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ANALYSIS OF RAINFALL AND TEMPERATURE CHANGES IN GOMBE STATE, NIGERIA

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ABSTRACT
This study analyses the rainfall and temperature trends of three (3) Agro-Ecological zones of Gombe State. The data for this study were sourced from the Nigerian Meteorological Agency (NiMet), Gombe State Agricultural Development Program (GSADP), and Upper Benue River Basin Development Authority (UBRBDA). The data were subjected to Linear Time Series Analysis, Mann-Kendall Z- Statistics, Sen's Slope Estimator and Linear Growth Model. The results revealed an increasing pattern of temperature in all the zone. The mean temperature for the study period revealed an increasing rate of 0.0352^{o}C, 0.0031^{o}C and 0.0281^{o}C in the Southern Guinea Savannah (SGS), Northern Guinea Savannah (NGS) and Sudan Savanna (SS) respectively. The annual rainfall revealed a decreasing trend at the rate -0.957mm, -2.74mm and -0.87mm per^{-1}in SGS, NGS and SS respectively while Gombe station in NGS revealed an increasing trend at the rate of 3.05mm per^{-1}. The projected trends revealed that there is going to be decreasing of temperature for Billiri station in SGS and an increasing trend of rainfall for Gombe station in NGS for the coming decades. The study concludes that there is a significant increase of temperature in all the zones and there is no statistical trend of rainfall in SS. The current trend will affect soil moisture, crop water requirement and subsequently lead to ecological change. The study recommends that inhabitants of the study areas should plan their cropping season based on climatic information of their area.

Keywords: Eco-Climatic, Trend, Prediction, Mann-Kendall Test, Sen's Slope Estimator

INTRODUCTION

The trend of climatic variable has never been static, it has been fluctuating over space and time. Changes in the frequency and pattern of the climatic variable have a significant impact on the natural and human system. These changes may cause certain extreme weather events such as flood, drought and heat stress increase, dry and wet spells, plant pest and diseases. According to IPCC (2007), global temperatures near the earth surface have increased by 0.74°C from 1906 to 2005 and are estimated to increase by about 6.4°C on average during the 21st century. In the Africa continent, there is an overall increase in temperature with an approximate rate of increase at 0.7^{o}C during the 20th century with the warming rate of 0.05^{0}C per decade (IPCC, 2007).

The general circulation models project an increase in warming across the African continent, ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario). The warming conditions in the African continent result to increases in rainfall around the equatorial region of East Africa where rainfall during the wet season may increase between 5% to 20%, and drought conditions may be exacerbated by 5% to 10% during the dry seasons (Hulme et al., 2001). Sivakumar, Das and Brunini (2005) studied the impact of present and future climate variability and change on agriculture and forestry in arid and semi-arid tropics where they indicates increasing surface temperature trends in recent decades. Odiana and Ibrahim (2015) observed that rainfall and temperature trends were on the increase in Bauchi by 0.2mm and 0.0299^{o}C per annum respectively, by implication Bauchi is vulnerable to flooding, ecosystem change and having a detrimental effect on agricultural produce thereby leading to food scarcity**.** Wanah and Mbaya (2012) noted increasing trend of rainfall and decreasing trend of rainy days in Gombe State, Msheliza and Bello (2016) reported increasing trend of temperature at the rate of 0.092 °C per^{-1} and a decreasing trend of rainfall at -1.705mm per^{-1} in Gombe State while Abashiya et al., (2017) reported an increase in the rainfall yield in Gombe metropolis. This study examines the variation in the behavior of the climatic variables across the three (3) Agro-Ecological Zones of the state**.** The implication of these changes may have impact on agricultural activities which are the major means of livelihood of the inhabitants of the study areas.

Rainfall and temperature are the major climatic elements that influence rain-fed agriculture which are on constant changes.

These changes may be positive or negative depending on the condition. The inhabitants of Gombe state were faced with the challenges of decreasing crop yield, crop failure, wilting of crops, flood and water scarcity (Msheliza and Bello, 2018). Previous studies by Wanah and Mbaya (2012) focus on just general patterns of climatic variables using time series analysis by adapting Hammond and McCollagh (1974) method. This study focused on the variation in the trends of rainfall and temperature within the three Agro-Ecological zones of the state using Mann-Kendell and Sen's slops Estimator.

The aim of this study is to determine the variation in the trend of the climatic variable within the three (3) Agro-Ecological zones of Gombe State. The specific objectives are to determine the trend of rainfall and temperature in the state and to predict the future trend of rainfall and temperature.

METHODOLOGY

Study Area

Gombe State is located between Latitude9°30' and 12° N and Longitude 8°45' and 11°45'E. It shares boundaries with Yobe State to the North, Borno and Adamawa States to the East, Bauchi State to the West and Taraba State to the South Figure 1. Gombe State has a flat landscape in the North while southern parts of the state have isolated hills. The elevation of the plain is at about 600 meters above sea level, the hills reach between 700 meters and 800 meters. According to Mayomi, et al. (2016) the relief is categorized into four units such as: the river basin (33.0%), plains (34.7), uplands (26.7%) and Highlands (5.8%). The climate is characterized by the alternating wet and dry season. The maximum daily temperature of 38ºC is experienced during the hot dry seasons (March to April), the minimum temperature is 25ºC and the annual mean temperature is 36.3ºC (Msheliza and Bello, 2016). The vegetation of Gombe State falls within the Sudan Savanna and the trees are measured up to three meters where some are in groups and others are isolated (Udo, 1981). The people are mainly farmers with a population of 2, 353, 879 during 2006 population census (National Population Commission [NPC], 2006). Gombe state falls within three (3) distinctive Agro Ecological zones namely; Southern Guinea Savannah (SGS), Northern Guinea Savannah (NGS) and Sudan Savanna (SS) Figure 1.

