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Department of Geography and Meteorology
Nnamdi Azikiwe University, Awka

Examination of Trend and Patterns of Rainfall and Temperature in Awka, Anambra State (1975 – 2020)

Ozoemene, M.L.[1*], Nwosu, A, C.[2], Obikwelu, M.C.[3] and Igboanugo, R.I.[4]

[1,2,3,4]Department of Geography and Meteorology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

[*]Corresponding Author Email: ml.ozoemene@unizik.edu.ng

Abstract

The study examined the trend and patterns of rainfall and temperature in Awka, Anambra State from 1975-2020. The study used long term historical data on rainfall, minimum and maximum air temperature to investigate observed climatic variability. Monthly rainfall, minimum and maximum temperature data were obtained from the Nigerian Meteorological Agency (NIMET), Abuja. The study usedMann–Kendall and Sen's slope estimator tests to detect monotonic trends in the mean annual and total rainfall, minimum, maximum and mean temperature and their magnitude with MAKESENS_1_0 application in EXCEL format. The result indicated an increasing trend in rainfall and temperature in the area. Rainfall pattern was characterized in terms of standardized anomaly index and seasonality index while temperature was characterized in terms of anomaly index. The result of rainfall seasonality index showed that annual rainfall has witnessed a shift from months to extreme seasonality. The rainfall and temperature standardized anomaly index showed that rainfall fluctuated in the area from dry and wet years. The maximum Standardized Rainfall Anomaly Index (SRAI) was 3.460 in 2019 indicating an extremely wet year while the minimum SRAI was -1.241 indicating moderately dry year. The maximum Seasonality Index(SI) was 1.5311 indicating an almost all rain in 1- 2 months while the minimum SI was 0.4256 indicating rather seasonal rainfall with a short drier season.

Keywords: Anomaly index, Climate Change, Rainfall, Seasonality index, Temperature, Trend analysis

Introduction

Climate plays a vital role in the earth's ecosystem and in the survival of the human race. It is the statistical description of the mean and variability of the meteorological parameters over a long period of time (Hegel et al, 2007). The examination of the long-term variability in the various weather elements is a necessary task in the study of climate change. The chronology and the understanding of the climatic parameter variation have attracted substantial attention through enhancements and extension of copious datasets and sophisticated data analytical tools across the world (Panda and Sahu, 2019). According to Pal and Mishtra, (2017) "global climate changes will influence long-term rainfall patterns thereby impacting the availability of water with the danger of increasing occurrences of droughts and floods". Singh, Arya and Chaudhary (2013), stated that temperature and rainfall are the most vital and fundamental weather parameters that determine the atmospheric condition and micro-climate of a particular locality which affects the agricultural productivity. Agriculture and other interrelated segments, food security of any region are momentously reliant on the timely availability of sufficient amount of water and a clement conducive climate (Panda, and Sahu, 2019).

Climate change is significantly impacting agriculture by increasing water demand, limiting crop productivity and by reducing water availability in areas where irrigation is most needed or has comparative advantage. Water availability has been shown to be influenced by rising temperatures and longer growing seasons. Increasing evaporative demand is predicted to increase crop irrigation by up to twenty percent globally by 2080 and up to fifteen percent in Nigeria (Fischer et al, 2007). Uncertainty around anticipated weather can impact decisions around crop production (e.g., date of planting, seed purchasing, date of harvest), leading to food shortages (Osuafor, 2014).

The robustness of the Nigerian economy is ominously dependent on the development and investment in the agricultural sector as agriculture employs over 70 percent of the population. Over 80 percent of crop production in Nigeria is dependent on rainfall (Tajudeen et al. 2022). Rainfall in Nigeria is highly variable on spatio-temporal scales. The south-west monsoon brings precipitation to Nigeria while the tropical continental air mass brings dry weather. According to Emenike, et al (2017), the annual precipitation/rainfall varies from 500m in the extreme north to 3000m along the coast. Nigerian's atmospheric condition in respect to rainfall is highly influenced by high pressure southwest monsoon winds from the Atlantic Ocean in June-July thereby pushing the inter-tropical front to the Sahelian region of the country. Livada and Asimakopoulos (2005) investigated rainfall regimes over 150 stations, distributed over Greece from 1950-2000 using the rainfall seasonality index (SI) of Walsh and Lawler (1986).The SI defined over the Greek territory was found to range between 'very equable' and 'markedly seasonal with a long drier season'. As a result, the closer the station was to the sea, the larger the SI value became. Seasonality index values were found to accurately depict inter-annual rainfall variability, indicating no statistically significant trend. Thus, it can be concluded that the observed rainfall regimes have not changed in the last 50 years, despite the observed reduced tendency in the annual rainfall amounts. Sharma and Singh (2019) analyzed monthly rainfall data for Jharkhand state, India in 18 stations for a period of 102 years (1901–2002) using the seasonality index. Individual seasonality index SI was calculated for each year and mean of SI of the long-term mean individual seasonality index was calculated. The value of SI represents the seasonality index ranged between 0.886 and 1.08, while the SI values ranged between 0.928 and 1.11 The SI value increases from the southeast to the northwest of the state. The values of both SI represents the seasonality index, and SI show that rainfall in Jharkhand state can be described as either markedly seasonal with a long dry season or most rainfall in less than 3 months. For the time series analysis, the Mann– Kendall (MK) test was applied to detect trends in the individual seasonality index and Sen's slope estimator was also applied to calculate the magnitude of the trend. The results of the MK test and Sen's slope showed a significant decreasing trend over the northeast of Jharkhand, and a statistically non-significant decreasing trend over the southwest. The decrease in seasonality could be attributed to the changing climate, and it can have both positive and negative effects on seasonality of crops and power generation. Rai and Dimri (2019) studied rainfall seasonality over India using individual seasonality index and mean individual seasonality over two periods- 1901-1970 and 1971-2015.trend analysis over the two periods showed a decreasing trend which indicates shorter dry periods in recent period. Fajemidagba, Sawa, Adeleke, and Ibrahim (2019) investigated rainfall seasonality in the South-Western region of Nigeria. The data used for this study were monthly rainfall data for Lagos, Ogun, Oyo, Osun, Ondo and Ekiti states for the period of 1983-2017. The calculated seasonality index (S.I) was subjected to time series analysis, where trend lines and linear line equations were fitted to show direction of change in these parameters. Furthermore, Crammer's t-test was used to determine if there was a significant variation in seasonality indices in the region for the period of study. Seasonality index for South-western Nigeria during the study period is characterized by marked variability from year to year during the study period. Rainfall seasonality indices in south-western Nigeria ranged between 0.59 and 0.64 with the mean rainfall seasonality index in the region being 0.60. This result indicates that wet season in south-western Nigeria occurred within 7-9 months during the period of study. The linear trend line equation was negative; meaning that the region experienced a shortening spread of rainfall during the study period. Adejuwon (2012) determined rainfall seasonality in the Niger delta, using both monthly and annual rainfall data from 1931 to 1997; to determine its seasonal variation, rainfall was calculated in terms of a percentage of the mean value, and it was found that more than 95% of rainfall occurs during the rainy season.

