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An Assessment of the Relationship between Built Environment and Socioeconomic Factors with the Incidence of Meningococcal Meningitis in Kaduna Urban Area, Nigeria

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Abstract

Meningococcal meningitis is an airborne disease that has been a threat to human life in many regions of the world, especially in West Africa. The disease has caused permanent physical impairment to some of its victims and many lives have been lost due to the disease. Factors that are associated with the incidence of the disease which are geographically referenced include built environment, geographical location and climatic conditions. Others are socioeconomic and demographic factors. This study established the relationship between built environment and socioeconomic factors with the incidence of the disease. Data that were used include the incidences of the disease from 2007 to 2011, housing conditions, population density, number of house ownership, employment, income level, and the number of hospitals, schools and refuse dumps. Neighborhoods were used as the unit of analysis in the study. The method of analyzing the data includes factor analysis and some statistical techniques in Geographical Information System such as the Ordinary Least Square (OLS). The findings of the study reveal the spatial variations of the incidence of *Meningococcal meningitis* in Kaduna Urban Area (KUA). The study recommends that there should be strict observance of the development control regulations especially at the high density residential neighborhood. The model can also be used for other communicable disease to ensure the health of the public.

Keywords

Meningococcal meningitis, Epidemic, Neighbourhood, Spatial

1. Introduction

Meningitis is the breakdown of the defensive sheath that is shielding the spinal cord and brain which is together called the meninges [1]. It is a very dangerous disease because of the ability to cause inflammation very close to brain and spinal cord. A condition like this is treated as a case that requires an urgent attention. Different kinds of germs which can both be viral and bacterial are the cause. The one that is more harmful however is caused by the bacterium *Neisseria meningitides*, which is commonly known as *Meningococcal meningitis*. This bacterium is very dangerous because it is very harmful to the people it affects and due to the fact that it has the potential to cause epidemics unlike most other causes of *meningitis* [2].

The bacteria of *meningitis* are spread from an individual to another individual via drops of respiratory or mouth discharge. Having intimate and delayed communion like kissing, coughing or sneezing on an uninfected person, co-habiting in adjoining accommodation, eating and drinking from the same utensil with the person that is infected ease the transmission of the disease [3]. On average, the period in which it takes for the bacteria to grow is about four days, it varies sometimes and can be from two to ten days. *Neisseria meningitidis* affects solely humans; it does not affect or live in animals. The bacteria can stay in the respiratory tracts and a few times can go to the extent of overpowering the defensive mechanism, thus allowing the disease to be transmitted via the blood stream to the brain [4]. Although it is not very clear, it was postulated that about 10% to 20% of the populace live with *Neisseria meningitidis* at any point in time. Most likely, the percentage of the carriage will be on the high side during outbreak periods [5].

Environmental factors play a major role in influencing the spread of the disease. The disease is associated with poor housing condition, deprived settlements and household overcrowding [6]. Overcrowded settlements that the inflow and outflow of ventilation are absent also play a major role in the spread of the disease. A study conducted by [6] in the United Kingdom shows that the spread of *Meningococcal meningitis* disease was common in an overcrowded settlement. Other environmental factors like high temperature, rainfall and relative humidity play a role in the spread of the disease. Studies by [7] [8] all proved that temperature, rainfall and relative humidity influence the spread of the disease.

The built environment is made up of housing condition, transportation patterns, land use, urbanization, housing density, building arrangements, networks of transit and parks. The built environment has a link with public health; one of such ways could be through individual transportation choices and environmental exposures that result from different built environment patterns. These choices and exposures impact our health as a population and as individuals [9].

Some studies revealed that socioeconomic factors influence the spread of the disease [6] [10] [11]. There are neighborhoods within the metropolis that are deprived in terms of facilities and services. People in the lower strata of neighborhood would prefer to live in such places because the rental value is low and affordable to them. Such neighborhoods are referred to as the high density neighborhoods and the housing conditions in most of these neighborhoods are very poor. Some studies also show that movement and large gatherings of people is another factor that influences the spread [12] [13] [14].

A number of studies conducted using the spatial pattern analysis, one of the methods in geographical information system shows that it is helpful in determining the locations of high and low incidence of diseases. A study by [15] investigated the spatial pattern of malaria in a province in China because it was the most affected in the whole of China from 2005-2006. It was very critical to understand the pattern of spread so as to identify those locations that have high cases for future public health planning and resource allocation. Spatial cluster analysis using spatial scan statistics techniques was used. The result show that some particular counties were at high risk for malaria. The study provides a means to quantify the risk of malaria disease but could not highlight the possible environmental factors that are influencing the spread of the disease. Similarly, a study by [16] also investigated the spatial and temporal pattern of malaria incidence at a village in Ethiopia. Global moran's I and the anselin local spatial autocorrelation statistics were used to analyze the malaria data. The anselin local spatial autocorrelation statistics reveals clustering or hotspots within five and ten kilometers distance of the villages in the study area. It was observed that there were temporal; variations in the malaria incidence. This study could not identify those environmental factors that influence the incidence of malaria.

The spatial pattern analysis method was also applied in the schistosomiasis disease in China. The study was conducted by [17] on the spatial pattern schistosomiasis in Xingzi in the province of Jiangxi in China. Xingzi is a location where the disease of schistosomiasis has been a threat to public health. Logistic regression model and variogram techniques were used in the study. The results revealed those locations that the disease is most common and also the spatial pattern. This has helped in giving an insight on the characteristics of the epidemiology of the disease and will help in the long term sustainable strategies for schistosomiasis control. Further study was conducted on the spatial pattern of schistosomiasis in Yangtze River valley by [18] between the years of 1991-2001 and 2007-2008. Luc anselin local spatial autocorrelation and Kuldorf spatial scan statistics were used in the study. The result shows that the magnitude and number of clusters vary from 1999-2001. The findings specifically show those locations that have consistent cases which the public health planners and authorities concerned will direct their attention on.

The use of spatial statistics in the study of epidemiology is very critical because of the kind of results that it produces. In the past, the conventional statistics cannot be combined with the spatial analysis, and that limits the understanding of the health planner on the epidemiological study that he is conducting. Only the distribution of disease maps are done by health geographers in the past, but spatial statistics integrates the conventional statistics with spatial analysis to solve epidemiological problems. The result of doing this gives a clear understanding of the epidemiological study that is been conducted and prediction is made easily. Previous studies helped in locating areas that have high and low cases of the disease. The limitation of these previous studies is that it could not identify those factors and their locations that were influencing the high cases of the disease. Therefore, the study aims at investigating the relationship between the built environment and socio-economic factors with the incidence of the disease in Kaduna Urban Area.

