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Application of geographical information system and remote sensing for investigating malaria's footprint: a case study of Iwo Metropolis, Nigeria

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Abstract
On a worldwide scale, the challenge posed by malaria fever has long been acknowledged as a significant peril to the global population. Nigeria, being situated within a tropical climate, has experienced an especially profound impact. The imperative to closely monitor this lethal disease cannot be overstated. Therefore, this research employs a comprehensive methodology that combines Geographic Information System (GIS) techniques with Epidemiology. The primary objective is to create a malaria risk map specifically for Iwo Metropolis while also gauging the extent of susceptibility within the region. Ultimately, the aim is to diminish the occurrence of malaria by implementing suitable medical interventions. The objectives of this study are the creation of spatial

database for the entities in the study area, performing spatial analyses on the database created; and analyzing the spread of malaria disease based on environmental factors in Iwo Local government and finally to generate Malaria Risk Map. This research work was designed to examine and analyze the incidence of malaria and clearer understanding of geographic distribution of malaria-infected people and locations of such inhabitants to the health facility being essential for monitoring the prevalence and for providing treatment, care and support services to the affected area. The study adopted the primary method of data collection using Global positioning system (GPS) to pick point locations of areas where malaria is prevalent and the locations of the different hospitals within Iwo metropolis. Also, topographic maps were collected from SAS planet and Google Earth and secondary data from the State General Hospital, Iwo, where malaria data of adults above 18 years were collected which is divided into old and new cases. In the build- up of this project, the data collected were then uploaded to ArcGIS 10.8, this software was used to perform spatial analysis like buffering operation, service area, trend analysis and neighborhood operation. This project is aimed at producing digital or hard copy maps showing malaria patterns in form of high and low risk areas in order to determine areas that require quick intervention programs.
Keywords: Remote Sensing. Geographic Information System. Malaria. Risk Map. ArcGIS.

1. Introduction

Malaria stands as an unquestionably severe vector-borne illness, impacting a significant segment of the global population. This life-threatening blood disease, caused by parasites and transmitted through the bites of Anopheles mosquitoes, poses a substantial threat. Following a mosquito bite, parasites multiply first in the host's liver before infiltrating and destroying red blood cells. While early diagnosis can enable control and treatment of the disease, unfortunately, this remains unattainable in regions lacking adequate medical infrastructure, leading to sporadic malaria outbreaks. Presently, the quest for a malaria vaccine remains unfulfilled, as noted by Chinery (2005).

In Africa, research has shed light on the intricate interplay between geo-environmental factors and malaria incidence. For instance, studies conducted in Côte d'Ivoire have highlighted the significance of rainfall and temperature as drivers of malaria prevalence, while elevation showed minimal influence Raso *et al*. (2012). Similarly, investigations in Malawi unveiled a noteworthy link between elevation and malaria risk, illustrating higher vulnerability in low-lying lake shore regions compared to safer zones in highland areas Kazembe *et al*. (2006). Another pertinent observation stems from Kenya, where a mere 10-meter elevation increase translated to a 12% reduction in malaria cases due to the associated temperature drop hampering parasite and mosquito development Cohen *et al*. (2008). The difference in findings could be attributed to variations in study area scope and spatial nuances.

Through the development of a spatial model, certain environmental factors surfaced as malaria presence indicators, particularly daytime land surface temperature and rainfall. Additionally, the analysis unveiled a correlation between distance from water bodies and malaria prevalence, peaking within a 4-kilometer range. The resultant malaria risk map, derived from this spatial model, exhibited a spectrum of prevalence in Nigeria, ranging from 20% in specific locales to 70% in others. Strikingly high prevalence emerged in regions including the Niger Delta states of Rivers and Bayelsa, zones encompassing the convergence of the Niger and Benue rivers, and isolated sectors of the northeastern and northwestern parts of the country.

According to Rai *et al*. (2013), it was established that malaria incidence tends to decrease as the distance from water bodies increases. Their research in Varanasi district, India, demonstrated that a significant 50.5% of malaria cases occurred within a 500-meter radius of watercourses. They also highlighted the influence of variables such as population density, proximity to ponds, and land use on malaria incidence. These factors impact the habitat and development of Anopheles mosquitoes. Therefore, an analysis of geo-environmental variables' significance, which shape malaria prevalence in specific areas, remains crucial (Carter *et al*., 2000; Singh *et al*. 2009). Haruna (2017) utilized malaria incidence records to ascertain disease rates between 2014 and 2016, along with severity and total confirmed cases during the study period. Through correlation analysis, the connection between disease prevalence and climatic factors was discerned. In this context, a malaria risk map was developed, integrating a malaria hazard map, vulnerability map, and elements-at-risk map to identify the most susceptible zones to malaria within the study area. The findings showcased that approximately 87% of the total study area bore a high risk of malaria. In line with this, Hoek *et al.* (2003) underscored that disease mapping serves the purpose of indicating "Where?" rather than "Why there?" These maps provide a descriptive tool for spatial epidemiology, succinctly summarizing complex geographic information and illustrating the prevalence of disease across different regions. Abdulkadir *et al.* (2015) demonstrated the practicality of employing Remote Sensing (RS) and Geographic Information System (GIS) technology to enhance malaria assessment, vector analysis, and disease distribution evaluation in Katsina state. This approach enhances comprehension of malaria outbreaks and supports mitigation strategies. The capabilities of GIS in contextualizing diverse information spatially were effectively harnessed, enabling digital analysis of malaria dynamics within the metropolis. Additionally, Pam *et al.* (2017) asserted that while Malaria's intricate drivers involve complex environmental interactions, technologies like Remote Sensing and GIS offer viable monitoring and analysis avenues. These tools not only provide current solutions but can also serve as preemptive warning systems, averting potential epidemics. Integration of GIS and Remote Sensing assists in identifying, characterizing, and monitoring vector breeding habitats. Curran *et al.* (2000) emphasized the relevance of remote sensing in malaria epidemiological studies, given the association between various environmental attributes—such as land use, land cover, land surface temperature, rainfall, vegetation, and elevation—and disease prevalence. Simon-Oke *et al.* (2016) echoed this sentiment, concluding that alterations in environmental conditions and lifestyle choices can mitigate malaria endemicity. Factors like altitude, presence of larvae, water bodies, and waste disposal sites contribute to heightened malaria risk.

Malaria presents a substantial public health challenge in Nigeria, accounting for approximately 100 million cases and over 300,000 deaths annually. This toll surpasses the mortality attributed to HIV/AIDS, and malaria contributes to around 11% of maternal deaths (WHO, 2010). Urbanization introduces additional complexities, with inadequate infrastructure and population density fostering environments conducive to infectious disease transmission. Addressing these issues, especially in developing nations, remains vital to controlling malaria's impact.

Considering malaria's persistence in many regions due to hygiene and control challenges, incorporating spatial data like topographical elevation and environmental indices can guide preventive strategies. The study aims to identify malaria case distribution patterns within Iwo Local Government, while also mapping environmental influencers to enhance our understanding of the intricate spatial relationship between malaria and its environmental determinants.

Given its endemic nature in Nigeria, epidemic understanding and coordinated responses can be facilitated through surveillance systems that provide early outbreak alerts. By employing models to decipher epidemic processes, effective control strategies can be designed.

2. Materials and Methods

2.1 Study Area

Iwo is an ancient town located in the Iwo Local Government Area of Osun State, Nigeria. Positioned at a distance of 42 km from Ibadan, 47 km from Oyo, 46 km from Osogbo, 33 km from Ejigbo, and 35 km from Gbongan, Iwo holds geographical significance. It is situated between latitudes 7°37’ and 7°40’ North of the Equator and longitudes 4°09’ and 4°13’ East of the Greenwich Meridian. The city covers a land area of 245 square kilometers. Iwo LGA shares its southern and western boundaries with Lagelu and Afijio Local Government Areas of Oyo State respectively. Additionally, it is bounded by Ola Oluwa LGA to the northeast and Ayedire LGA to the southeast, both within Osun State (see Figure 1). The term "Iwo and its environs" encompasses all settlements within these identified LGAs, Ayedire and Olaoluwa.

Iwo as one of the largest cities in Osun State, Iwo has been selected for study as it experiences rapid urban growth, leading to a densely populated area. A significant proportion of residents within

Iwo metropolis reside in substandard housing conditions that pose risks to their health and well-being. Challenges such as inadequate provision of clean and portable water, poor sanitation and drainage systems, low-quality housing, and limited access to healthcare facilities are prevalent. In general, the level of access to basic urban services like water and sanitation in Iwo is relatively low. The inner core of the area is densely populated with minimal infrastructure and social amenities. In most cases, accessibility is only available through footpaths.

