GLOBAL CLIMATE CHANGE IMPACTS ON HUMAN HEALTH IN SUB-SAHARA AFRICA

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The main aim of the study is to examine the relationship between climate variability and malaria transmission in Sub-Saharan Africa using Nigeria as a case study. For this study, climatic conditions considered suitable for its development and transmission through the mosquito stage of its life cycle are temperatures within the range 18°C to 32°C, but below 18°C parasite development decreases significantly. Above 32°C the survival of the mosquito is compromised. Relative humidity greater than 60% is also considered as a requirement for the mosquito to survive long enough for the parasite to develop sufficiently to be transmitted to its human host stage. The research findings show that seasonality of climate greatly influences the seasonality of malaria transmission. Specifically, rainfall plays an important role in the distribution and maintenance of breeding sites for the mosquito vector. Rainfall and surface water is required for the egg laying and larval stages of the mosquito life cycle and monthly rainfall above 80mm is considered as a requirement. Also, it is temperature that regulates the development rate of both the mosquito larvae and the malaria parasite (Plasmodium species) within the mosquito host. Relative humidity and temperature play an important role in the survival and longevity of the mosquito vector. This study are in conformity with the findings of IPCC (2001) that malaria is caused by four distinct species of plasmodium parasite, transmitted by mosquitoes of the genus Anopheles*,* which are most abundant in tropical/subtropical regions, although they are also found in limited numbers in temperate climes.

Key words: Climate variability, Malaria transmission, Nigeria

1. Introduction

Malaria is one of the most common and overwhelming public health concerns in Nigeria.The impact of climate change/variability on human health has received increasing recognition since it was first mentioned in the IPCC (Intergovernmental Report on Climate Change) FAR (First Assessment Report). Health and climate have been linked since antiquity and this is one of the reasons why SAR (Second Assessment Report) dedicated a chapter to health

(McMicheal et al., 2003). Climate variability is widely considered to be a major driver of inter-annual variability of malaria incidence in Africa. Several researches have suggests that climate can affect infectious disease patterns because disease agents (viruses, bacteria, and other parasites) and their vectors (such as insects or rodents) are clearly sensitive to temperature, moisture, and other ambient environmental conditions (Appawu, (2004); Ameneshewa and Service, (1996); Burkot and Graves, (1995).). The best evidence for this sensitivity is the characteristic geographic distribution and seasonal variation of many infectious diseases. It has been observed that vector species behavior, density, and the number of infective bites a person can receive per unit time are dependent on seasonal changes in climatic variables. Malaria is caused by four distinct species of plasmodium parasite, transmitted by mosquitoes of the genus Anopheles*,* which are most abundant in tropical/subtropical regions, although they are also found in limited numbers in temperate climes. Transmission is associated with changes in temperature, rainfall, humidity as well as level of immunity.

The IPCC Special Report on Regional Impacts of Climate Change (IPCC, 2001) acknowledges that climate have an impact on vector-borne diseases. Changes in climate affect potential geographical distribution and transmission of vector-borne infectious diseases such as malaria. There are many substantial research challenges associated with studying linkages among climate, ecosystems, and infectious diseases. For instance, climate-related impacts must be understood in the context of numerous other forces that drive infectious disease dynamics, such as rapid evolution of drug- and pesticide-resistant pathogens, swift global dissemination of microbes and vectors through expanding transportation networks, and deterioration of public health programs in some regions. 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 malaria occurs in younger children up to 3-4 times a year. It is also the reason for hospital attendance in 7 out of every 10 patients seen in Nigerian hospitals. 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 time periods for which case data are available. Furthermore, studies on the interaction between climate and malaria have focused in recent years on the potential role of climate change in determining recent increases in malaria transmission in highland areas in Africa where temperature rather than rainfall has been the parameter of greatest interest. These studies have served to highlight the significant methodologic difficulties in undertaking such analyses

Therefore, this study aims at examining the relationship between intra-annual climate variability and malaria transmission in Nigeria. The relationships of variability in rainfall, relative humidity and temperatures to malaria transmission are assessed at the national level. Knowledge of the magnitude of these spatial variations is critical to understanding the transmission dynamics of the disease and the evaluation of the efficacy of malaria control measures.

2. Study area

Nigeria is a tropical country which lies on the southern coast of West Africa between latitudes 4^0 and 14^0N of the equator and longitudes 2^045' and 15^030'E of the Greenwich meridian (Figure 1). The Republic of Niger borders it to the north, Republic of Chad and Cameroon to the east, Republic of Benin to the west and the Atlantic Ocean to the south. It has a total landmass of about 924,000sq.km, a coastline of about 853km, a population of 126,635,626 with a growing rate of 2.61% and a density of 95.8 per square kilometre according to 2001 estimate of the National Population Commission. The country s vegetation changes from sahel savannah in the far north followed by Sudan savannah merging into guinea savannah in the middle belt, then rain forest in the south and mangrove forest in the coastal areas. The geographical location, size and shape of Nigeria allows it to experience an array of ecological zones ranging from the mangrove swamps and tropical rain forest belts in the coastal areas to the open woodland and savanna on the low plateau which extends through much of the central part of the country, to the semi-arid plains in the north and the highlands to the east. Between the arid north and the moist south lies a Guinea Savanna Zone sometimes referred to as the middle belt. This type of environment is determined mainly by the climate. Two climatic regimes associated with the Inter-Tropical Discontinuity (ITD) are experienced in Nigeria: the wet and the dry seasons. These two seasons are highly influenced by the two prevailing air masses blowing over the country at different times of the year which are the warm and moist tropical maritime air mass (south westerlies) that originates from the Atlantic Ocean and bring rainfall, while the other one is the cool dry and dust laden continental air mass (harmattan winds) that originates from the Sahara Desert.

