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Full Length Research Article

Prevalence and Risk Factors of Malaria in Kano Metropolis, Nigeria

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ABSTRACT

Malaria has been the focus of multiple declarations, and a range of targets has been set since the beginning of the millennium. Poor people are at increased risk of both becoming infected with malaria as well as becoming infected more frequently. Malaria is also a major contributor to deaths among hospital inpatients in Africa. The purpose of this research is to employ geospatial techniques to map out areas that are vulnerable to malaria breeding vectors using weighted multi-criteria decision analysis to determine the risk levels within the study area and to determine the factors influencing the population at risk of malaria with a view to providing an effective malaria management. Malaria incidence records were used to determine the incidence rate of the disease from 2014 – 2016 and the rate of severity and total confirmed cases of the disease occurrence during the study period. Malaria risk map, which was produced through the integration of malaria hazard map, vulnerability map and elements at risk map, was used to determine the most susceptible areas to malaria attacks in the study area. The results showed about 87% of the entire study area being at high risk of malaria attack. It is observed that there is an increasing trend of malaria cases in the study area despite its variability over the years. It can be concluded that the study area as a whole is prone to malaria infestation and this requires immense attention in order to mitigate the scourge of the disease and its vector. It will be cost effective if GIS and remote sensing could be integrated in monitoring and early warning system in the ongoing malaria control and prevention activities especially in Nassarawa and Kumbotso local government areas that have a very high risk of malaria attacks. There is also the need to research more on the relationship between malaria prevalence and some key socio-anthropogenic factors such as literacy level, income level, HIV status, pregnancy status and meteorological factors.

Keywords: Malaria Risk, Vulnerability, Hazard, Weighted multi-criteria decision analysis.

INTRODUCTION

Malaria has been the focus of multiple declarations, and a range of targets have been set since the beginning of the millennium (WHO, 2015). In Africa`s malaria endemic countries, an average of 30% of all outpatient clinic visits are for malaria (Roll Back Malaria, 2008). In these same countries, between 20% and 50% of all hospital admissions are a consequence of malaria (Roll Back Malaria Partnership, 2013). With high case-fatality rates due to late presentation, inadequate management, and unavailability or stock-outs of effective drugs, malaria is also a major contributor to deaths among hospital inpatients in Africa (Roll Back Malaria Partnership, 2013). Poor people are at increased risk both of becoming infected with malaria and of becoming infected more frequently (Roll Back Malaria Partnership, 2013). Poor families live in dwellings that offer little protection against mosquitoes and are less able to afford insecticide-treated nets (Roll Back Malaria, 2011).

The population at high risk of malaria incidence in Nigeria is estimated at 135,552,389 (WHO, 2015). The countrys' confirmed and suspected cases of Malaria incidence as at 2015, stood at 19,555,575 people (WHO, 2015). Among vector-borne diseases, the malaria is influenced by seasonal or spatial changes in the environment (Messina et al., 2011). Environmental factors such as the presence of bushes and stagnant water around homes, rainfall, low altitude and high temperatures favor the breeding of malaria vectors, as well as parasite reproduction within them (Messina et al., 2011). Malaria has, therefore, been defined as an environmental disease (Hay et al., 2000).

The key to addressing the challenge of reducing malaria parasite prevalence is an integrated approach that combines preventative measures, such as Insecticide Treated bed Nets (ITNs), Indoor Residual Spraying (IRS), improved access to effective anti-malarial drugs (Kokwaro, 2009), as well as proper environmental management. Climate has been established as an important determinant in the distribution of vectors and pathogens (Odetoyinbo, 1969).

Tropical areas including Nigeria have the best combination of adequate rainfall, temperature and humidity allowing for breeding and survival of anopheles mosquitoes (Efe and Ojoh, 2013). An increase in rainfall and temperature enhances mosquito development and improved breeding sites leading to incidence of malaria (Vincent and Sunday, 2015). Rainfall provides the breeding sites for mosquitoes and increases relative humidity necessary for mosquito survival, leading to increase in the number of mosquitoes biting an individual per unit time (Lindsay and Martens, 1998). An adult mosquito`s chance of survivorship is determined by the ambient temperature, humidity and rainfall. Warmer ambient temperatures shorten the duration of the extrinsic cycle, thus increasing the chances of transmission (Jackson and Yang, 2010).

