

Temperature and Rainfall Trends as Indicators of Climate Change in a Rainforest Region of Nigeria

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abstract

This study examined temperature and rainfall trends as indicators of climate change in a rainforest region of Benin City in Nigeria. To achieve this, temperature and rainfall data spanning 32 years (1991 - 2022) were collected from the archives of the Nigerian Meteorological Agency (NIMET) in Benin City for the study. The data collected were analysed using linear regression and the result revealed an increasing trend in annual temperature ($R^2=0.439$, $p<0.000$). The mean temperature over the study period in the study area was 27.7 °C. Rainfall, on the other hand, showed no trends at ($R^2=0.005$, $p < 0.697$). The mean rainfall over the study period in the study area was 2284.5mm. The pattern of temperature and rainfall observed in this study could be attributed to climate change. As such, we recommend that efforts should be intensified toward mitigating climate change in the study area.

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Introduction

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change in the state of the climate that can be identified by changes in the mean and / or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC, 2012). The emission of greenhouse gasses as a result of human activities is one of the leading causes of climate change. Among the various environmental problems in the world today, climate change is the greatest humanity is facing. Its effect is more pronounced in Africa because of the poor capacity to cope and adapt to climate extremes (FAO, 2003; Bolaji-Olatunji *et al.*, 2010). Odjugo (2010) revealed that since 1901, trend of temperature in Nigeria has shown increasing pattern. This increase was gradual until the late 1960s and this gave way to a sharp rise in air temperature from the early 1970s which has continued till date. Likewise, the rainfall trend between 1901 and 2005 shows a general decline. Within 105 years, rainfall amount in Nigeria dropped by 81 mm. The decline in rainfall became worse from the early 1970s and the pattern has continued to date. This period of drastic rainfall decline corresponds with the period of sharp temperature rise. Although there is a general decrease in rainfall in Nigeria, the coastal areas of Nigeria are observed to be experiencing slightly increasing rainfall in recent times. This is a clear evidence of climate change because a notable impact is increasing rainfall in most coastal areas, and decreasing rains in the continental interiors (NEST, 2003). Rainfall is one of the major climatic parameters and can be used as an index for the measure of climate change. Crops, animals, and humans derive their water resources mainly from it. It also determines the time within which some crop types can be cultivated and the appropriate farming system for optimum yields (Ismail and Oke, 2012). Two air masses, namely the dry tropical-continental air mass, and the warm, tropical maritime air mass controlled the climate of Nigeria. The demarcation of these air masses is known as the Inter-Tropical Convergence Zone (ITCZ). The Inter-Tropical Convergence Zone (ITCZ) is the principal weather maker that is responsible for the summer monsoon precipitation in the country.

The two seasons observed in the country are rainy and dry seasons. The dry season (November-March) is due to the influence of the dry tropical-continental air mass from the Sahara Desert, while the rainy season (April-October) is due to the warm, tropical maritime air mass from the Atlantic Ocean (Audu and Okeke, 2018). Ojo and Aderoju (2017) noted that Benin City has been experiencing irregular rainfall patterns in recent years, with prolonged dry spells during the rainy season and increased intensity of rainfall resulting in floods. These changes in rainfall patterns have significant implications for food security in the region. The findings of Wali *et al.* (2020) revealed an increasing trend in temperature and a decreasing trend in rainfall in Uyo and Port Harcourt. However, Odiana and Ibrahim (2015) reported increasing trends in both rainfall and temperature in Bauchi Nigeria. Understanding the trends in rainfall and temperature is necessary in determining changing climate in a place. This study therefore, aims at determining the trends in temperature and rainfall in three cities in Nigeria as an indicator of climate change.