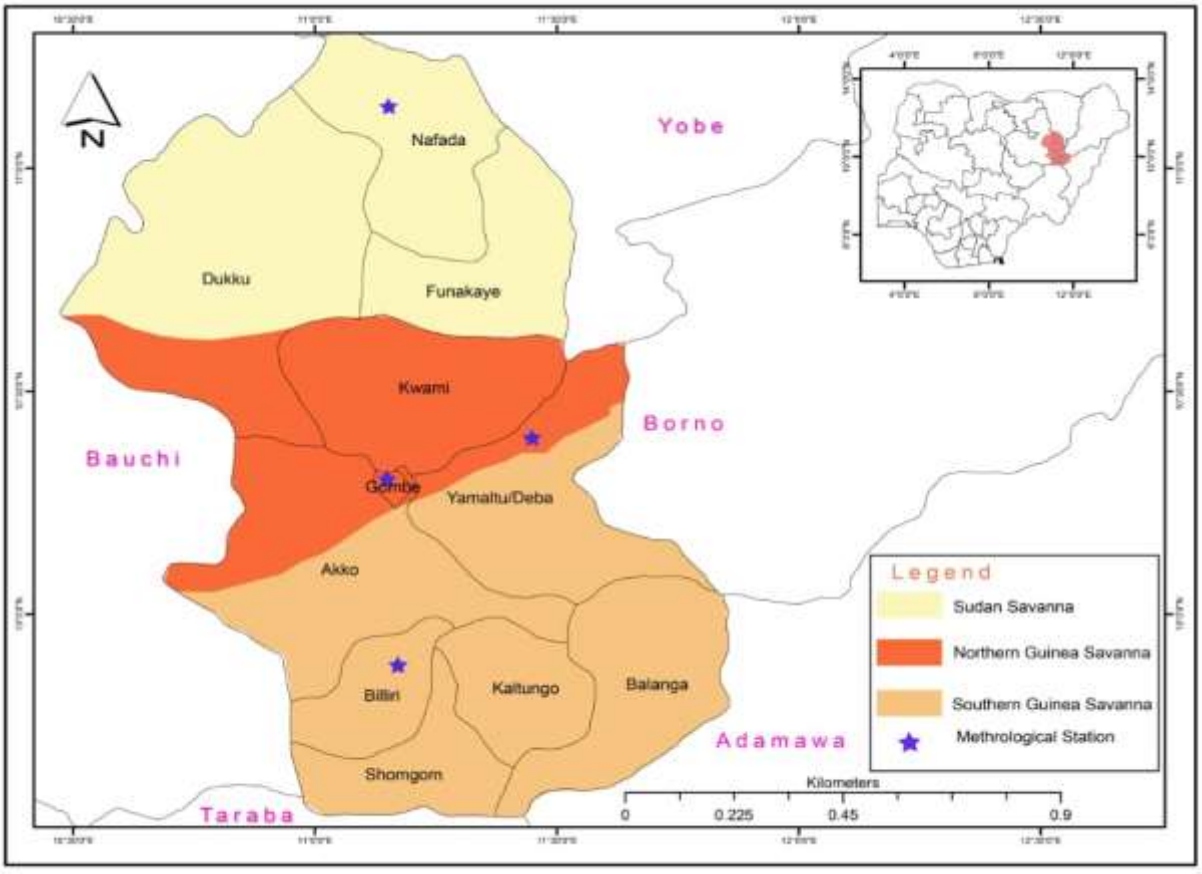

Fig. 1: Map of the Study Area

Source: International Institute of Tropical Agriculture (IITA), after FEWS NET, (2018)

DATA COLLECTION

Climatic data was obtained from three (3) sources: Upper Benue River Basin Development Authority Dadin-Kowa meteorological station, Nigerian Meteorological Agency (NiMet) and Gombe State Agricultural Development Program (GSADP) meteorological stations. The (Table 1.1) present the station where the climatic variable for this study was sourced. The weather stations were not established at the same time and some of the stations are no longer functioning that is why there is discrepancy in the onset and the end of the data available for this study. Due to incomplete data in some stations satellite climate data for the area close to the station was used to substitute the missing once.

Table 1: Meteorological Stations

Station	Latitude	Longitude	Period	No. of Years
Billiri *	11° 13'31" E	9°51'53'' N	1977- 2017	41
Dadin-Kowa **	11°28'54''E	10°19'19''N	1984- 2017	34
Nafada *	11°19'5''E	11°05'44''N	1983 - 2012	30
Gombe ***	11° 03' 0.0'' E	10° 18' 59''N	1975 - 2017	43

Source: * Gombe State Agricultural Development Program (GSADP)

** Upper Benue River Basin Development Authority (UBRBDA)

*** Nigerian Meteorological Agency (NIMET)

DATA ANALYSIS

Linear time series analysis, Mann-Kendall test and Sen's slope estimator were used to achieve objective one (1) where the trend of rainfall and temperature for a period of thirty years and above were determined. Regression analysis using Linear Growth Model (LGM) was used to project the future trend of the climatic variables to achieving objective two (2). The equation for the linear time series are as follows:

$Y_t = a + bt + e_t$ …….. (1)

Where Y_t= the amount of rainfall or temperature

a = intercept

b= slope, which measures the rate of change in rainfall or temperature with time **t**

e_t= random error component

Spearman's rank order correlation coefficient (r) was used to determine whether the trend in the linear time series analysis is either upward or downward. It is computed as:

$$\text{rho} = 1 - \frac{6\sum_d 2}{N\,(N^2-1)} \quad \text{……(2)}$$

Where (r) is positive, it indicate upward trend and where (r) is negative, it indicates down ward trend in the time series.

The trend analysis was further carried out by the following statistical tools: Mann-Kendall test and Sen's slope estimator. Due to the presence monotonic increasing or decreasing trend, a non-parametric Mann-Kendall test was used. The slope of a linear trend was also estimated with a non-parametric Sen's slope estimator.

Mann-Kendall Analysis

The non-parametric Mann-Kendall test is usually used to detect trends that are monotonic in the series of rainfall and temperature of the study areas. The null hypothesis (H_o) in the Mann-Kendall test is the independent variable and randomly ordered. It does not require the assumption of normality, and only indicates the direction but not the magnitude of significant trends. The alternative hypothesis, (H_1), is that the data follows a monotonic trend. The Mann-Kendall test statistic S is computed using the formula (Pohlert, 2018);

$$S = \sum_{k=1}^{n-1}\sum_{j=k+1}^{n} sign(x_j - x_k) \quad \text{……(3)}$$

Where X_j and X_k are the annual data values of (rainfall and temperature) in years j and k, $j > k$, respectively, and n is the length of the data.

$$sign(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_k > 0 \\ 0 & if\ x_j - x_k = 0 \\ -1 & if\ x_j - x_k < 0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

A very high positive value of S is an indicator of an increasing trend, while a very low negative value indicates a decreasing trend in the time series as in the equation above (4). so to find out the statistically significant of the trends, the probability associated with S and the sample size (n) need to be computed, The variance of the statistic S may be computed as;

$$E(s) = 0, \ \ var(s) \approx \frac{n(n-1)(2n+5)}{18} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The Man-Kendall parameter *S* and variance VAR(S) is used to compute the test statistic *Z* as

follows :

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

The Z statistic follows a normal distribution and is tested as; the critical value of Z at 95% level of significance ($Z_{0.025}$ = 1.96) and the critical value of Z at 99% level which is Z $_{0.001}$ = 2.58 are compared with the calculated values of Z. The trend is said to decrease if Z is negative and the absolute value is greater than the level of significance, the trend is said to increase if Z is positive and greater than the level of significance. There is no trend if the absolute value of Z is less than the level of significance.

Sen's Slope Estimator

This is a simple linear regression model used to detect trends in data using parametric models. The Sen's non-parametric test estimates the true slope of an existing trend (as a change per year). Sen's method is used in cases where the trend can is assumed to be linear:

$$y(t) = Qt + B \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where Q is the slope, B is a constant and *t* is time. To get the value of Q in the equation (6)

$$Sen's\ estimator,\ Q = \underbrace{median}_{j>k}\left(\frac{x_j - x_k}{j-k}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

For *n* values x_j in the time series, there will be as many as $N = \frac{n(n-1)}{2}$ slope estimates Q_i of which the median value gives the Sen's estimator, Q.

The test of significant for both Mann-Kendall and Sen's Model Estimator were test at 99% level of confidence. These statistical tests were executed using MATLAB software application.

Linear Growth Model (LGM)

CH_f = a (1+i) t +e ……………………………………………………(9)

Where;

CH_f = Rainfall and Temperature

a= coefficient of the model,

1= constant,

i= rate of growth,

t = period/time (integer values starting from the first year (1)……………. End (n)),

e = Error term

RESULTS AND DISCUSSION

The statistics for the climatic variable (Rainfall and Temperature) under investigation are presented in (Table 1.2).The mean volume of rainfall received in Billiri station in SGS is 787.4mm. The standard deviation of rainfall is 205.29 mm, the maximum volume of rainfall is 1407.9 mm while the minimum volume of rainfall is 363.8mm. The mean maximum temperature, mean temperature and the mean minimum temperature for Billiri station are 34.90 ^{O}C, 27.32^{O}C and 19.98^{O}C respectively. The standard deviations for mean maximum temperature, mean temperature and the mean minimum temperature for Billiri station are 1.18 ^{O}C, 1.10 ^{O}C and 0.42 ^{O}C respectively. The maximum value for the maximum temperature is 28.90 ^{O}C and the minimum value for the maximum temperature is 22.12 ^{O}C. Statistics of climatic variables for Dadi-Kowa station NGS show that the mean annual rainfall received is 837.8mm, the standard deviation of 141.2.The mean maximum temperature, mean minimum temperature, and mean temperature are 30.1^{O}C, 21.3^{O}C, and 25.7^{O}C respectively.

