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Assessment of Spatial Distribution of Health Facilities in Kaduna Metropolis

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Abstract -- Inadequate healthcare delivery in Nigeria can be attributed to uneven spatial distribution of HCF in the country. Some areas are more advantageous than others, creating disproportion in service delivery. In this study, GIS spatial analysis tool has been used to assess the distribution of health facilities in Kaduna Metropolis. Nearest Neighbourhood Analysis and Location quotient index were adopted to evaluate the distribution pattern of the HCF. The outcomes revealed clustered distribution of HCF with a nearest neighbour ratio of 0.545889. Using a scoring system, the location quotient index further exposed irregular spatial distribution of HCF in the study area. This study delivers a model to support the decision makers and other stake holders to carryout effective planning and development of HCF within Kaduna Capital, having identified the areas lacking adequate provision. This is important in order to meet the target of SDG by 2030.

Keywords -- HCF distribution, Location quotient, Nearest Neighbourhood Analysis, and GIS

1.0 Introduction

Globally, health is of universal importance in the political and social spheres. The World Health Organisation (WHO) defines health as "a state of complete physical, mental and social well-being" (WHO, 1978). Thus, the spatial distribution of healthcare facilities (HCF) is of great significance to city planners, since it reveals the adequacy or otherwise, of its provision and utilization. Rizyada, (2012) opined that the quality of life and prosperity of a country could be measured by the availability, number and the quality of health facilities within its urban areas.

GIS is a viable approach in analysing the relationship between epidemiological data, revealing patterns, dependencies and their interrelationships that would have been difficult to achieve in the traditional tabular approaches. Effiong et al (2019) observed that the overall component to be considered for effective healthcare system are the selection of suitable sites and the spatial distribution of HCF. These have impacts on the frequent influx of diseases distressing many countries. The mapping and database creation of HCF is significant in providing its spatial distribution and the physical relationships.

The availability of health care facilities and its accessibility could be measured in a variety of ways with regard to the context of its application, particularly in the planning of the health care systems. Halden et al (2000) were of the opinion that accessibility to HCF is the ability of the populace to obtain a required set of healthcare needs and services.

A lot of previous studies regarding the distribution of HCF have focused more on the attribute data of health facilities within their study areas. In some research works, such as Islam and Aktar (2011) and USAID (2013), whom researches were on the availability and accessibility of health care facilities, much emphases have been on the relationship between population, and the availability as well as adequacy of HCF. Ujoh and Kwaghsende (2014) analysed the spatial distribution of health facilities in relation to location as well as the proportion of doctors, nurses and hospital beds to the population being serviced. Some researchers like Mukhtar et al (2018), have analysed travel patterns of residents to health facilities, after administering questionnaires to patients and health workers alike. These were aimed at evaluating healthcare intervention and its accessibility to the surrounding communities.

This research however, is aimed at assessing the distribution pattern of health facilities in Kaduna Metropolis using GIS analysis. This is to provide a vivid pictorial knowledge on the state of health care facilities within the Metropolis with regard to its accessibility and spatial distribution. This would determine the availability, accessibility, adequacy and proficiency of the health facilities, which is significant in planning effective health care services and delivery.

2.0 Study Area

The study covers Kaduna metropolis situated between latitude 10°23‟ and 10°43‟ N and Long. 7°17‟ and 7°37‟E. The area covers about 12,347 km2 and comprises four Local Government Areas (LGA) namely; Kaduna North, Kaduna South, and parts of Igabi and Chikun LGAs (Figure 1).

The geological component of the study area consists of the Nigeria Basement complex majorly of metamorphic rocks. The plains have high undulating terrain that have the characteristic of passive interfluves, which is attributed to

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the weathering activities. Fluvial erosion influenced by the climatic factors of the surrounding environment added to the nature of the plains (Mortimore, 1970; Umaru, 2006).

