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# Mapping and Analysis of Malaria Incidence Rate in the Ecological Zones of Borno State, Nigeria

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**Abstract**

Malaria incidence rate per thousand among all the LGAs in the three ecological zones in Borno State was determined in this paper. Records of malaria reported cases in all the LGAs from 2011 to 2013 and 2016 to 2018 were obtained from the Epidemiological Unit of Borno State Ministry of Health. Records before 2011 were not available while only scanty records from few LGAs were generated by the unit between 2014 and 2015 because most of the LGAs were inaccessible during this period of insurgency. The population figures of the 2006 census of all the LGAs were projected to that of 2018. Appropriate formula was used to determine malaria incidence rate per thousand. Digital map of the state was created to generate the spatial pattern of malaria incidence rates among the ecological zones in the state using the acquired reported cases and the projected population. The result revealed that malaria prevalence is latitudinally inclined; that is, decreasing from the south to the north. The incidence rate was higher in Guinea savannah at the southern part of the state where environmental factors of high rainfall and humidity, moderate temperature, dense vegetation and presence of water bodies all favor the breeding and survival of mosquitoes which increases malaria prevalence. The Sahel at the extreme north with unfavorable environmental conditions to malaria prevalence, though recorded the least malaria incidence rate, but some parts of the Sahel still recorded high malaria incidence which shows that other factors other than environmental are responsible for high malaria prevalence in the ecological zone. It was recommended that all the agencies and ministries that are saddled with the responsibilities of providing epidemiological data should ensure that up-to-date, accurate and reliable data are provided since the accuracy of malaria incidence rate depends on the reliability of the generated malaria reported cases. The zones of higher incidence should be given higher priorities than the other areas that are less prevalent to malaria. The impact of socio-economic factors on malaria incidence rate in the ecological zones of the state is recommended for further studies.

**Keywords:** Borno State, Ecological zones, Malaria reported cases, Malaria incidence rates and Malaria prevalence

## Introduction

Malaria fever was recognized in ancient times in China, India and Mesopotamia, the Greeks and Romans were aware of the association of this fever with marshy lands and conducted one of the earliest health campaigns by draining marshes or drawing out the stagnant water (Akawu, 2012). Some species of plasmodium have long been recognized to infect humans in nature; *P. falciparum*, which is found worldwide in tropical and sub-tropical areas claimed more than one million people every year especially in Africa where this specie predominates (Menkin-Smith and Winders 2021). The female anopheles mosquito is the chief vector and the most common means for transmitting malaria to humans (Lazarus, 2012). The intensity of transmission depends on factors related to the parasite, the vector, the human host and the environment, transmission also depends on climatic conditions that may affect the number and survival of mosquitoes such as rainfall pattern, temperature and humidity (Marcia, 2017). Human immunity is another important factor especially among adults in areas of moderate or intense transmission conditions. Almost half of the people in the world are at risk of malaria infection (Malaria Fact Sheet 2014).

In sub-Saharan Africa, there are now between 350 and 500 million cases of malaria each year and 1.5 to 3 million deaths, mainly of children. Malaria affects almost all the population of people living in the area of Africa defined by the Southern fringes of the Sahara Desert in the north and latitude of about 28º in the south (UNHCR, 2022) where Nigeria including Borno state (the study area) belongs. Malaria poses serious economic, social and health burdens in tropical and subtropical countries where it is predominantly found, it has a major negative effect on economic development; it is commonly associated with poverty (Gallup and Sachs, 2001). According to Mark, *et al.,* (2014), malaria is estimated to have cost a loss of about US$12 billion a year in Africa due to increased cost of healthcare, decreased or loss of ability to work, and negative effects on tourism.

Several strategic plans have been developed to control this menace. In 2014, the malaria control program began implementation of a National Malaria Strategic Plan to achieve pre-elimination status (less than 5000 cases per 100,000) and reduce malaria related deaths to zero by 2020 (FMH, 2015). Some set targets for these strategies include reducing malaria case incidence by at least 90% by 2030, reducing malaria mortality rates in at least 30 countries (Nigeria inclusive), and preventing a resurgence of malaria in malaria free regions (WHO 2015). Some programes have also been put in place to reduce the incidence of malaria in Nigeria in general and Borno State in particular. Among them are the distribution of treated mosquito nets, administration of free malaria treatment especially among the infants and pregnant women among others. However, despite all these efforts, the incidence of malaria is still very high in Borno State (WHO 2020a).

Although tremendous progress has been made globally in fighting the vector and the parasite (Rima *et al.,* 2017), the situation is far from being resolved, especially in Africa. Although the burden of *Plasmodium falciparum* malaria is gradually declining in some parts of Africa, it is characterized by spatial and temporal variability that presents new and evolving challenges for malaria control programs (Nkumama *et al.,* 2017). Mapping the spatial patterns of malaria distribution has been an important epidemiological tool (Emmanuele *et al.,* 2021). Maps of malaria distribution are vital for optimal allocation of resources for anti-malarial activities. There is a lack of reliable contemporary malaria maps in endemic countries especially in Sub-Saharan Africa. In 1996, there was a renewed plea for better malaria cartography to guide malaria control in Africa (Emmanuele *et al.,* 2021) and over the last decade there has been a growth in spatial data on malaria and populations not available to malariologists or program control managers 60 years ago. The growth in data has been accompanied by the development of statistical approaches to model and map risk and intervention access in space and in time using Model Based Geo-Statistics (Emmanuele *et al.,* 2021). The need for geospatial analysis of the prevalence and spatial distribution of malaria endemic in Borno becomes necessary for better data generation and analysis for reliable information on monitoring and decision making on malaria prevalence in Borno State. Furthermore, one of the reasons responsible for this ineffectiveness in the control of malaria is the non-availability of data in most areas, and where available, most of them are in analogue format which are always difficult to keep, occupy large space, subject to excommunication and difficult to update.