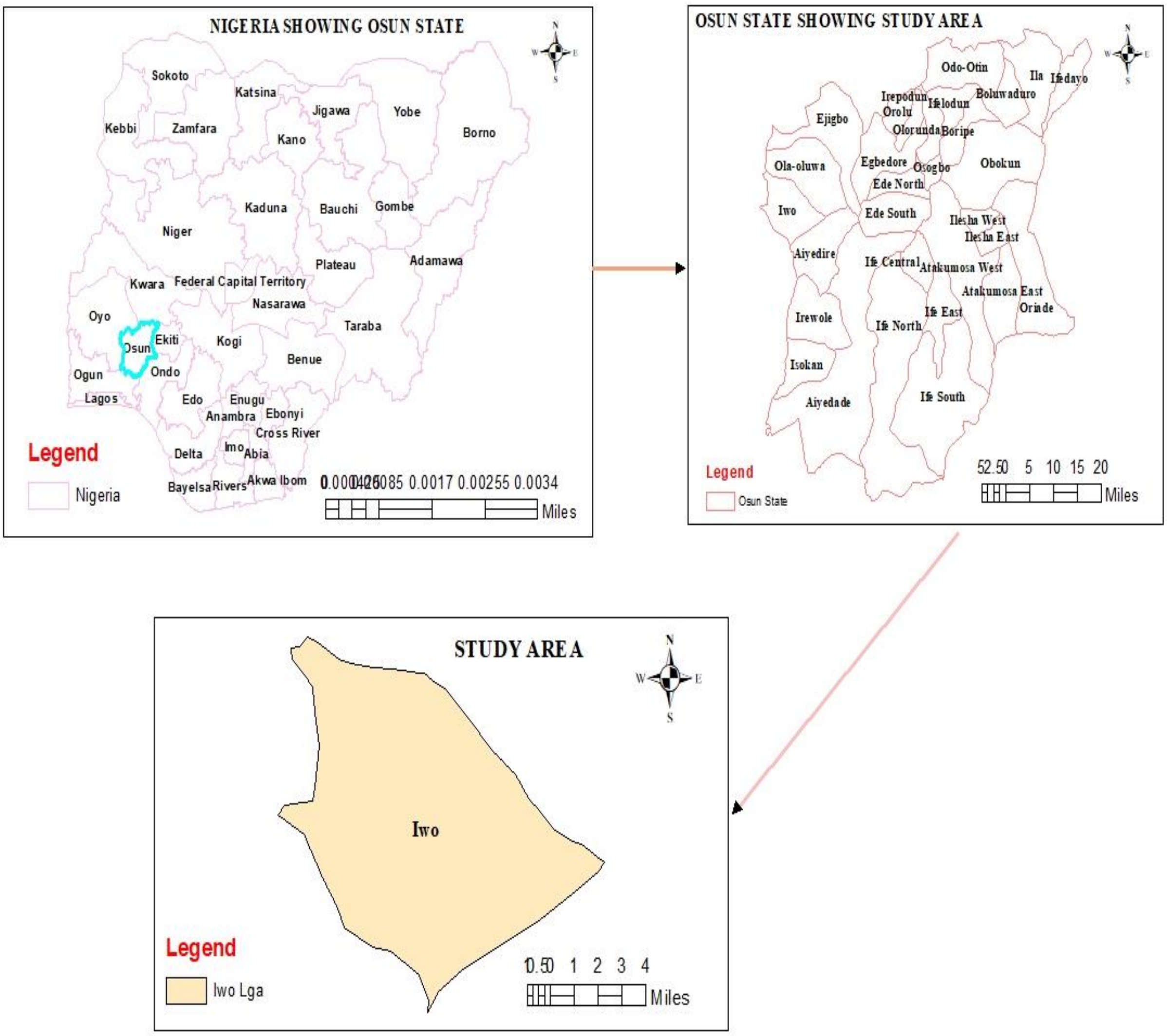

Figure 1-Map of Iwo Local Government

3. Methodological Procedures

3.1 Database Design

The database design process serves as a blueprint, outlining the intricate details of a database ranging from table relationships to the crucial data aspects and implementation strategies. Without a careful design, a database might fail to achieve its intended objectives. To translate the real world into a computerized format, we approach it through four levels of abstraction: the view of reality, conceptual design, logical design, and physical design (as depicted in Figure 2)

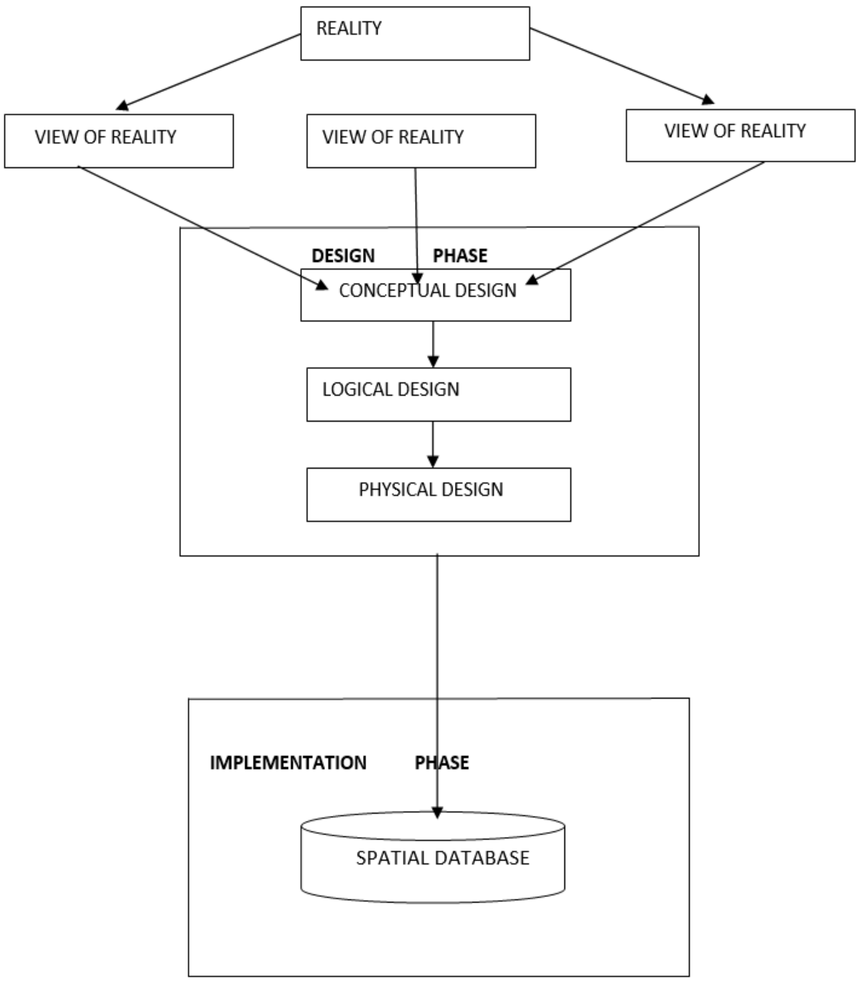

Figure 2 –Design and construction phase of spatial database (Kufoniyi,1998)

View of reality: This represents the mental abstraction of the relevant reality for a given application. The process formalizes the description or viewpoint at different levels of data abstraction. For this study, the view of reality is articulated based on geographic features, encompassing areas within Iwo metropolis, hospitals, roads, refuse dump sites, stagnant water bodies, and the topography of the area

Conceptual database design: This phase involves decisions regarding how the view of reality will be simplified while still satisfying user information requirements. The goal is to determine the fundamental entities, their spatial relationships, attributes, and modeling approaches to fulfill a specific organization's information needs. The entities generated, along with their corresponding entity-relationship diagrams, take the form of Building as a polygon, Area as a polygon, Hospital as a point, and Road as a line.

Entity relationship diagram: These diagrams illustrate the entities and their relationships. Rectangles represent entity types, while diamonds denote relationships. Arcs link relationships to their constituent entity types, with the degree of relationship indicated on the arc. The project employs entity types BUILDING, AREA, ROAD, and HOSPITAL. These are represented schematically (see Figure 3), and each area incorporates dump sites and water bodies.

