Bima Journal of Science and Technology, Vol. 8(2) June, 2024 ISSN: 2536-6041

DOI: 10.56892/bima.v8i2.668

Assessment of Rainfall and Temperature Trend in Zaria and its Environs, Kaduna State, Nigeria

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ABSTRACT

Trend assessment particularly in rainfall and temperature is one of the keys for understanding climate change in a given geographical area**.** Zaria and its' environs located in Northern Kaduna State, Nigeria, characterized as a region of high climatic variability, which may have changed the trend in rainfall and temperature (maximum, minimum and average). Objectives of the study are to determine variability and evaluate trends in rainfall and temperatures. Rainfall and temperature data for 30 years (1991-2020) was analyzed using Coefficient of Variability (CV), descriptive statistics, annual and decadal variability. The mean rainfall (1089.216mm), maximum (32.62℃), minimum (19.14℃) and average temperature (25.86℃) as the climate normal for the respective variables in 30 years. The 30 years (1991-2020) was divided into three decades (1991-2000, 2001-2010 and 2011-2020) to obtain mean for each decade. The mean of each decade was compared to climate normal to obtain decadal variability and percentage change. Result showed annual variation in all the variables with coefficient of variability (CV) of 15.8%, 5.3%, 6.7% and 5.1% in rainfall, maximum, minimum and average temperature respectively. Decadal variability of the three decades, rainfall revealed changes of -11.2%, 2.5% and 8.7%. Maximum temperature revealed -5.4%, 1.5% and 4.1%, minimum revealed -5.7%, 2.8% and 2.8% while average temperature showed -5.4%, 1.8% and 3.8% respectively. Positive values of rainfall indicated surplus (wet) decade while negative values indicated deficit (dry). The hottest decades in maximum, minimum and average temperatures show positive values while least hot (cool) decades show negative values. Kaduna state government should continue to provide early warning system for communities. This may help forecast the occurrence of floods.

Keywords: Rainfall, temperatures, descriptive statistics, coefficient of variability annual and decadal variability

INTRODUCTION

Rainfall and temperature are weather elements that are used to draw conclusions of forthcoming weather events. Others include atmospheric pressure, relative humidity, surface wind, precipitation, thunderstorm, fog, radiation, visibility, cloudiness and evaporation (WMO, 2015). Slight shift in the magnitudes of these elements such as rising temperatures, local rainfall variability are the most important keys in determining current and future climate impacts on water resources, agriculture as well as biodiversity (Intergovernmental Panel on Climate Change, [IPCC] 2014a). The IPCC also stated that in most cases, evaporation and rainfall are the major meteorological elements or climate-related elements triggering climate change (IPCC, 2014a). Rainfall as an important climatic element is most affected by global warming. Moreover, assessments of rainfall had explained its sudden modification at many different places in the world (Anghileri et al., 2014). Different locations across the

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globe have considerable variable rainfall intensity over time and the variability have positive or negative significance on water resources availability, possible management practices, and therefore causing hydrological consequences in terms of susceptibility to drought. Trend assessments at distinctive time scope around the globe indicating either decrease or increase in rainfall depends on the location on the other hand, rainfall is a major component in the hydrologic cycle affected in many parts of the world (Mondal et al., 2012). Decreasing pattern in rainfall is a recurrent phenomenon in many countries of the world which continue to become a primordial global problem.

Trends in rainfall and temperature has continued to receive the interest of researchers as a way to forecast their occurrence and for water resources management (Meshram et al., 2017; Hu et al., 2019) particularly in arid and semi-arid regions which recorded higher evaporation and minimal precipitation (Forooton, 2019). An increasing trend in temperature has been observed in different parts of the world including tropical region of Africa. Collins et al. (2011) revealed a significant increasing trend in temperature for all Africa (North and South), tropical Africa, and subtropical Africa. Furthermore, in a large part of Africa, temperatures close to the surface of the earth have increased by at least 0.5℃ in the last 50-100 years (IPCC 2014a). Niang et al. (2014b) reported that some parts of Africa witnessed increasing trends in minimum, maximum, and average annual temperatures during the final half of the last century, whereby minimum temperatures increased faster compared with maximum temperatures. Most environmental challenges of countries in Africa are associated with rainfall (Liebe et al., 2010).

