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Evaluating Accessibility of Healthcare Delivery in Edo South Senatorial District using Kernel Density Estimation

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Abstract

Sound health is a major requirement for living essential and productive life. Meanwhile, due to lack of access to quality healthcare delivery, some treatable health conditions often goes untreated and which has in turn reduced productive life of many generations. Kernel Density Estimations (KDE) and Geographic Information System (GIS) based spatial analytical tools and nearest neighbor methods were implemented. Results indicated that health facilities were majorly distributed in Benin City and its environs, while low accessibility to healthcare services was observed in some Local Government Areas. It was also noted that a gross inadequacy exists in healthcare facilities and physicians in the Senatorial District. Thus, the result identified the need for urgent improvements in healthcare delivery system in the region.

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1. Introduction

The importance attached to health in Nigeria and around the world cannot be over emphasized. Adequate and equitable distribution of health care facilities

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in any country is critical to human capital development. It is the right of every citizen to have their physical needs satisfied. This right, but not limited, is right to live without preventable suffering, to survive and right to a standard adequate good health. Sound health is a major condition for living a productive life in Millennium Development Goals (MDGs) that better health enables children to learn and adults to earn [15]. Reducing poverty, hunger and environmental degradation positively influences, but also depends on better health. It was showed in [9] that poor health inflicts great hardships on households, including substantial monetary expenditures, loss of labour and sometimes death.

Access is a complex and contested concept which entails need, demand and supply. Hence, an equitable service requires the provision of equal access for equal need. Access to adequate healthcare delivery is an important issue in Nigeria and other African countries as some population face extensive barriers in obtaining healthcare. Healthcare policies and constraints are affecting the location, quality, and quantity of services available with associated effects on access [1]. Geographical accessibility to healthcare has been defined as the extent to which the population finds the distance, travel time and means of transport to healthcare service acceptable [14]. Meanwhile access to healthcare services is a multidimensional process involving the quality of care, geographical accessibility, availability of the right type of care for those in need, financial accessibility, and acceptability of service. The utilization of healthcare services is related to the availability, quality and cost of services [4]. The inadequacies in the access to health facilities have reduced the life expectancy of rural inhabitant and increased infant mortality [2]. This is arguably one of the most fundamental, since an inability to physically reach a healthcare provider may effectively nullify any treatment which may otherwise be available. Hence, accessibility in the perspective of this study is the measure of limitations imposed on movement of households to desired health facilities otherwise, regarded as individual accessibility.

Enumerating the sufficiency of availability of healthcare services to a population group is a challenging endeavor. These challenges are not limited to the theoretical difficulties associated with measuring healthcare accessibility; there is the technical challenge of finding and employing a technique that is robust enough to adequately model the health system yet simple enough to understand [10]. Meanwhile access to healthcare services is a multidimensional process involving the quality of care, geographical accessibility, availability of the right type of care for those in need, financial accessibility, and acceptability of service. Thus, the study is undertaken to evaluate healthcare service accessibility using Kernel Density Estimation-GIS based analysis. The analysis of this kernel provides an efficient representation and simplifies the analysis of the data.

2. Kernel Density Estimation (KDE)

Kernel Density Estimation and Geographical Information Systems (GIS) statistics were employed to determine the extent to which the geographical distribution of healthcare service varied across the selected region. The KDE approach is given according to [12], [6], [8] and [11] as:

$$\widehat{\mathrm{f}}\,(\mathrm{X},\mathrm{H}) = \frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{K}_{\mathrm{H}}(\mathrm{x} - \mathrm{X}_{\mathrm{i}}) \tag{1}$$

where n is number of data point, x is centroid and X_i is the observed value, H is called bandwidth sample and

$$\mathrm{K}_{\mathrm{H}}\,(\mathrm{x}) = |\mathrm{H}|^{-\frac{1}{2}}\mathrm{K}(\mathrm{H}^{-\frac{1}{2}}\mathrm{x}) \tag{2}$$

where K is a d-variate kernel function satisfying $\int \mathrm{dK}\,(\mathrm{x})\,\mathrm{dx} = 1$, which can be chosen in different ways.

Kernel Density Estimation (KDE) is an important tool for exploring the distributional properties of a random variable in an unknown population [12]. It is known that the performance of a kernel density estimator is mainly determined by its bandwidth. The kernel determines the shape of the weighting function. The parameter h is called the bandwidth or smoothing constant. It determines the amount of smoothing applied in estimating $f(x)$. A kernel is a special type of probability density function (PDF) with the added property that it must be even. Thus, a kernel is a function with the properties of non-negative, real-valued and definite integral over its support set must equal to 1. Kernel Density Estimation (KDE) techniques in geospatial analysis may be applied to line or point datasets with spatially extensive attributes [13]. In Geographic Information Systems (GIS) the result of a KDE is usually a raster dataset where each cell has a density value1 that is weighted according to distance from the starting features [7].

2.1. **Geographic Information System (GIS).**

Geographic Information System (GIS) is a technology that provides the means to collect and use geographic data to assist in the development of a region or Nation. Geographic Information Systems is a computer-based tool that analyzes stores, manipulates and visualizes geographic information, usually in a map [3]. This software makes it possible to synthesize large amounts of different data, combining different layers of information to manage and retrieve the data in a more useful manner, and enables us to envision the geographic aspects of a body of data. The nearest neighbor analysis was introduced to examine the distance between each point and the closest point to it.