The mean annual rainfall is 853.2mm, the standard deviation is 171.2mm, the maximum and minimum volume of rainfall received are 1162.6mm and 519.00mm respectively for the study period in Gombe station in (NGS). The mean annual rainfall is 527.4mm, the maximum and minimum annual volume are 251.90mm, 859.80mm respectively for the study period in Nafada (SS). The mean maximum temperature of 37.07 **^{O}C** and the mean minimum temperature of 21.49 **^{O}C** while the mean temperature is 29.28 **^{O}C.**

Temperature Trends and Projections

The result presented in Figure 2 is the graph of annual trends of maximum temperature for Billiri station, 5-year moving average was used to smoothen the series. The results of the linear trend reveal an increasing pattern of the annual maximum temperature. Figure 3 also present the graphical trend of the minimum temperature for Billiri station and 5-year running mean was used to smoothen the series, the graph also reveal an increasing trend from the beginning to the end of the study period. The increasing trend for both maximum and minimum temperature are at the rate of 0.0449 ^{o}C per^{-1} and 0.0115 ^{o}C per^{-1} respectively.

Table 2: Summary Statistics for the Climatic Variables

Location	Stations	Climatic Variables	**Mean**	**Standard Dev.**	**Skewness (*Z1*)**	**Kurtosis (Z_2)**	**Min. Value**	**Max. Value**
Southern Guinea Savanna (SGS)	Billiri	Min.Temp. **(^{O}C)**	19.98	0.42	-0.380	-0.250	18.9	20.7
		Max.Temp. **(^{O}C)**	34.90	1.18	0.34	-0.73	32.91	37.40
		MeanTemp. **(^{O}C)**	27.32	1.10	-3.03	13.86	22.12	28.90
		Annual Rainfall (mm)	787.40	205.29	0.645	0.950	363.80	1407.90
Northern Guinea Savanna (NGS)	Dadi-Kowa	Min. Temp. **(^{O}C)**	21.3	2.14	-1.35	0.970	15.70	23.90
		Max. Temp. **(^{O}C)**	30.1	2.97	-0.40	-1.330	24.10	33.60
		Mean Temp. **(^{O}C)**	25.7	2.23	-0.087	0.140	19.90	28.10
		Annual Rainfall (mm)	837.8	141.2	-0.30	-0.45	508.50	1111.00
	Gombe	Annual Rainfall (mm)	853.20	171.53	-0.07	-0.89	519.00	1162.60
Sudan Savanna (SS)	Nafada	Min. Temp. **(^{O}C)**	21.49	0.46	0.28	-0.021	20.60	22.60
		Max. Temp. **(^{O}C)**	37.07	1.00	0.09	-0.76	35.00	38.90
		Mean Temp. **(^{O}C)**	29.28	0.67	0.045	-0.60	27.80	30.60
		Annual Rainfall (mm)	527.4	155.4	0.47	-0.05	251.90	859.80

Source: Authors' Computation, 2019

The difference between the rates of variation between maximum and minimum temperature in Billiri is 0.0334^{o}C per^{-1}. These findings are in line with the report of Williams, Adebayo and Abam (2015) who noted that maximum and minimum temperature in Michika shows an upward trend.

The mean temperature trend for Billiri station from 1977- 2017 is presented in Figure 4. The trend has been fluctuating from the beginning with a sharp decline in the year 1992 and then it continues, 5-year running means was equally used to smoothen the trend. The linear trend shows an increasing pattern from the beginning to the end and the rate of increase for the mean temperature is 0.035 ^{o}C per^{-1}. The increasing temperature in Billiri station is below the global rate of increase of 2.0^{o}C (IPCC, 2015) and 1.5^{o}C (IPCC, 2018). Due to the inability of the increasing temperature to meet up the global reports, its impact can still be felt most especially among those who rely on the climate system for their survival.

The projection of annual mean temperature for Billiri station is presented in (Table 1.3). If the current trend continue, the mean temperature in the next three (3) decades will be 28.98 ^{o}C, 28.63 ^{o}C and 28.28 ^{o}C. The results reveal that there is going to be decrease in the mean temperature for years to come in Billiri. These findings contradict the global prediction of a general increase in temperature (IPCC, 2007).

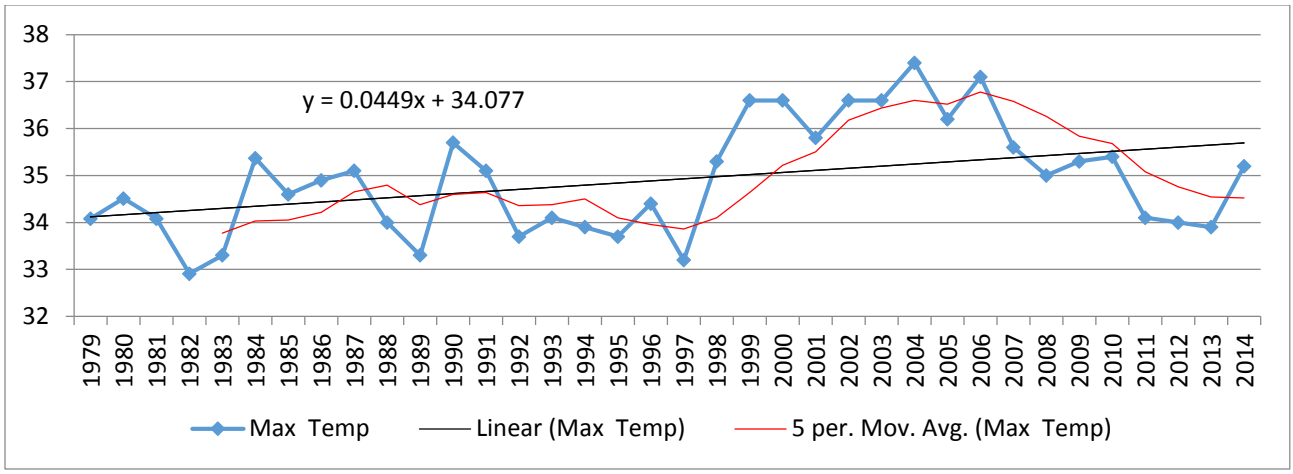

Fig. 2: Maximum Temperature Trend for Billiri 1979- 2014
Source: Authors' Analysis