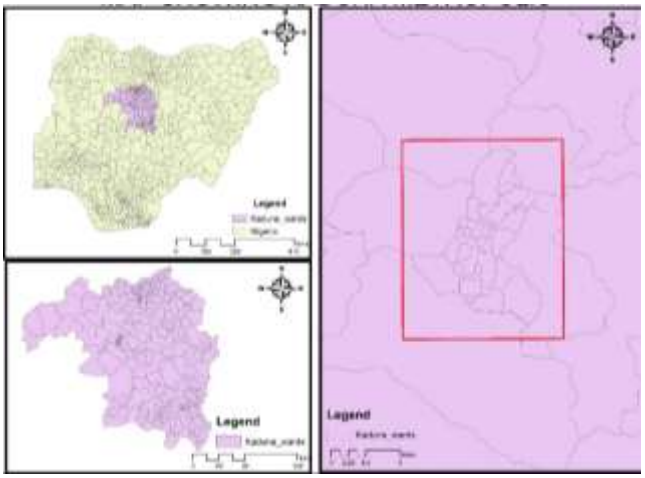

Figure 1: Kaduna Metropolis study area

3.0 Data and Materials

Data on the location of health facilities were obtained and incorporated into a GIS environment. Other data obtained include; Ward data and Population data.

Health Facility data was obtained from Kaduna State Bureau of Statistics, which defines the name, address, category, longitude, latitude and altitude of health facility locations across the study area. There are a total of 298 health facilities with various ownership statuses (Government (87), Community (1), Private (196), Faith-based Organisation (11), and Non-Governmental Organisations (3)). This study is limited to general practice health facilities only and does not include pharmacies and specialist hospitals (Orthopaedic, Dental care, Eye-care and Ear-care Clinics/Hospitals).

There are four levels of spatial extent boundary in Nigeria - National, State, Local Government and Ward levels. The ward level was chosen because it is the smallest defined areal boundary that is suitable for this research. The ward data was sourced from the Geo-referenced Infrastructure and Development and Demographic Data for Development (GRID^3), which is complete repository of geospatially referenced infrastructure data of various sectors in Nigeria, but most especially in the Health sector.

The official population dataset are carried out in Nigeria by the National Population Commission (NPC), usually derived from census, which supposed to be decennial. The data is usually housed and disseminated by the National Bureau of Statistics (NBS). However, Nigeria's latest census was conducted in 2006. Hence, the data had expired since it is more than the 10 years' validity period as recommended by the United Nations. Furthermore, the census data were only available at the local government level, which has an average population of 230,000 (NBS, 2012) and the dataset are not geocoded. Owing to this limitation, the GRID^3 gridded population data estimates, at ward level, was obtained. The data was obtained through surveys (WorldPop, 2019), combined with Dasymetric approach to derive population estimates for the entire country.

Table 1: Sources of the data used

S/N	DATA	FORMAT	SOURCE	YEAR
1	Kaduna State Health facility Location Data	Microsoft Excel File	Kaduna State Bureau of Statistics	2018
2	Second Level Administrative Boundary Data (LGA)	Shapefile (Polygon)	OSGOF	
3	Kaduna State Ward Data*	Shapefile (Polygon)	GRID3	2016
4	Gridded Population Data*	Shapefile (Raster)	GRID3	2017
5	Road Network	Shapefile (Line)	OSM	2019
6	Satelite Imagery	Raster (0.5m Resolution)	Kompsat	2015

