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Measuring spatial accessibility to healthcare for people living with HIV-AIDS in southern Nigeria

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Abstract

Equitable distribution of healthcare services towards the reduction of HIV-AIDS prevalence in Nigeria remains a major public health concern. One of several research model to solve this public health problem is the use Geographical Information System, a two-step floating catchment area (2SFCA), this model emerged in the last decade as a key measure of spatial accessibility, particularly in its application to healthcare access. The 2SFCA approach was used to study the influenece of distance to health center on people living with HIV-AIDS. Individual, health and administrative data from the South-South region of Nigeria were used in this study for two scenarios, at 30 and 60 minutes travel time. At a threshold travel time of 30 minutes, the 2SFCA results showed minimum accessibility index score of 0.45 HIV-AIDS services with access to services by 16% of HIV infected population. At 60 minutes threshold, there was a minimum of 0.24 HIV services accessible index score, only 12% had access to HIV-AIDS services. Spatial autocorrelations for Global Moran's I showed a significant clustered pattern at 30 minutes threshold. Anselin Local Moran's I revealed the extent of hotspots pattern identifying eleven LGAs to be of high-high cluster. Furthermore, analysis of variance test statistic also compared the effect of accessibility index score and the household knowledge on distance or travel time as a barrier to HIV services, the test statistic at ($p<0.05$) showed significant differences between the States. These results are key decision-making factor for local authorities to establish equitable access to HIV-AIDS population in the South-South region. Conclusively, this showed a shortage of HIV services in all the States, distance and means of transport remains a significant hindrance to healthcare access, these can be addressed with the incorporation of Geographical Information System in future monitoring strategy.

Keywords: geographical information system, healthcare, hiv-aids.

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List of Acronyms

2SFCA:	2 Step Flow Catchment Approach
DFID	Department for International Development
DHIS	District Health Information System
ESRI	Environmental Systems Research Institute
GF	Global Fund
GIS	Geographical Information System
HC	Health Center
HIV-AIDS	Human Immunodeficiency Virus-Acquired Immunodeficiency Syndrome
IBBSS	Integrated Biological Behavioural Surveillance Survey
INEC	Independent National Electoral Commission
LGA	Local Government Area
MoH	Ministry of Health
NACA	National Agency for Control of AIDS
NARHS	National AIDS and Reproductive Health Survey
NDHS	National Demographic Health Survey
NPC	National Population Commission
PEPFAR	Presidential Emergency Plan for AIDs Relief
PLWHA	People Living With HIV-AIDS
SDG	Sustainable Development Goal
SIDHAS	Strengthening Integrated Delivery of HIV/AIDS Services
SS	South-South
USAID	United States Agency for International Development
WHO	World Health Organization

1. INTRODUCTION

1.1 Background

Nigeria has the highest population in African countries; it is situated on the Gulf of Guinea in Western Africa. Bounded to the West by Republic du Benin and Cameroon in the East, in the North are Chad (NE) and Niger (NW). The area of the country is 923,768 square kilometer, having about 13,000 square kilometers as water bodies (Phillips, 2004). Nigeria is one of the fastest rising economies in the world (UNICEF, 2007). Nigeria accounts for 47% of West Africa's population, with an estimated population of 173 million people (Worldbank, 2015a). The country is geopolitically divided into six regions; they are the North East, North West, North Central, South East, South West, and South-South. The latest HIV-AIDS survey carried out in Nigeria showed that South-South (SS) geopolitical region has the highest prevalence of HIV-AIDS infection of approximately 5.5% (NACA, 2015).

The structure of healthcare delivery covers all the 36 States and 774 Local Government Area (LGA) in Nigeria. It has three tiers of healthcare delivery, each associated with every administrative level of government. The Primary HealthCare (PHC) for which local government areas (districts) are mainly responsible for, followed by the secondary care services, where specialized services are offered to patients referred from PHC. Lastly, is the tertiary care services (Federal government supported) which offer highly specialized health services to patients referred from both primary and secondary healthcare services (FMOH, 2006).

Figure.1.1 Map of West Africa highlighting Nigeria

1.2 HIV-AIDS definition, causes, and epidemics

Human Immunodeficiency Virus-Acquired Immunodeficiency Syndrome (HIV-AIDS) is a viral disease. HIV is the virus that causes AIDS, this virus tactically destroys the human immune system of the body, thus making infected individuals susceptible to innocuous organisms and other opportunistic infections (like malaria, tuberculosis, and fever). Once the immune system is destroyed, this sickness can lead to death (Onah, 2011).

The HIV-AIDS combat is one of the greatest health challenges of the 21st century that threaten the very essence of human existence and procreation, only anti retroviral drugs are used to manage the treatment, suppress the virus and boost the immune system. Neither a definitive cure for the disease nor any effective protective vaccine has been discovered. HIV-AIDS poses a major challenge to the socio-economic development of Nigeria because it continues to cause unexpected death, reduction in active working population, once it reaches the last stage of infection, dealing a blow to the nation's economy (Onah, 2011).

1.3 Specific study area:

This research study focused on SS geopolitical region of Nigeria; the region is displayed in Figure 1.2 below. A previous study carried out by National AIDS and Reproductive Health Survey (NARHS) in 2012 showed the highest HIV-AIDS prevalence of 5.5% in this region. Another recent survey carried out shows that SS still has the highest prevalence of HIV-AIDS infection at 5.5 percent (NACA, 2015).

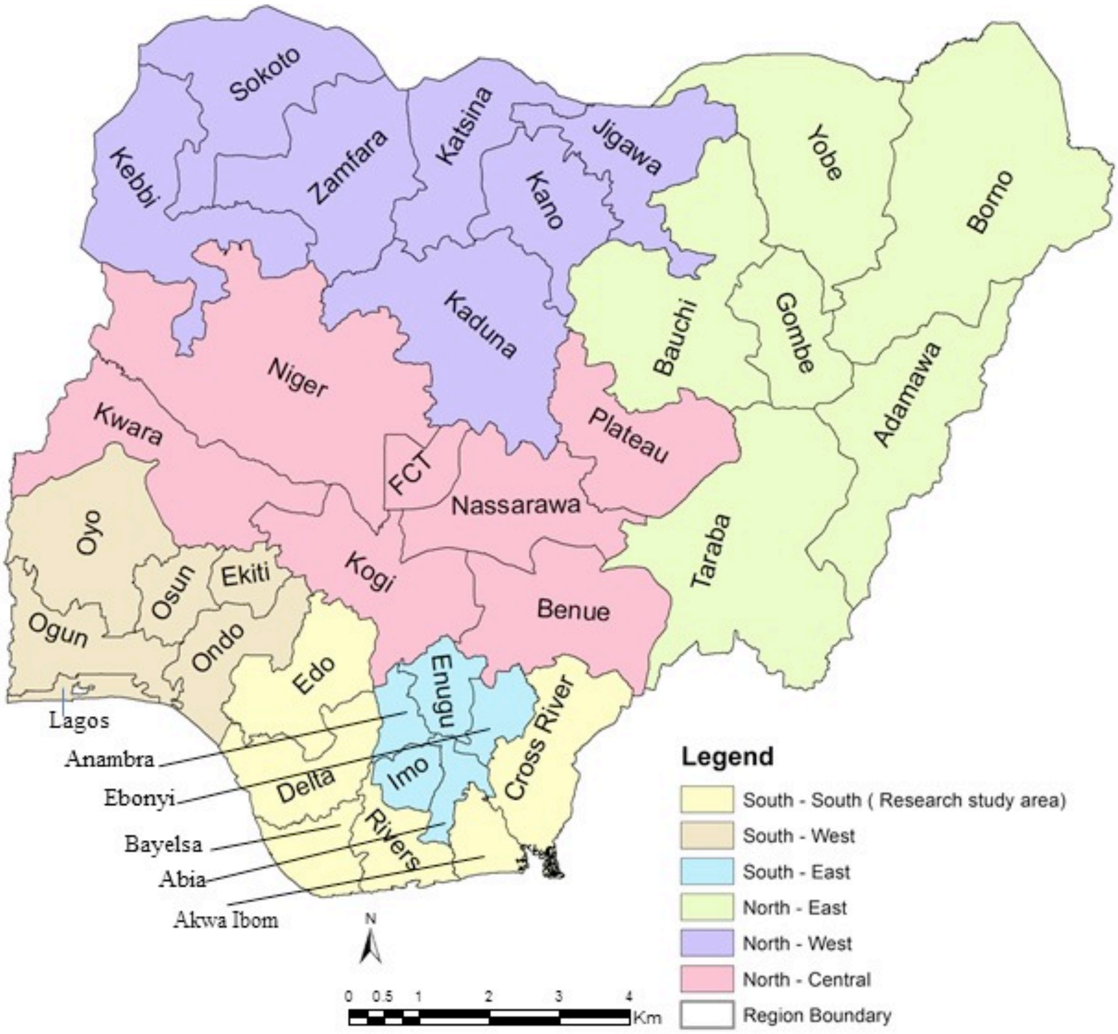


Figure 1.2 Map of Nigeria with the six-geopolitical Regions and States

The SS region has 6 States, 123 LGA, and 1,297 wards (INEC, 2016). An overview of the government administrative structure is shown in Table 1.1 below. The SS region is rich in crude oil exports; the area has diverse cultures and mixed lifestyles due to the presence of multinational oil companies and a lot of foreign workers. According to the Worldbank, the population growth rate in the SS is 2.7 percent, with active population class of age (15 to 49) years at 25,417,247 million (Worldbank, 2015b).

Table 1.1 *South-South geopolitical region's States with their respective numbers of Local Government Areas (LGA) and Wards within its boundary.*

State (Admin-2)	**# of LGA (Admin-3)**	**# of Ward (Admin-4)**
Akwa Ibom	31	287
Cross River	18	182
Edo	18	150
Delta	25	270
Bayelsa	8	99
Rivers	23	309

Since the year 2004, the United States Presidential Emergency Plan for AIDS Relief (PEPFAR) intervention in Nigeria, committed time and resources on care and treatment for People Living with HIV-AIDS (PLWHA) in Nigeria. In addition, PEPFAR extended its scale-up services via Strengthening Integrated Delivery of HIV/AIDS Services (SIDHAS) project from 2014 to 2018, designed to support the Government of Nigeria with a goal to increase access to high-quality, comprehensive HIV-AIDS services (USAID, 2015). United States Agency for International Development (USAID) and Department for International Development UK (DFID) funding in the last ten years had also supported the District Health Information System (DHIS) software for monitoring routine services at the LGAs.

1.4 Problem statement

In 2005, when the country launched Vision 2020, one of the President's seven-point agenda is *to halt and reverse the spread HIV-AIDS in Nigeria*, which led to the development of National HIV-AIDS Strategic Plan (2010-2015). The plan mandated the provision of free HIV-AIDS services, an extension of adequate healthcare to rural populations despite the challenges of the road network, increased demand for services and creation of equitable access to HIV-AIDS services (NACA, 2009). The strategic policy plan aligned with the United Nations commitment to the Sustainable Development Goals (SDG) by the year 2030, recently launched by the United Nations. However, the provision of a comprehensive HIV-AIDS services in the districts and most especially in rural cities remains a challenge.

The most relevant part of the SDG is Target 3: To reduce the global maternal mortality ratio to less than 70 per 100,000 live births (WHO, 2016), end preventable deaths of newborns and under-five children; reduce HIV-AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases, and other communicable diseases; reduce by one-third pre-mature mortality non communicable diseases (Jubril, 2015; United Nations, 2016). However, HIV-AIDS, tuberculosis, and malaria are major public health concern in Nigeria, with little to non-significant reduction in the HIV-AIDS prevalence rate, thus affecting many people socio-economic status of the affected population. Based on 2010 (FMOH, 2010) survey, the prevalence rate of HIV was 4.1% with the SS region of the country contributing to one-third of PLWHA.

Nigeria is said to be the Country with the second highest burden of HIV-AIDS globally, despite international aid and government effort, the national rate of HIV prevalence rose from 1.8% in the year 1991 to 5.8% by the year 2001 (Bashorun et al., 2014a). Nigeria was estimated to have 3.2 million people infected with HIV-AIDS. Although, the HIV prevalence was expected to drop from 3.3% in 2011 to 3.2% by 2012. however, it took ten years (from 2001 to 2011) before the country began to see a downward trend of HIV-AIDS infection.

