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An Assessment and Mapping of Malaria Risk in Lagos State

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Abstract
Malaria is a major public health problem in Lagos State. Over the years, the state government has been making efforts through the Eko Free Malaria programme and the Roll Back Malaria initiative to ensure the eradication of malaria in the state. Despite all the malaria intervention projects of the state, however, the incidence of the disease still remains significantly high. A major reason for this is that at present the State lacks adequate geographical mapping of malaria risk for proper spatial targeting of measures aimed at eradicating malaria. Using malaria data collected from the Lagos State Ministry of Health (LSMH) and climatic data (rainfall, temperature and humidity) from the Nigeria Meteorological Agency (NiMET), this study analyzed and mapped the spatial and seasonal variations in the distribution of malaria occurrence in Lagos State from 2008 to 2016. Geographic Information System (GIS) was used to create a malaria database and map the distributional patterns of malaria morbidity and mortality cases in all the twenty Local Government Areas (LGAs) of the State for the period under review. The study revealed significant variations in the distribution pattern of malaria morbidity and mortality across the state. It was also found that the state usually records a higher rate of malaria occurrence during the rainy season months (April – November) compared to the dry season months (December – March). Generally, the annual rate of malaria prevalence in Lagos is still high. The State should embrace routine micro-level malarial analysis and mapping, for effective geographical targeting of malaria eradication measures

Keywords: Malaria risk, mapping, Geographic Information System, Lagos State

Introduction

Malaria is a serious vector-borne disease affecting a greater proportion of the world's population than any other vector-transmitted disease. Large regions where malaria had been controlled are now suffering again from this significant public health problem. According to Craig, *et al.* (1999), malaria is an environmental disease with large-scale limits of its distribution being largely determined by rainfall, temperature and relative humidity. The temperatures between 20^{o}C and 30^{o}C and a relative humidity of above 60% are ideal for the malaria parasite (*ibid*).

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Malaria is a life threatening parasitic disease transmitted by mosquitoes. It is the 3rd leading cause of death for children under five years worldwide, after pneumonia and diarrheal disease. It is preventable and curable. According to World Health Organization (WHO) (2015), malaria transmission occurs in all six WHO regions. The report also indicates that globally, an estimated 3.3 billion people are at risk of being infected with malaria and developing disease, and 1.2 billion are at high risk. According to the latest estimates, 198 million cases of malaria occurred globally in 2013 (uncertainty range 124–283 million) and the disease led to 584, 000 deaths (uncertainty range 367,000 – 755,000). The burden is heaviest in the WHO African Region, where an estimated 90% of all malaria deaths occur, and in children aged less than 5 years, who account for 78% (437,000 cases) of all deaths (WHO, 2015). Pregnant women bear the major burden of the disease as a result of immature and weakened immunity. On the Africa continent a child dies of malaria every 30 seconds (WHO, 2003). Children that survive malaria episodes may suffer from anaemia and cerebral complications that affect long-term development. Low birth weights in infants, which are often as a result of malaria infection during pregnancy, undermine the chances of survival. In the eastern and southern African regions, an estimated 30% of all recorded death during pregnancy is attributed to malaria attack. About 80% of estimated malaria cases in 2013 occurred in 18 countries including Nigeria and 80% of deaths in 16 countries. The global burden of mortality and morbidity was dominated by countries in sub-Saharan Africa. Nigeria and Democratic Republic of Congo accounted for 39% of the estimated total malaria death globally in 2013 (WHO, 2015). Nigeria, Democratic Republic of Congo (DRC), Ethiopia, Cote d'Ivoire, Mozambique and Uganda account for nearly 50% of the global malaria cases. The most vulnerable groups are under-fives, pregnant women, visitors from non-endemic areas, those with sickle cell anaemia and HIV/AIDS (WHO, 2003).

Malaria affects the health and wealth of nations and individuals alike. The disease places various types and degrees of social, economic, psycho-physical, and health burdens on people including health facilities, services and personnel. Malaria has significant measurable direct and indirect economic costs to both individuals and governments (WHO 2002 and 2015; CDC 2016). The direct costs of malaria include a combination of personal and public expenditures on both prevention and treatment of the disease. The indirect costs of malaria include lost productivity or income associated with illness or death. Malaria impacts negatively on the Nigerian economy with about 132 billion naira lost annually to the disease as cost of treatment and in man-hours (LSMH, 2017).

In Lagos, State malaria has been identified as a major public health problem. According to Lagos State Ministry of Health (LSMH) (2015), malaria remained

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endemic in the state. The report shows that malaria is both a cause and consequence of under-development and remains one of the leading causes of morbidity and mortality in the state. As also contained in the LSMH (2015), hospital reviews show that in the State, malaria alone accounts for over 60% outpatients and equally responsible for 30% and 11% mortality in children under five years and pregnant women, respectively. In the same vein, malaria is said to be responsible for 70% of outpatient attendance at the secondary healthcare facilities and over 80% of all tracer diseases reported by primary healthcare facilities.

Over the years, a lot of effort and resources have been committed into the control of malaria by Lagos state government, notably with the launching of Eko Free Malaria programme in 2005. This programme involves the distribution of Long Lasting Insecticide Nets (LLINs) to pregnant women and children less than five years for those using public health facilities; free anti malaria drugs at the public health facilities and Indoor Residual Spraying in some local government areas.