2. Research Methodology

The study area for the research is Kaduna Urban Area. It is located within Kaduna, the capital of Kaduna state. Kaduna Urban Area is made up of two local governments, that is Kaduna north and Kaduna south, part of Chikun local government and also part of Igabi local government. Within the Kaduna city region lies the legally designated Kaduna Urban Area (KUA) which is an approximate rectangle of 40 km by 30 km lying roughly northeast/southwest with Kaduna in its center [19]. **Appendix Figure A1** and **Appendix Figure A2** are maps of Kaduna State and the map of Kaduna Urban Area.

The population estimate for KUA for 2011 based on the last census by National Population Commission (2011) is at 1,662,000. By this estimate it is Nigeria's fifth largest city behind Lagos (10,578,000), Kano (3,395,000), Ibadan (2,837,000), and Abuja (1,995,000). The projected city population in 2025 is 2,362,000. The same source estimates the rate of growth of population for the past five years at 2.55% per annum, similar to Kano but considerably less than Abuja, by far Nigeria's most rapidly growing large city at 8.33% per annum. The projected population estimate from the census of 1991 gives no indication of how the general global definition and boundaries of urban agglomeration in Nigeria and KUA are defined. **Table 1** is the breakdown of the population for Kaduna urban area at the level of neighbourhoods.

The data that is used in this study under this category includes the following:

1) Locations of the Refuse dump.

2) Locations of Hospitals.

The total number of all the refuse dumps and the hospitals (primary health care and secondary healthcare) for each of the neighborhoods were collected and it was aggregated and recorded in the polygon.

Other data includes the following:

1) Administrative Maps

Map of Nigeria and its Regions, Administrative Map of Kaduna State, District Map of Kaduna urban area and the Neighborhood map of Kaduna Urban Area. All the data were collected in a digital format.

They were all sourced from the Master Plan of year 2010 that was prepared for Kaduna town and also from Kaduna State Urban Planning and Development Authority (KASUPDA). Other data collected from the secondary source [19] are:

Table 1. Breakdown of the neighborhood population for Kaduna Urban Area.

S/N	Neighborhoods	Population	S/N	Neighborhoods	Population	S/N	Neighborhoods	Population
1	Doka	1119	40	Ungwan Pama	14,041	79	Angwan Kanawa	6481
2	Barnawa	6230	41	Refinery Qtrs	282	80	Angwan Shanu	18,517
3	Anguwan Mu'azu Low	27,391	42	Sabo GRA	1320	81	Badiko Barrack	302
4	Angwan Sanusi	29,141	43	Ungwan	15,190	82	Badiko	8457
5	Makera	18,124	44	Bayan Dutse	5675	83	College GRA	3407
6	Angwan Romi	27,236	45	Nafdac	715	84	Kurmin Mashi Barrack	302
7	Matagyi	43,707	46	Highcost	8820	85	SMC QTRS	2570
8	Narayi	26,974	47	Karatudu	11,904	86	Angwan Dosa	9264
9	Kakau	1864	48	FHA	1884	87	Angwan Maisamari	6990
10	Mararaban Rido	1320	49	Goningora	7520	88	Housing Estate	7319
11	PAN	10	50	Buwaya	5080	89	Malali Village	4365
12	New	0	51	Angwan Bije	19,000	90	Minister's QTRS	1250
13	Afaka	343	52	Chidunu	4980	91	Kwaru	28,607
14	Murtala Square GRA	2278	53	Nissi Village	463	92	Angwan Gado	6834
15	Maraban Jos	16,340	54	Rido Gbagyi	6502	93	Badarawa	27,206
16	Rigachikun	18,900	55	Rido Hausa	2792	94	Polytechnic	424
17	Kawo	22,267	56	Damishi	8164	95	Poly Qtrs	403
18	Military Barracks	3972	57	DIC	2157	96	Tudun Nupawa	7863
19	Kurmin Mashi	19,192	58	Kurmin Gbagyi	15,775	97	Sabon Gari	19,888
20	Malali GRA	10,947	59	Mando	15,170	98	Kudandan	12,046
21	Tudun Wada	29,958	60	Eye Centre	2591	99	Nasarawa Industry	544
22	Rigasa	94,107	61	Mando 2	18,507	100	Nasarawa Village	53,636
23	Kamazou	22,811	62	NDA	500	101	Tirkania	11,847
24	Kudandan Ext	151	63	Sultan Bello	5060	102	Kabala Costain	5897
25	Kabala	25,321	64	Ungwan Rimi	25,684	103	Bakin Ruwa	99,970
26	Stadium	2399	65	Rimi GRA	4445	104	Kabala West	6108
27	Magajin Gari	15,997	66	Angwan Sarki GRA	5321	105	Television	13,023
28	Abakpa	1421	67	Katabu	13,115	106	Angwan Sunday	12,963
29	Shagari	6431	68	Angwan Kaji	4496			
30	Complex	12,872	69	Barkalahu	7419			
31	Anguwan Barde	12,227	70	NTI	450			
32	Anguwan Mu'azu 1	7550	71	Angwan B	3417			
33	Anguwan Mu'azu 2	4808	72	Military Zone	3972			
34	Makera Textile	917	73	Kawo Extension	15,674			
35	Romi Extension	107,760	74	Kawo GRA	2550			
36	Angwan Yelwa	12,963	75	Airforce Base	800			
37	Poly	2300	76	Agric	4435			
38	Mahuta	3660	77	Hayin Banki	17,942			
39	Ungwan Boro	5826	78	College Rd Area	3407			

Source: [20].

2) Housing condition

For this study, the housing condition data were categorized into four which is the number of buildings under:

a) Housing condition 1, structure is fit for purpose.

b) Housing condition 2, structure is fit for purpose with sign of deterioration.

c) Housing condition 3, structure is not fit for purpose, can be fixed.

d) Housing condition 4, structure not fit for purpose, needs to be demolished.

3) Schools (aggregated) for each of the neighborhood. These data were collected in a digital format.

Data on Population density for the neighborhoods, housing ownership for each neighborhoods and Percentage of occupation in each of the neighborhoods were also collected and were sourced from the Ministry of Economic Planning Kaduna State.