The critical scrutiny of temperature and rainfall and other climatic parameters on different geospatial scales will aid in the prognosis of the future climate conditions (Partal and Kahya, 2006; Addisu, Sellassie, Fissha and Gedif, 2015; Neil and Notodiputro, 2016; Sinha and Srivastava, 2000; Arora, Goel, and Singh, 2005; Karaburun, Demirci and Kara, 2011; Meshram et al., 2018). According to Smadi (2006); Tabari and Talaee (2011) and Olofintoye and Sule (2010), temperature has an influence on the natural hydrological processes such as rainfall and rainfall has a corresponding effect on temperature. This study hence sought to examine the trend and patterns of rainfall and temperature in Awka, Anambra State from 1975 to 2020.

The Study Area

Awka is the capital of Anambra State. It was created on the 27th of August, 1991. The town witnessed rapid growth due to its expertise in blacksmith. It has a central location as well as proximity to tertiary institution such as Nnamdi Azikiwe University, Awka. Awka is located on latitude $6^0$25N and longitude 7^0E. Awka is predominantly a low lying region on the western plain of the Mamu River with all parts of 333 meters above sea level. The region is traversed by some streams like Iyiagu, Ofiachi, Olepalayan and Obibia. The major topographic feature in the region is two, the east-facing cuestas (escarpments and asymmetric ridges) with each escarpment trending southward outside the Awka urban to form part of the Awka-Orlu upland. The higher one is the Abagana-Agulu cuesta where the land rises above 333 meters or (1000ft) above mean sea level outside the Awka Urban. Awka has two seasonal climatic conditions, they are the rainy season and the dry season. The dry season is characterized with the harmattan. The harmattan which falls within December and February is a period of very cold weather when the atmosphere is generally mist (Ezeigwe, 2015). The dryness of the climate tends to be discomforting during the hot period of February to May, while the wet period, between June and September is very cold. Awka is characterized by the annual double maxima of rainfall with a slight drop in either July or August known as dry spell or (August break). The annual total rainfall is above 1,450 mm concentrated mainly in the wet season. Awka has a mean annual rainfall of about 1,524mm with mean daily temperature of 27^{0}C. The daily minimum temperature is about 18^{0}C with annual minimum and maximum temperature ranges at about 22^{0}C and 34^{0}C respectively. It has a relative humidity of 80 percent at dawn. In the riverine and low-lying areas particularly the plain west of Mamu River up to the land beyond the permanent site of Nnamdi Azikiwe University, the underlying impervious clay/shale cause water logging of the soil during rainy season. The soil sustaining forest vegetation on the low plains farther away from the river maintains a good vegetation cover. The soil are rich and good for root tuber crops like yam, cassava and also maize. The two main types of soil found in the area are ferruginous and hydromorphic soils. Ferruginous soil is rich in iron and is derived from marine complexes of sandstone, clay and shale. They therefore vary from the deep red and brown porous soil derived from the sandstones and shale to deep porous brown soil identified from sandstone and clay.