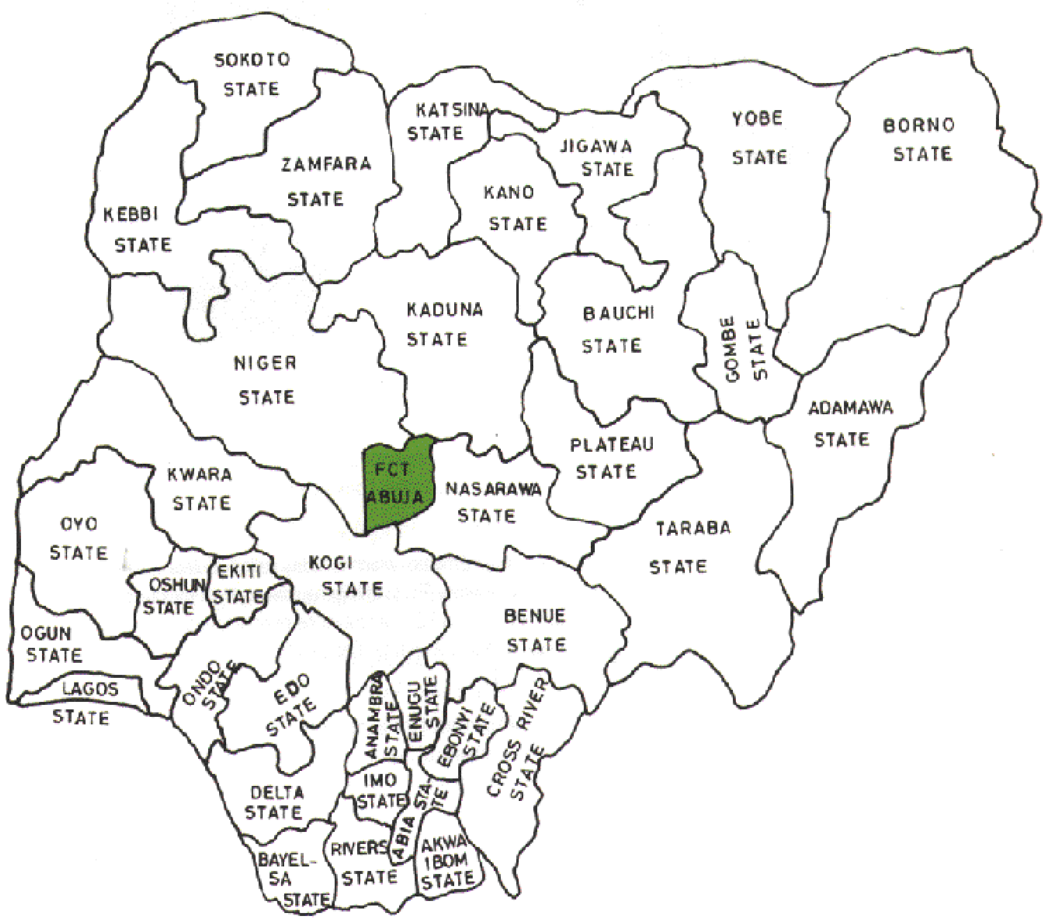

Figure 1: Map of the Study area, Nigeria.

The mean annual rainfall in the southeast varies between 2540 and 4060 mm and 500-1500mm in the north. Annual rainfall in Nigeria is highest in the coastal areas and decrease inland towards the north. The mean temperature ranges between 25^{o} and 30^{o}C towards the interior as a result of the moderating influence of the sea. In the dry season, temperature reflects more extreme conditions ranging from 20^{o}C and 30^{o}C. Much of the southern half of the country is characterized by a long growing period of between 200-365 days with a bimodal rainy season and annual rainfall between 1500-3000mm. The onset of wet season in this region is as early as February or March. Rain continues to the end of November. However, the northern half has a much shorter unimodal rainy season of about 90-200 days with annual rainfall levels of between 400-1300mm. The onset of the wet season may be as late as June while cessation may be as early as September.

The population of Nigeria was 88,992,220 based on the 1991 National Population Census however; the population is expected to have risen to about 255.6million by the year 2025 at a growth rate of 2.8%. Presently, National population commission (NPC) puts the population at 133million. Nigeria is made up of six geopolitical zones and 36 States including the Federal Capital Territory (NPC 2006). Malaria still constitutes a serious public health problem in Nigeria. It is responsible for 60% outpatient visit to health facilities, 30% childhood death, 25% of death in children under one year and 11% of maternal death (4,500 die yearly). In Nigeria, a child will be sick of malaria between 2 and 4 times in one year and 70% of pregnant women suffer from malaria; contributing to maternal anaemia, low birth weight, still birth, abortion and other pregnancy-related complications. The financial loss due to malaria annually is estimated to be about by 132 billion Naira in form of treatment costs, prevention, loss of man-hours among others yet, it is a treatable and completely evitable disease.

3. Materials and Methods

3.1 Data Acquisition and Geospatial analysis

Climate suitability for malaria transmission was defined as the coincidence of precipitation accumulation greater than 80 mm, mean temperature between 18°C and 32°C, and relative humidity greater than 60 percent. These ware thresholds that are intended to describe conditions that are suitable for both the development of the falciparum parasite and the life cycle of the mosquito vector. Therefore, both climate and malaria data were used in this study. Climate parameter that were used include; monthly rainfall, relative humidity and temperature. Monthly precipitation; Monthly temperature and Monthly specific humidity data (converted to rh) over land areas were extracted from the Climate Research Unit (CRU, Nowich, UK) Time Series (CRU TS). Monthly data on clinical malaria cases from health facilities in 774 local government areas of Nigeria were used in a novel stratification process. Malaria cases were summed over both age groups (under and over 5 years). Malaria incidence per 1000 persons per month was estimated using the year 2006 population by National Population commission (NPC).