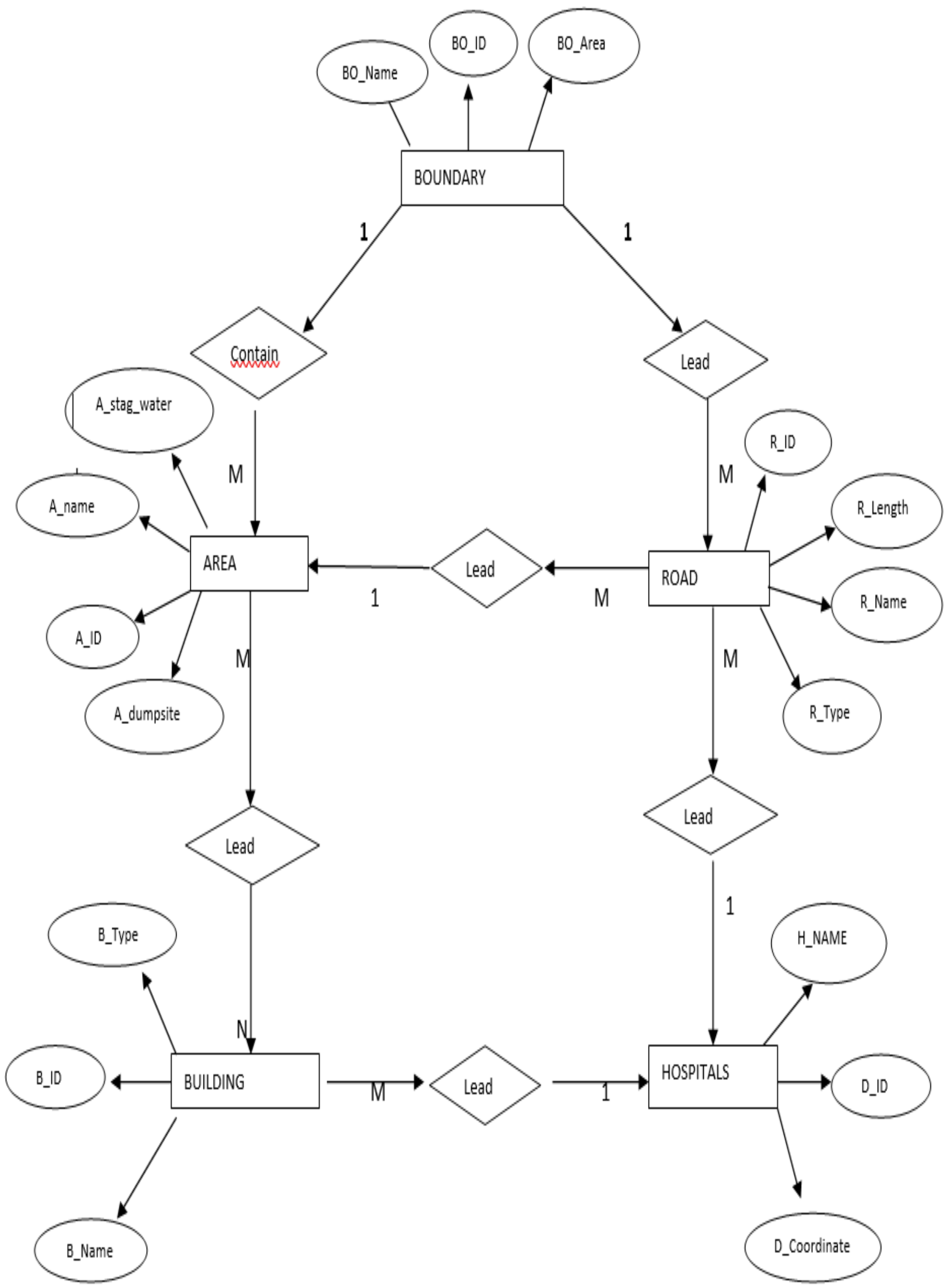

Figure 3 – Entity relationship diagram and their attributes

<u>Logical database design:</u> Within a relational data structure, data is stored in simple records called tuples or rows, containing sets of attribute values. This structure permits the presentation of tabular forms known as fields. It doesn't store pointers or hierarchy, making it user-friendly for applications like structured query language. The entities and their attributes are enumerated below;

- BUILDING (Bd id, Bd type, Bd address)
- AREA (A_id, A_name, No_of_D_S, No_ofStag_Water, Malaria_cases_year)
- HOSPITAL (H_id, H_name, X_Coord, Y_Coord, H_add)

Moreover, each of the entities with their description are presented in table and each table contains (i) field name and field description are show in the Table 1

Table 1- Description of Entity Types and their Attributes

	FIELD	**DESCRIPTION**
Area	A_id	Area Identifier
	Wd_name	Area Name
	No_of_D_S	Number of Dump Site
	No_ofStag_Water	Number of Stagnant Water
	Mal_cases_year	Malaria Cases per year
Building	B_id	Building Identifier
	B_type	Building Type
	B_add	Building Address
Hospital	H_id	HospitalIdentifier
	H_name	Hospital Name
	X_Coord	Latitude
	Y_Coord	Longitude
	H_add	Hospital Address
Road	R_id	Road Identifier
	R_name	Road Name
	R_type	Road Type
	R_length	Road Length

3.2 Data acquisition

This stage encompasses field procedures, methods, equipment used, and operations performed to gather the necessary data.

Sources of data: This is divided into primary and secondary source. Primary data source (Field Survey) is the coordinates of the dump sites and the hospitals were taken using hand held GPS and Secondary data source include the data gathered from various sources, the researcher collected information from research journals, internet services, high resolution satellite imagery of Iwo Local Government and hard copy of diagnosed malaria cases (Old and New) of adults above 18 years old.

3.3 System selection

Hardware requirements: The project employs the following hardware: (1) Computer System: Dell Inspiron 15 with Windows 8.1, 64-bit Operating System, 4.00GB RAM, and Intel Core i3 CPU 2127U @ 1.90GHz; (2) Handheld Global Positioning System (GPS): Garmin Extrex 10 for

geometric data collection; (3) Printer; (4) Storage Devices: External Hard Disk Drives, Compact Disc ROM, etc.
Software requirements: For this empirical analysis, the primary software utilized for computation, exploratory analysis, mapping, and visualization is ESRI ArcGIS version 10.8 by Environmental Systems Research Institute. This GIS software was selected due to its wide array of spatial statistical and geo-statistical modeling extensions, such as OLS, GWR, spatial autocorrelation, and other geostatistical analyst tools. These techniques aid in mapping spatial patterns, testing relationships, identifying variable redundancies, and facilitating geo-visualization.

3.4 Physical database design

During this stage, the data structure takes on the format of the implementation software. It's a high-level representation of data sets guided by well-defined constraints. Systems are selected, and data types are determined, based on the chosen software, ArcGIS 10.8. This phase typically initiates the database creation process. Table 2 outlines the physical design for the project, featuring entities, attributes, and the adopted data structures. The data is translated into tables structured within ArcGIS 10.8.

TABLE 3- RELATION, ATTRIBUTES AND THEIR DECLARATIONS

	FIELD NAME	DESCRIPTION	DATA TYPE	FIELD SIZE
Building	B_id	Building Identifier	ShortInteger	4
	B_type	Building Type	Text	15
	B_add	Buiding Address	Short Integer	15
Area	A_id	Area Identifier	ShortInteger	4
	A_name	Area Name	Text	25
	No_of_D_S	Number of Dump Site	Short Integer	3
	No_ofStag_Water	Number of Stagnant Water	Text	15
	Mal_cases_year	Malaria Cases per year	Text	20
Hospital	H_id	HospitalIdentifier	ShortInteger	4
	H_name	Hospital Name	Text	25
	H_Coord	Hospital Coordinates	Long Integer	20
	H_add	Hospital Address	Text	20
Road	Rd_id	RoadIdentifier	ShortInteger	4
	Rd_name	Road Name	Text	25
	Rd_type	Road Type	Text	20
	Rd_length	Road Length	Long Integer	20

3.5 Data creation

This is the actual storage of data into the software. After the database has been modeled and designed, the data is imputed into the software, in accordance with its data definition language, Arc GIS 10.8 was used for this project. Different tables were created for the different entities and populated with their attributes.