Materials and Methods

Description of Study Area

The study was conducted in Benin City, a tropical rainforest region of Nigeria. Benin City as shown in figure 1 below is located in the southern part of Nigeria, and is the capital of Edo State. It is positioned between latitudes 6°12'38.36"N and 6°27'25.00"N, and longitudes 5°29'46.03"E and 5°45'00.41"E. The city comprises five Local Government Areas (LGAs), namely Egor, Ikpoba-Okha, Oredo, Ovia North East, and Ununmwonde (Fabolude and Aighewi, 2022). Benin City has an annual rainfall exceeding 2000 mm, with an average monthly temperature of 28°C and relative humidity of 80%. The city is situated on the lower plain of the Esan Plateau, the city's eastern side is inclined towards the Ikpoba River, which drains the northeastern area, while the western side gently slopes towards the Ogba River. The highest point in Benin City stands at approximately 85 meters above sea level (Peter, 2012). Benin City is situated in the tropical rainforest region, characterized by abundant and diverse forest species that have been exploited for centuries. The soils are primarily acidic, deep, and heavily leached, with a reddish to brown color due to the prevalence of iron and aluminium oxides. The area is known for cultivating plantation crops such as Oil Palm, Cocoa, and Rubber, along with arable crops, in the southern section of Edo State, where Benin City is located (Fabolude and Aighewi, 2022).

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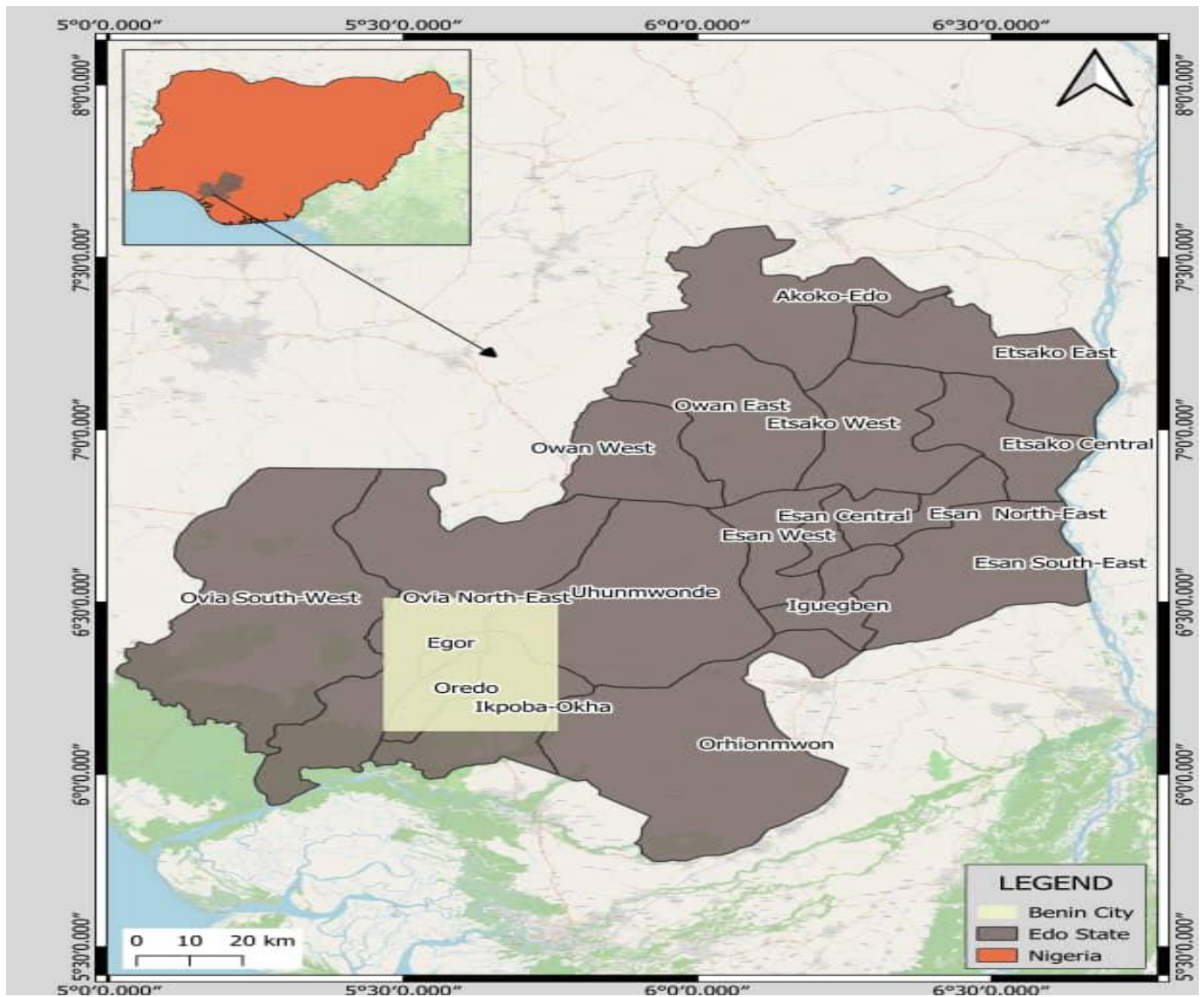