## Materials and Methods

### *The Study Area*

Borno State is located between latitudes 10˚ 0' 13.473"N and 13˚ 44' 40.23"N of the Equator and longitudes 11˚ 26' 20.555"E and 14˚ 34' 11.581"N of the Meridian (Fig.1). Republics of Cameroon, Niger and Chad shares international boundaries with Borno State in the East and the North East respectively. At the South, the state is bounded by Adamawa State, South West by Yobe State and the West by Gombe State. The State made up of twenty-seven (27) LGAs which collectively covered a total land area of 72,363.40 km2. The relief of the state consists of the plains which covers the entire northern and most of the central part of the state (Fig.1), The elevation of the plains ranges from 188 - 328 m above sea level. Biu Plateau and Gwoza hills are the main highlands/plateau regions within the state with elevation ranging from 569.1-1327 m above sea level. Altitude influences the distribution and transmission of malaria, as altitude increases, temperature decreases, so highlands are colder and consequently, malaria prevalence decreases while the lowlands areas are warmer and more suitable to malaria prevalence (Akawu, 2021). Drainage system in the state consists of Lake Chad at the extreme North Eastern part, while Rivers Komadougou Yobe forms a natural boundary between Nigeria and Niger Republic at the north, River Hawul is located at the southern part of the State. Other rivers include: River Ngadda and River Yedszeram which flows South-North and end into Lake Chad (Akawu, 2021).

Amount of rainfall decreases from the south to the north, that is, rainfall in the state is latitudinally inclined. Rainfall amount that ranges from 775.51 to 958 mm in the south, decrease to within a range of 228 to 410.5 mm in the North (Akawu, 2021). Mean annual temperature of Borno State is lowest (about 25°C) at the tops of the main hills and plateau of Gwoza and Biu respectively. Mean temperature is highest in the Sahel and at the extreme southern part of the State with about 31°C (Akawu, 2021). Relative humidity is highest around Lake Chad ranging from 48-55.5%, while relative humidity is as low as between 25.3 to 32.8% in the Sahel zone (Akawu, 2021). Borno state lies within Guinea, Sudan and Sahel vegetation zones. The density and heights of vegetation in the state also decreases from south northwards.

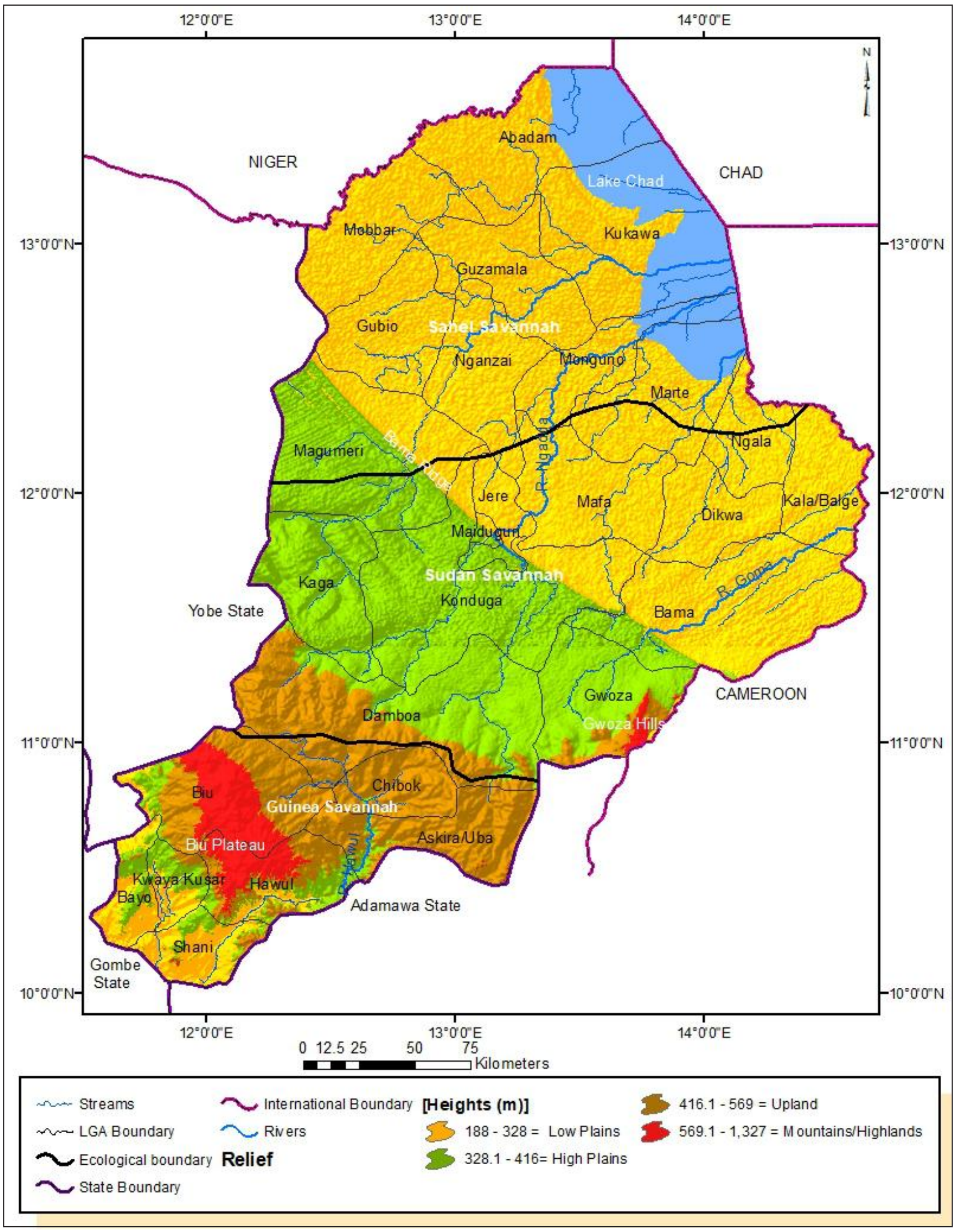


**Figure 1:** The Study Area

***Modeling malaria prevalence in Borno State***

Secondary data on the reported cases of malaria in each of the LGAs in the State from 2009 to 2018 were acquired from Borno State Epidemiological Unit, Ministry of Health, Maiduguri, for this study. While the establishment has adequate records on malaria reported cases between 2009 and 2013, the records of 2014 and 2015 were very scanty, this is as a result of inaccessibility of most parts of the state(especially the northern part) due to the extreme activities of the insurgents which has made the collection of data within this period basically impossible. Eight LGAs (Abadam, Bama, Damboa, Guzamala, Gwoza, Kaga, Kukawa, Mafa) out of the twenty-seven (27) LGAs in the state had no record at all for the two years. Scanty data were obtained from Maiduguri Urban (MMC and Jere LGAs) and the relatively peaceful Borno South (Askira Uba, Bayo, Biu, Chibok, Hawul, Kwayar Kusar and Shani) LGAs. These scanty records of 2014/2015 could not be used for spatial mapping because of the non-availability of such records in many LGAs. Therefore, records on malaria reported cases for 2009-2013 and 2016-2018 were found adequate and were used to generate digital maps of the state in this study.

