Appraising Malaria Incidence with Spatial-Oriented Decision Support System in Parts of Zaria, Kaduna State-Nigeria

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Abstract: Prevalence of malaria in certain parts of the world without adequate planning and monitoring based on ill-informed decisions has wreaked havoc on the health system and economy of many developing nations. The purpose of this study is to create a functional Spatial Decision Support System (SDSS) for malaria monitoring in parts of Zaria, Kaduna State. A Geographic Information Systems (GIS) SDSS was created using ArcGIS 10.5 software for the 2019 Malaria data obtained from the Ministry of Health, Kaduna State Roll Back Malaria (RBM) Programme for collation and analysis across 13 political wards in Zaria Local Government Area (LGA) of Kaduna State. The results revealed that a total of 443,852 cases of malaria were reported across the 13 political wards of the study area. The reported cases had predominant occurrences at the Gyellesu ward, followed by the Kwarbai A ward. The spatial incidence was displayed via vector control maps, malaria burden maps, malaria prevalence in Zaria maps, and service area maps. The map of demography indicated a higher prevalence of malaria of 73.35% for the male gender compared to the female (26.65%). However, the independent t-test revealed no significant difference between males' and females' malaria prevalence. It was also revealed that the adult population had the highest malaria prevalence followed by children less than 5 years while pregnant women were the least infected. The study further indicated that 38.5% of the existing political wards recorded a shortfall of at least two (2) healthcare facilities. This study identified areas that required the establishment of health facilities to offset the existing shortfall. The SDSS was able to effectively monitor and appraise malaria incidence for proper surveillance and management that will be required for malaria prevention and elimination activities. The study recommends that policymakers invest in the deployment of an SDSS for better and robust planning, monitoring and execution of their malaria intervention programmes as this aligns with the sustainable development goal (SDG) target 3. 3.

Keywords: Geographic Information System, Health Facility, Malaria Monitoring, Malaria Prevalence, Spatial Decision Support Systems.

1. Introduction

Malaria is one of the major causes of mortality in different parts of the world (Idowu et al., 2009). It is caused by the plasmodium parasite and transmitted by an infected female anopheles' mosquito when it bites a person (Besansky et al., 2004; Awosolu et al., 2021). Malaria has wrecked the economy and health system of many nations particularly in developing nations where it is more prevalent (Ahuru and Omon, 2018). Africa has been reported to be the worst hit by malaria as 80% of the 90% of global cases come from Africa (WHO, 2017). The WHO (2021) further reported that about 95% of all malaria cases and 96% of deaths were recorded in the African Region in 2020. The impact was mostly observed in children below the age of 5 years as over 80% of malaria deaths were reported in the Region. Hence, to achieve meaningful success in the fight against malaria globally, Africa needs to be given maximum attention.

In Nigeria, malaria remains one of the major causes of death (Bamidele et al., 2012). WHO (2021) reported that Nigeria accounted for 31.9% of malaria deaths globally in 2020. These results have pushed Nigeria to intensify the use of Long-Lasting Insecticidal Nets (LLIN) over the initial treatment approach adopted for the control of malaria (Omitola et al., 2021). Despite this, malaria continues to spread because the mosquitos still bite when people are not under the LLINs. This situation suggests the need for renewed research efforts into new tools and approaches to support malaria surveillance, control and elimination for the well-being of the populace (Idowu et al., 2009).

In line with this, many research efforts have been made to curtail the effect of malaria in Nigeria. In a community-based study, Dawaki et al. (2016) designed and investigated the prevalence and risk factors of malaria, and evaluated the knowledge, attitudes and practices (KAP) regarding malaria among rural Hausa communities in Kano State, Nigeria. The study revealed that malaria was still highly prevalent among rural Hausa communities in Kano State as significant gaps persisted inappropriate preventive practices.

Sturrock (2013) and Wangdi et al. (2016) opined that for malaria to be eliminated in any location, sustained effort is very fundamental. In the light of the foregoing statistics and trends, it is obvious that the steps taken towards malaria prevention and elimination in Nigeria, and in particular, Zaria are not completely effective. This gives room for further research that will enhance planning and coordination for effective malaria prevention and elimination.

This research aims to create a functional SDSS for malaria monitoring in parts of Zaria, Kaduna State, with the view of providing an effective system for planning and management of malaria. This was achieved through the following objectives; to carry out Geographical

Reconnaissance (GR) survey to map, define and quantify target population and household structures; and to develop a simple GIS-based SDSS to serve as the framework for adequate planning and coordination of improved malaria prevention and elimination in parts of Zaria.

2. Study Area

The study area is Zaria in Kaduna State (Figure 1). It is located approximately between Latitudes 11° 08' 11.7" and 11° 57' 43.0" North of the Equator and between Longitudes 7° 36' 33.9" and 7° 48' 08.1” East of the Greenwich Meridian. The city has a height of about 660m above mean sea level (Yusuf and Shuaib, 2012) covering an area of about 411.18 km². It is zoned to Kaduna North Senatorial District alongside Kubau, Ikara, Makarfi, Soba, Lere and Kudan Local Government Areas (LGAs). Zaria is bounded by Sabon Gari LGA to the North, Igabi LGA to the South, Soba LGA to the East and Giwa LGA to the west. The population of Zaria is about 565,571 people making it the second-largest city in Kaduna State.

The climatic condition of Zaria is a tropical savanna climate, with distinct wet and dry seasons each season lasting about six (6) months (Aliyu and Botai, 2018; Azua et al., 2020). The region falls within the Guinea Savannah vegetation. The climax vegetation of the area ought to be northern Guinea Savannah, but because nearly all vegetation within the stream system has been degraded due to human activities, the real climax vegetation is almost absent. What is seen presently are a few scattered trees interspaced with tall tree grasses about 1-15m and 2-5m, respectively (Nyagba, 1986).