4) *Meningococcal meningitis* Data

Data on *Meningococcal meningitis* cases were collected from the hospitals and clinics that are within the Kaduna Urban Area. The data were collected from the month of January to December 2007 to 2011. The *meningitis* cases data collected was aggregated and converted into incident rate using this formula: Table 2 shows the summary of data preparation and development.

$$\text{Incidence rate} = \frac{\text{Number of new cases of a disease during a given period}}{\text{Population at risk during a given period}} \times 100000$$

Source: [21].

3. Results and Discussion

Test of Normality for the Variables

Having standardized the data set to ensure that the measurement units are in proportion to each other using the standardization formula, a test for normality was also conducted using the Shapiro-Wilk statistics. The aim of doing this is to ascertain if the standardization data sets are normally distributed prior to using them for the modeling the spatial relations analysis. From Table 3, it was observed that all the data set are approximately normally distributed as the p-value returned by the Shapiro-Wiki test were all greater than 0.05.

After the standardization of the data was done, the next stage is the data extraction. The use of Principal Component Analysis is adopted in the study to summarize the inter-correlation patterns among the variables that are associated with the various components. Such a method was adopted in the investigation of how urbanization influences the spatial pattern of dengue in Taiwan [22].

Such variables like population density, primary health care (PHC), secondary health care (SHC), primary school, secondary school, tertiary school, house ownership and employment that relates directly to socioeconomic and built environment were extracted using the principal component analysis (PCA). Varimax rotation method with Kaiser normalization was used, and three exploratory factors which are Urbanization, Secondary facilities and Housing density were

Table 2. The summary of data preparation and development.

S/N	Data	Data Format	Source	Manipulations
1.	Administrative Map of Nigeria	Digital	Master plan (2010) Kaduna State Urban Planning and Development Authority (KASUPDA)	*Meningococcal Meningitis* data for the whole states in Nigeria in polygon format were added to the geodatabase that was developed for the analysis
2.	Administrative Regional Map of Nigeria	Digital	Kaduna State Urban Planning and Development Authority (KASUPDA)	*Meningococcal Meningitis* data for all the states in the region in polygon format were added to the geodatabase that was developed for the analysis
3.	Administrative Map of Kaduna State	Digital	Master plan (2010) Kaduna State Urban Planning and Development Authority (KASUPDA)	*Meningococcal Meningitis* data for the twenty three local governments in polygon format was added to the geodatabase and was developed for the analysis.
4.	Neighborhood Map of Kaduna Urban Area	Digital	Master plan (2010) Kaduna State Urban Planning and Development Authority (KASUPDA)	*Meningococcal Meningitis* data for one hundred and six neighborhoods were transferred into the geodatabase in polygon format.
7.	Housing Condition	Digital	Hospital Records	The housing condition data were transferred into the geodatabase as polygon format. The housing condition was categorized into 4 as buildings under: 1) Structure is fit for purpose 2) Structure is fit for purpose with sign of deterioration 3) Structure is not fit for purpose and can be fixed 4) Structure is not fit for purpose, needs to be changed.
8	Hospitals	Primary	Physical observation	The number of the hospitals were recorded for each neighborhoods and were transferred to geodatabase as part of the polygon data
9	Refuse dumps	Primary	Physical observation	The number of the refuse dumps were recorded for each neighborhoods and were transferred to geodatabase as part of the polygon data
10	*Meningococcal meningitis* data	Secondary	Hospital records	The incidence of the disease was recorded as a polygon data for each of the neighborhoods.
11.	Age	Secondary	Hospital records	It is also part of the attribute data. It is categorized into three based on the hospital records: 1) 0 - 10 2) 11 - 20 3) 21 and above It was transferred to geodatabase as part of the polygon data.
12	Income level	Secondary	Hospital records	It is also part of the attribute data. It is categorized into three: 1) High income: N300,000 and above 2) Medium income: N31,000 to N299,000 3) Low income: <N30,000 It was transferred to geodatabase as part of the polygon data.

Table 3. Test of normality for the data set.

	Shapiro-Wilk		
	Statistics	df	P-Value
Housing Condition 1	0.931	105	0.223
Housing Condition 2	0.876	105	0.613
Housing Condition 3	0.917	105	0.812
Housing Condition 4	0.771	105	0.078
Low Income	0.982	105	0.102
Medium Income	0.513	105	0.21
High Income	0.88	105	0.061
Age 0 - 10	0.906	105	0.924
Age 11 - 20	0.661	105	0.449
Age 20 and above	0.723	105	0.092
Population density	0.973	105	0.833
Primary Health Care	0.921	105	0.471
Secondary Health Care	0.837	105	0.0701
Primary School	0.822	105	0.0811
Secondary School	0.604	105	0.322
Tertiary School	0.711	105	0.57
House Ownership	0.865	105	0.051
Occupation	0.242	105	0.992
Refuse Dumps	0.776	105	0.0911
Rate 2007	0.88	105	0.205
Rate 2008	0.922	105	0.316
Rate 2009	0.812	105	0.244
Rate 2010	0.887	105	0.078
Rate 2011	0.778	105	0.069

extracted as their initial eigenvalues were greater one; and accounted for 64.61% of total variance for the nine variables. The eigenvalues having greater than one is the criterion for a factor to be useful. On the other hand, eigenvalues less than one show that the percentage of variance explained by the factor is insignificant.

The loadings are the values that represent how each of the items contributes in each of the component. Table 4 shows the rotated component matrix and Table 5 shows the data extraction table.

Looking at Table 4 and Table 5 which are the rotated component matrix for the factor analysis and the data extraction table, it is clear that under the urbanization factor, primary school loaded the highest, followed by refuse dump, secondary school, primary health care and employment. It is not surprising that the primary school loaded highest in KUA because there are many primary

Table 4. Rotated component matrix.

	Component		
	1	2	3
Pop_Density			0.795
PHC	0.619		
SHC		0.643	
Primary School	0.918		
Secondary Sch	0.720		
Tertiary School		0.814	
Hous_Own			0.630
Employment	0.534		
Refuse Dump	0.862		

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 5 iterations.

Table 5. Data extraction table.

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1. Urbanization	3.502	38.913	38.913	3.502	38.913	38.913	2.938	32.642	32.642
2. Secondary Facilities	1.255	13.950	52.863	1.255	13.950	52.863	1.628	18.091	50.733
3. Housing Density	1.057	11.742	64.605	1.057	11.742	64.605	1.248	13.872	64.605
4	0.963	10.699	75.304						
5	0.782	8.693	83.997						
6	0.536	5.960	89.957						
7	0.385	4.281	94.238						
8	0.328	3.642	97.880						
9	0.191	2.120	100.000						

Extraction Method: Principal Component Analysis.

schools (private and public) within KUA. A report by [23] reveals that within the last ten years there is a rapid increase in the number of primary schools in KUA. This implies that the population of KUA is rapidly increasing due to the urbanization.