Bashorun in his paper suggested that advanced analysis needs to be done to reveal key drivers of HIV prevalence further? (Bashorun et al., 2014b). The National HIV-AIDS Strategic Plan from 2010 to 2015, intended to reach all the populations in need of HIV-AIDS, tuberculosis, and malaria for treatment. Moreover, over the years, the effort has been geared towards covering all the rural communities in Nigeria, ensuring that its population has knowledge of HIV-AIDS prevention and treatment, with technical and financial support from international donors, including free treatment (Global Fund and the Federal Republic Nigeria, 2012).

Current studies have demonstrated the advantages of geospatial method in healthcare. Spatial patterns have been modeled to enhance health center accessibility. Accessibility to healthcare is of two dimensions, geographic and social (Donabedian, 1973), and these problems can be better addressed with the use of Geographical Information System (GIS), that is known to have a more scientific capability of using real indicators instead of perceived ones.

The first use of GIS in the field of HIV-AIDS in Nigeria was in 2007, where it was used to identify the most at-risk populations in Cross River and Kano States (FHI, 2008). The study was used to create a geospatial inventory of various HIV-AIDS services provided by hospitals and organizations within the two States. GIS was used to identify locations of populations at risk of HIV-AIDS infection. However, FHI (2008) did not perform any spatial analysis to understand the coverage and accessibility. Confronted with the need to apply geospatial methods to create better access to HIV-AIDS infected population.

1.5: Research Objectives:

This study delved into the use of 2SFCA geospatial analytical tool, a new approach to guide both governmental and non-governmental organisations in decision and policy making. Exploring the extent of services available to the population in need of HIV-AIDS services. Raising the following research questions:

a) Does the current distribution of health centers (HC) offering HIV-AIDS services reaches all the PLWHA?

b) How does travel time and distance to health center influences the decision to seek for HIV-AIDS services?

c) How does respondents knowledge of HIV-AIDS services, means of transportation to health center influences their decision to seek for HIV-AIDS services? Despite the fact that services are freely available.

2. LITERATURE REVIEW

A case study in Miami, Florida used GIS to demonstrate the relationship between where HIV-AIDS service providers are located in respect to patients residence (Logan, 1996; Cochran, Mays and Sullivan, 2000). It concluded that the location of health and social services is an important determinant of patients' utilization of services. Another study that was carried out on adults in Los Angeles County, USA, to know the outcome of distance to free, publicly funded HIV testing sites on HIV-AIDS. The study used a multinomial logit model to estimate the likelihood of an HIV-AIDS test in the past and testing in a private physician's office, a public clinic, or in a non-medical setting. The result showed that majority of the respondents prefer to travel far to access the free healthcare services (Brown et al., 2013). Another study described how distance does not affect HIV-AIDS testing among the non-poor, the cost of HIV-AIDS testing and waiting time overrides distance in this particular study (Arleen and Taylor, 2007). In Costa Rica, the census data was used to compare patients demand and HC's supply side of services to its population. The study measured the target population's demand for health services by computing accessibility index based on sums of weighted population per district. The results showed the inequitable distribution of health centers and proposal was made to the government to correct this inequality (Rosero-Bixby, 2004).

A gender and GIS discussion paper written in 2009 by Walker and Vajjhala, showed linkages between HIV-AIDS, gender disaggregated data and transport using GIS, explaining gaps and limitations. It further demonstrated how GIS technology improved the dimensions of transport by gender and health. The use of spatial complexity on multiple distances by using basic analytics of population, transport structure, and health services without relying on real measured distance showed where coverage is needed (Walker and Vajjhala, 2009). Another similar, study in Shenzhen, China, after setting the assumption that all the major illness in that city will be treated by any of the three levels of the hospital (primary secondary or tertiary), a 2 step flow catchment area method based on demand (accessibility by the city population) and supply (availability of physicians and healthcare resources) to demonstrate shortages of healthcare services in areas with access road networks. (Gang et al., 2016).

Tanser (2006) in his paper demonstrated the importance of GIS in many areas of healthcare research and planning in South Africa. Travel time was computed to estimate distance traveled from districts to the HC; the results demonstrated the need to keep using GIS to monitor coverage of services regularly (Tanser, 2006). Similarly, geospatial analysis showed that low-income and minority have disadvantages to accessing substance abuse treatment HC in the Dallas-Fort Worth metroplex area (Clary and Huang, 2014). A study in Mozambique, (Yao et al., 2012), considered how to measure outcome results against the need of Reproductive Health (RH) services, the analysis was used to detect potential spatial patterns and associations in health outcomes. The 2SFCA spatial accessibility methodology continues to grow; China used this method to guide its public health and city planning recently, the study illustrated how spatial methodology was used to inform in the equitable distribution of maternal health units in Shenzhen (Li,Q. An et al., 2013).

3. MATERIALS AND METHODS

3.1 Population Data

Dataset required for this study were gathered at the individual level which provided estimated number of PLWHA. Health level data provided the monthly routine treatment services data, health center service type, and geolocation coordinates. Finally, the administrate shapefiles gave us the attribute data needed for admin level 2 and 3, see Figure 3.1 for better illustration.

3.1.1 Individual

The National Population Commission (NPC) provided the last census population data for the year 2006 (NPC, 2006). A projected population estimate needed for this study was further calculated using the Worldbank's annual population growth rate from 2006 to 2013 (Worldbank, 2015b). Estimated number of PLWHA per LGA computation: an extract from the raw data on HIV prevalence rate per State provided by NARHS survey was collected (FMOH,2012). The HIV prevalence was further multiplied with our estimated census population data for the year 2013", this gave us the "*Number of PLWHA per LGA*". LGA is the Local Government Administrative units of the government system. A district level with legislative structures empowered to control community health and social services. See detailed map of prevalence distribution in Figure 3 below with a re-distributed SS prevalence.

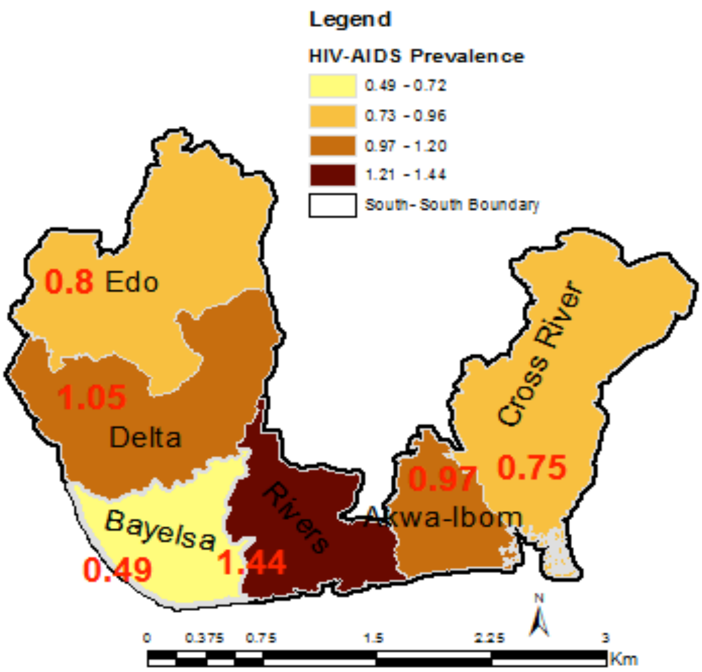


Figure 3: HIV-AIDS prevalence at the State level

Access to the National Demographic Health Survey (NDHS) data for Nigeria was granted by NDHS database unit. The survey sampled over 38,948 households of the population within the age of (15-49) years. This represents the entire national population, including LGA categorization at the urban-rural level for South-South region under study (NDHS, 2013). NDHS provided the needed indicators; knowledge of HIV-AIDS, cultural beliefs and means of transportation. The means of transportation captured in this survey was further re-categorized into two: (a). Use of Vehicle (owned car, motorcycle, commercial bus) and (b). Walking or use of bicycle.

3.1.2. Health Center

The Ministry of Health (MoH) provided a list of all the health facilities along with the type of HC categories. Moreover, we identified two distinct classes possible, *'Offering HIV-Services'* and *'Not offering HIV-AIDS services.'* The corresponding GPS coordinates of the HC were collected from every local HIV-AIDS offices. These HC geo-coordinates location points were collected by the LGA level health offices. All data collected at the LGA was cross-checked with the HC records at the national office of the ministry of health to confirm that services are currently being offered, using the monthly HIV-AIDS services report.

The *HC Offering HIV-AIDS* services were identified as currently providing HIV-AIDS services based on the following; a basic healthcare center activated by the MoH with a functioning HIV-AIDS viral load testing equipment, with at least one certified Pharmacist, one trained Medical doctor in HIV-AIDS treatment, one trained Nurse in HIV-AIDS treatment and counseling and testing room for HIV-AIDS services, while *Health center not offering Offering HIV-AIDS services*, does not meet any of the criteria stated above, with the exception of its ability to provide basic healthcare services.

3.1.3. Administrative

The Global Administrative Map was downloaded (GADM, 2009. vector shapefile; http://www.gadm.org/download; accessed on 2016-10-20) for Nigeria's administrative boundary polygons (GADM, 2009). The primary and secondary data from International Institute of Tropical Agriculture (IITA, 2008) also provided the point layers for every cities, town, and villages, as well as for the line layers for rivers, road (primary and secondary axis) and water bodies in Nigeria. The GPS coordinates collected were further verified via overlay with GADM and Open Street Map layers to ensure conformity with WGS-84 Geographic Coordinate System.

The HIV-AIDS services point layer was created using GPS coordinates gathered from the health centers for the year 2015, based on the HC spread across all the States. The distribution of HIV-AIDS services location is shown in Figure 3.2 below along with population density of PLWHA across all the LGA and States, represented by choropleth colors, with the deepest color having the most number of PLWHA (Figure 3.2).