The most noticeable meteorological variation in West Africa over the last four (4) decades was repeated decrease (downward sloping) of rainfall *(*Akinsola and Ogunjobi, 2014). There was a visible reduction (15-30%) of rainfall in the region depending on regional climatic differences (Abaje et al., 2010). The spatial and temporal pattern of temperature and rainfall across Nigeria from 1971-2000 using the Standard Anomaly Index (SAI) indicated a statistically significant increase in temperature in vast majority of the country (Akinsanola and Ogunjobi, 2014). In Northern Nigeria, rainfall is spread with high variability in space and over time indices including yearly differences between 15% and 20% (Odjugo, 2011).

Study Area

Zaria is located in Kaduna State, Nigeria at Latitude 11° 4' 54.91" N and Longitude 7° 42' 57.44" E. The description of the climate in the study area as stated by Iguisi and Abubakar (1998) as a zone of dry climate, depicted by strong seasonality in rainfall and temperature occurrences. The region has two distinctive seasons which include the dry/harmattan season (October to May) and wet season (April to November). The area has average annual rainfall from 1050mm to 1250mm. The mean monthly temperature is about 27℃. Temperature varies and it is highest between the months of March and May 28.9℃, which exhibit hot and dry periods while it is lowest in December and January to about 22 ℃ . Rainfall is reliable throughout May to September while absent from November to March. The rainy months are associated with the northward movement of the Inter-Tropical Discontinuity (ITD) across Kaduna State. The southward migration of the ITD across Kaduna state is associated with dry and dusty winds of harmattan (Water and Power Development Company, 1991). The highly leached ferruginous tropical soils that were formed on weathered layer of loose rocks overlain by a narrow deposit of silt dispersed

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by wind from tropical continental air mass are the major types of soils in the area (Wright and McCurry, 1970). The study area is a composition of a natural vegetation belt referred to as the Northern Guinea Savanna. Due to the rapid urbanization and other anthropogenic activities, coupled with poor management practices, the vegetation cover is remnants of savanna parklands. The most recognized tree plants species are *Mangifera indica, Parkia bislobose, Afzelia africana,*and *Daniella oliveri* used for making mortar and pistil while *Accacia balanites* are also present in the area.