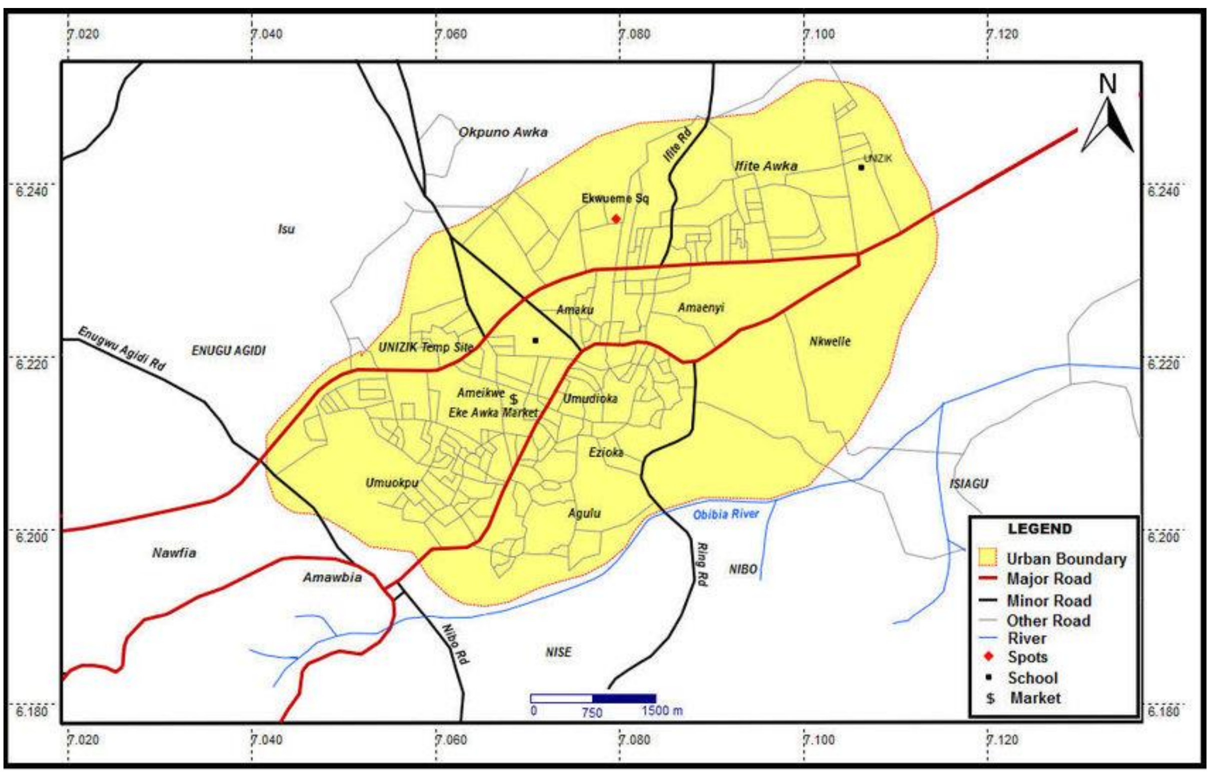

Figure 1: The Map of Awka, Anambra showing its Topography (Source: Office of the Awka Town Planning Authority (2017)).

Methodology

Methods of Data Collection

The climatological data required for this analysis was collected from secondary and historical data from Nigeria Meteorological Agency (NIMET) Data Management Unit, Abuja.

Methods of Data Analysis

The data was analysed to determine any indication of climate change within the study area from 1975-2020. The tools needed include descriptive and inferential statistical analysis as well as trend analysis. Statistical analyses of climatic variables can help to identify the cause and consequence of a shift in climate pattern (Dani and Pal, 2017). Trend analysis is an important and efficient method of identification of changes in climate (Auffhammer et al., 2011). Trend analysis of rainfall and temperature and patterns in the study area were carried out in the study area in order to detect evidence of climate change. The variability in rainfall were examined using seasonality index and standardized rainfall anomaly index.

Seasonality Index

Rainfall seasonality index was analysed using the Walsh and Lawler (1981) index. Seasonality Index is a function of mean monthly and annual rainfall, computed using the following formula:

$$SI_i = \frac{1}{R_i}\sum_{n=1}^{12}\left|X_i - \frac{R_i}{12}\right| \qquad (1)$$

Where SI represents the seasonality index, R_i is mean annual rainfall and Xi is mean monthly rainfall for month n. Theoretically, they can vary from zero (if all the months have equal rainfall) to 1.83 (if all the rainfall occurs in one month). Table 1 shows the different class limits of SI and representative rainfall regimes (Walsh and Lawler (1981).

Table 1: Seasonality index (SI) class values and the associated rainfall regimes (after Walsh and Lawler, 1981).

Rainfall regime	Seasonality Index (SI)
Very equable	≤ 0.19
Equable but with a definite wetter season	0.20 -0.39
Rather seasonal with a short drier season	0.40 – 0.59
Seasonal	0.60 – 0.79
Markedly seasonal with a long drier season	0.80 – 0.99

Most rain in 3 months or less	1.00 -1.19
Extreme, almost all rain in 1- 2 months	≥ 1.20

Standardized Anomaly Index

Standardized Rainfall Anomaly Index (SRAI) was calculated as the difference between the annual total of a particular year and the long term average rainfall records divided by the standard deviation of the long term data. This characteristic of the SRAI have contributed to its popularity for application drought monitoring and also makes possible the determination of the dry and wet years in the record (WMO, 2012). Its formula is given as:

$$Z = \frac{X-\mu}{\delta} \quad \text{.......... (2)}$$

Where, Z is standardized rainfall anomaly index; x is the annual rainfall total of a particular year; μ is mean annual rainfall over a period of observation and δ is the standard deviation of annual rainfall over the period of observation. Standardized Rainfall anomaly index value was categorized according to McKee (1993) classification (Table 2). Standardized anomaly index value of Kraus (1977) was categorized according to Mckee (1993) as shown in Table 2.

Table 2: SAI value classification table

SAI Value	Category
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and less	Extremely dry

(Source: McKee, 1993)

Trend analysis

The trend is an ideal statistical measure for the identification of changes in climate variables. Trend analysis refers to the general direction of a time series over a long period of time. It indicates whether there is a general increase or decrease in the quantity of a variable over time (Anyadike, 2009). The non-parametric Mann–Kendall rank test identifies monotonic trends, over time, for given variables, and establishes whether the trend is upwards or downwards. A positive correlation indicates that the ranks of both variables are increasing, and a negative correlation indicates that the rank of one variable increases while that of the other variable decreases. The test allows comparative evaluation by correlating different dependent and independent datasets. The Mann–Kendall test assesses the accuracy of two hypotheses, such that H_0 (the null hypothesis) represents no trend over time and H_A denotes the presence of a trend (increasing or decreasing), with a significance level α = 0.05. If the computed P-value is less than α, the null hypothesis H0 is rejected. The Mann-Kendall test statistic S is calculated using the formula that follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1} \text{sign}\ (\text{xj} - \text{xk}) \quad \ldots\ldots (3)$$

