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Mapping And Modelling Of Malaria Prone Areas In Bauchi Metropolis

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Abstract:** Malaria continues to be one of the highest killer diseases in the world, particularly among countries in the tropical region (Alhassan, et al 2019). The following objectives were set to assess malaria risk areas within Bauchi metropolis: to determine spatial distribution of health facilities within the study area, to identify environmental factors influencing the spread of malaria within the study area, to investigate relationships among environmental factors influencing the spread of malaria. Methods used for the set objectives were; ground surveying techniques were applied in acquiring spatial data of health facilities, and environmental factors influencing spread of malaria using Handheld Global Positioning System (H-GPS) with accuracy level of ± 5m, Slope and elevation maps of the study area generated from Digital Elevation Model (DEM), Support Vector Machine and Assessment Accuracy (confusion matrix) for Land-Use Land-Cover (LULC) of Landsat8 (OLI) 2020, and Conceptual model of malaria risk map. The procedures for production of slope and elevation maps involved the use of Digital Elevation Model (DEM) of 30m resolution was downloaded from USGS Earth Explorer. Landsat image of 30m resolution was used for determination of environmental changes. The research investigates vulnerable areas based on the environmental factors within the study area; it was achieved by capturing their spatial locations. Analytical Hierarchical Process (AHP) was used in malaria risk map production by assigning weight to the selected environmental factors. Of the total land area covering the study area, 748.59871ha (45%) is at low risk, 570.36051ha (34%) is at moderate risk, while 350.21742ha (21%) is at high risk. Government and relevant organizations should imbibe the use of GIS in disease control.

***Keywords:** Mapping, Modelling, Malaria.*

I. INTRODUCTION

Malaria is essentially an environmental disease since the vectors require specific habitats with surface water for reproduction, humidity for adult mosquito survival and the development rates of both the vector and parasite populations are influenced by temperature (Ashenafi, 2003). Malaria is a life threatening disease caused by parasites transmitted to humans by the bites of infected Anopheles mosquitoes (WHO, 2016). Malaria is a vector-borne disease that affects a large number of people around the world (Jiya, 2020). Malaria is a vector-borne disease that posed serious health challenge in Sub-Saharan Africa where millions of people lack access to health facilities. At least half of the world's population cannot obtain essential services according to World Bank and World Health Organization (WB and WHO, 2017). Almost half of all global cases were accounted for by five tropical countries; Nigeria 25%, Democratic Republic of the Congo 11%, Mozambique 5%, India 4% and Uganda 4% (Godwin et al., 2019). Malaria remained the leading cause of death in Nigeria with approximate 227,645 deaths in 1990 and 192,284 deaths recorded in 2015 (Khanam, 2017). Malaria cases are mostly found in the tropical regions of Africa, being an endemic, malaria is responsible for millions of deaths across the globe

(Sufiy et al., 2021). According to Bilewu et al., (2017), the health impact of stagnant water such as dams are influenced by mosquito dispersal distance; where flight distances established for some mosquito species include 3 km (Aedes), 3.5 km (Anopheles) and 5 km (Culex). It is also observed that residential buildings are about 1 – 1.5 km from the University Dam and the short-range dispersion of mosquitoes is influenced by the environment and environmental changes. Several researchers Conducted researches on malaria and other disease control, using GIS and other techniques and Most of these research works consider environmental and climate variables influencing the bread of this parasite (Mosquito), such as temperature, relative humidity, 'rainfall, forest cover, soil, slope, precipitation, altitude and the normalized difference vegetation index which are considerably influential to the bread of mosquito.

Malaria is essentially an environmental disease since the vectors require specific habitats with surface water for reproduction, humidity for adult mosquito survival and the development rates of both the vector and parasite populations are influenced by temperature (Ashenafi, 2003). The environmental factors influencing the spread of malaria were identified based on the environmental characteristics of the study area. The environmental factors that made it suitable for breeding malaria in the study area were identified as follows: dumpsites, stagnant water, slope and elevation where land-use land cover map and weighted overlay of the variables were used to produce malaria risk map for decision making and further research.