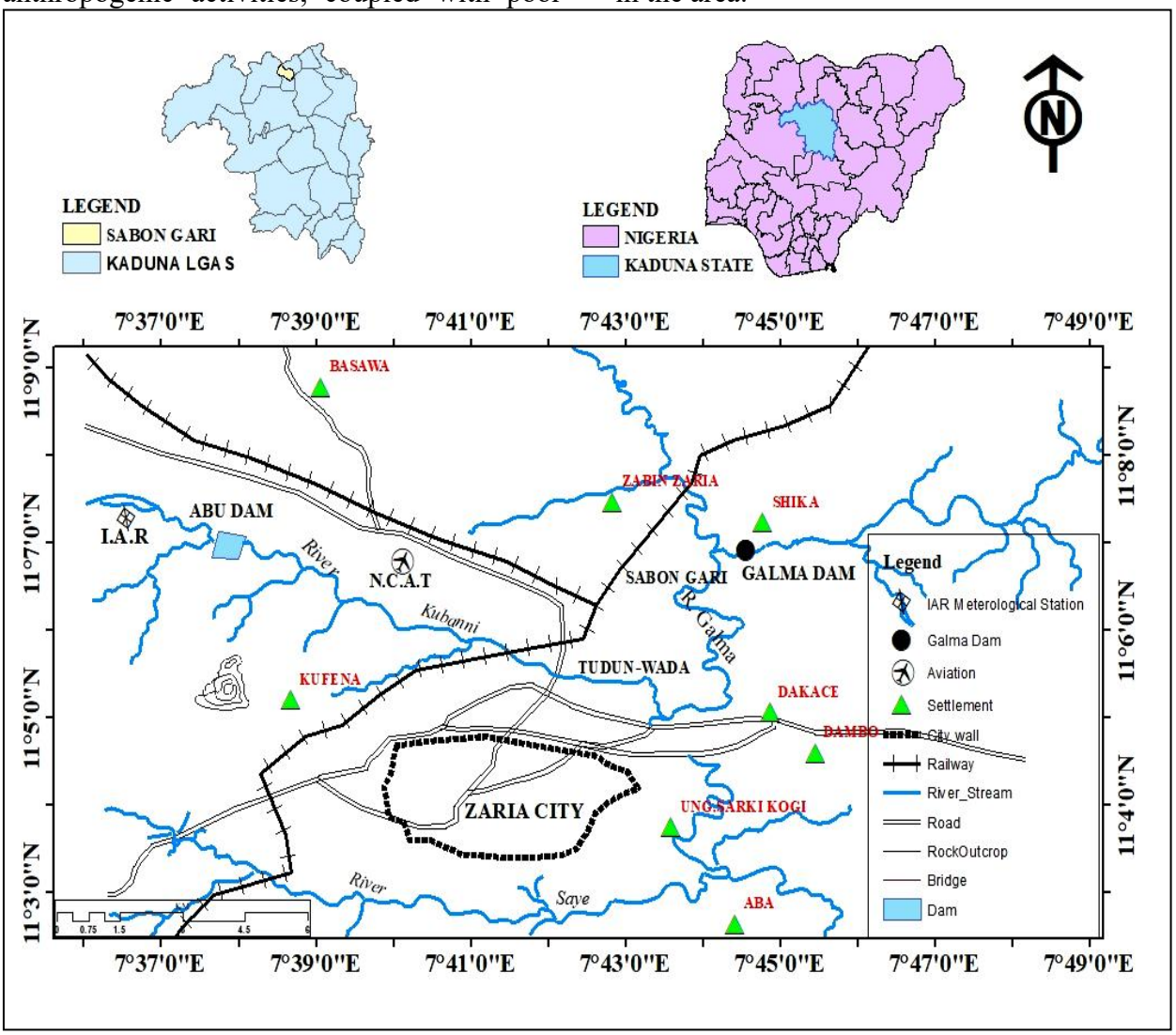

Figure 1: The Study Area

Source: Modified Zaria Topo Sheet 102 S.W

MATERIALS AND METHODS

The data used in this study were secondary data. Rainfall (mm) and temperature (maximum and minimum temperatures in ℃) data used for the study were obtained from the Institute for Agricultural Research (I.A.R) Ahmadu Bello University, Zaria. Average temperature for the period of thirty years (1991-2020) was determined using the equation below:

DOI: 10.56892/bima.v8i2.668

$$T_m = \frac{Tx+Tn}{2} \quad (1)$$

Where $T_m$is the mean/average temperature, *Tx* is the maximum temperature, *Tn* is the minimum temperature (Attah, 2013).

Methodology

The data collected for this study were analyzed and presented using descriptive and inferential statistics of Microsoft Excel and Minitab version 16. The statistics used in achieving the objectives of the study were as follows:

i. determines the variability of rainfall and temperature in the study area,

ii. evaluate the trends in rainfall of the study area.

Descriptive Statistics

Rainfall and temperature (maximum, minimum and average) were statistically described using highest, lowest, mean, standard deviation, kurtosis and skewness (Attah 2013). Right and left skewness indicated the tendency of the variables to have above and below average in the data distribution (Mustapha et al., 2018).

Coefficient of variability (CV)

In determining the variability coefficient, it compares the size of standard deviation relative to the mean of the data. Coefficient of Variability in hydro-meteorological variables was obtained using the equation 2:

$$CV = \frac{\delta}{\mu} \quad (2)$$

CV is the coefficient of variability, δ is the standard deviation and μ is the mean of meteorological variables.

CV value above 0.9 (90%) reveals high variability, 0.1 (10%) indicates low variability. Climate may be referred to as stable if *CV* is less than or equals 0.4 (40%). CV higher than 0.4 (40%) becomes unstable (Kingsley et al., 2020).

