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ANALYSIS OF RAINFALL AND TEMPERATURE TRENDS IN DUSTIN MA TOWN, DUTSIN-MA LOCAL GOVERNMENT AREA, KATSINA STATE, NIGERIA

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ABSTRACT

The study examined the trend detection of rainfall and temperature in Dutsin-Ma, Dutsin-Ma Local Government Area, Katsina State. The study was aimed at determining the significance of rainfall and temperature trends in the area if it is in accordance with the global climate change scenarios. Secondary data (rainfall and temperature) for thirty-one (31) years from 1984-2014 was used, the data was source from NOAA/NCEP and were subjected to the following analysis; Descriptive statistics, Mann Kendall, Sen’s Slope Model Estimator, Standardized Anomaly Index (SAI), and Rainfall Anomaly Index (RAI). The results revealed a significant decrease of rainfall at (p-value = - 0.0108mm), the values of Kendall Tau, Z- Statistics and Sen’s Slope for rainfall were (-0.3247mm, -2.5495mm and -26.11mm) respectively. There is a significant increase of temperature at (p-value = 0.0037 oC), the values Kendall Tau, Z- Statistics and Sen’s Slope for temperature were (0.3699 oC, 2.9068 oC and 0.0410 oC). The rainfall decrease at the rate of -0.0594-1 (mm) while temperature increase at the rate of 0.0597-1 (oC). There is (52%) of positive anomaly and (48%) of negative anomalies of rainfall while the temperature has (48%) of positive anomaly and (52%) of negative anomalies during the study period. The RAI is (-3.51mm), which indicates very dry condition and the rainfall pattern changes every decade. The study concluded that there is significant increase in temperature and decrease in rainfall, anomalies of the climatic variable influences, climate variability in the area and Dutsin-Ma is classified as very dry climate and the rainfall pattern changes every decade. The study recommended that human activities which influence increase in temperature should be reduced.

Keywords: Trend, Anomaly, Detection, Agriculture and Climate

INTRODUCTION

Rainfall and temperature are the critical climatic parameters that are mostly responsible for agricultural production. According to Adeleke & Orebayo, (2020) rainfall and temperature are among the major factors affecting food security especially in countries largely or highly dependent on rain-fed agriculture for their livelihood. These variables varied over space and time where some regions are experiencing increasing amount of rainfall others were experiencing decreasing amount of rainfall. Globally there is an increasing temperature as a results of global warming, urban heat effect amongst other factors. According to IPCC (2013) there will be increase in temperature from 1.1 to 4.8oC in subsequent years. A study by Akinsanola and Ogunjobi (2014) reported that there have been statistically significant increases in precipitation and air temperature, longtime trends and decadal trends reveled a decreasing and increasing trends in mean annual precipitation and air temperature in Nigeria. Nigeria is experiencing a significant increase in temperature, rainfall and sunshine hours (Adeleke & Orebayo, 2020). In another study by Msheliza and Bello (2016) reported that Gombe State is experiencing is experiencing decrease in rainfall yield also decreasing rainfall pattern was observed in Billiri LGA of Gombe state (Yusuf & Paul, 2018). In recent years there is an increasing linear trend of rain as a results of increase in June, July and August rainfalls in Katsina town (Abaje & Ogoh ,2018 ; Dogonyaro, Abaje & Bello, 2022) revealed that the linear trend lines for both rainfall and temperature in katsina state showed an increasing trend. Mmaduabuchi, Bello & Yaro (2020) reported there is increasing decadal trend of rainfall and decreasing decadal trend of temperature in Katsina town. The study focused on examine the behaviors of the climatic variables (Rainfall and Temperature) in accordance with the global climate change scenarios.

Study Area

Dutsin-Ma LGA is located on latitude 12°26' 00’’N and longitude 07°29' 00’’ E. It share sboundry with Kurfi and Charanchi Local Government Area to the North, Kankia LGA to the East, Safana and Dan-Musa LGAs to the West, and Matazu LGA to the South-east, see Figure 1. The area has an approximate landmass of 552.3 km^2 with a population of 169, 829 (National Population Commission, NPC, 2006). The people engage in primary economic activities like farming, fishing and mining.