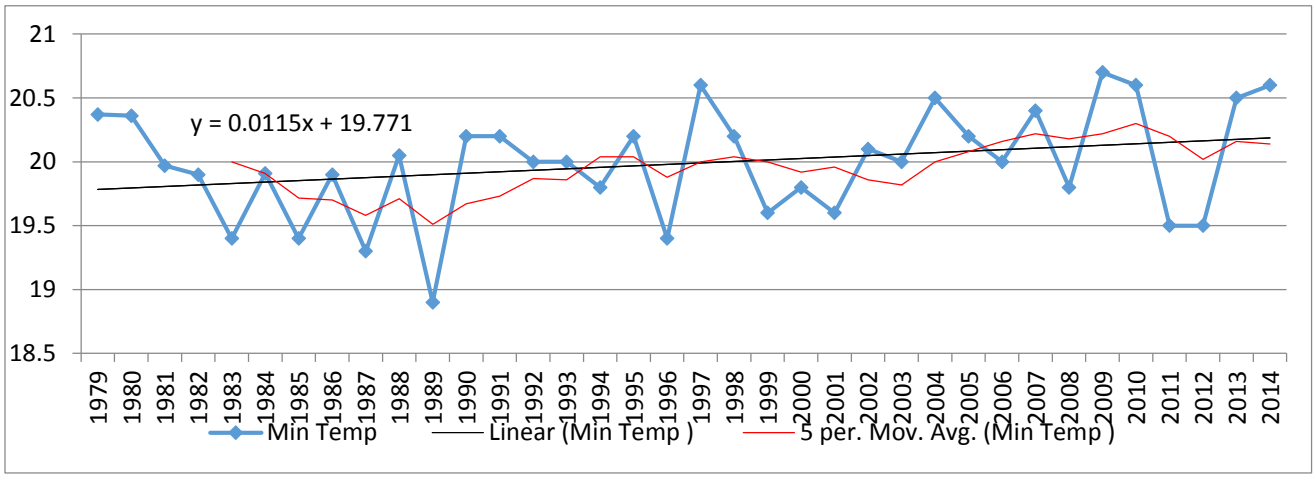

Fig 3: Minimum Temperature Trend for Billiri 1979- 2014
Source: Authors' Analysis 2018

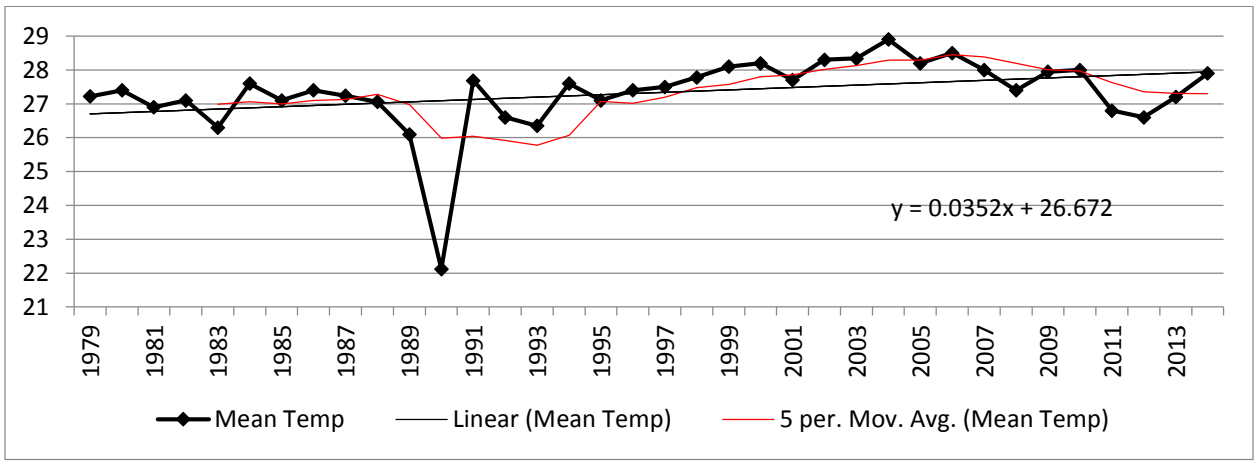

Fig. 4: Mean Temperature Trend for Billiri from 1979- 2014
Source: Authors' Analysis 2018

The analysis of temperature for Dadin-Kowa station is presented in Figure 5-7 .The trends lines revealed an increasing pattern of maximum temperature, minimum temperature and the mean temperature. The pattern for the maximum temperature indicates that year 1988 has the lowest value of 24.1°C while year 2010 has the highest value of 33.6 °C. The pattern shows an increasing trend from the beginning to the end at the rate of 0.240 °C year^{-1}. The minimum temperature also shows a similar pattern at the rate of 0.122 °C year^{-1} Figure 6. The mean temperature presented in Figure 8. The series exhibit a sharp fluctuation between 1988 and 1989 with about 6.7 °C difference. The rate of increase year^{-1} for the mean temperature is 0.179 °C. This result concur with Akinsanola & Ogunjobi (2014) indicates significant increases of air temperature in the vast majority of Nigeria.

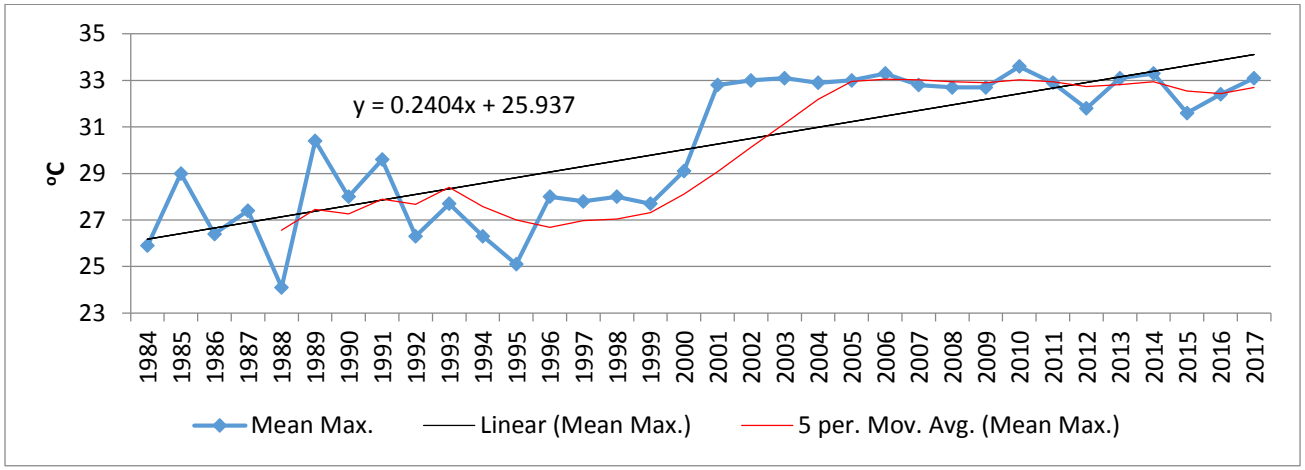

Fig. 5: Maximum Temperature Trend for Dadin-Kowa 1984-2017
Source: Authors' Analysis 2018

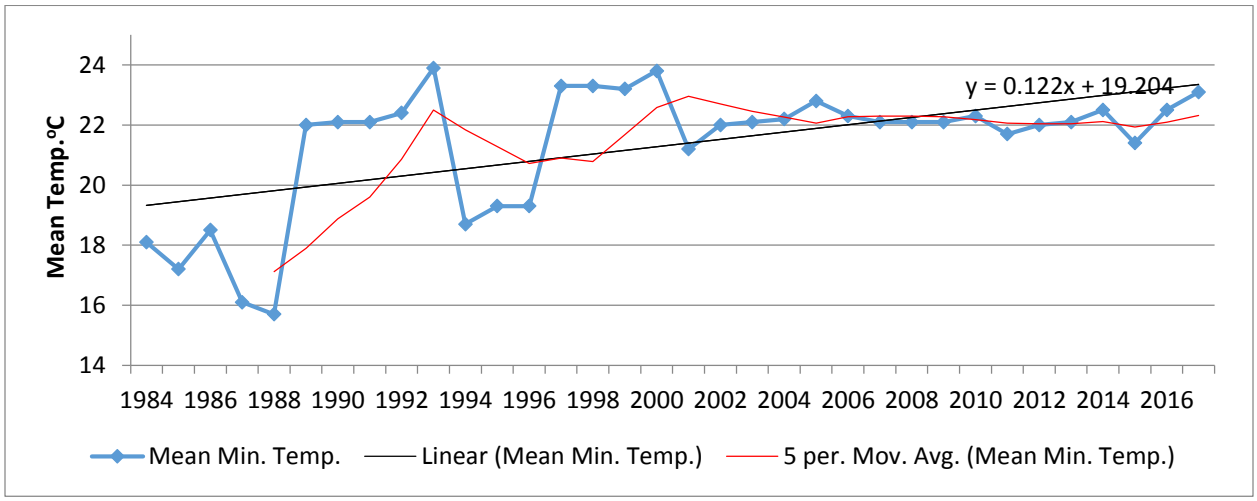

Fig. 6: Minimum Temperature Trend for Dadin-Kowa 1984-2017
Source: Authors' Analysis 2018