Decadal variability of meteorological variables:

In determining the decadal variation, the period was divided into three (1991-2000, 2001-2010 and 2011-2020). The decadal variability was determined using the deviation of decadal mean (μ_{10}) from climate normal (μ_{30}) or average of 30 years of the variable as presented in the equations below:

$$D_\alpha = \mu_{10} - \mu_{30} \quad (3)$$

$$D_\alpha = (\mu 10 - \mu 30)/(\mu 30) \times 100 \quad (4)$$

Where D_α is the variability, μ_{10} is the decadal mean and μ_{30} is the climate normal (Adamu, 2013; Attah, 2013). Detected change in a decade with either positive/negative values were presented by surplus/deficit rainfall while temperatures changes with positive values considered hot or cool decade.

RESULTS AND DISCUSSION

Descriptive Statistics of Rainfall and Temperature

The descriptive determination (statistics) of rainfall and temperatures during the study period (1991-2020) is presented in the Table 1. The meteorological variables are rainfall, maximum, minimum and average temperatures. From Table 1, the highest annual rainfall recorded in the study area is 1454.9 mm per annum while the lowest is about 747.6mm per annum with corresponding average, and standard deviation of 1089.216 mm, and 172.62 mm respectively. Maximum temperature recorded the highest value of 36.2 ℃ and the lowest value of 27.4 ℃ with corresponding average and standard deviation of 32.62 ℃ , and 1.741℃. Similarly, the maximum temperature is 36.2^{0}C with a minimum temperature of highest value of 21.8^{0}C, with corresponding

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average, and standard deviation of 19.13 ℃, and 1.293 ℃ respectively. Rainfall and minimum temperature are rightly skewed (0.264 and 0.122), implying that there is tendency of having above average rainfall and minimum temperature in Zaria and environs during the period of study. Maximum and average temperatures are left skewed (-0.576 and -0.345), which implies that there is tendency of having below averages of maximum and average temperatures in Zaria and environs during the period under study.

Table 1: Descriptive Statistics of Rainfall and Temperature (1991-2020)

Statistical Parameters	Rainfall (mm)	Maximum Temp. (℃)	Minimum Temp. (℃)	Average Temp. (℃)
Highest	1454.9	36.2	21.8	28.9
Lowest	747.6	27.4	16.7	22.4
Average	1089.216	32.62	19.14	25.86
Standard Dev.	172.62	1.741	1.293	1.341
Kurtosis(g_2)	-0.141	1.64	-0.655	0.279
Skewness(g_1)	0.264	-0.578	0.122	-0.345

Source: Authors' Computation, 2021

Average temperature recorded 28.9 ℃ as the highest value and 22.4 ℃ as the lowest value with corresponding average of 25.86 ℃, standard deviation of 1.341 ℃. The findings revealed that rainfall recorded the highest variability during the three decades as it recorded the highest standard deviation (172.62mm). Minimum temperature recorded the least standard deviation of 1.293 ℃ while maximum temperature recorded the standard deviation of 1.741℃. Attah, (2013) also found temperature increase (0.91 ℃) within the Lower Kaduna River Catchment. The study further tallies with the report of the Fifth Assessment of IPCC that in Africa the number of warm days and warm nights have increased in the last two decades (Niang, et al., 2014). The higher standard deviation in rainfall corroborates the observations by Nigerian Meteorological Agency (NIMET) on the problems of late onset and early cessation of rainfall in Nigeria from the beginning of the 19th century (Nigeria Climate Change Review Bulletin, Nigeria Meteorological Agency, 2010).

Variations in Annual Rainfall (1991-2020)

Figure 2 indicates yearly variability in the amount of rainfall in Zaria during the thirty years (1991-2020) under study. It was shown that 2015 year recorded the highest amount of rainfall of 1454.9 mm. Figure 2 shows the graphical representation of the variations in annual rainfall in Zaria (1991-2020).