Figure 1: Map of the Study Area

Source of Data

Data on climatic variables (temperature and rainfall) were collected from the archives of the Nigerian Meteorological Agency, Benin City, Edo State. The rainfall and temperature data collected was for a period of 32 years, from 1991 - 2022.

Method of Data Collection and Analysis

The data were collected and computed to get the sum and the mean for each of the years under study and were analyzed using linear regression. This is to determine whether the temperature and rainfall in the study area are either increasing or decreasing. The data were also computed to get the mean rainfall and temperature for each of the years under study using Equation 1

$$\text{mean} = \frac{1}{n} (\sum a_i) \text{----- (1)}$$

where

$\sum a_i$ ----- summation of all the individual items
 n----- total number of entries

The linear regression was done using Equation 2.

$$Y = a + bx \text{----- equation 2}$$

Where:

X is the independent variable

Y is the dependent variable 'a' is the intercept (value of y when x=0).

'b' is the slope

Results

Temperature Trends

The regression model as shown in Table 1 shows the simple correlation R is 0.663 indicating a strong degree of correlation between temperature and variations of years in Benin City. The R² value is 0.439, which indicates that 43.9% of the temperature in Benin is explained by variations in years. The result also shows that the differences in years has a significant statistical influence on the temperature pattern in Benin, p < 0.000, which is less than 0.05. As such, Ho (there is no statistically significant difference between the differences in years and temperature in Benin City) is rejected and the research hypothesis H1 (there is a statistically significant difference between the differences in years and temperature in Benin City) is accepted. The trend line in Figure 2 below reveals an increasing trend in temperature in Benin City. Although the temperature showed an overall increasing trend, there is a fluctuation across the years with 1991 as the least with 26.8°C, and 2015 having the highest with 28.5 °C. The coefficient for years as shown in table 2 below is 0.30. This implies that for each year, there is an increase of 0.30 °C of temperature in Benin City. Therefore, the temperature in Benin City increases by 0.30 °C annually. This study also reveals that the mean temperature of Benin is 27.7°C using Equation 1 above.

Table 1 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	DF	F	Sig.
1	.663 ^a	.439	.421	.3356	1	24.303	.000 ^b

Table 2 Standardized Coefficients

Model	B	Std. Error	Beta	t	Sig.
Constant	-32.988	12.314		-2.679	.012
Years	.030	.006	.663	4.930	.000

Table 3 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	DF	F	Sig.
1	.070 ^a	.005	-.027	408.7364	1	.154	.697 ^b

Rainfall Trend

The regression model as shown in Table 3 below shows the simple correlation R is 0.07 indicating a very low degree of correlation between rainfall and variations of years in Benin. The R² value is 0.005, which indicates that only 0.5% of the rainfall in Benin is explained by changes in years. The result also shows that the differences in years did not have significant statistical influence on the rainfall pattern in Benin, $p < 0.697$ which is greater than 0.05. As such H_0 (there is no statistically significant difference between the differences in years and rainfall in Benin City) is accepted. Thus, there is no trend. The trend line in Figure 3 below also depicts neither an increase nor a decrease. However, it has revealed a fluctuating pattern with a sharp and massive decline in 2015, making it the year with the least amount of rainfall (1159.5mm). It showed an abrupt ascension in 2016 and further increased in 2017, 2019 and 2021 tend to have the highest amounts of rainfall of 3107.2 mm and 3085.2 mm respectively. It was also shown that most of the rainfalls are between 2000.0 mm and 3000.0 mm. This study also reveals that the mean rainfall of Benin is 2284.5 mm using equation 1 above.