Mapping malaria prevalence in the States involves the following steps: (i) Generation of digital map of Borno State with each of the LGAs digitized as polygon so as to accommodate malaria attribute information of each of the LGAs. Reported cases and prevalence fields were created using the add field module of ArcGIS software. (ii) The 2018 population of each LGA was projected based on the figures of the 2006 housing and population census at a growth rate of 2.59 (World Development Indicators, 2018) in each of the LGAs in Borno State.

The equation for projecting population is Nt=P e (r * t). Where:

"Nt" represents the number of people at a future time.

"P" is the population at the beginning time.

"e" is the base of the natural logarithms (2.71828).

"r" is the rate of increase (natural increase divided by 100).

"t" represents the time period involved.

This was summarized as: present population * (base of the natural logarithms raised to (rate of natural increase/100*times period. To project the population of Damboa LGA in 2018 with population of 233200 in 2006, that is a period of twelve years: 233200 was the population in 2006 (p), the base of natural logarithms is 2.71828 (e), the rate of increase is 2.59 divided by 100 is 0.03 (r) while time difference is 12 (t). (iii) Malaria prevalence per 1000 was determined using the formular: *Total number of reported cases per LGA/Total population per LGA multiplied by 1000 (*Meyrecler *et al.,* 2019). *(iv).* Classifications of the LGAs into four prevalence classes: low, moderately low, moderately high and high based on the number of prevalence in each of the LGA per thousand. The generated digital maps for each of the study years (2009-2018) has the advantage of easy comparison of malaria prevalence among all the LGAs in each year in the State at a glance (the denser the colour, the higher the prevalence).

## Results and Discussion

***Malaria reported cases and incidence rate in Borno State***

Table 4.1 shows the projected population of all the LGAs in the State to 2018 based on the 2006 population census figures. The table also contains the numbers of malaria reported cases, the values of the calculated malaria incidence rate as well as the mean/grand mean malaria incidence rate in each of the LGAs. The least malaria incidence rate was recorded in 2016 which could be attributed to the problems of insurgency as most parts of the states were just been reclaimed from the insurgents at the period (Mentor Initiative 2020), hence, accessibility and record taking of malaria cases were minimal. Malaria incidence rate was highest in 2017 and 2018 due to higher number of reported cases as most of the LGAs within the state were accessible at this period.