On the contrary, 1999 recorded the lowest amount of rainfall of 747.6 mm in the study area. However, the figure revealed that during the period of thirty years recorded rainfall amount of 707.3mm between the year with lowest and the year with highest amount of rainfall. The Variability Coefficient of rainfall during the study period shows 0.158 (15.8%). This implies that rainfall is stable during the period under review. The results of variations in rainfall in the area agrees with the findings of Odjugo, (2011) which stated that in Northern Nigeria, rainfall is spread with high variability in space and over time indices including yearly differences between 15 and 20%. But the variability of 15-20% is referred to as low variability (Kingsley et al., 2020; Adamu, 2013). The result obtained in this study (15.8%) is in harmony with the findings

DOI: 10.56892/bima.v8i2.668

of Mustapha et al. (2018) on the assessment of the variation of rainfall in Northern Nigeria for the period of 1972-2012; which shows that 38% variation occurred in Kano within the study period. This makes Kano station with highest rainfall variability, followed by Katsina and Nguru with values of 29% and 30% respectively. Findings from several studies indicated that variability in rainfall increased from 2010 to date in Northern Nigeria. On the other hand, Kingsley et al. (2020) reported Coefficient of Variability (CV) 14.5% in rainfall during the period of 1978-2017 in South –South region of Nigeria, this shows that variability coefficient of rainfall is decreasing in South-South region of Nigeria.

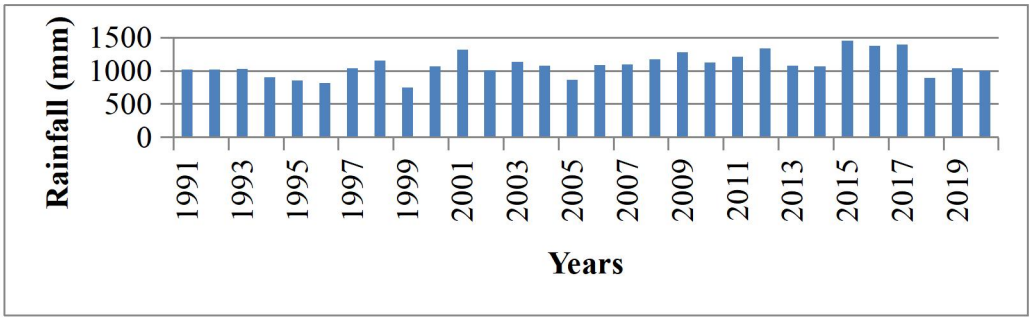

Figure 2: Variations of Annual Rainfall in Zaria (1991-2020)

Source: Authors' Computation, 2021

Variations in Annual Maximum Temperature 1991-2020

Figure 3 shows the graphical representation of the variation in annual maximum temperature in Zaria over the years (1991-2020).

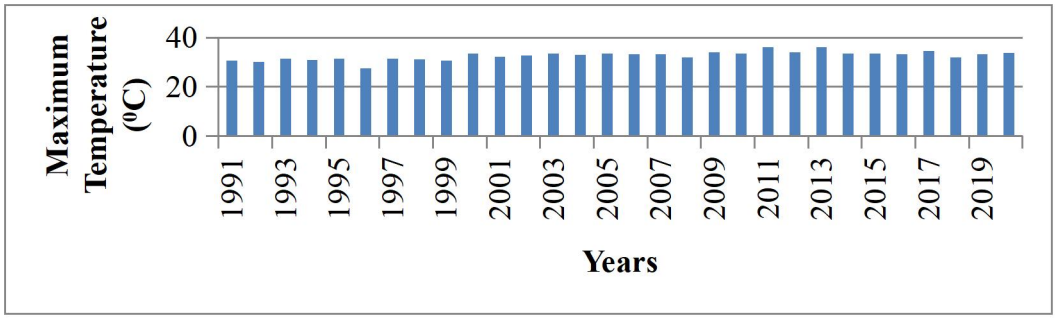

Figure 3: Variations of Annual Maximum Temperature in Zaria (199I-2020)