Table

Areas

FID	Shape *	Id	areas_name	2017_old	2017_new	2018_old	2018_new	2019_old	2019_new	2020_old	2020_new	2021_old	2021_new	no_dumpsit	no_stagnan
0	Polygon	0	OLUYORI AREA	7	11	39	43	29	61	20	44	22	49	3	1
1	Polygon	0	EBO-ALAWE	12	33	42	37	62	51	30	68	32	58	4	2
2	Polygon	0	OKE-AFO	35	41	31	62	46	30	37	57	10	29	3	1
3	Polygon	0	ALAYE COMMUNITY	33	21	47	60	74	55	33	44	21	47	2	1
4	Polygon	0	OLD OSOGBO ROA	10	23	36	52	62	39	49	60	21	58	4	2
5	Polygon	0	ODO-ORI	27	21	42	54	75	60	52	88	19	52	5	3
6	Polygon	0	FEESU	40	22	72	68	60	44	29	78	21	45	5	3
7	Polygon	0	OLOMO COMMUNITY	34	38	64	47	83	55	54	59	15	53	4	2
8	Polygon	0	OKE-IYE	26	20	50	46	62	56	54	71	24	48	5	3
9	Polygon	0	ADEEKE	23	33	54	45	30	38	21	33	12	44	3	1
10	Polygon	0	OLUPONA AREA	5	9	39	53	53	44	26	71	20	60	5	3
11	Polygon	0	PAAKU	29	24	55	47	42	53	36	45	14	43	3	1

Figure 4- Populated table for the area

Table

Hospitals

FID	Shape *	NAMES_OF_H	LATITUDES	LONGITUDES	address_of
0	Point	STATE GENERAL HOSPITAL	7.631693	4.200452	
1	Point	MOT HOSPITAL	7.63112	4.192088	Kuti junction
2	Point	DEE DIVINE GATE	7.623802	4.188382	Bowen road
3	Point	VICTORY HOSPITAL	7.63883	4.18032	Olumodan
4	Point	ALAYE PHC	7.633062	4.175427	Alaye
5	Point	ATIBA HOSPITAL	7.63583	4.173872	
6	Point	OLOBERE HEALTH CENTER	7.639045	4.165436	Olobere
7	Point	IWO MODEL PHC KARA	7.646387	4.165287	
8	Point	IWO MEDICAL CENTER	7.655457	4.188665	Odo ori
9	Point	FEESU HOSPITAL	7.645559	4.179533	Feesu
10	Point	PHC MOSINOLA	7.628792	4.172557	Oke ola
11	Point	VICTORY HOSPITAL	7.626965	4.161054	Adeeke

Figure 5-Populated table for hospital

Table

Roads

FID	Shape *	osm_id	name	ref	type	length
0	Polyline	366312415	Iwo - Ejigbo Road		secondary	1996.741
1	Polyline	371807538	Olupona - Iwo Road		tertiary	411.146
2	Polyline	371807540	Lawyer Adeogun Street		unclassified	1467.135
3	Polyline	371807541			residential	496.334
4	Polyline	371807543			tertiary	1686.977
5	Polyline	371810321	Awo - Iwo Road		secondary	2227.778
6	Polyline	371810322	Lawyer Adeogun Street		unclassified	530.69
7	Polyline	372164432			unclassified	1231.969
8	Polyline	384007348	Ibadan-iwo Rd		tertiary	947.219
9	Polyline	384007352	Testing Ground		tertiary	2585.965
10	Polyline	384139329	Testing Ground		secondary	5139.037
11	Polyline	384147955	Aponlogo		unclassified	756.173
12	Polyline	384147957	Palace Roads		residential	401.895
13	Polyline	384147958			unclassified	485.735
14	Polyline	384147960	Melegbe Street		residential	1144.2
15	Polyline	384147962			residential	227.934
16	Polyline	384147963	Adake jct		secondary	4028.176
17	Polyline	384147964			residential	455.407
18	Polyline	384147966			unclassified	945.926
19	Polyline	384147968	Iyana Elewe Street		unclassified	1047.122
20	Polyline	384147971			residential	352.23
21	Polyline	384147974			residential	243.004
22	Polyline	384147976	Ologun Village Road		residential	248.546
23	Polyline	384147978			residential	349.408
24	Polyline	384147981			residential	766.868
25	Polyline	384147983	Eleke Street		residential	212.564
26	Polyline	384147985			residential	801.277
27	Polyline	384147987			residential	499.676
28	Polyline	384147989			residential	525.628
29	Polyline	384147992			residential	738.1
30	Polyline	384147994			residential	505.731
31	Polyline	384147997			residential	1012.946
32	Polyline	384147999			unclassified	940.556
33	Polyline	384148001			residential	379.776
34	Polyline	384148004			residential	659.855
35	Polyline	384148007			residential	710.645
36	Polyline	384148010			residential	567.877
37	Polyline	384148012			residential	782.752
38	Polyline	384148015			residential	605.903

Figure 6- Populated table for road

3.6 Database management systems

Database management is the collection of software and hardware for organizing the information in a database. It consists of a set of programs that enable creating, storing, updating,

manipulating, organizing and querying information in a database. The objective of this in this project is to facilitate data integrity, ensure data security and maintenance.
Database security is a paramount importance to spatial information management because of the nature and legal significance of the records in a spatial database. In this study the security measures include creation of backup copies for all computers files and the use of passwords to protect data against access to unauthorized users.
Database integrity These measures were put in place in this project to ensure quality of data input and output. This starts with how accurate and reliable the data obtained were. One of the measures adopted in maintaining the integrity of data is the verification and cross checking the reliability of locational and attribute data for the project.
Data maintenance Proper observance, updating and management of database ensures its currency and quality for a proper Decision Support System (DSS). For this project to meet the above requirement, the storage media will from time to time be preserved by error checking and defragmentation. Also, the database will be programmed for virus scan at a particular interval, as well routine assessment of the system for physical deterioration.
Data quality In this project, data quality was maintained by taken data from the State General Hospital located within the study area.

4. Analysis and Presentation of Results

GIS software is capable of performing certain analyses which other information systems do not perform. GIS software aids to carryout various spatial analyses such as buffering, network analysis, overlay, clustering and so on. The spatial analytical capabilities of GIS such as buffering, union, spatial search etc. All these capabilities distinguished it from any other type of information system. The analyses that were performed include spatial search, buffering, service area, neighborhood and trend pattern analysis.

4.1 Criteria for malaria treatment center demand

In this research the criteria followed according to World Health Organization are thus;

(i) Access distance of 5 minutes in vehicle travel time or 1000m walking distance where density permits as the service area or zone of influence around treatment site. (WHO 2007)

(ii) The health care should not be sited at curve junctions of distribution for safe reason. (WHO 2007)

(iii) The health facility should be of distance not more than 20m from the major road. (WHO 2007)

4.2 Composite map of the study area

The composite map of the area consists of the location of all dump sites and hospitals. Also included in the composite map are road and buildings.