The Government of Lagos State has demonstrated continued commitment to the control of Malaria. The Eko Free Malaria programme, which was inaugurated in 2005, involves malaria diagnosis using Rapid Diagnostic Tests (RDTs) and treatment is provided free for all ages – children, pregnant women, adult men, women and the elderly. There is also the Roll Back Malaria (RBM) initiative, which is a multi-pronged approach that includes appropriate diagnosis and treatment of malaria cases, prevention of malaria in pregnancy, environmental management and integrated vector control with emphasis on operational research and using its results for evidence-based malaria eradication programming.

One important missing link in the concerted efforts to eradicate malaria in Lagos State has been that of malaria mapping. Geographical mapping has not been fully recognized and accorded its rightful place in the quest for malaria eradication in the State. The absence of micro-level malaria maps often hampers appropriate and strategic spatial targeting of malaria intervention measures (Bousema, *et al*, 2012). As a spatial data infrastructure, malaria maps are as critical as other basic products, services, policies, and stratagems targeted towards combating the menace of malaria.

In a Metropolitan area like Lagos State, where peoples' behaviour coupled with environmental factors (e.g. wetlands, gutters, canals, ponds, refuse dumps, open water containers and wells, etc.), encourage the breeding of mosquitoes and thus increase human vector contact which promote the continuous transmission of

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infection, it is important to position malaria control through mapping as a top priority for proper geographical targeting of Government interventions. Accordingly, this work is an attempt to provide an objective geospatial assessment and cartographic visualization of malaria risk in Lagos State, using Geographic Information Techniques. The main aim of this study is to evaluate and map the spatio-temporal pattern of malaria prevalence and risk in Lagos State over a 9-year period (2008-2016).

The imperativeness of malaria prevalence mapping in any effort aimed at malaria eradication cannot be overemphasized nor overlooked. Maps are heuristic models used to capture, store, communicate, interpret, and explain data. They aid in the visualization of differences, clustering, heterogeneity, or homogeneity within data. Spatial patterns can be perceived and correlations visualized through the use of maps. Symbols and colours can communicate detail or the relative importance of certain features. (Coetzee *et al.*, 2000). Maps have played an important role in human history, it can be said that almost any project will require a map of some kind (Pearce, 2014). Maps are perhaps as fundamental to society as language and the written word (Foote *et al*., 1995). Maps provide a powerful visual tool to identify areas where targeted strategies and resources are most likely to have the greatest impact (Omumbo *et al.*, 2013).

Malaria is a major health issue that often engages the attention of governments and non-governmental institutions especially in the developing nations. Malaria transmission is strongly associated with location and spatial targeting of malaria eradication measures is a highly efficient way to reduce malaria transmission at all levels of transmission intensity (Carter *et al*., 2000). Generally, having knowledge of the geographical dimension of any disease is quite essential for effective and efficient control of any disease. With particular reference to malaria, mapping is a powerful tool that could reveal the spatial variations in the distribution of locations of vectors as well as victims of malaria attack. According to Rytokonen and Mike (2004), the goals of disease mapping are: (i) to describe the spatial variation in disease incidence; (ii) to formulate an etiological hypothesis; (iii) to identify areas of high risk in order to increase prevention; and (iv) to provide a map of disease risk for a region for better risk preparedness. Public health practice requires timely information on diseases and other health occurrences to implement appropriate actions. The fact that health data have a location and time reference make them suitable for spatial and temporal analysis. Disease maps can reveal spatial or geographical patterns in the spread of any thematic variable of interest. Thus, disease maps are a veritable tool for disease monitoring and eradication. The availability or non-availability of malaria maps at

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locality level will make a difference between success and failure of malaria eradication. Malaria mapping helps to furnish policy makers and health workers with the much-needed understanding of the spatial distribution of malaria incidence.

MATERIALS AND METHODS

The Study Area

Lagos State lies approximately between Latitudes 6°22'N and 6°42'N and Longitudes 2°42'E and 3°22'E. It is bounded by Ogun State to the east and north and by the international boundary of Nigeria with the Republic of Benin to the west. The southern boundary is the 180km coast line of the portion of the Atlantic Ocean known as the Bight of Benin. The State is divided into 20 Local Government Areas (LGAs) with Ikeja as the state capital (Fig. 1).

Lagos state is situated in an area characterized by a network of creeks, lagoons, rivers and canals. The major creeks are Badagry, Five Cowries, Agboyi, and Majidun creeks. The main lagoons are the Lagos and the Ologe lagoons. It has important rivers such as Rivers Ogun and Owo together with their tributaries. The rivers have large catchments and therefore make drainage difficult due to high water table and flat marshy terrain. The terrain is relatively flat and extends over an area of 80,000 hectares or 800km^2 which represents 22.4% of the total area of Lagos State (Wikipedia online).

The study area falls within the rain forest belt as well as the mangrove swamp zone of the country. Near the lagoon are the shrubs and palm trees as well as some grasses. Further inland, there are the thick forests with scattered mangrove plant species especially in the waterlogged areas in the environment. Annually, there are two rainy seasons with the heaviest rains falling from April to July and a shorter rainy season in October and November. There is a brief relatively dry spell in August and September and a longer dry season from December to March. Monthly rainfall between May and July averages over 300mm (12inches), while in August and September it is down to 75mm (3inches) and in January as low as 35mm (1.5inches). The main dry season is accompanied by harmattan winds from the Sahara Desert, which between December and early February can be quite strong. The average temperature in January is 27°C and for July it is 25°C. On average the hottest month is March, with a mean temperature of 29°C while July is the coolest month (Ogunsote, 2015). According to NPC (2006) the population Lagos State was put at about 9,013,534 people. The annual growth rate is about 3.5%, this will put the present estimated population of the State at about 12,168,271 people.