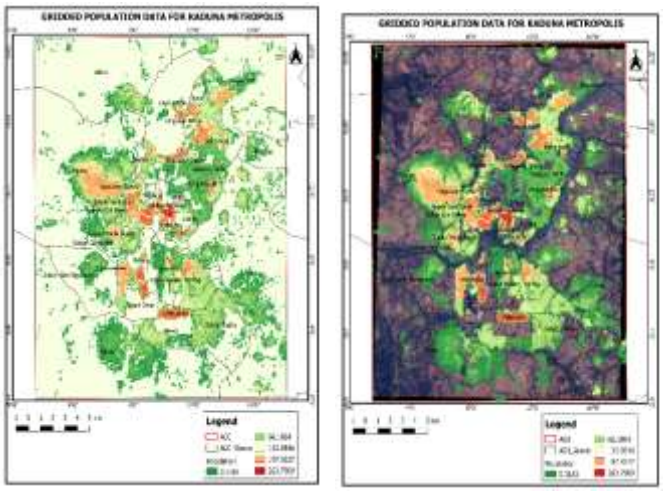

Fig. 2a: Gridded population data 2b: Gridded population data with image map

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Fig. 2c: GRID3 classification of wards (rural/urban)

3.1 Methods

The obtained data on the location of health facilities were incorporated into a GIS environment and overlaid with the population data. Several analyses were conducted in the study. They include Heat Map Analysis, Average Nearest Neighbour Analysis, Location Quotient Index and the Index map was generated.

Heat map Analysis was employed to visualise the distribution pattern of the HCF in the study area. Kriging tool in ArcGIS 10.5 was used to show areas of more concentration of health facilities compared to other areas with less concentration.

Average Nearest Neighbour Analysis was used to assess the spatial pattern of distances among public health facilities. The nearest neighbour is a measure of the distance between each spatial feature and its nearest neighbour centroids. It compares these two expected values for a random sample of points from a complete hypothetical random distribution and shows if it is regularly dispersed (probably planned), randomly dispersed, or clustered. The average nearest neighbour ratio is determined as the observed average distance, divided by the expected average distance with the same number of features, covering the same study area. The index (average nearest neighbour ratio) is thus less than the average for a hypothetical random distribution (less than one). In contrast, if the average distance is greater than a hypothetical random distribution, the spatial pattern of features is considered dispersed (ESRI, 2017; Mansour, 2016; Chen and Getis, 1998). Hussein et al (2018) confirm that the value of the index ranges from 0 (clustered pattern) to 1 (randomly dispersed pattern) to 2.15 (regularly dispersed /uniform pattern).

Location Quotient Index score was created, by dividing the normalised value for each health care facility (per ward) by the population (per ward) using the equation;

ISj=Vi/Pi, where; ISj = index score for ward j and Vi = total of health facility, and Pi = Population estimates per ward;

The index map provides a range of scores between 0 to 1, where lesser value indicates lower distribution of health facilities, and higher value predicts higher distribution of health care facilities. The index was validated with the real health data, to determine the distribution pattern, by displaying and visualizing the dispositions of the spatial points of health facilities and the distribution pattern.

4.0 Results and Discussion

The spatial distribution of health facilities within the study area is shown in Figure 3 and Figure 4 is a choropleth map of the distribution of health facilities per ward.

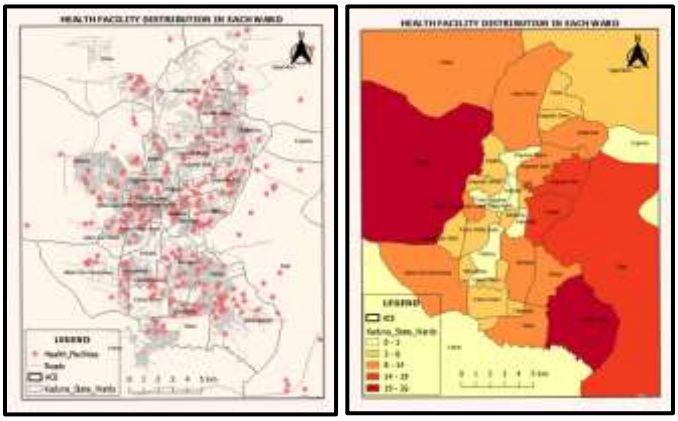

Figure 3 and 4: Distribution of health facilities per ward

The results from the heat map showed that the wards located around the middle of the study area, enjoy quite a significant number of health facilities, compared to the ward located closer to the edges. Parts of Kakau and Kujama wards are situated within the study area. These two wards have no health facilities located within them. This is why the results moving forward continuously point to them as wards lacking access to health facilities as indicated in table 2 and further depicted in Figures 5 and 6.