**Table 1:** Population, number of malaria cases and prevalence in Borno State

| LGAs | 2006 Pop | Pop 2011 | Cases | Prev | Pop 2012 | Cases | Prev | Pop 2013 | Cases | Prev | Pop 2016 | Cases | Prev | Pop 2017 | Cases | Prev | Pop 2018 | Cases | Prev. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abadam | 100,065 | 114,528 | 1135 | 9.91 | 117,662 | 1110 | 9.43 | 120,883 | 1698 | 14.05 | 131,082 | 1414 | 10.79 | 133,196 | 1110 | 8.33 | 136,704 | 1914 | 14.00 |
| A/Uba | 143,313 | 164,027 | 2206 | 13.45 | 168,516 | 2236 | 13.27 | 173,128 | 2515 | 14.53 | 187,735 | 246 | 1.31 | 190,763 | 2272 | 11.91 | 195,788 | 4297 | 21.95 |
| Bama | 270,119 | 309,161 | 1943 | 6.28 | 317,622 | 1511 | 4.76 | 326,315 | 1890 | 5.79 | 353,846 | 872 | 2.46 | 359,553 | 963 | 2.68 | 369,024 | 2815 | 7.63 |
| Bayo | 79,078 | 90,508 | 2379 | 26.29 | 92,985 | 2501 | 26.90 | 95,529 | 2731 | 28.59 | 103,589 | 174 | 1.68 | 105,260 | 2088 | 19.84 | 108,033 | 5482 | 50.74 |
| Biu | 175,760 | 201,164 | 1823 | 9.06 | 206,669 | 1775 | 8.59 | 212,325 | 1900 | 8.95 | 230,239 | 153 | 0.66 | 233,953 | 3854 | 16.47 | 240,115 | 8367 | 34.85 |
| Chibok | 66,333 | 75,921 | 1939 | 25.54 | 77,998 | 1776 | 22.77 | 80,133 | 2179 | 27.19 | 86,894 | 110 | 1.27 | 88,295 | 3901 | 44.18 | 90,621 | 2651 | 29.25 |
| Damboa | 233,200 | 266,906 | 1894 | 7.10 | 274,211 | 1114 | 4.06 | 281,715 | 1760 | 6.25 | 305,484 | 88 | 0.29 | 310,411 | 2950 | 9.50 | 318,587 | 5812 | 18.24 |
| Dikwa | 105,042 | 120,224 | 1141 | 9.49 | 123,515 | 1026 | 8.31 | 126,895 | 1361 | 10.73 | 137,601 | 925 | 6.72 | 139,821 | 834 | 5.96 | 143,504 | 1027 | 7.16 |
| Gubio | 151,286 | 173,152 | 1166 | 6.73 | 177,891 | 1014 | 5.70 | 182,760 | 1209 | 6.62 | 198,179 | 53 | 0.27 | 201,376 | 102 | 0.51 | 206,680 | 1186 | 5.74 |
| Guzamala | 95,991 | 109,865 | 1306 | 11.89 | 112,872 | 1306 | 11.57 | 115,961 | 1886 | 16.26 | 125,745 | 1464 | 11.64 | 127,773 | 1160 | 9.08 | 131,139 | 2001 | 15.26 |
| Gwoza | 276,568 | 316,542 | 4259 | 13.45 | 325,205 | 4204 | 12.93 | 334,105 | 3330 | 9.97 | 362,294 | 1903 | 5.25 | 368,138 | 1812 | 4.92 | 377,835 | 2637 | 6.98 |
| Hawul | 120,733 | 138,183 | 829 | 6.00 | 141,965 | 777 | 5.47 | 145,850 | 771 | 5.29 | 158,156 | 229 | 1.45 | 160,707 | 10831 | 67.40 | 164,940 | 6675 | 40.47 |
| Jere | 209,107 | 239,331 | 8479 | 35.43 | 245,881 | 3224 | 13.11 | 252,610 | 4859 | 19.24 | 273,923 | 441 | 1.61 | 278,341 | 12105 | 43.49 | 285,672 | 10381 | 36.34 |
| Kaga | 89,996 | 103,004 | 4445 | 43.15 | 105,823 | 2363 | 22.33 | 108,719 | 4016 | 36.94 | 117,892 | 74 | 0.63 | 119,793 | 552 | 4.61 | 122,948 | 2458 | 19.99 |
| K/Balge | 60,834 | 69,627 | 860 | 12.35 | 71,532 | 532 | 7.44 | 73,490 | 852 | 11.59 | 79,690 | 278 | 3.49 | 80,976 | 113 | 1.40 | 83,109 | 113 | 1.36 |
| Konduga | 157,322 | 180,061 | 1789 | 9.94 | 184,989 | 1670 | 9.03 | 190,051 | 1760 | 9.26 | 206,086 | 55 | 0.27 | 209,410 | 1893 | 9.04 | 214,926 | 5735 | 26.68 |
| Kukawa | 203,343 | 232,734 | 1204 | 5.17 | 239,103 | 930 | 3.89 | 245,647 | 2704 | 11.01 | 266,372 | 896 | 3.36 | 270,668 | 592 | 2.19 | 277,798 | 1021 | 3.68 |
| K/Kusar | 56,704 | 64,900 | 1485 | 22.88 | 66,676 | 1345 | 20.17 | 68,501 | 852 | 12.44 | 74,280 | 128 | 1.72 | 75,478 | 7502 | 99.39 | 77,466 | 8197 | 105.81 |
| Mafa | 106,600 | 122,008 | 485 | 3.98 | 125,347 | 351 | 2.80 | 128,777 | 463 | 3.60 | 139,642 | 394 | 2.82 | 141,894 | 56 | 0.39 | 145,632 | 345 | 2.37 |
| Magumeri | 140,257 | 160,529 | 883 | 5.50 | 164,923 | 832 | 5.04 | 169,436 | 1110 | 6.55 | 183,732 | 95 | 0.52 | 186,695 | 1606 | 8.60 | 191,613 | 1633 | 8.52 |
| Maiduguri | 540,016 | 618,068 | 9460 | 15.31 | 634,983 | 4083 | 6.43 | 652,361 | 6097 | 9.35 | 707,402 | 497 | 0.70 | 718,811 | 11464 | 15.95 | 737,745 | 16124 | 21.86 |
| Marte | 129,409 | 148,113 | 1425 | 9.62 | 152,167 | 1275 | 8.38 | 156,331 | 1424 | 9.11 | 169,521 | 1759 | 10.38 | 172,255 | 2785 | 16.17 | 176,793 | 2367 | 13.39 |
| Mobbar | 116,633 | 133,491 | 1127 | 8.44 | 137,144 | 933 | 6.80 | 140,897 | 1223 | 8.68 | 152,785 | 2122 | 13.89 | 155,249 | 3139 | 20.22 | 159,339 | 1814 | 11.38 |
| Monguno | 109,834 | 125,709 | 1151 | 9.16 | 129,149 | 1096 | 8.49 | 132,684 | 1220 | 9.19 | 143,879 | 4257 | 29.59 | 146,199 | 7895 | 54.00 | 150,050 | 2013 | 13.42 |
| Ngala | 236,498 | 270,681 | 5269 | 19.47 | 278,089 | 3468 | 12.47 | 285,699 | 4956 | 17.35 | 309,804 | 5523 | 17.83 | 314,801 | 10643 | 33.81 | 323,093 | 9090 | 28.13 |
| Nganzai | 99,074 | 113,394 | 1995 | 17.59 | 116,497 | 1348 | 11.57 | 119,685 | 1511 | 12.62 | 129,783 | 538 | 4.15 | 131,877 | 903 | 6.85 | 135,350 | 788 | 5.82 |
| Shani | 100,989 | 115,586 | 1037 | 8.97 | 118,749 | 1117 | 9.41 | 121,999 | 971 | 7.96 | 132,292 | 167 | 1.26 | 134,426 | 1386 | 10.31 | 137,967 | 689 | 4.99 |
| **Total Pop/ Cases** | | 4,777,415 | 63114 | | 4,908,162 | 44917 | | 5,042,488 | 57248 | | 5,467,927 | 24855 | | 5,556,117 | 94511 | | 5,702,471 | 107632 | |
| **Malaria Prevalence** | | | | **13.21** | | | **9.15** | | | **11.35** | | | **4.55** | | | **17.01** | | | **18.87** |

**Source:** Malaria reported cases from Epidemiological unit, Borno State, Population figures from NPC (2007).

Table 2 shows the ranking of malaria incidence rate of all the LGAs within the state and their respective ecological zones

