

## A GIS-based Spatial Analysis of Health care Facilities in Yola, Nigeria

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**Abstract**—In recent years, health care provision policies in Nigeria have addressed distribution and spatial equity questions at a gross or regional level, but have neglected to address the distribution of health care facilities within cities. This paper explores the potential use of GIS for modeling the spatial distribution and accessibility of the health care delivery system in Yola. Several digital and non-digital data sets were collected and transformed into GIS data. Spatial analysis tools, including symbols, overlay operations, Kernel Density Estimations (KDE), buffer operations, and a raster calculator were used for the analysis. All identified public and private facilities were classified as primary, secondary, or tertiary. The majority of these facilities were concentrated in Jimeta. The study also produced the three following accessibility models: (i) the distance to the health facility, (ii) the health facility-to-population ratios, and (iii) the physician-to-population ratios. Based on this analysis, it was concluded that a gross inadequacy exists in terms of health care facilities and physicians. Thus, these results identify the need for urgent improvements in the Yola health care delivery system, including the construction of new facilities, upgrades for existing facilities, increased physician employment, and the adoption of GIS technology by Yola health care planners and policy makers for effective planning and resource allocation.

**Keywords**—GIS; Spatial analysis; Health care facilities; Yola; Nigeria.

### I. INTRODUCTION

The idea that all people are entitled to have their physical needs satisfied is at the heart of the human rights movement. This includes the right to survive and to live without preventable suffering. The Declaration of Human Rights details the right to adequate health in Article 25 as follows:

“Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care...” [1].

Nigeria recognises the right to health and has committed itself to health protection by assuming obligations from international treaties and domestic legislations that mandate specific conduct regarding the health of individuals within Nigeria. Prior to the economic efforts in the mid-1980s, the health sector witnessed robust growth, mainly because of unfettered government support and assistance from international donor agencies. During this time frame, access to free health care was readily available at public hospitals

and clinics in urban areas. However, this positive development suddenly stopped by 1985 because of multiple factors. Of these factors, the two most notable factors were the precipitous economic decline and the military usurpation of power. The military usurpation of power marked the genesis of many intractable challenges that impacted the Nigerian health system [2]. Since then, the geographic maldistribution of regional, urban, and rural health care facilities in Nigeria has occurred. Moreover, the existing facilities are haphazardly distributed. This situation may be corrected by using reliable data with the Geographic Information System (GIS). These systems contain important tools that can help in health delivery service planning and decision-making processes. These tools include database management, planning, risk assessment, service area mapping, location identification, and accessibility tools [3]. For example, [4, 5] conducted hospital service area delineations, [6] calculated changes in the person-to-bed ratios within hospital catchment areas, [7] proposed a new location-allocation structure for primary health care centres by using a multi-criteria approach in a GIS environment, and [8, 9] computed the accessibility of physician locations and the physician-to-population ratio. The same principle was applied by [10], except non-spatial factors of health care accessibility were added, such as age and social class. [11, 12] used gravity models to define the population flow to health centres and to produce a combined accessibility indicator of distance and availability. Several of these studies are well acknowledged by researchers from Western European and other developed countries. In contrast, most health authorities, practitioners and researchers in Nigeria have not explored the potential use of GIS for improving the performance of essential public health services.

Thus, the aim of this study was to explore the use of GIS for modelling the spatial distribution and accessibility of the health care delivery system in Yola, Nigeria. This study was conducted to identify the underserved and over served areas and to create a model to guide health care planners and regulators in their creation of future proposals. The specific objectives of the study are to *i*) inventory all public and private health facilities, *ii*) create a GIS database of the existing health care centres, *iii*) characterise and identify the spatial pattern of the existing health care facilities, *iv*) map

the health facility services, and v) model the accessibility of health care facilities for Yola residents.

Considering the advantages of GIS relative to traditional analysis methods, the major contribution of this study is to demonstrate that spatial GIS information can be used to reach desired quality decisions in a short time frame and at a low cost. In addition, GIS will enable the establishment of a health care facility database, which can be easily retrieved and analysed at any time.