Malaria pandemic alone has caught the attention of both the local authorities and international agencies. Several measures have been adopted to reduce the rate of morbidity due to malaria. It is believed that climatic parameters had changed significantly over the past two/three decades (Akinbobola and Oluleye, 2010). Hence, a deeper knowledge of environmental variables, conducive to mosquito vector life cycle, is important to target control interventions. Modeling environmental variables are very valuable in defining foci of malaria transmission. The development of spatial analytical techniques has created an avenue to evaluate environmental variables that are generated by remote sensing satellite sensors and captured by Geographic Information Systems (GIS) for spatial and temporal environmental analysis (Tanser and Le Sueur, 2002; Thomas *et al*., 2002).

For an effective malaria management especially, the knowledge on how and where climatic and environmental conditions favouring the development and spread of malaria vector can be of great benefit to health management agencies, thus enabling containment and treatment efforts to be focused where most needed. A detailed survey needs to be carried out on the malaria prevalence and the associated environmental factors encouraging the malaria vector in Kano metropolis, Kano state.

Also, a dearth of research works carried out on the geographic distribution and the suitable environmental factors of malaria in Kano metropolis additionally justifies this research. Therefore, the application of GIS and remote sensing in identifying the areas that are prone to malaria attacks in Kano Metropolis will be addressed by this research work. This will be achieved by identifying the factors influencing the population at risk to malaria attacks within the study area and generating a malaria risk map of the study area.

MATERIALS AND METHODS:

Study Area:

Kano Metropolis is the largest city in the Sudan region of Nigeria; it is located between Latitude $12^{o}25'$ to $12^{o}40'$ North of the equator and Longitude $8^{o}35'$ to $8^{o}45'$ East of the Greenwich Meridian. It has a total land area of 499 km^2 and comprises of eight local governments, which includes Dala, Tarauni, Kumbotso, Fagge, Nassarawa, Ungogo, Kano Municipal, and Gwale (Figure 1). Kano Metropolis has a population of 2,828,861 (National population commission, 2006), and the projected population by the Nigerian Census Board was around 3,333,300 in 2011.