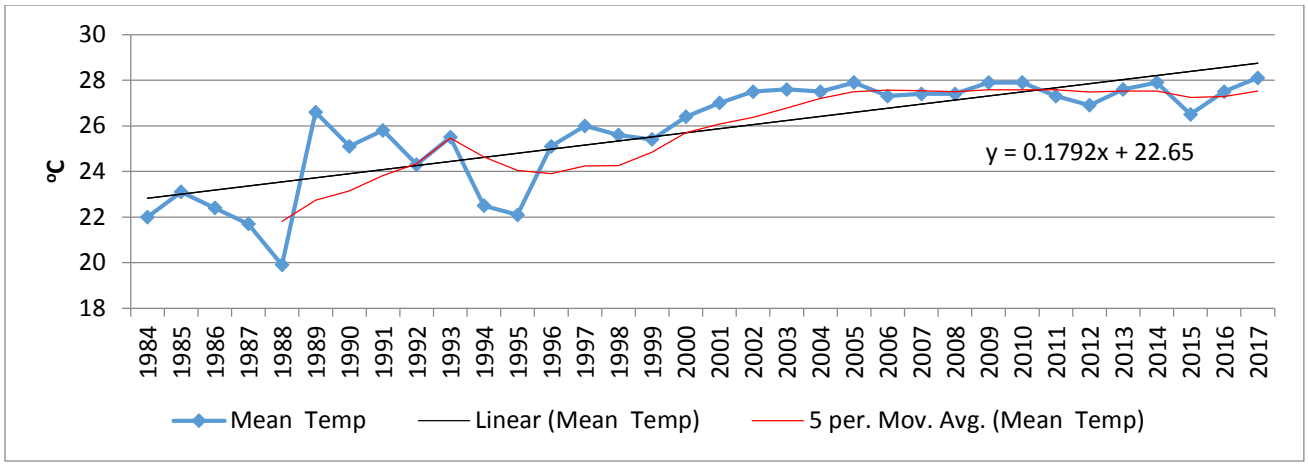

Fig. 7: Mean Temperature Trend for Dadin-Kowa 1984-2017
Source: Authors' Analysis

The prediction for the annual mean temperature for Dadin-Kowa station is presented in Table 1.3. The predicted mean temperature for the next three (3) decade will be; 24.57 ^{o}C, 25.7 ^{o}C and 27.01^{o}C if the current trend of 0.1792 ^{o}C per-^{1}continue. The increasing temperature in the NGS of the state is below the global raising temperature of 2.0^{o}C (IPCC, 2015) and 1.5^{o}C (IPCC, 2018) special report on global warming. Even at that, this result implies that there is going to be a risks to human and natural systems in the area which will affect the livelihood of the inhabitants.

The analysis of temperature trends for Nafada station is presented in Figure 8-10. The trends exhibit an increasing patterns for maximum temperature, minimum temperature and the mean temperature. The pattern for the maximum temperature reveal that the year 2006 has the highest value of 38.9^{o}C while the year 1989 has the lowest value of 35.0 ^{o}C. The pattern reveal an increasing trend from the beginning to the end at the rate of 0.0382 ^{o}C per -1. The minimum temperature also exhibit a similar pattern at the rate of 0.0208 ^{o}C and the rate of increase year^{-1} for the mean temperature is 0.0281 ^{o}C. This findings are in agreement with Julius (2016) reported an increasing trends of mean maximum and mean minimum temperatures in Kilimanjaro region.

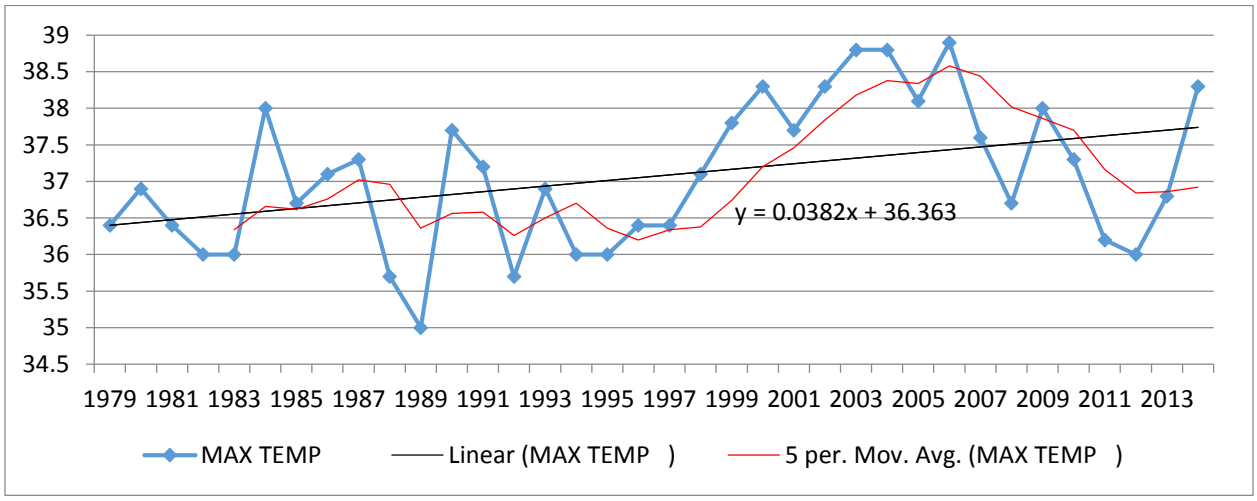

Fig. 8: Maximum Temperature Trend for Nafada 1984-2014
Source: Authors' Analysis 2018