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Lagos State has quite a number of different categories of healthcare facilities. Healthcare services in Lagos state are provided by the state government, the private entrepreneurs, and the federal government. In conformity with the federal government health policy, the primary healthcare scheme has been adopted amongst other policies by the state government.

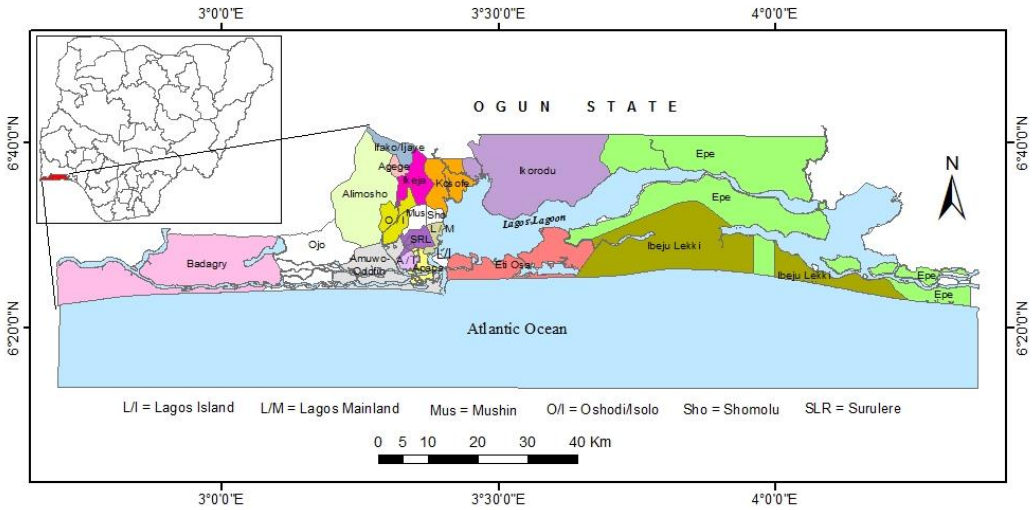

Fig. 1: The study area: Lagos State and an inset map of Nigeria

Data Collection and Analysis

The primary aim of this study was to undertake an assessment and mapping of the spatial and temporal patterns of malaria risk distribution in Lagos State. Monthly records of malaria reported at various public health facilities in the different local government areas for the period between the years 2008 - 2016 (9 years) were obtained from the Lagos State Ministry of Health. Due to the problem of insufficient details in terms of patients' addresses, ward, etc., the data was aggregated to local government areas. It should be noted that the set of data used in this study does not contain data from private health facilities or privately treated malaria cases.

Pertinent climatic data was equally collected for this study. Specifically, monthly temperature, rainfall, and relative humidity data for Lagos State covering the period under consideration were collected from the Nigerian Meteorological Agency (NiMET). The climatic data was used to carry out correlation analysis

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between malaria cases and climatic elements, to determine seasonal variations in malaria prevalence.

A spatial database containing the vectorised administrative map of the state was created in GIS (ArcGIS 10.3), to show the state boundary as well as the LGA boundaries. Similarly, an attribute database containing malaria data was created. Both the spatial database and the attribute database were linked together and used for cartographic exploration and visualization (choroplethic mapping) of malaria data. Besides, relevant statistical tables and graphs are also used for data presentation.

To identify and understand the spatial variations in the distributional pattern of malaria risk across the state, the total monthly malaria cases for each LGA within the 9-year period under investigation was calculated and mapped. To further refine and standardize the search for geographical variations in malaria prevalence and determine the actual degree of severity of malaria in the state, the malaria severity index (MSI) was calculated for each LGA. Basically, malaria severity index is a percentage ratio of the number of malaria cases to the total population of any given geographic unit such as ward, LGA, and so on (Malini and Choudhury, 2011). Usually, the higher the index value the higher the severity level of malaria, and vice versa.

$$MSI = (T/P)100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{eq. (1)}$$

Where:

T = Total number of malaria cases in a geographical area at a given time.

P = Population of the area

RESULTS AND DISCUSSION

Distributional Pattern of Malaria Morbidity in Lagos State

There is a marked variation in the distributional pattern of malaria morbidity in Lagos State. A geographical consideration of malaria severity and deaths resulting from malaria in the state within the period under review shows marked spatial variations across the state. The distributional pattern of malaria risk in Lagos State from 2008 to 2016 was analysed. The total annual malaria cases in the state within the period under consideration is shown in Fig. 2. The observed temporal pattern of malaria cases in the state is undulating in nature. The highest total number of malaria cases (672,219) was recorded in 2009 while the year 2008 had the lowest (474754). The average number of malaria cases for the 9-year period was 572,029.