**Table 2:** Ranking of malaria incidence rate among the LGAs in Borno State

| LGAs | 2011 | 2012 | 2013 | 2016 | 2017 | 2018 | Mean Prev. | Rank | Eco Zone |
|---|---|---|---|---|---|---|---|---|---|
| K/Kusar | 22.88 | 20.17 | 12.44 | 1.72 | 99.39 | 105.81 | 43.74 | 1 | Guinea |
| Bayo | 26.29 | 26.9 | 28.59 | 1.68 | 19.84 | 50.74 | 25.67 | 2 | Guinea |
| Chibok | 25.54 | 22.77 | 27.19 | 1.27 | 44.18 | 29.25 | 25.03 | 3 | Guinea |
| Jere | 35.43 | 13.11 | 19.24 | 1.61 | 43.49 | 36.34 | 24.87 | 4 | Sudan |
| Ngala | 19.47 | 12.47 | 17.35 | 17.83 | 33.81 | 28.13 | 21.51 | 5 | Sudan |
| Kaga | 43.15 | 22.33 | 36.94 | 0.63 | 4.61 | 19.99 | 21.28 | 6 | Sudan |
| Hawul | 6 | 5.47 | 5.29 | 1.45 | 67.4 | 40.47 | 21.01 | 7 | Guinea |
| Monguno | 9.16 | 8.49 | 9.19 | 29.59 | 54 | 13.42 | 20.64 | 8 | Sahel |
| Biu | 9.06 | 8.59 | 8.95 | 0.66 | 16.47 | 34.85 | 13.10 | 9 | Guinea |
| A/Uba | 13.45 | 13.27 | 14.53 | 1.31 | 11.91 | 21.95 | 12.74 | 10 | Guinea |
| Guzamala | 11.89 | 11.57 | 16.26 | 11.64 | 9.08 | 15.26 | 12.62 | 11 | Sahel |
| Maiduguri | 15.31 | 6.43 | 9.35 | 0.7 | 15.95 | 21.86 | 11.60 | 12 | Sudan |
| Mobbar | 8.44 | 6.8 | 8.68 | 13.89 | 20.22 | 11.38 | 11.57 | 13 | Sahel |
| Marte | 9.62 | 8.38 | 9.11 | 10.38 | 16.17 | 13.39 | 11.18 | 14 | Sahel |
| Abadam | 9.91 | 9.43 | 14.05 | 10.79 | 8.33 | 14 | 11.09 | 15 | Sahel |
| Konduga | 9.94 | 9.03 | 9.26 | 0.27 | 9.04 | 26.68 | 10.70 | 16 | Sudan |
| Nganzai | 17.59 | 11.57 | 12.62 | 4.15 | 6.85 | 5.82 | 9.77 | 17 | Sahel |
| Gwoza | 13.45 | 12.93 | 9.97 | 5.25 | 4.92 | 6.98 | 8.92 | 18 | Sudan |
| Dikwa | 9.49 | 8.31 | 10.73 | 6.72 | 5.96 | 7.16 | 8.06 | 19 | Sudan |
| Damboa | 7.1 | 4.06 | 6.25 | 0.29 | 9.5 | 18.24 | 7.57 | 20 | Sudan |
| Shani | 8.97 | 9.41 | 7.96 | 1.26 | 10.31 | 4.99 | 7.15 | 21 | Guinea |
| K/Balge | 12.35 | 7.44 | 11.59 | 3.49 | 1.4 | 1.36 | 6.27 | 22 | Sudan |
| Magumeri | 5.5 | 5.04 | 6.55 | 0.52 | 8.6 | 8.52 | 5.79 | 23 | Sahel |
| Bama | 6.28 | 4.76 | 5.79 | 2.46 | 2.68 | 7.63 | 4.93 | 24 | Sudan |
| Kukawa | 5.17 | 3.89 | 11.01 | 3.36 | 2.19 | 3.68 | 4.88 | 25 | Sahel |
| Gubio | 6.73 | 5.7 | 6.62 | 0.27 | 0.51 | 5.74 | 4.26 | 26 | Sahel |
| Mafa | 3.98 | 2.8 | 3.6 | 2.82 | 0.39 | 2.37 | 2.66 | 27 | Sudan |
| Grand Mean Prev. | | | | | | | 13.65 | | |

**Source:** Research work (2021)

The grand mean of malaria incidence rate was 13.65 as revealed in Table 2. This finding agrees with that of Nigeria Malaria Facts Sheet (2018) where malaria index rate of Borno state falls within the group of 20-30 incidence rate. The ranking of malaria incidence rate in each of the LGAs in the state as shown in Table 2 reveals that the first three LGAs were all in the Guinea Savannah zone. In fact, out of the eight LGAs that recorded more than 20 incidence rate per thousand, four of the LGAs were in Guinea Savannah which comprises only seven LGAs. Therefore, the Guinea Savannah was found to record the highest malaria incidence rate among the three ecological zones in the state. This finding could be attributed to the conducive environmental factors (rainfall, humidity, temperature, vegetation, and water body) for mosquito breeding in the ecological zone (Akawu, 2021). Lazarus, (2012) also opined that Guinea Savannah with higher rainfall, temperature. and humidity as well as denser vegetation are more environmentally conducive for mosquito breeding and survival. The environmental conditions in Guinea Savannah with denser woodland, numerous water body especially the floodplains of River Hawul, high rainfall, high humidity among others which have been found to be conducive for breeding of mosquito (Ricotta, *et al.*, 2014, Diana *et al.*, 2017, Joao *et al.*, 2018) have all supported the high malaria prevalence in the Guinea agro-ecological zones. The low malaria incidence rate in Shani LGA could be attributed to the high accessibility to medical facilities (the LGA has the highest medical accessibility of about 10 people per thousand among all the LGAs in the State (Akawu, 2021). Among the last five of the ranked LGAs, three were in Sahel and two in the Sudan (none from Guinea) which shows that malaria incidence rate in the Sahel Savannah was lesser than that of the Guinea.

***Malaria reported cases and incidence rate in the Ecological Zones in Borno State***

Malaria reported cases and incidence rate among the three ecological zones in the state were computed as presented in Tables 3-5. Tables 3 to 5 revealed that malaria incidence rate in Borno State was deceasing from the Guinea Savanah ecological zone in the south through the Sudan ecological zone at the central to the Sahel ecological zone in the north. This pattern of malaria incidence rate follows the same patterns of climate (decrease of rainfall from south to north), decrease of humidity in the same pattern except Lake Chad area and increase in mean temperature from south towards the north (Akawu 2021). This climatic patterns in the Guinea ecological zone have been proved to be conducive for mosquito breeding, growth and survival (OU, 2019, Lazarus, 2012, Akawu, 2021) which in turn leads to high malaria prevalence. While the climatic pattern in the Sahel (low rainfall, high temperature and low humidity) cannot support the breeding and survival of mosquitoes resulting into low malaria incidence rate in the zone. Other factors especially vegetation distribution also determines habitat for mosquito lavas (Ricotta *et al.*, 2014, Joao *et al.*, 2018)

**Table 3. Malaria reported cases and incidence rate in Sahel Ecological Zone in Borno State**

| LGAs | 2019 | Cases | 2015 | Case | 2013 | Cases | 2016 | Cases | 2017 | Cases | 2018 | Cases |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abadam | 114,528 | 1135 | 117,662 | 1110 | 120,883 | 1698 | 131,082 | 1414 | 133,196 | 1110 | 136,704 | 1914 |
| Gubio | 173,152 | 1166 | 177,891 | 1014 | 182,760 | 1209 | 198,179 | 53 | 201,376 | 102 | 206,680 | 1186 |
| Guzamala | 109,865 | 1306 | 112,872 | 1306 | 115,961 | 1886 | 125,745 | 1464 | 127,773 | 1160 | 131,139 | 2011 |
| Kukawa | 232,734 | 1204 | 239,103 | 930 | 245,647 | 2704 | 266,372 | 896 | 270,668 | 592 | 277,798 | 1021 |
| Magumeri | 160,529 | 883 | 164,923 | 832 | 169,436 | 1110 | 183,732 | 95 | 186,695 | 1606 | 191,613 | 1633 |
| Marte | 148,113 | 1425 | 152,167 | 1275 | 156,331 | 1424 | 169,521 | 1759 | 172,255 | 2785 | 176,793 | 2367 |
| Mobbar | 133,491 | 1127 | 137,144 | 933 | 140,897 | 1223 | 152,785 | 2122 | 155,249 | 3139 | 159,339 | 1814 |
| Monguno | 125,709 | 1151 | 129,149 | 1096 | 132,684 | 1220 | 143,879 | 4257 | 146,199 | 7895 | 150,050 | 2013 |
| Nganzai | 113,394 | 1995 | 116,497 | 1348 | 119,685 | 1511 | 129,783 | 538 | 131,877 | 903 | 135,350 | 788 |
| **Total** | 1,311,515 | 11,392 | 1,347,408 | 9,844 | 1,384,284 | 13,985 | 1,501,078 | 12,598 | 1,525,288 | 19,292 | 1,565,466 | 14,737 |
| **Prevalence** | | 8.69 | | 7.31 | | 10.10 | | 8.39 | | 12.65 | | 9.41 |
| **Mean Prev.** | | | | | | | | | | | | **9.43** |