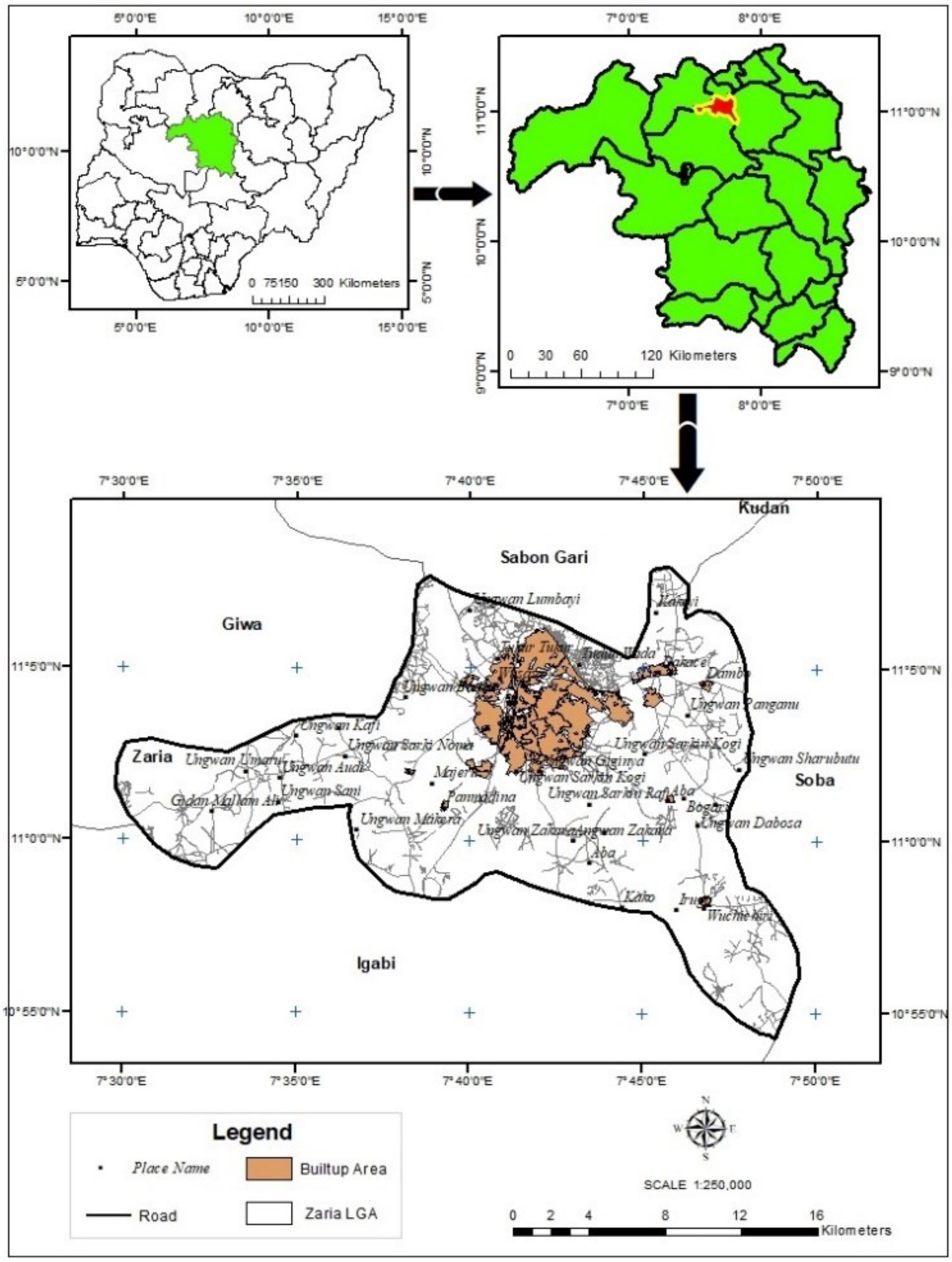


Figure 1. Map of the Study Area: Top left; Map of Nigeria: Top right; Map of Kaduna State: Bottom; The Study Location

3. Methodology Flow Diagram

The workflow diagram adopted in this study is shown in Figure 2. It entails the data capture, processing, analysis and presentation of reports.

4. Materials and Methods

4.1 Materials

The Data types used in this study include the primary and secondary datasets, which were obtained from reliable sources as shown in Table 1.