Source: Authors' Computation, 2021

Figure 3 revealed annual variations in maximum temperature for the period of thirty years (1991-2020). The year 2011 was discovered to have recorded the highest annual maximum temperature value of 36.2℃ which was the hottest year during the time series, followed by 2013 having values of 36.0℃. On the contrary, the lowest recorded maximum annual temperature was in the year 1996 with 27.4 ℃. The figure showed that there were changes in the recorded maximum temperature across the years. Some years recorded higher values in maximum temperature annually while other years recorded lower values of maximum temperature. The Variability Coefficient of

DOI: 10.56892/bima.v8i2.668

maximum temperature during the study period shows 0.052 (5.3%). This implies that maximum temperature had low variability during the period under review. The result obtained from this study (5.3%) is higher than the value of 2.6% obtained by Kingsley et al. (2020) in South-South region of Nigeria from 1978-2017. This shows that maximum temperature has higher variability in the study area than in South-South region of Nigeria.

Variations in Annual Minimum Temperature 1991-2020

Figure 4 shows the graphical representation of the variation in annual minimum temperature in Zaria over the years (1991-2020).

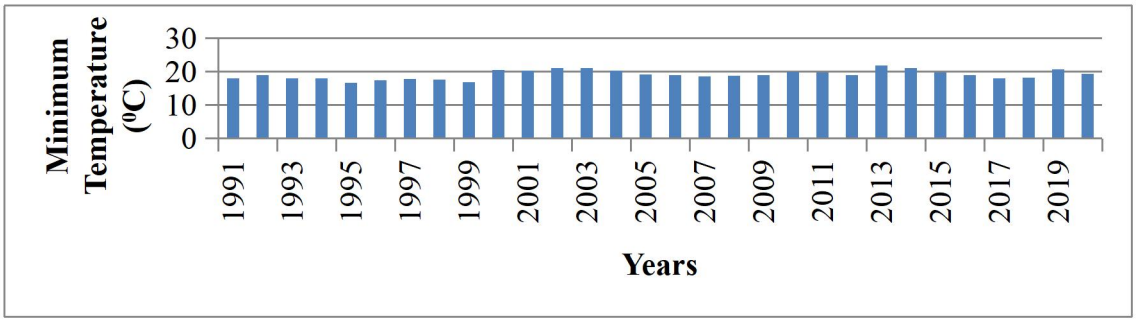

Figure 4: Variations of Annual Minimum Temperature in Zaria (1991-2020)

Source: Authors' Computation, 2021

Figure 4 revealed that year 2013 recorded the highest annual minimum temperature value of 21.8 ℃; this implies that 2013 was with the hottest night temperature, followed by 2002, 2003 2014 having 21 ℃ each. There was a repeated annual minimum temperature for three years, 1991, 1993 and 1994 having 18.1 ℃ each. On the contrary, the lowest recorded annual minimum temperature values were in 1995 and 1999 having 16.7 ℃ and 16.8 ℃ . The Variability Coefficient of minimum temperature during the study period shows 0.067 (6.7%). This implies that minimum temperature had low variability during the period under review. The result obtained from this study (6.7%) is higher than the value of 3.6% obtained by Kingsley et al. (2020) in South-South region of Nigeria from 1978-2017. This shows that minimum temperature has higher variability in the study area than in South-South region of Nigeria.

Variations in Annual Average Temperature 1991-2020

Figure 5 shows the annual variation of minimum temperature in Zaria over the years (1991-2020).

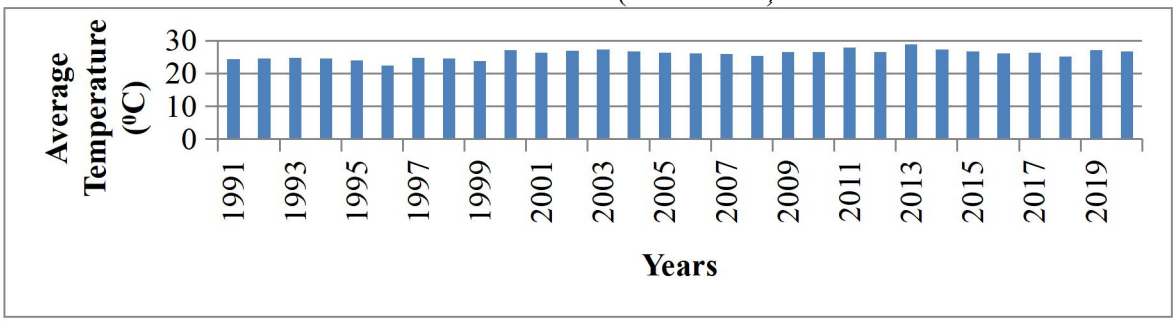

Figure 5: Variations in Average Annual Temperature in Zaria (1991-2020)