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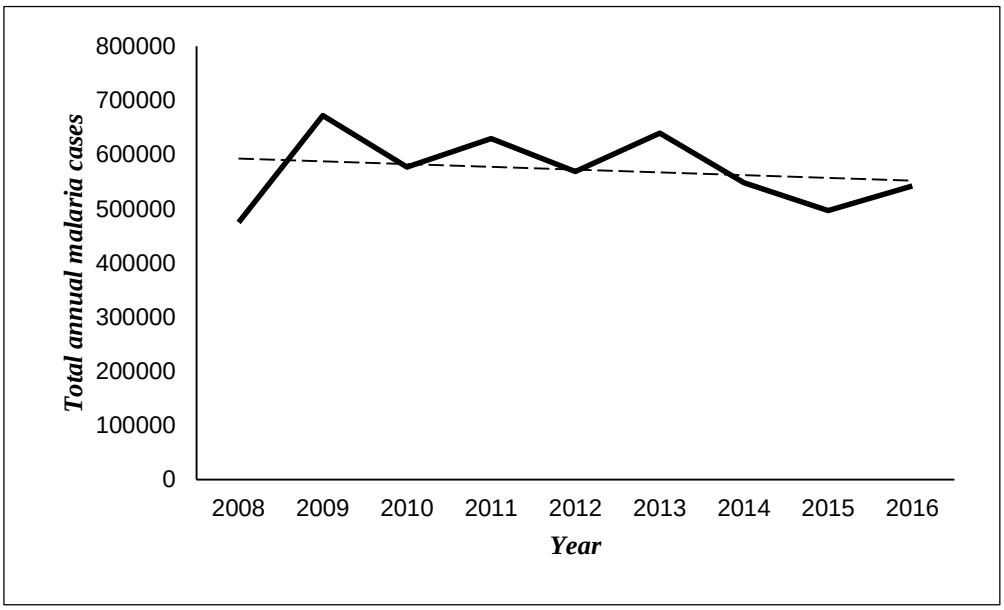

Fig. 2: Total annual malaria cases in Lagos State (2008-2016)

The 9-year malaria data for Lagos State used in this study was subjected to trend analysis. As the dashed linear trendline fitted to the line graph in Fig. 2 suggests, there was only a very slight general decline in the annual number of malaria cases recorded in the state from 2008 to 2016. The state still records high malaria occurrence despite the various intervention efforts by the government. Perhaps, the yearly malaria morbidity rate in the state could have been higher but for the various malaria intervention programmes launched by the state government since 2005.

The high prevalence of malaria in Lagos State could be attributed to several factors. One of such factors is the preponderance of mosquito breeding grounds across the state. Such breeding sites include open surface drainage systems (canals and gutters), wetlands, ponds and stagnant pools of water, open water containers, used and abandoned tires filled with water, pockets of bushes, illegal solid waste dumpsites, etc. More so, the State has a relatively flat terrain and this makes it prone to flooding once it rains. The flood water often persists for a while thus serving as breeding site for mosquitoes. The socio-physical environment of many parts of the State equally encourages mosquito breeding because some areas have slum settlements with ill-ventilated and poorly-lit houses, which serve as ideal

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hiding places for mosquitoes during the day time. Also, certain lifestyles of the people such as exposing one's body (especially the arms and legs), sleeping outdoors in the evening, or not having netted doors and windows, are equally factors that can render one vulnerable to mosquito bite and, hence, high rate of malaria occurrence. Overall, the prevailing social and physical environment in Lagos State encourages breeding of mosquitoes with its attendant high rate of malaria incidence. The persistent high malaria morbidity in the State could also be an indication that the malaria control measures put in place by government are not enough and/or not properly implemented and monitored. The high rate of malaria occurrence could equally be as a result of the failure of inhabitants to embrace and practice certain malaria control measures such as regularly ridding their immediate environment of mosquito breeding sites, using insecticide treated mosquito nets, avoiding sleeping outdoors in the evening or night, etc. In any case, the prevailing high rate of malaria incidence in the State underlines the need for efforts to be intensified in the struggle to eradicate malaria in the State.

Analysis of the total monthly malaria cases on LGA basis over the 9-year period reveals some geographical variations in the distributional pattern of malaria cases in the state. As Table 1 indicates, Alimosho LGA has the highest number of recorded cases of malaria followed by Apapa LGA. On the other hand, Ikorodu LGA recorded the lowest number of cases, followed by Lagos Mainland LGA. Alimosho having the highest number of recorded malaria cases could be attributed to the fact that it is the most populous LGA in the state.

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Table 1: Malaria morbidity and mortality for the LGAs in Lagos State (2008 – 2016)

LGAs	Population	Total malaria cases	Total death	Malaria Severity Index (MSI)	Severity Rating
Agege	459,939	197,839	1	43	Moderate
Ajeromi	684,105	288,714	2	42.2	Moderate
Alimosho	1,277,714	466,194	6	37	Low
Amuwo	318,166	282,413	7	89	Very High
Apapa	217,362	359,074	2	165	Very High
Badagry	241,093	160,389	26	67	High
Epe	181,409	207,064	12	114	Very High
Eti-Osa	287,785	178,758	1	62.1	High
Ibeju-Lekki	117,481	270,502	58	230	Very High
Ifako-Ijaye	427,878	205,116	6	48	Moderate
Ikeja	313,196	307,977	31	98.3	Very High
Ikorodu	535,619	156,119	46	29.2	Low
Kosofe	665,393	254,819	11	38.3	Low
Lagos Island	209,437	175,637	77	84	Very High
Lagos Mainland	317,720	158,372	0	50	Moderate
Mushin	633,009	212,393	10	34	Low
Ojo	598,071	282,427	4	47.2	Moderate
Oshodi	621,509	219,587	3	35.5	Low
Somolu	402,673	337,603	21	84	Very High
Surulere	503,975	182,458	0	36.2	Low

Source: Modified from Lagos State Ministry of Health (2017).

