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Correlation between Climate Parameters and the Spread of Malaria in a Southern City of Nigeria

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ABSTRACT

Malaria is a familiar sickness in the tropics. The occurrence of malaria outbreaks is governed by several factors like rainfall and temperature. This study assessed the association between climatic parameters (temperature and rainfall) and malaria occurrence in Benin City, Nigeria. Climate data was obtained from the Nigeria Meteorological Agency (NIMET) covering the period from 1991 to 2022. Malaria incidence data was collected from the University of Benin Teaching Hospital covering 2014 to 2022. The data obtained was analysed using Mann Kendall test and multiple linear regression analysis in SPSS Version 25. The results showed that monthly temperatures were generally highest in February and least in August, and the annual temperature trends revealed a rise that is statistically significant (P=0.000) over the period studied. Rainfall reveals no statistically significant trends (P=0.41). The study also revealed that there was a correlation between climate parameters (temperature and rainfall) and malaria prevalence (R=0.598). Also, rainfall and temperature contributed to only 35.8% of malaria occurrence over the study period. This can be inferred that climate parameters to some extent influence malaria prevalence in the study area. However, factors other than climate parameters contribute immensely to the prevalence of malaria in the study area. Therefore, public awareness should be carried out on climate change and malaria risk so as to control malaria prevalence.

1. INTRODUCTION

Climate is a key environmental factor which influences the occurrence of many phenomena on Earth. Among the parameters of climate are rainfall, temperature, relative humidity and wind speed (M'Bra *et al.,* 2018). Variation can occur in these climatic parameters which could make them to increase or decrease. Thereby exacerbating conditions, they can influence such as spread of diseases. This variability is a result of periodic, natural alterations in factor such as the oceanic and air circulations, and volcanic eruptions (Mahmood *et al.*, 2019). The outbreaks of diseases which are spread by vectors, especially insects, are affected by these climatic parameters. This is because they are key determinants of the suitability of breeding grounds for the disease vectors. One of such diseases is malaria (Haque *et al.*, 2010).

Malaria is a contagious disease. Its transmission occurs via the bite of female

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Anopheles mosquitoes which contain *Plasmodium,* the malaria-causing parasite. Malaria in man is triggered by several species of *Plasmodium* among which are *Plasmodium malariae, Plasmodium ovale, Plasmodium vivax* and *Plasmodium falciparum* (Philips *et al.,* 2017). The hot areas of the world are home to the Anopheles mosquito as the climatic situations in these areas are suitable for the development and lifecycle of these organisms. For this reason, countries which lie in the sub-tropic and tropical regions have become endemic for malaria (Tiu *et al.,* 2021).

Around the world, an approximate 3.4 billion individuals who live in 92 countries are at risk of malaria infections. In 2018, the number of malaria cases across these countries was in excess of 219 million, with an annual 450,000 deaths occurring due to malaria (WHO, 2020). The spread of malaria into humans is a process which encompasses the vector role which the mosquito plays, the malaria-causing parasites and humans as host. The lifecycle of the malaria is made up of two stages, namely, the sexual stage which occurs in the body of the mosquito and the asexual stage which occur in the human body (Philips *et al.,* 2017). The process of reproduction in the Anopheles mosquito is influenced by environmental conditions which are, in turn, determined by climate. Among the most important influencing climate factors are rainfall, humidity and temperature (Hurtado *et al.,* 2018). Variations in the conditions of weather and climate have an effect on the lifecycle of mosquitoes and, by extension, the *Plasmodium* parasite (Tiu *et al.,* 2021). For instance, rise in rainfall or temperature will upset the frequency of malaria (Hurtado *et al.,* 2018). Due to the linkages between malaria and the patterns of climate, especially for parameters such as rainfall and temperature, the prevalence of malaria is expected to continually change as climate change continues (M'Bra *et al.*, 2018). Efe and Ojoh (2013) carried out an assessment of the prevalence of malaria and variations in climate in Warri, Nigeria using multiple linear regression. From the results of the study, it was observed that the incidence of malaria was significantly dependent on the temperature, relative humidity and rainfall. It was, therefore, projected that a continued increase in rainfall and temperature would lead to an increase in the incidence of malaria within the study area and its environs. Adewoyin and Adeboyejo (2017) explored how malaria prevalence in Nigeria is influenced by climatic and socio-economic variables using multiple regression and Pearson correlation analyses. It was reported that78.2% of the changes in malaria prevalence was a result of variations in climatic and socio-economic parameters. Kassa and Beyene (2014) investigated the relationship between variability in climate parameters such as rainfall and temperature, and the transmission of malaria in Fogera district of Ethiopia. They observed that changes in temperature and rainfall were not correlated with malaria prevalence. *Bi et al.* (2013) determined the impacts of variability in climate on malaria caused by two species of Plasmodium in areas along the Melong River in Yunnan, China. They found that outbreaks of malaria is significantly dependent on climatic factors. Therefore, climate is an important factor determining the spread of malaria in a place. This study assesses the correlation between climate parameter and the spread of malaria in Benin City.