## II. MATERIALS AND METHODS

### A. Study Area

Yola is the administrative capital of Adamawa State, Nigeria. Yola is a twin settlement that encompasses Jimeta (the administrative and commercial centre) and Yola-Town (the traditional settlement). Yola is located at a latitude of 9°14" N and a longitude of 12°28' E (Figure 1), and has a total population of 395,871. Specifically, Jimeta and Yola-Town have populations of 199,674 and 196,197, respectively [13]. The estimated population projection for 2011 is 399,598.

Yola has a tropical climate with rainy and dry seasons. The maximum and minimum temperatures can reach 40°C and 18°C in April and between December and January, respectively. The mean annual rainfall is less than 1,000 mm [14].

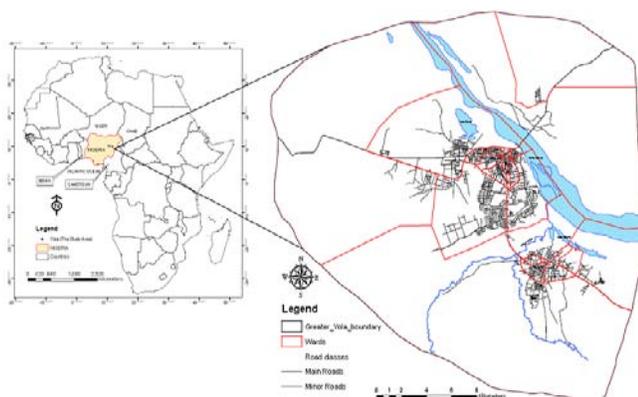


Figure 1. The study area.

### B. Data and Methods

Several digital and non-digital data sets that contain spatial data were collected through a literature review and from field work. The spatial data sets included analogue maps of the road network and administrative boundaries, global positioning system (GPS) coordinates of strategic road junctions (Table I) [15], and a Google earth satellite image of the study area. The GPS coordinates were used as a georeference for the analogue maps. The Google image was used to update the analogue maps and to identify the health facility locations. To depict the service supply environment, an inventory of all health care facilities (public and private) in the study area was conducted. This inventory was conducted by compiling an exhaustive list of facilities that

were documented by [16] and the Adamawa State Ministry Health and Health Service Management Board in their official records.

TABLE I. THE GPS COORDINATES OF THE YOLA ROAD JUNCTIONS [15].

Road Junctions	Northing	Easting	Altitude (meters)
Abuja Road/Modibbo Adama Way	1019260	221732	123.72
Abuja Road/Polo Road Junction	1019062	223734	129.30
Abuja Road/Modibbo Adama Way	1018700	224418	134.42
Modibbo Adama way/Bye pass Junction	1017959	225980	143.72
Mafias Quarters Road/Bye – pass	1017551	224029	144.42
Madaki Street/Bye – pass Junction	1017397	223757	153.45
Madaki Street/Modibbo Adama Way	1018452	223818	153.02
Sokoto Street/Modibbo Adama way	1018549	223374	145.58
Chiroma street/Modibbo Adama way	1018473	222953	148.60
Modibbo Raji/Bye – pass (Phase I Road Junction)	1017483	223298	141.63
Phase II Road/Bye – pass	1017513	227780	146.74
Abdullahi Bashir/Yola Road (80 Unit Junction)	1021929	220437	136.51
Police Round About	1024445	220536	157.21
Justice Buba Ardo/Ibrahim Kashim (Gov't House Junction)	1024520	221890	169.30
Zaki Crescent/Abdullahi Bashir Road	1023508	222318	160.93

This study used the ArcGIS® 9.3 software. Thus, all data sets were transformed into the ArcGIS® data format (shapefile). Each of the analogue maps was scanned and georeferenced to UTM zone 32 N and to the “Minna-Nigeria” datum by using the GPS data (Table 1) as ground control points. In addition, the spatial data were captured and organised into different layers with on-screen digitisation as described below. Figure 2 shows the methodology schematic. Finally, a database was created and filled for each of the layers.

