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Effects of Climate Variability on Malaria Prevalence in Bauchi Local Government Area, Bauchi State, Nigeria

Mohammed Abdulsalam[1], Ahmed C. Abdullahi[2],
Jamil Hassan Abdulkareem[3], Malam Lukman S. Sadiq[4]
[1]Bauchi Local Government Primary Health Care Department, Bauchi State, Nigeria;
[2,4]Abubakar Tafawa Balewa University Bauchi, Bauchi State, Nigeria;
[3]Frontier University Garowe, Somalia
mohasalam87@gmail.com

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Abstract

This study examined the impact of climate variability on malaria prevalence in Bauchi Local Government Area, Nigeria, using a retrospective survey design. Archival data on climate variables, temperature (maximum and minimum), rainfall, and relative humidity, were obtained from the National Aeronautics and Space Administration (NASA), while epidemiological records of malaria cases were sourced from the Bauchi State Agency for the Control of HIV/AIDS, Tuberculosis, and Malaria (BACATMA), as well as from international databases including WHO, IPCC, and WMO. Data covering the period from 2008 to 2018 were analyzed using descriptive statistics, trend analysis, and Pearson's correlation, implemented through SPSS version 26 and XLSTAT 2017. Trend analyses revealed notable climate variability, with annual rainfall peaking at 1301.83 mm in 2012 and reaching a low of 761.95 mm in 2016. Maximum temperatures ranged from 24.5°C in 2008 to 30.1°C in 2018, while relative humidity fluctuated between 52.5% in 2008 and 37.3% in 2018. Malaria cases exhibited a sharp increase from 2015, peaking in 2016 (291,607 cases), with consistently high figures in 2017 and 2018. Correlation analysis found no statistically significant relationship between malaria prevalence and rainfall ($r = -0.050$, $p = 0.566$), minimum temperature ($r = 0.114$, $p = 0.194$), or relative humidity ($r = -0.080$, $p = 0.361$). However, a strong positive and statistically significant correlation was observed between malaria prevalence and maximum temperature ($r = 0.974$, $p = 0.030$). These findings suggest that maximum temperature is a key climatic driver of malaria transmission in the region, highlighting the need for climate-informed disease surveillance and control strategies.

Keywords: Climate variability; Malaria prevalence; Maximum temperature; Epidemiological trends; Bauchi Local Government Area

INTRODUCTION

According to the definition of world meteorological organization (1), Climate Variability is defined as variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events.

The term "Climate Variability" is often used to denote deviations of climatic statistics over a given period (e.g. a month, season, or year) when compared to long-term statistics for the same calendar period. Climate variability is measured by these deviations, which are usually termed anomalies.

Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external factors (external variability).

Climate change is any change in climate over time, whether due to natural variability or as a result of human activity.(2) has further given a more elaborated definition to climate change stating that climate change is “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods.” Both definitions acknowledged that climate change is attributable to human activities altering the atmospheric composition, and climate variability is attributable to natural causes. Climate change also embraces the observed and projected rise in average global temperature, and the related impacts, including an increase in severe weather incidents; glaciers and sea level rise, melting of icebergs, and changes in the timing and amount of rainfall (3).

Climate variability can also result from external forcing, when events outside of the climate system's components nonetheless produce changes within the system. Examples include changes in solar output and volcanism. Climate variability has consequences for sea level changes, plant life, and mass extinctions; it also affects human societies. World Meteorological Organization defined climate variability as "variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events." In simpler terms, variability is the range of climate compared to its average. The fluctuations comprising climate variability can influence patterns of rainfall, temperature, and other variables on timescales anywhere from a few weeks to a few decades. (1).

Malaria, a vector-transmitted disease, has long plagued many nations across the world. Even with many efforts to prevention the disease, malaria continues to be a major cause of death among people living in the tropics. This disease is geographically specific and is often found in the tropical part of the globe. In these countries, ecological factors and climatic factors control the spread of the disease and also the life cycles of both vector and parasite (5). According to the latest estimates from World Health Organization (WHO), there were 214 million new cases of malaria worldwide in 2015 (range 149–303 million)[6].