Refuse dump which is the next, equally has a high loading which is due to the fact that in urban areas more waste is generated because of the population size and also the high standard of living. A report by [23] reveals that the general level of waste generation by individual household in KUA is high as the majority of the people's standard of living is improving.

Similar to the primary schools, many secondary schools are found within the urban areas in Nigeria because the population is higher in urban areas and it therefore needs schools to serve the populace. A report by [23] [24] reveals that in the last ten years, the number of secondary schools in KUA has grown tremendously implying that the population is rapidly increasing.

Primary health care (PHC) which is another service that the urban populace requires within their neighbourhoods is mostly found within the urban areas. Report by [19] has indicated that there is a rapid increase in the number of PHC facilities in KUA which also implies that the population in KUA has increased due to urbanization. Employment which is the least in the loadings for the urbanization factor is also another variable that indicates the level of urbanization of an area. A report [25] indicates that job opportunities has increased over the years and has caused KUA to increase in its population size and making it to be more urbanized.

Through the PCA, [22] identified three principal components namely: urbanization, percentage of elder population and percentage of aborigine population as the major components. According to the authors, the important variables that loaded significantly in the urbanization factor are population density, service occupation, agricultural occupation household ownership, number of clinics and income level. In this study, urbanization factor, secondary facilities, and housing density factors were identified as the major components. For the urbanization factor, the major variables that loaded significantly are primary school, followed by waste generation, secondary school, primary health care and employment. In view of this, it is obvious that some of the attributes reported in this study are similar to those reported by [22].

Scree Plot

The scree plot on **Figure 1** shows all the factors that were used in the factor analysis. As can be seen in the figure, the first factor has an eigenvalue if of 3.5 followed by the second factor with 1.3 and the third one having 1.1 as the eigenvalue. The other factors that are below one were not used because of their low eigenvalue.

The summary of the major components and the percentage of variance explained by each is presented in **Table 6**. The first factor (urbanization) accounted for 32.64% followed by the second (secondary facilities) 18.09% and the third (housing density) 13.87%.

The result of the principal component analysis (PCA) gave three different components namely; urbanization, secondary facilities and housing density. These three components with other additional variables such as housing condition, age and level of income was used in the next section for the analysis. In this study, urbanization means two things; as developed urban area or a less developed urban area (squatter settlements). The influence of urbanization as a factor is looked at from this two angles. This study looks at housing density from the view point of the population of people with the number of homes per unit of land.

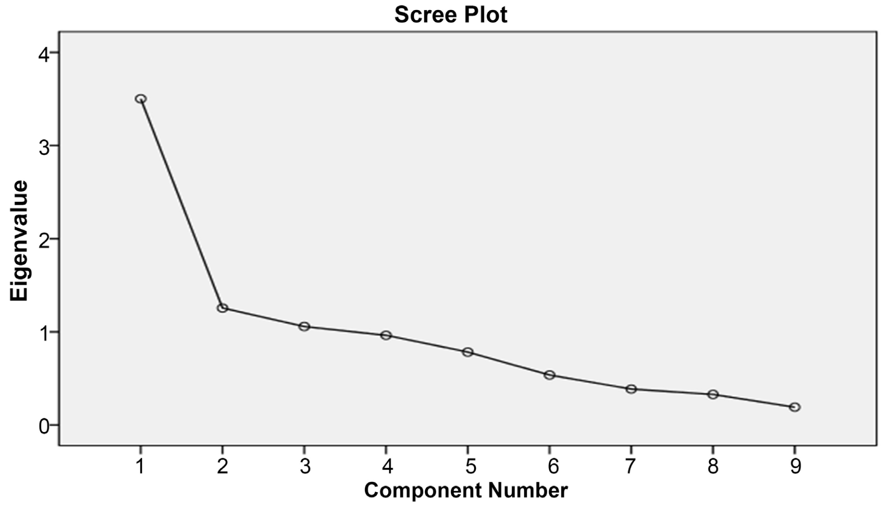


Figure 1. Scree plot.

Table 6. Summary of factors loading and percentage of variance explained.

Components	Variance Explained	Loading
Factor 1: Urbanization		
Primary Health Care	32.64%	0.619
Primary School		0.918
Secondary School		0.720
Employment		0.534
Refuse Dump		0.862
Factor 2: Secondary Facilities		
Secondary Health Care	18.09%	0.643
Tertiary Institutions		0.814
Factor 3: Housing Density		
Population Density (person/km^2)	13.87%	0.795
Housing Ownership		0.630
Sum of Variance Explained	**64.61%**	

The OLS model was carried out but it was graduated in such a way that it will detect multi colinearity among the explanatory variable and the result revealed that low income level and age 11 - 20 variables had a variance inflation factor (VIF) of 13.732 and 11.234 respectively. Because the value is higher than the set of redundancy threshold of 10, the low income level and age 11 - 20 variables were removed from the model. The result of the OLS model is shown on Table 7. In the table, all the predictors have a VIF values between 1 - 4 which indicates that none of the variables are redundant. From the results of the OLS in Table 7, it showed that explanatory variable for housing condition 4, housing condition 3, urbanization and housing density returned the parameter estimate of 0.618, 0.688, −0.276 and 0.183 and with its significant t values of 4.2447, 4.7736, −2.1398 and 2.4689 respectively. This implies that these four variables are making a significant impact on the incidence of *Meningococcal meningitis* in KUA. All the

Table 7. Summary of OLS results.