Source: Authors' Computation, 2021

Bima Journal of Science and Technology, Vol. 8(2) June, 2024 ISSN: 2536-6041

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Figure 5 showed annual variations of average (mean) temperature during the period of thirty years (1991-2020). The figure revealed that the highest average temperature value of 28.9℃ occurred in 2013; this implies that year 2013 was the warmest year amongst the thirty years under study. However, year 2011 was regarded as the second warmest year having the value of average temperature of 27.95℃. The least warm year was 1996 having 22.4℃. However, the least annual average temperature in the study area 22.4 ℃, this implies that none of these years within 1991-2020 recorded average annual temperature below 22.4℃. The Variability Coefficient of average temperature during the study period shows 0.051 (5.1%). This implies that average temperature had low variability in Zaria and environs during the period under review (1991-2020).

Decadal Variability of Rainfall 1991-2020

The decadal variability of rainfall for the three decades (1991-2000, 2001-2010 and 2011-2020) was determined using rainfall climate normal (1089.216 mm) which is the mean of thirty years rainfall records. Table 2 contains the averages and percentage changes in rainfall for the three decades separately. The surplus of rainfall (wet) per decade showed positive value(s) while rainfall deficit (dry) showed negative value(s).

Table 2: Decadal Variability of Rainfall Using Climate Normal (μ_{30}= 1089.216 mm)

Decades	μ_{10} (mm)	μ_{10}-μ_{30} (mm)	% change
1991-2000	966.56	-0.112	-11.2
2001-2010	1116.59	0.03	2.5
2011-2020	1184.499	0.08	8.7

Source: Authors' Computation, 2021

Table 2 reveled the decades that measured wets were 2001-2010 and 2011-2020 while 1991-2000 decade was related to dry decade when compared with the established normal climate (rainfall). However, 2001-2010 decade had recorded the wet of 27.372 mm (2.5%). It was followed by the 2011-2020 that recorded 95.28 mm (8.7%) higher than normal; while the 1991-2000 recorded dry of -122.656 mm (11.2%) lower than normal. Furthermore, rainfall fall increases in the study area during the last two decades (2001-2010 and 2011-2020). The result tally Akinsanola et al., (2014) reported decadal variation in Nigeria from 1971-2000 showing increase per decade. In Northern parts of Nigeria, annual rainfall amounts have been on the increase especially from the late 1990s (Abaje et al., 2012).

Decadal Variability of Maximum Temperature 1991-2020

The decadal variability of maximum temperature for the three decades (1991-2000, 2001-2010 and 2011-2020) was determined using the maximum temperature μ_{30}=32.62℃ as climate normal (mean of thirty years maximum temperature). Table 3 contains the averages and percentage change in maximum temperature for the three decades.

DOI: 10.56892/bima.v8i2.668

Table 3: Decadal Variability of Maximum Temperature Using μ_{30}=32.62℃

Decades	μ_{10}(℃)	μ_{10}-μ_{30}(℃)	% Change
1991-2000	30.86	0.053	-5.4
2001-2010	33.03	0.013	1.5
2011-2020	33.97	1.5	4.1

Source: Authors' Computation, 2021

Results from Table 3 shows that decade of 2001-2010 and 2011-2020 had percentage increase in maximum temperature of 1.3% and 4.1% which are higher than normal; while decade of 1991-2000 had percentage decrease in maximum temperature of 5.4% which is lower than normal. It can be concluded that maximum temperature over the last two decades (2001-2010 and 2011-2020) increased. However, 2011-2020 recorded the highest maximum temperature which was above normal by 1.35℃. This finding agrees with the report by WMO, (2011) that out of 102 countries, 48 are recording higher national maximum temperatures.