The climate is influenced by two (2) distinctive seasons Tropical Continental (TC) and Tropical Maritime (TM) dry and wet seasons respectively. The rainfall is between the months of May/June and September/October with the peak in the month of August. The mean annual temperature ranges from 29 °C -31°C (Abaje, Sawa & Ati, 2014). The coldest month of year is between January/February while the hottest month April. The vegetation of the area is the Sudan Savanna type which combines the characteristics and species of both the Guinea and Sahel Savanna (Abaje, 2007; Tukur *et al.*, 2013, in Abaje, Sawa & Ati, 2014). The study area is made up of different landforms such as gentle undulating landform with occasional granite outcrops and small hills, it has a well define drained system hosted by rivers and streams which empty at Zobe dam and Dutsin-ma dam.

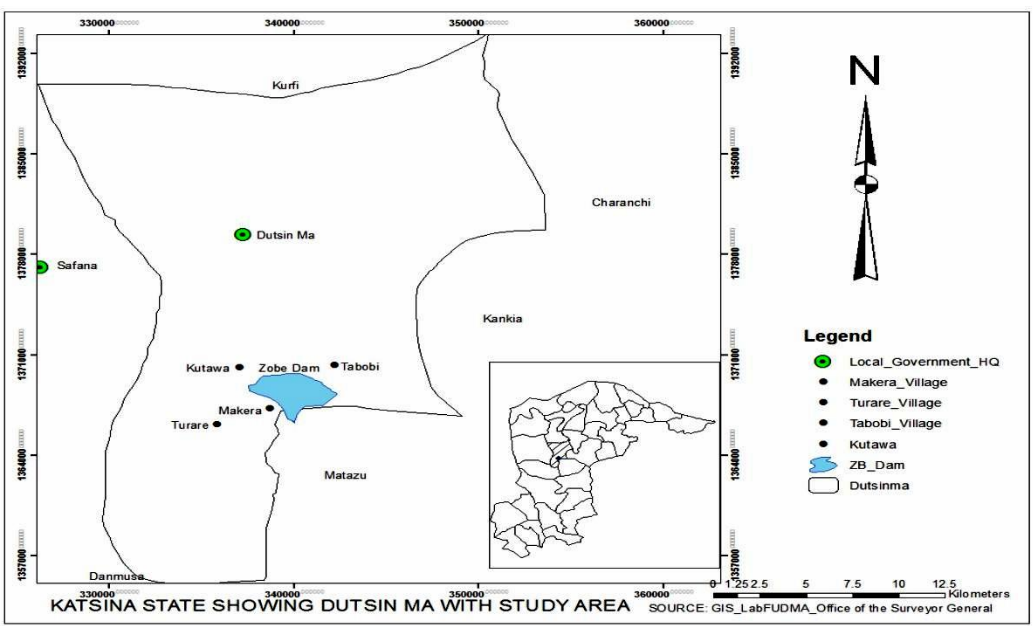

Figure 1: Map of Katsina showing Dutsin-Ma

Source: Katsina State Ministry of Land and Survey (2021)

Research Hypothesis

i. Null Hypothesis (H_o): there is no significant increase in temperatures in Dutsin-Ma Local Government Area.

ii. Alternative Hypothesis (H_1): there is significant increase in temperature in Dutsin-Ma Local Government Area.

iii. Null Hypothesis (H_o): there is no significant decrease in rainfall amount in Dutsin-Ma Local Government Area.

iv. Alternative Hypothesis (H_1): there is significant decrease in rainfall amount in Dutsin-Ma Local Government Area.

MATERIALS AND METHODS

Source of Data and Data Analysis

The climate data was sourced from Climate Forecast System Reanalysis (CFSR) for daily and monthly climatic data source that was downloaded from globalweather.tamu.edu website which was developed by National Oceanic and Atmospheric Administration (NOAA's)/National Center for Environmental Prediction (NCEP) Maryland, United State of America (2014). This covered at least thirty-one (31) years from 1984 – 2014 for the study area. Descriptive statistics was used to analyzed the characteristic of the climatic variables, Mann-Kendall Analysis and Sen's Slope Estimator were used to analyze significances of the trend as postulated by the hypothesis and Standardized Anomaly Index (SAI) was used to determine the anomalies of both rainfall and temperature while Rainfall Anomaly Index (RAI) was used to calculate the intensity of dry or drought years and rainy or wet years during the study period. Years with positive values imply positive anomalies while those with values imply negative anomalies years.