II. MATERIALS AND METHODS

A. STUDY AREA

Location and Extend of the study area cover the whole of Bauchi metropolis, the capital of Bauchi State and of the Bauchi Local Government within the state. The area lies between latitude 58°74"55" and 11° 56"02"north of equator and longitudes 52°32"34" and11°14"34" east of green witch meridian and cover a total area of 14.85 km^2 (Yusuf et al., 2021).

The study area covered eight administrative wards of Bauchi local government area which includes: Miri, Birshi, Dankade, Makama A, Dan-iya, Dan amar, Dawaki and Makama B. the wards covered a total land area of 441,046.105km^2 with an estimated population of 469,100 (NPC, 2017). The study area lies within, latitude 10° 05'00''N and 10° 25'00''N North of the equator and longitude 9° 35'0''E and 9° 55' 0''E, East of the Greenwich meridian.

Bauchi State is one of the six states that form the North-East geopolitical zone of Nigeria. It is bounded by Jigawa and Kano States to the Northwest; Kaduna State to the West; Plateau, Taraba and Gombe States to the South; and Yobe State to the East. Bauchi is the state capital. Bauchi State covers an area of 49,119.1 square kilometres. It lies at latitude 10°30' North and longitude 10°00' East. It has a population of 4,653,066 (2006 census) 6,537,314 (2016 forecast) and a population density of 95. The state accounts for 3.31% of Nigeria's total population (Zaccheus, 2023).

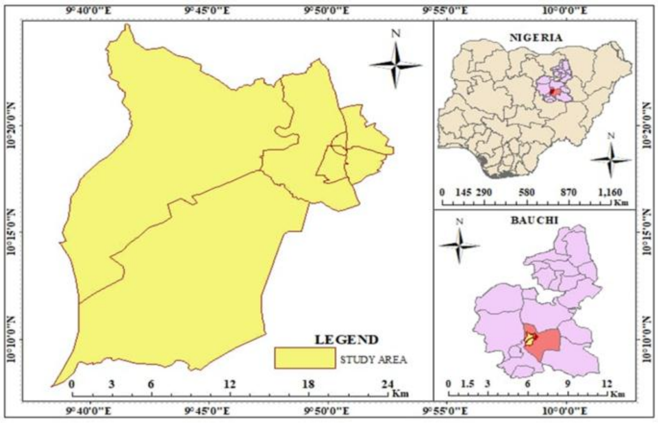

Figure 2.1: Map of the study area

B. METHODOLOGY FLOWCHART

This flow chart describes the step by step procedure that was carried for the set objectives. The method adopted showed flow of data analysis using geographic information system (GIS). A Geographic Information System (GIS) is a system of computer software, hardware and data, personnel that make it possible to enter, manipulate, analyze, and present data, and the information that is tied to a location on the earth's surface (Ershad and Ali, 2020).

GIS is a computer program designed to perform certain functions by inserting, storing, manipulating, analyzing, and displaying data in a geographic context. GIS capabilities are ideal for use in monitoring and evaluation of geographic features with respect to their positional location. The whole processes were shown in the flow chart.