2.2. **Nearest neighbor analysis.** The nearest neighbor analysis is a measure of the distance between each spatial feature and its nearest neighbor centroids. The average/mean nearest neighbor ratio is calculated based on dividing the observed distances by the expected distances with the same number of features covering the same study area. The equations used to calculate the average nearest neighbor distance index are as follows.

2.2.1 **The Mean Nearest Neighbor Distance is:**

$$\bar{d} = \left(\sum_{i=1}^{N} d_i \right) \Big/ N \tag{3}$$

where N is the number of points while d_i is the nearest neighbor distance for point i

2.2.2 **The Expected Value of the Nearest Neighbor Distance in a Random Pattern is:**

$$E\left(d_i\right) = 0.5\sqrt{\frac{A}{N}} + \left(0.0514 + 0.041\right) \Big/ \sqrt{N} \times B/N \tag{4}$$

where A is the area and B is the length of the perimeter of the study area.

2.2.3 **The Variance is given as**

$$Var\left(\partial\right) = \frac{0.070A}{N^2} + 0.037B\sqrt{\frac{A}{N^2}} \tag{5}$$

2.2.4 **Euclidean Distance**

The Euclidean distance measures each point relationship to a source or a set of sources based on a straight-line distance. The formula for this distance measure between a point $X(X_1,\ X_2\ ,\ \ldots\ X_n)$ and $X(Y_1,\ Y_2\ ,\ \ldots\ Y_n)$ is as follows:

$$d = \sqrt{\sum_{i=1}^{n} \left(X_i - Y_i\right)^2} \tag{6}$$

2.3. **Study Area.** Edo is a state in Nigeria, with Benin City as capital. It is made up of four major ethnic groups; namely the Edo's (Benins), Esan, Owan, and Etsako. It is situated approximately 40 km (25 mi) north of the Benin River and 320 km (200 mi) by road east of Lagos. One of the most cosmopolitan Senatorial Districts in Nigeria is Edo South Senatorial District, home to the State Capital – Benin City. Edo South is one of the three senatorial districts in Edo State with district code SD/036/ED. It is made up of the following LGAs - Egor, Ikpoba Okha, Oredo, Orhionmwon, Ovia North East, Ovia South-West and Uhunmwode with estimated population of 2,208,700, as displayed in Figure 1.

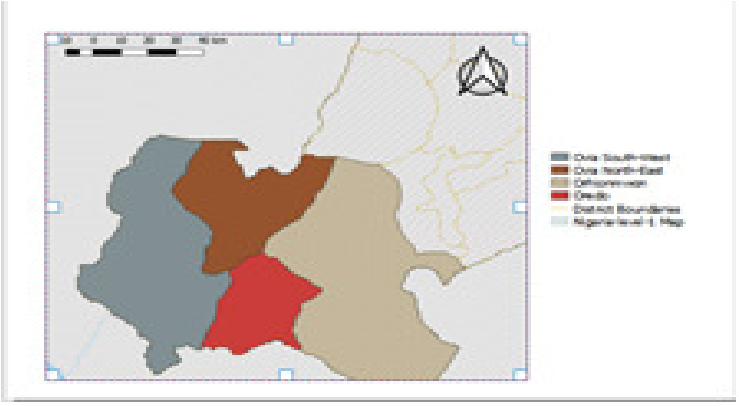

Figure1: Map of Edo South Senatorial District
Source: http://www.maplibrary.org/library/stacks/Africa/index.htm

3. Numerical Analysis of Accessibility to Health Facilities and Personnel

The concept of accessibility for a given utility depends on how easy it is to get to the location. Data on the distribution of health personnel and facilities in Edo South Senatorial District extracted from [15] is presented in Table 1, while the health facilities and their corresponding geographical coordinates are presented in Table 2. Adopting a bandwidth of 100km, a computer code in the appendix was created to generate KDE columns in Table 2 to determine the distribution of health personnel of Edo South Senatorial District, the results are displayed in Figures 2-10.

TABLE 1. Summary of Distribution of Health Personnel and Healthcare Facilities

LGA	EPp	Area in Km^2	ND	PpD	NN	PpN
Egor	445800	88.8	191	2,334	504	884.5238
Oredo	490600	317.8	140	3,504	359	1366.574
Ikpoba-Okha	487400	814.5	67	7,275	171	2850.292
Uhunmwode	159500	2062.4	6	26,583	77	2071.429
Orhionmwon	241000	2339.99	18	13,389	87	2770.115
Ovia North-East	203500	2351.2	5	40,700	18	11305.556
Ovia South West	180900	2839.3	12	15,075	79	2289.873
	2208700	10813.99	445	86,660	1318	17196.22

LGA	NH	PpH	AsbH	NPH	PpPHC	AsPHC
Egor	61	7,308.20	1.455738	8	55725	11.1
Oredo	55	8,920.00	5.778182	10	49060	31.78
Ikpoba-Okha	70	6,962.86	11.63571	15	32493.33	54.3
Uhunmwode	39	4,089.74	52.88205	38	4197.368	54.27368
Orhionmwon	41	5,878.05	57.07293	36	6694.444	64.99972
Ovia North-East	27	7,537.04	87.08148	27	7537.037	87.08148
Ovia South West	33	5,481.82	86.03939	30	6030	94.64333
	326	46,177.70	301.9455	164	161737.2	398.1782