- i. The road network layer: describes the road network patterns and contains the road name, length, width, class, and condition. This layer enables health planners to understand the spread of a city network and can be overlaid onto a health centre location map to examine their relationships.
- ii. The health care facility location layer: contains a record of health centre locations in Yola. In addition, this layer contains the following attributes: (a) general information regarding the health facility (including name, ownership, ward and local government, legal status, and bed capacity), and (b) medical personnel data (for physicians, pharmacists, technicians, and nurses/midwives). Health centres can be classified by any of these attributes and then used for comparing the functional differences between the different health centres.
- iii. The administrative boundary or service extent of the health centre layer: is a polygon layer that divides Yola into 20 different administrative wards. Each ward shows the spatial extent of the health

centres. Attributes of population, area, and density were linked to this layer. Because population census data on a ward basis is lacking, the 2007 voters register from the Independent Nigerian Electoral Commission (INEC) [17] and the 2006 population census data of Yola were used to derive the ward populations. Population data help health planners to define the catchment area of each health centre and indicate whether these centres can offer adequately serve a population of a certain size.

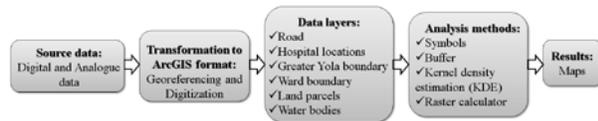


Figure 2. Methodology.

### C. Methods

- i. *Symbols*: are used on maps to represent various geographic phenomena that are related to location, distance, volume, movement, function, process, and correlation. These phenomena can be classified into the four following basic categories: *point* (non-dimensional data), *line* (one-dimensional data), *area* (two-dimensional data), and *volume* (three-dimensional data) [18]. In this study, the *point* category is used to represent the health care facilities.
- ii. *Overlay operation*: is a spatial operation that combines different geographic layers to generate new information. This operation is performed in raster and vector domains by using arithmetic, boolean, and relational operators [19]. However, in this study, this operation is only applied in the vector domain. Detailed descriptions of the overlay operations can be found in standard GIS textbooks, such as those by [20, 21, 22]. Furthermore, [23, 24] describe these principles in more detail and [25] detail some of the key overlay algorithms.
- iii. *Kernel density estimation (KDE)*: estimates the density by using a “kernel function”  $K$  and a smoothing parameter  $h$ . Generally, the estimated density does not depend on the kernel function choice, but is strongly affected by the smoothing parameter value. Larger smoothing parameters obscure small irregularities and smaller smoothing parameters result in a bumpy density surface [26]. There are two types of KDE functions, fixed and adaptive kernels. The fixed kernel function is usually less computationally intensive than the adaptive kernel function and uses an optimal spatial kernel (bandwidth) over the study space. Unfortunately, this method produces high local estimation variance in areas where data are sparse, which may mask subtle local variations in areas where data are dense [27, 28, 29]. In contrast, the adaptive kernel function ensures that a certain

number of nearest neighbours are considered as local samples, which better represents the degree of spatial heterogeneity [28]. In this study, the Gaussian adaptive kernel function found in the ArcGIS® 9.3 Spatial Analyst Tool was used. The general form of the KDE is given by [30] as follows:

$$\lambda(s) = \sum_{i=1}^n \frac{1}{\pi r^2} k\left(\frac{d_{is}}{r}\right) \quad (1)$$

where  $\lambda(s)$  is the density at location  $s$ ,  $r$  is the search radius (bandwidth) of the KDE (only points within  $r$  are used to estimate  $\lambda(s)$ ), and  $k$  is the weight of point  $i$  at a distance of  $d_{is}$ , which is used to locate  $s$ .