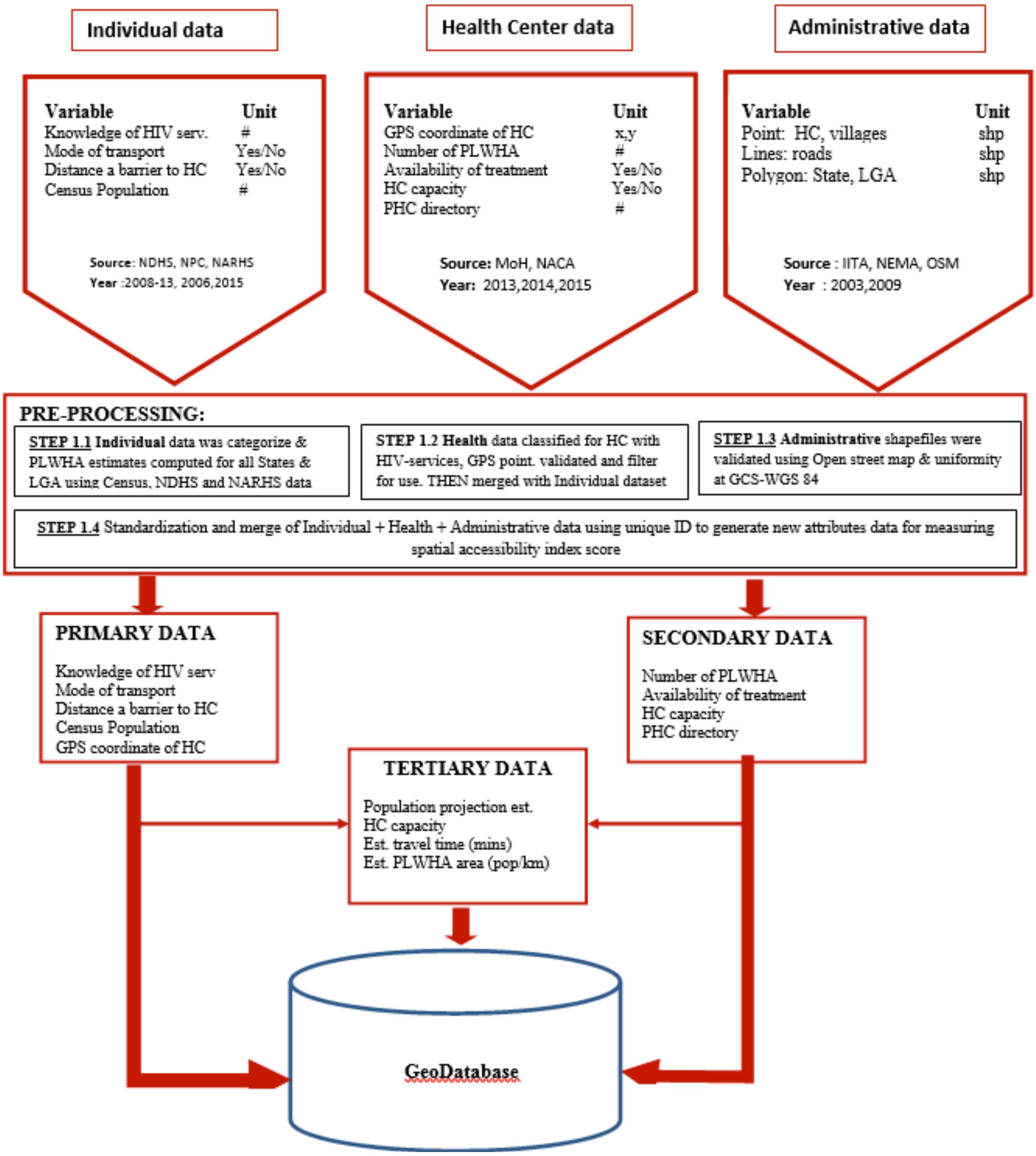
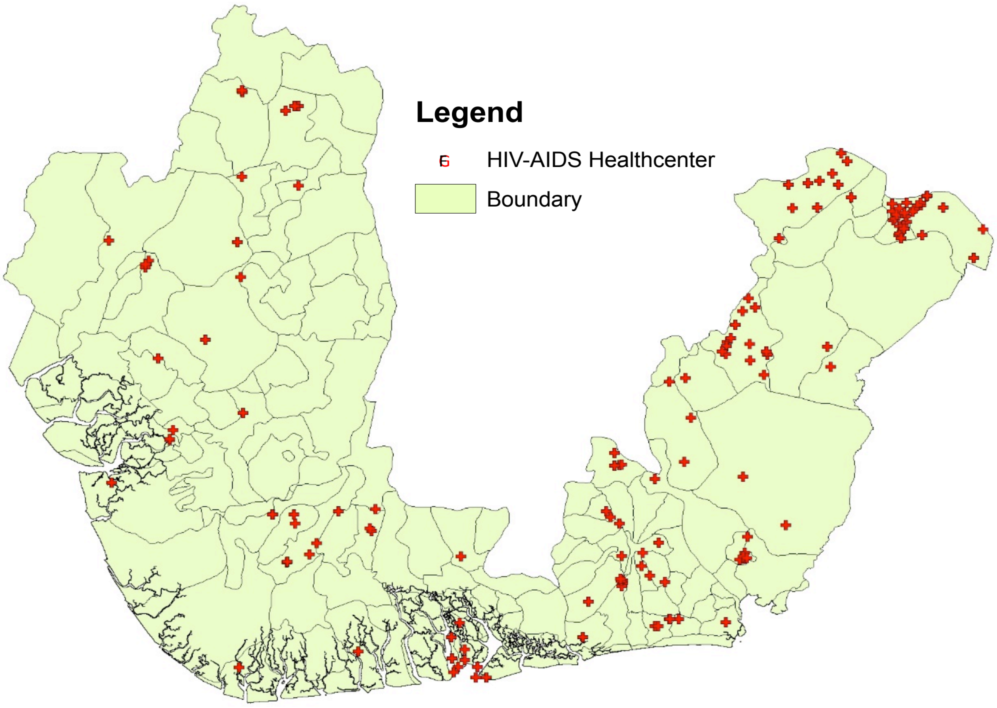


Figure 3.1: Data gathering and process flow

HIV-AIDS services point



People Living with HIV-AIDS (PLWHA)

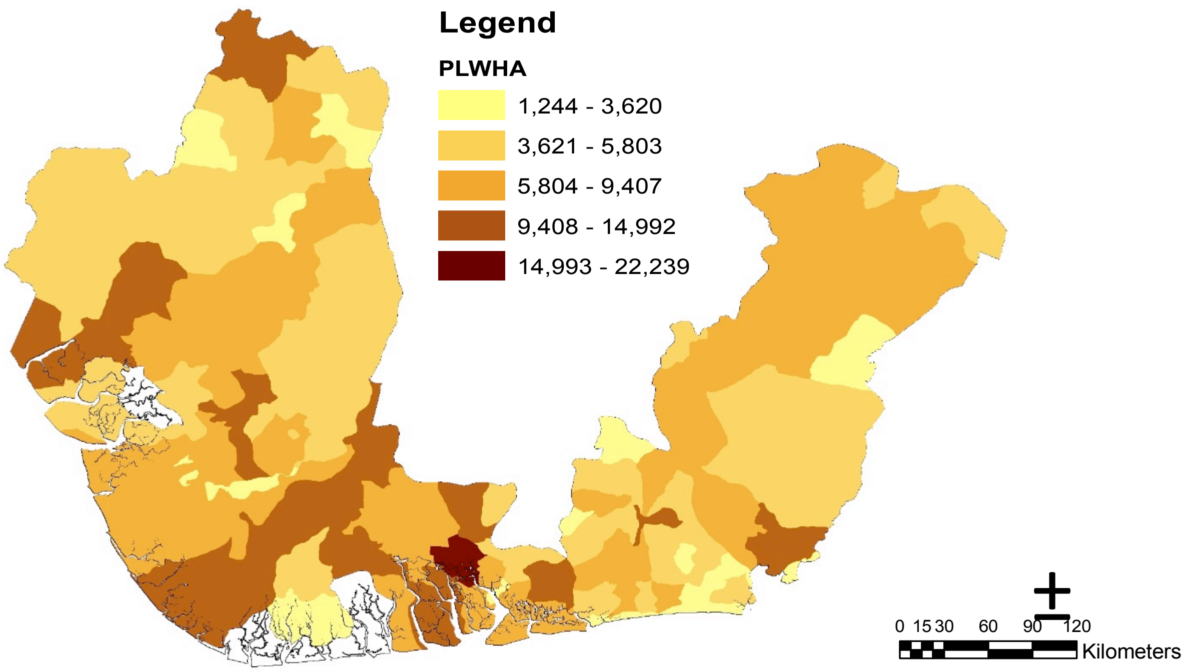


Figure 3.2 Map of geographical location of HIV-AIDS service centers and population density of People living with HIV-AIDS in South- South Nigeria.

3.2 Fitting data into the spatial accessibility network model

The Claremont geospatial learning laboratory lecture notes described a two-step Floating Catchment Method, as a method with two steps of performing road network analysis (Claremont, 2015). The monthly routine data for the year 2013 and NACA, 2015 were joined using unique administrative codes by LGA and gathered into one dataset. The national health information database in the Ministry of Health (MoH) generated the monthly routine data on the number of PLWHA that visited the HC.

Accessibility index used in this study was a 2SFCA method derived by Radke and Mu (2000) and improved on by Luo and Wang (2003a, b). Although there exists gravity model used as well in recent times, however, the 2SFCA is still like gravity model with even more advantages based on its demand (health center location with the required trained health worker on HIV-AIDS services) to supply (population of PLWHA) ratio concept. The implementation of 2 steps (demand and supply) is shown in the equation described below (Luo and Wang, 2003; Wang and Luo, 2005).

First step: For each (health center location with the required trained health worker on HIV-AIDS services) location *j*, search all population of PLWHA *(k)* that are within a threshold travel time *(d_0)* from location *j* (implying the catchment of health center location with required medical professional on HIV-AIDS *j*), and compute the HIV-AIDS services center location with population of PLWHA ratio, R_j, within the catchment area (Luo and Yi, 2009).

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj \leq} d_0\}} P_k} \qquad \textit{Eq.1}$$

where P_k represent the 'population of PLWHA' at their residential location point, such that the computed centroids stay within the catchment where j ($d_{kj \leq d_0}$), S_j stands for the 'health center location with the required health worker' and d_{kj} is the minutes spent as travel period between *k* and *j* .

Second step: For each population location of PLWHA *i,* search all health centers location with required health worker (*j*)*,* that are within the threshold travel time *(d_0)* from the location i.e. catchment area (*i*). Then summing up the required health worker on HIV-AIDS to-population of PLWHA ratios (as derived in the first step), $\boldsymbol{R_j}$**,** at these locations (Luo and Yi, 2009).

$$A_i^F = \sum_{j\in\{d_{ij\leq}d_0\}} R_j = \sum_{j\in\{d_{ij\leq}d_0\}} \frac{S_j}{\sum_{k\in\{d_{ij\leq}d_0\}} P_k} \qquad \textit{Eq.2}$$

Where A_i^F represents the accessibility of PLWHA population at location *i* to HIV-AIDS health center using the two-step floating catchment area method.

R_j is the HIV-AIDS health center -to- PLWHA population ratio at health center location *j* whose centroid falls within the catchment centered at population location *i*.

Moreover, and d_{ij} the travel time between i and j. *Equation 2* above, is basically a ratio of the health center with HIV-AIDS ready services (supply) to PLWHA population (demand), (Luo and Qi, 2009). Each step creates an area of coverage called catchment and are eventually floated on each other (Luo and Wang in 2003), this approach was also modified optimally to a Floating Catchment Area Methodology Family (Vo et al., 2015).

3.2.1 Application of the 2SFCA supply and demand

Firstly, using the SS region administrative polygon shapefiles, overlaid with point layers of every city town and villages, household survey and a population data were all added into ESRI-ArcGIS 10.2 version (ESRI, 2011). The survey and population table were then joined with the SS region shapefiles; this allows us to locate the center point of every LGA and its attributes. Secondly, using the ArcGIS toolbox for network analysis, the point distance functionality was employed to identify all the layers at a specified search radius of r = 30 minutes (2.5kilometer) and 60minutes (5kilometer). This action generated a new variable field called 'r-availability' and was then added to the admin base shapefile for computing the sum of the population under every 'r-availability' distance index.

Fitting this model for PLWHA access measurement to HC offering HIV-AIDS services, this was employed inside the ESRI ArcGIS 10.2.2 desktop application by invoking the network analyst module, and the ArcGIS extension calculates the driving distance. The data for our study were fitted into the 2SFCA model as described in the first and second step below. First, we identified the HC that offer HIV-AIDS services which essentially fits into the place of "required health worker" as the supply side of the 2SFCA model. Then for the demand side, the data collected from the health ministry provided the classification of "HC offering HIV-AIDS services".

Secondly, for the demand side of the model, we computed accessibility to "HC by PLWHA, per location." The accessibility scores for this study were computed with the ArcGIS network analyst toolbox. This was done by first adding the two shapefiles, the LGA level boundary and its corresponding HIV-AIDS services center points layers. The network analyst generated availability scores and employed the use of "feature to points option" to find the center point of the LGA where the PLWHA household resides. Further step was taken, using the analytical module to select the "point distance" and a search radius option was insert again at r = 2.5 and 5-kilometer thresholds, this process generates r-accessibility score value representing the PLWHA location center point and HIV-AIDS services center point onto the existing attribute data. Finally, the accessibility index score was then computed by summarizing the population of PLWHA per LGA, based on the r-availability to r-accessibility ratio.

The set of assumptions for this study are:

i. Any PLWHA will seek for free HIV-AIDS treatment from the public health center

ii. To reach the HC for HIV-AIDS services, it can only be via any of these 2-transportation types to access services; (a). Use of Vehicle (owned car, motorcycle, commercial bus) and (b). Walking or use of bicycle.

iii. Speed limit or incremental speed of vehicle was not considered. So, any means of transportation used must reach the health center within 30 minutes for the first threshold and 60 minutes for the second threshold.

The assumption in (ii) above was guided by the NDHS 2013 survey report, it noted that most household in rural and urban areas used commercial bus as means of transportation once the HC is more 30 minutes travel time via any means of transportation.