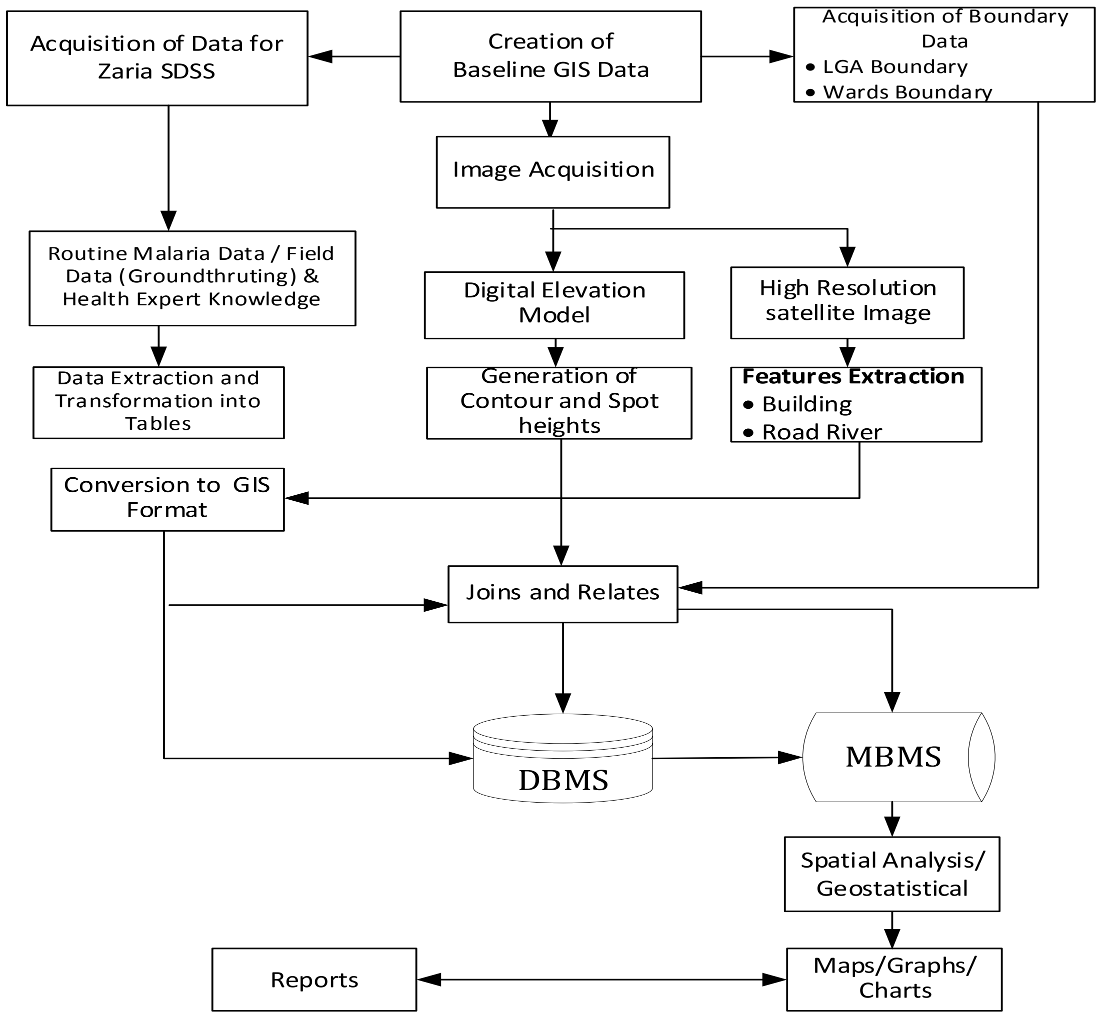


Figure 2. Workflow Diagram

Table 1. Datasets Used

S/N	Dataset Type	Name	Source/Year	Resolution
1.	Secondary	Google Earth Satellite Imagery/SPOT	Google Earth	2.5m × 2.5m
2.	Secondary	LGA Boundary	UN-OCHA Nigeria	N/A
3.	Secondary	Ward Boundary	GRID3	N/A
4.	Secondary	Malaria Intervention Data Elements	RBM M&E Kaduna State/2019	N/A
5.	Secondary	List of Primary Health Care	KSPHCDA	N/A
6.	Secondary	The population of study wards	GEOPODE (2019)	N/A
7.	Secondary	SRTM Elevation Data	USGS Earth Explorer/2016	30m × 30m
8.	Primary	Geographic Reconnaissance	Ground-Truthing/Field work	N/A

UN-OCHA – United Nations Office for the Coordination of Humanitarian Affairs, Nigeria.
GRID 3 – Geo-Referenced Infrastructure and Demographic Data for Development
RBM M&E- Roll Back Malaria Monitoring & Evaluation, Ministry of Health, Kaduna State
KSPHCDA - Kaduna State Primary Health Care Development Agency
GEOPODE (2019). Geographic Population and Demographic Data
N/A – Not Applicable

4.2 Methods
First, the extent of the satellite imagery covering the study area was determined using the administrative boundary map of Zaria LGA. This was followed by the creation of spatial layers such as roads, railways, water bodies and buildings from the satellite imagery using the ArcMap version 10.5 software.

Second, Geographic Reconnaissance (GR) was carried out to verify spatial locations. This method has been used successfully by Kelly (2010) and Ojo et al. (2016). A random selection of about seven (7) health facilities was visited for field verification and to acquire the spatial locations of these facilities. During the capture of the spatial locations of the facilities, the location serial number generated by the GPS receiver was recorded against the facility names in the field book to ensure easy tracking. The data was then downloaded and filtered using the Garmin MapSource Software V.5 and Microsoft Excel spreadsheet. All points were plotted on the satellite imagery and checked to be okay.

Third, the malaria datasets acquired contained about Seventeen (17) key malaria data elements and indicators, categorised as General attendance, Pregnant women got Intermittent Preventive Treatment (IPT) & Long-Lasting Insecticidal Nets (LLIN), Children who got LLIN, Persons with uncomplicated malaria, Persons with severe malaria etc. All the data were accounted for at the various health facilities throughout 2019. Generally, the data was figure based, with spatial references.

The data was extracted by collating certain data elements (such as attendance to health facilities and persons with malaria) into monthly, quarterly and annual since each of the data elements is facility-based, each having a coordinate and a primary key of Zar1 to Zar48 to easily transform the data into usable and acceptable GIS format. The datasets were then loaded into the DBMS and linked to WGS 1984 UTM Zone 32N as a spatial reference.

4.3 Data analysis and interpretation
The maps of people with malaria for the year 2019 were created from the Zaria wards layer. Five (5) maps were created, four (4) of them were prepared for each quarter (Q) of the year namely; Q1, Q2, Q3 and Q4 and the fifth one showed the annual malaria. During the map creation, the Z values used were the aggregate of persons presented with malaria in 2019 and a different colour ramp was employed. Other maps created include malaria prevalence maps, malaria burden maps and service area maps amongst others. The malaria Prevalence map combined a 3D stacked bar chart using the aggregate data values of children under five years, pregnant women and adults with confirmed malaria cases as input. Both maps had health facilities as the reference point.

The Service area map was produced using the Network Analyst tool where the roads, buildings and health facility locations layers were employed as inputs data. Firstly, a new network dataset was built to create network elements, establish connectivity and assign values to defined attributes, using the roads layer as a source feature. Then, the health facility feature was loaded as reference locations where the service area emerged from the predefined distances of 500 metres. This measurement was adopted from Masoodi and Rahimzadeh (2015) who stated that the maximum distance a patient is expected to travel to the health centre is 500m. However, different polygon colour codes were used to signify varying distances from a given health facility as used by Abduselam et al. (2020). Further analysis was carried out on the health centres and the required serviced population. This was done based on the guidelines provided by the WHO (2012) in Eta et al. (2021) which stated that each health centre should service a maximum population of 10,000.

5. Results and Discussion

5.1 Persons with malaria
Malaria is a deadly disease with a huge burden that affects the health system and growth of many nations. Therefore, providing valuable information to decision-makers on the level of malaria prevalence in Zaria is very vital for its management and control. Figure 3 shows the first, second, third and fourth quarter cases of malaria in the study area while Table 2 summarised all the results for the first, second, third and fourth quarters. The malaria prevalence in the first quarter (Figure 3a) appears to be higher at Dutsen Abba indicating 2,206 which represents 18.95% of the total cases reported, Wuciciri had 1,566 which represents 16.45%, Kufena had 1,447 which represents 12.43% and Kwarbai B had 1,557 which represents 13.38%, while Kaura had the least cases of malaria with 238 which represent 2.10%.