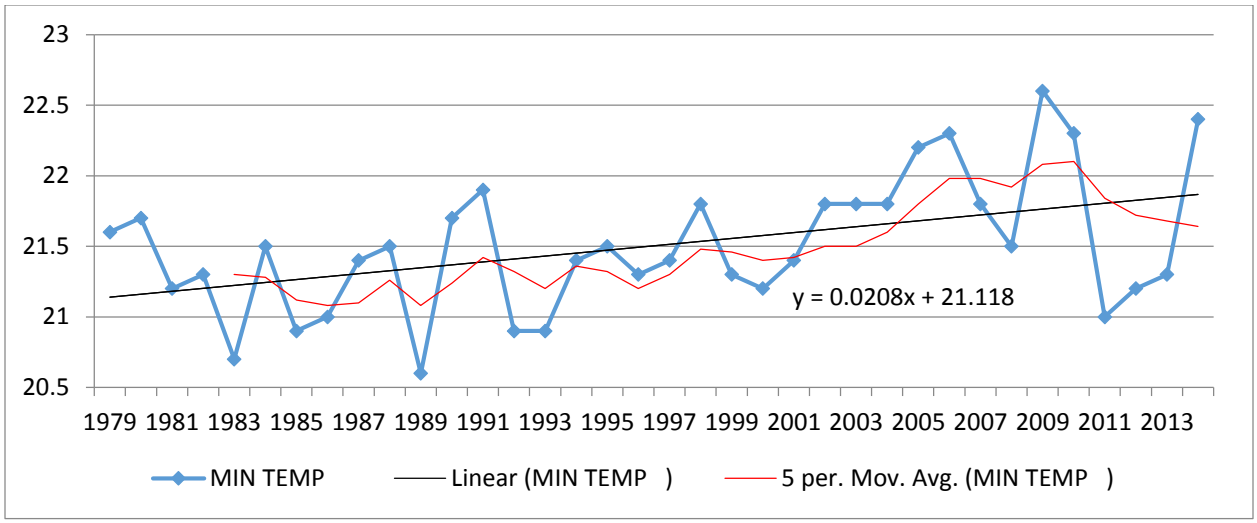

Fig. 9: Minimum Temperature Trend for Nafada 1984-2014
Source: Authors' Analysis 2019

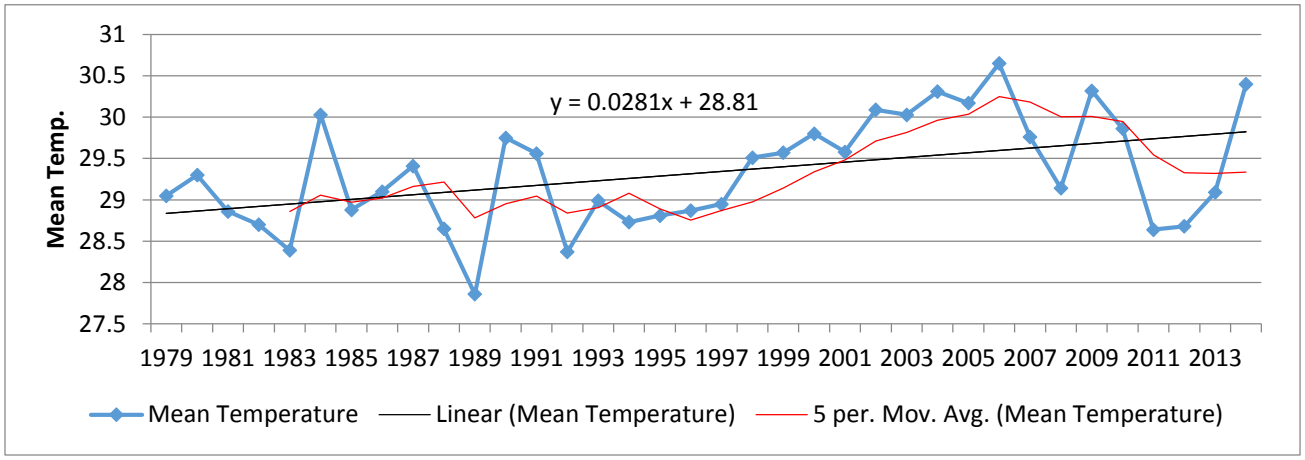

Fig. 10: Mean Temperature Trend for Nafada 1979- 2014
Source: Authors' Analysis 2019

The annual mean temperature prediction for Nafada station for the next 30 years is presented in Table 1.3. The current rate of increase per^{-1} for the trend is 0.028 ^{o}C and if the current trend continue the way it is, the annual mean temperature will be (30.10 ^{o}C, 30.38 ^{o}C and 30.66^{o}C) by decade. The increasing rate of temperature in Nafada (SS) the northern part of the state is below the global raising temperature of 1.5^{o}C (IPCC, 2018). Because the rate of increase is below the global standard, which does not mean the impact of changing climate may not be experienced in the area. The Projected mean temperatures presented in Table 1.3 reveals that NGS and SS predicted trends were in agreement with findings of Emaziye (2015) who reported an increasing trend of the mean temperature in Delta state while SGS projected trend does coincide because it is predicting the decreasing trend of annual mean temperature.

Table 3: Projected Temperature for Various Stations

Station	**Rate**	**2024**	**2034**	**2044**
Billie from 1979 - 2014	0.0352 by 2014	28.98 ^{o}C	28.63^{o}C	28.28 ^{o}C
Nafada from 1979- 2014	0.0281 by 2014	30.10 ^{o}C	30.38 ^{o}C	30.66 ^{o}C
Station	**Rate**	**2027**	**2037**	**2047**
Dadin-Kowa 1984 – 2017	0.1792 by 2017	24.57 ^{o}C	25.7 ^{o}C	27.01 ^{o}C

Source: Authors Computation 2019

Rainfall Trends in Gombe State

The annual rainfall totals have been varying in volumes from year to year and from one meteorological station to another within the state. The pattern of rainfall for Billiri station is presented in Figure 11. The highest volume of 1407mm was recorded in the year 1989 while the lowest volume of 363.8mm was recorded in the year 1987. The trend of rainfall indicate a decreasing pattern from the beginning to the end of the series, the pattern exhibit a major fluctuation between 1987 and 1989. The trend of rainfall for Billiri station is decreasing at the rate of -0.957 mm per-^{1}for the period under investigation.

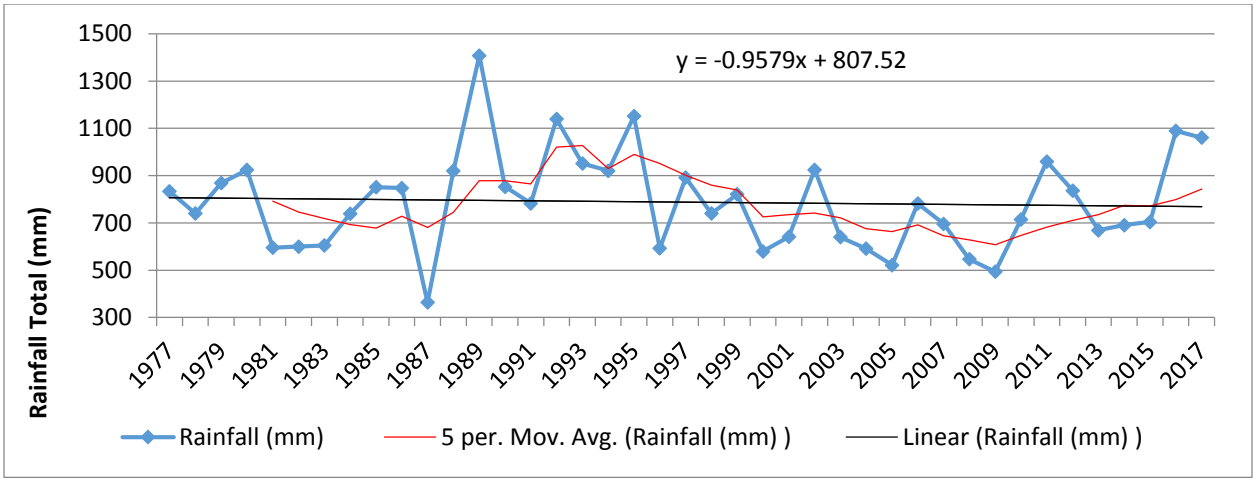

Fig. 11: Rainfall Trend for Billiri 1977-2017
Source: Authors' Analysis 2018

The rainfall pattern for Dadin-Kowa station is presented in Figure.12. The graph revealed a decreasing trend of rainfall at the rate of - 2.748mm per^{-1} for the period under investigation and five-year running mean was used to smooth the series. The patterns of changes in the rainfall trends for Billiri and Dadin-Kowa stations have a similar pattern of decreasing trends. This results is in line with the findings of Odjugo (2010) who reported general decrease of rainfall in Nigeria. Abaje, Ishaya, and Usman (2010) whom reported decline in the annual rainfall yield in Kafanchan.

