60	154.7	86.8	198	195.7	57.7	0	0	**805.7**
1995	0	0	0	83.7	127.3	234.1	243.2	261.7	121.9	30.7	0	0	**1102.6**
1996	0	9	0	96.1	195.3	79	164.5	217.4	286.4	96.3	0	0	**1144.0**
1997	0	0	0	35.9	168.3	401.2	256.2	357.1	378.7	37.6	0	0	**1635.0**
1998	0	0	0	46.8	170.2	270.6	116.4	276.4	312.4	80.9	0	0	**1273.7**
1999	0	0	0	27.4	82	182.6	79.6	289.5	317.3	100.7	0	0	**1079.1**
2000	0	0	0	68.3	116.7	261.4	187.9	173.7	207	61	0	0	**1076.0**
2001	0	0	0	27.3	49.3	278.1	311.6	243.9	286.7	83.4	0	0	**1280.3**
2002	0	0	0	51.4	112.5	70.5	113.9	413.1	307.3	130	0	0	**1198.7**
2003	0	0	0	23.2	142	211.3	157.1	162	215.1	95.7	0	0	**1006.4**
2004	0	0	0	73.1	112.7	154.3	180	217.3	184.8	81.7	0	0	**1003.9**
2005	0	0	0	41	119.2	158.1	213	388.5	198.5	75	0	0	**1193.3**
2006	0	0	0	59.5	91.7	131.5	131.5	270.9	371	112.4	0	0	**1168.5**
2007	0	0	0	94.7	127.6	246.5	117.9	215.2	200.9	80.2	0	0	**1083.0**
2008	0	0	0	48	200.1	176.9	232	281	317.3	91.5	0	0	**1346.8**
2009	0	0	0	51	79.7	173	198.1	190.4	235.9	75.9	0	0	**1004.0**
2010	0	0	0	41.5	57.3	147.8	158.2	341.7	253.4	68.6	0	0	**1068.5**
2011	0	0	0	67	69.3	203	252	411	389.3	67.9	0	0	**1459.5**
2012	0	0	0	2.5	58.8	29.9	75.7	134.1	210	55.9	0	0	**566.9**
2013	0	0	0	12	108	213.4	157.1	162.8	189.5	67.2	0	0	**910.0**
2014	0	0	0	86.8	61	142.4	93.8	120	178.7	40.9	0	0	**723.6**
2015	0	0	0	53	100.8	69.2	135.7	185.2	205.3	56.5	0	0	**805.7**
2016	0	0	0	71.5	76.4	175.4	57.4	211.5	287.8	48.3	0	0	**928.3**
2017	0	0	0	48.2	115.5	211.3	102.7	284.7	197	52	0	0	**1011.4**
2018	0	0	0	57.2	66.5	134.3	148.1	162.4	156.9	75.9	0	0	**801.3**
2019	0	0	0	19.5	28.2	50.9	156.7	203.2	216.4	57.4	0	0	**732.3**
2020	0	0	0	46.2	226.3	256.1	113.8	208.6	198.7	30.2	0	0	**1079.9**
2021	0	0	0	91.5	83.7	181.4	219.2	170.2	265.1	49	0	0	**1060.1**

Table 2. Trend analysis of annual rainfall mean of Yola (1992 to 2021)

Location	Minimum	Mean	SD	Maximum	Kendall'stau	PValue(5%)	Sen'sSlope
Yola	566.9	1064.30	227.20	1635.00	-0.203	0.121	-7.227

Table 3. Decadal trend of rainfall over Yola from 1992–2001

Location	Minimum	Mean	SD	Maximum	Kendall's tau	P-Value (5%)	Sen's Slope
Yola	1004	1153	153.9	1460	0.111	0.721	10.7

Table 4. Decadal trend of rainfall over Yola from 2002 to 2011

Location	Minimum	Mean	SD	Maximum	Kendall's tau	P-Value (5%)	Sen's Slope
Yola	566.90	862.00	165.2	1079.90	0.467	0.074	37.900

Table 5. Decadal trend of rainfall over Yola from 2012 to 2021

	Minimum	Mean	SD	Maximum	Kendall'stau	P-Value (5%)	Sen's Slope
Yola	805.70	1114.80	244.30	1635.00	0.422	0.1074	45.05

Table 6. Summary of the ARIMA (1,0,0) Model

Mean	Rmse	Aic	Mase	Acf	Accuracy	Kendall'sTau	P-Value (5%)
1041.322	1.850	49228	16.11132	0.779	84%	-0.0157	0.6743