- iv. *Buffer*: involves drawing an Euclidean buffer around each facility. Areas within the buffer limits are considered accessible to a facility, while those outside of the limits are considered inaccessible. Areas where overlapping buffers are abundant may represent areas of over service (and vice-versa) [31]. This method can provide a useful access indicator for certain circumstances [32]. For example, this method is useful for assessing the feasible walking range of facilities. However, for many purposes, this method does not sufficiently account for the constraints of availability or transport infrastructure.
- v. *The Raster calculator*: allows one to create and execute a Map Algebra expression that will output a raster.

## III. RESULTS AND DISCUSSION

### A. Classification and spatial distribution of health care facilities in Yola

Three categories of health care facilities exist in Yola. These categories include *primary*, *secondary*, and *tertiary* facilities. Furthermore, these facilities are owned by Federal, State, and Local governments, and by private individuals or organisations.

- i. *Primary health care*: provision of health care at this level is largely the responsibility of local governments and is supported by the State ministry of health.
- ii. *Secondary health care*: this level of health care provides specialised services to patients who are referred from the primary health care level. These services are provided through out-patient and in-patient hospital services, which include general medical, surgical, and paediatric cases and community health services. Secondary health care is available at the district, divisional and zone levels of the State. Adequate supportive services, such as laboratory, diagnostics, blood bank, rehabilitation and physiotherapy are also provided.

iii. *Tertiary health care*: consists of highly specialised services, such as orthopaedic, eye, psychiatric, and paediatric cases. These services are provided by education and at specialist hospitals. Appropriate support services are incorporated into the development of these tertiary facilities to provide effective referral services. There are two such facilities in Yola, the Federal Medical Centre (FMC) and the Specialists Hospital.

Generally, maps that depict the locations of health facilities are very useful for health planners. For example, these maps help planners to quickly identify the spatial distribution of health facilities within a community. In addition, these maps allow planners to determine which areas lack such facilities. However, such maps do not exist in Yola. Using *Symbology* from the *Spatial Analyst Tool*, the health care facilities in Yola were mapped based on different classes (i.e., dispensaries, clinics, and general hospitals) and ownership (public and private). Presently, there are 56 health care facilities in Yola, of which 64% are public and 36% are private. Forty of these facilities are located in Jimeta (i.e., the administrative and commercial centre). It can also be observed that the northern and western parts of Jimeta, and southern part of Yola-Town are underserved (Figure 3).

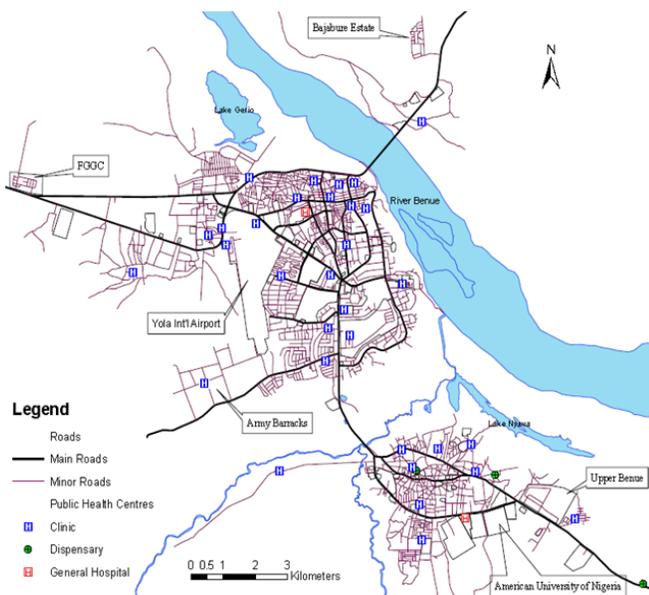


Figure 3. Public health care centres in Yola.

From Figure 4, it can be observed that only three private health care facilities are found in Yola-Town. This means that the residents of Yola-Town have very few options in terms of private health care services or rather they have to travel beyond 10 kilometers to access these facilities in Jimeta. This is quite different for residents of Jimeta that have access within a distance of less than 2,000 m or few

kilometers. Though, the majority of the facilities is concentrated in the central part of the city.