3.2 Statistical analysis

Principal Component Analysis (PCA) and Nonhierarchical Clustering were used to define eight areas with distinct malaria intensity and climate seasonality suitability patterns, to guide future interventions and development of an epidemic early warning system. PCA is a technique for simplifying a data set by reducing multidimensional data sets to lower dimensions in the data. The reduction in dimensions of the data set is necessary to run and accelerate the clustering analysis, which is a classification of objects into different groups such that each group shares a common trait. A total of eight principal components were generated from the monthly average incidence data. The data were initially clustered into eight clusters for analysis. Clusters were visualized in the maps using Geographical Information System (GIS) Techniques. The GIS raster techniques were used to convert the climate data to climate suitability maps. The maps depict fractions between 1 and 12 which represent months suitable for malaria transmission. For this study, climatic conditions considered suitable for its development and transmission through the mosquito stage of its life cycle are temperatures within the range 18°C to 32°C, but below 18°C parasite development decreases significantly. Above 32°C the survival of the mosquito is compromised. Relative humidity greater than 60% is also considered as a requirement for the mosquito to survive long enough for the parasite to develop sufficiently to be transmitted to its human host stage. Rainfall and surface water is required for the egg laying and larval stages of the mosquito life cycle and monthly rainfall above 80mm is considered as a requirement. To improve epidemic control based on climate sensitive for the country, this study has developed a framework for the development of integrated malaria early warning systems (MEWS), based on vulnerability monitoring, seasonal climate variability data, and epidemiologic surveillance. Here this study used a framework developed by International Research Institute for Climate & Society (IRI), The Earth Institute at Columbia University, Lamont Campus, Palisades, New York, USA. IRI framework and climate tools were explore in the development of a malaria early warning system in Nigeria.

3. Results and discussion

3.1 Climatic suitability for malaria transmission

The county is divided into eight zones which represent the climatic suitability for malaria transmission rainfall, temperature and humidity which are the most significant parameters (Figure 2 and Table 1). Figure 2 show regional differences in how long the combination of climatic conditions may be suitable for malaria transmission in Nigeria. The map displays the number of months during the year that are suitable for malaria transmission, based on monthly climatological averages. Map was derived from climate-driven malaria transmission models have been used to indicate monthly climate suitability for malaria and thereby indicate areas vulnerable to climate related malaria epidemics. Figure 2 clarifies the seasonal pattern and intensity of malaria transmission in different areas within the country.

Table1: Number of months suitable for malaria transmission in Nigeria.

Zone	Numbers of Months Suitable for Malaria Transmission	Months Suitable for Malaria Transmission	Name of states within the zone	Illustration
A	8 ½ months	Ma, Ap, My, Ju, Jy, Ag, Sp, Oc, No.	Bayelesa, Rivers, Akwa-Ibom, and southern part of Cross Rivers state	**Ja- January** **Feb- February** **Mr-Mach,** **Ap- April,** **My-May,** **Ju- June,** **Jy-July,** **Ag-August,** **Sp-September,** **Oc-October,** **No-November** **De- December**
B	7 ½ months	Ap, My, Ju, Jy, Ag, Sp, Oc,	Osun, Edo, Delta, Imo, Abia, Anambra and southern part of Ondo and Ogun	
C	6 ½ months	My, Ju, Jy, Ag, Sp, Oc	Oyo, Ogun, Kogi, Benue, Nasarawa, southern part of Taraba, Abuja and Kwara	
D	5 months	My, Ju, Jy, Ag, Sp,	Niger, Pleteau, Kwara, Taraba and northern part of Abuja	
E	4 ½ months	Ju, Jy, Ag, Sp,	Kebbi, Kaduna, Bauchi, Gombe	
F	4 months	Ju, Jy, Ag, Sp,	Adamawa, and Southeren part of Borno	
G	3 months	Jy, Ag, Sp,	Sokoto, Zamfara, Katsina, Kano,	