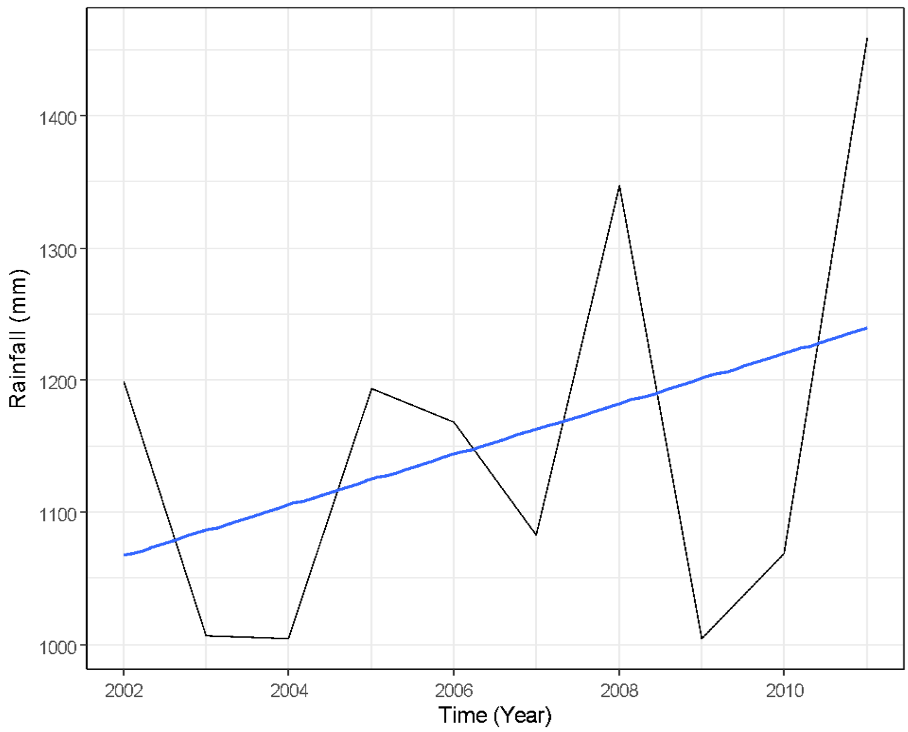

Fig. 4. Decadal rainfall trend in Yola from 2002 to 2011

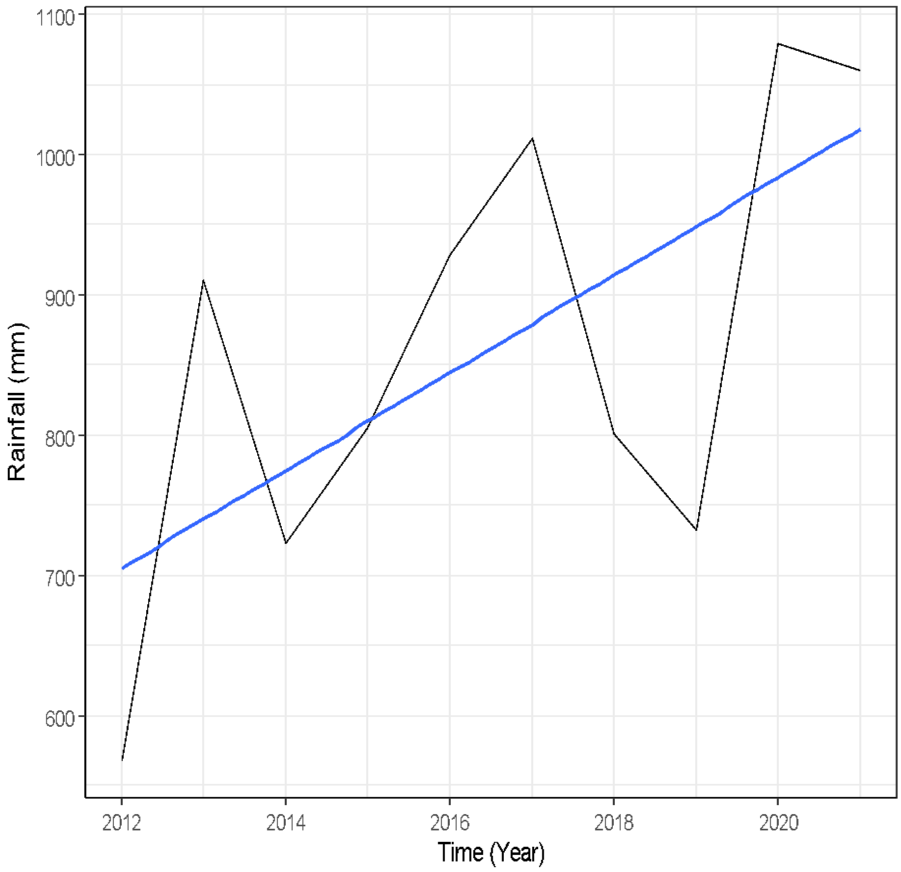

Fig. 5. Decadal rainfall trend in Yola from 2012 to 2021

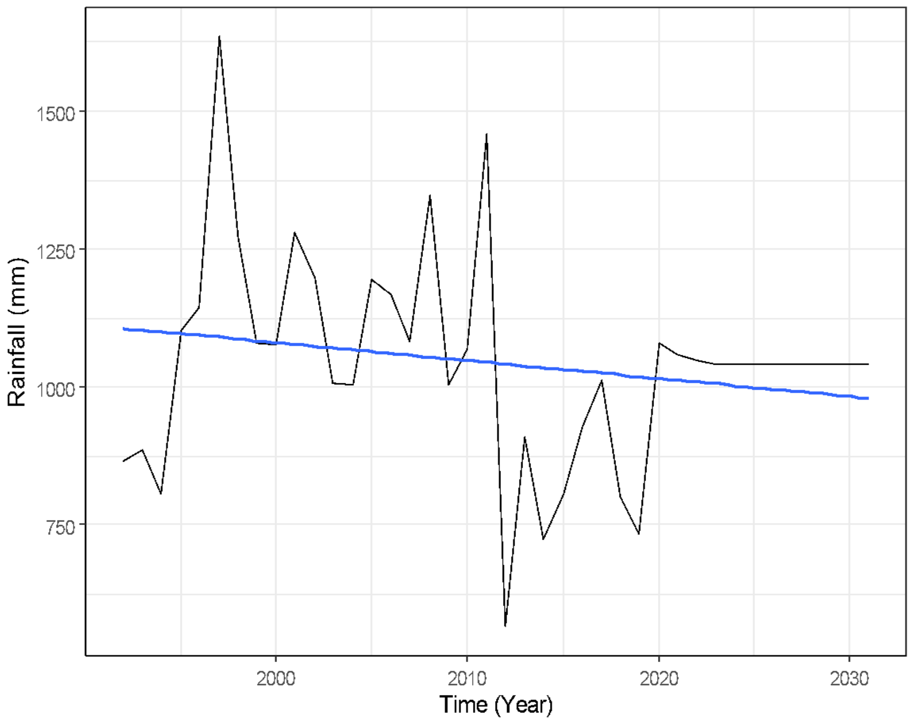

Fig. 6. Time series plot of rainfall trend in Yola from 1992-2031

4.2 Decadal Rainfall Trend

Tables 3 to 5 show the results of the statistical analysis performed using the Mann Kendal test and the Sen's slope of the decadal rainfall trend. According to the results, as shown in figures 3 to 5, the rainfall can be grouped into three decades. The Sen's slope provides the trend's magnitude alongside the Mann-Kendal trend analysis test. During the first decade (1992-2001), the maximum rainfall value of 1635 mm was observed in the year 1997 while the minimum rainfall value of 805.70 mm was observed in the year 1994. This decade recorded the highest and lowest rainfall amount during the study period. The decade received an increased trend in rainfall as revealed by the Mann-Kendal with 45.05 mm decade^{-1}as the magnitude of change. Positive trend was observed in the second decade, 2002-2011. The maximum rainfall value of 1460 mm was observed in the year 2011 while the minimum rainfall value of 1004 mm was observed in the year 2009. The Sen's slope estimator estimated 10.7 mm decade^{-1}as the decadal magnitude change quite lower than the first decade. The decadal trend for the third decade (2012-2021) also shows a positive trend. The maximum rainfall value of 1079.9 mm was observed in the year 2020 while the minimum rainfall value of 566.90 mm was observed in the year 2012. The Sen's slope estimator estimated 37.9 mm decade^{-1} as the decadal magnitude.

It can be noted that while all the three decades show a positive trend, it does not mean that rainfall increased progressively; rather it only shows that the rainfall amount received at the end of each decade is greater than the start of the decade. This occurs because of the non-parametric test adopted for the analysis which work based on ranking. Therefore, following the Sen's slope values, it can be inferred that the first decade had the highest rainfall decade in Yola while the second decade is the lowest rainfall decade. It therefore means that rainfall increased considerably in the third decade compared to the second decade.