METHODOLOGY FLOW CHAT

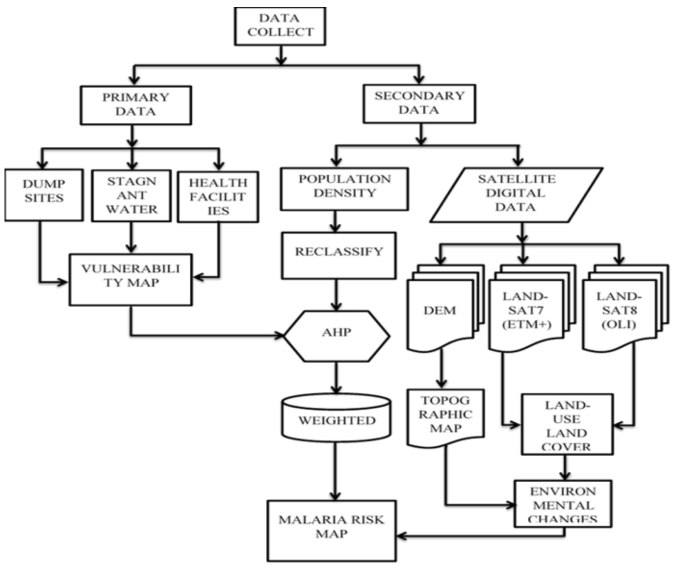

Figure 2.2: Flowchart

C. MATERIALS

DATA SOURCE: The sources of data for this work as proposed are basically primary and secondary sources, which include office reconnaissance, field reconnaissance, and

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spatial locations of health facilities, stagnant waters, and dumpsites in the study area. The information about the data set and their sources is represented in table 3.1

PRIMARY DATA			
S/NO	**ITEM**	**DATA SOURCE**	**RESOLUTION/ACCURACY**
1.	Spatial location of health facilities, stagnant waters and dumpsites.	Handheld GPS	±3m
SECONDARY DATA			
2.	Digital Elevation Model for terrain modeling of the study area, and Landsat images.	USGS Earth Explorer	30m
3.	Estimated Population	National Population Commission (NPC)	2017Estimated Population

Table 3.1: Data Sources

III. METHODS

The used of GIS in spatial analysis has great impact in analyzing spatial data. It is a computer program designed to store, manipulate, analyze, and display data in a geographic context.

According to (Galati, 2006), GIS is a collection of computer hardware, software, and geographic data for capturing, storing, updating, manipulating, analyzing, and displaying all forms of geographically referenced information. GIS capabilities are ideal for use in monitoring and evaluation of geographic features with respect to their positional location. GIS for the measurement of physical accessibility is well established and has been applied in so many research projects in different areas; this includes retail site analysis, transport, emergency service and health care planning (Black et al., 2004).

A. SECONDARY DATA

The secondary data for the purpose of this project includes; Digital Elevation Model from Shuttle Radar Topographic Mission (SRTM) for topographic analysis and delineation of elevation of the study area. The data was used in defining the boundary of the study area by selecting a polygon which was exported as a shape-file for the study area. Population data was used in determining the population density of the study area.

Landsat image of 30m resolution was obtained for multi date changes in land use land cover of the study area; the data was downloaded from United State Geological Survey (USGS) Earth Explorer website. Landsat8 Operational Land Imager 2022 (OLI) was used for the purpose of assessing environmental changes of within the study area using Support Vector Machine (SVM) Algorithm.

In this study, accuracy assessment of Land-use Land-cover of the study area was performed and the following factors; User Accuracy, Producer Accuracy, Overall Accuracy and Kappa Coefficient (T) was computed using Accuracy Assessment Formula.

Accuracy Assessment Formula;

User Accuracy =

$$\frac{Number\ of\ Correctly\ Classified\ Pixels\ in\ each\ Category}{Total\ Number\ of\ Classified\ Pixels\ in\ that\ Category\ (Total\ Row)} \times 100$$

Producer Accuracy =

$$\frac{Number\ of\ correctly\ classified\ pixel\ in\ each\ category}{Tatal\ number\ of\ Referencnce\ pixel\ in\ each\ category\ (Total\ Column)} \times 100$$

Overall Accuracy

$$= \frac{Total\ Number\ of\ Correctly\ Classified\ Pixels\ (Diagonal)}{Total\ Number\ of\ Reference\ Pixels} \times 100$$

Kappa Coefficient (T) =

$$\frac{(TS\ X\ TCS) - \Sigma\,(Total\ Column\ X\ Total\ Row)}{TS2 - \Sigma\,(Total\ Column - Total\ Row)} \times 100$$