**Source:** Malaria reported cases from Epidemiological unit, Borno state, Population based on NPC (2017).

**Table 4:** Malaria reported cases and incidence rate in Sudan Ecological Zone in Borno State

| LGAs | 2019 | Cases | 2015 | Cases | 2013 | Cases | 2016 | Cases | 2017 | Cases | 2018 | Cases |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bama | 309,161 | 1943 | 317,622 | 1511 | 326,315 | 1890 | 353,846 | 872 | 359,553 | 963 | 369,024 | 2815 |
| Damboa | 266,906 | 1894 | 274,211 | 1114 | 281,715 | 1760 | 305,484 | 88 | 310,411 | 2950 | 318,587 | 5812 |
| Dikwa | 120,224 | 1141 | 123,515 | 1026 | 126,895 | 1361 | 137,601 | 925 | 139,821 | 834 | 143,504 | 1027 |
| Gwoza | 316,542 | 4259 | 325,205 | 4204 | 334,105 | 3330 | 362,294 | 1903 | 368,138 | 1812 | 377,835 | 2637 |
| Jere | 239,331 | 8479 | 245,881 | 3224 | 252,610 | 4859 | 273,923 | 441 | 278,341 | 12105 | 285,672 | 10381 |
| Kaga | 103,004 | 4445 | 105,823 | 2363 | 108,719 | 4016 | 117,892 | 74 | 119,793 | 552 | 122,948 | 2458 |
| K/Balge | 69,627 | 860 | 71,532 | 532 | 73,490 | 852 | 79,690 | 278 | 80,976 | 113 | 83,109 | 113 |
| Konduga | 180,061 | 1789 | 184,989 | 1670 | 190,051 | 1760 | 206,086 | 55 | 209,410 | 1893 | 214,926 | 5735 |
| Mafa | 122,008 | 485 | 125,347 | 351 | 128,777 | 463 | 139,642 | 394 | 141,894 | 56 | 145,632 | 345 |
| Maiduguri | 618,068 | 9460 | 634,983 | 4083 | 652,361 | 6097 | 707,402 | 497 | 718,811 | 11464 | 737,745 | 16124 |
| Ngala | 270,681 | 5269 | 278,089 | 3468 | 285,699 | 4956 | 309,804 | 5523 | 314,801 | 10643 | 323,093 | 9090 |
| **Total** | 2,615,613 | 40,024 | 2,687,197 | 23,546 | 2,760,737 | 31,344 | 2,993,664 | 11,050 | 3,041,949 | 43,385 | 3,122,075 | 56,537 |
| **Prevalence** | | 15.30 | | 8.76 | | 11.35 | | 3.69 | | 14.26 | | 18.11 |
| **Mean Prev.** | | | | | | | | | | | | **11.92** |

**Source:** Malaria reported cases from Epidemiological unit, Borno state, Population based on NPC (2017).

**Table 5:** Malaria reported cases and incidence rate in Guinea Ecological Zone in Borno State

| LGAs | 2019 | Cases | 2015 | Case | 2013 | Cases | 2016 | Cases | 2017 | Cases | 2018 | Cases |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Askira Uba | 164,027 | 2,206 | 168,516 | 2,236 | 173,128 | 2,515 | 187,735 | 246 | 190,763 | 2,272 | 195,788 | 4,297 |
| Bayo | 90,508 | 2,379 | 92,985 | 2,501 | 95,529 | 2,731 | 103,589 | 174 | 105,260 | 2,088 | 108,033 | 5,482 |
| Biu | 201,164 | 1,823 | 206,669 | 1,775 | 212,325 | 1,900 | 230,239 | 153 | 233,953 | 3,854 | 240,115 | 8,367 |
| Chibok | 75,921 | 1,939 | 77,998 | 1,776 | 80,133 | 2,179 | 86,894 | 110 | 88,295 | 3,901 | 90,621 | 2,651 |
| Hawul | 138,183 | 829 | 141,965 | 777 | 145,850 | 771 | 158,156 | 229 | 160,707 | 10,831 | 164,940 | 6,675 |
| K/Kusar | 64,900 | 1,485 | 66,676 | 1345 | 68,501 | 852 | 74,280 | 128 | 75,478 | 7,502 | 77,466 | 8,197 |
| Shani | 115,586 | 1,037 | 118,749 | 1,117 | 121,999 | 971 | 132,292 | 167 | 134,426 | 1,386 | 137,967 | 689 |
| **Total** | 850,289 | 11,698 | 873,558 | 11,527 | 897,465 | 11,919 | 973,185 | 1,207 | 988,882 | 31,834 | 1,014,930 | 36,358 |
| **Prevalence** | | 13.76 | | 13.20 | | 13.20 | | 1.24 | | 32.19 | | 35.82 |
| **Mean Prev.** | | | | | | | | | | | | **18.24** |

**Source:** Malaria reported cases from Epidemiological unit, Borno state, Population based on NPC (2017).

***Spatial patterns of malaria incidence rate in the ecological zones in Borno State***

Fig. 2 shows the spatial pattern of malaria incidence rate among the LGAs and the ecological zones in Borno State.