Linear regression equation is given as:

$$y = a + bx \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where;

a = the intercept of the regression line on the y-axis

b= is the slope of the regression line, where

the values of a and b ware obtained from the following equations;

$$a = \frac{\sum y - b(\sum x)}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad \ldots\ldots (3)$$

Mann-Kendall Analysis

The non-parametric Mann-Kendall test is usually used to detect trends that are monotonic (flat) 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 follow a monotonic trend. The Mann-Kendall test statistic 'S' is computed using the formula (Pohlert, 2018);

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

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.

$$sign(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_k > 0 \\ 0 & if\ x_j - x_k = 0 \\ -1 & if\ x_j - x_k < 0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

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 (2). 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;

$$E(s) = 0,\ \ var(s) = \frac{n(n-1)(2n+5)}{18} \quad \text{......................................} (6)$$

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

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases} \quad \text{..} (7)$$

The Z statistic follows a normal distribution and is tested at 95% level of significance ($Z_{0.025}$ = 1.96). Its value describes the trend as follows;

i. The trend is said to be decreasing if Z is negative and the absolute value is greater than the level of significance,
ii. The trend is said to be increasing if Z is positive and greater than the level of significance.
iii. 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 nonparametric test estimates the true slope of an existing trend (as change per year). The Sen's method is used in cases where the trend can is assumed to be linear:

$$y(t) = Qt + B \quad \text{...} (8)$$

Where Q is the slope, B is a constant and *t* is time.

$$Sen's\ estimator,\ Q = \left(\frac{x_j - x_k}{j-k}\right),\ j > k \quad \text{..} (9)$$

For *n* values x_j in the time series, there will be as many as $N = \frac{n(n-1)}{2}$ slope estimates Q. Where Q is Sen's slope estimate. $Q > 0$ indicates upward trend in a time series. Otherwise the data series presents downward trend during the time period.

Standardized Anomaly Index

The Standardized Anomaly Index (SAI) was used to determine years of positive and negative anomalies.

$$z = \frac{x - \overline{x}}{S} \quad \text{..} (10)$$

X= Actual value

$\overline{X}$ = Mean

S = Standard Deviation

RAI was calculated to analyse the frequency and intensity of dry and rainy years in the study area. RAI was developed by Rooy (1965) is given by the equation:

$$RAI = 3[(p - \overline{p})/(\overline{m} - \overline{p})] \quad \text{…. ……………………………………….. (11)}$$

for positive anomalies and

$$RAI = -3[(p - \overline{p})/(\overline{x} - \overline{p})] \quad \text{… ………………………………………. (12)}$$

Where, p is the actual rainfall, $\overline{P}$ is the long-term average rainfall, $\overline{M}$ is the mean of the ten highest values of p on record and $\overline{X}$ is the mean of the ten lowest values of p on record. The arbitrary threshold values of +3 and – 3 have been assigned to the mean of the ten most extreme positive and negative anomalies respectively.

Table 1: Classification table of Rainfall Anomaly Index (RAI)

	RAI Range	**Classification**
Rainfall Anomaly Index (RAI)	Above 4	Extremely Humid
	2 to 4	Very Humid
	0-2	Humid
	-2 to 0	Dry
	-4 to -2	Very Dry
	Below - 4	Extremely Dry

Source: Rooy (1965**)**

RESULTS AND DISCUSSION

Rainfall and Temperature

The results presented on Table 2 indicates the descriptive statistics of the two climatic variables: rainfall and temperature of the study area for thirty-one years from 1984 - 2014. The average temperature and rainfall were 27.7 ^{o}C and 820.51mm respectively, Standard Deviation for temperature and rainfall is 0.664 ^{o}C and 422.77mm, the range of temperature and rainfall were 23.7 ^{o}C and 1529.23mm, the minimum temperature and rainfall were 26.41 ^{o}C and 74.99mm and the maximum were 28.78 ^{o}C and 1604.22mm respectively.

Table 2: Statistics of rainfall and temperature

Variables	Temperature (oC)	Rainfall (mm)
Mean	27.77	820.51
Std. Deviation	0.660	422.77
Range	2.370	1529.2
Minimum	26.41	74.990
Maximum	28.78	1604.2

Source: Authors Analysis, 2021

The mean monthly rainfall pattern for the study period is presented in figure 2. The rainy season last from the month of April to October approximately seven (7) months. The month of August received the highest amount of rainfall while the month of April received less amount of rainfall. It has annual rainfall total of 1,257.32mm. These results relate with the findings of Olalere, Bulama & Umar (2021) report that rainfall arrive in April and ceases in October, the highest amount is recorded in August which is the single maximum stations like Yelwa, Kano, Gusau and Sokoto.