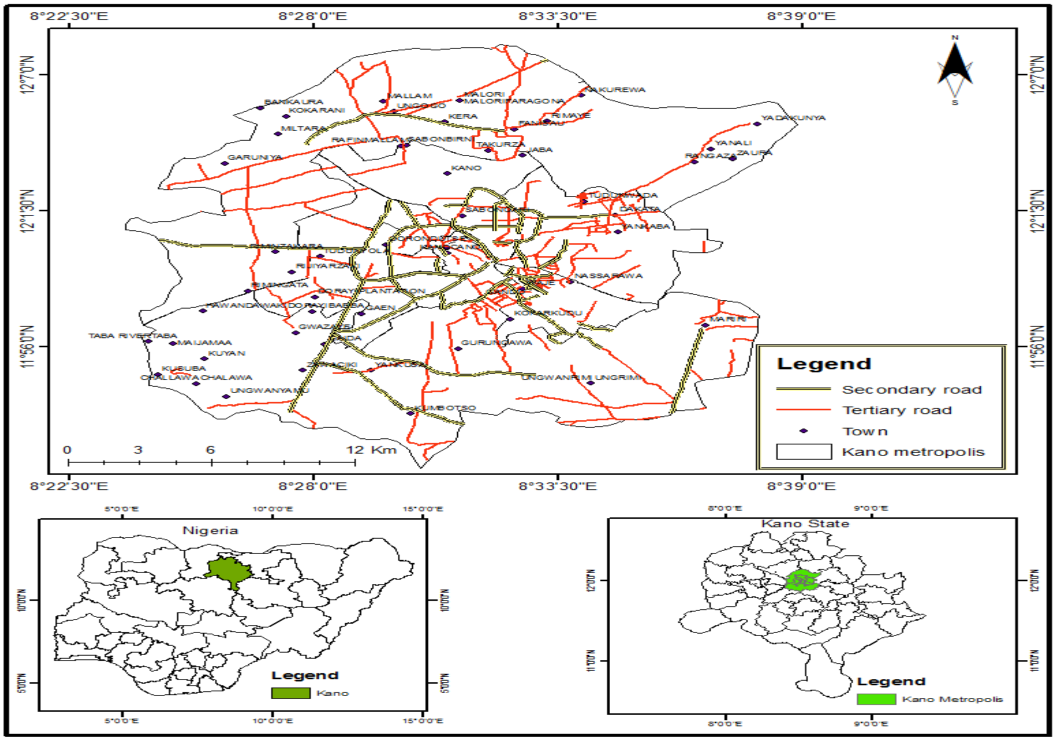

Figure 1: Map of the study Area

METHODOLOGY

This research work covers ten (10) months of study from January to November, 2017. A total of 397 questionnaires were systematically administered across the eight local government areas making up the study area. Data on people`s frequent use of Long Lasting Insecticide Treated Nets (LLIT), house condition (mud/traditional house, modern house and others), outdoor sleeping and animal domestication among others, were obtained. The data were later used to generate a chlorophlet map of each of the factors considered, reclassified and integrated with other variables to generate a malaria vulnerability map of the study area.

Lansat ETM+ was used to extract the land use/cover classes of the study area. Five classes were identified; Bare-lands, built-up, cultivated lands, uncultivated lands and water bodies. These classes were later reclassified according to their effects on the survivorship of anopheles mosquito.

Location of all available primary health care facilities were taken using hand held GPS. A buffer analysis was carried out to determine the maximum distance a patient covers to access health facility. According to WHO (2003), areas found within 3 Km radius from a health facility is assumed to be less risky than areas found beyond this distance. From Advance Space-borne Thermal Emission and Reflection Radiometer (ASTER) data (ASTER) data, Drainage, slope and elevation of the study area were derived. These data were reclassified to derive malaria hazard map of the study area. Population density map was derived from the population data of the study area. The map was further reclassified to determine the people at risk of malaria.

In generating the vulnerability map of the study area, health facilities locations were taken using handheld GPS, computed on Microsoft excel and imported into ArcGIS. The maximum allowable distance a patient should cover to access health services is 3km and as such, multiple ring buffer analysis was carried out to come up with places farthest away from health care centres. The vulnerability raster was further reclassified into three subclasses and the reclassified subgroups of vulnerability raster layer were ranked according to the maximum distance covered to arrive at nearby health facility. Minimum distance to cover to nearby health facilities were considered as less malaria vulnerable area.The general systematic flowchart of the steps conducted in this study is shown in Figure 2.

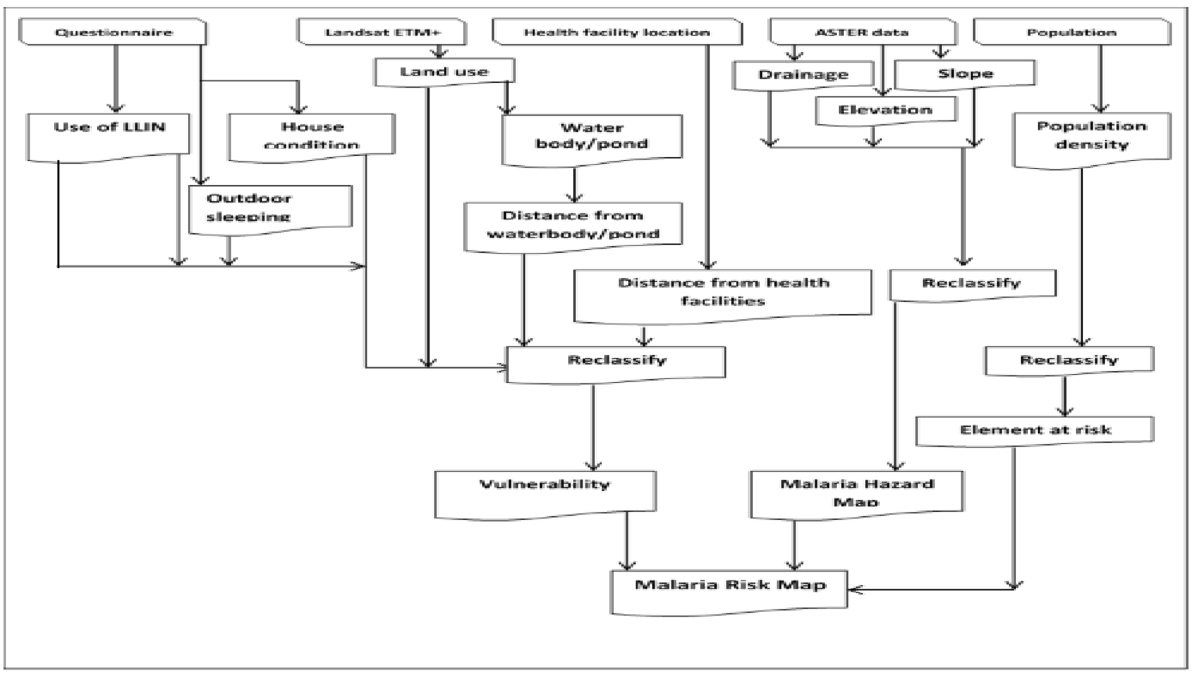

Figure 2: Methodology workflow adopted in this study.