Definition of terms used in Table 1
PpD: Population per doctor
PpH: Population per hospital
PHC: Public health centre
PpPHC: Population per public health centre
AsPHC: Areas served by public health centre
PpN: Population per nurse
AsbH: Area served by hospital
EPP: Estimated Population
ND: No of Doctors
NN: No of Nurses
NH: No of Hospital
NPH: No of PHC

TABLE 2. Extracted Health Facilities and their Corresponding Geographical Coordinates

Facility Name	**Type**	**Facility id**	**Nurses**	**Doctors**	**LGA**
Oviasuyi Medical Centre	PHC	AATPG	9	3	Egor
District Hospital Ekiadolor	Hospital	AIEUQ	3	2	Ovia North East
Iguiye PHC	Maternity	AKAZA	0	0	Ovia North East
Ekea Health Centre	PHC	ALYXQ	5	1	Oredo
Primary Health Centre Aduhanhan	PHC	AMYCI	2	0	Uhunmwonde
Time Medical Clinic and Maternity	PHC	APSVT	5	2	Oredo
Otobaye Dekuns Clinic	PHC	BDFPX	4	2	Orhionmwon
Amso Specialist Medical Centre	PHC	BIJYM	8	4	Egor
Nikorowa P H C	PHC	BINGA	2	0	Ovia South West
Redemption Med. Centre	PHC	BTKFZ	9	2	Egor
Ugbiyokho Pry Health Centre	PHC	BTSWF	5	1	Uhunmwonde
Pry Health Centre Iguelaba	PHC	BUEJZ	3	0	Orhionmwon
Oviguetue Pry Health Cent	PHC	BVWBR	1	0	Ovia North East
Iguobazuwa General Hosp	Hospital	BYXKM	8	2	Ovia South West
District Hospital Egba	Maternity	BGDSF	2	1	Uhunmwonde
General Hosp. Urhonigbe	Hospital	BVXRS	4	2	Orhionmwon
Emiloju Clinic	Hospital	BZSAE	5	1	Ovia South West
Akugbe Medical Centre	Hospital	CETST	3	1	Ikpoba Okha
Igbinedion Sch Med. Cent	Hospital	CSTRA	3	2	Ikpoba Okha
Idiakor Medical Clinic	Hospital	CDQUT	3	1	Ikpoba Okha
Central Hosp Benin City	Hospital	CQWSA	22	10	Oredo

Facility Name	Latitude	Density	Longitude		Density
Oviasuyi Medical Centre	6.362680	0.016939	5.62237		0.016472
District Hospital Ekiadolor	6.49428	0.043302	5.58536		0.042086
Iguiye PHC	6.56624	0.044336	5.50029		0.041242
Ekea Health Centre	6.26556	0.010152	5.63035		0.017881
Primary Health Centre Aduhanhan	6.322115	0.027280	5.79612		0.026750
Time Medical Clinic and Maternity	6.335364	0.018993	5.60509		0.018154
Otobaye Dekuns Clinic	6.295708	0.027802	6.02824		0.029808
Amso Specialist Medical Centre	6.378684	0.016668	5.62149		0.016569
Nikorowa P H C	6.256531	0.008573	5.35431		0.033555
Redemption Med. Centre	6.373600	0.016969	5.59188		0.016938
Ugbiyokho Pry Health Centre	6.650010	0.011552	6.08756		0.016810
Pry Health Centre Iguelaba	6.322331	0.025703	6.21687		0.014301
Oviguetue Pry Health Cent	6.669921	0.040984	5.76611		0.019272
Iguobazuwa General Hosp	6.572286	0.036884	5.35152		0.033773
District Hospital Egba	5.75031	0.025652	5.75031		0.022594
General Hosp. Urhonigbe	5.974622	0.016681	6.18199		0.018222
Emiloju Clinic	6.562014	0.037121	5.35771		0.033274
Akugbe Medical Centre	6.291207	0.015563	5.66436		0.015619
Igbinedion Sch Med. Cent	6.314514	0.017180	5.63031		0.012841
Idiakor Medical Clinic	6.299614	0.016361	5.65069		0.015310
Central Hosp Benin City	6.329302	0.0191242	5.622720		0.018439

The results showed a high concentration of health in urban area, especially in Benin City (i.e. an unequal distribution pattern which hampers access to qualitative healthcare delivery in the rural area). As shown in Figure 2, there are quite large parts of Edo South with low health centers. This scenario reflects the imbalance of healthcare facility to deliver adequate quality healthcare in some part of Orhionmwon and Uhunmwonde LGAs.

3.1. **Distribution of Facilities per Population.** The distribution of health facilities to a population are important components in addressing issues arising from geographic accessibility of healthcare services. Specifically, healthcare services should be provided at a finite number of fixed locations. In order to assess health facilities across all districts from Table 2, location accessibility to healthcare facilities was established for all the electoral wards in the region under study using GIS as shown in Figure 2.