Furthermore, we analyzed for the PACE spatial pattern, at 30 minutes and 60 minutes threshold. PACE can be described as a movement related to distance covered; this threshold was guided based on the known traveling habit of the general population under consideration (NDHS, 2013), supported with standard area measurement for Africa landcover type with the use of a mean walking speed of 5 kilometers per hour. i.e., 60 minutes threshold (Ray and Ebener, 2008). Finally, we derived PACE I and II accessibility threshold to HC using the established travel time, irrespective of the means of transportation used, provided they arrived at the HC within an acceptable threshold of 30 or 60 minutes.

3.3 Spatial autocorrelation (Global Moran's I)

Spatial autocorrelation is an attribute of spatial data that describes the systematic pattern in the values recorded at the locations shown on a geographical map (FAO, 2003). Specifically, where high values of a variable at one area are associated with high values at neighboring localities, the spatial autocorrelation is positive, and where high values correspond to low values in the adjacent localities, the spatial autocorrelation is negative (FAO, 2003).

To describe spatial associations and spatial autocorrelation, standard global and local spatial statistics must be employed to describe its associations and autocorrelation. These statistics include Moran's I, Geary's C, G statistics (Getis and Ord, 1996), LISA (Anselin, 1995) and GLISA (Bao and Henry, 1996). These techniques are known to first start from the assumption of a spatially random distribution of data, describing the degree to which the distribution deviates from random. One popular way of measuring spatial autocorrelation in a spatial dataset is computing Moran's I statistic. Equation 3 shows how Moran's I is calculated (Rogerson, 2001).

$$I = \frac{n \sum_i^n \sum_j^n w_{ij}(y_i - \bar{y})(y_i - \bar{y})}{\sum_i^n \sum_j^n w_{ij} \sum_i^n (y_i - \bar{y})^2} \qquad Eq.3$$

where:

n: total number of features

y_i and y_j : individual observations

y: sample mean of the variable

w_{ij}: weights between the i^{th} and the j^{th} features

(if i and j are adjacent wij = 1, otherwise wij = 0)

Moran’s, I measure spatial autocorrelation based on both feature locations and feature values. Like classical correlation, Moran’s I range from -1 to +1 and the value of zero means there is no spatial autocorrelation. When the Moran’s Index is positive, it means that the dataset is clustered spatially (neighboring spatial units have similar values) and when Moran’s Index

is near 0 it means that there is no clustering of high or low values in the dataset, see pictorial representation in Figure 3.3 below.

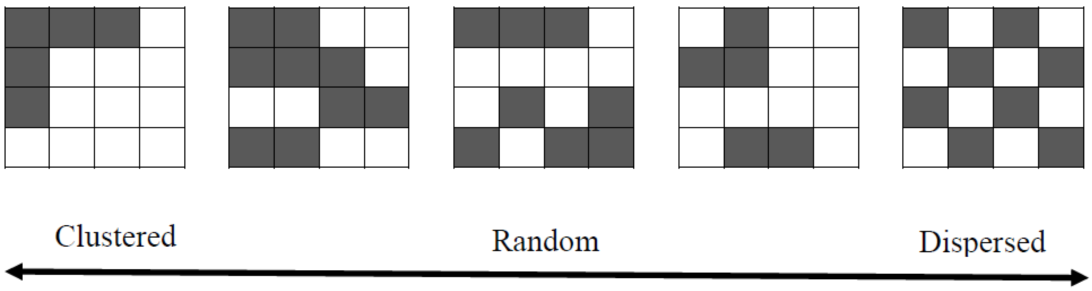


Figure 3.3 A simple illustration of clustered, random and dispersed pattern.

Since Global Moran’s I is an inferential statistic, the null hypothesis is defined to interpret the result of the analysis. The null hypothesis stated that “the attribute being analyzed is randomly distributed among the study area.” In other words, the statistical framework is designed to allow one to decide whether there is a significant difference between any given pattern and a random pattern. So, a z-statistic is created using the mean (E(I)) and variance (V(I)) of I in equation 4, 5 and 6 (Rogerson 2001).

$$\frac{\mathrm{I} - E(I)}{\sqrt{\mathrm{V(I)}}} \qquad \textit{Eq.4}$$

The expected value (E) and variance (I) value of Moran's I for a sample size can thus be computed according to an assumed pattern of dispersal. With the assumption of normal distribution:

$$\left.\begin{aligned} E(I) &= \frac{-1}{\mathrm{n}-1} \\ V(I) &= \frac{n^2(n-1)S_1 - n(n-1)S_2 + 2(n-2)S_0}{(n+1)(n-1)^2 S_0} \end{aligned}\right\} \qquad \textit{Eq. 5}$$

While, for the assumption of random distribution:

$$\left.\begin{aligned} S_0 &= \sum_{i}^{n} \sum_{j \neq i}^{n} w_{ij} \\ S_1 &= 0.5 \textstyle\sum_i^n \sum_{j \neq i}^n (w_{ij} + w_{ji})^2 \\ S_2 &= \sum_{k}^{n} \left(\sum_{j}^{n} w_{kj} + \sum_{i}^{n} w_{ik}\right)^2 \end{aligned}\right\} \qquad \textit{Eq.6}$$

Given that S_0, S_1 and S_2: represents the random step increment gradually approaching to normality as the distance is increased, while summing all the elements in the spatial weights matrix w_{ij} (Getis and Ord, 1992). This way, we have specified interdependence among observations via the use a spatial weight matrix. The spatial weight matrix (w_{ij}) is an n × n exogenous nonnegative matrix where 0 indicates that observation *i* depends upon neighbouring observations *j* (Pace and LeSage, 2010). The z-score value is then compared with the critical value found in the normal table. In this HIV-AIDS services location study, the global Moran's I in ArcGIS 10.2 version was used which returns the z-score and *p*-value produced (ESRI, 2016).

Table 3.1 shows how to interpret the Moran's I p-value and z- score results.

$p > 0.05$	There is no spatial clustering in the data set
$p < 0.05$ & $z > 0$	There is cluster of high values or low values in the dataset
$p < 0.05$ & $z < 0$	There is a dispersed spatial pattern in the dataset

3.4 Anselin's local Moran's

Although, we might see spatial cluster pattern visually on the map. However, the objective analysis should be used to identify the hotspot area statistically. Some common method such as Getis's G index (Getis and Ord 1996) and local Moran's I index which was developed by Anselin in 1995 can be used (Anselin 1995). The Local Moran's I recognized the hotspot areas by relating one feature with respective to another within its neighborhood (Zhang et al. 2008). By referencing the representations from equation 2 above, we can infer that for every attribute in the feature the local Moran's I statistic can be expressed as equation 7, where the Moran's I statistic (I_i) reflects where the local government area is surrounded by the same high values as itself.

$$I_i = \frac{x_i - \bar{X}}{S_i^2} \sum_{j=0, j \neq i}^{n} w_{i,j} \, (x_i - \bar{X})$$

$$S_i^2 = \frac{\sum_{j=1, j \neq i}^{n} (x_j - \bar{X})^2{}_j}{n-1} - \bar{X}^2$$

Eq. 7

3.5 Mean comparison statistic and dependent variable

Comparing the spatial relationship between the means of accessibility index and distance as a barrier obtained from different States can be accomplished by the computation of the F-test statistic using mean squares. A mean square is an average of squared values, for example, any variance is a mean square. The F-test statistic is the ratio of these two mean squares. If the null hypothesis is true, then each sample comes from the same population whose mean is 'μ' and whose variance is 'δ^{2}'. So, we set the null hypothesis (H_0) to be true and accept it, unless it is indicated otherwise. In testing the hypothesis with respect to k population means, we assume that $\mu_1 = \mu_2 = \mu_3 \ldots\ldots = \mu_k = \mu$, that is, we assume that all k samples on population 'n' come from the same normal population whose mean is 'μ' and variance is 'δ^{2}'. The sample mean of the entire set of data is a good estimate of 'μ,' Thus we can call this sample mean Ẍ. Similarly, the sample mean of sample 1 will be $Ẍ_1$, the sample mean of sample 2 will be $Ẍ_2$ and so on. Hence to estimate a measure of variation in sample means from one sample to the next, weighted by the sample size of the corresponding sample group is called the mean square test due to the selected sample, denoted MST.

$$MST = \frac{n_1(\bar{X}_1 - \bar{X})^2 + n_2(\bar{X}_2 - \bar{X})^2 + \ldots + n_k(\bar{X}_k - \bar{X})^2}{k-1} \qquad Eq.8$$

So, if the null hypothesis (H_0) is true, then MST is an unbiased estimator of the variance δ^2 of the population. A second approach is by computing the sample variance for each sample, and then to find a weighted average of the sample variances. We call this the mean square due to error, denoted MSE. The mean square due to error is an unbiased estimator of whether or not the null hypothesis is truly calculated as;

$$MSE = \frac{(n_1-1){s_1}^2 + (n_2-1){s_2}^2 + . . . + (n_k-1){s_k}^2}{k-1} \qquad Eq.9$$

Where *n* is the total sample size. The F statistic is the ratio of the two estimates of δ^2. Such that

$$F = \frac{\text{mean square due sample group or treatment}}{\text{mean square due to error}} = \frac{\text{MST}}{\text{MSE}} \qquad Eq.10$$

The F-test statistic is the ratio of the two estimates. If the null hypothesis (H_0) is true, both MST and MSE gave unbiased estimates of the population variance, and we would expect the F-test statistic to be close to 1. However, if the null hypothesis is not true, at least one of the sample means from a sample group will be “far away” from the sample mean of the entire dataset (Sullivan, 2012).

Recall that standardized spatial accessibility index score was considered as the dependent variable. However, there was no individual-level data on PLWHA to be used in our study as the independent variable on socio-economic and demographic factors. The only proxy data available was 'distance as a barrier to HIV-AIDS services,' which we had to use to perform mean comparison analysis.

4. RESULTS

4.1. Exploratory data analysis

Overall, in our dataset, 813,352 individuals are living with HIV-AIDS in the SS region of Nigeria. Rivers and Delta States has the highest number of PLWHA at 26.2 % and 19.1%, while Bayelsa has the least 8.9%. The bar chart below in Figure 4.1 shows a pictorial representation.

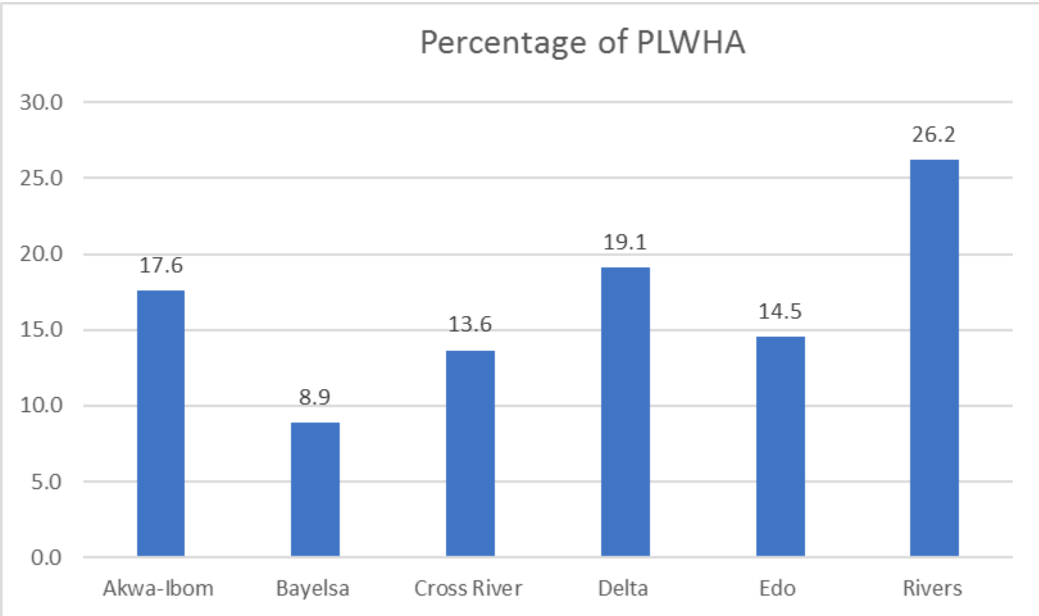


Figure 4.1 Percentage distribution of People Living with HIV-AIDS (PLWHA) in the South-South region.