The actual degree of severity of malaria across the geographical space of the state, was determined by calculating the malaria severity index (MSI) for each LGA. The MSI for the twenty LGAs in the state was found to range from 29.2 to 230 (Table 2). Based on the MSI values, the twenty LGAs were grouped into five quartile severity levels comprising very low severity index (29-38), low severity (39-50), moderate severity (51-67), high severity (68-114), and very high severity (115-230). Figure 3 shows a cartographic rendition of the severity index levels using a proportional symbol mapping technique. In a study of this kind, what is mostly of importance is to ascertain the areas with high or very high severity levels of disease prevalence. As Table 2 and Fig. 3 clearly reveal, the LGAs that fall into the category of 'very high severity' are Ibeju-Lekki and Apapa, while Epe, Ikeja, and Amuwo-Odofin belong to the 'high severity' class. Conversely,

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Ikorodu, Oshodi/Isolo, and Mushin LGAs are found in the 'very low severity' group.

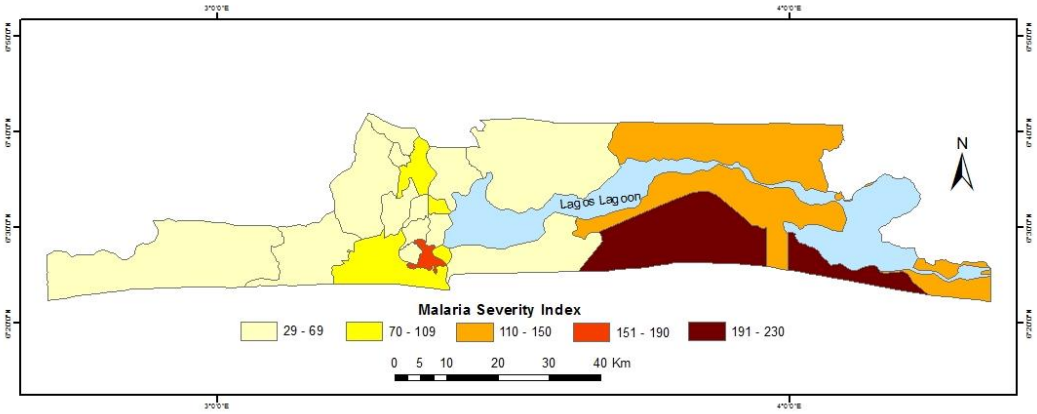

Fig. 3: Spatial distribution of malaria severity index in Lagos State

Malaria Mortality Rate

A geographical consideration of deaths resulting from malaria in Lagos State within the period under review shows marked variations in the geographical distribution. Available statistics as shown in Table 1 indicate that two LGAs namely, Lagos Mainland and Surulere recorded no death resulting from malaria while Lagos Island with 77 mortality cases recorded the highest number of deaths, followed by Ibeju-Lekki with 58 cases. Figure 4 shows the spatial distribution of total malaria mortality cases in Lagos State from 2008 to 2016.

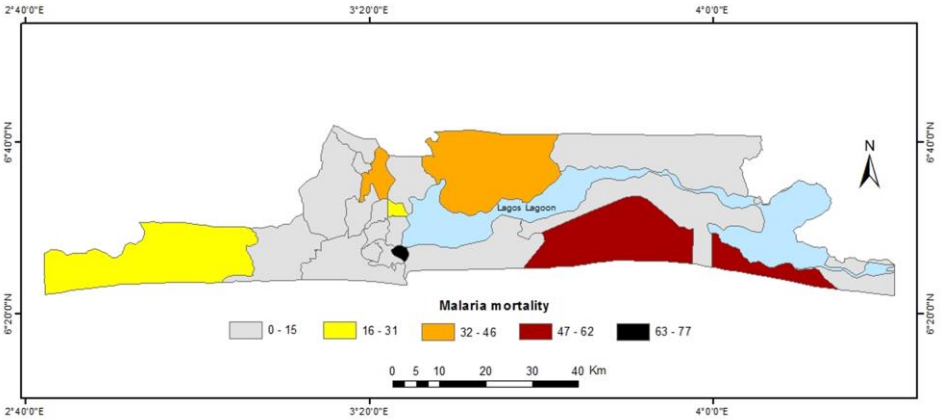

Fig. 4: Distribution of malaria mortality in Lagos State (2008 – 2016)

Seasonal Pattern of Malaria Prevalence in Lagos State

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Malaria incidence varies with season and climatic variables, particularly rainfall, temperature and relative humidity (Malini & Choudhury, 2011). Hence, a correlation analysis was done to establish the nature and strength of the relationship between each of these climatic variables and malaria prevalence in Lagos State. (See Table 2). The correlation coefficient obtained for temperature and malaria cases for the period under consideration is -0.5872, indicating a moderate negative correlation. On the other hand, a coefficient of 0.7161 was obtained for rainfall and malaria cases, which is indicative of a strong positive correlation. The correlation analysis between relative humidity and malaria cases for the state for the same period being considered, produced a coefficient value of 0.4671, which means low or weak positive correlation.