4.3 Projected Rainfall Trend

The summary of projected rainfall trend analysis using the Autoregressive Integrated Moving Average (ARIMA) model is shown in Table 6. The performance of the work shows about 84% accuracy with a root means squared error (RMSE) of 16.1. The table further shows that 1041.32mm rainfall expected in Yola on average, for the next decade.

Rainfall peaked in Yola in the year 2022 within the projected decade with a value of 1046.5 mm and a minimal in 2027 with a value of 1041.3 mm is expected. The amount of rainfall in Yola is expected to increase at the start of the decade and drop considerably towards the end of the decade according to the Mann-Kendal test value of -0.0157.

5. CONCLUSION

This study evaluated the variation and trend of rainfall in Yola, Adamawa state Nigeria for the period of 30 years (1992-2021) which represents a climatic period. The analysis of the inter annual trend of rainfall shows an overall decreasing trend in Yola within the study period (1992-2021). The decadal analysis revealed a positive trend for the three decades show that the first decade has the highest rainfall while the second decade is the lowest rainfall decade. There was a considerable increase in the amount of rainfall experienced in the third decade compared to the second decade. The amount of rainfall in Yola is expected to increase at the start of the next decade and decrease considerably towards the end of the decade. In conclusion, rainfall is expected to decrease in the next decade. Therefore, stakeholders in the area are expected to made adequate arrangements to mitigate the effects of declining rainfall in the area by implementing the recommendations below.

6. RECOMMENDATIONS

Based on the findings of this work, it is thereby recommended that the farmers should adopt irrigation practice to support farming activities due to the decrease in rainfall expected in the state. Relevant government agencies should formulate policies geared towards helping farmers to adapt to the climate change menace. The government should consider erecting dams to harvest water during raining season to aid irrigation farming. Drought resistance seeds should be made available to the farmers for planting.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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