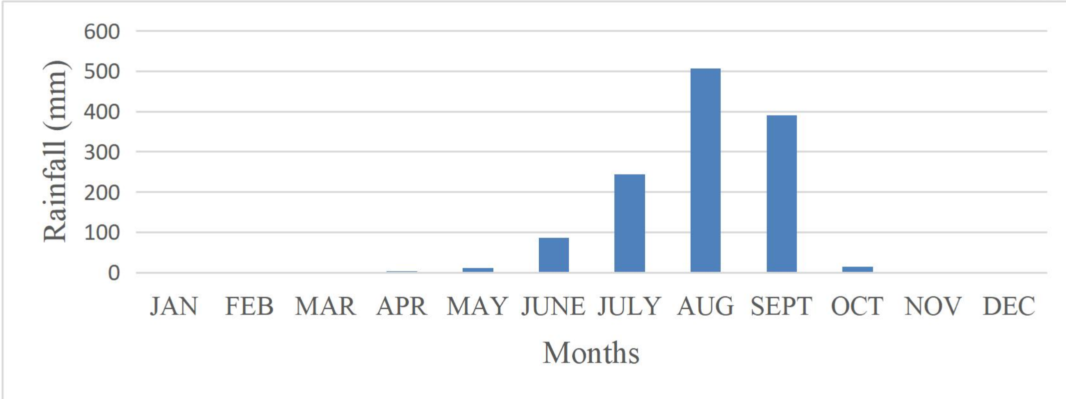

Figure 2: Monthly Rainfall Pattern in Dutsin-Ma

Source: Authors Analysis, 2021

The mean monthly temperature pattern for the study period is presented in figure 3. The pattern indicates that the lowest peak temperature was recorded in January while the highest peak temperature was recorded in April. Higher temperatures were recorded during the Hot Dry Season (HDS) in the months of March, April, May and June, this were as a result of absence of cloud cover during the period. Lower temperatures were during Warm Hot Season (WHS) and Cold Dry Season (CDS). During the WHS in the months of July, August and September, these low in temperatures were as a result of availability cloud cover during rainy season. During CDS the temperature also drops because of *Harmattan* season in the months of November, December and January.

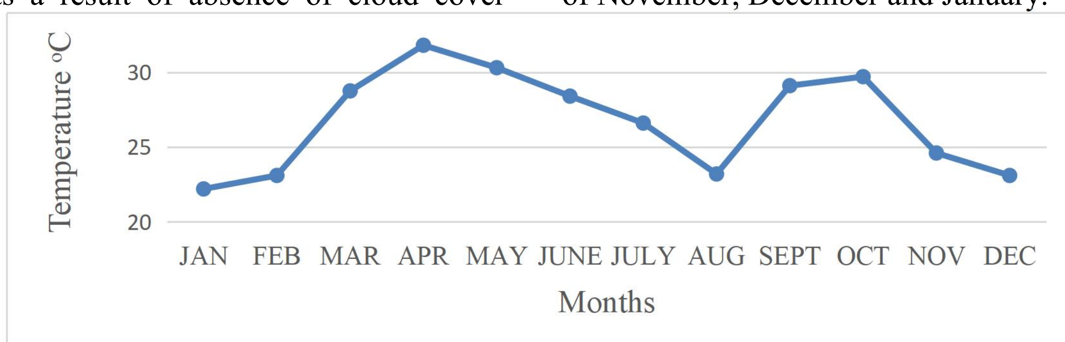

Figure 3: Monthly temperature pattern of Dutsin-Ma

Source: Authors Analysis, 2021

Trend of Climatic Variables

The result presented in Table 3 reveals the test of significant trend for both temperature and rainfall during the study period. For temperature, the p-value (0.0037) which is significant at 1%. Therefore, (H_o) is rejected and (H_i) is accepted and thus the researchers concluded that there is significant increase in temperature during the study period in Dutsin-Ma. This result concur with a study by Adedapo (2020) which revealed that temperature (minimum and maximum) significantly increase in Kwara State for rainfall, the p-value (-0.0108) which is significant at 1%. Therefore, (H_o) is rejected and (H_i) is accepted and concluded that there is significant decrease in rainfall during the study period in Dutsin-Ma. This result agrees with (Aho, *et al.,* 2019) who reported with a similar study by Aho, Akpan and Ojo, (2019) which reported that the trend of total annual rainfall in Makurdi is negative (decrease) and statistically insignificant.