Where xj and xk are the annual values (years) j and k, j > k, respectively, and sign (x_j-x_k) is given by:

$$\text{Sign}\ (x_j\text{-}x_k) = \begin{cases} 1\ if\ \text{xj} - \text{xk} > 0 \\ 0\ \ if\ \ \text{xj} - \text{xk} = 0 \\ -1\ if\ \ \text{xj} - \text{xk} < 0 \end{cases} \quad \ldots\ldots (4)$$

In MAKESENS the two-tailed test is used for four different significance levels α: 0.1, 0.05, 0.01 and 0.001. At certain probability level H_0 is rejected in favour of H_1 if the absolute value of S equals or exceeds a specified value S α /2, where S α /2 is the smallest S which has the probability less than α /2 to appear in case of no trend. A high positive value of S is an indicator of an increasing trend, while a low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend. The variance of S is computed as:

$$\text{VAR (S)} = \frac{1}{18}\left\{n(n-1)(2n+5) - \sum_{p=t}^{q} t_p(t_p - 1)(2t_p + 5)\right\} \quad \ldots\ldots (5)$$

Here q is the number of tied groups and t_p is the number of data values in the p^{th} group. If n is at least 10 the normal approximation test is used. For n > 10, the test statistic Z approximately follows a standard normal distribution. The values of S and VAR(S) are used to compute the test statistic Z as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{VAR (S)}}},\ S > 0 \\ 0\ , \quad\ S = 0 \\ \frac{S+1}{\sqrt{\text{VAR (S)}}},\ S < 0 \end{cases} \quad \ldots\ldots (6)$$

The Z values will be tested at the 95% ($Z_{0.025}$=1.96) and 99% ($Z_{0.001}$=2.58) level of significance. The trend is said to be decreasing if Z is negative and the absolute value is greater than the level of significance, while it is increasing if Z is positive and greater than the level of significance. If the absolute value of Z is less than the level of significance, there is no trend.

Sen's Slope Estimator

Sen's estimator of slope, which is a non-parametric method, was used to develop linear models in this study. To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear that is:

$$f(t) = Qt + B \quad \text{……(7)}$$

Sen's non-parametric method was used to estimate the magnitude of trends in the time series data:

$$Tt = \frac{xj - xk}{j - k} \quad \text{……(8)}$$

Where xj and xk represent data values at time j and k respectively. A positive Qi value represents an increasing trend; a negative Qi value represents a decreasing trend over time. The magnitude of the trend over time Qi is given by:

$$Qi = \begin{cases} \frac{T(N+1)}{2} & N \text{ is odd} \\ \frac{1}{2}\left(T\frac{N}{2} + T\frac{N+2}{2}\right) & N \text{ is even} \end{cases} \quad \text{……(9)}$$

Results

This study investigated the changes on rainfall and temperature in Awka, Anambra State from 1975 to 2020. Investigation was conducted using data on monthly rainfall, minimum and maximum air temperature.

Rainfall Variability in the Study Area

In this study, we used seasonality index, rainfall anomaly index and coefficient of variability to characterize rainfall variability. Rainfall distribution in the study area was found to exhibit a great intra-annual variability with a mean monthly rainfall of 151.23mm and coefficient of variability of 128.8 percent. The lowest monthly rainfall of about 8.43 mm was received in January while the highest rainfall was received in the month of September with about 288.315 mm. Figure 2 shows the mean monthly rainfall distribution for Awka for the period 1975 to 2020. From the figure, rainfall in Awka starts from April, peaks in July and declines in August and peaks again till October. This shows that most of the rainfall fell in the wet season (April-October) with a double maxima rainfall pattern.

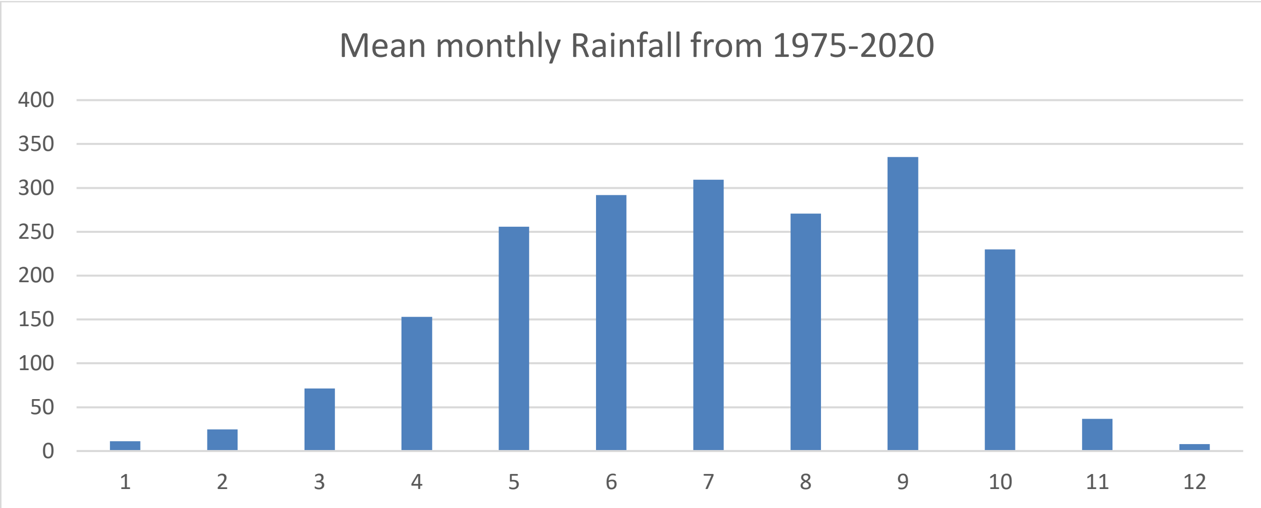

Figure 2: Variation of Mean Monthly Rainfall in Awka from 1975-2020

Rainfall distribution in the study area also exhibits a great inter-annual variability with a mean annual rainfall of 1997.0 mm with a standard deviation of 539.4 and coefficient of variability of 27.21 percent (Table 4). The lowest rainfall of about 1327.6 mm was received in 1983 while the highest rainfall of about3363.4 mm was received in the 2019.