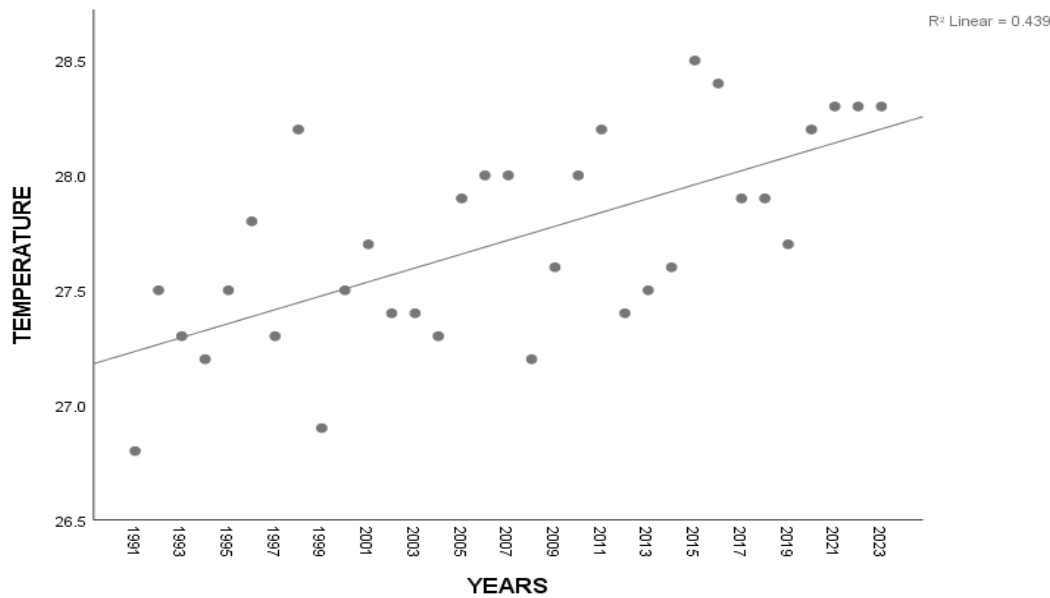


Figure 2 Scatterplot with a fit line of temperature in Benin City

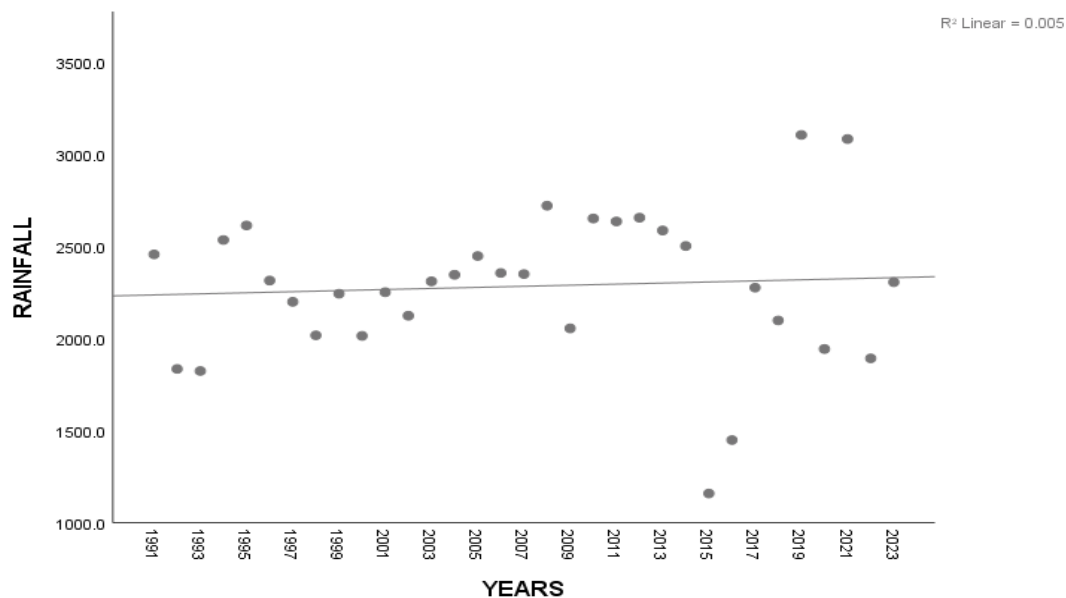


Figure 3: Scatterplot with fit line of rainfall in Benin City

Discussion

Basically, the temperature of the study area showed an overall increasing trend with positive correlation, but fluctuates across the years with 1991 as the least and 2015 as the highest. This shows that 2015 is the warmest year in the study area over the period studied. Similarly, the study showed that the recent years have experienced higher temperatures. This could therefore, connote that recent years have been the warmest in Benin City. This could be attributed to the rising global temperatures due to global warming and climate change. The mean temperature gotten in this study is 27.7 °C, which relatively connotes a warmer climate. According to Odjugo (2010), the temperature trend in Nigeria has shown an increasing pattern; since 1970s, there has been a sharp rise in air temperature, which continued until 2005. Prior to 1970s, temperature increase was more gradual and this was also stated in (Ayoade, 2003). The upward trend in temperature especially since the 1970s is worrisome evidence of regional warming (Odjugo, 2010). This warming trend agrees with Floyd *et al.* (2016) and Balogun *et al.* (2023) in their studies in Benin which showed an increasing trend of temperature. Odiana and Ibrahim (2015) in their study in the Bauchi metropolis showed an increasing trend in temperature. Efe and Ojoh (2013) also reported increasing trends in temperature in Warri. The increasing trend of temperatures recorded in this study is an indication of the impact of global warming in the study area. This increase in temperature in the study area may lead to reduced soil moisture content through the processes of evapotranspiration as temperature and soil moisture are inversely related (Lakshmi *et al.*, 2003). Similarly, the increasing temperatures are connected to incidences of crop pests and diseases which can affect food production in the study area consequently affecting food security. Temperature is an important element of climate and a major influencer of other parameters of climate like rainfall. As such, any alteration in it could have an impact on other parameters. With the increasing trends observed in