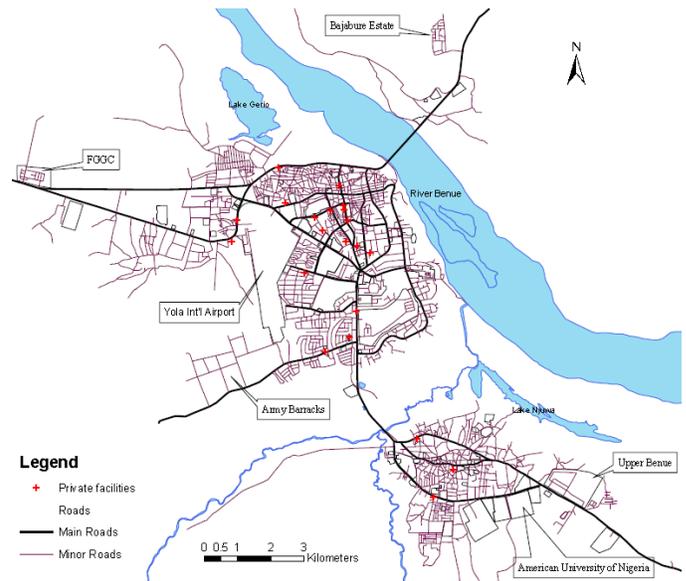


Figure 4. Private health care centres in Yola.

In addition, a KDE was applied by using a search radius of 1,000 m and a cell size output of 100 to determine the density of health care facilities in Yola (Figure 5). The results showed a high concentration of health care facilities in Jimeta, especially in the city centre (i.e., a lopsided distribution pattern which hinders good access to health care service in the city).

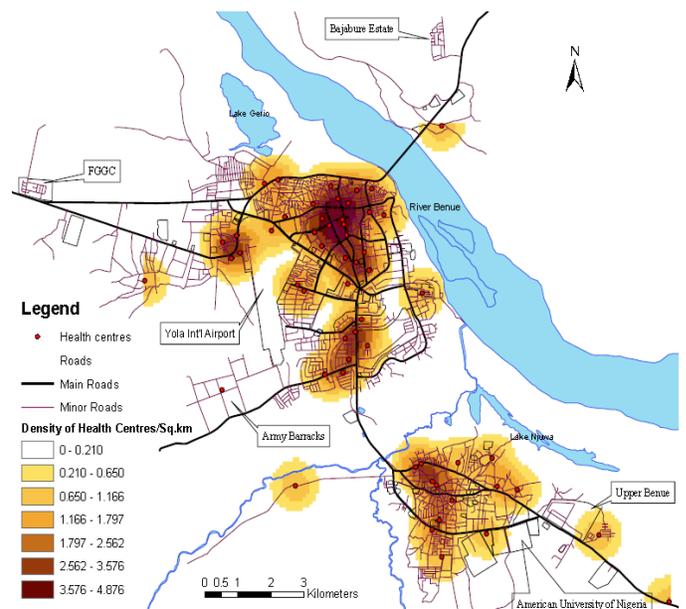


Figure 5. Density surface of health care centres in Yola.

**B. Population distribution**

Population variables impact the level, nature, type, and variety of health service demands and the resulting service

provisions. Thus, knowledge regarding these demographic variables is essential for the development and delivery of health services because it is used to plan and target service provisions. This observation is particularly true for population based and location based health care planning and community health programs [33, 34].

In an attempt to understand the spatial distribution of the Yola population, the projected 2009 population based on the political ward was used to generate a population density surface by applying the KDE. After several trials, a search radius of 1,500 m with a cell size output of 100 was selected as the most suitable for this application. The result showed that the high density area cover parts of the Rumde, Yelwa, Alkalawa, Luggere, Nassarawo and Doubeli wards in Jimeta. In addition, the Mbamoi, Makama A and B, and Toungo wards were identified in Yola-Town (Figure 6). As expected, these wards are generally high density residential areas, while the low population density areas comprised of medium and low density residential areas. The spatial pattern of the Yola population indicated an increased density in the old city centres and a decreased density in the southern and western areas of Jimeta and in the southern area of Yola-Town. This increasing population density in the old city centres suggests that the demand for health care services in these areas is high relative to other parts of the city.