Table 4: Descriptive Statistics of Total Rainfall

Variable	N	N*	Mean	SE Mean	StDev	CoefVar	Minimum	Q1	Median
Annual	46	0	1997.0	79.5	539.4	27.01	1327.6	1682.3	1885.9
Variable	Q3	Maximum							
Annual	2072.3	3863.4							

The result of the annual and mean monthly rainfall for 46 years (1975-2020) was subjected to time series analysis. The time series plot and trend analysis of the total annual and mean annual rainfall distribution is given in figure 3a and 3b. The result shows slight level of variation especially in the monthly mean rainfall between 1975 and 2020. According to the figure, the area has witnessed alternating years of wet and dry years. Extreme wet years include 2019 while extreme dry years include 1983.

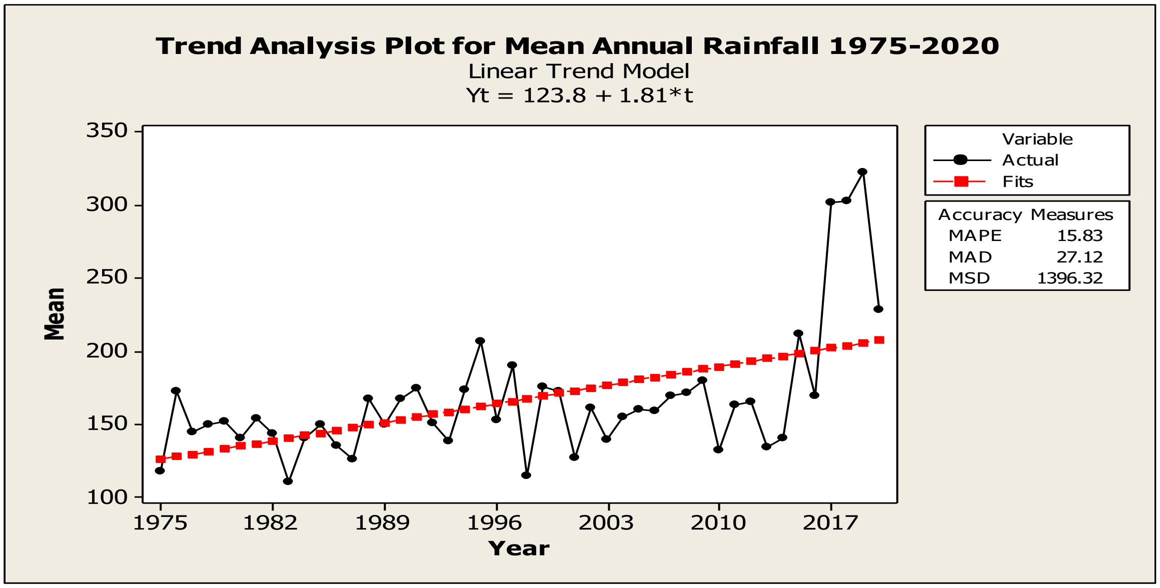

Fig 3a. Time series plot and trend of Mean Rainfall in Awka from 1975-2020.

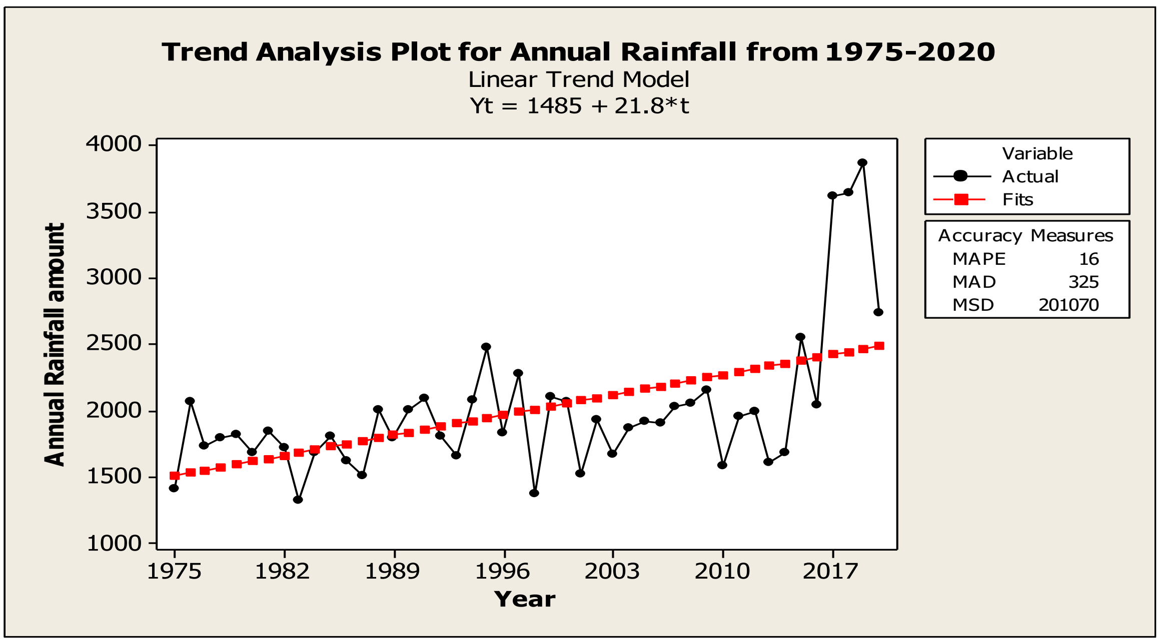

Fig 3b. Time series plot and trend of Annual Rainfall in Awka from 1975-2020.