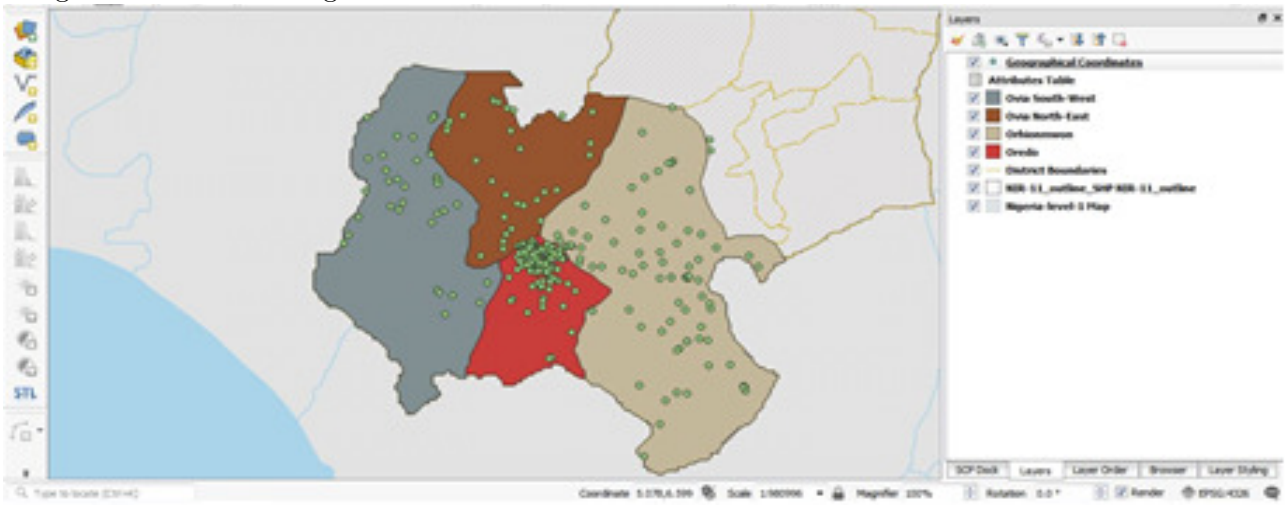

Figure 2: Distribution of Healthcare Centers

It is observed from Figure 2 that healthcare facilities in some of the wards are grossly inadequate, their distribution is random or spatial, hence, many of the electoral wards are poorly served or underserved. This shows that access to health facilities in the region varied by district boundaries. In general, the least accessible facilities were found in the marginal districts, Orhionmwon = (Orhionmwon + Uhunmwonde) LGAs areas as indicated in Figure 2. The average nearest neighborhood analysis was done to determine the spatial closeness of healthcare facilities as shown in Table 3.

TABLE 3. Analysis of Nearest Neighborhood

Source Hospital	**Target Hospital**	**Distance (m)**
Itohan Medical Clinic	St John's Hospital	188.9627
Ise Clinic and Maternity	St Mary's Hospital	359.8391
Urhohi Basic Health Center	N.Y.S.C Basic Health Centre	5.414438
Private Dental Clinic	Okaniman Maternity Home	217.2696
Ofure Clinic and Maternity	Central Primary Health Care	292.0789
Michael lmodu PHC	Joe Alufohai Medical Centre	948.4258
O.C (Nursing) Clinic & Maternity	Uzebba Primary Health Care Centre	346.5871
Christabel Maternity	Michael lmodu phc	1398.652
Auntie Robin Maternity	Bamby Hospital	237.6915
Standard Medical Clinic & Maternity	Graceland Maternity and clinic	433.8461
Iyare Clinic and Maternity	A1 Winners Clinic	259.0047
PHC Auchi	Fate Medical Centre	292.8698
Crown clinic	God's Will Maternity	684.753
Fate Medical Centre	Jey M Jey Hospital	216.1423
Sametu Medical Centre	Central Hospital Auchi	1141.283
Niger Clinic & Maternity	Owen Nursing and Maternity Home	566.7889
Idiakor Medical Centre	Kings Care Medical Centre	348.2207
Presco Industrial Clinic	Utesi Primary Health Centre	8435.739
Quick Recovery Hospital	Family Solution Medical Complex	464.3754
Oke Primary Health Centre	Orhua Primary Health Centre	11949.85
Police Cottage Hospital	Ogida P.H.C	1.76947

From Table 3, it was observed that the minimum distance (1.76947m) occurred between Police Cottage Hospital and Ogida P.H.C while the maximum distance (11949.85m) was between Oke Primary Health Centre and Orhua Primary Health Centre.

3.2. **Distribution of Personnel per Population.** Provision of suitable number of health personnel at every geographical location is a major concern of health managers, most importantly when it require future planning of healthcare system. Using the population and physician density results (Tables 1 and 2), the output showed that a gross shortage of physicians and nurses occur in Edo South senatorial district as displayed in Figures 3-10.