2. MATERIALS AND METHODS

Description of the Study area

This study was done in Benin City a southern city in Nigeria. Benin City as shown in Fig 1 below is located at an elevation of 77.4m above sea level. Benin City is characterised by a wet season lasting from March to October, and a dry season lasting from November to February, with rainfall ranging from 150 - 300mm monthly. The temperature in the area is generally high and ranged from 26^0C to 34^0C, although it gets as hot as 38^0C between February and April. High humidity is a characteristic of Benin City, with values ranging from 70 - 90% being recorded. Harmattan is also experienced between December and February, and characterised by lower temperatures, decreased humidity and visibility. High amounts of sunshine are also recorded with sunshine hours ranging from 6 to 8 daily.

For the purpose of this work, secondary sources of data were utilised. Data on rainfall and temperature were gotten from the Nigerian Meteorological Agency, Benin City, Edo State. The rainfall and temperature data collected was for 32 years from 1991 to 2022. Also, data on the incidences of Malaria covering a period of nine years (2014 - 2022) was obtained from the medical records department of the University of Benin Teaching Hospital, Benin City, Edo State. Data on malaria cases were available for nine years only.

Method of Data Collection

The researcher visited the Nigeria Meteorological Agency and University of Benin Teaching Hospital in the year 2023 for the collection of meteorological data (rainfall and temperature) and data on malaria prevalence. The meteorological data collected was monthly data covering the 32-year period from 1991 to 2022. These data were then computed to obtain the sum and mean for each of the years under study. Likewise yearly data regarding incidences of malaria was collected by the researcher from the medical record department of UBTH.

Method of Data Analysis

Data collected was organised and entered in SPSS version 25. The rainfall and temperature data collected from Nigeria Meteorological Agency were analysed Mann Kendal test to determine significance of trend and direction. Multiple linear regression modelling was used to determine the associations between the climatic parameters and the incidence of malaria in the study area. The multiple linear regression was determined using equation 1 and the Mann Kendall Test was determined using equation 2.

$$Y = a + b1\ X1 + b2\ X2 + \ldots + bkXk \quad (1)$$

where:

X is the explanatory variable

Y is the independent variable

‘a’ is the intercept (value of y when x=0).