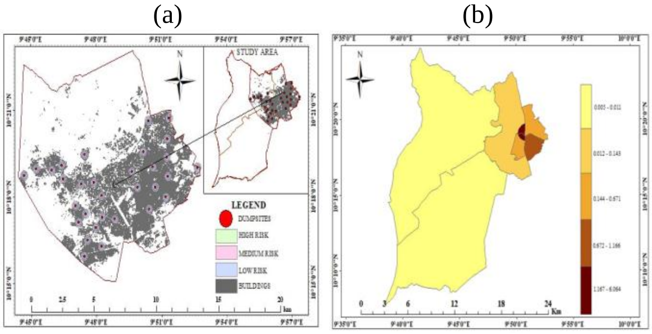
B. PRIMARY DATA

These are data that will be collected for the first time and are original, authentic and independently collected. The primary data include capturing spatial locations of features of interest using Handheld Global Positioning System (GPS) Garmin 76 Series with accuracy of ±3m. The primary data for this study includes; geographic locations of health facilities, stagnant waters and dumpsites. The data will be randomly collected at different geographic locations within the study area and will be analyzed. The analysis will be achieved with the aid of geographic information system software (ArcGIS 10.7).

IV. DATA ANALYSIS

Data for the respective factors were collected, and analyzed using GIS. Data used for this research includes; primary and secondary data. The primary data consists of dumpsites point data, stagnant water point data, health facility point data. While secondary data consists of DEM for evaluation of slope, elevation and Landsat8 (OLI) 2020 for environmental changes within the study area. Microsoft excel was used in analyzing qualitative and quantitative data with descriptive analysis of the data set carried out in the form of averages and percentages. The set of data were analyzed using multi-criteria analysis for malaria risk map of the study area. The values 3,2,1, were used to classify the areas as high moderate and low respectively.

(a) (b)



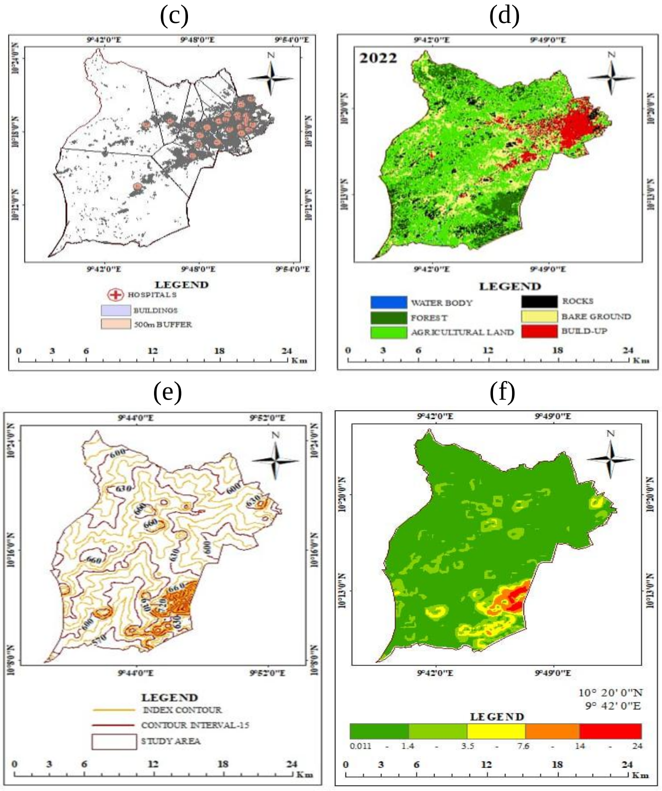


Figure 4.1: Thematic maps of various factors within the study area

In figure 4.1. (a) map of the study area showing the spatial distribution of dumpsites being buffered, at 100m, 200m and 300m radius respectively. (b) map of the study area showing the population density of the study area. (c) of the study area showing the distribution of health facilities buffered at 500m radius (d) Land Use Land Cover (LULC) Analysis of the study area depicting Water Body, Agricultural Lands, Forest, Built Up Areas, Rocks, Bare Ground, And Build Up Areas. (e) Contour map of the study area at 15m interval. (f) Digital elevation model of the study area showing the hilly area (7.6 - 24km above sea level), moderate areas (1.4 – 7.6km above sea level) and the low lands as (0.011 – 1.4km above sea level)