4.2 Accessibility index score and hotspot:

The use secondary road network shapefiles provided by International Institute of Tropical Agriculture (IITA), which was further authenticated with open street map (OSM) was utilized to generate distance centroid as against the Euclidean distance in the network analyst toolbox. This gave us the travel time thresholds between the household location where PLWHA resides and health center offering HIV services.

This study shows a notable variation in the accessibility index score, as highlighted by the standard deviations of 3.99 and 1.06 for 30 and 60 minutes thresholds, respectively. Highlighted below in Table 4.1 are the mean, median, and standard deviation values.

Table 4.1 Exploratory analysis for spatial accessibility index, time thresholds and socio-demographic indicators.

	Mean	**Median**	**SD**
30 minutes threshold index	4.09	2.92	3.99
60 minutes threshold index	1.93	1.74	1.06
Distance as a Barrier (%)	**27.71**	**25.5**	**8.30**

SD: Standard Deviation

The map can be seen in Figure 4.2; it describes the spatial pattern of the accessibility index score at 30 and 60 minutes thresholds, its concentration at every State and LGA. At 30 minutes threshold, it shows a lack of accessibility to HIV-AIDS services for PLWHA in some areas of Bayelsa and Delta as reflected with a white background. The areas covered with the darkest brown background color represent high accessibility to HC by PLWHA residing there, while the others in between these two, represents a spatial pattern with an insufficient accessibility index score.

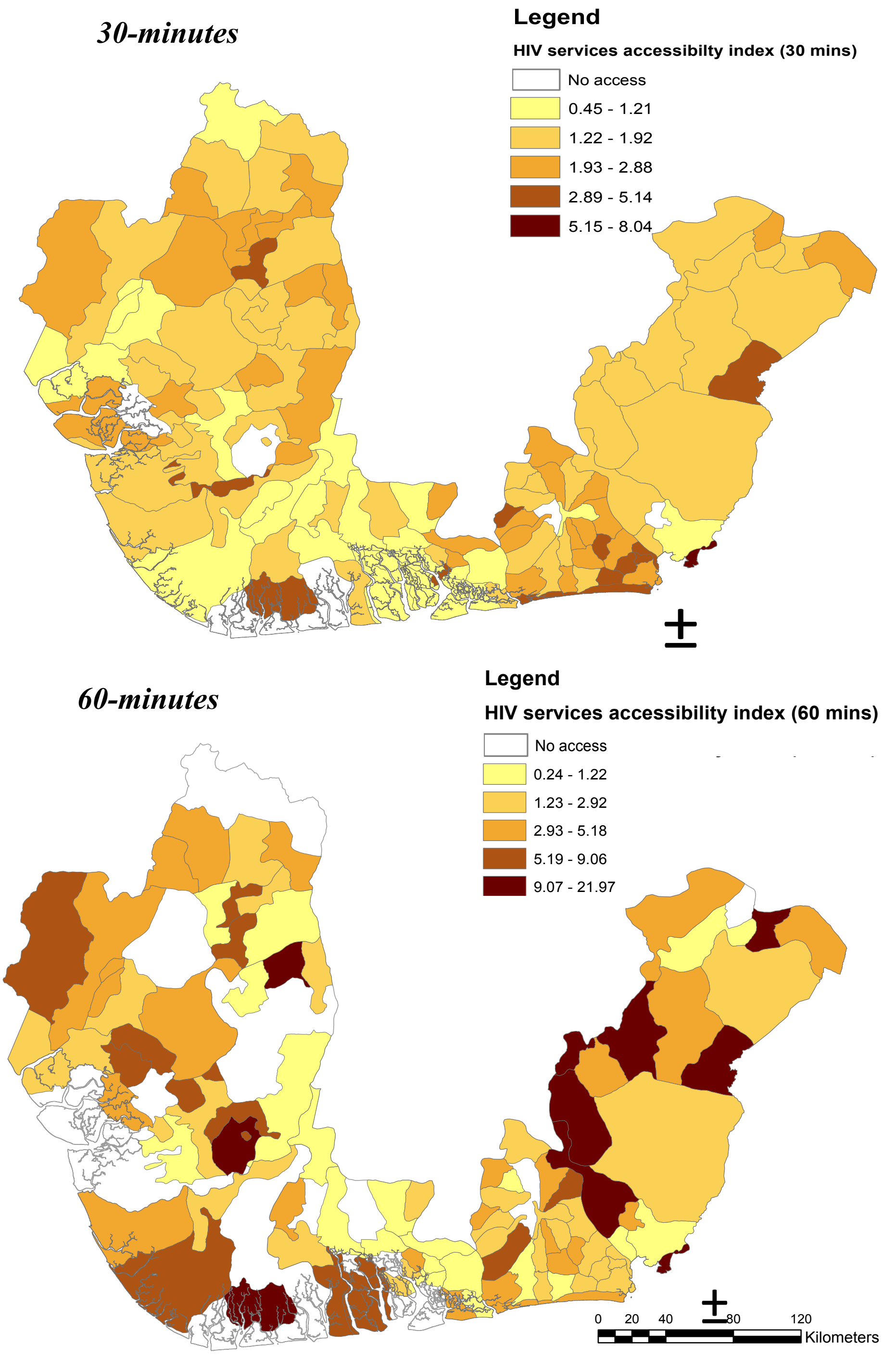
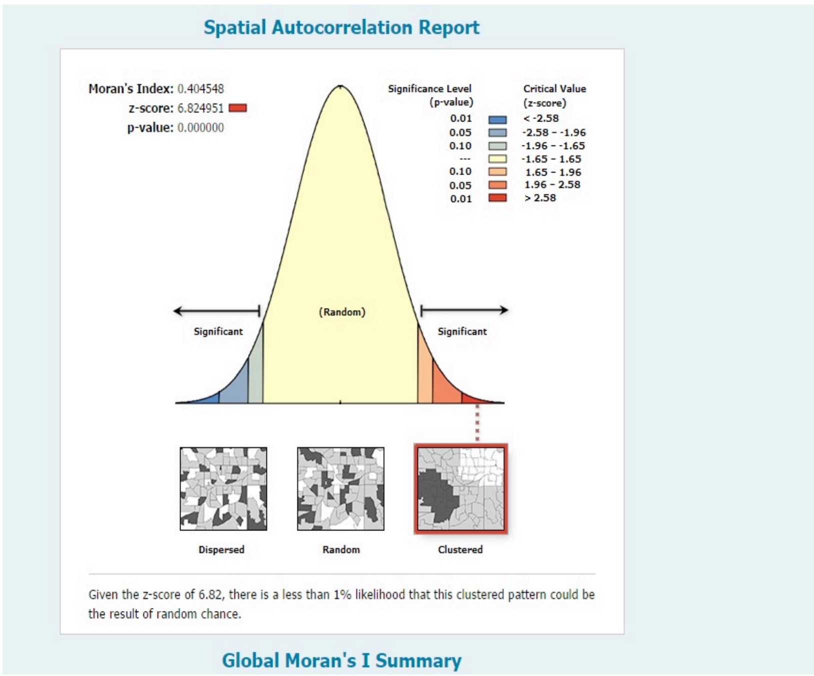


Figure 4.2 Map showing accessibility index score at 30 and 60 minutes thresholds.

The cluster’s significant values for accessibility can be seen visually in Table 4.2 and 4.4 below. However, spatially clustered LGA needs to be identified statistically. Consequently, the spatial autocorrelation statistic Global Moran’s I was applied to identify any statistically clustered pattern in the accessibility index score at differing thresholds. The result of the global Moran’s I is also shown in Table 4.2, as tabulated in Table 3.1. At the 30minutes threshold, it showed a high significant spatial pattern in the clustering, explained in Table 3.1, with a significant *p*-value and positive z-score.

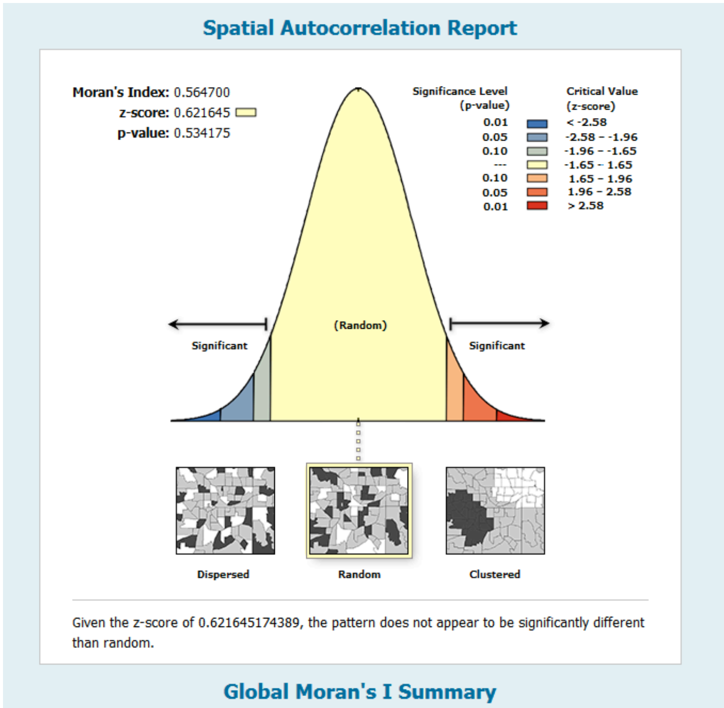
Table 4.2: Result of spatial autocorrelation (Global Moran’s I) at 30 minutes threshold.

Moran’s Index	0.40	
Z-score	6.82	
***p*-value**	0.00	

Taking a similar approach, Global Moran’s I was applied at a threshold of 60 minutes as shown in Table 4.3. The pattern was randomly positive, interpreting the result with Table 3.1, though it has *p*-value and positive z-score, there is no significant spatial pattern in the clustering found at this threshold.

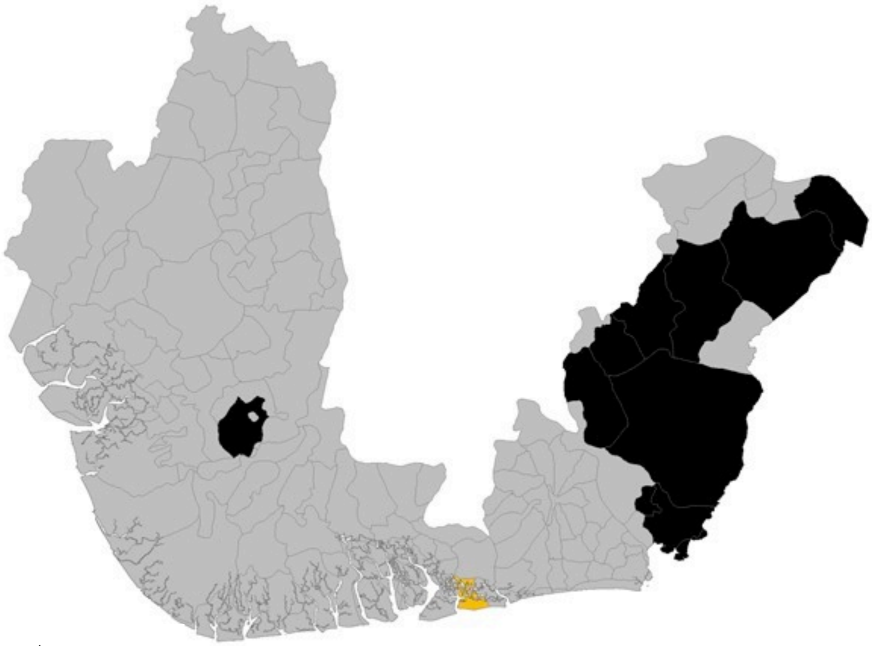
Table 4.3: Result of spatial autocorrelation (Global Moran's I) at 60 minutes threshold.

Moran's Index	0.56
Z-score	0.62
***p*-value**	0.53



Although global Moran's I demonstrated there was a cluster of access to HC in some locations in the dataset, we need to know the extent and locality of any identified hotspot detected using Anselin Local Moran's I. Figure 4.3 below shows the results of Anselin Local Moran's I. According to the result, eleven LGAs (Isoko South, Akamkpa, Akpabuyo, Biase, Boki, Calabar, Calabar South, Obubra, Obanliku, Ikom, and Yakurr) were identified as statistically significant clusters of high accessibility index values at a threshold of 30 minutes. However, at the 60 minutes threshold, only the cluster values around Biase and Odukpani LGAs can be seen as highly statistically significant clusters.