In the second, third and fourth quarters (Figure 3b, c and d), it was observed that Dutsen Abba had the highest number of cases of about 4567 (22.83%), 5646 (18.60%) and 4488 (13.45%), respectively. This was equally followed by Gyellesu with 3063 (15.31%), 4819 (15.87%) and 4176 (12.52%) for the second, third and fourth quarters, respectively. It was, however, observed that Unguwar Fatika had the least number of cases of about 329 (1.64%) and 1366 (4.09%) for the second and fourth quarters, while Dambo had the least malaria prevalence of 659 (2.17%) in the third quarter.

The annual persons with malaria show that Dutsen Abba had the highest number of cases of 16907 which represents 17.74%, followed by Gyellesu with 12454 which represents 13.06%, Ungwar Fatika had the least number of cases of about 3320 which represents 3.48% of the total number of cases in the study area (Figure 4).

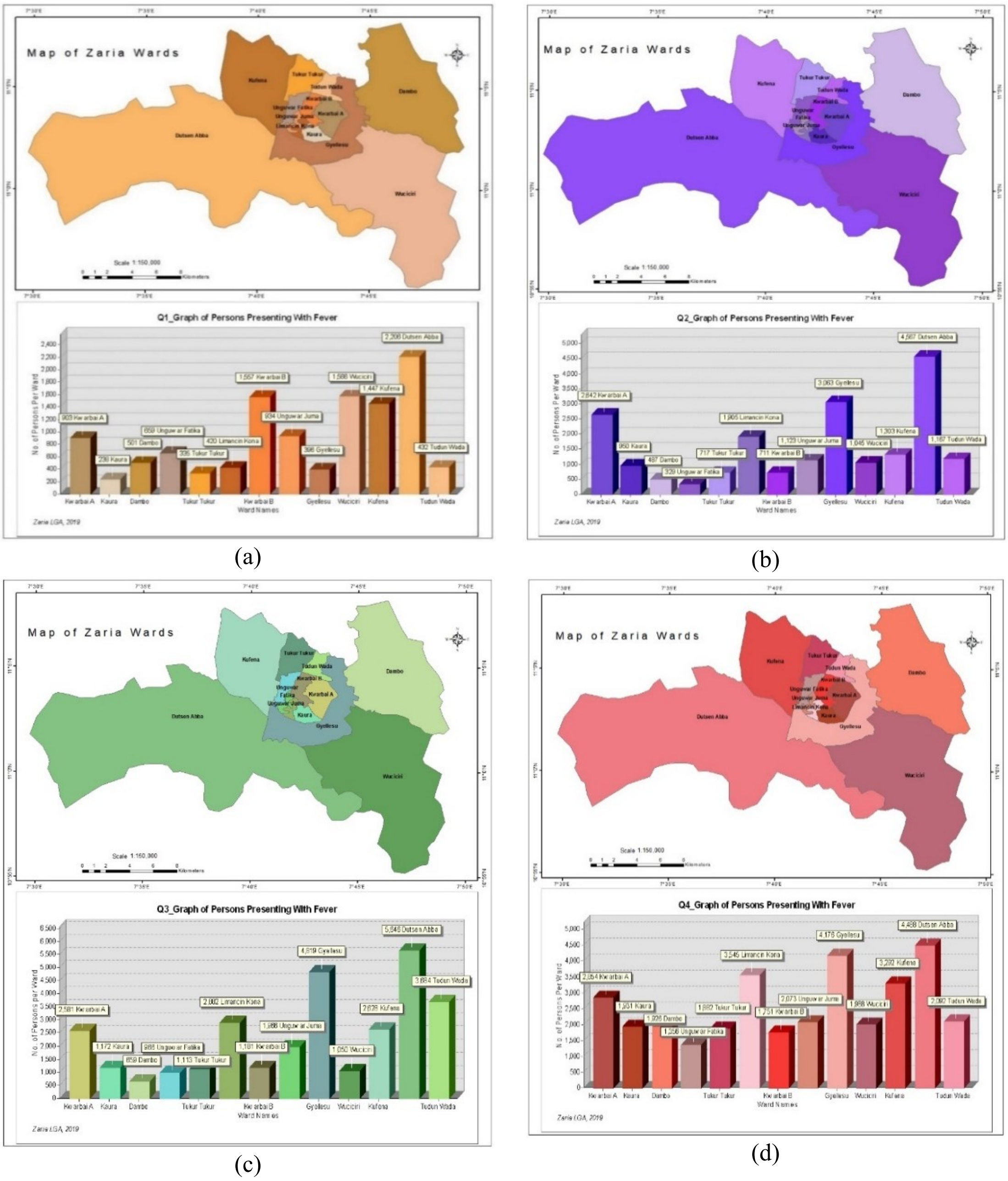


Figure 3. Persons with malaria; (a) First quarter; (b) Second quarter; (c) Third quarter; (d) Fourth quarter

Table 2. Summary of persons with confirmed cases of malaria in the study area

S/N	Name of location	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Annual cases of malaria
1	Kwarbai A	903	2642	2581	2854	8980
2	Kaura	238	950	1172	1931	4291
3	Dambo	501	487	659	1926	3573
4	Ungwar Fatika	659	329	966	1366	3320
5	Tukur-Tukur	335	717	1113	1882	4047
6	Limancin Kona	420	1905	2882	3545	8752
7	Kwabai B	1557	711	1181	1751	5200
8	Ungwar Juma	934	1123	1966	2073	6096
9	Gyellesu	396	3063	4819	4176	12454
10	Wuciciri	1566	1045	1060	1988	5659
11	Kufena	1447	1303	2628	3292	8670
12	Dutsen Abba	2206	4567	5646	4488	16907
13	Tudun Wada	432	1167	3684	2092	7375
Total		**11594**	**20009**	**30357**	**33364**	**95324**