Standardized Rainfall Anomaly Index (SRAI)

Standardized anomaly index value of Kraus (1977) was categorized according to Mckee (1993) as shown in table 2. Analysis of the standard anomaly index for the stations is presented in figure 4. This result indicated that the minimum standard anomaly values of -1.241 categorized as moderately dry occurred in the 1985, 1983 and 1998 in Awka while values of 1.0 and above indicate very wet years. The result showed that 2015 and 2020 were moderately wet while 2017 to 2019 were categorized as extremely wet in Awka.

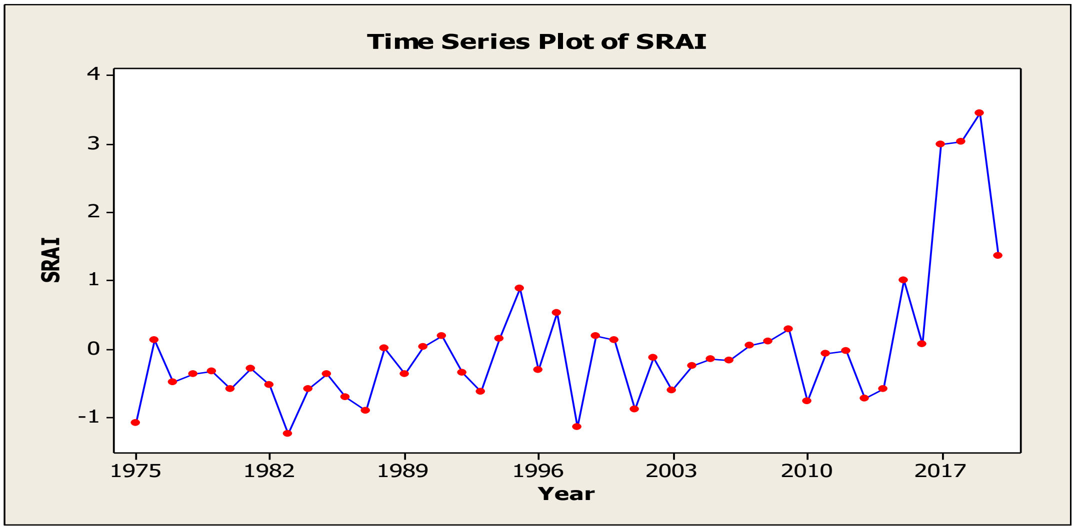

Fig 4. Time series plot of Standardized Rainfall Anomaly Index in Awka from 1975-2020.

A trend analysis of the standardized rainfall anomaly index is shown in figure 5. From the figure, it can be seen that the rainfall anomaly has been showing an increasing trend signifying a change in rainfall pattern.

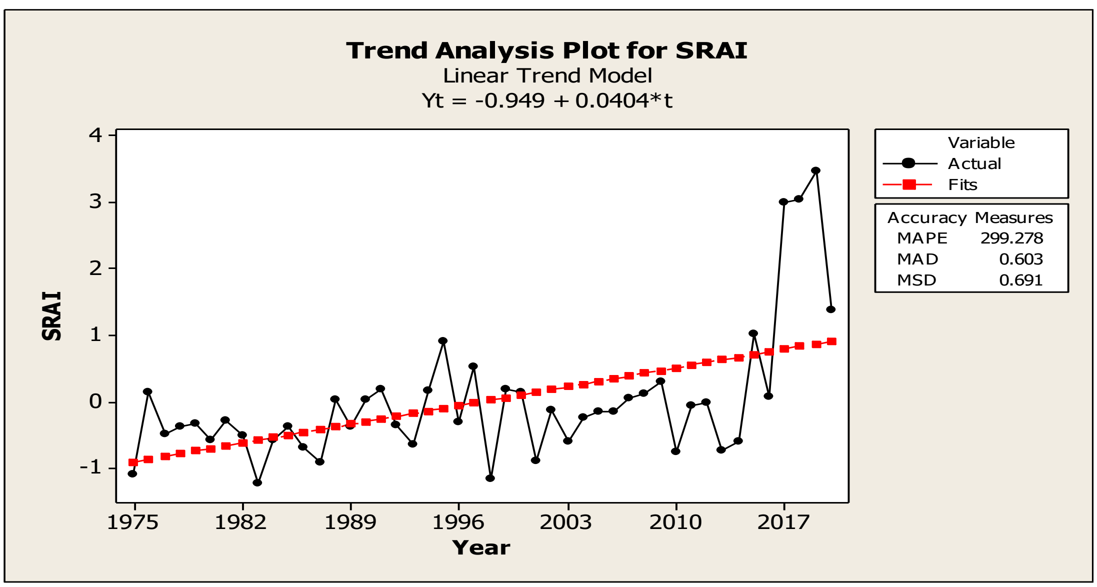

Fig 4. Time series plot of Total Annual Rainfall in Awka from 1975-2020.

Rainfall Seasonality Index

The temporal variation of rainfall in the area was also characterized using the seasonality index. The result of rainfall seasonality index for Awka is presented in figure 6.