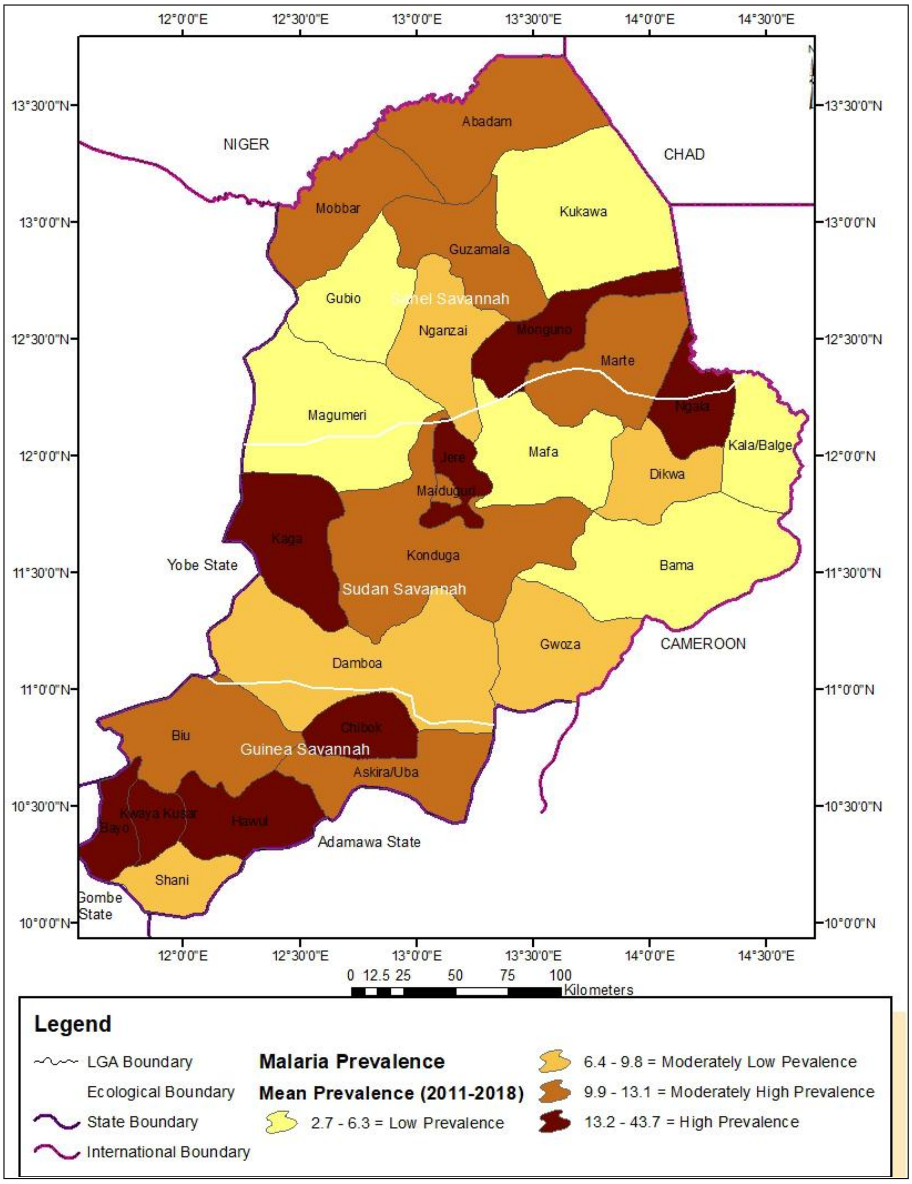


**Figure 2:** Spatial pattern of malaria incidence rate in Borno State

Fig. 2 also revealed that malaria incidence rate in the state is more in the Guinea Savanah than the other two ecological zones. Guinea savannah which comprises only seven out of the twenty-seven LGAs in the state had four (Bayo, Chibok, Hawul and Kwaya Kusar) out of the eight LGAs with high incidence rate. Three from the remaining four LGAs with high prevalence were found in Sudan and only one LGA (Monguno LGA) was in the Sahel. Moguno which shares parts of its land area with Lake Chad was also relatively assessible throughout the study period (though sometimes with military escort) which contributed to the high number of reported cases than the other LGAs in the Sahel. Shani LGA which falls within the moderately low malaria incidence rate has been attributed in this study to the fact that the LGA has the highest accessibility to medical facilities in the State, so, though the LGA may be prone to malaria due to its environmental factors, but the high medical facilities helps to reduce the impact on the inhabitants.

In the Sahel with unconducive environmental factors to malaria incidence rate, four (Abadam, Guzamala, Marte and Mobbar) out of their eight LGAs fall within the moderately high malaria incidence rate zone. This shows that other than environmental factors, other factors like social-economic factors can also increase malaria prevalence especially in the Sahel. This include housing quality: the importance of overall house design in reducing the risk of malaria has been demonstrated convincingly by (Perera *et al.,* 2019). Poverty is another strong factor as poverty sustains the condition where malaria thrives and malaria impedes economic growth and keeps communities in poverty (WHO 2020). Unkempt environment such as dirty houses, bushes around the house, presence of stagnant water and unclean drainage system (sanitation) were significantly associated with high prevalence of malaria (Amoran *et al.,* 2014). Finally, various kinds of mosquito deterrent from entering a house and variation in the frequencies with which the deterrents are used, contributed to difference in the prevalence of malaria between village and between households in the same community**.**

## Conclusion

Malaria incidence rates per thousand among the three ecological zones in Borno State has been carried out in this study. The level of the incidence rate was observed to decrease from Guinea Savannah in the south through the Sudan Savannah at the central to the Sahel ecological zone in the north. The pattern of malaria incidence rate in the state was high at the areas where environmental conditions like climatic factors (rainfall, temperature and relative humidity), vegetation cover, relief, and water body are favourable to mosquito breeding, survival and growth, while the low prevalence areas have unfavourable environmental conditions to mosquito breeding. Social economic factors were also suggested as possible factors that determines malaria incidence rate i especially in the Sahel region where environmental conditions are unfavourable but some areas still record high malaria incidence rate. The role of medical facilities on malaria prevalence was also highlighted in this study as Shani LGA which falls within the Guinea Savannah with favourable environmental conditions to breeding of mosquitoes falls under the moderately low category of malaria incidence rate because the LGA had the highest access to medical facilities among the entire LGAs in the state. Malaria incidence rate is largely determined by population and number of reported cases, therefore, the higher the reliability of the acquired data, the higher the accuracy of the derived incidence rate. The impact of social economic factors on malaria incidence rate in the ecological zones of the state is recommended for further studies.

## Recommendations

Environmental factors such as climatic elements (rainfall, humidity and temperature), vegetation cover, presence of waterbody and relief should be seriously considered in the monitoring and control of malaria prevalence because the factors largely determine malaria incidence rate.

Social-economic factors like poverty, nature of houses, lifestyles, standard of living and availability/cost of mosquito repellants could increase malaria prevalence even at where environmental factors are not favourable. Therefore, efforts should be made to provide and maintain conducive social-economic conditions against malaria prevalence.