A. POPULATION DENSITY (POP DENS)

According to estimated population data of June, 2017, obtained from Bauchi state office of the Nigerian National Population Commission (NPC Bauchi office); the eight (8) wards have a total population density of 477,104 out of 6,537,314. Birshi and Miri ward have a total population of 81,581 and 32,453 covering an area of 184.873ha (42%) and 184.33853ha (42%) respectively, Also, Dan Amar, Dan Iya, Dan kande, Dawaki, Hardo and Makama, have a population of 93,917; 32,453; 53,494; 41,485; 51,889; 8,004 and 32,453 covering an area of 6.85971 (2%), 49.0867 (11%) 1.09593(< 1%), 8.93916(2%), 0.659636(< 1%) and 4.62586 (1%) respectively, out of the total land covered (440.477996ha**),** by the eight (8) wards.

WARDS	POPULATION DENSITY	AREA (ha)	PERCENTAGE (%)
BIRSHI	81,581	184.873	42
DAN AMAR	93,917	6.85971	2
DAN IYA	53,494	49.0867	11
DAN KANDE	41,485	1.09593	< 1
DAWAKI	51,889	8.93916	2
HARDO	8,004	0.659636	< 1
MAKAMA	114,281	4.62586	1
MIRI	32,453	184.338	42
Grand Total	**477,104**	**440.477996**	**100%**

Table 4.1: Area Coverage in hectare and Percentage Share of Wards

B. DUMP SITES

Data for dump sites were collected using ground surveying method, the data was evaluated using Microsoft excel where it was imported into ArcGIS interface for further analysis. Buffer analysis was carried out on the data for dump sites, and the spacing for the buffer was given as 100m for high risk areas, 200m for moderate risk areas, and 300m for low risk areas.

C. HEALTH FACILITIES

Data for health facilities were collected using ground surveying method. and buffered in the ArcGIS environment. The spacing for this Buffer was of 500m radius. The overlapped buffer space was classified as over-served areas, the served areas are those areas that have facilities but there is no any overlap. The under served areas those areas that have no facility.

D. SLOPE/DIGITAL ELEVATION MODEL

The slope and elevation data was sourced from the USGS earth explorer and was processed in the ArcGIS environment to produce the respective models. Areas with steep slope were classified as areas with low malaria risk, those with gentle slope were areas with moderate risk while flat grounds were classified high risk areas.

SLOPE CLASSES	MALARIA RISK CLASSIFICATION	AREA (ha)	PERCENTAGE (%)
High	1	2494.296	6
Low	3	35070.95	81
Moderate	2	5475.595	13
Grand Total		**43040.84**	**100%**

Table 4.2: Area Coverage in hectare and Percentage Share of Slope

LAND USE LAAND COVER (LULC)

Land use land cover of the study area was carried out, using Landsat8 image of Operational Land Imager 2022 (OLI). Forests and settlements (buildup areas) were classified as high risk areas, Agricultural lands were classified as areas moderate risk, while rocks and bare grounds are classified as low risk areas. The LULC classification can be seen in table 4.3.

S/N0.	LULC CLASSES	CLASSIFI CATION	AREA (ha)	PERCENTAGE (%)
1.	(Forest)	3	4698.456	11
2.	Agricultural Land	2	23999.21	55
3.	Bare Ground	1	9014.506	20
4.	Rocks	1	3011.035	7
5.	Settlements	3	3073.366	7
6.	Water Body	3	229.2723	1
7.	**Grand Total**		**44025.84**	**100%**

Table 4.3: Area Coverage in hectare and Percentage Share of LULC

V. RESULT AND DISCUSSION

A. RISK MAP

The study consists of different environmental factors for malaria risk mapping. The factors used for conceptual model of malaria risk were, dumpsites, stagnant water, elevation and slope. These topographic elements formed the basis for analysis and evaluation of all layers by assigning weight in order of importance. Analyzed factors were assigned the following weight: Dump sites = 35, Population density = 30, Slope = 25 Elevation = 8, Hospitals = 2, making a total of 100%. To produce the final risk map of the study area, the result of the weighted overlay was multiplied with the result of LULC in GIS environment using raster calculator. The risk map can be seen in figure 4.2.