Table 2: Monthly averages of temperature, relative humidity, rainfall and malaria cases in Lagos State (2008 – 2016)

Months	Monthly Averages Maximum Temperature (in ^{o}C)	Monthly Average Amount Rainfall (in mm)	Average Monthly Relative Humidity	Average Malaria Cases per month
Jan	33.3	36.5	79	18999
Feb	33.8	60.26	79	19728
Mar	33.5	72.88	79	22208
Apr	32.8	119.42	79	20971
May	32.1	213.97	82	24257
Jun	30.2	302.74	87	23213
Jul	28.8	225.78	86	25425
Aug	28.9	90.59	86	21996
Sep	29.6	187.91	86	20945
Oct	30.9	196.34	84	20360
Nov	32.6	152.37	83	21101
Dec	33.6	26.26	82	18210

Sources: Malaria data from LSMH (2017); climatic data from NIMET (2017).

Malaria prevalence varies with season and climatic variables (rainfall, temperature and relative humidity) in the State. As the above analysis indicates, seasonal analysis of malaria in Lagos State indicates that there are more malaria cases in Lagos State during the rainy season than during the dry season. The results of the correlation analysis done show that generally in the State, malaria incidence increases with increasing rainfall (Fig. 6) and relative humidity (Fig. 7), but with decreasing temperature (Fig. 8). Ordinarily, high temperature induces mosquito

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breeding and, hence the potential for high malaria occurrence. Lagos State experiences high average monthly temperatures throughout the year. However, the monthly temperature of the state often declines slightly during the rainy season months (see Table 2). In reality, the slight decrease in temperature in the state during the rainy season, does not significantly affect the breeding of mosquitoes. Hence, the state usually records a higher rate of malaria occurrence during the rainy season months (April – November) compared to the dry season months (December – March). This is perhaps owing to the fact that during the rainy season there are more stagnant and lentic waters and humid conditions, which translates to more mosquito breeding sites during the rainy season than during the dry season. This result, therefore, suggests that more precautionary measures should be taken against contracting malaria during the rainy season. People should avoid exposing themselves to mosquito bites by properly covering their bodies, especially the arms and legs in the evening time. Also, people should learn to regularly use mosquito sprays and insecticide treated mosquito nets. Importantly, people should cultivate the habit of environmental cleanliness and take proper care of potential mosquito breeding sites such as open gutters, open water containers, uncovered wells, refuse dumps, disused tyres, and so on.

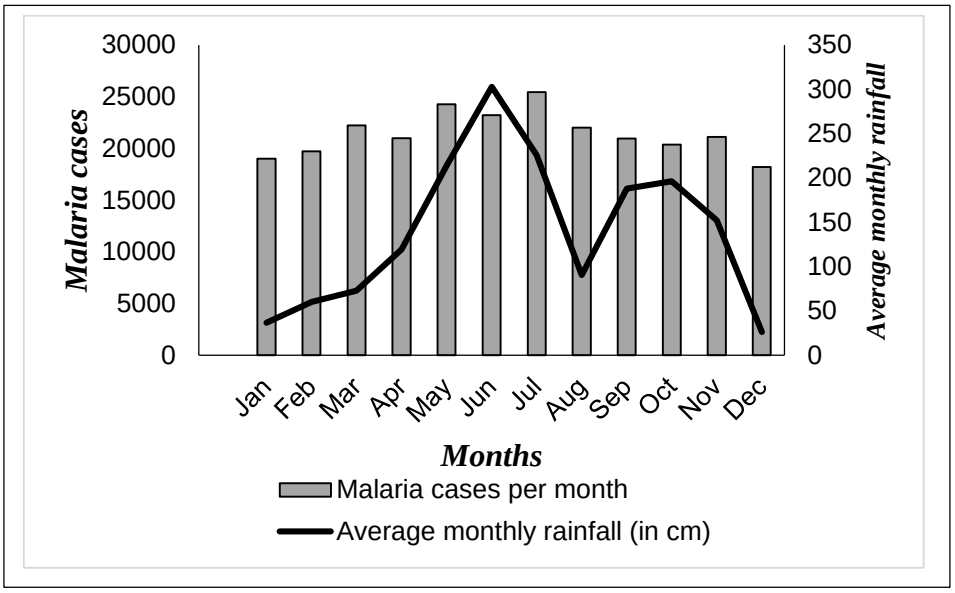

Fig. 6: Malaria cases and rainfall variations in Lagos State (2008-2016)