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Table 2: Health facility distribution at ward level

S/N	ward_name	lga_name	state_name	HCF_Num	AOI Population	Ratio
1	Badarawa	Kaduna North	Kaduna	13	60323	4640
2	Kawo	Kaduna North	Kaduna	6	38104	6351
3	Kakuri Gwari	Kaduna South	Kaduna	4	11478	2870
4	Sabon Gari South	Kaduna South	Kaduna	2	23182	11591
5	Badiko	Kaduna South	Kaduna	7	26770	3824
6	Barnawa	Kaduna South	Kaduna	14	36645	2618
7	Tudun Wada South	Kaduna South	Kaduna	7	33864	4838
8	Sabon Gari North	Kaduna South	Kaduna	11	27560	2505
9	Kabala	Kaduna North	Kaduna	18	31934	1774
10	Yelwa	Chikun	Kaduna	9	46803	5200
11	Afaka	Igabi	Kaduna	11	30607	2782
12	Tudun Nupawa	Kaduna South	Kaduna	2	20939	10470
13	Rigasa	Igabi	Kaduna	26	201295	7742
14	Rigachikun	Igabi	Kaduna	8	62120	7765
15	Unguwan Sanusi	Kaduna South	Kaduna	6	19163	3194
16	Narayi	Chikun	Kaduna	13	71371	5490
17	Tudun Wada North	Kaduna South	Kaduna	1	10238	10238
18	Nassarawa	Chikun	Kaduna	6	37952	6325
19	Dadi Riba	Kaduna North	Kaduna	0	16790	0
20	Sabon Gari Nassarawa	Chikun	Kaduna	11	25855	2350
21	Kakuri Hausa	Kaduna South	Kaduna	7	13556	1937
22	Kakau	Chikun	Kaduna	0	34933	0
23	Sabon Tasha	Chikun	Kaduna	24	89046	3710
24	Kujama	Chikun	Kaduna	0	8608	0
25	Television	Kaduna South	Kaduna	6	23223	3871
26	Shaba	Kaduna North	Kaduna	6	9507	1585
27	Unguwar Shanu	Kaduna North	Kaduna	3	22767	7589
28	Sabon Gari West	Kaduna South	Kaduna	7	33754	4822
29	Unguwar Rimi	Kaduna North	Kaduna	19	40476	2130
30	Unguwan Dosa	Kaduna North	Kaduna	5	24323	4865
31	Hayin Banki	Kaduna North	Kaduna	10	26823	2682
32	Maiburiji	Kaduna North	Kaduna	2	10875	5438
33	Unguwar Sarki	Kaduna North	Kaduna	11	19058	1733
34	Makera	Kaduna South	Kaduna	0	24020	0
35	Sardauna	Kaduna North	Kaduna	6	9051	1509
36	Rido	Chikun	Kaduna	17	80831	4755

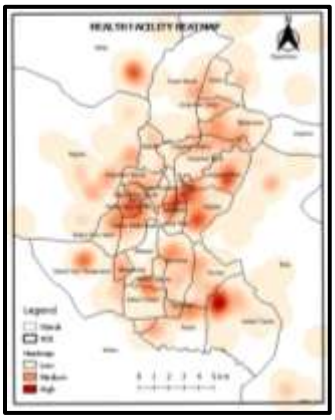

Figure 5: Heat map of health facilities pop.

