Geospatial Analysis of Malaria Risks in the Ancient Town of Akure, Ondo State, Nigeria

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Article history: Received 23 March 2017, Revised 26 April 2017, Accepted 5 June 2017, Published 21 June 2017.

Abstract: Globally, menace of malaria fever has been considered as a threat to human population. Nigeria as a country in tropical climate is worse hit. Monitoring of this deadly disease desires a greater attention. Hence, this study exploits the integrated approach of Remote Sensing and GIS in Epidemiology with the aim of generating malaria risk map of Akure with a view to determining the degree of vulnerability of the study area and reducing the malaria incidence through appropriate medical intervention. The objectives are to generate a mean malaria incidence map of Akure, Analyse the factors responsible for the mean malaria distribution (i.e. Hazard map) of Akure and finally to generate Malaria Risks Map. The mean monthly malaria data across the 23 electoral ward was interpolated using the Inverse Distance Weighted (IDW) techniques. The Hazard map was generated using the multi criteria evaluation, where eight different environmental factors were overlaid using fuzzy overlay techniques. Malaria Risk map was generated by dividing the malaria incidence by the total population at the beginning of the study, and the result showed that places the probability range of very low, low, medium, high, and very high risk of malaria diseases is 0%-1.6%, 1.6% - 10.9%, 10.9% - 27.14%, 27.14% -50.33% and 50.33% - 81.99% respectively such that, places like Moferere, Aba Igbira and Igbatoro the very high risk of
the diseases. The study recommends the establishment of health centers should be made at high and very high risk areas at reasonable distance away from the existing health facilities so that people at a distance can easily access the service.

**Keywords:** Remote Sensing, GIS, Epidemiology, Hazard, Malaria risk, Malaria incidence

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1. **Introduction**

Malaria is undoubtedly a serious vector-borne disease affecting a greater proportion of the world's population. Malaria is a life-threatening blood disease caused by parasites and is transmitted to humans by the *Anopheles* mosquito. Once bitten, parasites multiply in the host's liver before infecting and destroying red blood cells. The disease can be controlled and treated if diagnosed early on. Unfortunately, this is not possible in some areas of the world lacking in medical facilities, where malaria outbreaks can occur. At the moment, a vaccine for the disease is still yet to be discovered (Chinery, 2005).

Malaria may no longer be considered as just a rural issue in Africa. A significant and increasing proportion of the African population lives in urban areas. As urban centres continue to grow, the scale and impact of urban malaria is increasing (Breman et al., 2004) as rapid urbanization alters the frequency and transmission dynamics of malaria (Keiser et al., 2004). Importantly, the declining economies of the African countries and their cities struggling to cope with the pace and the extent of urbanization, poses unique challenges to the control of the diseases as poor housing, lack of sanitation and drainage water surface increases vector breeding and human-vector contact (Knudsen et al. 1992; Martens et al. 2000). It has been noted that a high proportion of the urban population at any age is at risk of malaria due to lack of acquired immunity Castro et al. (2004). In order to determining which households are in critical need of intervention, Ayele et al. 2013 identified socio-economic, demographic and geographic risk factors associated with the prevalence of malaria by using data obtained from the rapid diagnosis test and the study revealed that the prevalence of malaria is related to poor socioeconomic conditions.

Malaria is a major public health problem in Nigeria where it accounts for more cases and deaths than any other country in the world. Malaria is a risk for 97% of Nigeria’s population. The remaining 3% of the population live in the malaria free highlands. There are estimated 100 million malaria cases with over 300,000 deaths per year in Nigeria. This compares with 215,000 deaths per year in Nigeria from HIV/AIDS. Malaria contributes to an estimated 11% of maternal mortality (WHO, 2000). Malaria is a leading cause of morbidity and mortality in the developing world, especially Sub-Saharan Africa where the transmission rates are highest and where it is considered to be a major impediment to
economic development (Robert et al., 2003). The vast majority of malaria deaths occur in Africa, south of the Sahara, where malaria also presents major obstacles to socio-economic development. Malaria has been estimated to cost Africa more than US$ 12 billion every year in lost GDP, even though it could be controlled for a fraction of that sum (Ahmed, 2014).