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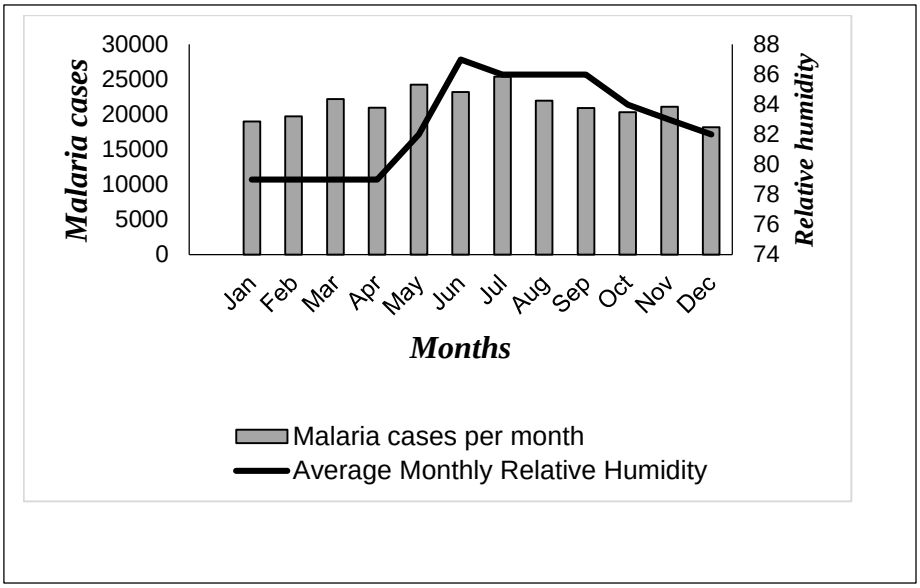

Fig. 7: Malaria cases and relative humidity variations in Lagos State (2008-2016)

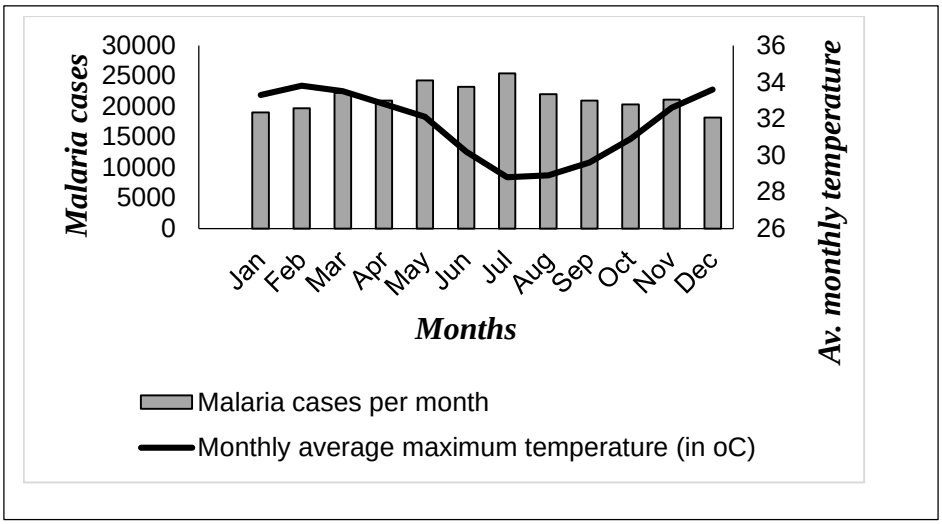

Fig. 8: Malaria cases and temperature variations in Lagos State (2008-2016)

Analysis of malaria prevalence in Lagos State on monthly basis shows a clear seasonal variation in the disease occurrence in the State. As both Table 2 and Fig. 9 indicate, there are more malaria cases during the rainy season months (April – November) than during the dry season months (December – March).

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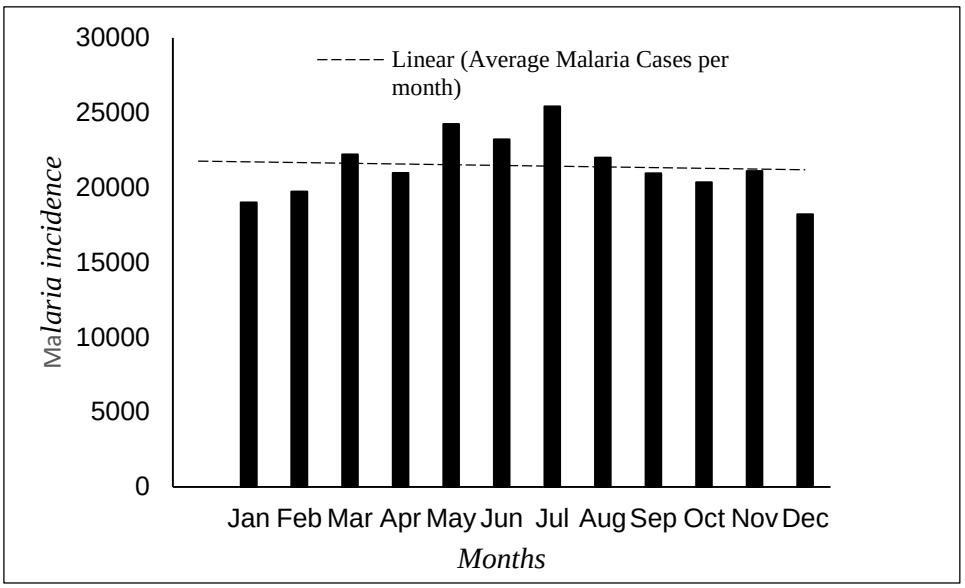

Fig. 9: Average monthly cases of malaria in Lagos State (2008 – 2016)

Conclusion

Generally, the annual rate of malaria prevalence in Lagos is still on the increase. This is despite the various efforts being made by the State government towards managing the disease. On local government basis, there is a high spatial disparity in the occurrence of malaria in the state, both in terms of number of cases as well as the severity level and mortality rate. There is also significant seasonal variation in malaria prevalence in the state. The study shows that malaria occurs more during the rainy season than during the dry season.