Environmental and Population Data

Shape files of digital elevation model (DEM), slope, Lansat 8 OLI/TIRS (2016) were obtained from Kano State Geographic Information System (KANGIS). Demographic data about population was obtained from National Populations Commission (NPC).

Data Preparing for Use and Processing

Factors influence on malaria hazard including distance to water bodies, distance to dumpsites slope and elevation were considered (Table 1). The last two shape files were prepared using DEM. Idrisi 17.0 was used for analyzing the lansat image and preparing land use/land cover layer of the area. The image was classified using a supervised classification method and GPS points collected from the field used as ground accuracy in the classification process. A total of five classes were identified by this classification, i.e., bare-land, built-up, cultivated areas, uncultivated grass land, and water bodies. This layer was reclassified in to five classes based on the order of vulnerability for mosquito breeding site, source of blood and resting places for the vector (s). Thus, the new values were assigned to each class based on this classification as 5, 4, 3, 2 and 1 (Table 2).

Hazard map, i.e. a map that highlights areas which are vulnerable for breeding and maintenance of malaria vectors and parasites, was prepared by weighting and overlaying environmental factor. For selecting and weighting of different factors for hazard and risk maps, a questionnaire was sent to experts in the field of malaria, who were familiar with situation of the study area. Each expert suggested some factors and their vulnerability in malaria transmission cycle. After collecting and evaluation of their comments, suggested ratings and classes for each factor were ranked as low (rank = 1), moderate (rank = 2), high (rank = 3) and very high (rank = 4). The figure for hazard was considered as very low (rank = 1), low (rank = 2), moderate (rank = 3), high (rank = 4) and very high (rank = 5) as shown in Tables 1 and 2. Every layer was then re-classified based on these ranks. Rating was standardized followed by using analyst of Arc GIS 10.3 software. Re-classified layers were multiplied by their standard weight and then added to others for providing the hazard/risk layer/maps. Factors that influence on malaria hazard are elevation, slope, distance to water bodies and distance to dumpsites.

Similarly risk map, i.e. a map that shows risk of malaria transmission in the area was prepared by hazard, population density, land use/ land cover, distance travelled to health services, use of long lasting insecticide treated nets (LLITN), outdoor sleeping without LLITN, animal domestication and house type. The obtained risk map was then divided into very high, high and moderate risk areas as three strata for planning control interventions.

Table 1 shows the weight assigned to each of the malaria hazard factors used in mapping and identifying malaria hazard areas within the study area. Table 2 shows the weight assigned to each of the Malaria risk factors considered in mapping and identifying malaria risk areas within the study area.

STATISTICAL ANALYSIS

Data collection procedures and statistical analyses carried out in the course of conducting this research were discussed as follows:

Incidence Rate

The incidence rates provide a direct measure of the rate at which new illnesses occur in a population, and therefore it was adopted in this work. For the correct calculation, population data of the area and health centers reports containing the number of malaria cases of the patients were used. These data were then used to calculate the total malaria incidence and severe malaria incidence per 1000 population of the study area. The results of these calculations were used to generate chloropleth maps showing the spatial distribution of malaria in the study area from 2014 – 2016.

Factors Influencing Population at Risk

Based on previous works and interviews with malaria experts; the following environmental factors that greatly influence on malaria prevalence were identified. These include elevation, slope, distance to water body/ponds, distance to rivers and distance to dumpsites. To determine the factors influencing the population at risk, firstly a malaria hazard (infected) areas were mapped using the five environmental factors, which include elevation, slope, distance to water body/ponds, distance to rivers and distance to dumpsites. The malaria hazard areas were mapped using a Weighted Linear Combination (WLC) technique of Multi-Criteria Evaluation (MCE).