Malaria is a complex disease related to the interaction among parasites, vectors, human hosts and environment, it is fundamental to study these factors together in order to be able to control it. Previous studies established that future change in climate and its impacts vector borne diseases could be better understood using statistical and mathematical models (Akinbobola, 2013; Awolola, 2002). Thus, Geoinformatic Technology can obviously contribute to refining the estimates and can potentially fill gaps of knowledge about the effects of urbanization and malaria (Tatem et al., 2004). However, the use of geospatial technology to study the combine effects of weather parameters, geomorphological factors, vegetation index, streamlines and dumpsite locations on malaria distribution in the study area has not been comprehensively studied.

In view of the above, the thrust of this study is to apply geospatial technology in mapping out malaria risk zones over Akure with a view to determining the degree of vulnerability of the study area and reducing the malaria incidence through appropriate medical intervention with the following objectives: to analyse the spatial distribution of the mean Malaria incidence across the study area between 2013 and 2015; analyse the factors responsible for the spatial distribution of Malaria incidence; and Generate Malaria risk map.

1.1. Study Area Description

The study area is Akure South and North Local Government Areas (LGAs). It is situated on Latitudes 7° 3′ 30.6"N – 7° 26′ 54.9"N and Longitudes 5° 4’ 54.8”E – 5° 29’ 10.4”E. It is about 370m above the mean sea level. The population of the study area in 1963 was put at 71,006 and by 1999, the total population has risen to 239,124 according to the 1991 census. By the year 2006, the total population has increased to 340,021 inhabitants (NPC, 2006). The rainfall is about 1524mm per year. The atmospheric temperature ranges between 28 °C and 31 °C and a mean annual relative humidity of about 80%.

2. Materials and Methods

2.1. Materials

The study utilized 2015 LANDSAT Operational Land Imager (OLI) with path and row of 190 and 55 respectively of the study area with 30m resolution of bands 4 and 5. The image was acquired from global land cover facility (glcf) site, www.glcf.org. Health data for malaria cases from 2013 to 2015 were collected for all the basic and comprehensive health centres within the study area from the
Federal Ministry of Health via https://dhis2nigeria.org.ng. The Geomorphological data which include elevation and slope were extracted from the Shuttle Radar topographic mission (SRTM) imagery. The Rainfall Data were obtained from 3B43 Monthly (0.25 × 0.25degree resolution) of the Tropical Rainfall Measuring Mission (TRMM). TRMM is a joint endeavor between NASA and Japan's National Space Development Agency. Temperature and Relative Humidity data between 2008 and 2012 were acquired from an EL-USB-2 data logger which was mounted in five different location across the study area which are: Oshinle, Alagbaka, Airport, Oja Oba and Ijapo. The study investigated one legal and eleven illegal dumpsites across the study area with the aid of the Global Positioning System (GPS). The drainage map of the area was derived from the SRTM imagery after several image processes and analysis. As a result of poor update in the population census in the country and the unavailability of such data to the electoral ward level, the study then use an estimated population which was derived from the high spatial resolution imagery of the study area using the occupancy ratio (1:6, meaning that, One building to Six persons) of the 2006 National population Census.

2.2. Methods

2.2.1. Mean spatial distribution of malaria incidence

In order to determine how the malaria incidence spread across the study area, the study made use of at least one Health Centre in each electoral ward and their respective catchment areas, thus, the frequency of occurrence of each of the catchment areas was calculated using the General Outpatient Data (GOPD) register. A dataset which include the geographic location of each of the catchment areas, annual and monthly mean malaria incidence was created in Microsoft Excel Software. The dataset was later imported into the ArcMap 10.3 Environment, where it was spatially analyzed using the Inverse Distance Weighted (IDW) Interpolation techniques of ArcGIS 10.3 Software. IDW is the most widely used method and the easiest to handle in spatial Interpolation (Lai, P.C., et al, 2009)

Table 1: Malaria Environmental Factors and their respective Fuzzy Membership Type

<table>
<thead>
<tr>
<th>Factor(s)</th>
<th>Membership Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>small</td>
</tr>
<tr>
<td>Slope</td>
<td>small</td>
</tr>
<tr>
<td>Temperature</td>
<td>large</td>
</tr>
<tr>
<td>Rainfall</td>
<td>large</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>small</td>
</tr>
<tr>
<td>Vegetation</td>
<td>large</td>
</tr>
<tr>
<td>Distance to stream</td>
<td>small</td>
</tr>
<tr>
<td>Distance to Dumpsites</td>
<td>small</td>
</tr>
</tbody>
</table>
2.2.2. Spatial analysis of the factors responsible for the distribution of malaria incidence

This approach makes use of a Multi Criteria Evaluation (MCE) techniques known as the Fuzzy Overlay. To run Fuzzy overlay, the map of selected environmental factors such as topographic factors (elevation, slope and flow distance to stream), breeding sites, vegetation index and climatic factors (temperature, rainfall and relative humidity) was developed, such that, the membership function with a specific membership type (table 1) map of each of these environmental factors was also derived through the Spatial Analyst extension of the ArcGIS 10.3. Thus, the membership functions were overlaid to generate malaria hazard map by intersecting all regions of high membership function.

