



## **The Spatial Distribution of HIV Prevalence Rates in Nigeria**

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### **Authors' contributions**

*This work was carried out in collaboration between all authors. Author OJD designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors OAA and KSO managed the statistical analyses of the study. Authors EOJ and TWLA managed the literature searches. All authors read and approved the final manuscript.*

### **Article Information**

DOI: 10.9734/BJMMR/2017/33184

#### Editor(s):

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Complete Peer review History: <http://www.sciencedomain.org/review-history/19098>

**Original Research Article**

**Received 1<sup>st</sup> April 2017**  
**Accepted 12<sup>th</sup> May 2017**  
**Published 17<sup>th</sup> May 2017**

### **ABSTRACT**

Nigeria has witnessed a gradual decline in the national trend of HIV prevalence from the peak of 5.8% in 2001 to 3.4% in 2012. In spite of the decline nationally, there is a wide variation in the distribution of HIV at the sub-national level. This study therefore aims to explore the spatial distribution of HIV in Nigeria. The study was an ecological study of secondary data of the National HIV prevalence studies conducted between 2008 and 2012. The global Moran's *I* and Local Moran's *I* (LISA) test were used to measure spatial autocorrelation. A final choropleth map of local Moran's FDR-adjusted *p* values was produced and a *p* value of  $\leq 0.05$  was regarded as statistically significant. The analysis of the data was carried out in R statistical package version 3.2.3. Twenty seven (73%) states showed decline in HIV while 10 (27%) states showed an increase in the HIV prevalence rate between 2008 and 2012. Global Moran *I* statistics for the country indicates a significant positive spatial autocorrelation of HIV in 2008 and 2010 however, there was no

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significant relationship in 2012. The choropleth map identified four hot spot significant clusters of HIV in 2008 which reduced to three states in 2010 and one state in 2012. The study showed a number of significant hot spot clusters for HIV in Nigeria though there was a general significant decline in the national HIV prevalence rate in the country. There is need to further understand the drivers of the epidemic in hot spot areas and target specific localized action to stem the tide of the epidemic focusing the scarce resources in the identified hotspot states.

*Keywords: HIV; HIV prevalence; spatial analysis; spatial distribution; spatial epidemiology; geographical analysis; Nigeria.*

## 1. INTRODUCTION

Globally an estimated 36.7 million people are living with human immune deficiency virus (HIV) and about 2.1 million were infected with the virus in 2015 representing 6% decline in HIV infection rate globally since 2010. A similar decline of about 45% (2 million in 2005 to about 1.1 million in 2015) AIDS-related deaths was also recorded in 2015 [1]. The increase investment in AIDS response especially in low and middle income countries and the increase in the number of people accessing anti-retroviral treatment (from 7.5 million in 2010 to 17 million in December 2015) maybe responsible for the decline in death rate [1].

Nigeria ranked third among high HIV burden countries in the world and it is estimated that about 3.5 million people are currently living with HIV in the country. Although HIV burden has declined in the general population from 5.8% in 2001 [2] to 3.4% in 2012 [3,4], there is a wide variation in the distribution of HIV within the 36 states and the Federal Capital Territory (FCT) of the country [3,4].

Spatial analytic techniques have been a valuable tool in the study of infectious diseases including HIV. Spatial analysis can assist in the detection of spatial variation, clustering or hot spots where targeted action can be deployed and also in the general understanding of the influence of neighbouring states on the identified hotspots. Few studies have been done using spatial analytic techniques in the understanding of HIV in Nigeria [5,6], however none of these studies have looked at the trend of HIV epidemic in the last decade. This study therefore explored the spatial distribution of HIV in Nigeria between 2008 and 2012.

## 2. METHODS

### 2.1 Study Design

The study was an ecological study of National HIV prevalence studies conducted between 2008

and 2012. The 2008 and 2010 national HIV prevalence rates at the subnational (state) level was obtained from the 2010 Nigerian HIV sentinel survey report [7] while the 2012 report was obtained from the National agency for the control of AIDS (NACA) in Nigeria [3]. The HIV prevalence rate for each of the 36 states and the Federal Capital Territory (FCT) was extracted from the prevalence report from 2008-2012. The percentage difference in the HIV prevalence rate in 2008 and 2012 was calculated while the percentage rate of change was calculated by finding the percentage HIV prevalence difference divided by the rate in 2008 multiplied by 100% for each state and the FCT.