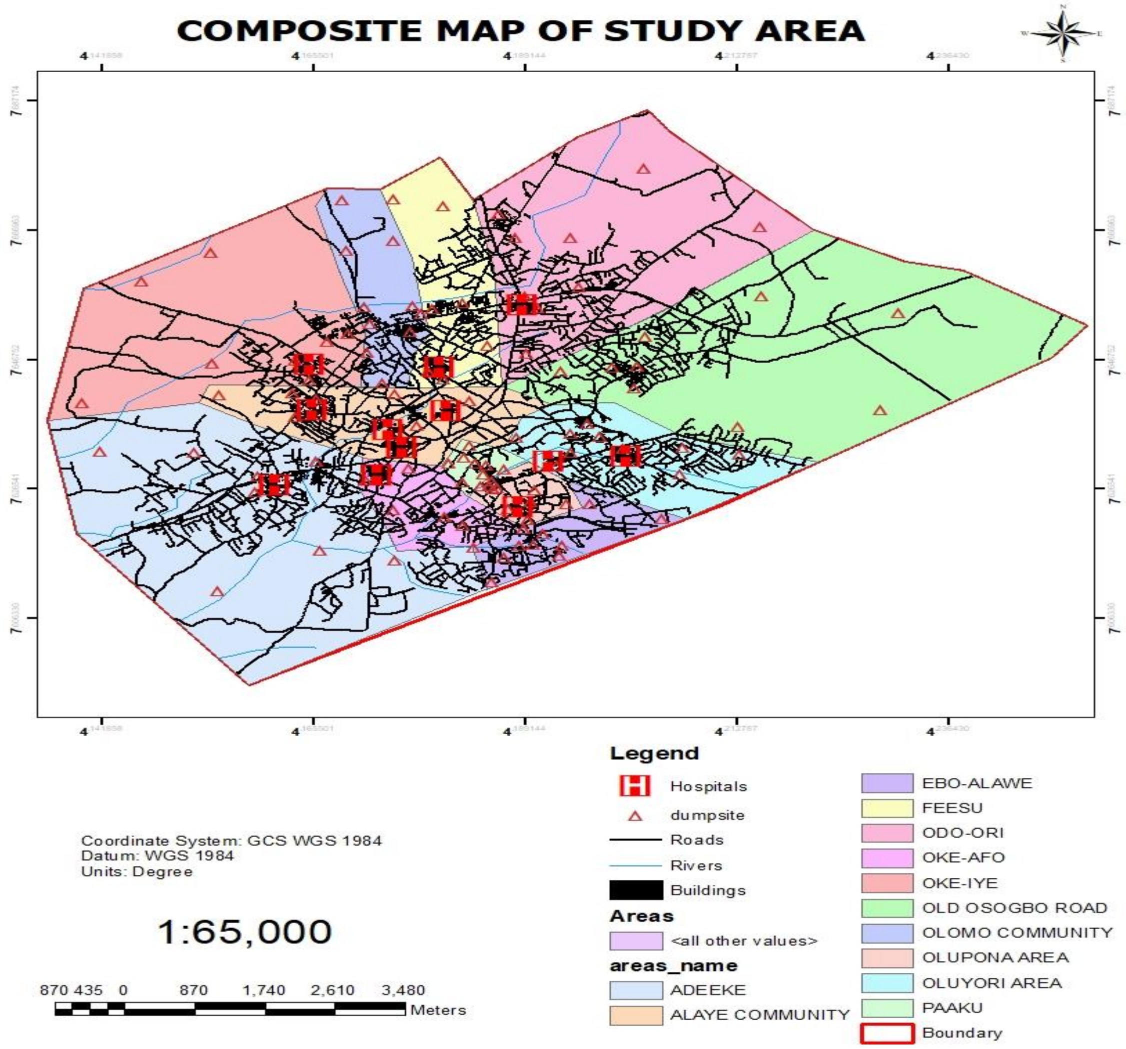

Figure 7- Composite map of Iwo metropolis

4.3 Testing of database

The databases created underwent rigorous testing through various analyses conducted within this project, employing spatial queries. A query constitutes the process of extracting information from a database based on specific predetermined criteria. This capability was achieved due to the logical and systematic relationship/link established between geospatial data and attribute data within the study area. Consequently, this enabled the database to respond to spatial queries aimed at addressing questions such as 'what is where'. Within the study area, two primary spatial search operations were undertaken: single criterion queries and multiple criteria queries.

<u>Single criterion query</u>

This was used to retrieve necessary information by posing query to answer simple generic question.

Query for Malaria Areas "2017">=23

The single criterion query was done using selection by Attributes of areas affected by malaria in 2017 using the syntax SELECT CASE_2017 FROM (AREAS) GREATER or EQUAL TO 23 CASES CONFIRMED. Figure 8 shows the areas affected mostly by malaria in 2017 which are Olomo Community, Paaku, Oke-Afo and Adeeke.

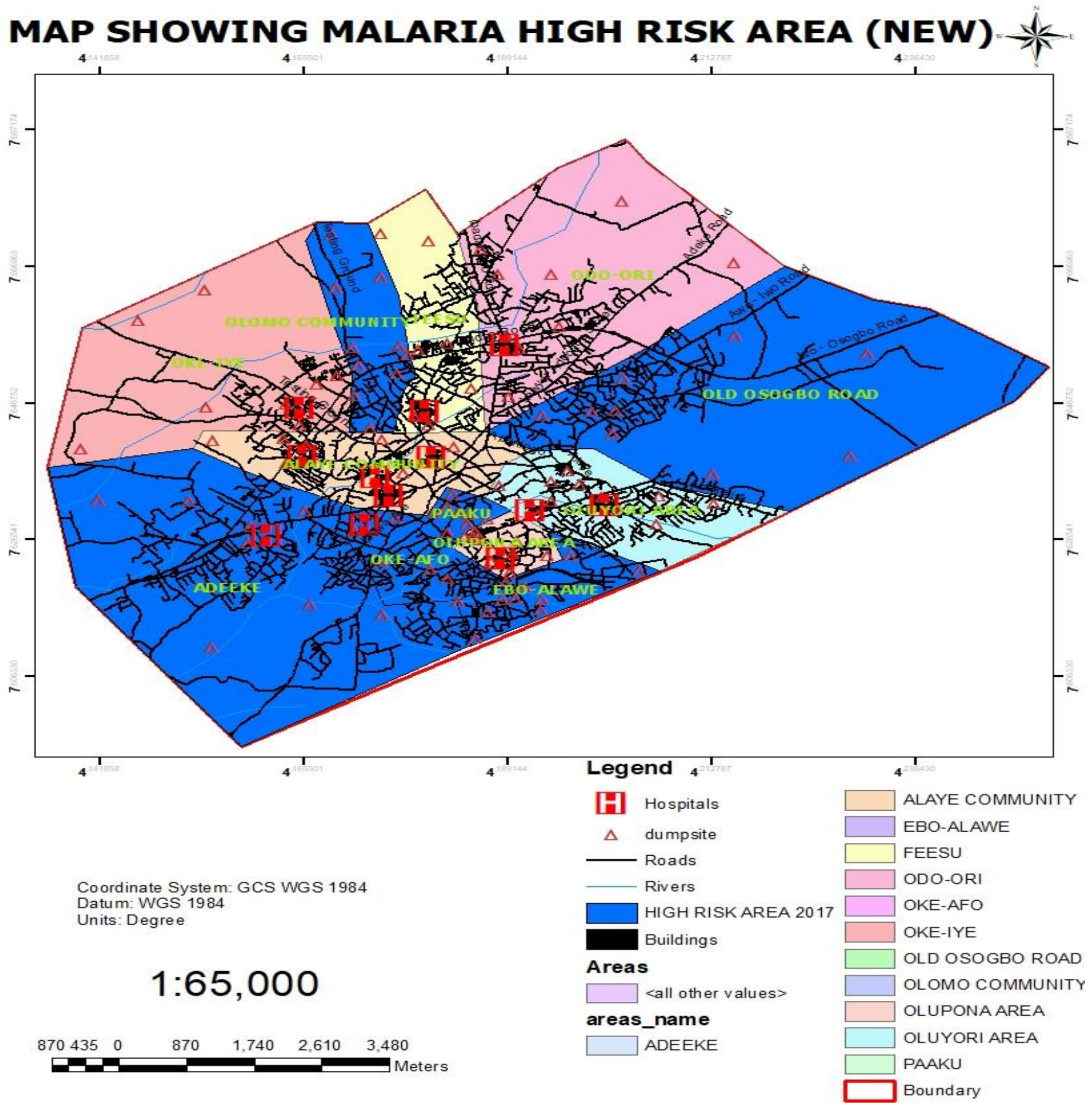

Figure 8-Map showing malaria high risk areas “2017”>=23

Query for Malaria Areas "2017"<=23

Likewise, the single criterion query was done using selection by Attributes of Areas affected by malaria in 2017 using the syntax SELECT CASE _2017 FROM AREAS LESS THAN 23 CASES CONFIRMED. Figure 9 shows the areas that are less affected by malaria in 2017 are Oluyori area, Alaye Community, Feesu, Oke-Iye and Oluponna Area. Thus, it reveals that there might be few factors that aids the low spread of malaria among the inhabitants in the study area.