Adequate and equal access to medical facilities should be provided by the government/NGOs and individuals as it will lower malaria incidence rate as revealed in this study.

All the agencies and ministries that are saddled with the responsibilities of providing epidemiological data should ensure that up-to-date, accurate and reliable data are provided so as to increase the reliability of the generated malaria incidence rate.

The zones of higher prevalence should be given more attentions than other areas that are less prevalent to malaria

**References**


Akawu, C., (2012). Spatio-temporal variation in the incidence of malaria in Maiduguri Metropolis; An unpublished MSc. Thesis submitted to the Department of Geography, University of Maiduguri

Akawu, C., Ikusemoran, M, and Akawu B, D. (2018). Analysis of spatial patterns of malaria prevalence in southern Borno State, Nigeria. *Academic research international*, VOL. 9, No. 2. Jun. 2018. PP 24 – 38.

Akawu, C., (2021). Geospatial analysis of malaria prevalence and vulnerability in Borno State; An unpublished Ph.D. Thesis submitted to the Department of Geography, University of Maiduguri.

Amoran, O. E., Onwumbe, O. O., Salami, O.M., and Mautin, G.B. (2014). The influence of environmental sanitation on prevalence of malaria in a rural town in south-western Nigeria. *Niger J Med Jul-Sep 2014;23(3):254-62.*

Diana, G., Emely, G., Zaida, H., Policarpo, N., María, R., Martín, E. O. M., Gloria, N., Matilde, R., Maria, A. S., Basilio, V., Pilar, A., & Agustín, B. (2017). Spatial clustering and risk factors of malaria infections in Bata district, Equatorial Guinea. *Malaria Journal, 16, 146.*

Emmanuele, G., Claudio, F., Peter, M.M., and Victor, A. (2021). Model building and assessment of the impact of covariates for disease prevalence mapping in low-resource settings: to explain and to predict. *Journal of The Royal Society Interface18(179):20210104 DOI:10.1098/rsif.2021.0104*

FMH (2015). *The National Malaria Strategic Plan (2014 - 2020*). National malaria elimination programme Federal Ministry of Health.

Gallup, E. and Sachs, T., (2001). The intolerable burden of malaria: A new look at the numbers. *Supplement to volume 64(1) of the American Journal of Tropical Medicine and Hygiene*

Joao, L. F., Sergio N., Jorge, M. M., and Marco, P. (2018). Mapping and modeling malaria risk areas using climate, socio-demographic and clinical variables in Chimoio, Mozambique. *Int. J. Environ. Res. Public Health 2018, 15, 795; doi:10.3390/ijerph15040795*

Lazarus, M. S. (2012). A study on the malaria vector *(anopheles spp)* in a Sudano-Sahelian Savannah area of Borno State, North Eastern Nigeria and the insect growth regulator pyriproxyfen (s-31183). An Unpublished thesis submitted to the Department of Zoology, Faculty of Natural Sciences, for the award of the degree of Doctor of Philosophy of the University of Jos

Malaria Fact Sheet. No. 94. Updated March 2014. Retrieved May 25th 2022 from https://reliefweb.int › report › malaria…

Marcia, C.C. (2017). Malaria transmission and prospects for malaria eradication: The role of the environment. Cold Spring Harb Perspect Med. 2017 Oct; 7(10): a025601. doi: 10.1101/cshperspect.a025601

Mark, M., Aklesso, E.M. and Bruce, A.M. (2014). Analysis of the cost of malaria in children and use of insecticide-treated bednets in Africa. *African Development Review 26 (1) DOI:10.1111/1467-8268.12065*

Menkin-Smith, L and Winders, W. T. (2021). Plasmodium vivax malaria; In statpearls [Internet]. Treasure Island (FL): statpearls publishing; 2022 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK538333/

Mentor Initiative, Maiduguri, (2020). Fighting malaria in Borno State, Nigeria. Retrieved from https://thementorinitiative.org

Meyrecler, A. O. P., Janille, O. M., Guilherme, R., Marcos, V. M. L.., Wladimir, J. A.l., Maria, A. M. S. and Gabriel, Z. L. (2019). Comparison of malaria incidence rates and socioeconomic-environmental factors between the states of Acre and Rondônia: A spatio-temporal modelling study. *Malar J (2019) 18 (1):306.*

Nigeria Malaria Fact Sheet (2018). Malaria in Nigeria. Economic section, United States Embassy in Nigeria. Retrieved from http://nigeria.usembassy.gov. on 25th, May, 2022

Nkumama, I. N., Meara, P. O., and Osier, F. H.A. (2017). Changes in malaria epidemiology in Africa and new challenges for elimination. *Trends Parasitol 2017 Feb. 33(2):128-140.doi10.1016*

Open University (2019). Communicable diseases module: 6. Factors that affect malaria transmission. **https://www.open.edu/openlearncreate/mod/oucontent/... Retrieved November 4, 2019.**

Perera, W.H., Gunathilaka, P.N., Taylor-Robinson, A.W. (2019). Malaria in Sri Lanka: Investigating causes of the recent elimination and making plans to prevent reintroduction. *J Vector Borne Dis 2019;56:179-88*

Ricotta, E.E., Frese, S.A., Choobwe, C., Louis, T.A. and Shiff, C.J. (2014). Evaluating local vegetation cover as a risk factor for malaria transmission: A new hypothetical approach using Image J. *Malaria Journal 2014, 13:94. Pp 1-7*

Rima, S., Jenny, L., Chris, C., Justin, C., Charlotte, D., Kudzai, M., Gretchen, N., Didier, M., Allison, P., Allison, T., Roly, G., and Richard, F. (2017). *Major Infectious Diseases: Malaria elimination and eradication. 3rd edition. Chapter 12 pp 315-334.*

UNHCR (2022). The global malaria action plan for a malaria free world For a malaria-free world: Roll back malaria. Retrieved May 25th 2022 from https://www.unhcr.org

World Development Indicators (2020). Population Growth (Nigeria). Retrieved from http://data.worldbank.org/indicators/SP.POP.GROWTH

World Health Organization (2015). 58th World health assembly. Technical support document.

Geneva.WHO 2015.http:/www.who.int/nutrition/topics/WHA58.

World Health Organization (2020a). The Africa malaria report, 2020. Geneva: World Health Organization; 2020.www.who.int/ctd/htw/malaria.htwI World Health Organization.

World Health Organization, (2020b). Guidelines for the treatment of malaria (2nd ed.). Geneva: World Health Organization. p. ix. ISBN 978-92-4-154792-5