Nigeria is the largest country in West Africa with a projected population of about 170 million people. It has 36 independent states and the Federal Capital Territory (FCT) which are grouped into six geopolitical regions. The 36 states and the FCT were used as the unit of geographical analysis. The shape file of the country at the first administrative level (i.e 36 states and FCT of the federation) was obtained online from the global administrative areas database website ([www.gadm.org](http://www.gadm.org)).

### 2.2 Spatial Exploration

The global Moran's *I* and Local Moran's *I* (LISA) test were used to measure spatial autocorrelation in the data set [8]. The global autocorrelation is a single measure used to assess the global spatial autocorrelation for HIV in the country as a whole. A positive spatial autocorrelation shows clustering of similar values across geographical space than what is expected if it was a random distribution while a negative spatial autocorrelation shows that the neighbouring values are more dissimilar than expected.

The global Moran *I* is expressed by the formula.

$$I = \frac{N}{\sum_i \sum_j \omega_{ij}} \frac{\sum_i \sum_j \omega_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2} \quad (1)$$

Where N is the number of spatial units indexed by i and j; X is the variable of interest,  $\bar{X}$  is the mean of X; and  $W_{ij}$  is an element of a matrix of spatial weights. The value of Moran's I test statistics range from -1 to +1. A Moran of +1 suggests a strong positive autocorrelation while a value of -1 suggests a strong negative spatial autocorrelation. The Local spatial autocorrelation (LISA) [9] is a measure of local spatial autocorrelation for each individual location. It is expressed as

$$I_i = z_i \sum_j \omega_{ij} z_j \quad (2)$$

Where  $z_i$  is the original variable  $x_i$  in standardized form and  $w_{ij}$  is the spatial weight.

A choropleth thematic map was used to visualise possible clustering and the states with significant spatial autocorrelations were identified by mapping the p values of the Local Moran's I statistics. The false discovery rate (FDR) method by Benjamin and Hochberg's was used for the adjustment of the local Moran's I p values [9]. A final choropleth map of local Moran's FDR-adjusted p values was produced and a p value of  $\leq 0.05$  was regarded as statistically significant.

The analysis of the data was carried out in R statistical package version 3.2.3 [8].

### 3. RESULTS

Nigeria is divided into 36 states and the Federal Capital territory (FCT) but for the purpose of this study the country is divided into 37 spatial units as shown in Fig. 1. Fig. 2 showed the trend of the national HIV prevalence rate from 2008 to 2012. The national HIV prevalence rate has been on the decline from 4.6% in 2008, 4.1 in 2010 and 3.4% in 2012. However, there has been wide geographical variation within the country. Table 1 showed the subnational HIV prevalence rate for the 36 states and the FCT between 2008 and 2012. Twenty seven (73%) states showed a decline in HIV prevalence rates between 2008 and 2012 while 10 (27%) states showed an increase in the HIV prevalence rate between 2008 and 2012. Nineteen states (51.4%) had HIV prevalence rates above the national average of 4.6% in 2008 which reduced to 18 states (48.7%) in 2010 and 12 states (32.4%) in 2012. Figs. 3, 4 and 5 showed the maps of the distribution of HIV in the country in 2008, 2010 and 2012 respectively.