Malaria also creates a significant economic burden on families and the nation as a whole targeting the most vulnerable groups [7,8] Temperature increases facilitate the development of arthropod vectors that carry many parasitic organisms and the parasites themselves [9].

Climate Variability and Malaria in the African Context

Climate variability is expected to have adverse ecological, social, economic, and health impacts. Climate change affects many institutions and productive sectors including agriculture, forestry, energy, and coastal zones, across the world. The economy of developing nations will be more affected by climate change, partly due to their greater exposure to climate shocks and also because of their limited adaptive capacity. However, no country is immune [10] and of the developing countries, many in Africa are seen as being the most vulnerable to climate variability and change [11; 12; 13]. Climate change will create large incremental risks [14] and a small incremental risk of more droughts can lead to large human development setbacks.

Detailed studies of the interaction of rainfall and malaria in the general community in Africa are limited. There are many reasons for this deficiency. These include the general weakness of the health information systems in most African countries, the lack of diagnostic facilities resulting in a paucity of extended times series of confirmed case data, and difficulties in accessing appropriate rainfall data for the specific locations and periods for which case data are available [15].

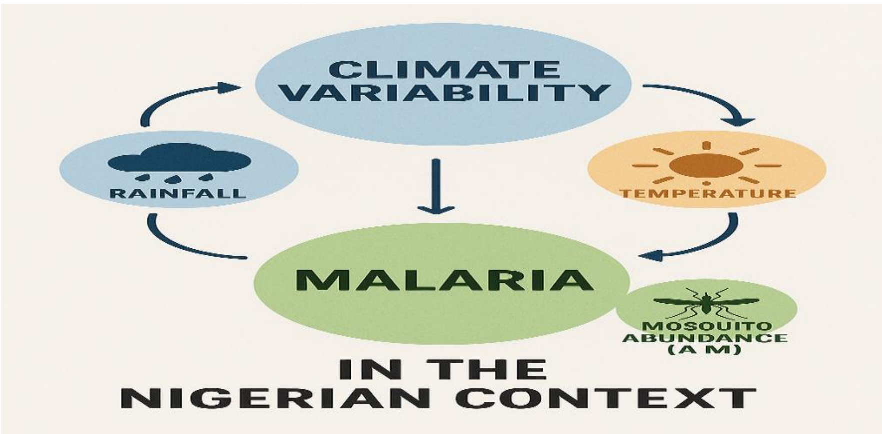
Climate Variability and Malaria in the Nigerian Context

Malaria is a serious disease and remains a public health problem in many parts of Nigeria. According to the [6] 212 million people were infected with human malaria parasites globally with Africa accounting for about 90% of these cases in 2015. Eighteen countries together accounted for 90% of the total cases in sub-Saharan Africa with 37 million reported cases representing (29%) of these cases from Nigeria alone. It is estimated that about 97% of Nigerians are exposed to the danger of contracting malaria with the disease accounting for about 60% of outpatient visitation at different health centers, 30% of child and 11% of maternal mortality making malaria the most important cause of mortality among children [16].

In Nigeria malaria is the cause of one in four deaths recorded in infants and young children and, worse still, for every 10 women that die around childbirth, one is caused by malaria. About half of Nigerian adults have at least one episode of malaria each year, while in younger children malaria occurs up to 3–4 times a year [15]. There are over 100 million people at risk of malaria every year in Nigeria and indeed it is estimated that about 50% of the adult population in Nigeria experience at least one episode yearly while the under five children have up to two – four attack of malaria annually [17]. The yearly economic loss due to malaria in Nigeria has been put at 132 billion naira due to costs of treatment and transport to source of treatment, loss of man hours, absenteeism from schools and other indirect costs [18]. Thus malaria imposed a heavy cost not only on a country's income, but also on its rate of economic development [18].