Table 3: Mann-Kendall Trend Analysis of Meteorological Variables

Variable	Kendall tau	Mann-Kendall coefficient S	Z statistic	*p-value*	CI Lower	CI Upper	Trend description (from Z value)	Hypothesis test (h=1: significant, h=0: not significant)	Trend Significance
Rainfall (mm)	-0.3247	-151	-2.5495	-0.0108	- 40.5984	-8.3027	Decreasing trend	h=1	Significant
Temperature (℃)	0.3699	172	2.9068	0.0037	0.0144	0.0700	Increasing trend	h=1	Significant

Source: Authors Analysis, 2021

Results from Sen's Model Equations presented on Table 4 revealed that the slope (Q) values from the equation for temperature is (0.0410 ℃) which is positive, indicating increasing pattern while for rainfall is (-26.11mm) which is negative, indicating decreasing pattern. In a related study Wali *et al.,* (2020) revealed that temperature increases while rainfall decreases in the coastal states of Niger Delta, Nigeria. Similarly Bello, Adebayo and Bashir 2020) reported an increase in temperature and a decreasing rainfall in Nafada, Dadin-Kowa and Billiri LGA in Gombe state. The annual rainfall total decrease at the rate of -0.0594^{-1} (mm) while temperature increase at the rate of 0.0597^{-1} ℃.

Table 4: The Developed Sen's Model Equations for The Linear-Time Trend Evaluation

Variable	Model equations: T = Qt + B	Trend Description	Rates
Rainfall (mm)	T = -26.11*t + 53097	Decreasing	-0.0594^{-1}
Temperature (℃)	T = 0.0410*t – 54.159	Increasing	0.0597^{-1}

Source: Authors Analysis, 2021

Anomalies of Rainfall and Temperature and Rainfall Anomaly Index

The result presented in figure 4 depict the standardized anomalies of rainfall over Dutsin-Ma town, indicating both positive and negative anomalies. It clearly showed that it began with negative and end with negative anomaly. It clearly shows negative anomaly in 1984, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2011, 2013 and 2014 and positive anomaly from 1985 to 1998 and in 2007 and 2012. The maximum positive anomaly was observed in 1989 and the maximum negative was observed in 2000. There is (52%) of positive anomaly and (48%) of negative anomalies. Thes result relates with the findings of Bello, Abaje & Mshelize (2019) that report more years of negatives anomalies than positive anomalies in Billiri and Nigerian Meteological Agency [NIMET], (2022) report more years of moisture deficit in than moisture surplus in the northern Nigeria.