30-minutes



60-minutes

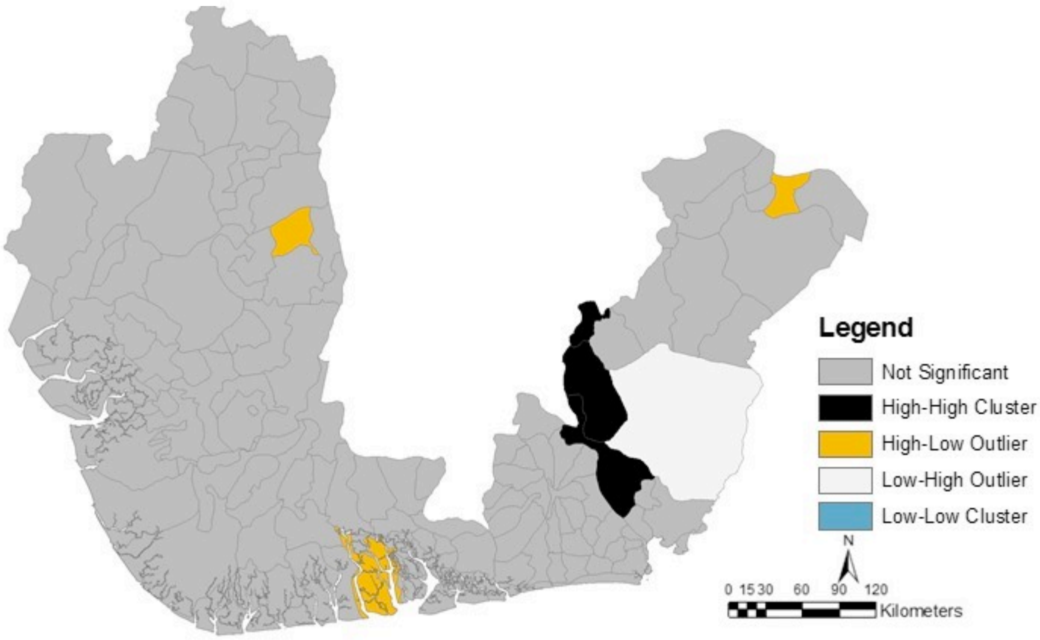


Figure 4.3 Anselin Local Moran's I map.

Table 4.4 detailed the extent and location of cluster pattern by LGAs, identifying the area of high-high value as the hotspots, while no coldspot was recorded for low-low values. The observed area of cluster outliers was also recorded for High-Low and Low- High values based on the statistical results.

Table 4.5 List of LGA (districts) clusters statistical result by the travel time threshold

Time threshold	**High-High**	**High-Low**	**Low-High**
30 minutes	Akamkpa, Akpabuyo, Biase, Boki, Calabar, Calabar-South, Obubra, Obanliku, Ikom, Yakurr	Andonio/O	
60 minutes	Biase, Odukpani	Aniocha/N, Degema, Obudu	Akamkpa

4. 3 Comparing test statistics on distance as a barrier and accessibility index scores

The analysis of variance statistic was produced using these two key variables under study to measure accessibility to HIV-AIDS healthcare using the IBM SPSS software (SPSS, 2011). This procedure was conducted to compare the "accessibility index score" and "adequate access to HC in South-South," relying on the survey response data "Is distance a barrier to accessing HC in South-South". Setting the null hypothesis (H_0) to be true, where H_0 = *the travel time/distance does not matter for PLWHA* and H_1 = *the travel time / distance does matter for PLWHA*.

According to the results shown in Table 4.5 below, there is a significant difference between the six States based on the level of accessibility to HC; at *($p<0.05$),* the test statistic showed highly significant differences between the States. Post hoc comparisons using the Tukey HSD test indicated that the mean score for distance as a barrier to HC was significantly different from one State to another in all the six States.

Table 4.5: ANOVA statistic comparing accessibility and distance as a barrier to HIV-AIDS services.

		Sum of Squares	df	Mean Square	F	Sig.
Accessibility Index score	Between Groups	21.005	5	4.201	14.164	<0.001
	Within Groups	26.990	91	0.297		
	Total	47.995	96			
Distance as a Barrier to HC	Between Groups	1.007	5	0.201	5.281	<0.001
	Within Groups	3.433	90	0.038		
	Total	4.441	95			

5. DISCUSSION

This study engaged the use of 2SFCA geospatial method to examine the effectiveness of HIV-AIDS services coverage in South-South Nigeria.The Global morans' I clearly showed that; given the 30 minutes threshold, there is a significant clustered pattern in the level of accessibility (high, low and no-access) from one LGA to another and from one State to another. However, at 60 minutes threshold, the level of accessibility defers, showing a random pattern that is not significant statistically. The extent of the pattern hotspots detected, used Anselin Local Moran's I, see Figure 4.3 below. The high-high cluster with black color as shown in Figure 4.3 implies that districts that has a high concentration of PLWHA with high accessibility to HIV-AIDS services center are surrounded with neighbourhood with similar high PLWHA and high accessibility to HIV-AIDS services. High-Low cluster with yellow color implies that districts with high concentration of PLWHA with high accessibility to HIV-AIDS services center are surrounded by neighbourhood of low PLWHA and low accessibility to HIV-AIDS services.

Low-High cluster with white color implies that districts that has a low concentration of PLWHA with low accessibility to HIV-AIDS services center are surrounded with neighbourhood of high PLWHA and high accessibility to HIV-AIDS services. Low-Low cluster with blue color was not represented in the map, that is none of the districts that has a low concentration of PLWHA with low accessibility to HIV-AIDS that are surrounded with neighbourhood of low PLWHA and low accessibility to HIV-AIDS services.

These results are a key decision-making factor for local authorities to establish equitable access to PLWHA in the South-South region. The non-significant area on the map with color grey implies that these areas do not even have HIV-AIDS services center within to account for the pattern of association. Hence these grey areas call for the most attention by the government of the country to prioritize activation of HIV-AIDS services center immediately. Seconded by the neighborhood of the High- Low and Low-High clusters, where we low accessibility of HIV-AIDS services have been identified.

The South-South region requires attention with practical measures on how to better provide adequate HIV-AIDS services to areas with no access to low accessibility. The results of this study have shown some critical answers to the objectives of this study. The study demonstrated how the current existing health centers offering HIV-AIDS services are inequitably distributed. It also confirmed that travel time and distance to health center affects the accessibility to services by PLWHA in the South-South region.

These results confirmed the slow rollback of HIV-AIDS prevalence in the South-South region, which could be due to healthcare accessibility as demonstrated in this study. Additionally, lack of good roads in most rural areas in Nigeria is another hindrance. According to NDHS, 2013 study, which noted that 62% of the population lived in rural area, travel time for healthcare access remains a challenge (NDHS, 2013).

6. CONCLUSIONS

With regards to all the three objectives of the study, the results showed a significant lack of accessibility to services by PLWHA in some LGAs. The use of 2SFCA as an appropriate GIS model in this research demonstrated how distance influences accessibility to HIV-AIDS services by the population in need of it. The results confirmed the slow roll back of HIV-AIDS prevalence in the South-South which requires improved coverage. Shortages of HIV-AIDS services were observed in seven LGAs at a threshold of 30 minutes, while if given a threshold of 60 minutes, two LGAs still showed up as hotspots that requires better coverage and accessibility. This study has demonstrated how distance can be seen as a barrier to healthcare services.

Any future monitoring strategy plan should include the use of 2SFCA spatial methodology, as this will obviously guide the government in optimal re-allocation of resources needed for HIV-AIDS services. Secondly, further studies in the future should explore additional socio-demographic variables that may reveal more informations on any individual who needs healthcare; these variables are not limited to 'do you seek request to get a permission to go to the HC' from head of household; 'educational level', 'cultural believes' and 'attitude of the health workers at every designated HC for HIV-AIDS services'.

Currently, the allocation of medical doctors and nurses to a particular health center might have played a large role in the reasons why several districts(LGA) outside the urban center or around its neighbourhood continue to face shortages of trained health workers. Therefore, there is an urgent need to fill the gaps by scaling up existing health centers that are not currently offering HIV-AIDS services. One option could be the implementation of rotational roster for health workers providing HIV-AIDS services. This rotaitonal method will serve as a temporary measure to help HC not offering HIV-AIDS services to make such services available on the days HIV-AIDS trained health workers are deployed to their HC.

Responding to SDG 2030, it is recommended that the country should ensure that whenever health coverage evaluation is required, it must employ the use of a geospatial method to measure equitable distribution of HIV-AIDS services. Furthermore, priority should be given to LGAs with no accessibility to HIV-AIDS services over the next coming years. A similar study of this sort should be carried out at the national level, as this study has demonstrated the usefulness of GIS in measuring coverage and accessibility of healthcare.

PLWHA can be classified as vulnerable individuals, most especially in the rural setting, their poverty status has continually denied them access to healthcare services. If healthcare is made accessible within every 30 to 60 minutes travel time, it eliminates the burden of transport cost to reach a health center. It also allows family members to carry out home based care support needed in a way that will not further lower the socio-economics productivity. As part of global effort to eradicate poverty and inequality. Fighting the drivers of poverty and poor healthcare with a safer household, cleaner healthcare environment and improved district health systems is needed to deal with HIV-AIDS threats. Finally, the national health information system used for reporting aggregated health data on a monthly basis should include patient's social-economic and demographic data to facilitate and expand this sort of analysis in the future.

7. References

Anselin, L. 1995. Local indicators of spatial association—LISA. *Geographical analysis*, 27: 93-115.

Arleen A. Leibowitz and Stephanie, L. Taylor. 2007. Distance to Public Test Sites and HIV Testing. *Med Care Res* RevOctober 2007 vol. 64 no. 5 568-584. doi: 10.1177/1077558707304634.

Bao, S. and Henry, M.S. 1996. Heterogeneity issues in local measurements of spatial association. Geog. Sys., 3: 1-13.

Bashorun, A., Nguku, P., Issa. Kawu, I.,Ngige, E., Ogundiran, A.,Sabitu, K., Nasidi, A and Nsubuga, P. 2014. A description of HIV prevalence trends in Nigeria from 2001 to 2010: what is the progress, where is the problem?.*Pan Afr Med J*. 2014; 18(Suppl 1): 3. doi: 10.11694/pamj.supp.

Brown, C. H., Mohr, D. C., Gallo, C. G., Mader, C., Palinkas, L., Wingood, G.,Jacobs, C. et al (2013). A Computational Future for Preventing HIV in Minority Communities: How Advanced Technology Can Improve Implementation of Effective Programs. *Journal of Acquired Immune Deficiency Syndromes* (1999), *63*(0 1), S72–S84. http://doi.org/10.1097/QAI.0b013e31829372bd.

Claremont Geospatial Learning Lab. 2015. GIS Tutorial. Two-step Floating Catchment Method;https://docs.google.com/document/d/13lb9wwHAz1wl9QqIE8vExHes_gVd_VE5HmU4vmm-SsQ/mobilebasic, 2015.

Clary, C and Huang, Y. 2014. Spatial Access to Substance Abuse Treatment for Low-Income and Minority Households: A Case Study in Dallas-Fort Worth Metroplex, Texas. *Third ACM- SIG.Spatial International Workshop on the Use of GIS in Public Health*.Health.doi:10.1145/2676629.2676632.

Cochran SD, Mays VM. 2000. Lifetime prevalence of suicidal symptoms and affective disorders among men reporting same-sex sexual partners: Results from the NHANES III. *American Journal of Public Health.* 2000;90:573-578.

Donabedian, A.1973. *Aspects of medical care administration: specifying requirements for health care.xiv,* 649 p, ISBN: 0674049802dge, published for the Commonwealth Fund by Harvard University Press, . Cambridge.

ESRI .2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute

ESRI. Retrieved July 2016, from.

http://resources.arcgis.com/en/help/main/10.1/index.html#//005p0000000n000000.

FAO. 2003. The Application of a Spatial Regression Model to the Analysis and Mapping of Poverty; Chapter 4*, Environment and Natural Resources Service No. 7*.Sustainable Development Department.

Family Health International (FHI). 2008. HIV-AIDS Inventory Mapping of six Strengthening National Response(SNR) supported states in Nigeria.