Malaria still constitutes a serious public health problem in Nigeria. It is responsible for 60% of outpatient visits to health facilities, 30% of childhood deaths, 25% of death in children under one year, and 11% of maternal deaths (4,500 die yearly). In Nigeria, a child will be sick with malaria between 2 and 4 times a year and 70% of pregnant women suffer from malaria contributing to maternal anemia, low birth weight, still birth, abortion, and other pregnancy-related complications. The annual financial loss due to malaria is estimated to be approximately 132 billion NGN (Naira; 1 NGN is 0.01 USD) in form of treatment costs, prevention, and loss of man-hours among others. Yet, it is a treatable and completely evitable disease [19]. The mean annual rainfall in the south-east of the country varies between 2,540 and 4,060 mm, while in the north 500–1,500 mm. The annual rainfall in Nigeria is the highest in the coastal areas and decreases inland towards the north. The mean temperature ranges between 25°C and 30°C towards the interior as a result of the moderating influence of the sea. In the dry season, temperature reflects more extreme conditions ranging between 20°C and 30°C. Much of the southern half of the country is characterized by a long growing period of 200–365 days with a bimodal rainy season and an annual rainfall of 1,500–3,000 mm. The onset of the wet season in this region is as early as February or March. The rain continues to the end of November [20].

However, the northern half has a much shorter unimodal rainy season of about 90–200 days with annual rainfall levels of 400–1,300 mm. The onset of the wet season may be as late as June, while its cessation may be as early as September [15].



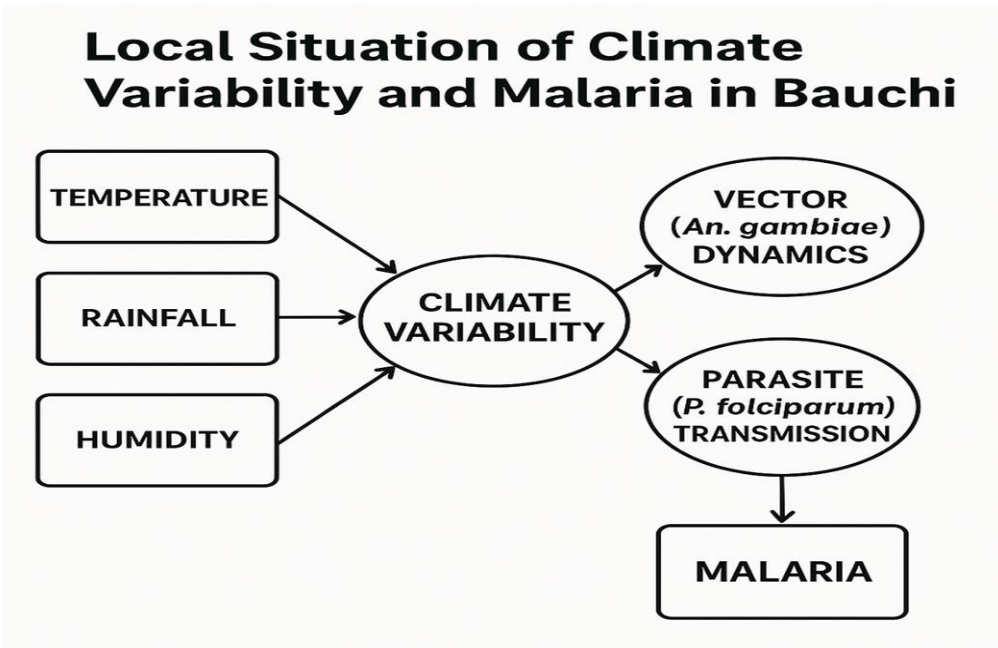
Source: Adapted from WHO, 2023.

Local Situation of Climate Variability and Malaria in Bauchi

In Bauchi, the people are vulnerable to mosquito bites resulting in malaria because some of the houses are within the fringes of water bodies, waste disposal centers, drainage, and grasses as well as within flight distance from their respective breeding habitats. Mosquitoes also breed on the edges of ponds and streams, open septic tanks, open cesspools, in salt marshes, overflowing sewages, holes in stumps or trees, water barrels, clogged troughs, street catch basins, empty tin cans, and jars. People tends to suffer from the impact of mosquitoes as a result of their biting and piercing leading to swollen body parts when they are in their houses or come out at night to receive cool air from their surroundings.