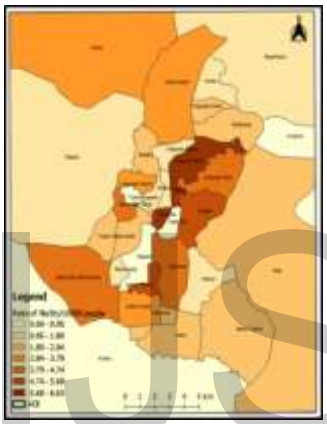

Figure 6: Health Facility per 10,000 Ratio

The Health Facility to Population ratio provided an overall pattern of the number of persons each facility should on average cater for. The yellow-coloured area in Figure 6 denotes that the number of health facilities is inadequate for the population in those wards. The brown areas on the other hand indicate adequacy of health facilities in relation to the number of people residing in the ward. Rigasa for example houses 26 Health facilities (the highest number of facilities in a single ward), it also has a population of approximately 201,295 people, which translates to a ratio of 1.2916. This ratio has met the acceptable standard of 1:10,000 (equals to 1 when formula is applied) as recommended by WHO (WHO 2012; USAID 2009; Global Fund 2009). The indicator of distribution of health facilities per 10,000 people was calculated by:

10,000 × (Number of public health facilities/Total population in each district) (Mansour, 2016; WHO, 2010).

In other developing countries, the indices may vary for example, Bhatt and Joshi (2013) stated that in India, a primary health care facility is expected to cater to a total population of 20,000 people in tribal areas and 30000 people in other areas. Similarly, Hazrin et al (2013) opined that the norm for the siting a health clinic in Malaysia one per 20,000 people. However, this norm is relaxed to the population of 5000 per health centre, for the rural areas, where accessibility is a problem.

To determine the spatial accessibility of Health Care Facilities (HCF) in the Kaduna Metropolis, the WHO (1997) standard for primary HCF in developing countries was adopted. The standard recommended maximum distance of 5km or 30 minutes' walk. This accessibility was achieved using the ArcGIS Network Analyst extension. A network service area is a region that encompasses all accessible streets i.e. streets that are within a specified impedance (ESRI, 2017).

Figures 7a and 7b show how accessible the health facilities are, to the residents. Generally, the wards in the middle, have relatively easy access to health facilities, as travel distance is about 1000m on average. Significantly, it is important to note that these are also the more densely populated areas. By contrast, the wards closer to the boarders of the study area such as Kakau, Rido, Kujama among others, have to travel beyond 5km to access their nearest health facility (Figure 8). While wards such as Dadi Riba and Makera, even though they are located in the middle of the study area, have to travel about 2000m – 3000m on average to get to the nearest health facility. Their advantage however is that they have access to good road network. It is worthy to mentioned as observed by Mansour (2016) that the lack of HCF in some districts, especially those close to the borders of the study area, may be attributed to their low population size or because the basic infrastructure of these districts are being developed.

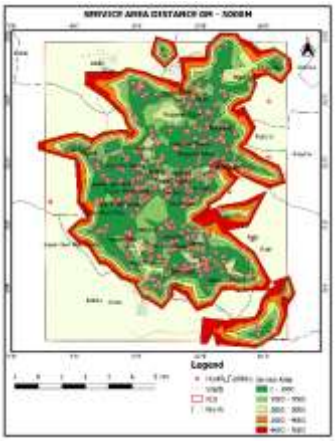

Figure 7(a): Service area map

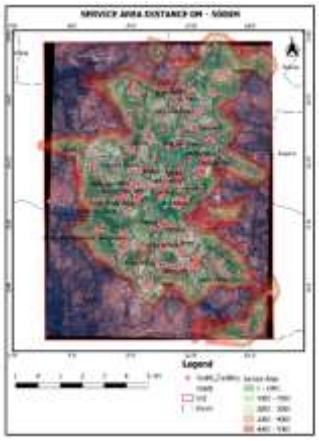

Figure 7(b): 5km satellite image service area

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Figure 8: A section of Kakau ward where residents have to travel above 5km to gain access to the nearest health facility

The results for Nearest Neighbour Analysis revealed that health facilities across Kaduna Metropolis were spatially clustered. The average nearest neighbour ratio of 0.674643 ($p < 0.001$), which is less than 1 and the z-score of -10.744820 ($p < 0.001$), signifies that the spatial distribution of the health facilities within Kaduna metropolis is of a clustered pattern (Figure 9). Consequently, the null hypothesis of no spatial pattern among the health facilities in the study area was rejected. Owing to the large Z-score, there was less than 1% likelihood that this clustered pattern could be the result of random chance.