Variable	Coefficient	St Error	t-Statistic	Probability	Robust_SE	Robust_t	Robust_Pr	VIF
Intercept	0.005732	0.069908	0.081992	0.934821	0.066066	0.086760	0.931041	--------
HSGCON4	0.618795	0.145779	4.244749	0.000054*	0.236963	2.611356	0.010493*	4.308841
HSGCON3	0.688743	0.144280	4.773670	0.000008*	0.158091	4.356618	0.000036*	4.217028
HSGCON2	−0.022317	0.075800	−0.294425	0.769087	0.031546	−0.707460	0.481028	1.164934
HSGCON1	0.203048	0.113227	1.793275	0.076149	0.119812	1.694720	0.093445	2.599114
MED_INC	−0.103202	0.121660	−0.848286	0.398426	0.138810	−0.743478	0.459042	2.994767
HIG_INC	0.081512	0.077394	1.053204	0.294942	0.107630	0.757331	0.450741	1.214029
Age0_10	−0.031845	0.142969	−0.222740	0.824222	0.162616	−0.195829	0.845166	4.144584
ABOVE_21	−0.188244	0.135729	−1.386905	0.168757	0.150175	−1.253498	0.213135	3.728204
Urbanization	−0.276158	0.129057	−2.139803	0.034956*	0.150678	−1.832767	0.040006*	3.361738
Secondary Facilities	0.032857	0.082070	0.400358	0.689809	0.067298	0.488236	0.626525	1.362797
Housing density	0.183478	0.074315	2.468935	0.015352*	0.073396	2.499841	0.014152*	1.116434

*Significant at 0.05, **Significant at 0.01.

explanatory variables except urbanization level are making positive contribution in influencing the incidence of *Meningococcal Meningitis*.

The urbanization level influence is on the inverse, meaning that as the explanatory variable decreases, the incidence of *Meningococcal Meningitis* increases. The explanation to this is that as the neighborhoods that have inadequate facilities and services keeps growing in size and it continues to go below the level of a developed area. Moreover, as the neighborhoods gets more populated, the cost of rent reduces unlike the neighborhoods that have adequate facilities and services which are known as the developed areas with high rental cost. Such facilities and services include planned neighborhoods with good roads, drainages, schools, health center, pipe borne water supply, electricity supply, well planned environment and good housing conditions. Invariably, urbanization influences the incidence of *Meningococcal meningitis* in Kaduna Urban Area in an inverse way because the less the developed the neighborhood, then the more the influence of the disease in the neighborhood. As buttressed [6] this fact that the disease of *Meningococcal meningitis* is associated to deprived neighborhoods.

Due to the nature of OLS model which only gives the global or general results on the relationship existing between the dependent and independent variable, this model too it is not specifying the exact neighborhoods where the relationship between the incidence of *Meningococcal meningitis* and urbanization is significant or less significant in KUA. The result it gave is a general result that there exist a significant relationship between *Meningococcal meningitis* and urbanization in the whole of KUA.

To buttress the fact that urbanization plays a role in influencing the epidemics of disease, [26] stated that "The urban environment fostered the spread of diseases with crowded, dark, unventilated housing; unpaved streets mired in horse manure and littered with refuse; inadequate or nonexistent water supplies; privy vaults unemptied from one year to the next; stagnant pools of water; ill-functioning open sewers; stench beyond the twentieth century imagination; and noises from clacking horse hooves, wooden wagon wheels, street railways, and unruffled industrial machinery." Infectious diseases have taken over the health profile of early cities, which did without clean water, sewage treatment, inadequate health facilities, inadequate educational facilities and trash collection. We still have some of these problems today, although it has been tamed to some extent. Infectious diseases continue to spread in urban populations, as the HIV epidemic, dengue fever, malaria fever and recent outbreaks of Ebola fever in west Africa illustrates [27] [28]. And the problems of poverty and social dislocation, poor facilities and services continue to plague the poor parts of every urban areas. This has further confirmed the findings of this study that urbanization plays a significant role in the transmission of *Meningococcal meningitis* in KUA as the neighborhoods that are less developed and are deprived from basic facilities and services are more affected.

Those neighborhoods that have low facilities and services (less developed areas) are characterized with poor housing conditions, problems of poverty, social dislocation and their housing densities are high. The OLS result about the poor housing conditions has confirmed the speculation because housing conditions 3 and 4 are also significant in influencing the incidence of the disease with t-values of 4.77 and 4.24 respectively. The incidence of *Meningococcal meningitis* is mostly located at neighborhoods that have poor housing conditions. This has confirmed the findings of the earlier studies that poor housing condition contributes to the spread of *Meningococcal meningitis* [6].

In KUA, high density residential neighborhoods are known to be having two compounds or houses on a plot size of 15 m × 30 m or 18 m × 15 m which is an average of 0.1 acre to a house of 24 persons. The OLS result has confirmed the assertion made that the incidence of *Meningococcal meningitis* is common in the high density residential neighborhoods. **Figure 2** is the satellite image of the high density residential neighborhood with the plot sizes of 15 m × 30 m and 18 m × 15 m. A plot size of 15 m × 30 m or 18 m × 15 m with an average of 24 people living in such houses makes the house overcrowded. In a situation where there is an outbreak of the disease, it spreads easily within the neighborhoods because of the nature of the plot sizes and the number of people.

Similarly, the OLS result for housing density shows that it is significant with t-value of 2.46 (p-value < 0.05) indicating that it is contributing to the influence of *Meningococcal meningitis* in KUA. This finding has shown that the *Meningococcal meningitis* disease depends largely on some local risk factors for it to be able to be transmitted within KUA and housing density is one of those factors. The speculation that was made in the earlier section that the disease is more common in locations that are less developed and the housing conditions are poor is confirmed in this finding. Such locations are characterized with high