Socio-economic Factors for Identifying Malaria risk Areas

Some of these socio-economic factors were generated through the questionnaires administered using a systematic random sampling method.

Table 1: Assigned weight of malaria hazard factors

FACTOR	WEIGHT	CLASS	RANKING	SUSCEPTIBILITY
Elevation	30	395-452	5	Very High
		454-512	4	High
Slope	10	0-1.86	3	Very high
		1.86-4.02	2	High
		4.02-18.32	1	Moderate
Distance to water body/ponds	30	0-500	5	Very high
		500-1000	4	High
		1000-2000	3	Low
		2000-Above	2	Very low
Distance to river	15	0-500	5	Very high
		500-1000	4	High
		1000-1500	3	Moderate
		1500-2000	2	Low
		2000-Above	1	Very low
Distance to dumpsites	15	0-1000	5	Very high
		1000-2000	4	High
		2000-3000	3	Low
		3000-Above	2	Very low

$$\text{Incidence} = \frac{\text{Total Malaria Cases (per year)}}{\text{Total Population of an area}} \times 1000 \ldots\ldots \text{Equation 1}$$

$$\text{Incidence} = \frac{\text{Total Severe Malaria Cases (per year)}}{\text{Total Population of an area}} \times 1000 \ldots\ldots \text{Equation 2}$$

The sample size for this study was determined using an epidemiological formula put forward by Lwanga & Lameshow, (1991).

$$\mathrm{n} = \frac{\mathrm{Z}^2\mathrm{P}(1-\mathrm{P})}{\mathrm{D}^2} \quad \text{------------- Equation 3}$$

Where:

n= Sample size,

Z= Z statistic for a level of confidence,

P= prevalence obtained from past study (56.3%) or Expected prevalence,

D= precision = 0.05.

$$\mathrm{n} = \frac{(1.962)^2 \times 0.563 \times (1-0.563)}{(0.05)^2}$$

n= 378

378 + 5% attrition= $\frac{378\times5}{100} = 18.9$

The Sample size will be 378.1+18.9=397.

Table 2: Assigned weight of malaria risk factors

FACTOR	WEIGHT	CLASS	RANKING	SUSCEPTIBILITY
Malaria hazard	20		5	Very high
			4	High
			3	Low
Landuse/cover	20	Built-Up	5	Very high
		Cultivated land	4	High
		Water body/Pond	3	Moderate
		Bareland	2	Low
		Uncultivated grassland	1	Very low
Distance to health facilities	5	0 – 3000	4	Very high
		3000 – 4000	3	High
		4000 – 5000	2	Low
		5000 – Above	1	Very low
Population density	15	581,289-810,389	4	Very high
		400,009-581,289	3	High
		301,436-400,009	2	Low
		271,885-301,436	1	Very low
Use of LLITN	15	22-31	4	Very high
		19-22	3	High
		18-19	2	Low
		0-18	1	Very low
Out-door sleeping	15	20-33	5	Very high
		19-29	4	High
		12-19	3	Moderate
		10-12	2	Low
		0-10	1	Very low
House type	5	15-20	5	Very high
		11-14	4	High
		4-10	3	Moderate
		1-3	2	Low
		0	1	Very low
Animal domestication	5	27-33	5	Very high
		9-27	4	High
		8-9	3	Moderate
		7-8	2	Low
		0-7	1	Very low

The sample size (397) was divided in to eight according to the number of local governments making up the study area. Then, 49 questionnaires were administered to seven of the local governments each while in Nassarawa local government, 54 questionnaires were administered because it has the highest number of wards among all the local governments.

Using similar procedures used in generating the malaria hazard map, the malaria risk map was produced by including population density, distance from health facilities, land use/land cover, use of Long Lasting Insecticide Treated Nets (LLITN), out-door sleeping without LLITN, house type, animal domestication and malaria hazard layer.

RESULTS

Table 3 shows the percentage total confirmed malaria incidence in the study area over the years of this study, whereas trend analysis of malaria prevalence in the study area over the years is presented in Figure 3, The total confirmed malaria incidence rates in 2014, 2015 and 2016 are presented in the Figures 4, 5 and 6, respectively.