With regard to the Location Quotient Index, Figure 10a depicts that the health care centers vary at different ward levels. The degree of concentration is higher in some areas such as Unguwar barki, Kabala, Sardauna, Kakun Hausa. This signifies that more concentration of health care centers are being made available to the populace (Figure 10b). While in areas such as Badiko, Unguwan Sanusi, Sabon Gari, Tudun Wada South, Sabon Gari west, Unguwan Dosa, Badarawa, Sabon Tasha and Unguwan Television, the location quotient indicates that the health care facilities is sufficient to the inhabitants of the areas. The location quotient of some areas that include Makera, Dadi Riba, South Tukum, North Tukum and Marburiji, reveals that the available health care facilities are deficient to the populace of those areas. Thus, the location quotient in relation to the current spread of the HCF, shows that they are not evenly distributed across the various wards within Kaduna Metropolis.

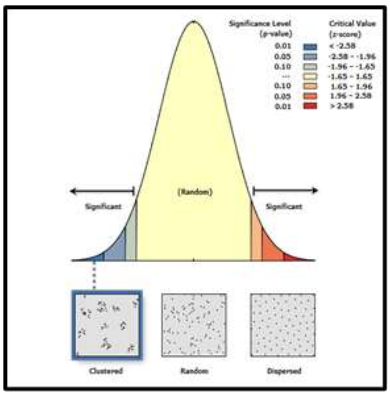

Figure 9: Nearest Neighbour Analysis

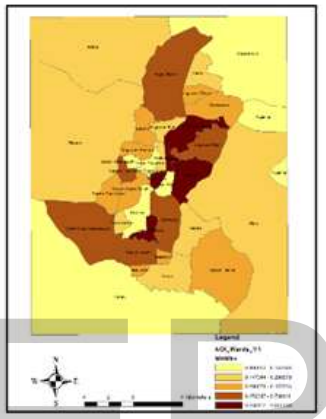

Figure 10a: Location Quotient Index

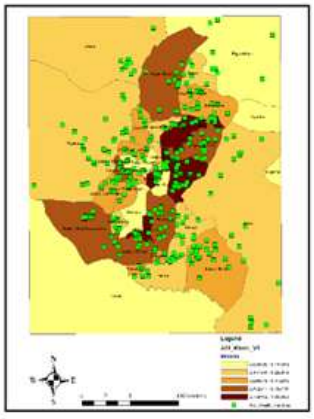

Figure 10b: Validation for Location Quotient

5.0 Conclusion

The main goal set to accomplish in this study is to assess distribution pattern of health care facilities across Kaduna Metropolis. The findings revealed that the distribution pattern of health facilities in Kaduna Metropolis is uneven. The pattern is rather clustered towards the middle of the study area. This further revealed the influence of market forces, as they are mostly located in densely populated areas (especially the private HCF), as espoused by Hazrin et al (2013). In most cases, the favoured wards have been classified as urban localities. This is also the observation of GRID3 assessment of the wards (Appendix 1). As a result of this, it is clear that the application of GIS techniques offers great potential for policy/decision makers to improve the distribution of health facilities.

In recent times, GIS analysis is increasingly applied in the health sector and has turned into a valuable tool for ensuring vulnerable and underprivileged populations, have access to health care facilities as observed by Hu et al (2013). If Nigeria expects to meet the goals and targets of Sustainable Development Goal - 3 (Ensure healthy lives and promote wellbeing for all at all ages), it is imperative that geospatial technology is embraced as quickly as possible.

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This will ensure efficiency in decision making and equity in the distribution of HCF and services.
Suitability analysis can be carried out to determine perfect locations for siting new health facilities and other health services. These are some of the areas that could be looked into for further research.

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