‘b’ is the slope

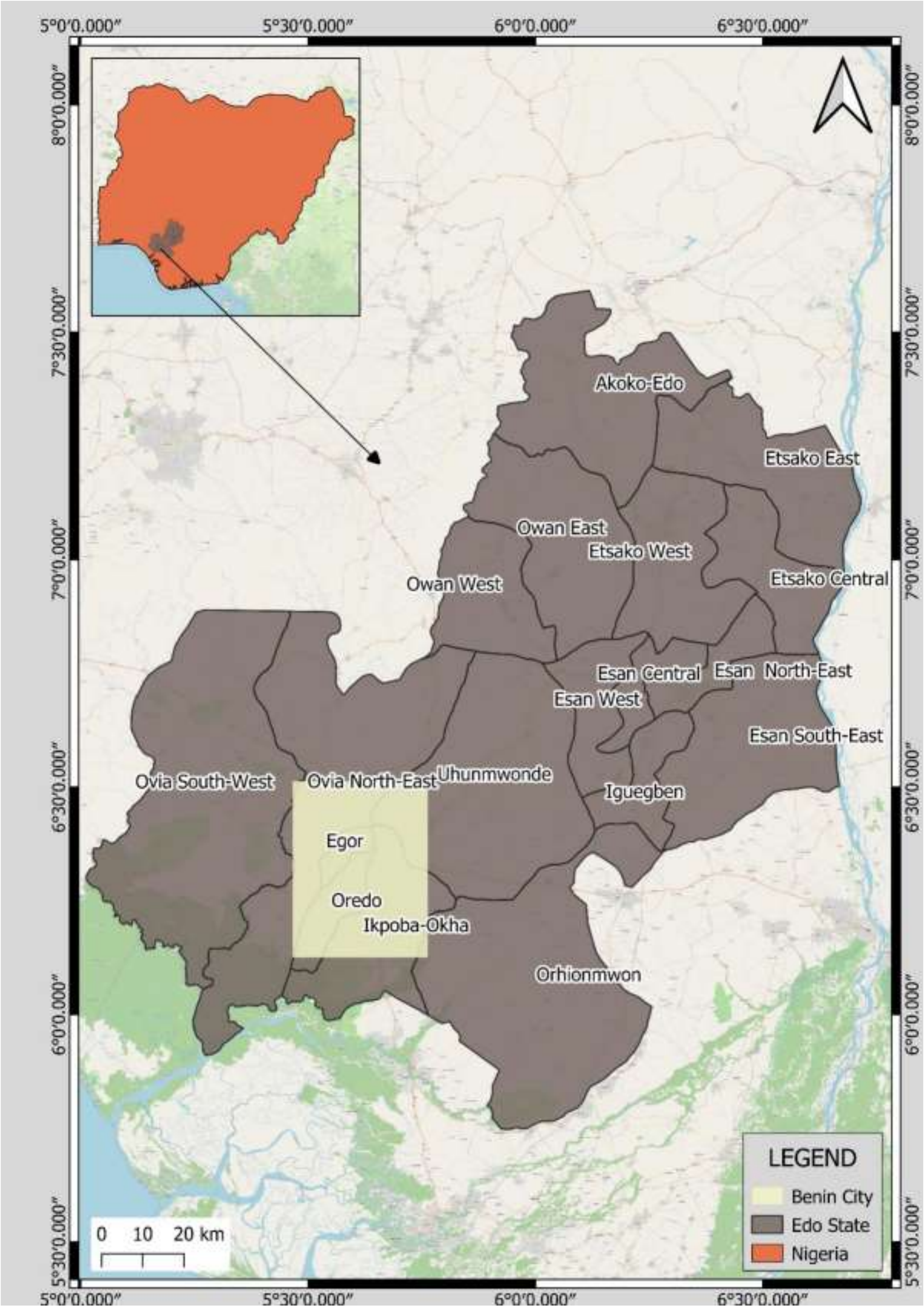

Figure 1: Map of the study area

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(y_j - y_i) \quad \text{---------------- } 2$$

Where

S is the slope which can either be positive, zero or negative,

y_j and y_i are the sequential values of observations at a given time i and j

n is the length of the data set

The test statistic tau gives a positive/negative trend when the value of tau is positive/negative and no trend when tau is zero. The level of significance used in this study was 0.05, and the trends were considered significant when the P-value was less than 0.05. A positive value S indicates an increasing trend, a negative S value shows a decreasing trend, while a zero value denotes no trend (Ahmad *et al.*, 2015). Mann Kendall test was also used by Yue *et al.* (2002), McLeod (2005); Hamed (2008) and Ngaina and Mutai (2013).

3. RESULTS

Trends in Temperature over the Study Period

The Mann Kendall result in table 1 shows increase in temperature trend that is statistically significant (P = 0.000 which is less than 0.05). As such, Ho (There is no statistically significant trend in temperature in Benin) is rejected and H1 (There is statistically significant trend in temperature in Benin) is accepted. The annual temperatures as shown in Figure 2a revealed a generally increase from 1991 to 2022. The lowest mean annual temperatures were recorded in 1991and 1999, both were below 27°C, and the highest was recorded in 2015 at approximately 28.5°C making it the warmest year. The rising trend of temperature in this study as seen in figure 2b is an indication of global warming being experienced in the study area.

The monthly temperature during the period under consideration as shown in Figure 3 below revealed that most of the values fell within the range of 24°C - 31°C. However, the values recorded for April 2015 and December 2011, which represent month with the maximum recorded value, exceeded 32°C. On the other hands, September 2004 and June of both 2012 and 2013, which had the least of all temperature values, were less than 24°C. In most years, temperature rose to highest in February, followed by a downward trend which extended until the lowest recorded values in August. Then there was an increasing trend in temperatures until February.