Decadal Variability of Minimum Temperature 1991-2020

The decadal variability of minimum temperature for the three decades (1991-2000, 2001-2010 and 2011-2020) was determined using the minimum temperature μ_{30}= 19.14℃ as climate normal (mean of thirty years minimum temperature). Table 4 shows the averages and percentage change in minimum temperature for the three decades. Result revealed that decades with high temperature were indicated using positive sign while that with low temperature was indicated using negative sign.

Table 4 shows the decadal variability of minimum temperature from 1991-2020 by establishing the normal minimum temperature of 19.14 ℃ . It was found that 1991-2000 recorded low minimum temperature among the three decades while the remaining two decades of 2001-2010 and 2011-2020 were slightly higher than normal.

Table 4: Decadal Variability of Minimum Temperature, μ_{30}= 19.14℃

Decades	μ_{10} (℃)	μ_{10}-μ_{30} (℃)	% Change
1991-2000	18.03	-0.057	-5.7
2001-2010	19.69	0.028	2.8
2011-2020	19.69	0.028	2.8

Source: Authors' Computation, 2021

The 1991-2000 decade had percentage decrease in minimum temperature of -5.7% lower than normal; while the 2001-2010 and 2011-2020 decades had percentage increase in minimum temperature of 2.8% and 2.8% higher than normal. The last two decades (2001-2010 and 2011-2020) were hotter than the first decade (1991-2000) by 1.66 ℃ and 0.55 ℃ hotter than climate normal of minimum temperature.

Decadal Variability of Average Temperature 1991-2020

The decadal variability of Average temperature for the three decades (1991-2000, 2001-2010 and 2011-2020) was determined using the average temperature μ_{30}= 25.86℃ as climate normal. Table 5 shows the mean and percentage change in average temperature for the three decades. The hottest decades were indicated using positive sign while the least decade was indicated using negative sign.

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Table 5 presented the decadal variability of average temperature during the decades (1991-2020). It was found that the first decade (1991-2000) recorded least average temperature of 24.44^{0}C; while the remaining two decades (2001-2010 and 2011-2020) recorded higher than normal average temperature in Zaria and its environs. The decade 1991-2000 had percentage decrease in average temperature of -5.4%; while 2001-2010 had percentage increase in average temperature of 1.8% and 2011-2020 had percentage increase in average temperature of 3.6% higher than normal.

Table 5: Decadal Variability of Average Annual Temperature, μ_{30}=25.86℃

Decades	μ_{10} (℃)	μ_{10}-μ_{30} (℃)	% change
1991-2000	24.4	-0.054	-5.4
2001-2010	26.3	0.08	1.8
2011-2020	26.8	0.04	3.8

Source: Authors' Computation, 2021

Therefore, it is an indication that the last decade was hotter than the second decade by 0.5 ℃ . 2001-2010 was 0.46 ℃ hotter than normal average temperature. Average temperature therefore is at increase during the last two decades with each decade having higher average than the decade before it. The findings of this research corresponded to the report by IPCC (2013), which discovered that global average temperature possesses decadal and inter-annual variability. In conclusion, global trend in temperature as reported by WMO, (2011) is similar to the findings of this study.

CONCLUSION

All the meteorological variables used in this study revealed low variability (rainfal15.8%, maximum temp. 5.3%, minimum temp. 6.7% and average temp. 5.1%) respectively during the study period (1991-2020). The recently passed decades (2001-2020) measured surplus rainfall and temperatures while the first decade of the study period (1991-2000) recorded less rainfall and temperatures. Therefore, increase in temperature is the cause of increasing rainfall amount and vice-versa in Zaria. Lastly, the findings from the research revealed that the study area is one of the regions where maximum and minimum temperatures increase during the period of thirty years (1991-2020). The maximum temperature with a higher standard deviation (1.741 ℃) is increases faster than minimum temperature with lower standard deviation (1.293℃).

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