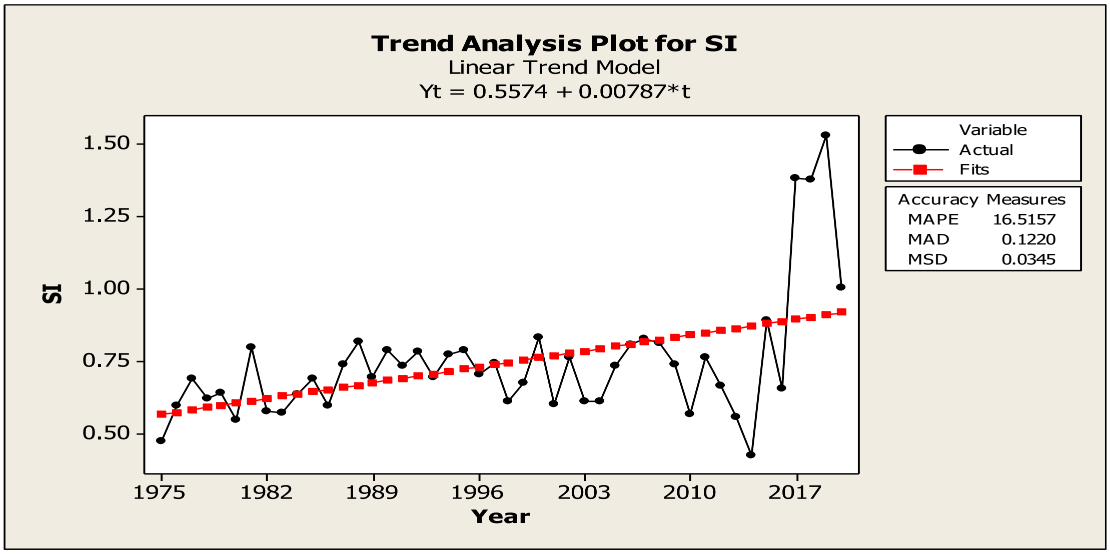

Fig 6. Time series plot of Total Annual Rainfall in Awka from 1975-2020.

Analysis of the annual rainfall seasonality index shows that the pattern of rainfall has been changing in the area which may have impact in extreme rainfall events. The annual rainfall seasonality index in the area has a mean value of 0.7424 which indicates that most of the rainfall in the area is seasonal. Over the period, the minimum and maximum seasonality index was 0.4256 and1.5311respectively which indicate a rather seasonal with a short drier season and extreme, almost all rain in 1-2 months respectively. The increasing trend of the seasonality index shows an increasing tendency towards high intensity of rainfall which is liable to cause flooding. A high seasonal pattern of rainfall is resulting in most of the unstable total annual runoff being only a few months of the year. The coefficient of variability of rainfall seasonality index is 29.02 percent which indicates the normal variable nature of rainfall in the area (Table 3).

Table 3: Descriptive Statistics: SI

Variable	N	N*	Mean	SE Mean	StDev	CoefVar	Minimum	Q1	Median
SI	46	0	0.7424	0.0318	0.2154	29.02	0.4256	0.6102	0.7004
Variable	Q3	Maximum							
SI	0.7918	1.5311							

Temperature Variability

The monthly maximum and minimum temperatures were converted to mean temperature. The time series plot of the mean annual temperature variation in Awka is presented in figure 7

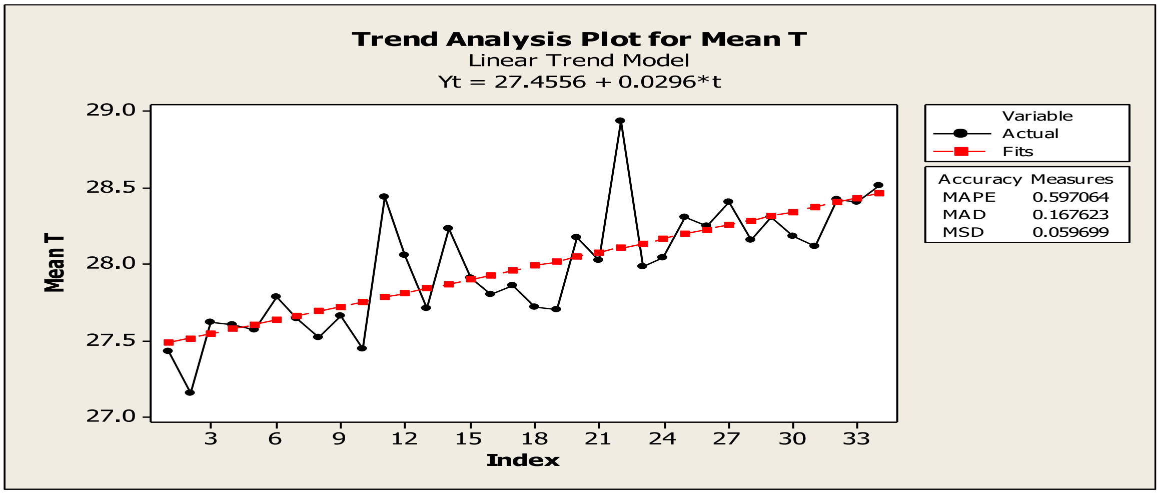

Figure 7: Trend analysis plot of mean temperature in Awka from 1975-2020.

The temperature variability over the study period was characterized in terms of anomaly index. The result is presented in Figure 8.