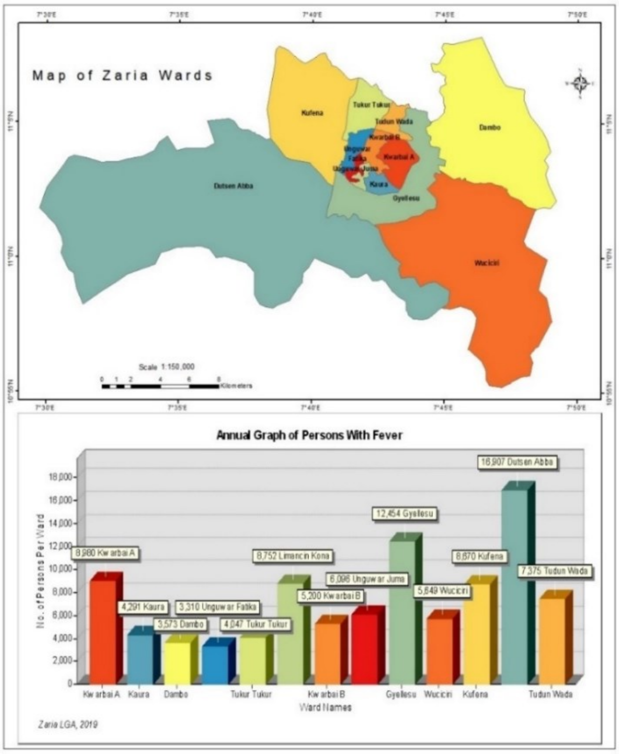


Figure 4. Annual Persons with Malaria

The results of the ANOVA one way test conducted on the persons confirmed with malaria showed that the prevalence of malaria incidences is significantly different between the various hospital locations. A Tukey posthoc test showed that the prevalence of malaria at Dutsen Abba is significantly different from Kaura (p = 0.001), Dambo (p = 0.004), Ungwar Fatika (p = 0.003), Tukur-Tukur (p = 0.006), Kwarbai B (p = 0.02), Ungwar Juma (p = 0.05) and Wuciciri (p = 0.032), respectively. This means that the incidences of malaria reported at Kwarbai A, Limancin Kona, Gyellesu, Kufena and Tudun Wada are not significantly different from Dutsen Abba.

5.3 Malaria burden maps

The malaria burden maps show how the malaria disease affects the most susceptible population. According to WHO (2018) and Awosolu et al. (2021), malaria affects children below five years and pregnant women more than other adults. Figure 5 (a) and (b) shows the prevalence of malaria disease amongst pregnant women and children under age 5, respectively. In Figure 5(a), it was observed that Zaria PHC, Tundun Wada at location 42, was the highest hit by malaria, followed by locations 9, 10, 48 and 35. In Figure 5(b), about four malaria hotspots at locations 2, 15, 42 and 47 were observed. This was followed by locations 12, 18, 19, 24, 36 and 44.

Generally, the incidence rate for children was observed to be higher than that of pregnant women. However, an independent t-test analysis conducted revealed that there was no significant difference between children below five years and pregnant women (p=0.066).

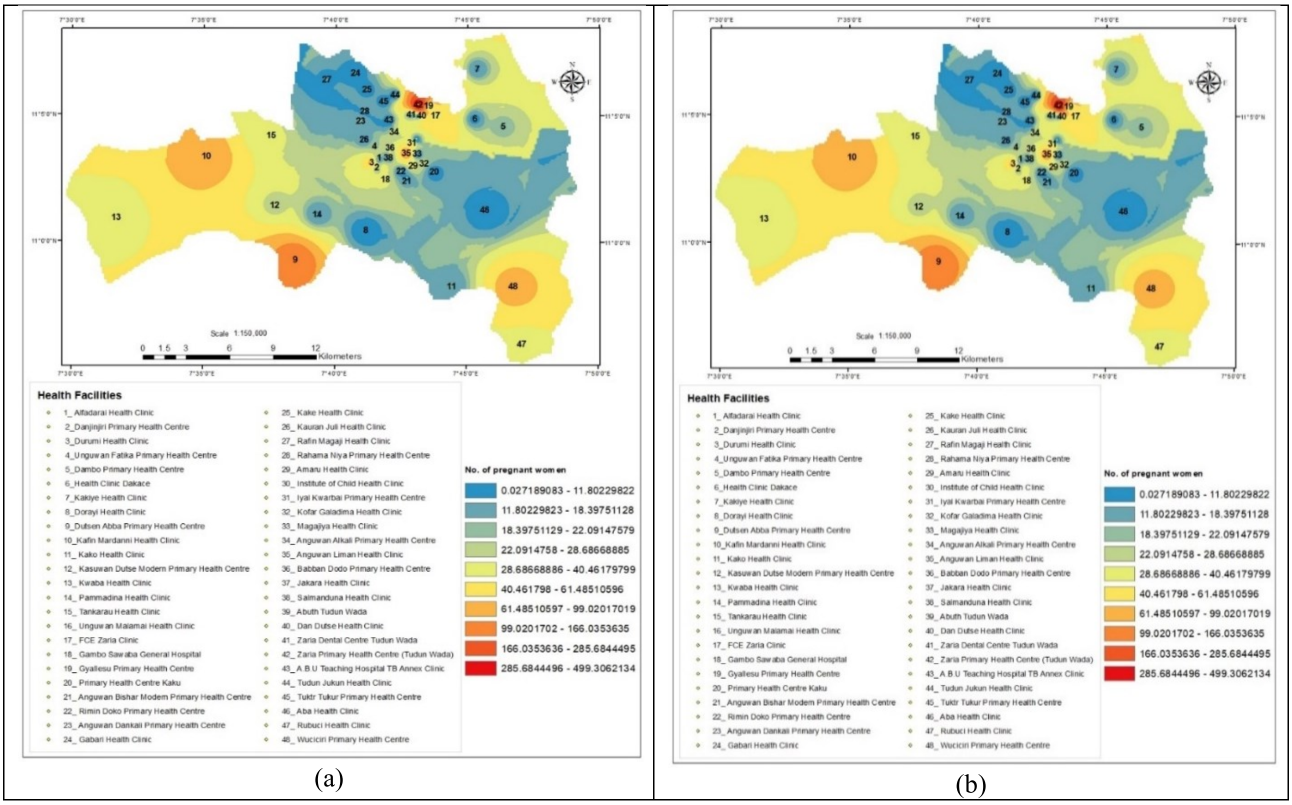


Figure 5. Distribution of malaria cases in 2019 amongst; (a) Women; (b) children less than 5 years