			Jigawa	
H	1 ½ months	Ag, Sp,	Yobe and Borno	

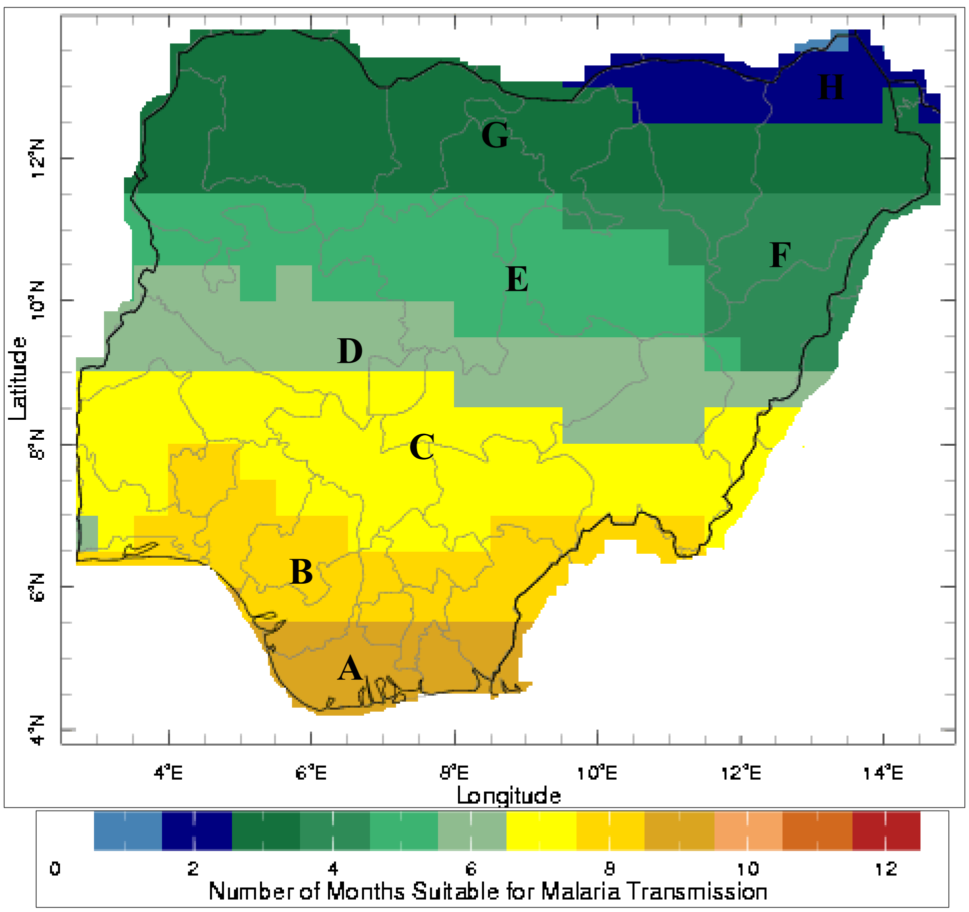

Figure 2: Map of Nigeria showing number of months suitable for malaria transmission.

The table 1 and figures 3,4,5,6,7,8,9 and 10 show number of months suitable for malaria transmission in Nigeria based on percentage of monthly rainfall, temperature, humidity and malaria occurrence. The figures show how often all these circumstances have concurrently been met at the point of enquiry for each month of the year, based on a historical record. The analyses and the figures show the percent occurrence of the climatic conditions for each month. Generally, Rainfall averages over 2000 mm per annum in the southeast, 1000 mm in the centre reducing to as low as 500 mm in the north east of the country. Thus, it is observed from the figures that the seasonality of climate greatly influences the seasonality of malaria transmission. Specifically, rainfall plays an important role in the distribution and maintenance of breeding sites for the mosquito vector (Anopheline species). Also, it is that temperature regulates the development rate of both the mosquito larvae and the malaria parasite (Plasmodium species) within the mosquito host. Relative humidity and temperature play an important role in the survival and longevity of the mosquito vector. For example, coastal part of Nigeria (zone A) receives substantial amounts of rainfall in the months of April through October (9 months) and greatest rainfall concentration occurs in the months of July to September (table 1 and figure 3). Nine months (Between May and November.) were fund suitable for malaria transmission in the coastal part of the county. The observations (see figure 2) also show that three states fall within the zone A (Bayelesa, Rivers, Akwa-Ibom, and southern part of Cross Rivers state). Within the nine months, in this zone precipitation accumulation is greater than 80 mm, mean temperature between 18°C and 32°C, and relative humidity greater than 60 percent within April to October which make months suitable for malaria transmission.

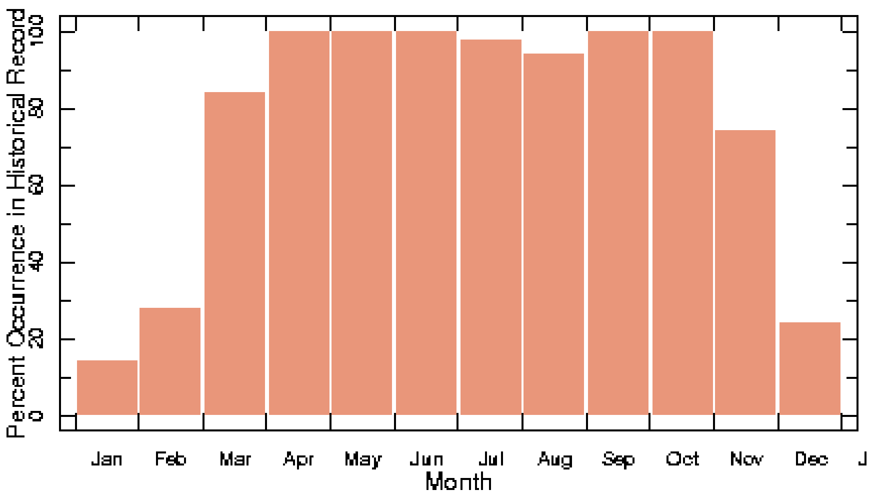

Figure 3: Monthly Climate Conditions Suitable for Malaria Transmission in Zone A (Bayelesa, Rivers, Akwa-Ibom, and southern part of Cross Rivers state)

In zone A (Bayelesa, Rivers, Akwa-Ibom, and southern part of Cross Rivers state) the rainfall pattern is bimodal, the first peak occurring in June-July, and the second in September, with August relatively dry. Variations in annual rainfall make it difficult to draw a strict geographical boundary between these two distribution patterns in relation to malaria transmission. In reality, zone A is within coastal area and usually receive more rainfall than the inland locations. The zone receive more rainfall ranging from1487.9 to 2865.2 mm than the other zones in the area. Malaria transmission, based on climatic parameters occurred between April and October in zone B (Osun, Edo, Delta, Imo, Abia, Anambra and southern part of Ondo and Ogun) while in Zone C (Oyo, Ogun, Kogi, Benue, Nasarawa, southern part of Taraba, Abuja and Kwara) about six and half months (between May and October) of rainy season are responsible for malaria transmission (see Figures 4 and 5). Variability in rainfall totals for the period between May and September accounts for more than two-thirds of the inter-annual variability in malaria transmission in Zone D (Niger, Pleteau, Kwara, Taraba and northern part of Abuja). The result shows that 6 ½ and 5 ½ months are suitable for malaria transmissions in Zones C and Zone D respectively (Figures 5 and 6). Zone B is in southern part of the country and has April as their onset month while October is their cessation month. These zones are characterized by two peaks of rainfall in June/July and September while the northern stations have only one peak per year. Rainfall starts earlier in the southern stations in April/May and it ceases last in this region in October (Table 1). A period when rainfall ceases within the wet season exists in the south, and is referred to as ‘August break’ or little dry season (Odekunle, 2004).