3.2.3. Data analysis on malaria risk map

In Epidemiology, Risk is defined as the ratio of the incidence of Health Outcome (diseases) to the total population of the study area at the start of the study (US Environmental Protection Agency). Thus, in this study, Malaria Risk is calculated as the malaria incidence divided by the total population of the study area at the beginning of the study. In the absence of the ward map for the study area, a grid of equal size was created on the study area boundary map. The gridded map was overlaid on a high resolution imagery (Google Earth) and the total number of the house in each grid was multiplied by Six (NPC Occupancy ratio, 2006). Another field of malaria incidence for each of the grids was added to the grid attribute table. The gridded map was symbolized with the malaria incidence cases and Normalized with the population field. Thus the Malaria Risk map was created.

3. Results and Discussion

Figure 1 showed the mean spatial distribution of malaria recorded cases between 2013 and 2015 and it was observed that highest number of cases were recorded at Araromi, Arisoyin, High School and Ogbese area with an average of about 3000 malaria cases recorded, while relatively high cases were recorded at Orita Obele, Esure and Oba Ile. In addition, it was also realized that with an average case of 600 were recorded and Iju, Itaogbolu while Oda recorded the lowest number of cases with an average of 93 cases recorded. The high mean incidence of reported case in some parts of the study area may be due to poor socio-economic conditions of the people where there is non-use of insecticide net, poor roofing materials, bad toilet facilities and poor electricity supply (Ayele et al., 2013; Ifatimehin 2009). Ayele et al., 2013 in his study on “semiparametric models for malaria rapid diagnosis test result” identifies poor socio-economic conditions as a major contributing factor or determinant for the spread of malaria. In order to reduce the high incidence of malaria, the study recommends the correct use of mosquito nets, indoor residual spraying with insecticide and other preventative measures. In addition, improving housing conditions is a means to reduce the risk of malaria. Other measures such as creating awareness
of the use of mosquito nets, indoor residual spraying with insecticide, and malaria transmission, can lead to a further reduction in the number of malaria cases.

Figure 1: Mean Spatial Distribution of malaria recorded cases in Akure

Figure 2 showed the malaria hazard potentiality of different areas in Akure Township. Places like high school, Danjuma, Oba Ile, Orita Obele, Ughele, Iju, Itaogbolu and Ogbese were found to be very highly vulnerable to malaria disease while Igbatoro and Ilu abo were of low vulnerability. Figure 3 revealed that 477km² (48%) of the study area was very highly, 19.875km² (2%) was high, 119.25 km² (12%) was medium, 228.625km² (22%) was low and 159km² (16%) was very low vulnerable to vector borne diseases like Malaria.

Figure 2: Bar chart of Malaria Hazard Map with respect to the Land Area Covered
Figure 3: Malaria Hazard Map

Figure 4 showed that there was a strong relationship between the degree of vulnerability and the mean spatial distribution i.e. the higher the degree of vulnerability in an area, the higher the mean incidence of malaria in the same area and vice versa. Thus, places like Araromi, Aratusi, High School e.t.c. were observed to be very highly prone to malaria and as well as high value of malaria incidence, unlike Ilu abo and Igbatoro that had low vulnerability and as well as low value of mean spatial distribution.

Figure 4: Malaria Hazard Map overlaid with the Mean Malaria Incidence
The Figure 5 showed the spatial distribution of Akure estimated population from a high resolution imagery adopting the 2006 occupancy ratio (1:6) of National Population Commission (NPC, 2006). The result showed the 2015 estimated population of Akure to be 4,152,363. The map shows that the highest population ranged from 385,000 – 675,000 people and found in Esure, high school, Danjuma, Isolo, Araromi and Orita Obele area of Akure. The medium populated areas can be attributed to Ughele, Oba Ile where population ranges from 170,000 – 267,953 persons. The Oda, Iju abo, Ogbese, Aponmu, Iju and Itaogbolu were regarded as the lowest populated areas in Akure Township. The figure 8 showed that low, medium and high population area occupy 650km² (70%), 100km² (11%) and 195km² (19%) of the study area respectively.