Federal Ministry of Health (FMOH). 2006. Department of Health Planning and Research: National Health Management Information System -revised Policy-Programme and Strategic Plan Of Action.

Federal Ministry of Health (FMOH). 2010. Nigeria Integrated Biological and Behavioural Surveillance.

Federal Ministry of Health. (NARHS). 2012. National HIV & AIDS and Reproductive Health Survey, 2012 (NARHS Plus).

Federal Ministry of Health. 2013. National Routine Healthh Informaytion Systems data reports, Nigeria.
GADM. 2009. Global Administrative Areas shapefile, http://www.gadm.org/country
Gang, C. G., Zeng, X., Duanb, L., Lua, X., Suna,H., Jianga, T., and Lia. Y. 2016. Spatial difference analysis for accessibility to high level hospitals based on travel time in Shenzhen, China. *Habitat International*, Volume *53*.pp. 485–494.
Getis A. and Ord, J.K .1992. Local Spatial Autocorrelation Statistics: Distributional Issues and an Application.
Getis, A and Ord,J.K .1996. *Local spatial statistics*: an overview. Spatial analysis: modelling in a GIS environment, 374.
Global Fund (GF) and Federal Republic of Nigeria (FRN). 2012. Program implementation and grant agreement plan between FRN and GF to Fight AIDS, tuberculosis and malaria Agency and the Federal Republic of Nigeria. Program -Scaling-up gender sensitive HIV/AIDS prevention, treatment, and care and support interventions for adults and children in Nigeria.
Independent National Electoral Commission (INEC). 2016. LGA Analysis nationwide. Retrieved December 20, 2016, from http://www.inecnigeria.org/wp-content/uploads/2013/03/RA-LGA-ANALYSIS-NATIONWIDE.pdf.
International Institute of Tropical Agriculture (IITA). 2008, *State and LGA, Nigeria shapefiles*
Jubril. S. 2015. *Report on Towards achieving sustainable development for all: prioritizing targets for implementation*: which way forward for Nigeria; Center for Public Policy Alternatives, Lagos Island, Nigeria.
Li, Q.An, Song P, Zhu Y, and Mao X. 2013. Assessing Spatial Accessibility to Maternity Units in Shenzhen, China. *PLoS ONE* 8(7): e70227. doi:10.1371/ journal.pone.0070227.
Logan, Sadye. 1996. *Epilogue*: Understanding Help-Seeking Behaviour and Empowerment Issues for Black Families, Boulder: Westview Press.
Luo,W and Wang. F .2003. .Measures of spatial accessibility to healthcare in a GIS environment: synthesis and a case study in the Chicago region. *Environment and Planning B: Planning and Design*, 30 (6) (2003), pp. 865–884.
Luo, Wei and Yi Qi, 2009. *An Enhanced Two-Step Floating Catchment Area (E2SFCA) Method For Measuring Spatial Accessibility To Primary Care Physicians*. Department Of Geography, Northern Illinois University, Davis Hall 120, Dekalb, IL 60115, USA.
National Agency for Control of AIDS (NACA).2015. [The HIV Epidemic in Nigeria]. Retrieved December 15, 2015, from https://naca.gov.ng/article/hiv-epidemic-nigeria
National Agency for Control of AIDS (NACA). 2009. National HIV-AIDS Strategic Plan for the year 2010 -2015.
National Population Commission (NPC). 2006 Census Population data for States and LGA in Nigeria.
NDHS.2013. National Demographic Health Survey dataset. ACF-Macro NDHS data.*religious perspectives*. PhD Thesis, Nigeria: University of Nigeria,Nsukka.

Pace, R.K. & LeSage, J. 2010. Spatial Econometrics in Gelfald, A.E.; Diggle, P.J.; Fuentes, M. and Guttorp, P.eds, Handbook of spatial statistics. Taylor and Francis, London.ips, A., D. 2004. *Nigeria*, Philadelphia: Chelsea House Publisher, p. 10.

Radke, J and L. Mu, L. 2000. Spatial decomposition, modeling and mapping service regions to predict access to social programs. *Geographic Information Sciences*, 6 (2) (2000), pp. 105–112.*Health Geogr* , 7:63.

Rogerson, P. A. 2001. *Spatial Patterns*. Statistical Methods for Geography. SAGE Publications, Ltd. London, England: SAGE Publications, Ltd.

Rosero-Bixby. L. 2004. Spatial access to healthcare in Costa Rica and its equity: A GIS-based study (Ctro. Centroamericano de Poblacion, Universidad de Costa Rica, San Jose 2060, Costa Rica). *Social Science and Medicine*, v 58, n 7, p 1271-1284, April 2004.

Sullivan 2012. Chapter. 4: Comparing Three or More Means (One-Way Analysis of Variance) http://www.napavalley.edu/people/cburditt/Documents/Math%20232%20-%20Statistics/Sullivan%20ANOVA.pdf.

Statistical Packagers for Social Sciences (SPSS). Released 2011. *IBM SPSS Statistics for Windows*, Version 20.0. Armonk, NY: IBM Corp.

Tanser, F. 2006. Geographical Information Systems (GIS) innovations for Primary HealthCare in developing countries. *Innovations Technology Governance Globalization* 1(2):pp.106-122.

United Nations. 2016. Sustainable Developments Goals; 17 Goals to Transform our World. Retrieved from http://www.un.org/sustainabledevelopment/health.

UNICEF. 2007. The Nigerian situation. Retrieved November 20, 2016, from https://www.unicef.org/nigeria/1971_2199.html

USAID. 2015. Strengthening Integrated Delivery of HIV/AIDS Services (SIDHAS) Project Mid-term Evaluation Final Report.

Vo, Au Miloslava Plachkinova and Rahul Bhaskar. 2015.Assessing Healthcare Accessibility Algorithms: A Comprehensive Investigation of Two-Step Floating Catchment Methodologies.Twenty-first Americas Conference on Information Systems, Puerto Rico.2015 Family Full Paper.

Walker, M and Vajjhala. P. 2009. *Gender and GIS*: Mapping the Links between Spatial Exclusion, Transport Access, and the Millennium Development Goals in Lesotho, Ethiopia, and Ghana. August 2009 RFF DP 09-27.

WHO. 2016.Maternal mortality, http://www.who.int/entity/mediacenter/factsheets/fs348/en/.accessed December 03, 2016.

Wang.F, W Luo. 2005. *Assessing spatial and non spatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas*. Department of Geography, Northern Illinois University, *DeKalb*, IL 60115-2854, USA.

Worldbank.2015a.Working for a world of free poverty [Worldbank country overview]. Retrieved November 20, 2016, from http://www.worldbank.org/en/country/nigeria/overview.

Worldbank.2015b. Population growth (annual percentage). Retrieved November 20, 2016, fromhttp://data.worldbank.org/indicator/SP.POP.GROW?end=2013&locations=NG&start=1960.

Yao, Ying, Murray, Alan. T., Agadjanian, Victor and Hayford, Sarah R. 2012. Geographic influences on sexual and reproductive health service utilization in rural Mozambique. *Appl Geogr* 2012;32(2): pp.601-607.

Zhang, C., L. Luo, W. Xu, and V. Ledwith. 2008. Use of local Moran's I and GIS to identify pollution hotspots of Pb in urban soils of Galway, Ireland. *Science of the total environment,* 398**:** 212- 221.

8. APPENDIX

1: Summary of data collected

S/N	Name	Where /How (Source)	Data Type & Level
1	Census data 2006, Population projection estimates data 2015.	National Population Commission (NPC) & National Bureau of Statistics (NBS), United Nations Population Fund(UNFPA)	Age disaggregation data on population by Geo-regions, state, LGA and Ward.
2	National HIV & AIDS and Reproductive Health Survey 2012	National Agency for Control of HIV-AIDS (NACA), National AIDS and Sexually Transmitted Infection Control Programme (NASCAP), Family Health International (FHI360).	PLWHA figures by state, relevant indicators on knowledge, attitude & access to treatment
3	IBBSS Survey 2007, 2010 and 2014, Annual PEPFAR reports since 2004 till date	FHI360, Ministry of Health (MoH), USAID-Nigeria country office	Data and reports on HIV indicator. Reports on input, output and impact of program
4	List of all PHC in South-South	National Primary HealthCare Dev. Agency (NPHCDA)	State, LGA and ward level points and address of PHCs

5	Shapefiles for Nigerian villages, town cities,ward,LGA, State and Geo-regionss, road layers, waterbodies and topography,	Federal office of Survey (FoS), International Institute of Tropical Agriculture (IITA) and National Emergency Management Agency (NEMA).	Point shapefile/layers Line shapefile/layers Polygon shapefile/layers
6	GPS coordinates of Primary, Secondary Tertiary health Center	DHIS2/HMIS unit of Ministry of Health (MoH) Dept of planning Research & Statistics.	GPS coordinate of health centers, relevant variables/ indicators of routine data; like # of HIV-positive identified, HIV-enrolled, # on treatment services & drug dispensed.
7	Nigeria Health referral directory and type services offered	Ministry of Health (MoH)	Updated health center contacts, location, services, staff strength and accreditation
8	National Demographic Health Survey (NDHS)	NDHS 2008 and 2013	Key household indicators relevant to transport, knowledge and access

2: NDHS Questionnaire on Distance as barrier

1008	Many different factors can prevent women from getting medical advice or treatment for themselves. When you are sick and want to get medical advice or treatment, is each of the following a big problem or not?		BIG PROB-LEM	NOT A BIG PROB-LEM
	Getting permission to go to the doctor?	PERMISSION TO GO ...	1	2
	Getting money needed for advice or treatment?	GETTING MONEY	1	2
	The distance to the health facility?	DISTANCE	1	2
	Not wanting to go alone?	GO ALONE	1	2
	Attitude of the healthworkers ?	ATTITUTE	1	2
1009	Are you covered by any health insurance?	YES .... NO	1 2	

3: NDHS Questionnaire on Knowledge and attitude to seek for HIV-AIDS services

SECTION 7. HIV/AIDS

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
701	Now I would like to talk about something else. Have you ever heard of an illness called AIDS?	YES . . . . . 1 NO 2	 → 723
702	Can people reduce their chance of getting the AIDS virus by having just one uninfected sex partner who has no other sex partners?	YES . . . . . 1 NO . . . . . 2 DON'T KNOW 8	
703	Can people get the AIDS virus from mosquito bites?	YES . . . . . 1 NO . . . . . 2 DON'T KNOW 8	
704	Can people reduce their chance of getting the AIDS virus by using a condom every time they have sex?	YES . . . . . 1 NO . . . . . 2 DON'T KNOW 8	
705	Can people get the AIDS virus by sharing food with a person who has AIDS?	YES . . . . . 1 NO . . . . . 2 DON'T KNOW 8	
706	Can people get the AIDS virus because of witchcraft or other supernatural means?	YES . . . . . 1 NO . . . . . 2 DON'T KNOW 8	
707	Is it possible for a healthy-looking person to have the AIDS virus?	YES . . . . . 1 NO . . . . . 2 DON'T KNOW 8	
708	Can the virus that causes AIDS be transmitted from a mother to her baby: During pregnancy? During delivery? By breastfeeding?	YES NO DK DURING PREG. . . . . . 1 2 8 DURING DELIVERY . . . 1 2 8 BREASTFEEDING . . . 1 2 8	
709	CHECK 708: AT LEAST ONE 'YES' ☐ ↓ OTHER ☐		→ 711
710	Are there any special drugs that a doctor or a nurse can give to a woman infected with the AIDS virus to reduce the risk of transmission to the baby?	YES . . . . . 1 NO . . . . . 2 DON'T KNOW 8	