Table 1: Mann Kendall result

P	Z	Tau
0.000	3.67	0.46

Trends in Rainfall over the Study Period

The Mann Kendall result in table 2 shows rainfall with no statistically significant trend (P = 0.41 which is greater than 0.05). As such Ho (There is no statistically significant trend in rainfall in Benin) is accepted. Figure 4a shows that rain drops in 1992 then ascend sharply from 1993 to 1994. It gradually declines from 1995 to 1997 and fluctuated from 1998 to 2002. It gradually ascends from 2003 to 2005 where it decreases and then increase again from 2007 when a gradual fluctuating pattern occurred up to 2010. From 2010, a gradual decline took place till 2015

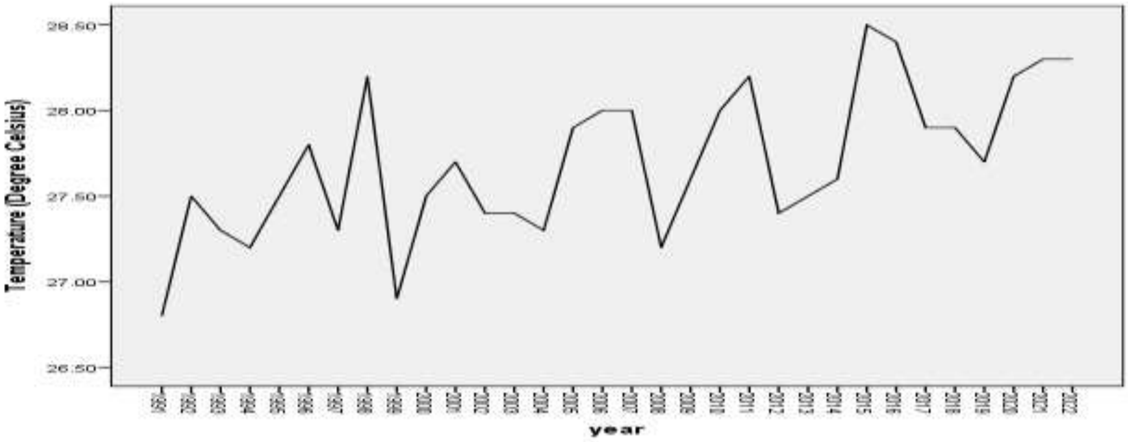

Figure 2a: Annual temperature pattern in Benin City

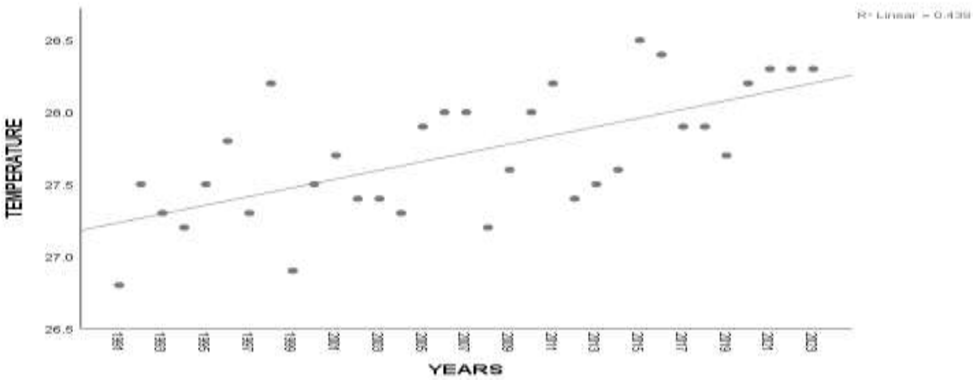

Figure 2b Scatterplot with fit line of temperature in Benin City

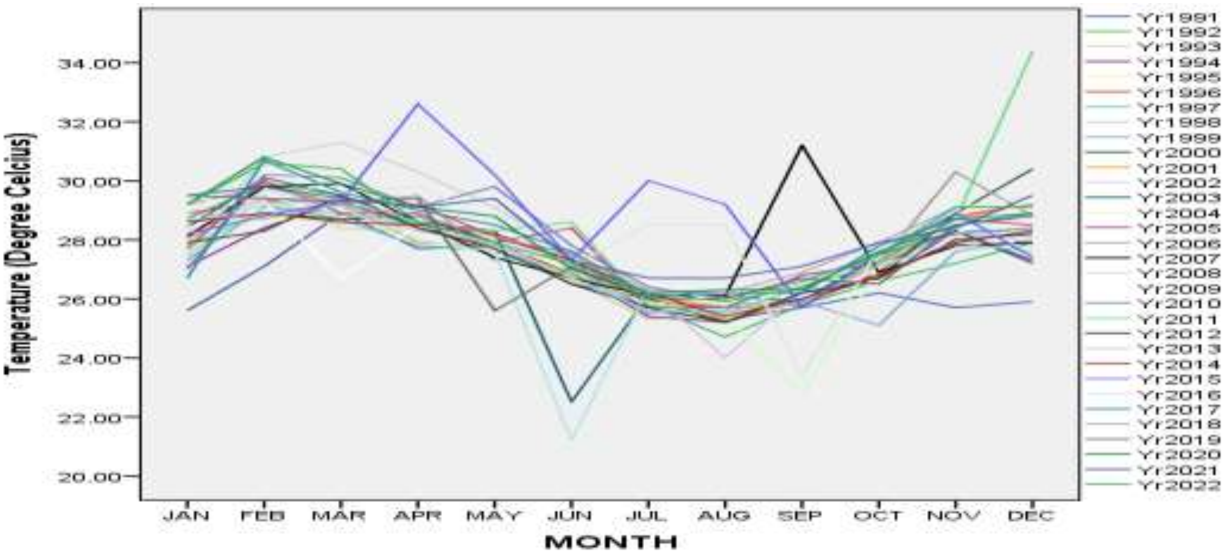

Figure 3: Monthly temperature trends in Benin City

which had the lowest amount of rainfall in the period studied. There was a rise in the rainfall from 2016 and underwent a rise and fall pattern with 2019 and 2021 having the highest amount of rainfall. As such, the least value recorded was below 1500mm in 2015, while 2019 and 2021 had rainfall values exceeding 3000mm. These later years signifies periods with increasing amount of rainfall relative to the previous years. Figure 4b reveals a trend line which depict a neither increase nor decrease

The monthly rainfall as seen in figure 5 reveals that there was a general increase in the amount of rainfall recorded from March to July where it peaks and reduces in August. It then ascends and peaks again in September then declines till December. The highest rainfall value recorded in a month was approximately 850mm in September of 2000.