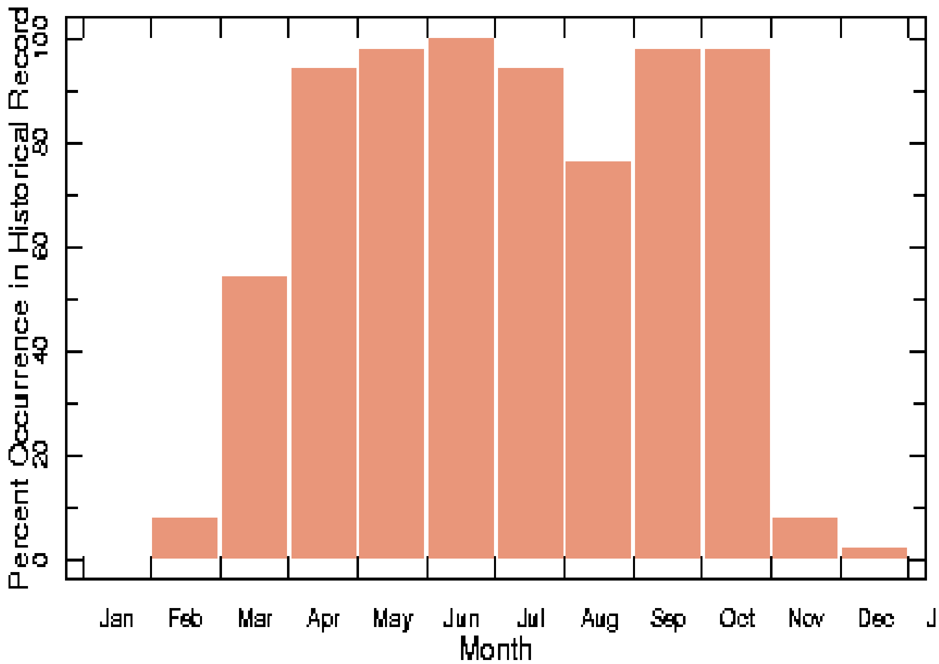

Figure 4: Monthly Climate Conditions Suitable for Malaria Transmission in Zone B (Osun, Edo, Delta, Imo, Abia, Anambra and southern part of Ondo and Ogun)

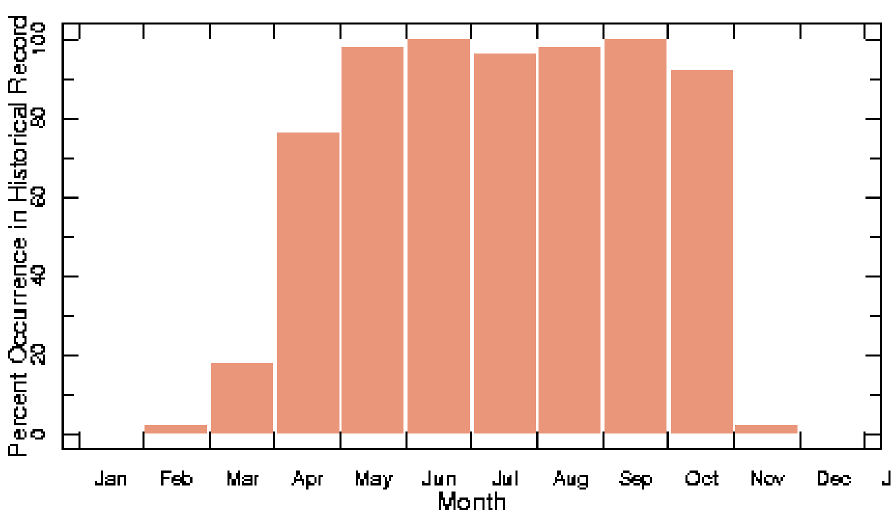

Figure 5: Monthly Climate Conditions Suitable for Malaria Transmission in Zone C (Oyo, Ogun, Kogi, Benue, Nasarawa, southern part of Taraba, Abuja and Kwara)

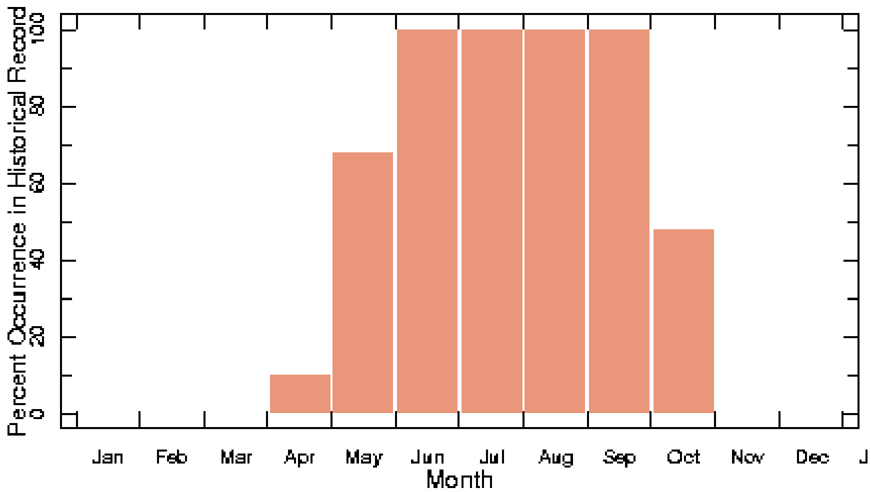

Figure 6: Monthly Climate Conditions Suitable for Malaria Transmission in Zone D (Niger, Pleteau, Kwara, Taraba and northern part of Abuja)

Zone E (Kebbi, Kaduna, Bauchi, Gombe) and Zone F (Adamawa, and Southeren part of Borno) receive substantial amounts of rainfall in the months of July through September (see Figures 7 and 8). This actually indicates that only four months are suitable for malaria transmission in the zones. Three months rainfall and temperature anomalies are observed to be a major driver of inter-annual variability of malaria transmission in Zone G (Sokoto, Zamfara, Katsina, Kano, Jigawa) while one and half month is suitable malaria transmission in Zone H (Figures 9 ans 10) rainfall together with temperature accumulations from August to September were significant predictors of log-confirmed malaria transmission in Zone H (Yobe and Borno).