Table 3: Total malaria prevalence

LGA/YEAR	2014	2015	2016
DALA	13.20%	13.30%	12.60%
FAGGE	4.20%	5.90%	16.30%
GWALE	2.20%	23.00%	0.21%
KANO MUNICIPAL	30.90%	5.10%	10.20%
KUMBOTSO	13.80%	13.70%	14.80%
NASSARAWA	17.40%	20.60%	15.30%
TARAUNI	4.90%	8.30%	14.80%
UNGOGO	13.40%	10.00%	15.60%

From Table 3 and Figure 3 the malaria cases varied throughout the years; with an increasing trend. It was interesting to note that there was a sharp rise in cases of malaria in the year 2014 in Kano Municipal Local Government area and with a sudden decline in the year 2015. This decline could be as a result of state government`s declaration made by the executive governor of the state, Dr. Abdullahi Umar Ganduje on his inauguration on 29th May, 2015, a seven day period for municipal waste collection which he physically took part .

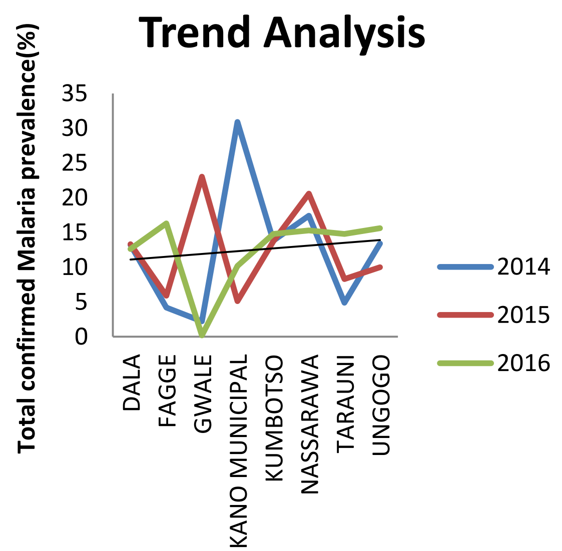

Figure 3: Trend analysis of malaria prevalence in the study area over the years of study

Despite these, there was a steady trend increase in malaria incidence across the local governments making up the study area. Thematic maps of these variability from 2014-2016 as shown in Figures 4,5,6,7,8 and 9, respectively.