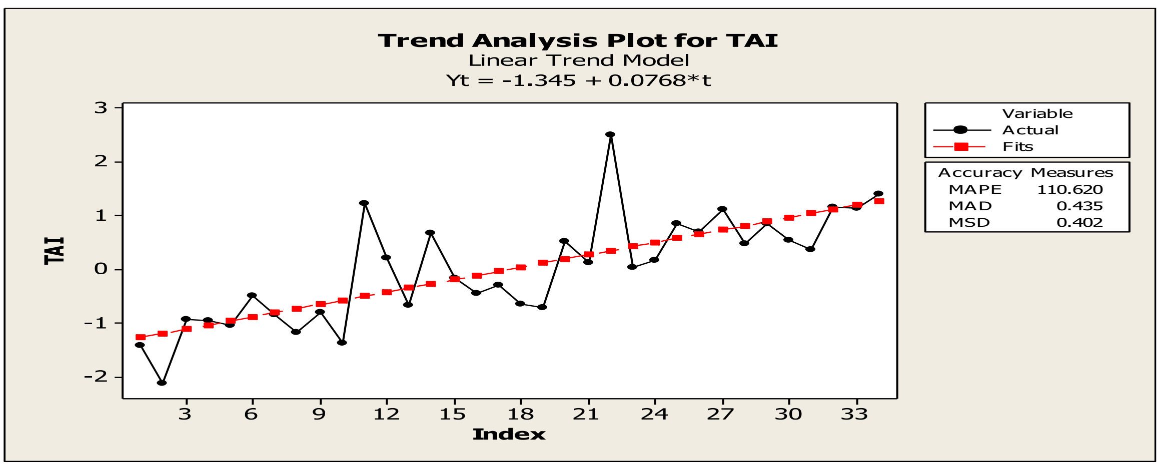

Figure8: Time series plot of temperature anomaly index in Awka from1975-2020.

Trends Analysis of Rainfall and Temperature

Time series for the variables were tested for trends and slopes annually using the Mann–Kendall test. These include maximum, minimum and mean temperature, annual and mean annual rainfall. It has been carried out for various hydrological components such as rainfall data analysis, and stream flow analysis (Oguntunde et al. 2000; Oguntunde et. al.2012; Kumar et al. 2000). The Mann-Kendall trend analysis and Sen's slope estimator was done with MAKESENS_1_0 software. The result of the analysis is shown in Table 5.

Table 5: Result of Mann–Kendall trend test.

Time series	First year	Last Year	n	Test S	Test Z	Signific.	Q
Tmax	*1975*	*2020*	*46*		4.63	***	0.034
Tmin	*1975*	*2020*	*46*		2.16	*	0.023
Tmean	*1975*	*2020*	*46*		5.13	***	0.030
Annual Rainfall	*1975*	*2020*	*46*		3.31	***	12.392
Mean Rainfall	*1975*	*2020*	*46*		3.31	***	1.033

For the four tested significance levels the following symbols are used in the template:

*** if trend at α = 0.001 level of significance

** if trend at α = 0.01 level of significance

* if trend at α = 0.05 level of significance

+ if trend at α = 0.1 level of significance

If the cell is blank, the significance level is greater than 0.1.

n: Number of years, Z: Mann-Kendall test statistic f (year); Q is the Sen's slope n.s. non-significant.

The Mann-Kendall trend analysis indicate that annual rainfall and mean annual rainfall amount has increased with a. Z-score is 3.31which is greater than $Z_{0.025}$ ($Z_{0.025}$ = 1.96 at 5 percent) which makes it statistically significant, indicating an increase in rainfall amount. The Sen's slope is 12.392 and 1.033 for annual and mean annual rainfall respectively. The result also indicate that rainfall has been increasing at the rate of 12.392 mm per year and 123.92 mm per decade. The Mann-Kendall trend analysis also indicate that minimum temperature has increased with a z-score of 2.16 which is greater than $Z_{0.025}$) where with $Z_{0.025}$ = at 1 percent confidence interval, which makes it statistically significant and with a Sen's slope of 0.023. The maximum temperature showed an increasing trend with Z score of and 4.63 and a Sen's slope of 0.034that is significant at 5 percent while the mean temperature increased with a Z-score of 5.13 and a Sen's slope of 0.030 and is statistically significant at 1 percent confidence level. This indicates that the increases in minimum, maximum and mean temperature are statistically significant. The mean temperature has been increasing at the rate of 0.3^0 C per year and 3^0 C per decade. The result is supported by the findings of Olofintoye and Adeyemo (2011) and Salami, Sule and Okeola (2011). This increase could be as a result of climate change.

Discussion

The distribution of rainfall throughout the seasonal cycle is as important as the total annual amount of monthly or annual rainfall and has its impact on hydrology, ecology, agriculture or in water use. The time and duration of the seasons of high precipitation at a place or watershed is most important for the planning and design of agriculture or water management. The distribution of rainfall through the season or year plays an important role in recharging the ground water. It is very important to identify the historical changes in the mean annual precipitation. But even in the absence of changes in annual total precipitation, changes in the seasonal receipt of precipitation greatly affect partitioning of water into runoff, evapotranspiration and infiltration and thus flood forecasting, stream discharge and ecosystem responses.

From the results, it can be seen that rainfall and temperature data over the research period have shown noticeable and significant increase in annual and mean rainfall amount, minimum, maximum and mean temperature. Analysis of rainfall patterns show that the pattern of rainfall has changed as a result of changes in climate. Changes in seasonal rainfall shows an increasing significant trend in rainfall during the wet season while the dry season shows a downward significant trend. At the beginning of the measuring period in 1975, the area received its most precipitation between the months of April and October but is shifting beyond months of maximum rainfall. This result reveals that Awka is becoming wetter in recent years. The upward trend of rainfall in the study area could have implications for flooding, soil erosion and agricultural water use. The change in seasonality of rainfall is giving rise to high intensity rainfall, resulting in flash floods across the area and increasing the rate of soil erosion in the area. The increase in trend of temperature could have implications for groundwater recharge as the evaporation rates increases.

Conclusion

Climate change has led to an increase in temperature of the study area which resulted in an increase in the annual and mean amount of rainfall and temperature. The research shows that there has been a significant upwards trend in temperature while rainfall as been increasing at the rate of

12.92mmyr−1. However, there is a seasonal shift in rainfall. Careful planning and design are required due to the occurrences of extreme weather events caused by climate change, so as to come up with sustainable means of managing these changes.

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