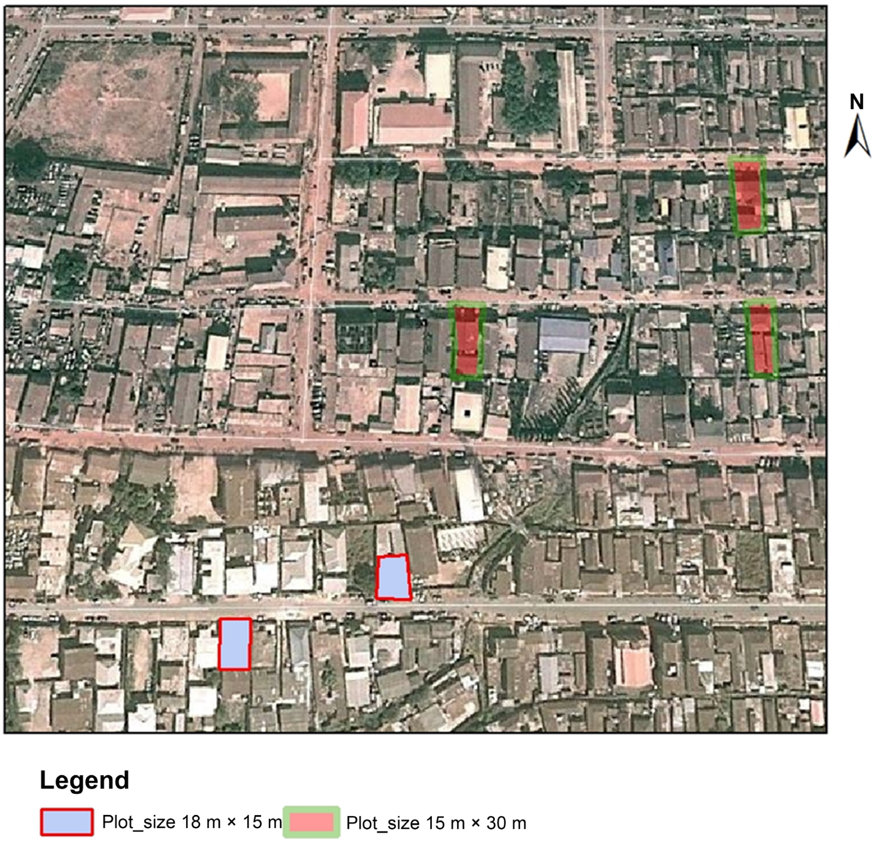


Figure 2. Satellite image of high density residential neighborhood with plot sizes of 15 m × 30 m and 18 m × 15 m.

population in a household and also with overcrowded and unplanned neighborhoods. The rental value is low in such neighborhood which makes so many people rush to such places to seek habitation. In the case of *Meningococcal meningitis* outbreak, the transmission rate is high in such locations.

To further investigate the spread pattern of the residuals, the generated residuals of OLS were mapped as shown in **Figure 3**. By critically looking at the result it reveals that there is a random pattern existing, the model residuals displays a random noise which infers that no clustering of under predictions and over predictions in the model. To further confirm the result statistically, spatial autocorrelation statistics (global moran's I) was conducted and the result in **Figure 4** shows that the pattern of the residuals is not significantly different from random with moran's index value of 0.02 with a z score value of 1.58. The residual does not have a statistically significant spatial autocorrelation which all points out to the fact that OLS model fits correctly. Invariably, having a random pattern with no clustering of over predictions and under predictions means that the result of the model is reliable and it can be trusted.

As shown on **Table 8**, the OLS model revealed that it explained about 53 percent of the variation of the incidence of *Meningococcal meningitis* (R^2 = 0.53) and with an Aikaike information criterion (AICc) of 254.32. The ANOVA returned a significant F-value of 9.80 and the Wald statistics has a significant chi-squared