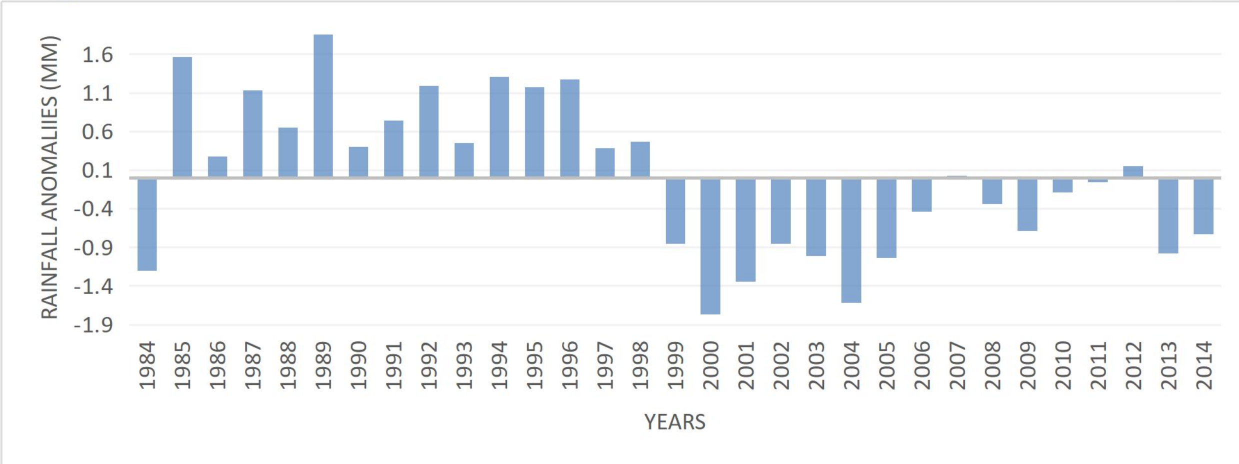

Figure 4: Rainfall Anomalies 1984 - 2014

Source: Authors Analysis, 2021

Result presented in Figure 5 depict the standardized anomalies of temperature over Dutsin-Ma, indicating both positive and negative anomalies. It clearly showed that it began with positive and end with positive anomaly. It clearly shows negative anomaly from 1985 -1989, 1991- 1997, 2008, 2011 and 2012 and positive anomaly from 1984, 1990, 1999 -2007, 2009, 2010 and 2013. The maximum positive anomaly was observed in 2004 while the maximum negative was observed in 1989 and 1992. There is (48%) of positive anomaly and (52%) of negative anomalies. This results relates with findings of NIMET, (2022) report more years of negative anomalies than positive anomalies in northern Nigeria.

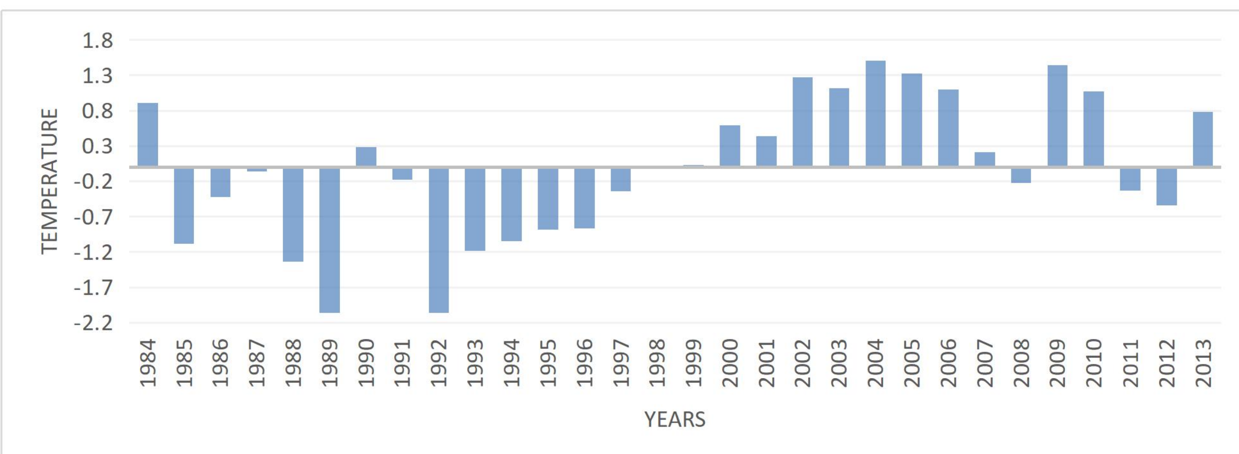

Figure 5: Temperature Anomalies 1984 - 2014.

Source: Authors Analysis,2021

Rainfall anomaly index was used to analyze the dry and raining years of a study area. There are formulae for positive and negative anomaly. The RAI is -3.51, this indicates (very dry) based on (Rooy, 1965) classification Table1. This implies that Dutsin-Ma is getting drier. This result is in line with the findings of Itiowe Itiowe, Hassan

& Agidi 2019) who reported rainfall in Abuja was classified as (severe dryness) indicating meteorological drought and Aho, *et al*., (2019) noted that Makurdi is getting drier meaning it is (moderately dry).

Decadal Variation of the Rainfall Patterns

The decadal variation of the rainfall patterns in Dutsin-Ma during the study period (1984-1993), (1994-2003), (2004-2013) revealed that the first decade indicates an increasing pattern at the rate of 34.9 mm per-^{1} (Figure 6). The second decade reveals a decreasing pattern at the rate of -143mm per-^{1} (Figure 7) while the third decade indicate an increasing pattern at the rate of 38.5mm per-^{1} (Figure 8). From the results obtained reveals that rainfall pattern in Dutsin-Ma changes every ten years. This result is in agreement with the findings of Bello, Msheliza & Abaje, (2019) report that rainfall pattern changes every decade in Billiri.