5.4 Malaria prevalence in Zaria

Mapping of the malaria prevalence provides information about the level of infection amongst the different strata of the population. Figure 6 shows how the infection rate varies from one place to another amongst children, pregnant women and adults. Each location on the map is represented by a graduated colour bar where yellow indicates children, red indicates pregnant women and green indicates adults. It was observed that pregnant women were the least affected as the red bar could only be seen at locations 3, 9, 1 and 42. This was followed by the children as the yellow bar could be seen across all the locations, however high malaria prevalence was observed at locations 15, 18, 19, 22, 24, 29, 42 and 47. Finally, the adult population (i.e., the entire population excluding children less than 5 and pregnant women) had the highest malaria prevalence in the study area as a high level of green is seen in all the locations. The highest values were observed at locations 19, 23, 31, 40, 42, 44 and 46 amongst others. Generally, the least infected population strata were the pregnant women while the most infected were the adult population.

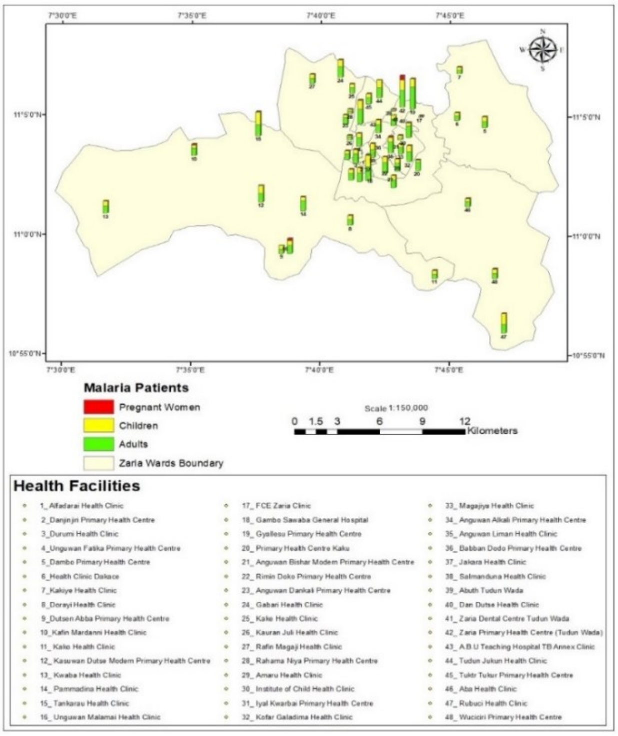


Figure 6. Malaria prevalence in Zari

Further comparison was carried out on the prevalence of malaria in the males and females in the study area. A higher prevalence of malaria of 73.35% was observed in the male compared to the female counterpart with a malaria prevalence of 26.65%. However, the independent t-test showed no significant difference between males and females (p=0.447).