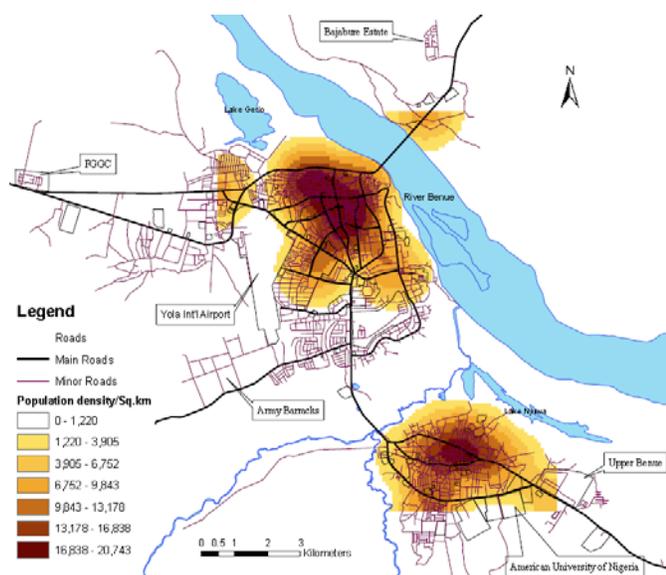


Figure 6. Population density surface of Yola.

C. Examining the accessibility of health facilities

The simplest definition of accessibility for a given location considers how easy it is to get to the location. Defining accessibility to health care centres is an important task for health planners [9]. The concept of health care accessibility is one of the most analysed and debated concepts in public health [35, 36, 37]. The debate on this issue was framed by researchers in terms of economic, structural, infrastructural, and behavioural aspects. This study is concerned with geographic proximity, which is a form of potential spatial accessibility [35, 36].

i) Proximity to health facilities

In this study, a buffer analysis is applied to define the proximity to health care facilities. Buffers were created around all of the facilities in the study area by using the Municipal planning standard with a radius of 1 kilometre in the catchment area of the health care facilities (Figure 7). The results show that some areas in Yola are located outside of the 1 kilometre accessibility zones, especially in the western and northern parts of Jimeta. In addition, it is clear that the existing health care centres must serve a catchment area that is larger than the standard size. Based on this output, different parts of Yola were determined to have low health care accessibility. Health care planners can use this model to make decisions regarding where to build new health centres in Yola. For example, areas beyond the 1,000 m accessibility zones can be used as a reference for determining potential locations for additional health care centres in Yola.

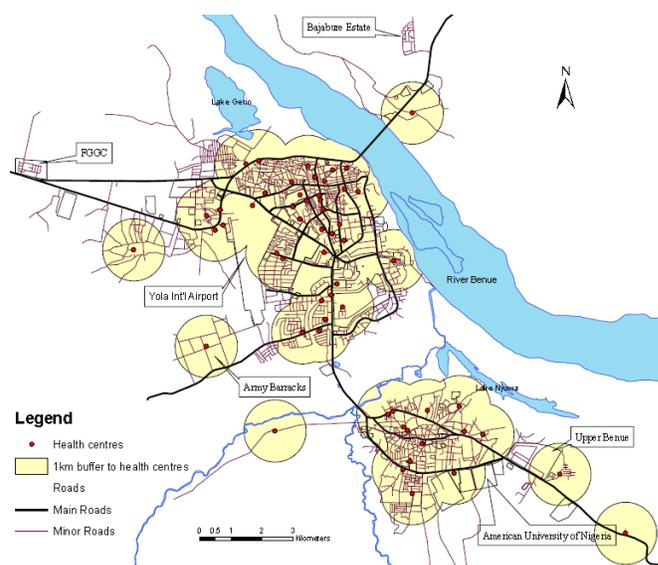


Figure 7. Proximity to health care facilities in Yola from using the Euclidian buffer.