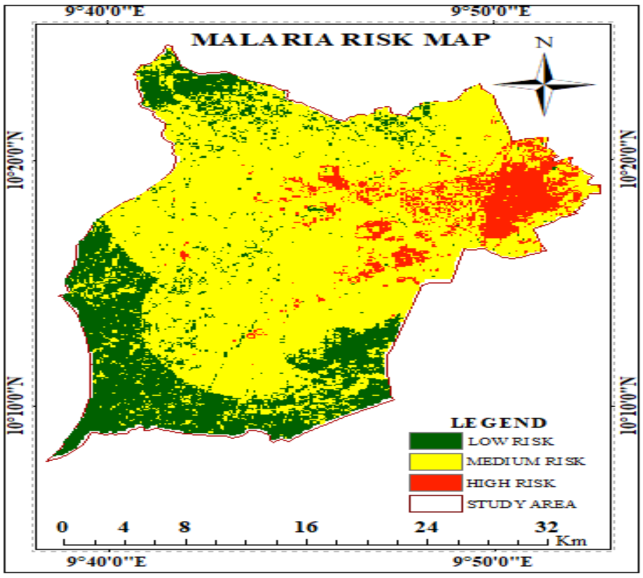


Figure 4.2: Malaria risk map of the study area

S/N0.	MALARIA RISK LEVEL	AREA (ha)	PERCENTAGE (%)
1.	Low	570.36051	34%
2.	Medium	748.59871	45%
3.	High	350.21742	21%
4.	**Grand Total**	**1,669.18**	**100%**

Table 4.4: Area Coverage in hectare and Percentage Share of Malaria Risk

The malaria risk map of the study area was classified as can be seen in table 4.4. the area with high risk is 350.21742ha which is (21%) of the total area, moderate area covers a total of 748.59871ha which is (45%) of the total land area and the low risk area covers a total area of 570.36051ha which is (34%) of the total area.

B. DISCUSSION

Base on the population density map of the study area; Makama A, Makama B, Dan Amar A & B and parts of Dawaki. Dan kade, and Dan iya. are at high risk of malaria infection, because of their high population density. Because of high population density within these wards there is a greater number of refuse dumpsites compared to other wards. Likewise, the health facilities are not allocated base on the population but rather base on wards. Also, in the final risk map these respective wards are almost 90% which is 21% of the entire study area are at high risk of the infection.

But Miri and Birshi wards, covering 84% the total study area is at moderate risk, based on population density analysis of the entire study area but the buildup areas within these words also indicate high risk. The buildup areas within Dawaki and Dan amar B, also depict a higher percentage of high risk of malaria infection.

C. CONCLUSION

In conclusion, the risk map produce by this study shows that, base on these factors that were analyzed, 66% of the buildup areas within the respective wards of the study area (Bauchi Metropolis) are at high risk of malaria infection. The findings of this study should be able to guide policy makers and other nongovernmental organizations on how to plan a more precise, effective and positive control measures. the application of GIS and remote sensing in producing this risk map that cover this little area has given more insight on the capability of GIS and remote sensing in disease control and eradication as it is directly related to our environment.

D. RECOMMENDATION

There is need for more coverage of the metropolis, possibly the entire state for a wholistic, effective and precise malaria eradication planning, of the entire state. Population distribution should be taken into consideration in terms of distribution of amenities e.g. health facilities. Bauchi state environmental protection agency (BASEPA) should take note of the identified dumpsites and stagnant water points for immediate action. Data collection, management and preservation should a serious business within the state's health sector. This would guarantee success in related research.

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