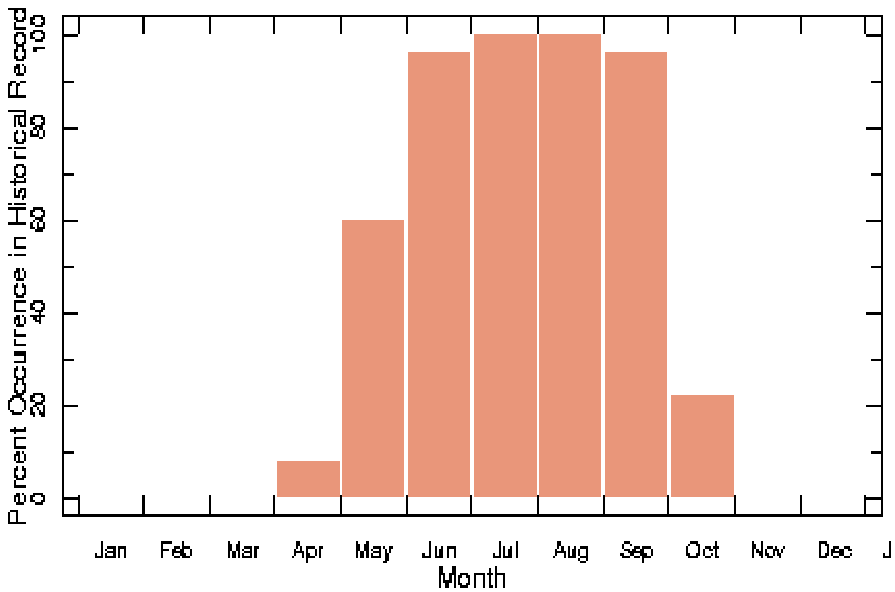

Figure 7: Monthly Climate Conditions Suitable for Malaria Transmission in Zone E (Kebbi, Kaduna, Bauchi, Gombe)

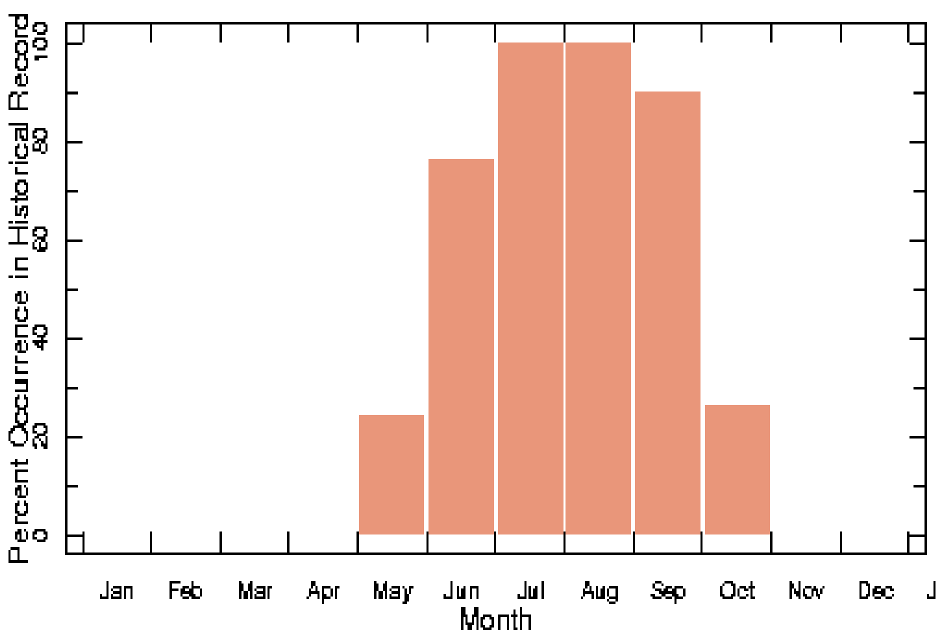

Figure 8: Monthly Climate Conditions Suitable for Malaria Transmission in Zone F (Adamawa, and Southeren part of Borno)

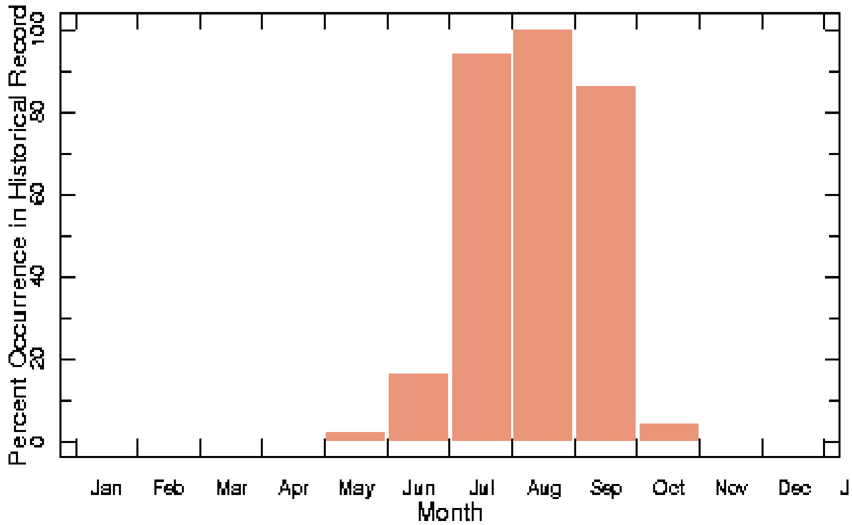

Figure 9: Monthly Climate Conditions Suitable for Malaria Transmission in Zone G (Sokoto, Zamfara, Katsina, Kano, Jigawa)