![Figure 5: Spatial Distribution of Estimated Population of Akure](image)

From the basics of Epidemiology, Risk refers to the probability that a disease will occur and it can be expressed as a proportion and ranges from 0% to 100%. The Figure 6 showed the malaria risk map such that the very low risk areas had the probability range of 0% - 1.6% depicting places like Ughele, Oda, Iju and Itaogbolu the very low risk areas to malaria diseases, the low risk areas had the probability range of 1.6% - 10.9% i.e places like Arisoyin, Ogbese, Araromi, Oke Ijebu, Isolo e.t.c. were observed as all low malaria risk areas, the medium risk areas had the probability range of 10.9% - 27.14%, the high risk areas had the probability range of 27.14% - 50.33% of the population making Oke Iju, Aba Igbira and Aponmu to be the high malaria risk areas, and the very high risk areas had the probability ranges from 50.33% - 81.99% making places like Moferere, Oke Afa and Igbatoro the very high risk of malaria diseases. The study revealed that 1800, 13920, 26160, 1733900 and 2376583 persons were estimated to be at very high, high, medium, low and very low risk to malaria diseases respectively.
This revealed that less than 1% of the population were at very high and high risk to malaria disease, this success can be attributed to the special intervention of the Ondo state government on health related issues by ensuring there is at least one public health centre in each electoral ward, thus, the inhabitants have access to good health care services at their door step. The population at very high risk were found to be areas with poor socio economic conditions. This is in agreement with the study of Ayele et al. 2013 which revealed that Malaria disproportionately affects poor people who cannot afford treatment or who have limited access to health care, households who can have enough money to have proper toilet facilities, more number of rooms in the house, clean drinking water, and well built houses were found to be less affected by malaria.

![Figure 6: Malaria Risk Map of Akure](image)

No recent global maps of malaria endemicity have been developed since those of Lysenko in 1968 (Lysenko et al. 1968) despite significant advances in the collection of empirical data, global environmental information from satellites, and the statistical techniques that can be used to integrate them (Hay et al., 2000), this study gives an insight to how to determine the level of endemicity of a particular region which can later be joined together to generate malaria endemicity map for a larger region or perhaps the entire globe.

4. Conclusions

Risk maps are fundamental for estimating the scale of the population at risk, and hence appropriately deploying the resources needed to combat malaria. They provide benchmarks for assessing
the progress of control and indicate which geographic areas should be prioritized. According to the result of the findings small area of the study area is located on risk area for malaria. The mean spatial distribution of malaria was produced from the online data source provided by the Federal Ministry of Health. The result revealed that the western part of the study area (which include Aratuyi, Arisoyin, Aponmu e.t.c.) recorded highest number of malaria cases within the study periods. The factors responsible for the distribution was individually analyzed, thus a malaria hazard map was using upon some of the physical parameters which are capable of providing fertile environmental situations for mosquito breeding. The study focused on elevation, slope, distance from rivers, distance from dumpsites, climatic factors, geomorphological and vegetation, the membership function of each parameters was derived as requested by fuzzy overlay technique. Hence, from the result of the overlay analysis of the physical parameters, it is possible to conclude that about $477\text{km}^2$ (48%) of the study area is very highly, $19.875\text{km}^2$ (2%) is high, $119.25 \text{km}^2$ (12%) is medium, $228.625\text{km}^2$ (22%) is low and $159\text{km}^2$ (16%) is very low vulnerable to vector borne diseases like Malaria. Meanwhile, the malaria risk map was developed as a function of mean malaria incidence and the estimated population and the result revealed that less one percent of the entire population was at risk. Despite the complexity in the environmental drivers that determine the life cycles of both the vector and the parasite, the study was able to monitor and analyze these variables using newly available technologies of RS and GIS. This research has shown that GIS and remote sensing is important to create both thematic and operational maps which could help the vector control agencies to view the spatial distribution of mean malaria incidence, identify hazard and risk areas for disease control.

It will be cost effective if the state government will incorporate the malaria hazard and malaria risk maps of the results of this study in the current ongoing health development activities so as to target on the priority areas identified by the study; Proper databases about detail patient data, the seasonal incidence of epidemics and about other related aspects of the malaria disease should be made using GIS.

References


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