Bauchi, located in northeastern Nigeria, experiences a tropical climate characterized by distinct wet and dry seasons. The rainy season (typically from May to September) significantly influences mosquito breeding due to the availability of stagnant water, which serves as habitats for Anopheles mosquitoes, the primary vectors for malaria. [21]

Climate variability in the region particularly increasing temperatures, irregular rainfall patterns, and humidity changes has been strongly linked to fluctuations in malaria transmission. Prolonged or erratic rainy seasons contribute to increased breeding sites and extended mosquito lifespans, while poor drainage systems, open water storage, and inadequate waste disposal near residential areas in Bauchi exacerbate the risk of infection. This study is therefore set to determine climate variability and malaria prevalence in the Bauchi local government area, to provide necessary answers to the questions raised relating climate variability measured at the surface with malaria prevalence which will help to seek particular interventions for malaria control. Therefore, a knowledge of climatic variability and its effect on the prevalence of malaria can be used to predict malaria occurrences and hence provide early warning system information to health administrators and decision and policymakers for the control of the disease. [22]. Malaria prevalence in Bauchi remains seasonal and climate-sensitive, with peaks typically observed following heavy rainfall periods. Studies suggest that localized climate monitoring combined with public health interventions can help predict and mitigate malaria outbreaks.



Source: DALL·E, May 2025. [23]

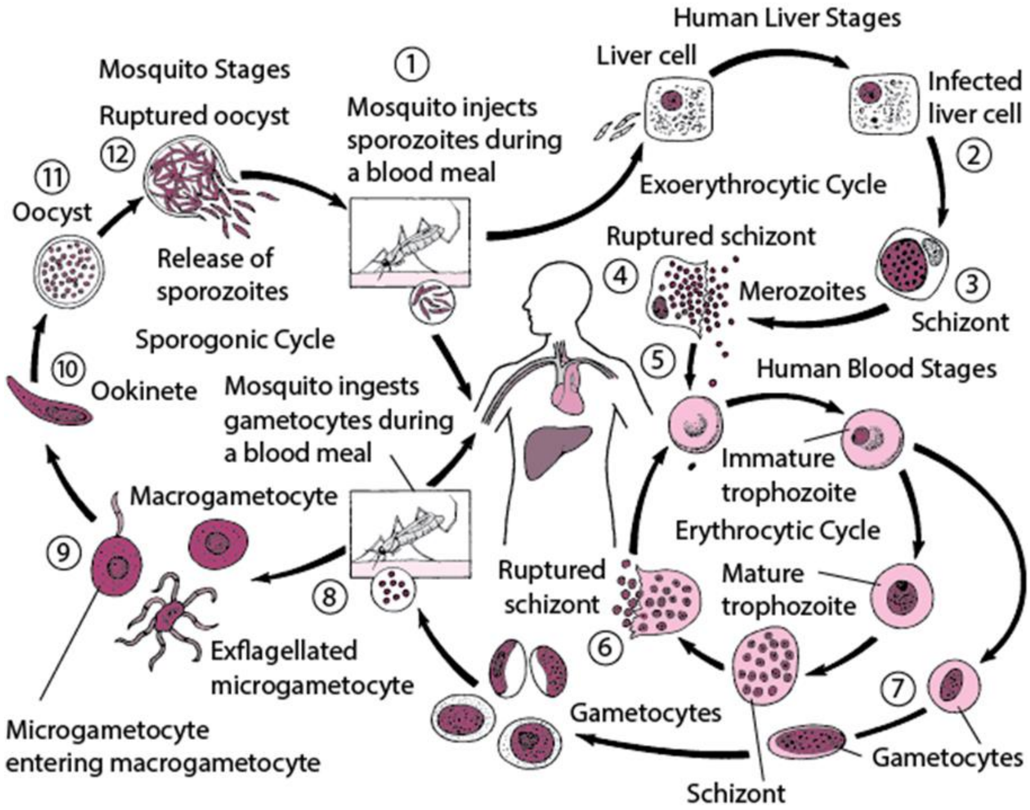
It is evidently clear that before the control of communicable diseases such as HIV/AIDs, Tuberculosis, Leprosy and Malaria had been a serious concern to the government and people of Bauchi state, as there was no clear direction on how to curb the menace of these disease until the advent of Bauchi State Agency for the Control of HIV/AIDs, Tuberculosis, Leprosy and Malaria [24] on 9th April, 2008 was established. As part of the effort over 4,044,000 Artemisinin Based Combination Therapy (ACT) for the treatment of malaria were distributed to health facilities in the state, in the same vein, a new technology for rapid diagnosis of malaria was also introduce for used in primary health care centers and other facilities in addition to the distribution of microscopes to all general hospitals to aid early diagnosis off malaria. The agency also distributed over 2,500,000 Long Lasting Insecticidal Nets (LLIN) in 2009 and another 3.2 million distributed in 2014 for the replacement campaign to all households free of charge. About 1million doses of Sulphadoxin Pyrimethamine (SP) medicine to pregnant women to prevent being infected by malaria were distributed to health facilities free of charge, as well as indoor residual and outdoor spraying had been conducted in addition to environmental management by larviciding drainage in town and villages of the entire 20 local government area in the state to prevent malaria [24].