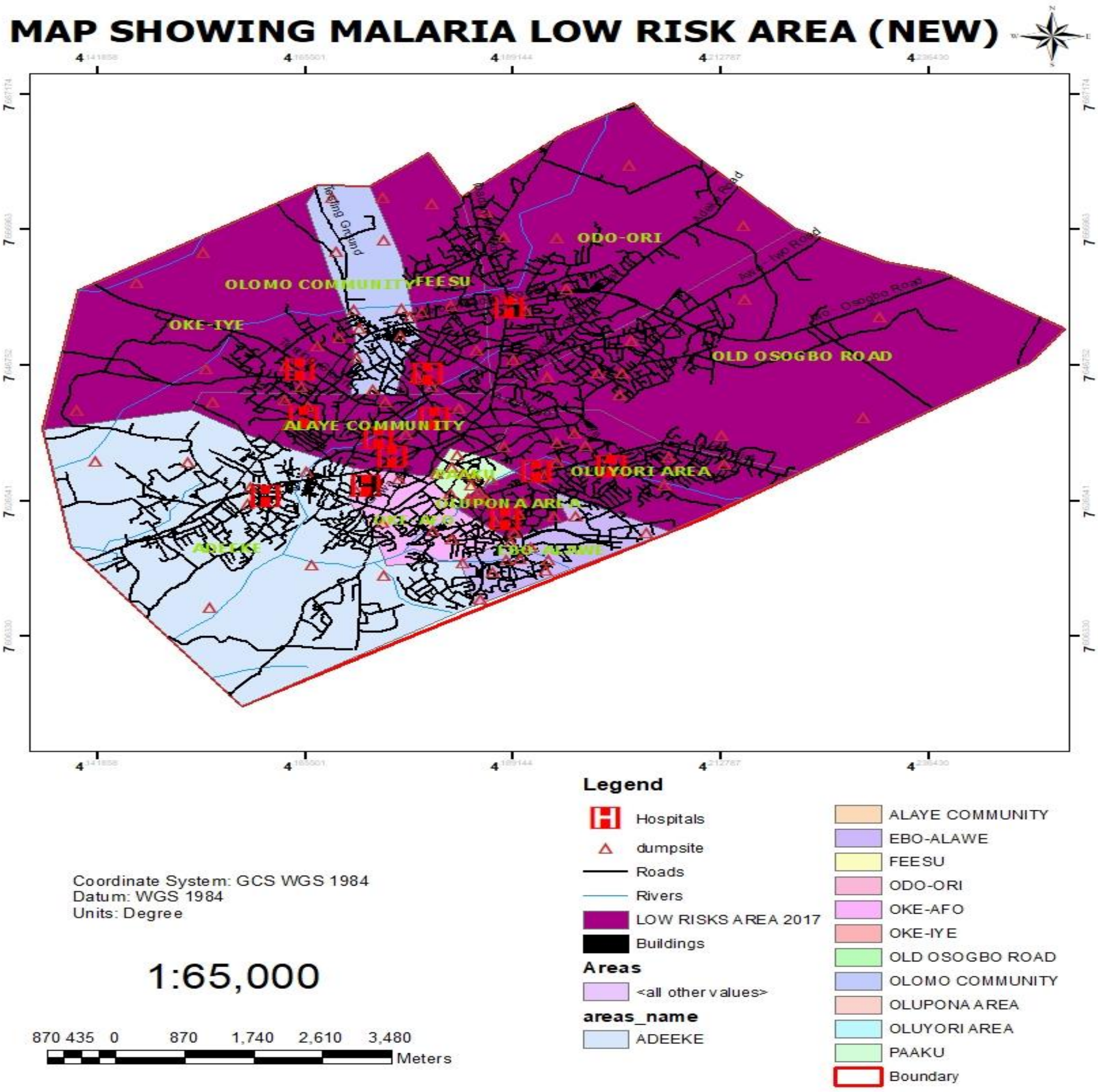

Figure 9-Map showing malaria low risk areas "2017"<=23

<u>Multiple criteria query</u>

Multiple criteria queries were performed to query for highest number of dump site considered as one of the factors influencing malaria prevalence.

Query for Malaria Areas "2017" >=23 and "No _of D_S">=8

This query is performed using syntax SELECT CASE_2017 FROM AREA GREATER THAN OR EQUAL TO 23 CASES CONFIRMED AND NUMBER OF DUMP SITE GREATER THAN OR EQUAL TO 8. Figure 10 shows that six areas affected by malaria prevalence in 2017 and having the highest number of dump site greater than and equal to 2 are Olomo Community having 38 malaria cases in 2017 and 4 dump sites and Oke-Afo having 41 malaria cases and 3 waste points. Whereby the increase in the number of dump sites might be the major cause of malaria in those areas. Other areas that have high malaria prevalence include Paaku, Oke-Afo and Adeeke.

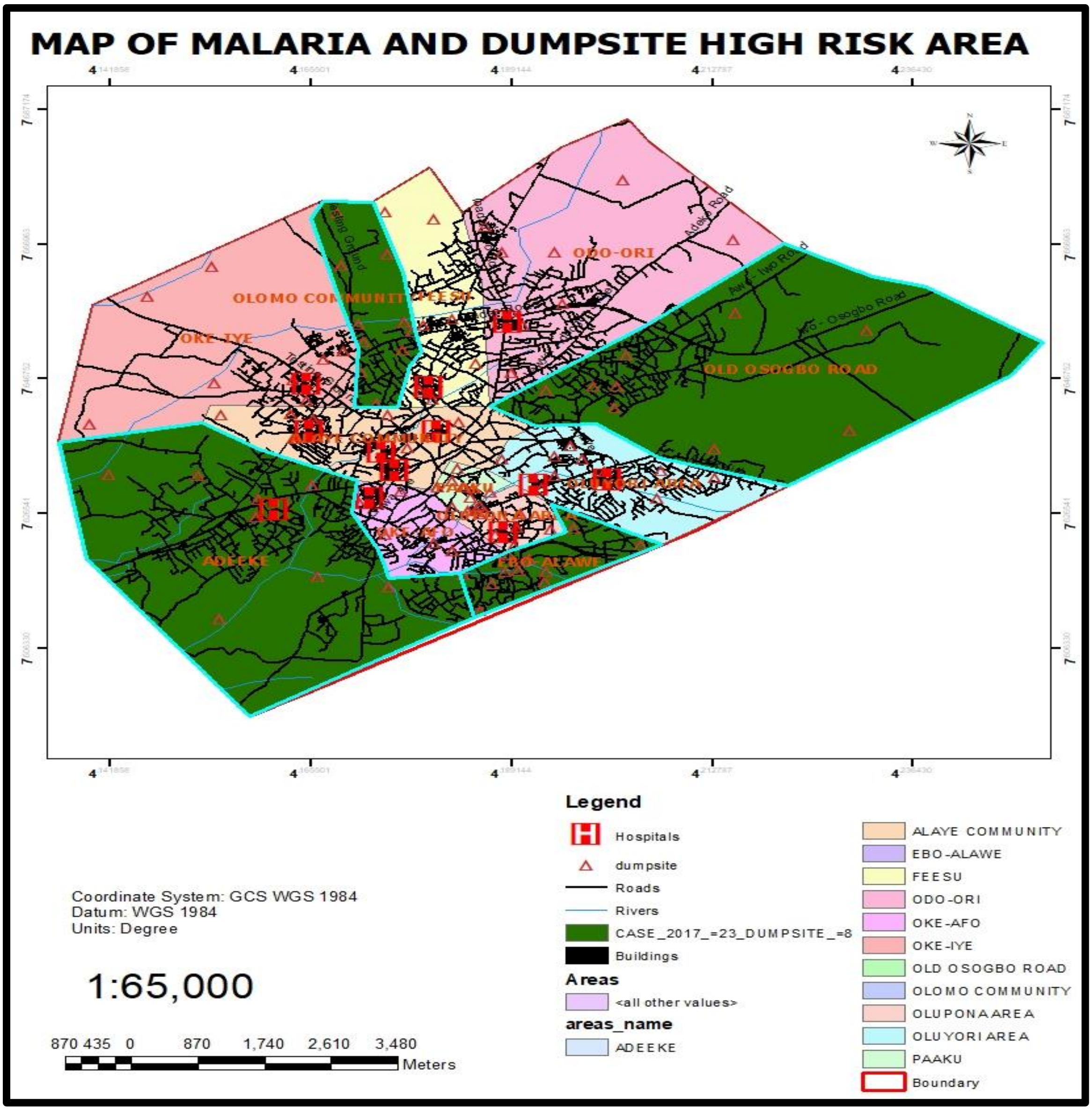

Figure 10- Map showing malaria and dump site high risk areas “2017”>=23 and “No _OF_DUMP_SITE”>=8

Query for Malaria Areas “2017” <=23 and “No _of D_S”<=8.

Likewise, another query was performed using syntax SELECT CASE_2017 FROM AREA LESS THAN OR EQUAL TO 23 CASES CONFIRMED AND NUMBER OF DUMP SITE LESS THAN OR EQUAL TO 8. Figure 11 shows that Oluponna Area, Alaye area, Oke-Iye are less affected by malaria in 2017 with less number of dump sites.