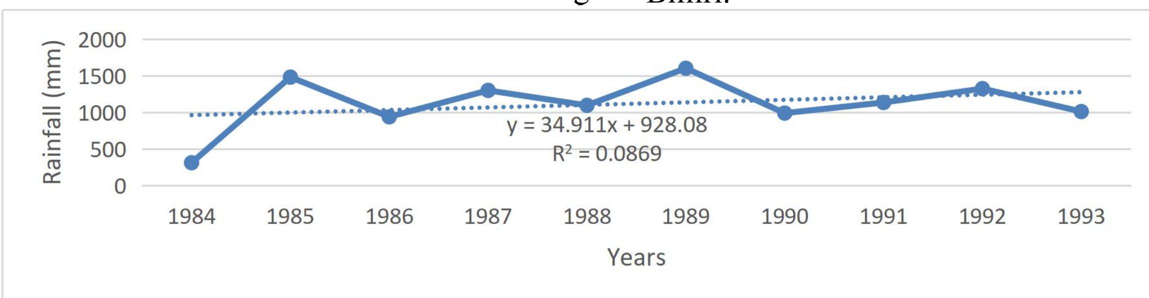

Figure 6: Rainfall Pattern from 1984-1993.

Source: Authors Analysis,2021

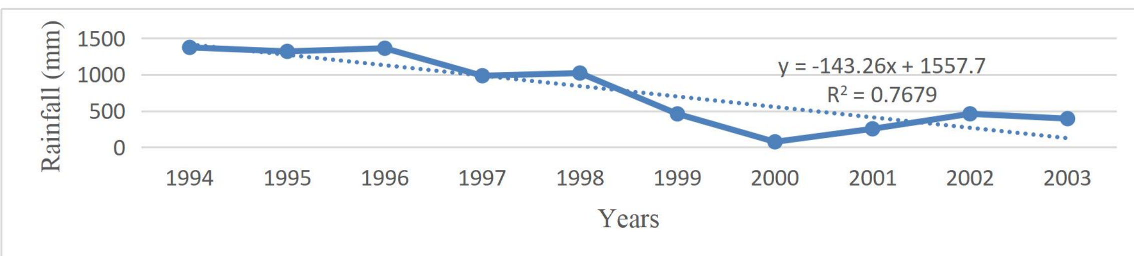

Figure 7: Rainfall Pattern from 1994-2003.

Source: Authors Analysis,2021

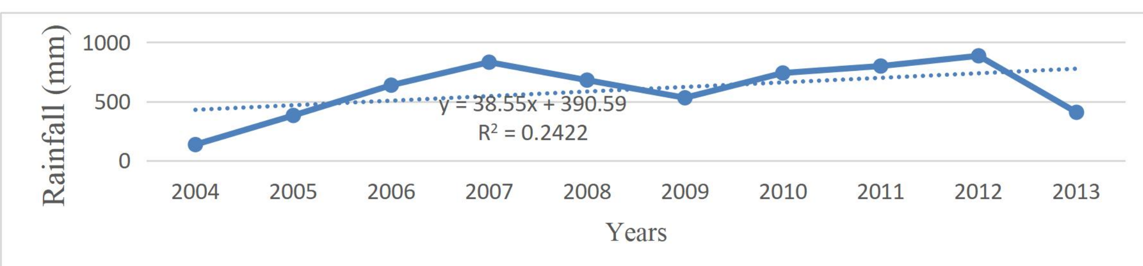

Figure 8: Rainfall Pattern from 2004-2013

Source: Authors Analysis, 2021

CONCLUSION

The study concluded that there is a significant increase in temperature at the rate of 0.0597^{-1}

^{o}C and a significant decrease in rainfall at the rate of -0.0594^{-1} mm which indicates the existence of climate change in Dutsin-Ma. There are more years of positive than negative anomalies of rainfall and more years of negative anomalies than positive anomalies of temperature, the rainfall pattern changes every ten (10) years. Dutsin-Ma is classified as very dry climate based on rainfall anomaly index. The study recommends planting of trees in the environment to regulate the increasing temperature and farmers should take note of decreasing amount of annual total rainfall and it is classified as dry climate in their planning for agricultural activities.

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