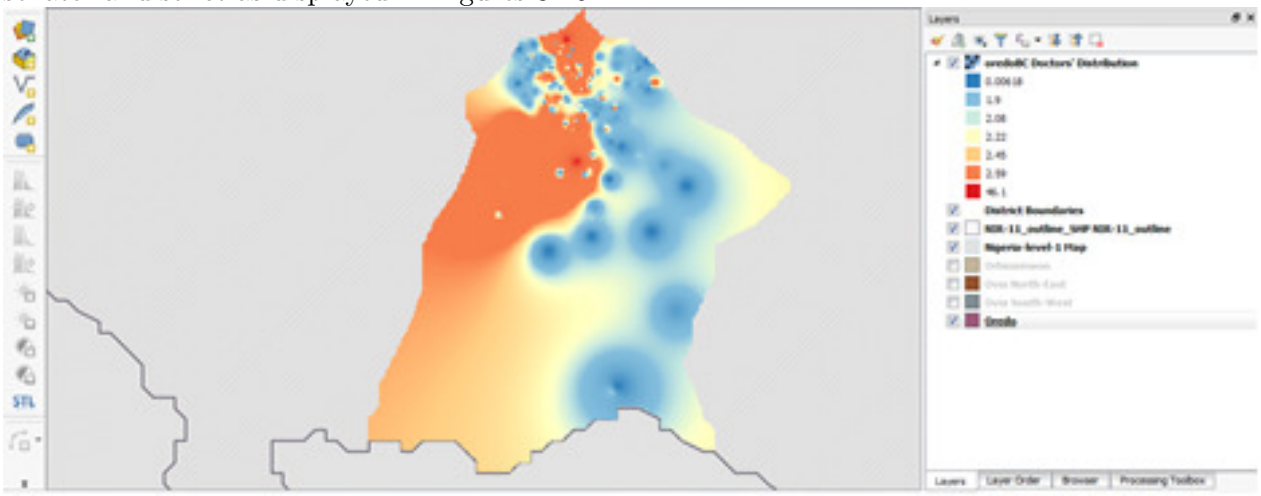

Figure 3: Doctors' Distribution per Population per 10,000 inhabitants in OREDO/Benin City

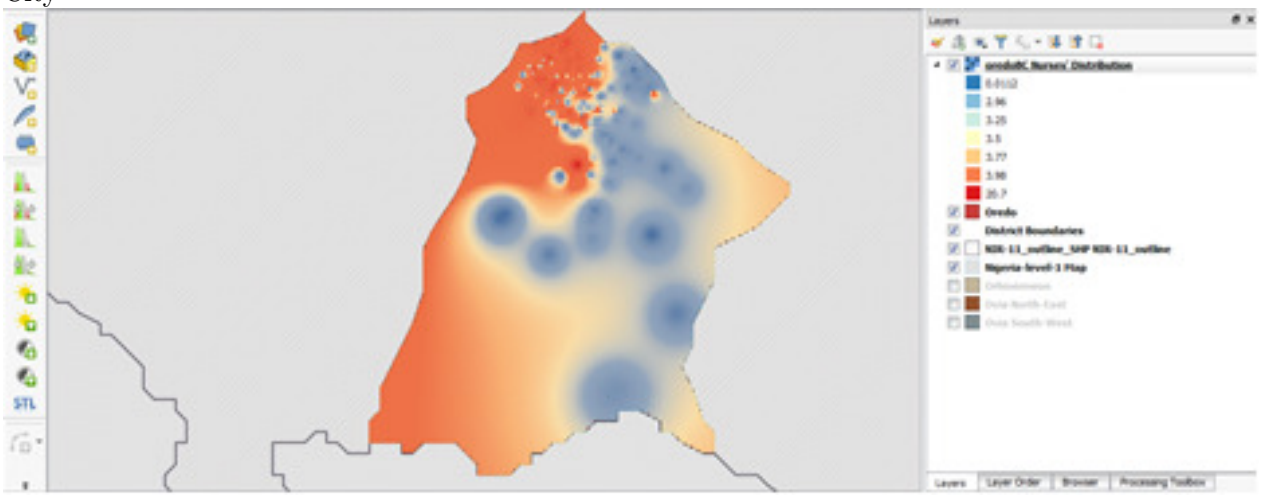

Figure 4: Nurses' Distribution per 10,000 inhabitants in OREDO/Benin City

Figures 3 and 4 are kernel density maps showing the distribution of doctor and nurse per 10,000 inhabitants in Oredo/Benin City (Oredo + Egor + Ikpoba-Okha) LGAs of Edo State, Nigeria. The density distribution goes from red

darkest reds to the lightest of blues (i.e. lowest intensity of the distribution is represented by lightest of blues, and highest distributions are the darkest of reds). About 85% (22) of physicians are located in the highest intensity areas, while areas with the lowest intensity have about 15% (4) of doctors. Also, 89% of nurses (60) in this region are associated to the highly populated area and about 11% (7) serve low intensity area as shown in Table 2. This shows gross uneven distribution in the health personnel per population.