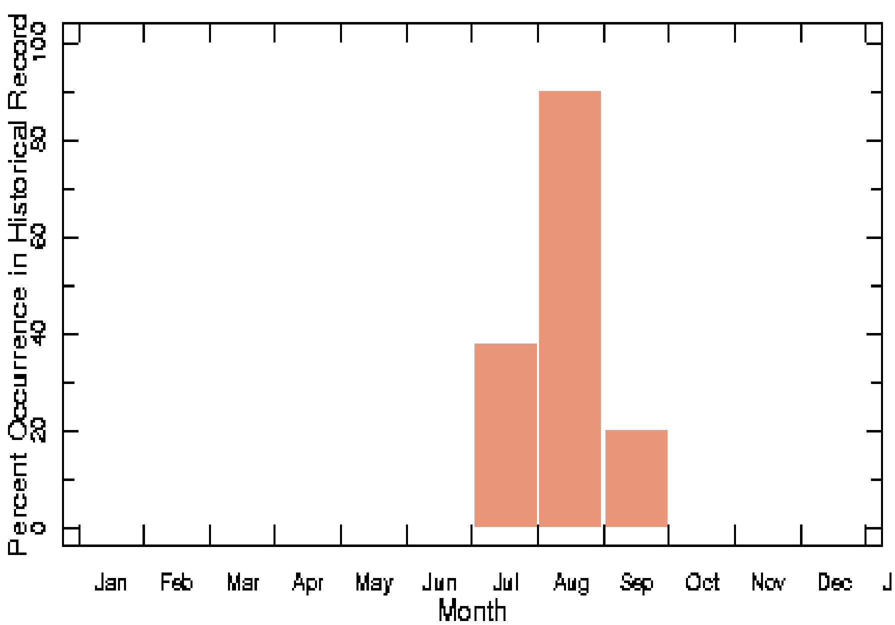

Figure 10: Monthly Climate Conditions Suitable for Malaria Transmission in Zone H (Yobe and Borno)

Observations show that of the zones A,B and C have bimodal rainfall distribution and zones D,E,F,G and H have unimodal rainfall distribution. This actually affects the transmission of malaria in the zones (Figures 3,4,5,6,7,8,9 and 10). In addition to clarifying the seasonal pattern and intensity of transmission in different areas, the figures are useful for targeting and timing interventions, such as indoor residual spraying to the highest-risk areas. These zones are in the northern part of the country. The northern part usually received less rainfall than southern locations (Figures 8, 9 and 10). The onset period for the northern stations is May/June while the cessation period is September/October. The northern stations have only one peak, which is in August. Annual trend of precipitation is positive in most of the southern stations while it is negative in most northern stations. At the ninety-nine percent confidence limits, all the stations have mean annual rainfall close to or within the limits except during El Nino Southern Oscillation (ENSO) years. These zones have unimodal rainfall distribution in which rains increase in frequency and amount, beginning in May and peaking in August. The period of rainfall in these zone are between 3 and 5 months; the onset month is May/June while the cessation month is September/October (Table 1). These findings are factual because generally, Nigeria receives rainfall from the southwesterlies which invade the country from the Gulf of Guinea coast, i.e. the tropical Atlantic. This moist airstream is overlain by the northeast trades which originate from above the Sahara and are thereby dry and dust laden. The zone of contact of the two air masses at the surface is a zone of moisture discontinuity and it is known as the Inter Tropical Discontinuity (ITD) zone. The position of the ITD fluctuates seasonally and the different ITD zones affect different areas of the country at various times. Between January/February and August, the ITD migrates northward and there is a corresponding shift northward of the area of rainfall activity. However, from the end of August when the ITD is at its most northerly position, it migrates a short distance inland causing a period of reduced rainfall in the costal area, a phenomenon known as the 'little dry season' or the 'July/August break'. During this period the southwesterlies become deflected into westerlies which bring little or no rain. This causes rainfall to increase eastward over southern Nigeria during the July – August period.

3.2 seasonality of climate influences the variation in malaria transmission

The results of this study show that seasonality of climate influences the variation in malaria transmission in Nigeria. It is observed in this study that rainfall plays an important role in the distribution of breeding sites for the mosquito vector thereby influence malaria transmission. Though relative humidity and temperature play an important role in the survival and longevity of the mosquito vector, but it is rainfall that regulates the development rate of both the mosquito larvae. A high relative humidity lengthens the life of the mosquito and helps the parasite to complete the necessary life cycle so that it can transmit the infection. When the relative humidity drops below 60%, it is believed that malaria transmission cannot occur because of the reduced lifespan of mosquitoes. The relative humidity throughout the year ranges from 69% to 93%, so the relative humidity is probably not a limiting factor for malaria transmission in this tropical rain forest area. Rainfall generally increases the number of breeding places for mosquitoes. It was noted that both temporary and permanent water bodies are dependent on rainfall. The results of this study are inconsistent with a few studies in the literature, which find a negative or neutral effect of rainfall. Provided that rainfall has a linear dose-response effect on fluctuations in malaria transmission, this effect would emerge after filtering out the seasonal component. The inconsistent relationship between rainfall and malaria transmission could result from the saturating effect of rainfall, for an increase in rainfall fails to produce additional malaria cases when aquatic breeding sites are not limiting for mosquitoes.