Table 2: Mann Kendall result

P	Z	Tau
0.41	0.83	0.11

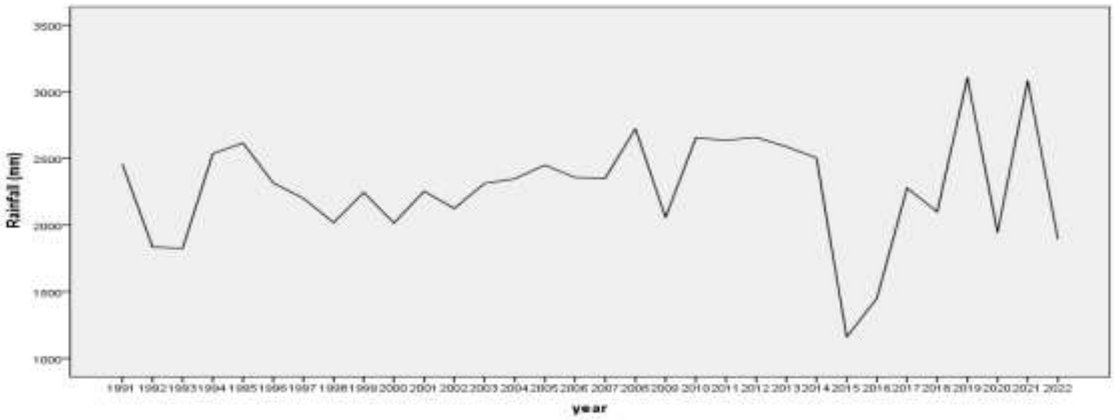

Figure 4a: Annual rainfall in Benin City

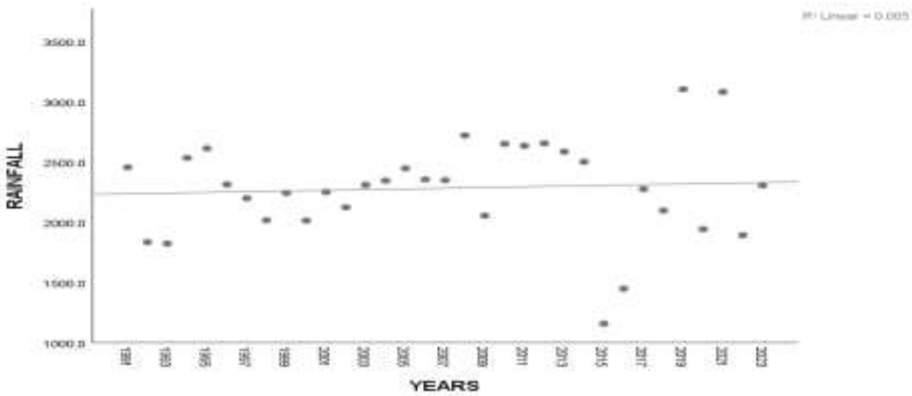

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Figure 4b: Scatterplot with fit line of rainfall in Benin City

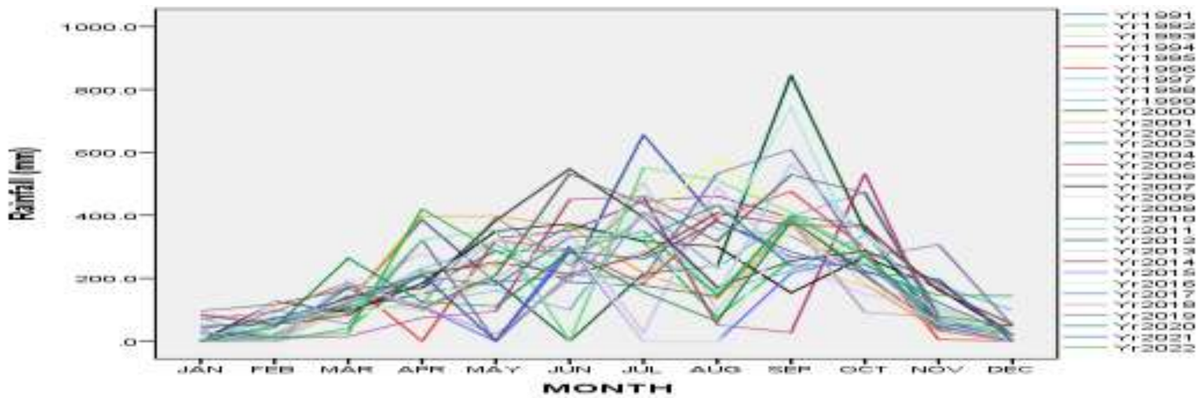

Figure 5: Monthly rainfall trends in Benin City

Cases of Malaria in Benin City

The number of cases of malaria recorded for individuals aged 5years and above is shown in Table 3. The lowest recorded number of malaria cases was 987 in 2014, while the highest was 6860 in 2019. The total number of cases between 2014 and 2022 was 20,659.

Table 3: Incidences of Malaria for aged 5 and above

Year	Sum of cases
2014	987
2015	1233
2016	888
2017	833
2018	1644
2019	6860
2020	2678
2021	2668
2022	2868
TOTAL	20,659

Relationship Between Malaria Prevalence and Climatic Parameters

The R value in table 4 represents the simple correlation between temperature and rainfall on one side and malaria on the other side. The value is 0.598 which indicates a positive and moderate degree of correlation. The R^2 value (35.8%) indicates how much of the total variation in Malaria can be explained by the independent variables (temperature and rainfall). It can be deduced from the model that only 35.8% of malaria incidences in the period studied in the study area is influenced by temperature and rainfall. Furthermore, table 3 below revealed that the regression model did not predict/influence malaria incidences significantly well. It could therefore be inferred that factors other than meteorology have more effect on malaria in the study area under the period investigated to which malaria data were available for this study (2014-2022).