Life Cycle of Malaria

The life cycle of malaria parasites is split in two between the human and female mosquito.

There are different species of the malaria parasite, and the basic life cycle of each follows the same basic pathway described. The life cycle of the malaria parasite begins in a female Anopheles mosquito where two *gametocytes* (sexually differentiated Plasmodium parasites) that were ingested by the Anopheles mosquito from the human host fuse to form the keynote or egg. The ookinete develops in the midgut of the mosquito and eventually breaks open, releasing sporozoites, which circulate through the mosquito, eventually arriving at the salivary glands where they can then be injected into a host when the mosquito next feeds. This stage, which occurs within the mosquito, is called the extrinsic cycle.

Once injected into the human host, the sporozoites move to the liver and enter liver cells where they asexually reproduce to form merozoites, which then spread through the blood and invade red blood cells. Inside the red blood cells, the merozoites synthesize all the necessary components for the multiplicative production of more merozoites.



Source : Merck, 2023.[25]

MATERIAL AND METHODS

The search for this review was conducted throughout the period of the study (January, 2008 – December, 2018) to track new developments and published reports and articles. This review was carried out according to a method (York Methodology) outlined by by Arksey and O'Malley

2005 from the University of York, United Kingdom. This study adopted a qualitative approach, so as to adequately describe the study aims and objectives. The study was based on secondary data. The secondary data for this study were collected through scientific database sources and web engine searches, i.e. BACATMA Bauchi State Control HIV/AIDS, Tuberculosis, Malaria, United Nation International Children's Emergency Funds (UNICEF), World Health Organization (WHO), Nigerian Metrological Agency (NIMET), World Meteorological Organization (WMO), Intergovernmental Panel on Climate Change(IPCC), United States Agency for International Development (USAID), United Nation Development Programs (UNDP and relevant articles from African Journals Online. Secondary data were also based on direct observation and relevant documents/reports from the Nigerian Ministry of Health (FMOH), Bauchi State Control of HIV/AIDS, Tuberculosis BACTMA Related articles, reports, and web page documents those that met inclusion criteria for this study were selected and reviewed as well. The inclusion criterion was all the data related to malaria and climate variability challenges in African, Nigeria and Bauchi (2009 on word). Reports not wholly focused on the topic of this study were excluded. All the retrieved publications were reviewed with emphasis on the Malaria and climate variability Bauchi Metropolis Nigeria, African and world at large.