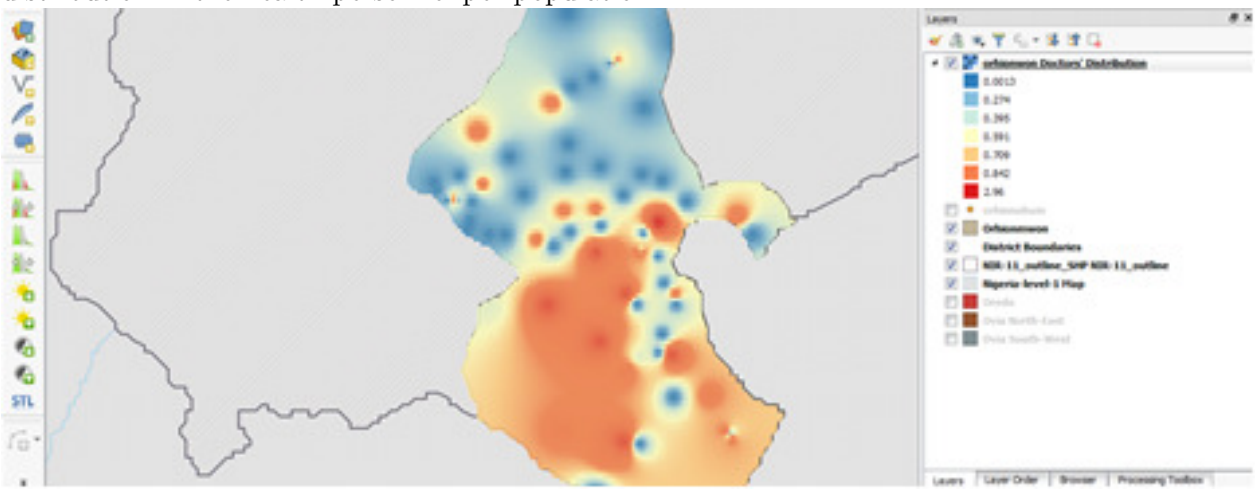

Figure 5: Doctors' Distribution per 10,000 inhabitants in Orhionmwon

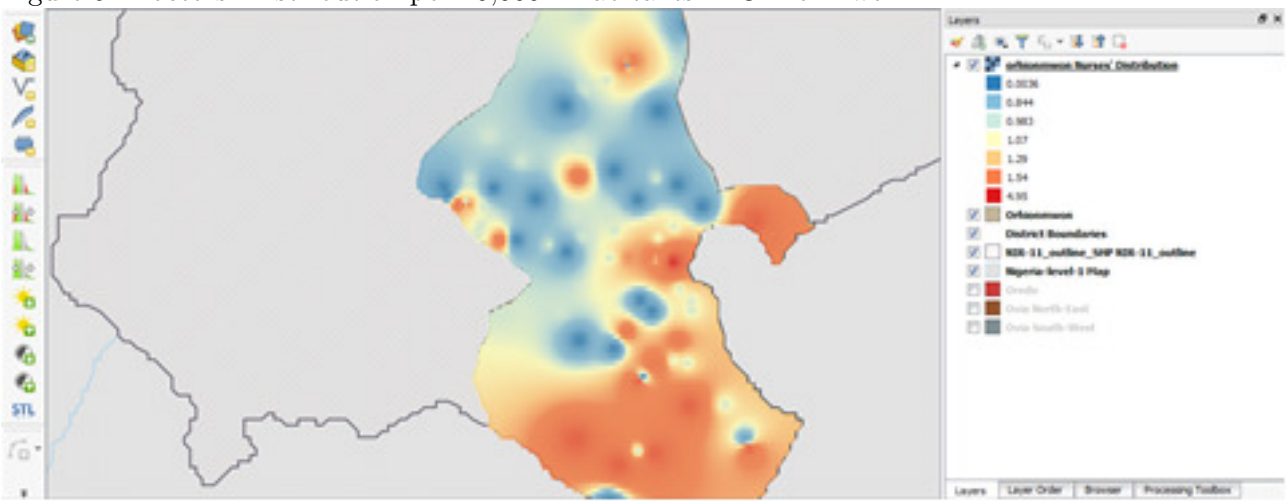

Figure 6: Nurses' Distribution per Population per 10,000 inhabitants in Orhionmwon

Similarly, in Orhionmwon (Orhionmwon + Uhunmwonde) as displayed in Figures 5 and 6, the doctors' and nurses' distribution show that there are appropriately 83% (5) doctors and 85% (17) nurses in densely distributed region, and 1 doctor

(17%) and 3 nurses (15%) in the extreme low distributed areas as also shown in Table 2.

Meanwhile, there are appropriately 2 doctors (100%) and 3 nurses (75%) in densely distributed region of Ovia North-East LGA, and areas with the lowest intensity have zero number of doctor and 1 nurse (25%) as shown in Figures 7 and 8.