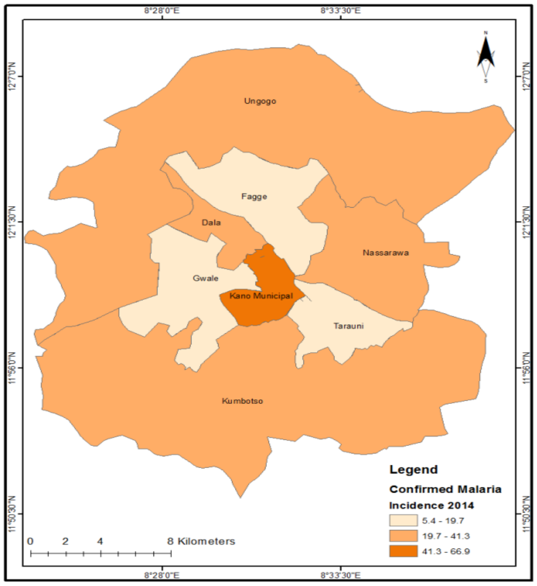

Figure 4: Map of Total confirmed malaria incidence rate in 2014

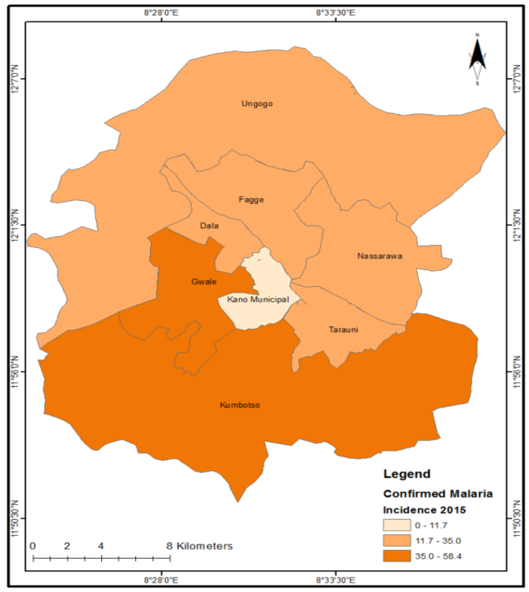

Figure 5: Map of Total malaria confirmed incidence rate in 2015

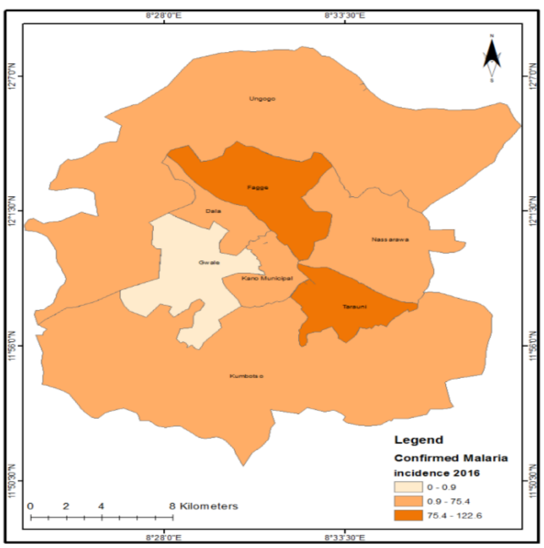

Figure 6: Map of Total confirmed malaria incidence rate in 2016

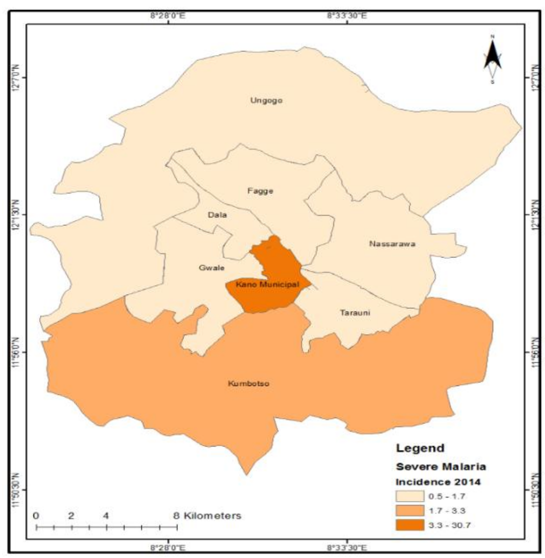

Figure 7: Map of Total severe malaria incidence rate in 2014

The total severe malaria incidence rates in 2014, 2015 and 2016 are presented in the Figures 7, 8 and 9, respectively. The Malaria hazard map in Figure 10 shows that 91.02km^2 (18.30%), 321.3 km^2 (65.40%) and 81.34 km^2 (16.3%) of the total area were subjected to very high, high, and moderate malaria vulnerability, respectively. It can be deduced that about 65% of the total area was highly exposed to malaria hazard. The risk map in Figure 11 shows that 28.84 km^2 (5.78%), 434.13 km^2 (87.43%) and 33.78 km^2 (6.77%) of the total area was subjected to moderate, high and very high of malaria risk, respectively. It is possible to conclude that most parts of the study area were at high risk of malaria attacks. These areas include Dala, Ungogo, most parts of Tarauni and Kumbotso local government areas. Nassarawa and some parts of Kumbotso have a very high malaria risk.