In addition, the duration of the rainfall season is important. Heavy rainfall or storms may destroy existing breeding places, interrupt the development of mosquito eggs or larvae, or simply flush the eggs or larvae out of the pools. However in the case of Nigeria, rainfall is also related to humidity and saturation deficit (factor that affect mosquito survival). In region where temperature is high but rainfall is limiting, such as northern part of the country, mosquito population increase rapidly at thee onset of rain. This is as result of short development cycle. Thus, two to three months of rainfall may be sufficient to constitute one transmission season. However, where temperature is limiting during the colder season, as is the case in southern part of the country and high areas like Jos, mosquito populations increases slowly at the onset of rain. This is so because the area is know for gradual rising in temperature and long development cycle.

The findings of this study support the results of (Craig et al (1999); Connor et al (1999); McMicheal, et al (2003); Thomson et al (2005 a and b)) that transmission of malaria varies by weather, which affects the ability of the main carrier of malaria parasites, anopheline mosquitoes, to survive or otherwise. Tropical areas including Nigeria have the best combination of adequate rainfall, temperature and humidity allowing for breeding and survival of anopheline mosquitoes. The burden of malaria varies across different regions of the world and even within a country. This is driven by the variation in parasite– vector–human transmission dynamics that favour or limit the transmission of malaria infection and the associated risk of disease and death. Of the four species of *Plasmodium* that infect humans—*P. falciparum, P. vivax, P. malariae* and *P. oval*. Plasmodium falciparum causes most of the severity and deaths attributable to the disease, which is most prevalent in Africa south of the Sahara, where Nigeria has the largest population. Also the results of this study concur with the report of World Health Organization (WHO, 2000), that approximately 50% of the Nigerian population experience at least one episode per year of malaria as a result of climate variability. However, official estimate suggests as much as four bouts per person per year on the average (WHO, 1995 and 2002). The trend is rapidly increasing due to the current malaria resistance to first line anti-malarial drugs (WHO, 2000). The magnitude of incidence and death due to it is a multiple of all other tropical diseases put together.

Also, the results of this study are in conformity with the findings of IPCC (2001) that malaria is caused by four distinct species of plasmodium parasite, transmitted by mosquitoes of the genus Anopheles*,* which are most abundant in tropical/subtropical regions, although they are also found in limited numbers in temperate climes. Transmission is associated with changes in temperature, rainfall, humidity as well as level of immunity. Very high temperatures are lethal for the parasite. In areas where the annual mean temperature, is close to the tolerance limit of the parasite, a small temperature increase would be lethal for the parasite. IPCC noted that at low temperatures, a small increase in temperature can greatly increase the risk of malaria. Hence, the areas most susceptible to malaria are those at the fringes of its current distribution such as central Asia and Eastern Europe. In this context, climate change is unlikely to affect overall mortality and morbidity in tropical Africa as environmental conditions are already favourable for its transmission. The vulnerable areas are those where transmission is currently limited, mainly by highland temperatures, such as in East Africa (Kenya highlands, for example). This study adds to the growing evidence linking human diseases to climate fluctuations and suggests that variations in the transmission of malaria in Nigeria and elsewhere are associated to annual changes in climatic conditions. Recently, Craig and others studied the relationship between climatic and non-climatic factors and a 30-year time series of malaria case data in KwaZulu-Natal, South Africa. They found significant linear relationships between seasonal changes in case totals and mean maximum daily temperatures (January–October) of the preceding season, and total rainfall in the current summer months of November–March. A combination of these climatic factors explained approximately 30–50% of the variance in differential case numbers depending on the climate data source used. Although climate appears to account for much less of the variance of malaria in KwaZula Natal than in Botswana (where a quadratic function of rainfall alone accounted for more than 60% of standardized malaria incidence anomalies), it is interesting to note that key high malaria years in KwaZulu-Natal area, e.g., 1988, 1993, 1996, and 2000, also correspond with high malaria anomaly years in Botswana, suggesting that regional rather than local processes are likely to be responsible for much of the inter-annual variation. Given the substantial burden of disease associated to vector-borne diseases in developing tropical countries, it is of utmost relevance to incorporate climate changes into public health thinking.

The National Malaria Control Program in Nigeria and other endemic countries should be intensified to reduce the devastating effects of the disease on both the economy and human lives. The development of an effective vaccine along with other malaria control measures is needed for reducing the burden of malaria in sub-Saharan Africa and worldwide. Although this study may have some limitations such as a lack of incorporation of other meteorological factors into the analysis, we strongly believe that the findings are relevant from a public health perspective to better understand the ecoepidemiology of this and other tropical infections. However, further research is considered necessary in this region and in other endemic areas to develop monitoring systems that will help in predicting the impact of climate variability on malarial incidence in the region.

4. Conclusion

Climate variability is widely considered to be a major driver of inter-annual variability of malaria incidence in Africa. The relationships of variability in rainfall, relative humidity and temperatures to malaria transmission in Nigeria were assessed in this study. Malaria still constitutes a serious public health problem in Nigeria. It is responsible for 60% outpatient visit to health facilities, 30% childhood death, 25% of death in children under one year and 11% of maternal death (4,500 die yearly). In this study, Climate suitability for malaria transmission was defined as the coincidence of precipitation accumulation greater than 80 mm, mean temperature between 18°C and 32°C, and relative humidity greater than 60 percent. Monthly precipitation; Monthly temperature and Monthly specific humidity data (converted to rh) over land areas were extracted from the Climate Research Unit (CRU, Nowich, UK) Time Series (CRU TS). The results of this study show that seasonality of climate influences the variation in malaria transmission in Nigeria. It is observed that rainfall plays an important role in the distribution of breeding sites for the mosquito vector thereby influence malaria transmission. The findings of this study are relevant from a public health perspective to better understand the ecoepidemiology of this and other tropical infections.

5. ACKNOWLEDGEMENTS

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