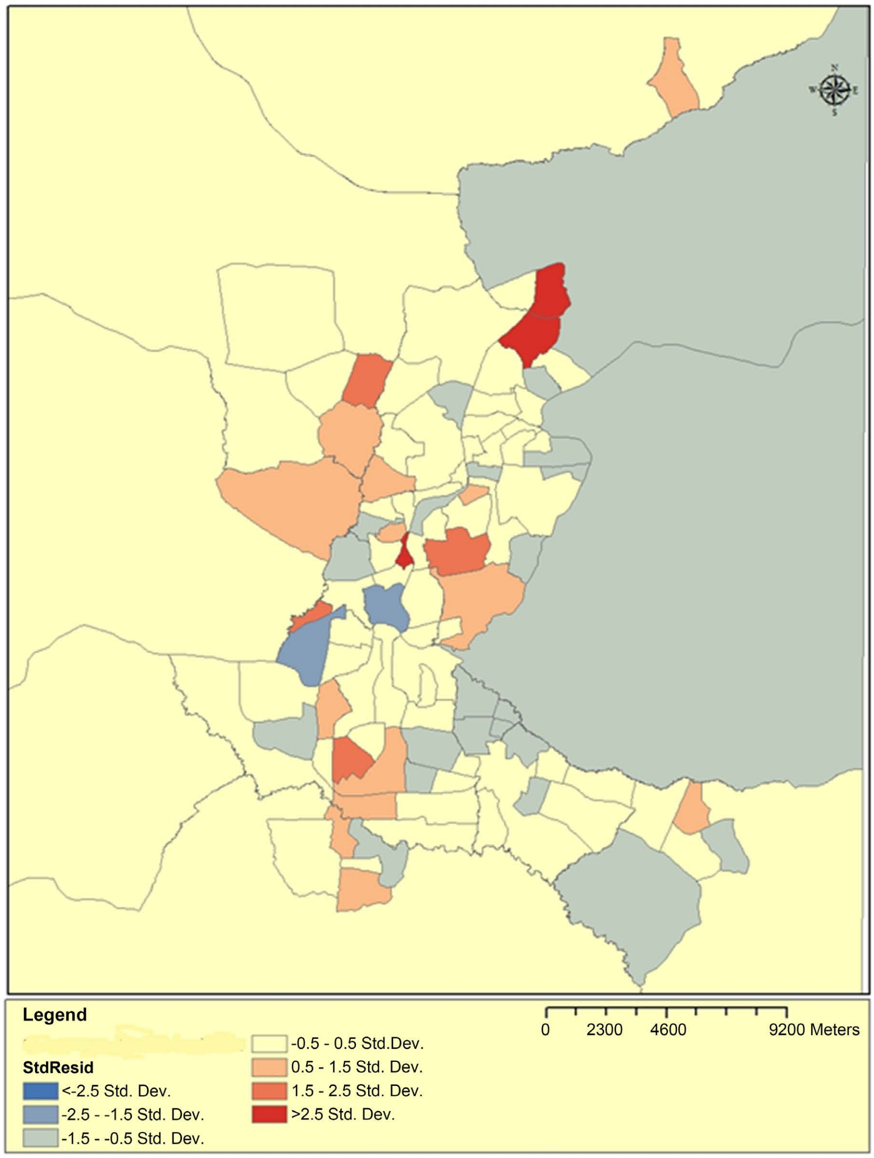


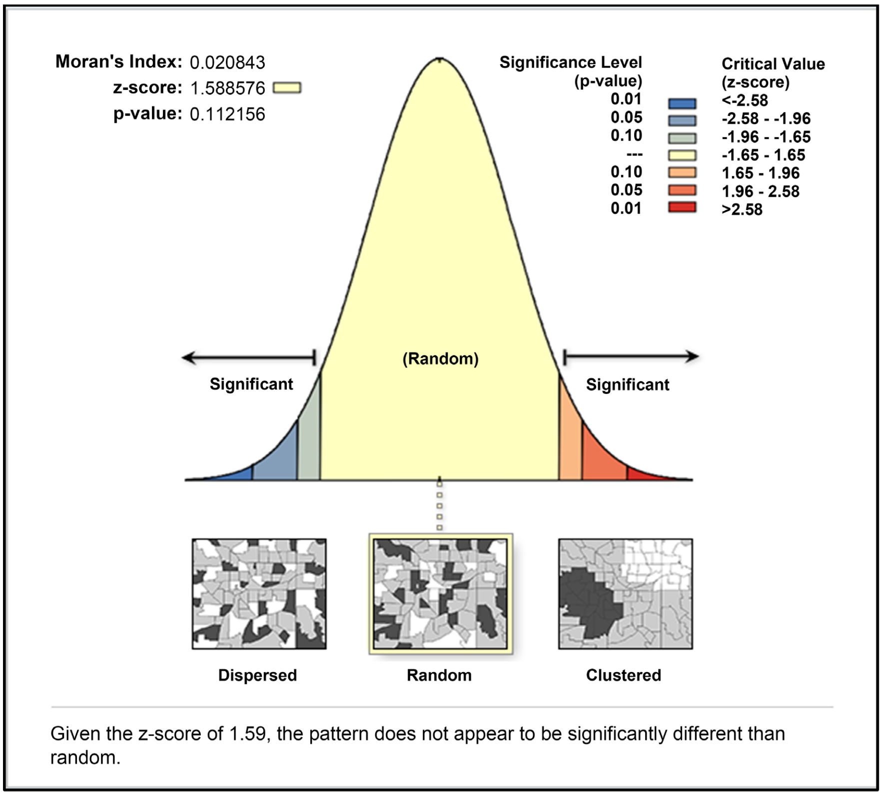
Figure 3. Standardized residuals for OLS model.

Table 8. OLS diagnostics statistics.

Parameters	Values	P-Value
Joint F-Statistic	9.808415	0.000001*
Joint Wald Statistic	913.003606	0.000000*
Koenker (BP) Statistic	23.729772	0.013922*
Jarque-Bera Statistic	172.123310	0.070000

R^2 = 0.534406; Adjusted R^2 = 0.479921; AIC = 254.320893; *Significant parameter at 0.05 level.

value of 913. This means that generally, the model has proved to be statistically significant. Jarque-Bera statistics returned a non-significant chi-squared value of 172 indicating that models prediction is free from bias, meaning that the residuals



Global Moran's I Summary

Moran's Index:	0.020843
Expected Index:	-0.009524
Variance:	0.000365
z-score:	1.588576
p-value:	0.112156

Figure 4. Global Morans *I* spatial autocorrelation results.

are normally distributed. The chi-square value of 23.7 of the koenker statistics is statistically significant. This indicates that the relationship between some or perhaps all of the explanatory variables and the criterion variable are non-stationary or inconsistent across KUA.

The implication of this is that some independent variables may be more important with respect to predicting the outcome of *Meningococcal meningitis* in some neighborhoods, while in some neighborhoods it may demonstrate weak predictive capability. This is a clear indication that the model fitness will be likely improved with GWR since the Koenker statistic detected non-stationarity in the relationship because GWR assumes that relationships across space are non-static. Some of the independent variable that has an insubstantial predictive capacity to influence the incidence of *Meningococcal meningitis* include housing condition 1, housing condition 2, medium income, high income, age above 21 years and secondary facilities.

With the summary of the OLS showing a significant Koenker statistics, it means that there is non stationarity in the relationship because there is a local fluctuations existing in the relationships. This implies that the contribution that each of the variables makes in the incidence of *Meningococcal meningitis* in KUA is not the same all through, it is high in some areas and low in some other areas. OLS has helped to establish the findings that there are strong relationships existing between the incidence of Meningococcal meningitis with the built environment and socioeconomic factors, however the model could not specifically locate the areas that these factors are significant.

4. Conclusions and Recommendations

Applying the global form of regression, ordinary least square (OLS) model which considers the relationship between *Meningococcal meningitis* and the independent variable at a global level revealed that urbanization, poor housing condition and housing density are significant in the incidence of *Meningococcal meningitis* in KUA.

The findings in this model proposed that built environment factors and socioeconomic factors have contributed greatly in the spread of *Meningococcal meningitis*. The most critical factor that contributes to the incidence of the disease is the less developed neighbourhoods. High concentrations of the disease were identified in some specific locations that are mostly less developed and characterized with high density residential neighbourhoods. The less developed neighborhood is made up of some attributes that influence the incidence of *Meningococcal meningitis* disease. They are poor housing condition, overcrowding, low income and social interaction.

Methodologically, the study has improved on the techniques medical geographers utilize to investigate the risk of disease that is environment dependent. It's impossible to use this type of methodological analysis in a non-spatial environment, but the use of GIS and spatial analysis has made this possible. This study has revealed the importance of some spatial statistical methods in the study of *Meningococcal meningitis*.

Development control activities should be taking more seriously in the high density residential neighborhoods since that is where the substandard and overcrowded houses are found. Through development control, neighborhoods that are within the high density residential zone should be giving more attention to by ensuring that each building meets the specific standards for that particular location. Buildings that will accommodate the exceeded number of people for any particular location based on the planning standard for Kaduna State Planning Authority should not be giving the approval in order to checkmate the overcrowding.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