Table 4: Correlation between malaria prevalence and climatic parameters

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.598[a]	.358	.144	1756.950

a. Predictors: (Constant), RAINFALL, TEMPERATURE

Table 3: Regression model and ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	10311726.408	2	5155863.204	1.670	.265[b]
	Residual	18521245.814	6	3086874.302		
	Total	28832972.222	8			

a. Dependent Variable: MALARIA

b. Predictors: (Constant), RAINFALL, TEMPERATURE

Discussion

The monthly temperature revealed that in most years during the study period, temperatures were higher in February which denotes the end of the harmattan season after which the temperature decreased until August which is a period of rainy season in the study area. The outcome of this study showed that there has been a net upsurge in the average temperature of Benin City over the duration of the study signifying that the study area is affected by global warming more so with relatively higher temperature being experienced during the harmattarn period. This period is likely to have lower temperature because of the impact of the North East Trade Wind that is typically cold. Efe and Ojoh (2013) also reported increasing trends in temperature in Warri. Similarly, Odiana and Ibrahim (2015) reported an increasing trend in temperature in Bauchi. The increasing trends of temperatures recorded is an indication of the impact of global warning and could suggest that global warming plays a role in increasing the spread of diseases including malaria (Akinbobola and Hamisu, 2022). Kibret *et al.* (2019) stated in their study that the changes in climatic parameters which may be due to global warming modify the life cycles and behaviours of mosquitoes. Likewise, researchers have submitted that temperature could be a main influencer of malaria outbreak in West Africa (Arab *et al.*, 2014). *Plasmodium* falciparum a common malaria parasite species has been known to show varied rates of growth at the temperature range 15–35 °C, but cannot do well outside this range (Blanford *et al.* 2013). Therefore, alterations in temperature away from the range can affect malaria spread (Jonathan *et al.*, 2018). With the rise in temperature in the study area, malaria spread will be continuously influenced by it.

The no significant trend in rainfall observed in this study is consistent with the work of Edokpa (2020) who detected no significant increasing or decreasing trend of rainfall in south -south region of Nigeria in which this study area belongs to. This is however contrary to the study done by Odiana and Ibrahim (2015) in Bauchi which revealed an increasing trend of rainfall. Changes in rainfall patterns recorded, points to the increasing influence of climate change/variability in the study area. This corroborates with the work of Canirs *et al.*, (2015). The outcome of this study can be inferred that there is abundant rainfall in the study area. This rainfall could result to the availability of stagnant water spots in different locations in the study area which would enhance the proliferation of the malaria causing vector (mosquito). Nchinda (1998) reported that changing rainfall patterns can determine malaria spread. Climatic variations affect mosquito lifespan, how they feed and development, which largely affect malaria spread (Christianen-Jucht *et al*. 2014). These situations also disturb with sporogonic development of Plasmodium, the substance in mosquitoes that cause malaria (Jonathan *et al*., 2018). Therefore, knowing how events in the environment influence malaria is necessary towards efforts in its control (Thomson *et al.*, 1999). A notable environmental factor is rainfall pattern.

There is a positive association between climate parameters (rainfall and temperature) and malaria incidence over the period. Kim *et al*. (2012); Bi *et al*. (2013); Sena *et al.* (2015); (Kigozi *et al.* (2016), and Jonathan *et al.*, (2018) are among the numerous studies that have re-counted climate change linked modifications in the incidence and/or prevalence of malaria. Harp *et al*. (2016) also stated that rainfall was highly linked with malaria incidence. Mosquito proliferation and related malaria prevalence are influenced by changes in climatic parameters like rainfall, temperature and relative humidity (Bi *et al.* 2013; Kigozi *et al*. 2016, Adeola *et al*. 2017). Efe and Ojoh (2013) using multiple linear regression observed that the incidence of malaria was significantly dependent on the temperature, relative humidity and rainfall. The survival and proliferation of Anopheles mosquitoes, depend on the handiness of stagnant water sources, wetness of soil surfaces, and temperature (Patz *et al*. 2003). The stagnant water is a good site for the breeding of mosquitoes. These stagnant water sites are mostly supplied by rainfall. Therefore rainfall is essential in the spread of malaria. This is buttressed by the key informant interview done on medical doctors of the University of Benin Teaching Hospital which proved that malaria prevalence is high during the raining season. Efe and Ojoh (2013) also stated high spread of malaria during raining season. The relevance of rainfall as an important element determining the prevalence of malaria can be seen in the work of Ayinlade *et al* (2013) where they stated that in the areas where temperature is high but rainfall is limited, such as the northern part of the country, the mosquito upsurge rapidly at the start of rain. This is due to reduced development cycle. Thus, two to three months of rainfall may be enough to herald one transmission season. The study area therefore with rainfall in most part of the year could be said to be prone to malaria prevalence. As noted in this study, there were 20,659 cases of malaria reported in the study area for a period of nine years for age five and above. However, high amount of rainfall could be detrimental to malaria spread because the rain could disturb the development of mosquito eggs. It could also wash away eggs or larvae thereby lowering the population of mosquitoes.