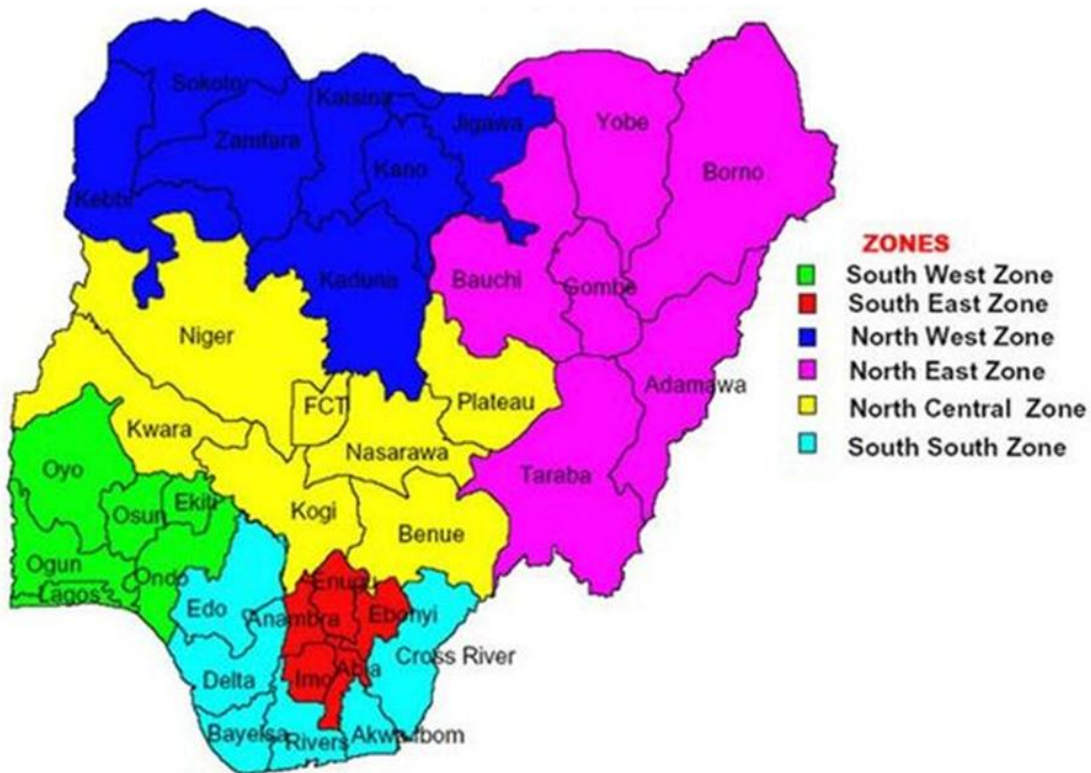


Fig. 1. The 36 states and FCT distributed in the six geopolitical zone in Nigeria

**Table 1. The HIV prevalence rates in the 36 states and FCT in Nigeria 2008-2012**

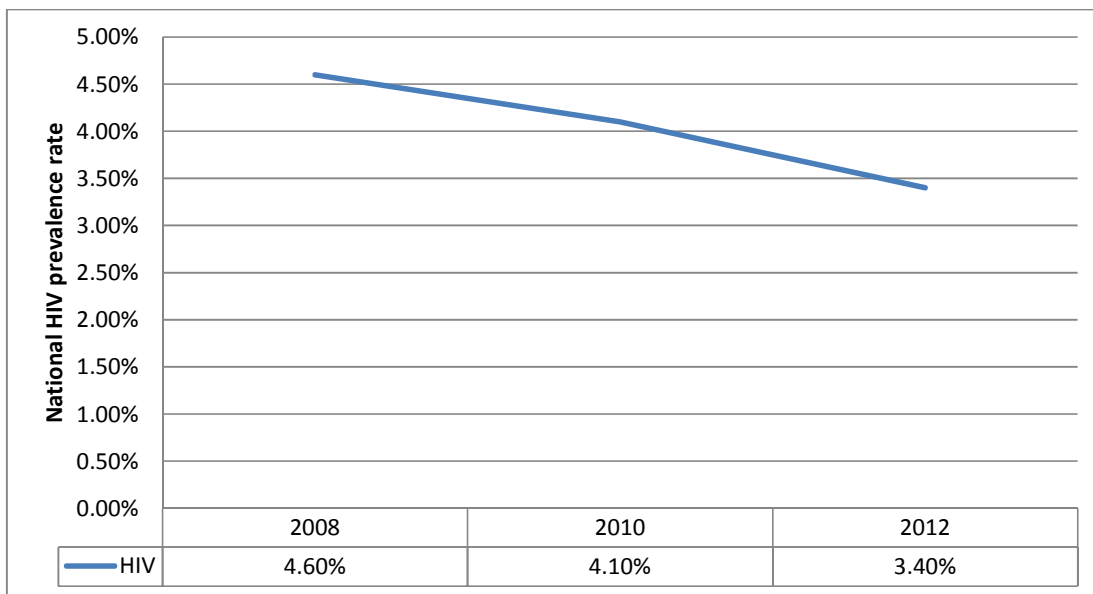
States	HIV (%) 2008	HIV (%) 2010	HIV (%) 2012	Percentage difference (2012-2008)	Percentage change
Abia	5	7.3	3.3	-1.7	-34.0
Adamawa	6.8	3.8	1.9	-4.9	-72.1
Akwa Ibom	9.7	10.9	6.5	-3.2	-33.0
Anambra	5.6	8.7	1.2	-4.4	-78.6
Bauchi	3.1	2	0.6	-2.5	-80.6
Bayelsa	7.2	9.1	2.7	-4.5	-62.5
Benue	10.6	12.7	5.6	-5	-47.2
Borno	2	5.6	2.4	0.4	20.0
Cross River	8	7.1	4.4	-3.6	-45.0
Delta	3.7	4.1	0.7	-3	-81.1
Ebonyi	2.8	3.3	0.9	-1.9	-67.9
Edo	5.2	5.3	0.8	-4.4	-84.6
Ekiti	1	1.4	0.2	-0.8	-80.0
Enugu	5.8	5.1	1.3	-4.5	-77.6
Federal Capital Territory	9.9	8.6	7.5	-2.4	-24.2
Gombe	4.2	4.2	3.4	-0.8	-19.0
Imo	4.6	3	2.5	-2.1	-45.7
Jigawa	1.6	1.5	2.1	0.5	31.3
Kaduna	7	5.1	9.2	2.2	31.4
Kano	2.2	3.4	1.3	-0.9	-40.9
Katsina	2.6	2	0.7	-1.9	-73.1
Kebbi	2.9	1	0.8	-2.1	-72.4
Kogi	5.1	5.8	1.4	-3.7	-72.5
Kwara	1.8	2.2	1.4	-0.4	-22.2
Lagos	5.1	5.5	2.2	-2.9	-56.9
Nasarawa	10	7.5	8.1	-1.9	-19.0
Niger	6.2	4	1.2	-5	-80.6
Ogun	1.7	3.1	0.6	-1.1	-64.7
Ondo	2.4	2.3	4.3	1.9	79.2
Osun	1.2	2.7	2.6	1.4	116.7
Oyo	2.2	3	5.6	3.4	154.5
Plateau	2.6	7.7	2.3	-0.3	-11.5
Rivers	7.3	6	15.2	7.9	108.2
Sokoto	6	3.3	6.4	0.4	6.7
Taraba	5.2	5.8	10.5	5.3	101.9
Yobe	2.7	2.1	5.3	2.6	96.3
Zamfara	2.1	2.1	0.4	-1.7	-81.0