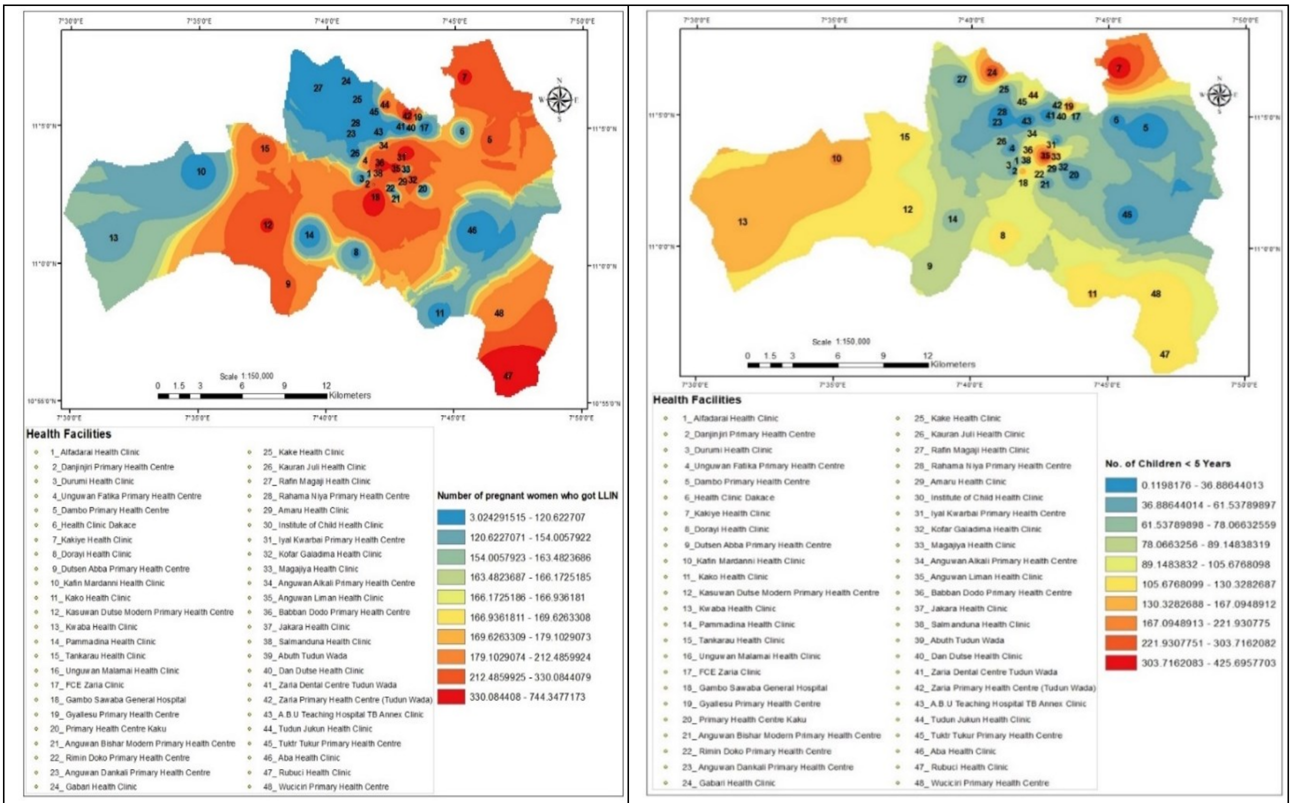
5.5 Malaria vector control maps

Vector control is a major prevention method and a continuous update of these maps provides a means to follow up to the elimination stage. Figure 7 shows the distribution of LLIN to pregnant women and children in 2019. These maps visually present the level of the spatial coverage of the distributed LLIN. The serial numbers on the maps correspond to the numbers and names of health facilities in the legend. Distribution of LLIN is carried out by each of the health facilities and the colour gradient represents the number of recipients as shown in the legend. The red and blue shades on the map indicate areas of high and low distribution, respectively. Based on these distribution results, it was observed that other health facilities that had high malaria prevalence such as Alfadarari H. C. (1), Durumi H.C. (3), Rimin Doko H.C. (22), Anguwan Dakari H.C. (23), Gabari H.C. (24) and Dan Dutse H.C. (40) did not receive adequate numbers of LLIN for their communities. This information provides the health workers in the LGA, the relevant details to take adequate measures to ensure adequate distribution of the LLIN to attenuate the spread of malaria in the area.

5.6 Service area map

Figure 8 shows the service area map used to define the catchment areas of each health facility based on the accessibility of the surrounding buildings. Buffers were created around the health facilities based on the travel distance (by footpath and road). The 0 – 3000m buffers were generated at 500m intervals. A width of 500m was specified as the optimal radius as used by Masoodi and Rahimzadeh (2015). This means that the maximum distance a patient is expected to travel to the health centre is 500m. Different polygon colour codes were used to signify varying distances from a given health facility. The result shows that none of the health facilities meets the requirement of accessibility of less than 500m. This means that most residents in the study area will have to travel more than 500m to receive medical services. Further, 28 health centres which represent 57.14% had accessibility of less than 1000m, while the remaining 21 which represented 42.86% had accessibility above 2000m. This implies that, the identified healthcare centers did not meet the 500m requirement. However, based on the study by Palaniyandi (2008), the 57.14% of clinical centers within the 1km buffer indicate that there is optimum healthcare services in the study area.

Analysis of the health centre to population ratio (1:10,000) stipulated by WHO (2012) in Eta et al. (2021) showed that some of the health centres did not meet the requirement as shown in Table 3. Based on these results, Kwarbai B with a population of 64,710 and currently having only 2 health centres, will require an additional 5 if adequate malaria services are to be provided. Kaura, Turkur-Turkur and Anguwar Fatika will require additional 3 health centres each, while Kwarbai A will require additional 2 health centres. It was also observed that, while some wards did not have adequate health centres, some wards had more than they require. Hence, Dutsen Abba had an excess of 4 while Kufena and Wuciciri both had 1 each.



(a) (b)

Figure 7. Distribution of LLIN in 2019; (a) Pregnant women; (b) children less than 5 years

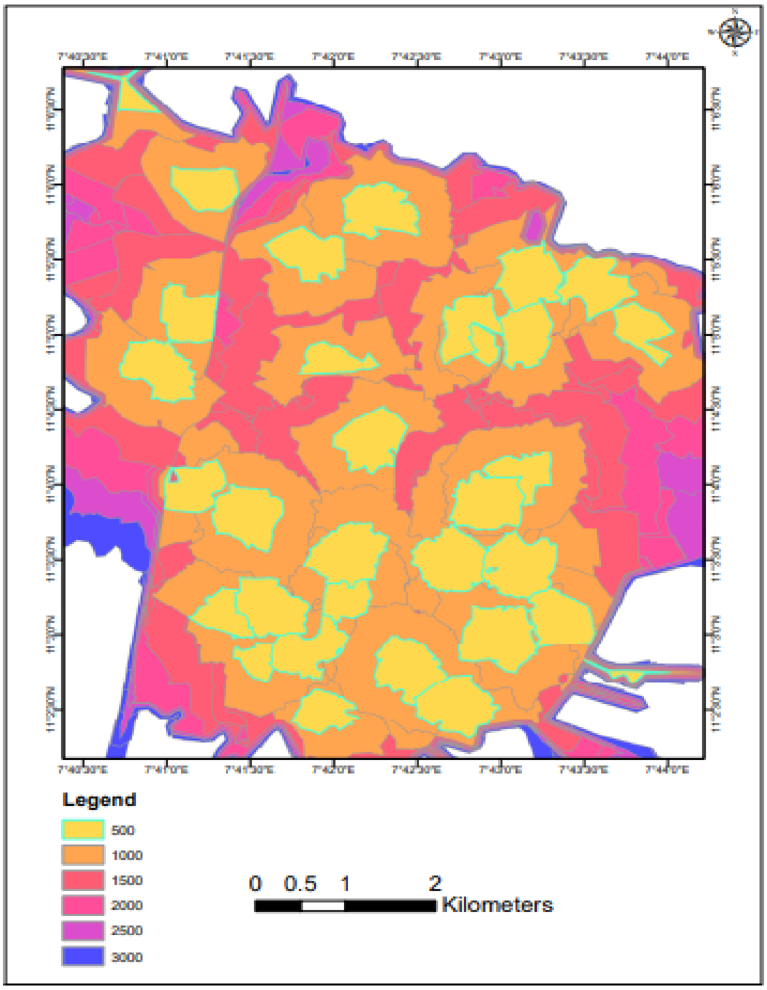


Figure 8. Service Area Coverage

Table 3. Wards population in Zaria Local Government

Wards	2019 Population Projection	Required by WHO 2012	Available ward	Shortfall	Excess
Dutsen Abba	46,383	5	9	-	4
Dambo	24,598	3	3	-	-
Gyellesu	42,041	4	4	-	-
Kaura	45,958	5	2	3	-
Kufena	49,791	5	6	-	1
Kwarbai A	69,943	7	5	2	-
Kwarbai B	64,710	7	2	5	-
Limancin Kona	33,733	3	3	-	-
Tukur Tukur	56,334	6	3	3	-
Tudun Wada	37,532	4	4	-	-
Unguwar Fatika	38,643	4	1	3	-
Unguwar Juma	31,956	3	3	-	-
Wuciciri	23,949	2	3	-	1
Total	**565,571**				

The overall ratio of the health centre to the population was computed using equation 1 (Mansour, 2016; Eta et al., 2021):

$$\frac{10{,}000 \times (\text{number of health centre})}{\text{population in each district}} \quad \text{----------} \quad 1$$

Based on equation 1, it was observed that Zaria LGA with an overall population of about 565,571 people had a ratio of 1.768. This indicates that the result meets the acceptable standard of 1:10,000 as recommended by Eta et al., (2021).