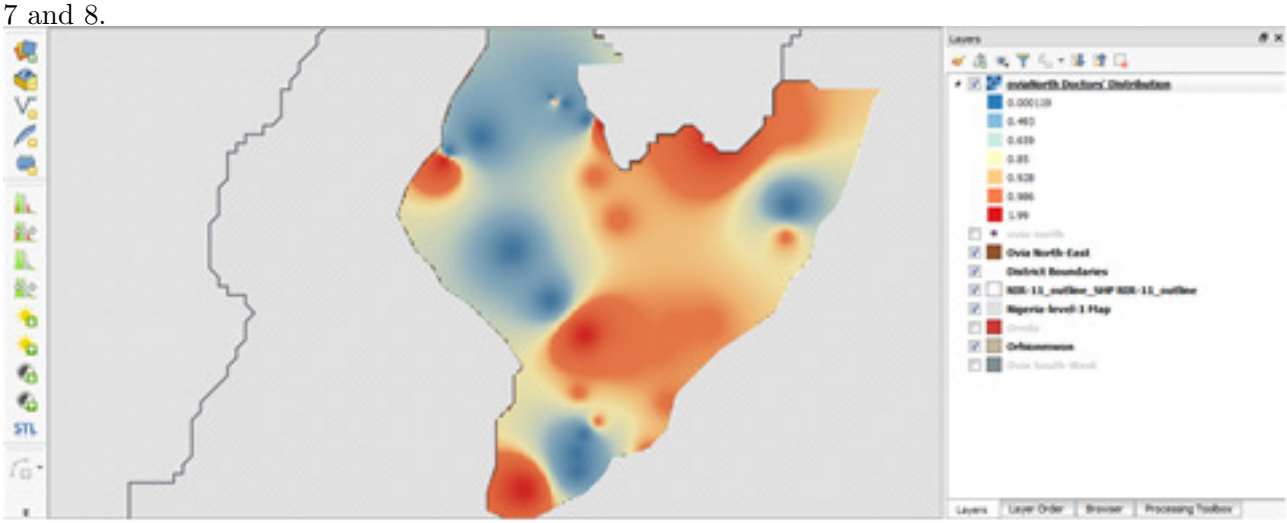

Figure 7: Doctors' Distribution per 10,000 inhabitants in Ovia North-East LGA of Edo State

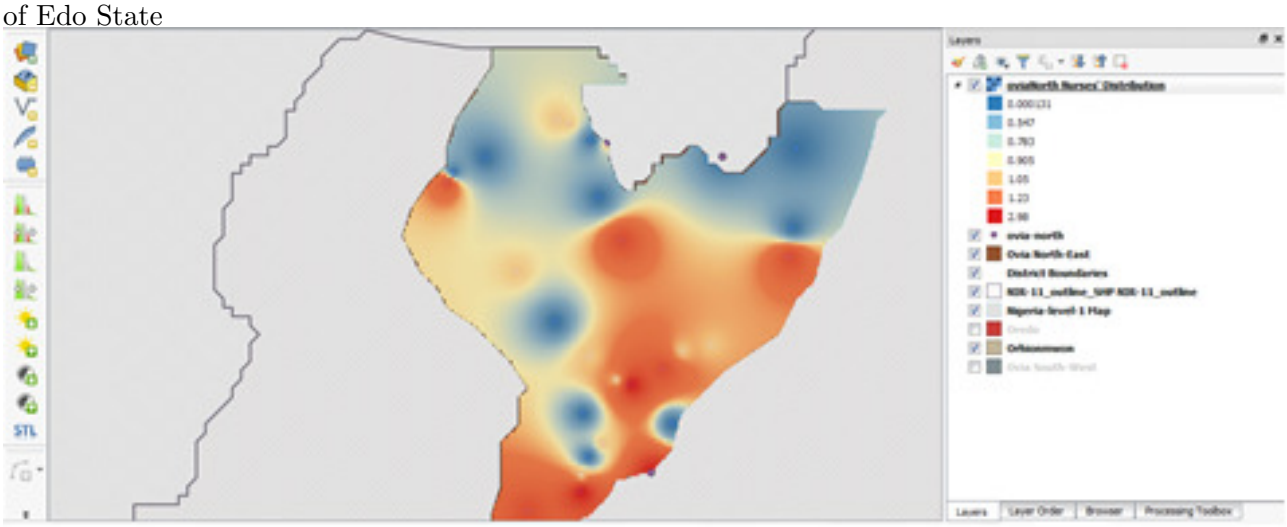

Figure 8: Nurses' Distribution per 10,000 inhabitants in Ovia North-East LGA of Edo State

The situation is similar in Ovia South-West LGA as indicated in the Figures 9 and 10 below. There are 3 doctors (100%) and 12 nurses (80%) in the highly populated area, with 0 doctor and 3 nurses (20%) in the extreme less dense areas.