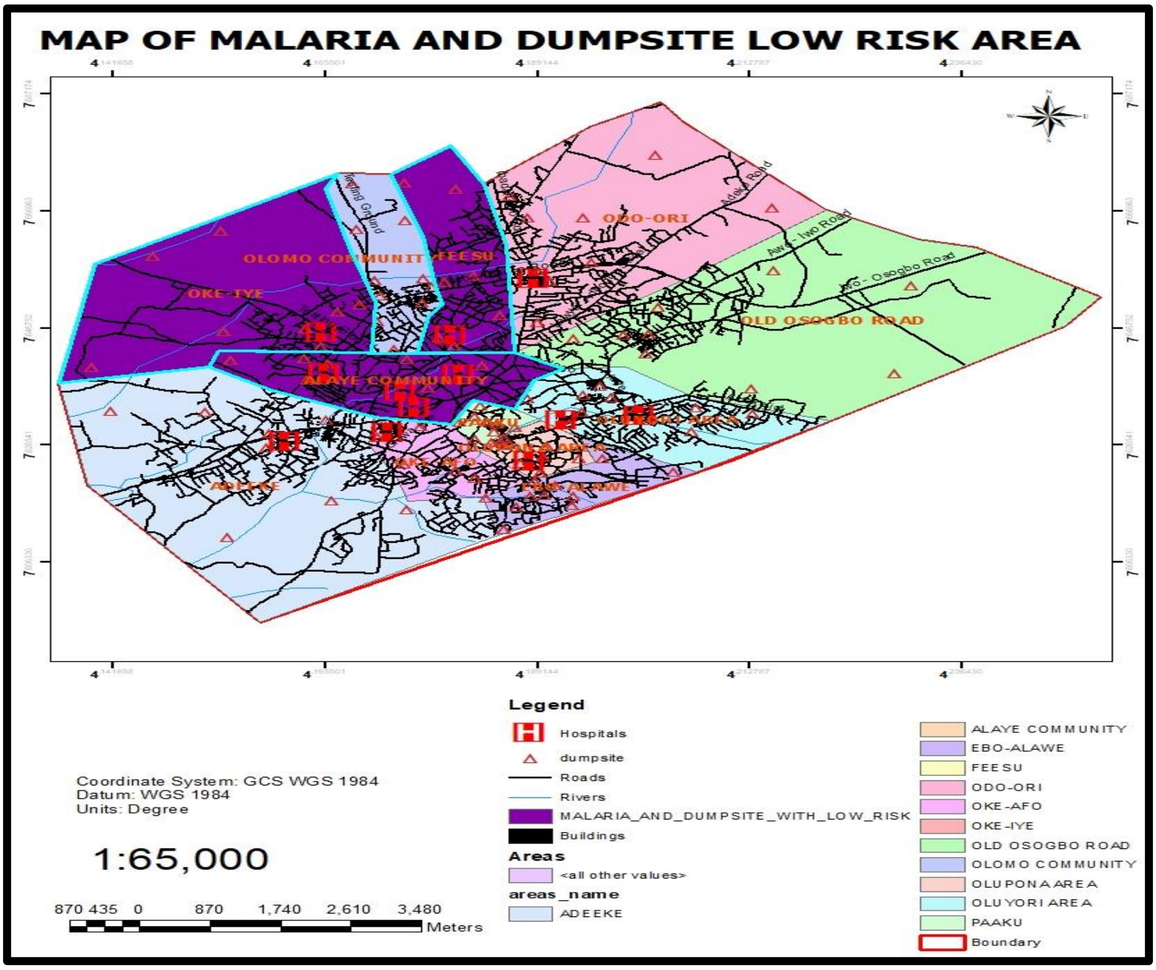

Figure 11- Map showing malaria and dump site low risk areas "2017"<=23 and "No _OF_D_S"<=8

4.4 Spatial analysis

Spatial analysis is the process of extracting or generating new information about a set of geographic features to perform routine examination, assessment, evaluation, analysis, or modeling of data in a geographic area based on pre-established and computerized criteria and standards. This section explains the spatial analysis performed for buffering operations, service area determination, trend analysis, and neighborhood assessment

Buffering operation Buffering operation creates zones consisting of areas within a specified distance of the selected features. It was utilized in this project to determine the level of travel time or 1km walking distance where densities permit as the service area or the optimum distance zone of influence around the treatment site. To justify these criteria in the sitting of the treatment center in Iwo Local Government, a buffer distance of 1km was created around the treatment center, to serve as the service area based on the earlier stated criteria. This was used to determine the population that is being served and those that are underserved. The result of the 1000m buffer on the hospitals, as seen in Figure 12, shows those areas being covered within a specific location. For example, Alaye Community, Oke-Afo, Paaku, and Oluponna area are well-served because they have adequate access to hospitals within the range of 1000 meters as specified by WHO 2007. However, some areas such as Ebo Alawe, Old Osogbo road, Oke-Iye, and the larger percentages of the periphery area...

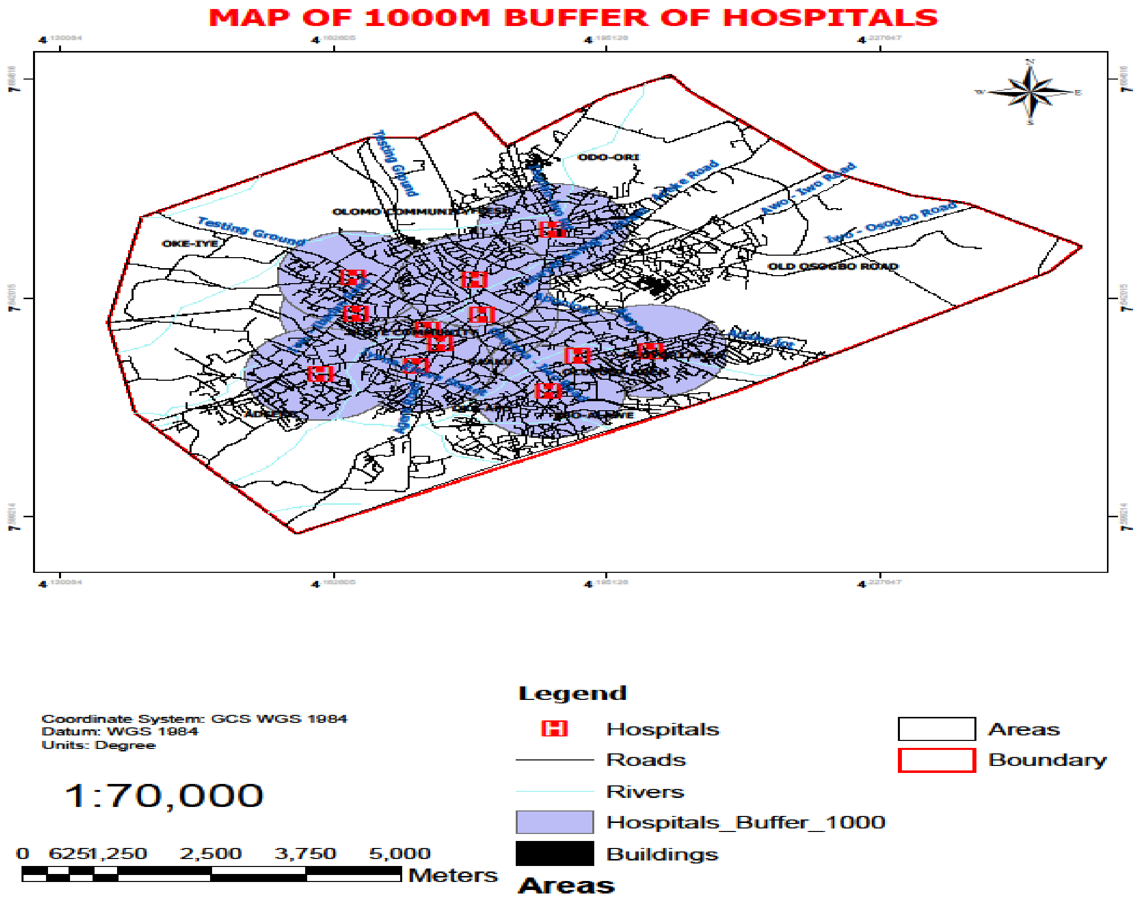

Figure 11-Map showing buffer of hospitals by 1000m

4.5 Trend analysis of malaria cases from 2017 to 2021

Trend analysis of malaria cases (old)