The rainfall pattern for Gombe station is presented in Figure 13. The maximum volume of 1162.6mm was recorded in the year 2012 and the minimum volume of 519mm was recorded in the year 2000. The trend revealed increasing pattern from the beginning to the end of the series at the rate of 3.05mm per$^{-1.}$ This result is related to the outcome of some researchers such as; Williams, Adebayo and Abam (2015) reported that annual rainfall in Michika is increasing, also Hayelom, Chen, Marsie, and Negash (2015) reported that precipitation pattern for Southern Tigray is increasing. Abaje, Achiebo and Matazu (2018) noted increase in annual rainfall amount in Kaduna State. Abaje and Ogoh, (2018) reported increasing rainfall trend in Katsina State. Umar (2016) observed that the annual trend of rainfall totals in Kano metropolis is increasing. Nzoiwu, Ezenwaji, Enete and Igu (2017) reported positive trend of rainfall in Awka. The findings from other researchers revealed that the deviation of rainfall pattern for Gombe station against the other stations is in line with the global patterns of climatic variables. The implication of these findings is the annual occurrence of urban flood within the Gombe town.

The trend of rainfall for Nafada station is presented in Figure 14. The maximum volume of 1244.3mm was recorded in the year 1995 while minimum volume of 325.5mm was recorded in the year 1993.The rainfall pattern revealed a decreasing trend at the rate of – 0.871mm per^{-1}. This finding is in line with the result of Umar (2016) who observed that the annual rainfall totals in Katsina, Gusau and Sokoto stations revealed a declining pattern, also Bello, Msheliza and Abaje, (2019) noted a declining trend of rainfall in Billiri. The implication of these results will be reduction in the outcome of the agricultural production and also possible decline in the availability of water in the study area