There is urgent need for greater commitment on the part of the Lagos State government to invest in malaria surveillance, mapping and control in the state. This is quite critical, given the fact that there is a high rate of migration into Lagos State on a daily basis from across the country and neighbouring African sub-regions (Oyibo, 2017). Some of the people migrating into the state may already be carrying the malaria vector; hence there is need to put in place effective mechanisms to properly checkmate or screen migrants against malaria.

Recommendations

Based on the findings of this study, the following recommendations are hereby made with a view to improving the management of malaria risk in Lagos State:

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The Lagos State government should fully embrace micro-level malarial mapping, for proper and effective geographical targeting of malaria eradication measures. Malaria risk mapping should be made part of the malaria eradication campaign, since malaria maps are quite useful in designing, financing and implementation of malaria control measures. Furthermore, the state government, through the Ministry of Health, should strengthen the malaria data gathering, processing, archiving, and maintenance mechanism to ensure that comprehensive and current monthly malaria data are collected and stored. The malaria data collection should not be limited to public primary health centres alone; instead it should as well be extended to private health facilities.

A more robust and all-inclusive malaria eradication campaign should be formulated for the state. To this end, private health facilities should be involved by the state government in pursuing her malaria control programmes such as the Eko Free Malaria Programme which involves the distribution of LLINs to pregnant women and children less than five years, and the free anti-malaria drugs distribution scheme. More so, the Indoor Residual Spraying exercise should be extended to all local government areas in the State. Effort should also be intensified to spread the malaria awareness campaigns and other measures with the onset, and indeed throughout the entire duration of, every rainy season.

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References

Bousema, T., Griffin, J. T., Sauerwein, R.W., Smith D. L., Churcher, T.S., Takken, W., Ghani, A., Drakeley, C., & Gosling, R. (2012). Hitting Hotspots: Spatial Targeting of Malaria for Control and Elimination. *PLoSMed* 9(1) http://journals.plos.org/plosmedicine (Retrieved 1/7/17).

Carter, R., Mendis, C. & Roberts, D. (2000). Spatial targeting of interventions against malaria. *Bull World Health Organization 2000, 78,* 1401-1411.

CDC (2016). Impact of malaria: Social and Economic Toll. www.cdc.gov (Retrieved 12/12/16).

Coetzee, M., Craig, M. & Le Sueur, D. (2000). Distribution of African Malaria Mosquitoes Belonging to the Anopheles Gamblae complex. *Parasitology Today 16,* 74-77.

Craig, M. H., Snow, R. W. and le Sueur, D. (1999). A climate-based distribution model of malaria transmission in Africa. *Parasitology Today 15*(3), 105-111.

Cromley, E. K. & McLafferty, S. L. (2012). *GIS and Public Health* (2nd Edition). New York: The Guilford Press.

Foote, K. E. & Crum, S. (1995). The Geographer's Craft Project, *Department of Geography, The University of Colorado at Boulder.* http://www.colorado.edu/geography/gcraft/notes/cartocom/cartocom.html (Retrieved 1/7/17).

Lagos State Ministry of Health (2015). http://www.lsmoh.com/programmes/malaria-control-program. (Retrieved 13/6/17).

Lagos State Ministry of Health, (2017). http://www.lsmoh.com/programmes/malaria-control-program (Retrieved 30/1/18).

Malini, B. H. & Choudhury, P. (2011). Remote Sensing Applications in the Identification of Malariogenic Zones in Visakhapatnam City. In N. Izhar (ed.), *Geography and Health: a study in Medical Geography* (321-336). New Delhi: A.P.H. Publishing Corporation.

Ogunsote, O. (2015). Combating Environmental Degradation through Sustainable Landscaping in Emerging Mega City: a case study of Lagos, Nigeria. *Academia*. http://www.academia.edu (Retrieved 2/6/17).

Omumbo, J. A., Noor, A. M., Fall, I. S., & Snow, R.W. (2013). How Well Are Malaria Maps Used to Design and Finance Malaria Control in Africa? *PLoS ONE 8*(1): e53198. https://doi.org/10.1371/journal.pone.0053198. (Retrieved 4/4/17).

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Oyibo, W. A. (2017). Parasitus Facultas et Humanum Intelligentia: The Footprints of a Medical Parasitologist in the Neglected Tropical Parasitic Diseases and Malaria Landscape. An Inaugural Lecture Delivered at the University of Lagos on 7th June, 2017.

Pearce, D. (2014). What is Cartography? *Mapping Sciences Institute, Australia*, http://www.mappingsciences.org.au/what-is-cartography. (Retrieved 4/4/17).

Rytokonen, A. and Mike, J. P. (2004). Not All Maps are Equal: GIS and Spatial Analysis in Epidemiology, *International Journal of Circumpolar Health 63*(1): 11-21.

WHO, (2002). RBM: Economic Cost of malaria. www.rbm.who.int (Retrieved 23/1/18).

WHO (2003). Malaria in Africa, Roll Back Malaria. www.rbm.who.int. (Retrieved 5/6/17).

WHO (2015). Global Malaria Mapper. http://www.who.int/malaria/publication. (Retrieved 5/6/17).

Wikipedia, the free online encyclopedia. *Lagos.* http://en.wikipedia.org/wiki/Lagos (Retrieved 23/6/17).

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