ii) Density of physician in Yola

An adequate supply of well-trained and geographically distributed doctors is critical for providing patients access to high-quality medical care. Moreover, physicians make many of the key decisions regarding the diagnosis and treatment of patients, and they orchestrate the demand for human and other resources in health care [38]. Figure 8 is a KDE map showing the density of physicians based on physician available at each health care centre. Although 71.43% of health care facilities are located in Jimeta, Yola-Town has a higher density of physicians. This distribution pattern is attributed to two factors. First, if a health care centre has a larger number of physicians, then its surrounding areas would have a higher provider density. This scenario was in the case in Yola-Town where the FMC had three times as many available physicians than were available in the Specialist Hospital that is located in Jimeta. Secondly, the

closer the health centres are to each other, the higher the provider density. This scenario was mainly found in Jimeta, where several health centres are located close to each other that have a comparatively larger supply of physicians than those located in other parts of the city, except for the FMC. In addition, it is important to note that areas with lowest physicians (eastern and western) parts of Jimeta comprised of medium and low density residential areas. On the other hand, it is the high and medium residential densities in the case of Yola-Town.

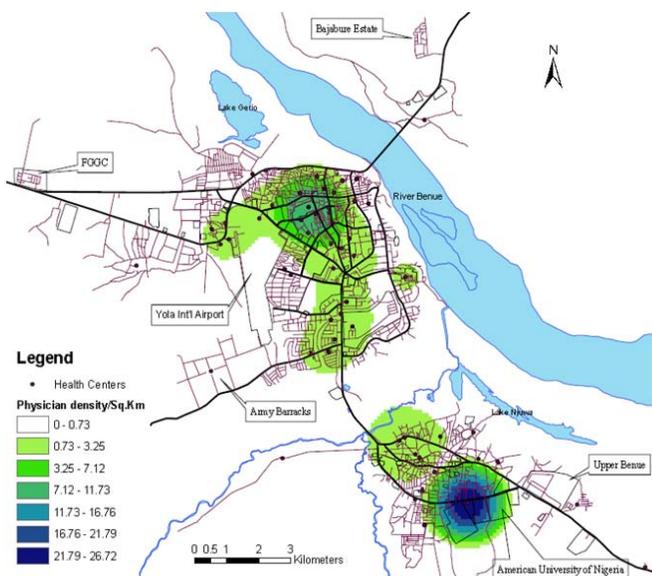


Figure 8. Density of physicians per square kilometre.

**D. Health centre-to-population ratio**

One way of define the accessibility of health centres is to identify the provider-to-population ratios. This measure is useful for gross supply comparisons between geopolitical units and service areas and is used by policy analysts to set the minimum local supply standards and to identify underserved areas [11]. GIS can be used to compute these ratios by using the KDE, as in [36], or the buffer and overlay functions, as in [8].

The health care centre density and population results (Figures 5 and 6) was analysed by using a raster calculator tool to perform mathematical operations. This type of GIS function was used to assign weights to the raster data for suitability analysis. The population density (in persons per square kilometre) was divided by the density of health care centres per square kilometre. This step was achieved by using the ArcGIS® model builder, which was based on the arithmetic overlay function (Figure 9). The output showed that the majority of in the Yola areas are not well served by health care facilities. This scenario reflects the imbalance of health care facility provisions in the central part of Jimeta and Yola-Town, which have larger population sizes but a limited supply of health care centres. Thus, the existing model(s) that were used by health care planners to providing health care facilities in Yola failed to achieve its ultimate goal. Therefore, several parts of Yola need additional health

care facilities. These areas are located in the northern and southern city central districts. This model will be useful if local health authorities plan to increase the supply of health care facilities.