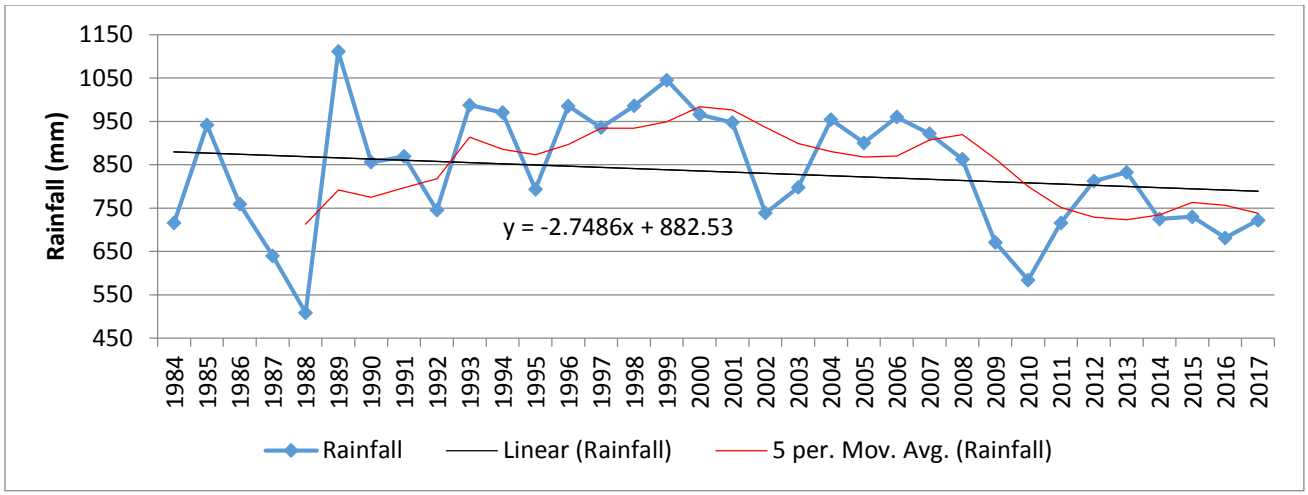

Fig. 12: Rainfall Trend for Dadin-Kowa 1984-2017
Source: Authors' Analysis

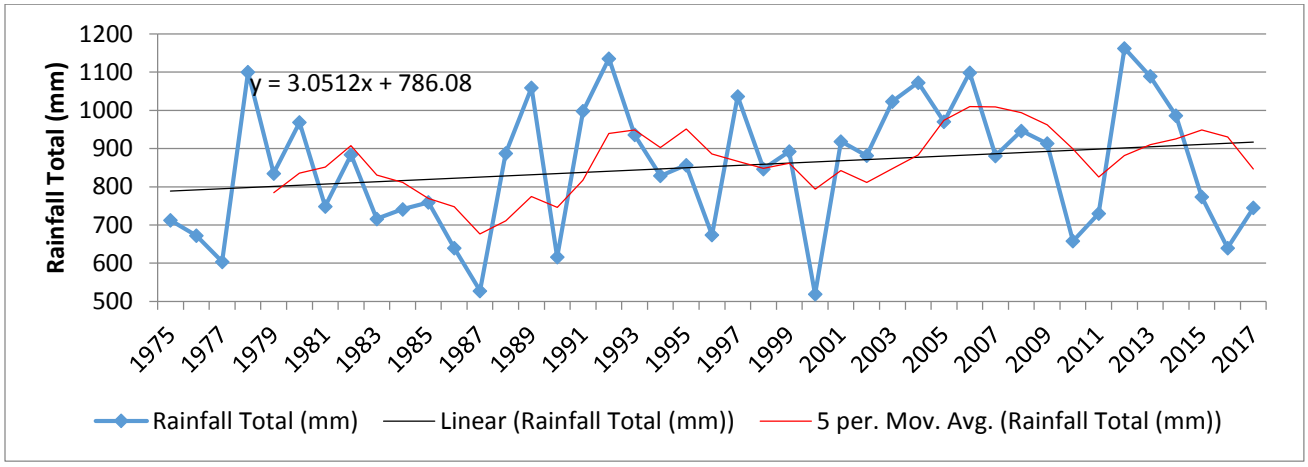

Fig. 13:.Rainfall Trend for Gombe 1975-2017
Source: Authors' Analysis

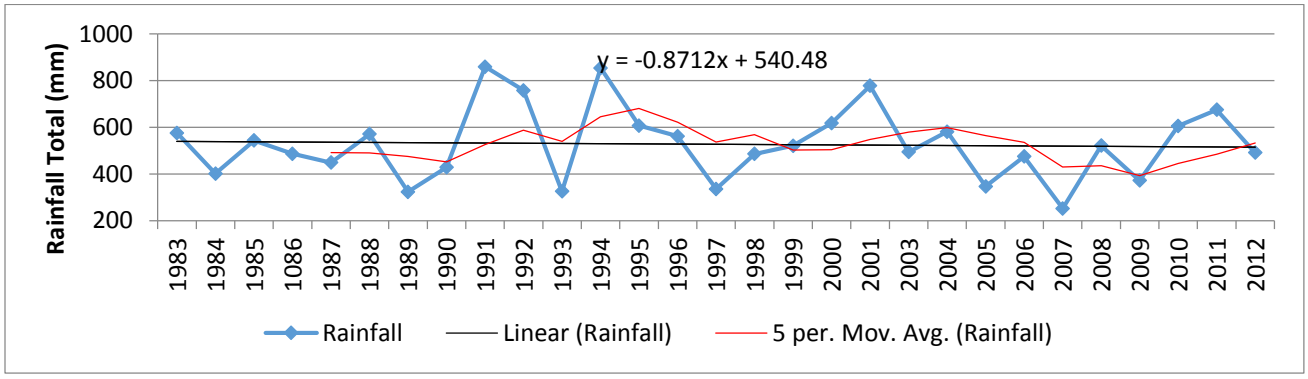

Fig. 14: Rainfall Trend for Nafada 1983 – 2012
Source: Authors' Analysis

Rainfall Projections in Gombe State

The rainfall projections from the four (4) stations were presented in (Table 4). The results revealed that three (3) stations indicate evidence of declining rainfall trends except Gombe station which exhibit increasing pattern. The rainfall pattern for Billiri station indicates a declining trend at the rate of -0.957mm, if the present trend continues the projected volumes of rainfall for the next three decades will be 758.66mm, 749.08mm and 739.50mm. The declining trend of rainfall in Dadin-Kowa station is at the rate of -2.74 ^{o}C, and if the present trend continue the projected volumes for the next three (3) decades will be; 744.85mm, 713.13mm and 681.40mm. The rainfall trend in Gombe station shows an increasing pattern at the rate of 3.051mm, the projected volumes for the coming three (3) decades are 30.51mm, 61.02mm and 91.53mm. The pattern of rainfall in Nafada reveal a decreasing trend at the rate of -0.8712mm, if the current trend continue the projected rainfall volumes will be; 506.50mm, 497.79mm and 489.07mm for the coming three (3) decades. The above projections can only stand if the trends rate remain unchanged. The predicted results shows that only Gombe station in NGS relate with the findings of Emaziye (2015) who reported projected an increasing trend of the projected rainfall in Delta state while results from other Stations does not coincide.

Table 4: Projected Volumes of Rainfall

Station	**Rate**	**2027**	**2037**	**2047**
Billiri from 1977 2017	-0.957 by 2017	758.66 mm	749.08 mm	739.50 mm
Dadin-Kowa from 1984- 2017	-2.74 by 2017	744.85 mm	713.13 mm	681.40 mm
Gombe from 1975- 2017	3.0512 by 2017	938.64 mm	978.30 mm	1008.81 mm
Station	**Rate**	**2022**	**2032**	**2042**
Nafada 1983 – 2012	-0.8712 by 2012	506.50 mm	497.79 mm	489.07 mm

Source: Authors' Computation 2019

Table 5: Mann-Kendall Trend Analysis Results for Annual Rainfall

Location	Kendall Tau	Mann-Kendall coefficient S	Z statistic	*p-value*	C.I Lower	C.I Upper	Trend description (from Z value)	Hypothesis test (h=1: significant, h=0: not significant)	Trend Significance
Gombe	0.1573	142	1.4757	0.1400	-1.4025	8.1833	Increasing trend	h=0	Not Significant
Billiri	-0.0549	-45	-0.4942	0.6211	-6.3218	4.4215	decreasing trend	h=0	Not Significant
Dadinkowa	-0.1943	-109	-1.6010	0.1094	-10.2280	1.3497	decreasing trend	h=0	Not significant
Nafada	0.0049	2	0.0188	0.9850	-6.5069	3.6781	No Trend	h=0	Not significant

C.I - Confidence interval

Source: Author Computation 2019

Table 6: The Developed Sen's Model Equations for the Linear-Time Trend Evaluation of Annual Rainfall

Location	Model equations: R = Qt + B	Trend description
Gombe	R = 3.8091*t - 6742.4	Weak increasing
Billiri	R = -1.0420*t +2857.3	Weak decreasing
Dadinkowa	R = -4.30*t + 9447.1	Weak decreasing
Nafada	R = 0.0067*t +507.1331	No trend

Source: Author Computation 2019

Table 7: Mann-Kendall Trend Analysis Results for Mean Temperature

Location	Kendall Tau	Mann-Kendall coefficient S	Z statistic	*p-value*	C.I Lower	C.I Upper	Trend description (from Z value)	Hypothesis test (h=1: significant, h=0: not significant)	Trend Significance
Billiri	0.3190	201	2.7283	0.0064	0.0129	0.0516	Increasing trend	h=1	Significant
Dadinkowa	0.2834	159	2.3558	0.0185	0	0.1636	Increasing trend	h=1	Significant
Nafada	0.3317	209	2.8334	0.0046	0.0109	0.0546	Increasing trend	h=1	Significant

C.I - Confidence interval

Source: Author Computation 2019

Table 8: The Developed Sen's Model Equations for the Linear-Time Trend Evaluation of Mean Temperature

Location	Model equations: R = Qt + B	Trend description
Billiri	R = 0.0321*t - 36.4782	Increasing
Dadinkowa	R = 0.0733*t – 125.1267	Increasing
Nafada	R = 0.0333*t - 37.1300	Increasing

Source: Author Computation 2019

The results of Mann Kendall test and Sen's slop for temperature were presented in (Tables 1.7 and Table 1.8). The result reveals that there is an increasing trend of temperature in all the zones and they are all significant at the rate of 0.0064 ^{o}C, 0.0185 ^{o}C, 0.0046 ^{o}C in SGS, NGS and SS respectively.

Sen's Model Equation reveals an increasing trends at the rate of 0.0321 ^{o}C, 0.0733 ^{o}C, 0.0333 ^{o}C in SGS, NGS and SS respectively. From the Mann-Kendall Z test result for Gombe station in NGS indicate an increasing trend of rainfall at 1.4757mm which is in agreement with the findings of Bose et al. (2015) of an increasing trend of rainfall in Adamawa, Bauchi and Borno state using the same Mann Kendall test and those states are all neighbouring Gombe state. The trend of Mann-Kendall Z test of rainfall for Billiri in SGS is -0.4942mm and Dadin-Kowa in NGS is-1.6010mm indicating decreasing pattern, only Nafada in SS station indicates evidence of no statistical trend based on Mann Kendall Z test of 0.018mm (Table 1.5). The Sen's result presented in Table 1.6 revealed a weak increasing trend of rainfall for Gombe station in NGS, a weak decreasing trend of rainfall for Billiri station in SGS, and weak decreasing of rainfall for Dadin-Kowa station in NGS while there is also no statistical trend of rainfall for Nafada station in SS based on Sen's Slop Estimator Equation.

CONCLUSION

The susceptibility to climate variability and change is evident in Gombe state. Fluctuations of climatic parameters (rainfall and temperature) is a recurring phenomenon within the three (3) Agro-Ecological Zones of the state. There is a significant increase of temperature trends in all the zones. There is insignificant decreasing trend of rainfall for both Billiri and Dadin-Kowa stations. There is increasing trend of rainfall for Gombe station but it is not significant. The trend of rainfall for Nafada station revealed a decreasing pattern. The Projected trends reveals that rainfall for Gombe station in NGS is increasing per decade while mean temperature for Billiri station in SGS is decreasing per decade. This results may affect the soil moisture, crop water requirement, ecological change and crop yield. Since the majority of the people rely on rain-fed agriculture for their livelihood, if proper adaptive measures are not taken into consideration, these may result to social and economic unrest among the inhabitants of the state. Further studies should focus on other climatic elements such as humidity, wind and solar radiation and other methods of analysis should be exploit.

RECOMMENDATIONS

i. The study recommends that Inhabitants of the study areas should plan their cropping seasons based on climatic information of their area as elicited by this work.

ii. Inhabitants of Gombe area should initiate preventive and coping strategies to deal with the impending flood because of the increasing trend of rainfall.

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