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- this study, it means rainfall and other parameters could be affected. As temperature increases, there is a corresponding increase in evapotranspiration thereby affecting the availability of water. Odiana and Ibrahim (2015) in their study in Bauchi revealed that the water source has dried up more quickly in recent years than before due to the increasing trend of temperature in the city.
- The rainfall pattern in this study depicted no trend with a fluctuating pattern which is in line with the report of Ofordu *et al.* (2022). Edokpa (2020) also detected no significant increasing or decreasing trend of rainfall in South South region of Nigeria in which this study area belongs to. The mean rainfall in this study signifies a high amount of rainfall in the study area which could be beneficial to agriculture and water resources replenishment. Studies that revealed the impact of climate change on crop production include those of Usman and Reason (2004); Kabote *et al.* (2013); Ouma *et al.* (2018); Matata *et al.* (2019), and Bukola (2021). Another point to note is that the high amount of rainfall could increase the susceptibility of the study area to flooding which could destroy lives and properties. The findings of Odiana *et al.* (2022) showed that rainfall is a major cause of flooding in the study area. Furthermore, crop farmers in the study area had poor coping capacity and were not better prepared against flooding (Odiana *et al.*, 2023).

Conclusion and Recommendation

This study was carried out to determine the trends in temperature and rainfall as indicators to climate change in a rainforest region of Nigeria. The results showed an increasing trend in temperature and no trend in rainfall which could be attributed to climate change. The observed temperature and rainfall patterns could have significant implications in agriculture, public health, and urban planning. Therefore, there is a need for addressing climate change in Benin City and Nigeria at large.

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