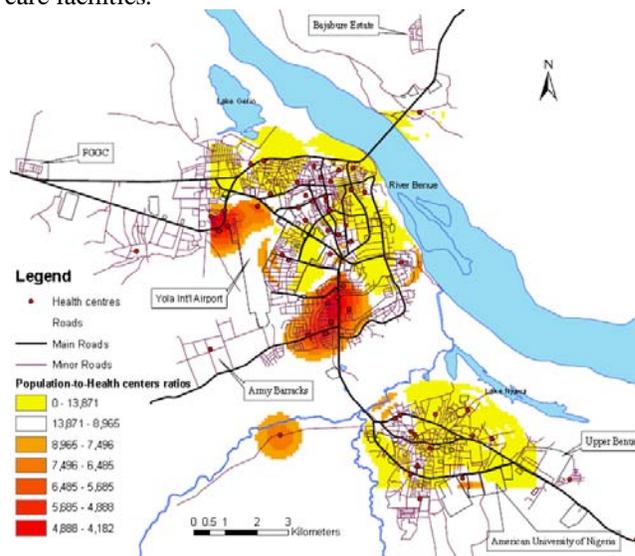


Figure 9. The Population-to- Health centre ratios.

**E. Physicians-to-population ratio**

For most developing countries, service use and health status data are lacking at an individual level. Thus, the use of the **physician/population ratio** as a proxy to measure the availability of health services and to assess health needs is tested here [38]. Providing the appropriate number of physicians at each location is a prime concern of most health planners, especially when planning the future development of health care systems [39].

Using the population and physician density results (Figures 6 and 8), the same approach that was discussed in section D was applied. The output showed that a gross shortage of physicians occurs in both Jimeta and Yola-Town (Figure 10).

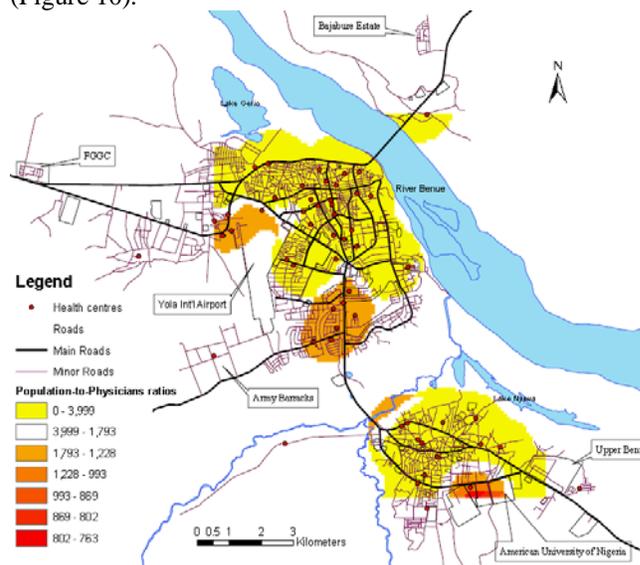


Figure 10. The Population-to-Physicians ratios.

#### IV. CONCLUSION AND RECOMMENDATIONS

In this study, we explore the potential use of GIS for modeling the spatial distribution and accessibility of the health care delivery system in Yola. Several digital and non-digital data sets were collected and transformed into GIS data. The GIS tools used in this study included symbols, overlays, KDEs, buffers, and a raster calculator.

Based on the analysis in this study, a gross inadequacy of health care facilities and physicians occurs in Yola. Thus, this study recommends the following: *i)* The urgent improvement of the health care delivery system in Yola for the benefit of the general public should be conducted by providing new health care facilities, upgrading some of the low level health care centres to a higher level, rehabilitating the existing facilities to an international standard, employing more qualified physicians and other supporting personnel, providing incentives for private individuals or organisations to encourage investment in the health sector, and by formulating new policies. *ii)* The adoption of GIS technology by health care planners in Yola.

The study demonstrated that access to spatial GIS information and analysis will help planners make better decisions quicker and at a lower cost than required for the traditional methods. In addition, GIS will enable the establishment of a health care facilities database that can easily be retrieved for analysis at any time.

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