RESULTS AND DISCUSSION

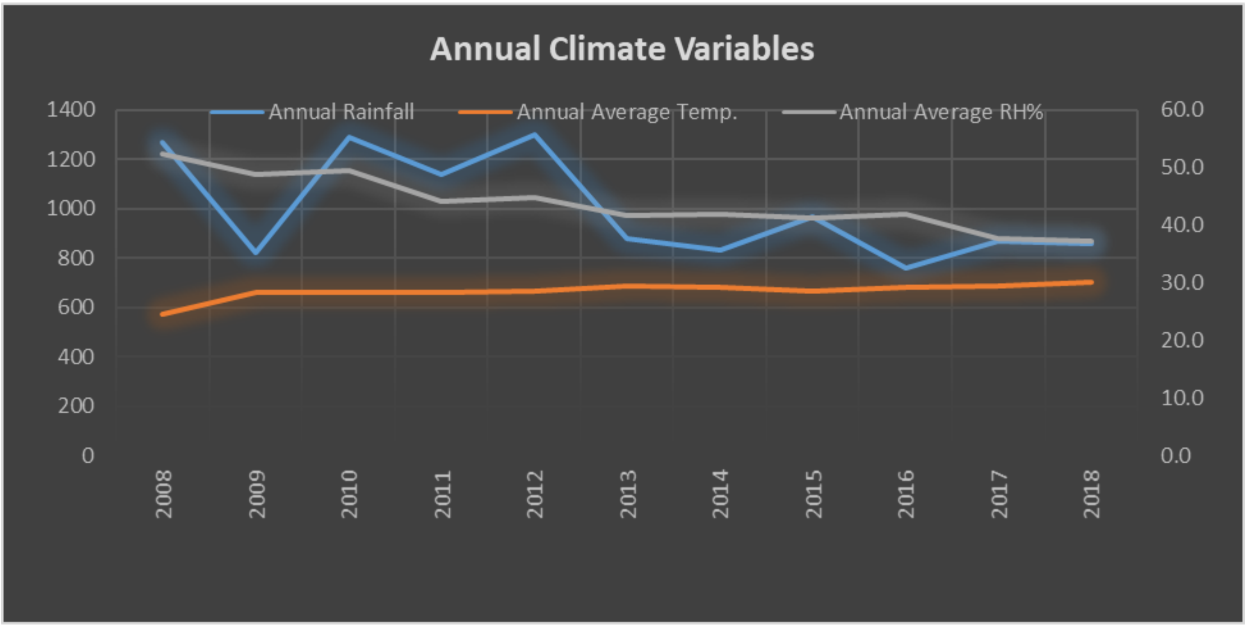
The incidence of Climate Variability in the study Area

As shown in table: 1 and figure: 6 the Climate variables (annual rainfall is high in 2012 with 1301.83mm and low in 2016 with 761.95, annual average temperature is high in 2018 with 30.1℃ and low in 2008 with 24.5℃ while relative humidity is high in 2008 with 52.5% and low in 2018 with 37.3%).

Table 1: Showing Variation in Annual Rainfall, Annual Average Temperature and Annual Average Relative Humidity of Bauchi Local Government Area from 2008 – 2018.

Years	Annual Rainfall (mm)	Annual Average Temperature (℃)	Annual Average Relative Humidity (%)
2008	1267.58	24.5	52.5
2009	823.78	28.3	48.8
2010	1288.1	28.4	49.4
2011	1137.92	28.3	44.2
2012	1301.83	28.6	44.9
2013	877.28	29.4	41.7
2014	833.52	29.2	42.0
2015	968.68	28.7	41.3
2016	761.95	29.3	41.8
2017	869.79	29.4	37.8
2018	860.06	30.1	37.3

Source: NASA, 2023 .



Source: NASA, 2023.

Figure 2: Shows the trend pattern of Annual Climate Variables (rainfall, temperature and relative humidity) in Bauchi Local Government Area from 2008 – 2018.