4: Tables of estimated PLWHA by LGA using HIV-Prevalence

STATE	SID	LGA	LID	Total Pop	TotPop_15_49 yearss	KnowHIV_Pop	PLWHA_Estimate
Akwa-Ibom State	3	ak Abak Local Government Area	39	373759	158647	149684	5077
Akwa-Ibom State	3	ak Eastern Obolo Local Government Area	40	162690	69187	65278	2214
Akwa-Ibom State	3	ak Eket Local Government Area	41	463691	196995	185864	6304
Akwa-Ibom State	3	ak Esit Eket Local Government Area	42	171177	72638	68534	2324
Akwa-Ibom State	3	ak Essien Udim Local Government Area	43	517732	219748	207332	7032
Akwa-Ibom State	3	ak Etim Ekpo Local Government Area	44	283278	120238	113445	3848
Akwa-Ibom State	3	ak Etinan Local Government Area	45	454895	193063	182155	6178
Akwa-Ibom State	3	ak Ibeno Local Government Area	46	202558	85883	81031	2748
Akwa-Ibom State	3	ak Ibesikpo Asutan Local Government Area	47	368415	156359	147524	5003
Akwa-Ibom State	3	ak Ibiono Ibom Local Government Area	48	509597	216270	204051	6921
Akwa-Ibom State	3	ak Ika Local Government Area	49	196000	83182	78482	2662
Akwa-Ibom State	3	ak Ikono Local Government Area	50	354450	150467	141966	4815
Akwa-Ibom State	3	ak Ikot Abasi Local Government Area	51	354770	150563	142056	4818
Akwa-Ibom State	3	ak Ikot Ekpene Local Government Area	52	384473	163205	153984	5223
Akwa-Ibom State	3	ak Ini Local Government Area	53	266558	113133	106741	3620
Akwa-Ibom State	3	ak Itu Local Government Area	54	341359	144866	136681	4636
Akwa-Ibom State	3	ak Mbo Local Government Area	55	279499	118609	111907	3795
Akwa-Ibom State	3	ak Mkpat Enin Local Government Area	56	478414	203081	191607	6499
Akwa-Ibom State	3	ak Nsit Atai Local Government Area	57	200451	85222	80407	2727
Akwa-Ibom State	3	ak Nsit Ibom Local Government Area	58	291858	123860	116862	3964
Akwa-Ibom State	3	ak Nsit Ubium Local Government Area	59	344579	146237	137975	4680
Akwa-Ibom State	3	ak Obot Akara Local Government Area	60	398457	169251	159689	5416

Akwa-Ibom State	3	ak Okobo Local Government Area	61	279619	118665	111960	3797
Akwa-Ibom State	3	ak Onna Local Government Area	62	331526	141092	133121	4515
Akwa-Ibom State	3	ak Oron Local Government Area	63	235022	99747	94111	3192
Akwa-Ibom State	3	ak Oruk Anam Local Government Area	64	463953	197267	186121	6313
Akwa-Ibom State	3	ak Udung Uko Local Government Area	65	143167	60749	57316	1944
Akwa-Ibom State	3	ak Ukanafun Local Government Area	66	341359	145234	137029	4647
Akwa-Ibom State	3	ak Uruan Local Government Area	67	317894	134913	127290	4317
Akwa-Ibom State	3	ak Urue Offong/Oruko Local Government Area	68	191218	81133	76549	2596
Akwa-Ibom State	3	ak Uyo Local Government Area	69	831879	353807	333817	11322
Bayelsa State	6	by Brass Local Government Area	112	497259	245325	231464	7850
Bayelsa State	6	by Ekeremor Local Government Area	113	726230	358325	338080	11466
Bayelsa State	6	by Kolokuma/Opokuma Local Government Area	114	207698	102478	96688	3279
Bayelsa State	6	by Nembe Local Government Area	115	351836	173602	163793	5555
Bayelsa State	6	by Ogbia Local Government Area	115	483495	238564	225085	7634
Bayelsa State	6	by Sagbama Local Government Area	116	502895	248134	234114	7940
Bayelsa State	6	by Southern Ijaw Local Government Area	117	858321	423506	399578	13552
Bayelsa State	6	by Yenegoa Local Government Area	118	949498	468497	442027	14992
Cross River State	9	cr Abi Local Government Area	170	389109	173850	164027	5563
Cross River State	9	cr Akamkpa Local Government Area	171	406101	181357	171111	5803
Cross River State	9	cr Akpabuyo Local Government Area	172	729286	325768	307362	10425
Cross River State	9	cr Bakassi Local Government Area	173	87025	38873	36677	1244
Cross River State	9	cr Bekwarra Local Government Area	174	284364	127026	119849	4065
Cross River State	9	cr Biase Local Government Area	175	454626	202990	191521	6496
Cross River State	9	cr Boki Local Government Area	176	500193	223372	210752	7148

Cross River State	9	cr Calabar Municipal Local Government Area		482057	215390	203220	6892
Cross River State	9	cr Calabar South Local Government Area	177	514945	230157	217154	7365
Cross River State	9	cr Etung Local Government Area	179	215502	96218	90782	3079
Cross River State	9	cr Ikom Local Government Area	180	436351	194952	183937	6238
Cross River State	9	cr Obanliku Local Government Area	181	296462	132550	125060	4242
Cross River State	9	cr Obubra Local Government Area	182	463387	206983	195288	6623
Cross River State	9	cr Obudu Local Government Area	183	430233	192157	181300	6149
Cross River State	9	cr Odukpani Local Government Area	184	517132	230851	217808	7387
Cross River State	9	cr Ogoja Local Government Area	185	461928	206306	194649	6602
Cross River State	9	cr Yakurr Local Government Area	186	527896	235846	222521	7547
Cross River State	9	cr Yala Local Government Area	187	566572	253148	238845	8101
Delta State	10	de Aniocha North Local Government Area	188	281376	124207	117189	3975
Delta State	10	de Aniocha South Local Government Area	189	377827	166811	157386	5338
Delta State	10	de Bomadi Local Government Area	190	232827	102790	96982	3289
Delta State	10	de Burutu Local Government Area	191	563409	248544	234502	7953
Delta State	10	de Ethiope East Local Government Area	193	539565	238193	224735	7622
Delta State	10	de Ethiope West Local Government Area	192	547089	241493	227848	7728
Delta State	10	de Ika North East Local Government Area	194	493520	217878	205568	6972
Delta State	10	de Ika South Local Government Area	195	436919	192927	182027	6174
Delta State	10	de Isoko North Local Government Area	196	387370	171012	161350	5472
Delta State	10	de Isoko South Local Government Area		611902	270108	254847	8643
Delta State	10	de Ndokwa East Local Government Area	198	277240	122364	115450	3916
Delta State	10	de Ndokwa West Local Government Area	199	401263	177002	167001	5664

Delta State	10	de Okpe Local Government Area	200	349411	154156	145446	4933
Delta State	10	de Oshimili North Local Government Area	201	309874	136833	129102	4379
Delta State	10	de Oshimili South Local Government Area	202	402009	177295	167278	5673
Delta State	10	de Patani Local Government Area	203	181942	80312	75774	2570
Delta State	10	de Sapele Local Government Area	204	461894	203924	192402	6526
Delta State	10	de Udu Local Government Area	205	385236	170078	160469	5443
Delta State	10	de Ughelli North Local Government Area	206	862660	380859	359341	12187
Delta State	10	de Ughelli South Local Government Area	207	573917	253270	238961	8105
Delta State	10	de Ukwuani Local Government Area	208	323509	142847	134776	4571
Delta State	10	de Uvwie Local Government Area	208	514518	227154	214320	7269
Delta State	10	de Warri North Local Government Area	209	368951	162840	153639	5211
Delta State	10	de Warri South Local Government Area	210	815335	359789	339461	11513
Delta State	10	de Warri South West Local Government Area	211	313542	138257	130446	4424
Edo State	12	ed Akoko-Edo Local Government Area	226	704336	301004	283997	9632
Edo State	12	ed Egor Local Government Area	227	913370	390431	368372	12494
Edo State	12	ed Esan Central Local Government Area	228	282987	120932	114099	3870
Edo State	12	ed Esan North-East Local Government Area	229	320703	137060	129316	4386
Edo State	12	ed Esan South-East Local Government Area	230	450697	192567	181687	6162
Edo State	12	ed Esan West Local Government Area	231	338159	144519	136354	4625
Edo State	12	ed Etsako Central Local Government Area	232	254140	108599	102463	3475
Edo State	12	ed Etsako East Local Government Area	233	392317	167702	158227	5366
Edo State	12	ed Etsako West Local Government Area	234	531012	226925	214104	7262

Edo State	12	ed Igueben Local Government Area	235	187132	79976	75457	2559
Edo State	12	ed Ikpoba-Okha Local Government Area	236	997229	426245	402162	13640
Edo State	12	ed Oreo Local Government Area	237	1006809	430291	405980	13769
Edo State	12	ed Rhiannon Local Government Area	238	490994	209837	197981	6715
Edo State	12	ed Ovia North-East Local Government Area	239	413419	176626	166647	5652
Edo State	12	ed Ovia South-West Local Government Area	240	363726	155372	146593	4972
Edo State	12	ed Owan East Local Government Area	241	414859	177229	167215	5671
Edo State	12	ed Owan West Local Government Area	242	261699	111821	105503	3578
Edo State	12	ed Uhunmwonde Local Government Area	243	324647	138695	130858	4438
Rivers State	33	ri Abua/Odual Local Government Area	683	760438	363566	343024	11634
Rivers State	33	ri Ahoada East Local Government Area	684	448078	214104	202007	6851
Rivers State	33	ri Ahoada West Local Government Area	685	670250	320449	302344	10254
Rivers State	33	ri Akuku Toru Local Government Area	686	419215	200438	189113	6414
Rivers State	33	ri Andoni Local Government Area	687	567020	271092	255775	8675
Rivers State	33	ri Asari-Toru Local Government Area	688	591448	282766	266790	9049
Rivers State	33	ri Bonny Local Government Area	689	578705	276757	261120	8856
Rivers State	33	ri Degema Local Government Area	690	671184	320772	302648	10265
Rivers State	33	ri Eleme Local Government Area	691	512939	245018	231175	7841
Rivers State	33	ri Emuoha Local Government Area	692	542544	259378	244723	8300
Rivers State	33	ri Etche Local Government Area	693	670328	320260	302165	10248
Rivers State	33	ri Gokana Local Government Area	694	614903	293981	277371	9407
Rivers State	33	ri Ikwerre Local Government Area	695	509827	243749	229977	7800
Rivers State	33	ri Khana Local Government Area	696	790614	377947	356593	12094
Rivers State	33	ri Obio/Akpor Local Government Area	697	1248971	597081	563346	19107

Rivers State	33	ri Ogba/Egbema/Ndoni Local Government Area	698	763185	364883	344267	11676
Rivers State	33	ri Ogu/Bolo Local Government Area	699	200686	95957	90535	3071
Rivers State	33	ri Okrika Local Government Area	700	596622	285246	269130	9128
Rivers State	33	ri Omumma Local Government Area	701	269702	128941	121656	4126
Rivers State	33	ri Opobo/Nkoro Local Government Area	702	407138	194653	183655	6229
Rivers State	33	ri Oyigbo Local Government Area	703	329683	157586	148682	5043
Rivers State	33	ri Port-Harcourt Local Government Area	704	1454074	694974	655708	22239
Rivers State	33	ri Tai Local Government Area	705	316542	151339	142789	4843

5: NDHS Questionnaire on Mode of Transport

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
117B	How many rooms are used for sleeping in your household?	NUMBER OF ROOMS (SLEEPING)	
118	Does any member of this household own: A watch? A bicycle? A motorcycle or motor scooter? An animal-drawn cart? A car or truck? A boat with a motor? A canoe?	YES NO WATCH .... 1 2 BICYCLE .... 1 2 MOTORCYCLE/SCOOTER . 1 2 ANIMAL-DRAWN CART ... 1 2 CAR/TRUCK .... 1 2 BOAT WITH MOTOR .... 1 2 CANOE 1 2	
119	Does any member of this household own any agricultural land?	YES .... 1 NO 2	 → 121
120	How many plot/acres/hectares of agricultural land do members of this household own? IF 95 OR MORE, CIRCLE '9950'	PLOT .... 1 ACRES .... 2 HECTARES .... 3 95 OR MORE PLOTS/ACRES/ HECTARES .... 9950 DON'T KNOW 9998	
121	Does this household own any livestock, herds, other farm animals, or poultry?	YES .... 1 NO 2	 → 123
122	How many of the following animals does this household own? IF NONE, ENTER '00'. IF MORE THAN 95, ENTER '95'. IF UNKNOWN, ENTER '98'. Milk cows or bulls? Horses, donkeys, or mules? Goats?	COWS/BULLS .... HORSES/DONKEYS/MULES . GOATS	

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