5.7 Discussion

The results of the annual persons with malaria show variation across the wards with Dutsen Abba and Gyellesu recording the highest prevalence of malaria in the study area. The results of the ANOVA one way test showed that the prevalence of malaria incidences is significantly different between the various hospital locations. A Tukey posthoc test showed that the prevalence of malaria at Dutsen Abba is significantly different from Kaura, Dambo, Ungwar Fatika, Tukur-Tukur, Kwabai B, Ungwar Juma and Wuciciri. These results corroborate the findings of Jimoh et al. (2019) who showed significant differences in the prevalence of malaria by hospital locations in Kaduna State. The result, however, disagrees with the findings of Awosolu et al. (2021), who reported lower cases of malaria in urban areas. The high reported cases of malaria in urban areas observed in this study may be due to the level of awareness of the consequences of malaria which encouraged the residents to report any symptoms related to malaria. It may also be due to the facilities available in the various health centres and the high population in some of these areas that lead to high malaria cases reported.

The highest prevalence of malaria (17.74%,) observed in the study area is lower than the highest prevalence observed in some of the studies that reported above 50% in the southern part of Nigeria (Kalu et al., 2012; Nmor, 2015; Awosolu et al., 2021). This may be due to the difference in environmental condition of the area as there is more rain in the south leading to favourable environmental conditions for mosquitoes to breed.

Our findings on the incidence rate of malaria for children less than five years old (≤ 5 years) were observed to be higher than that of pregnant women. However, the independent t-test showed no significant difference ($p = 0.066$). This result agrees with the findings of Nmor (2015) and Ocheje and Dogara (2016), who obtained similar results in southern Nigeria and Jigawa, respectively. The result is, however, different from the findings of Dawaki et al. (2016) and Jimoh et al. (2019) who reported that the effect on children below five years is significantly different from that of pregnant women in Kano and Kaduna States, respectively. The result is also at variance with the findings of Bajoga et al. (2019) and Awosolu et al. (2021) who reported that children are more affected than pregnant women in Kaduna State and Ibadan, in Oyo State, respectively. The low prevalence of malaria in children less than 5years may be due to the improvement in the use of preventive measures such as the LLINs and insecticides by parents in the study area. These results provide health authorities with relevant information by which to scale up interventions in high hit areas which can be easily tracked by the serial numbers on the maps.

The comparison of the effect of malaria amongst the various groups revealed that the adult population were the most infected followed by children, while pregnant women were the least infected across the study population. This result is contrary to Awosolu et al. (2021), who reported that malaria infection decreased with increased age in Ibadan, Nigeria. This may be due to the involvement of adults in outdoor activities that keeps them late outside the home until night time which exposes them to mosquito bites more than others.

Concerning gender, the result showed that females were more affected by malaria than their male counterparts. However, the independent t-test revealed no significant difference in malaria prevalence between males and females ($p = 0.447$). This result is contrary to other studies that reported differences between males and females (Ocheje and Dogara 2016; Awosolu *et al.,* 2021).

Our findings also revealed that the distribution of LLIN in the study area is not based on the prevalence of malaria in the area as some health centres with high cases of malaria prevalence (1, 3, 22, 23, 24 and 40) did not receive adequate numbers of LLINs. The information provided in this study informs the health authorities saddled with the responsibility of malaria control in the area, with the necessary details to ensure fair distribution of the LLIN to the wards.

The service area map showed that none of the health centres meets the minimum requirement of 500m for residents for easy accessibility. This is contrary to the findings of Masoodi and Rahimzadeh (2015) who reported some health facilities to have an accessibility of less than 500m. Most of the health centres were concentrated in the urban areas where there is a high population. This left some of the areas such as Dakace, Panmadina, and Unguwar Malamai, amongst others, underserved. The implication of this is that, residents in such areas will have to travel long distances to access health facilities. This might lead to health complications as many residents find it difficult to transport themselves to the health centres. This report corroborates the result of Aliyu *et al.* (2020) who observed a similar situation in Borno State, Nigeria. One way to cushion this effect is to provide more health care centres, especially in highly populated areas. Thus, Alfadarai, Jakara, Salmanduna and Rimin Doko health centres may need additional health centres to attenuate the pressure on the health workers and to enhance service delivery.

Finally, our findings also show that the health centre to population ratio (1:10,000) provided by WHO (2012) in Eta *et al.* (2021) did not meet the requirement in some of the wards. However, the overall health centre to population ratio was 1.768 which shows agreement. This result corroborates the findings of Eta *et al.* (2021) who obtained a similar result in the Kaduna metropolis. The results also show that some wards had more health centres than the required number despite the limited number in some wards. This means that the location of the health centres in the area was not entirely based on population. This agrees with the findings of Ujoh and Kwaghsende (2014) who reported similar findings in Benue State. The implication of this is that the wards with limited health centres will be overstretched and residents will have to travel several kilometres to access health services. It is important, therefore, to consider wards with limited health centres for addition to enhance service delivery in the area.

6. Conclusion

This study set out to create an SDSS for malaria monitoring in parts of Zaria using GIS techniques. By integrating the existing malaria data with other secondary data in a GIS environment, it was possible to identify malaria prevalence and also appraise the spatial variability of malaria as it affects pregnant women, children and adults. After several data analyses, the resulting maps were presented to convey different types of information, one at a time while showing the various patterns of malaria incidence in Zaria. The maps produced can be used effectively as a means of monitoring, evaluation and surveillance to reduce the spread of malaria in Zaria. Based on the findings of this study, it is recommended that the Kaduna State Ministry of Health should invest in the deployment of a GIS-based SDSS for effective planning and management of malaria incidences in the Zaria metropolis as this aligns with the sustainable development goal (SDG) target 3.3.

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