Temperature variations on the other hands disturb development of Plasmodium spp. the parasite of malaria. This study revealed that temperature is a determining factor of malaria spread in the study area. This also conform with the finding of Adu-Prah and Kofi Tetteh (2015); Dabaro et al. (2021) and Akinbobola, A., and Hamisu, (2022) which revealed that temperature influences the spread of malaria disease. The rate of development of *Plasmodium falciparum* rise outrageously when temperature rose from 15 °C to 35 °C, and massively declined to zero above 35 °C and below 15 °C (Blanford *et al*. 2013). Therefore when temperature goes below 15°C the parasite cannot survive. Similarly at higher temperatures survival will also be difficult. Just like higher amount of rainfall which may hamper malaria spread, higher temperature could also naturally control malaria. However, the rise in temperature will make conditions favourable in place where the parasite could not survive due to low temperature. Basically, changes in temperature can substantially adjust the metabolic rates of malaria causing vectors and the parasites they host (Gillooly et al., 2001 and Hundessa et al., 2018). Anopheline mosquitoes in places with high temperature have a higher metabolite rate, which in turn determines the development of larvae that take less time to mature (Kibret et al., 2016). Furthermore, temperature increase enhances the speedy digestion of blood supply, which in turn results to substantial increase in fecundity, with the development of better reproductive fitness and a higher tendency to produce more offspring (Afrane *et al.,* 2012). Also, an increase in the ambient temperature can intensely rise the feeding manner in the hosts and increase the annual temporal patterns of mosquito activity (particularly biting rates) and promotes a reduction in the time of sporogonic development of Plasmodium from an average of 14 days to 12.6 days (Afrane *et al*., 2012).Therefore, temperature play a very important role in determining the survival of mosquito and malaria parasite, and also influences the period of the gonotrophic cycle. Hence, a minimum temperature could hamper the development of mosquitoes' larvae and pupae. As a result, a minimum temperature could slow down the potentials of mosquitoes to cause infections and brng about drop in malaria spread (Darkoh *et al*., 2017).

The model reveals that the influence of temperature and rainfall on the incidence of malaria was low (35.8%) as such other factors aside these had more influence on malaria incidence between 2014 and 2022 in the study area. Some studies (Omonijo 2011 and Devi *et al.,* 2013) stated that climatic variables somewhat or completely correlated with malaria. However, Haque *et al.,* (2010) showed neither association between the numbers of malaria cases with climatic variables. It therefore means that factors like attitude of residents, sanitation and other social and environmental factors play a major role in malaria incidences in the study area. Several studies reported that, in addition to rainfall and temperature, relative humidity was another factor contributing to malaria incidence (Ayanlade et al., 2013; Ade-Prah and Tetteh, 2015; Jonathan et al., 2018; Akinbobola and Hamisu, 2022). This is further buttressed by Adewoyin and Adeboyejo (2017) who reported that a number of socio-economic variables including capital health expenditure, national poverty level, national unemployment rate and national inflation rate had an influence on malaria incidence. Furthermore, Dabaro et al (2021) stated that meteorology is not the only element affecting malaria spread. Other factors like land-use, land cover, water management, populations at risk, demographic and socioeconomic status of a community, poor hygiene, may substantially regulate the spread of malaria. Therefore, to curtail malaria spread in the study area, social and environmental factors enhancing its spread should be tackled.

4. CONCLUSION AND RECOMMENDATIONS

This study evaluated the relationship between climatic parameters (rainfall and temperature) and malaria incidence in Benin City using climate data from 1990 to 2022 and malaria incidence data from 2014 to 2022. The results showed an increasing trend in temperatures over the study period with a steady trend observed for annual rainfall. Findings showed that there was a correlation between rainfall and temperature, and malaria spread. However, the impacts of these two climatic parameters accounted for only 35.8% of malaria cases indicating that there were other factors which contributed to malaria incidence in the study area. Thus further studies should be carried out to identify other factors, meteorological or otherwise, which play important roles in increasing the incidence of malaria in the study area. Also, adoption and strengthening of the existing malaria control programs to be more resilient in the face of changing climatic conditions.

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