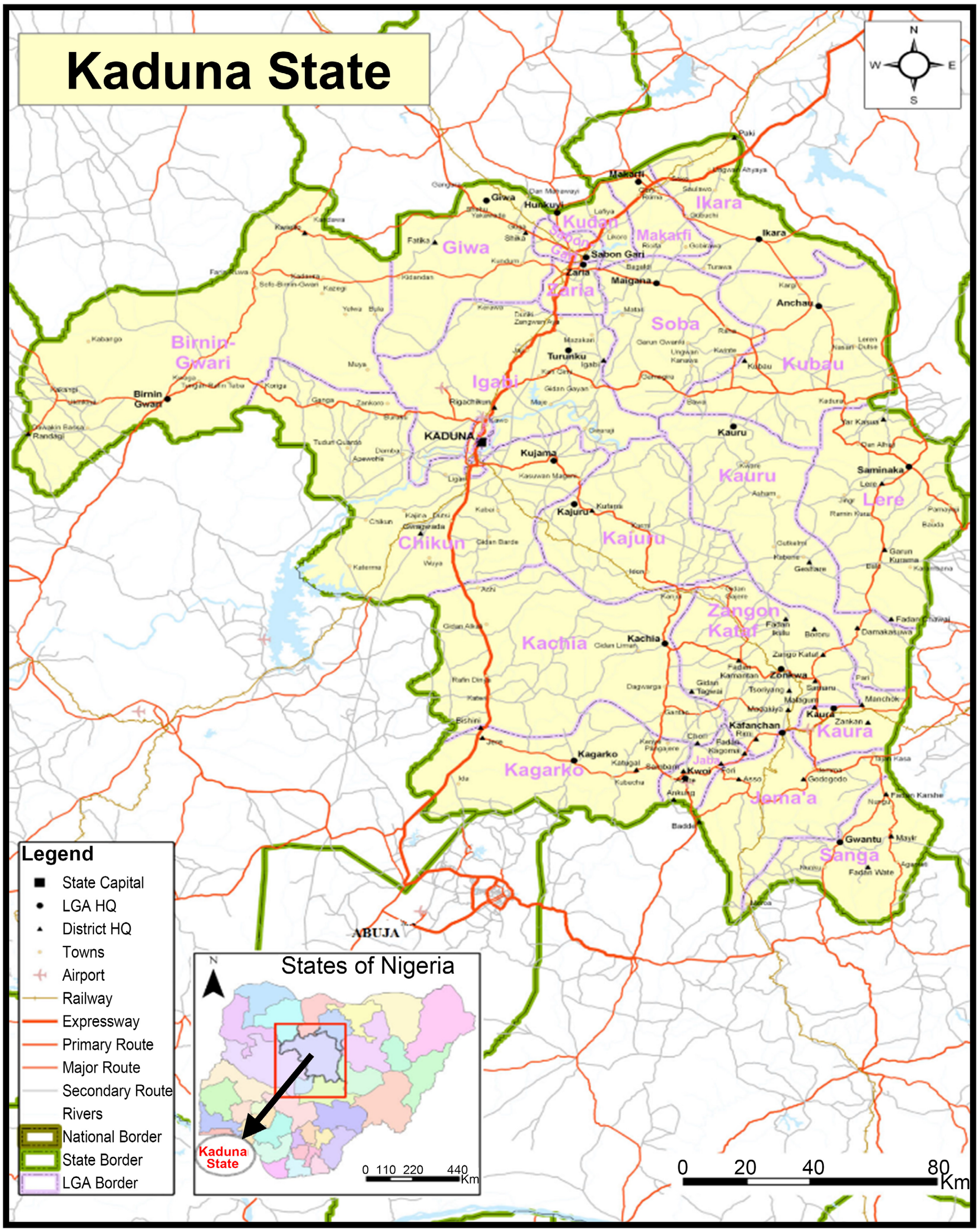

Figure A1. Map of Kaduna State (Source: Lock, 2010).

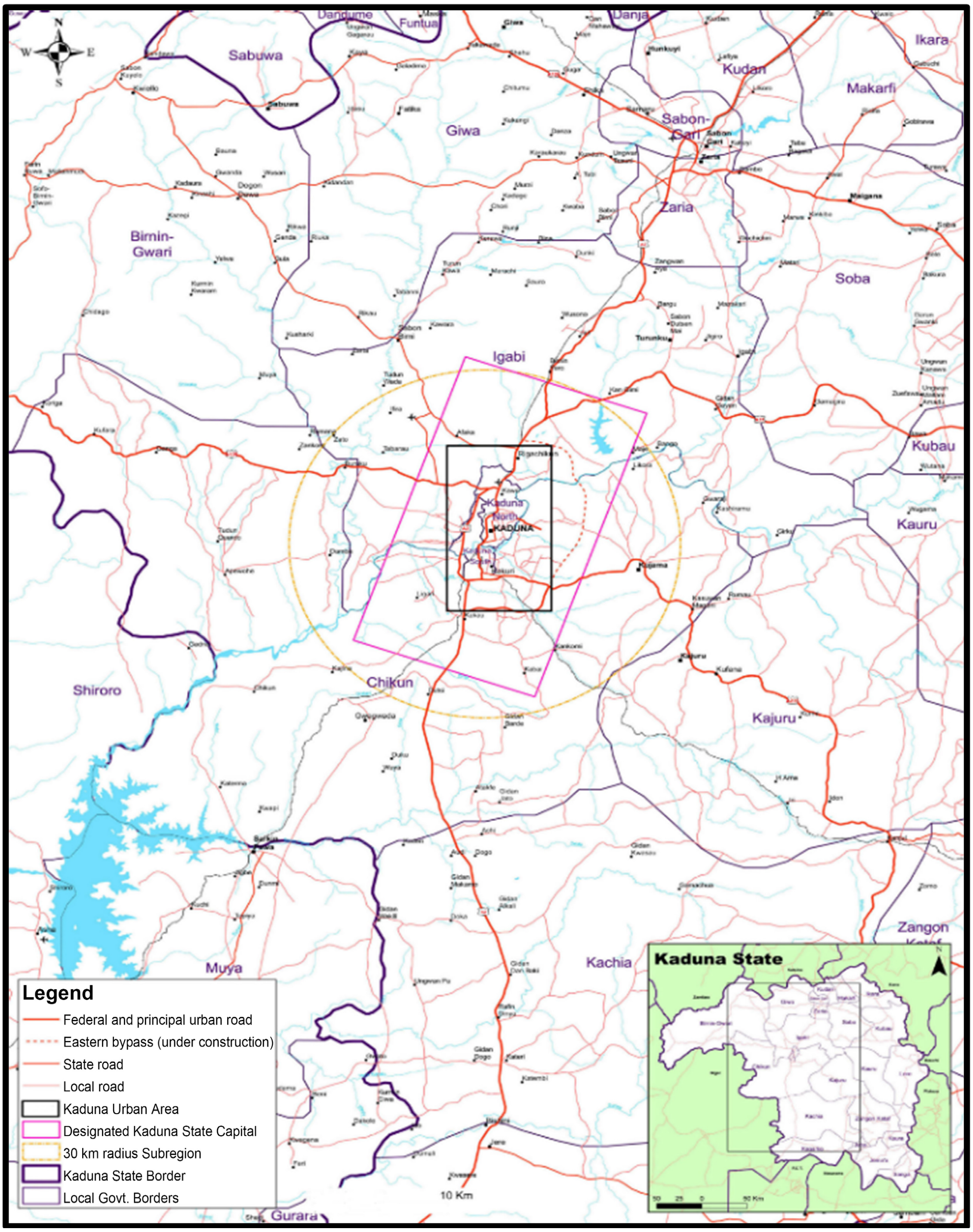

Figure A2. Map of KUA (Source: Lock, 2010).