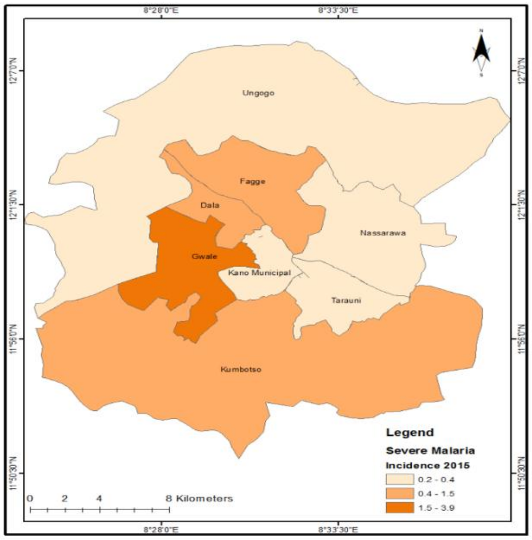

Figure 8: Map of Total severe malaria incidence rate in 2015

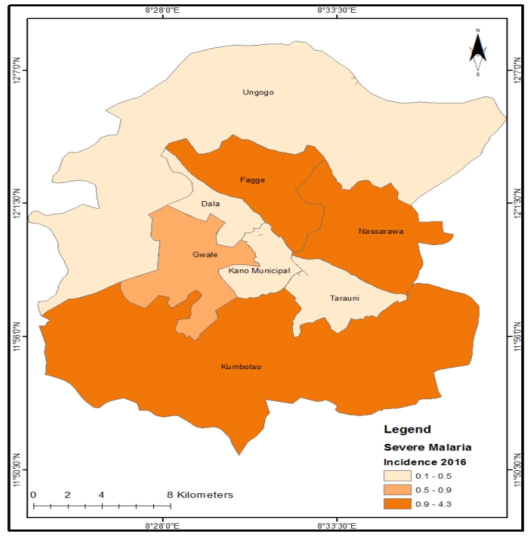

Figure 9: Map of Total severe malaria incidence rate in 2016

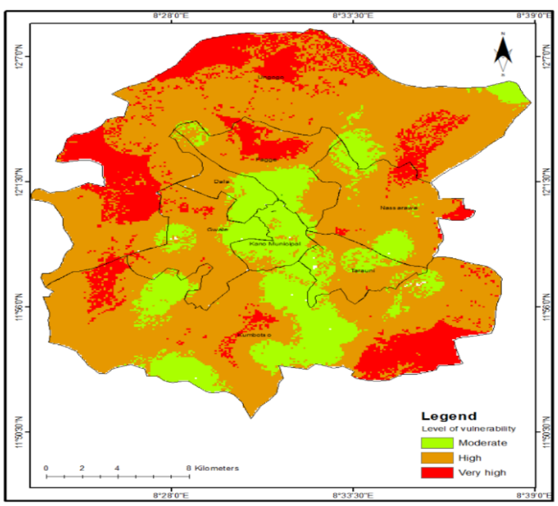

Figure 10: Malaria Hazard map of the study area 2016

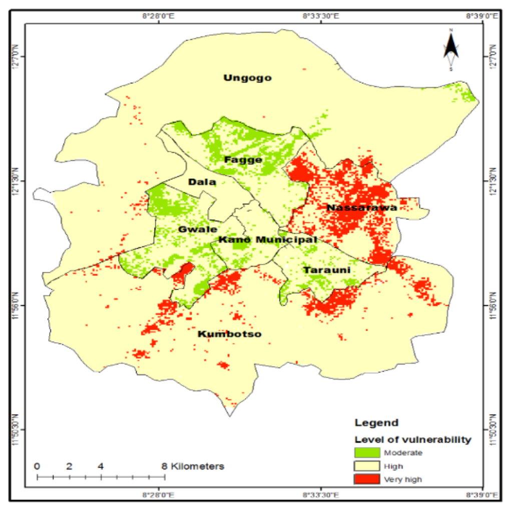

Figure 11: Malaria Risk Map of the study area 2016

DISCUSSION

The total confirmed malaria incidence across most of the local governments were increasing over the years despite all the interventions. Hazard mapping show the potential breeding places for these mosquitoes based on environmental factors used to map the malaria hazard. From the Malaria hazard map in Figure 10, it can be concluded that over 65% of the study area were highly vulnerable to malaria attack. Proper sanitation of the environment could greatly reduce mosquitoes breeding places and thus, the rate of malaria attack as seen in the year 2015.

From the study, it was observed that residents living in Nassarawa local government area were found to be more at risk of malaria attack than those living in other local government areas making up the study area.

Environmental conditions identified, coupled with other socio-economic factors such as waste disposal practices, agricultural lands which provide shelter and resting place for adult malaria vectors and high population density as seen in Nassarawa local government area provide adequate supply of blood meal to the vectors, as also observed by Kamath et al. (2012) and Garima et al. (2013), hence, increase their longevity.

CONCLUSION

The results from this research shows the importance of GIS and remote sensing in creating operational maps which could help malaria vector control agencies to identify malaria hazard and priority areas for malaria disease control. In conclusion, we can stratify the study area into three strata for planning malaria control. The first stratum or very high risk area, targeting indoor residual spraying (IRS), vast distribution of long lasting Mosquito nets and larviciding is recommended as intervention methods.

For the second stratum or high risk area, distribution of LLINs, and larviciding, is recommended while for the third stratum or Medium risk areas, larviciding is recommended as intervention method. This study stresses the need to further explore the role played by meteorological factors to actually determine the weather transition period that have most significant effects on malaria disease in the study area.

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