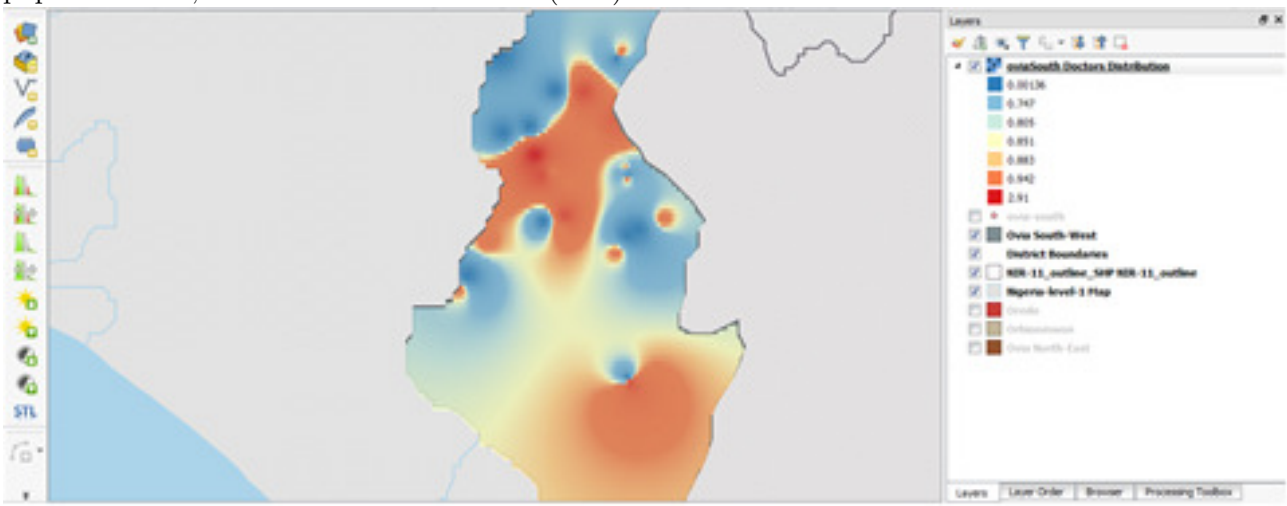

Figure 9: Doctors' Distribution per Population per 10,000 inhabitants in Ovia South-West LGA

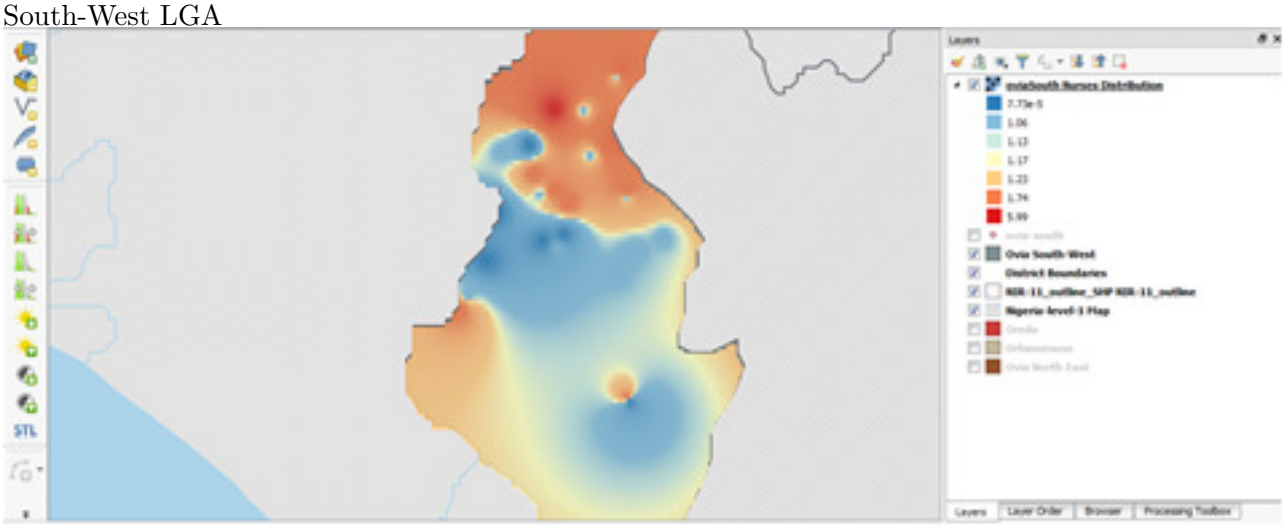

Figure 10: Nurses' Distribution per 10,000 inhabitants in Ovia South-West LGA

Conclusions: This study has explored the used of KDE and the GIS to evaluate the accessibility of healthcare delivery in Edo South Senatorial district. After collecting the required data related to health personnel, health center locations and road network travel times, Kernel density provided a way to spread both the population and the facilities across space, thereby permitting the ability to compute basic population to facility and population to staffing ratios, while GIS

was used to determine how far or how close health facilities are from residential districts in Edo South. There are 326 health centers located in different parts of the region of this study (column 8 and last row of Table 1). The resulting location pattern (Figure 2) indicates that existing health centers are densely located in Benin City (Egor, Ikpoba-Okha, Oredo and Orhionmwon) 227 (69.6%), and sparsely distributed across other LGAs, Uhunmwode has 39 (12%), Ovia North-East with 27 (8.3%) and Ovia South-West has 33 (10.1%) health centers. The results of the analysis indicated that health facilities were majorly distributed in Benin City and its immediate environs. Some Local Government Areas (LGAs) in the district under study have low accessibility to healthcare services as indicated by their spatial distribution. Based on this analysis, it was observed that a gross inadequacy exists in healthcare delivery in terms of healthcare facilities and physicians in Edo South Senatorial District. Thus, the result identified the need for urgent improvements in healthcare delivery system in the region. This study therefore called for the implementation of KDE and GIS as tools for obtaining desired quality decisions on health accessibility which can be reached in a short time frame and at a low cost.

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Appendix: Kernel Density Estimate Computer Codes

```
den_est = function(x, i, h, n = length(x)){ #density estimate at index i
u = (x[i] - x)/h
k = (1/sqrt(2*3.142))*exp(-0.5*u∧2)
estimate = (1/n*h)*sum(k)
estimate
}
all_den_est = function (x,h)
{
estmate = vector("numeric", length(x))
count = 1:length(x)
for(i in count) {
d = den_est(x,i,h)
estmate[i] = d
}
estmate }
```