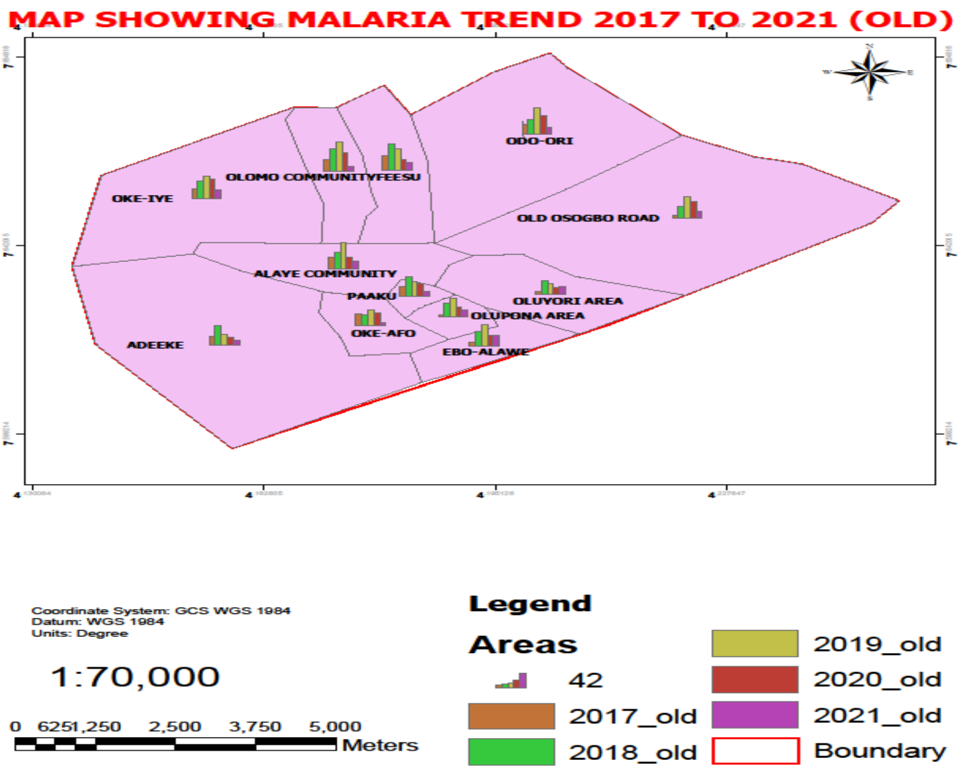

Figure 12 Map of malaria trend from 2017-2021 (old cases)

4.6 Service area

A network service area is a region encompassing all accessible streets within a specified impedance. This shows how far a facility can service in a road network or the distance a service can reach to provide their service. For example, this analytical tool will help medical personnel to know how far an ambulance can service from a starting point facility (hospital) within an allotted amount of time.

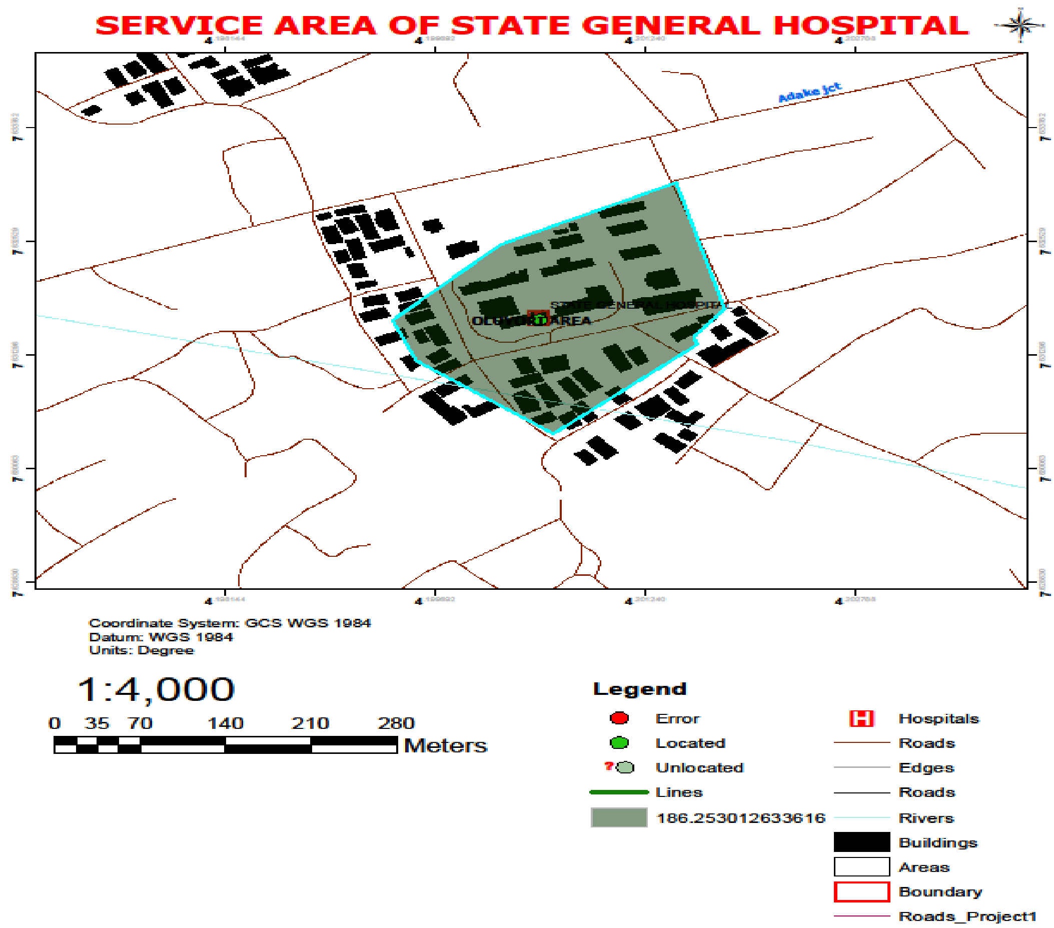

Figure 12- Map of service area of state general hospital

4.8 Neighourhood analysis

<u>Neighborhood Operation of Hospitals</u>

Figure 4.18 shows the result of the nearest neighbourhood analysis for the hospital within Iwo metropolis. The Table shows that an observed mean distance of 819.0764 Meters between the hospitals was recorded with an expected mean distance of 533.7305 Meters. The analysis also recorded a nearest neighborhood ratio of 1.534626, while a z-score of 3.543001and a p-value of 0.000396 was recorded. Therefore, given a z-score of 3.543001, it implies that the spatial distribution pattern of all the hospitals is dispersed (Figure 4.18). Given the z-score of 3.5433001, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

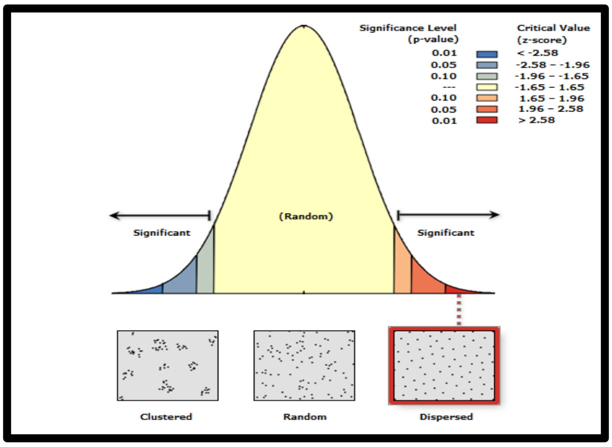

Figure 4- Neighbourhod operations of hospitals

Table 4- Average nearest neighborhood for the hospitals

Observed Mean Distance:	**819.0764 Meters**
Expected Mean Distance:	533.7305 Meters
Nearest Neighbour Ratio:	1.534626
z-score:	3.543001
p-value:	0.000396

5. Conclusion

Malaria prevalence in Nigeria follows a marked of spatial pattern and the risk rate at which the State or Local Government level is positively correlated. The prevalence of malaria in the selected study area based on the secondary data collected from the State General Hospital attest to the fact that some areas are higher than each other due to the accessibility to the health facility, and environmental factor such as waste site points and stagnant water considered in the research. Understanding the spatial distribution will enhance the efficiency of the prevention efforts which will help policy maker, stakeholders, healthcare providers, health workers in health sector to respond positively to the information needs of the people that are affected by the scourge of malaria and to sensitize people, also, by identifying such risk factors and exploring avenues to improve access to malaria treatment centers and other response required. The study Area was divided into Areas which enable analysis to be carried out on the input data. Part of the risk factor that enhance the spread of malaria within those Areas was identified and its attributes stored in the database in which can serve as decision support system.

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