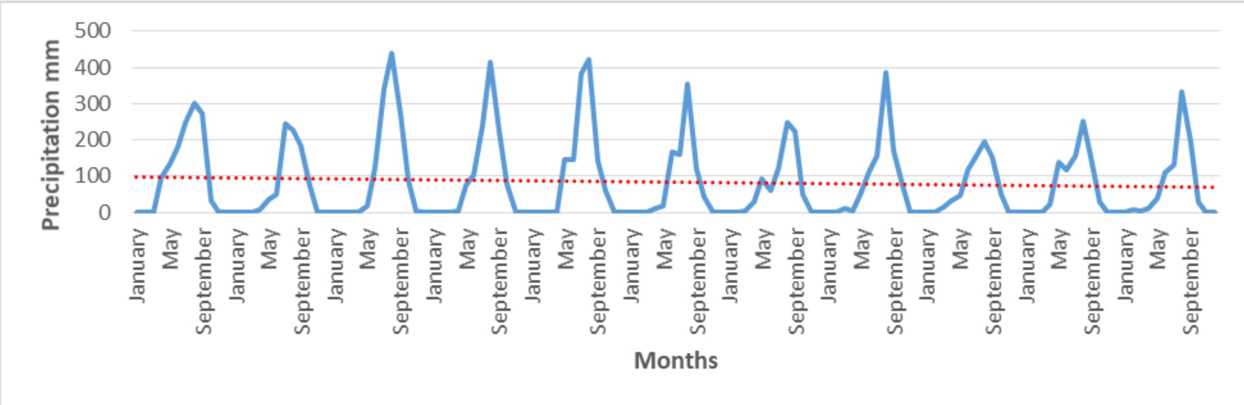
The pattern of monthly rainfall distribution in Bauchi from 2008 to 2018.

The relationship between mosquito abundance and rainfall is complex and best studied when temperature is not limiting.

The prospection shows that precipitation has could have a positive and negative effect on malaria distribution in most of the African countries. To analyze the consequence of precipitation on malaria, monthly data of both precipitation and malaria patience cases were collected that helped us to analysed between them and see the effects of precipitation on malaria distribution and variability in Bauchi.

The precipitation data is available for various years for a long period of time from 2008 to 2018 which was recorded from rain gauge stations. The entire data was analyzed to find the period or the months with the highest precipitation and the months with the lowest precipitation of the specified years in order to help us identify the variability of that data. Based on the result presented in figure 2 The Bauchi average precipitation distribution, it can be observed that the highest precipitation is about 441mm, 422mm and 414mm were recorded in August respectively, however in the months of March there was a low precipitation recorded compared to July, August and September. While at the other hand, the lowest precipitation recorded in the months of February and march which has little or no precipitation that is less than 20 mm and raining season start for the months of April with about 100 mm and October with about 200 mm. However, significant negative trend in annual precipitation within the West African Sahel and the Northern Nigeria have been pointed out by Bose et al 2018. Several authors have pointed out to that effect that the circulation in precipitation variability over West Africa exhibits the most basic characteristics of a monsoon: a pronounced seasonal wind shift that is produced by thermodynamic contrasts between the land (i.e., the Sahara) and ocean (i.e., the equatorial Atlantic). South-westerly flow is established between the Atlantic cold tongue (cool water close to the equator between the boreal spring and summer) and the Saharan heat low, bringing moisture into the continent [27].

According to Mohammadkhani et al Studies have shown that temperature has increased and precipitation has decreased in Kerman city from 1997 to 2000 [28].



Source: NASA, 2023.

CONCLUSION

This study highlights the significant role of climate variability particularly temperature changes in influencing malaria prevalence in Bauchi Local Government Area, Nigeria, over the period 2008–2018. The findings indicate a marked variability in climatic factors, with peak rainfall recorded in 2012 and lowest in 2016, while maximum temperature rose steadily, reaching its highest in 2018. Although rainfall and relative humidity did not show statistically significant correlations with malaria cases, maximum temperature demonstrated a strong positive and statistically significant relationship with malaria prevalence (r = 0.974, p = 0.030). This suggests that rising maximum temperatures are a key driver of malaria transmission in the region. The complex and inconsistent relationship between rainfall and malaria further supports the need for context-specific analysis, as mosquito abundance is influenced by precipitation only when temperature conditions are favorable. These findings underscore the importance of integrating climate data, especially temperature trends, into malaria surveillance and control programs to enhance public health preparedness in the face of climate change.

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