**Table 2. Global Moran I statistics of HIV prevalence rate in Nigeria 2008-2012**

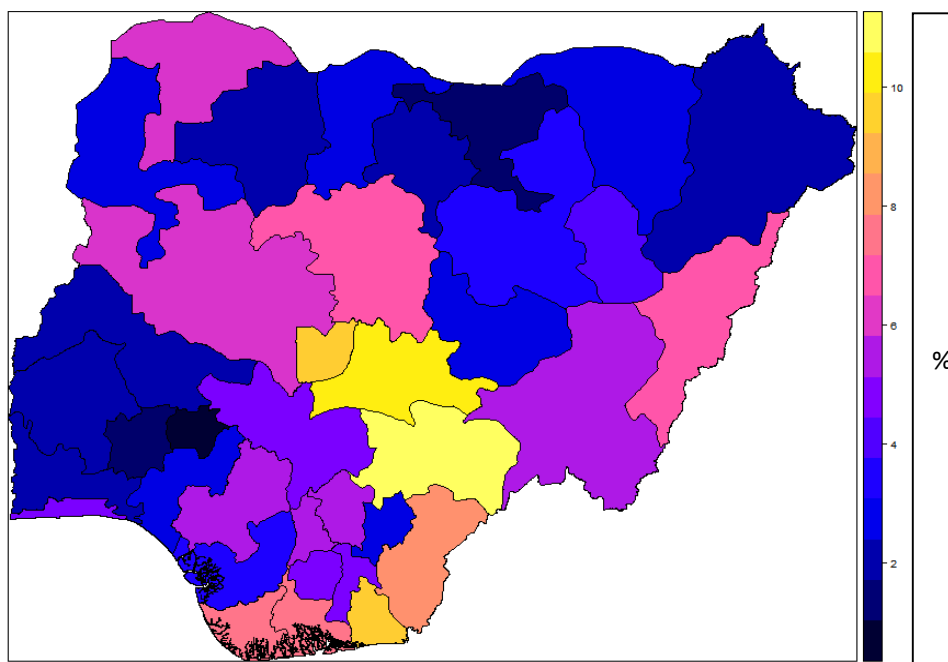
	Moran/ statistic 2008	P value 2008	Moran I statistic 2010	P value 2010	Moran I statistic 2012	P value 2012
Moran I test under randomisation	0.38	0.00001	0.36	0.00002	0.01	0.1331
Moran I test under normality	0.38	0.0001	0.36	0.0001	0.01	0.3488
Monte-Carlo simulation of Moran I	0.38	0.0002	0.36	0.0005	0.01	0.3151

Table 2 showed the Global Moran *I* statistics for the 2008 to 2012. In 2008 and 2010, there was a significantly positive Global Moran *I* statistics for the country which indicated a positive clustering of HIV in the country. This result was sustained both with the Moran test under randomization

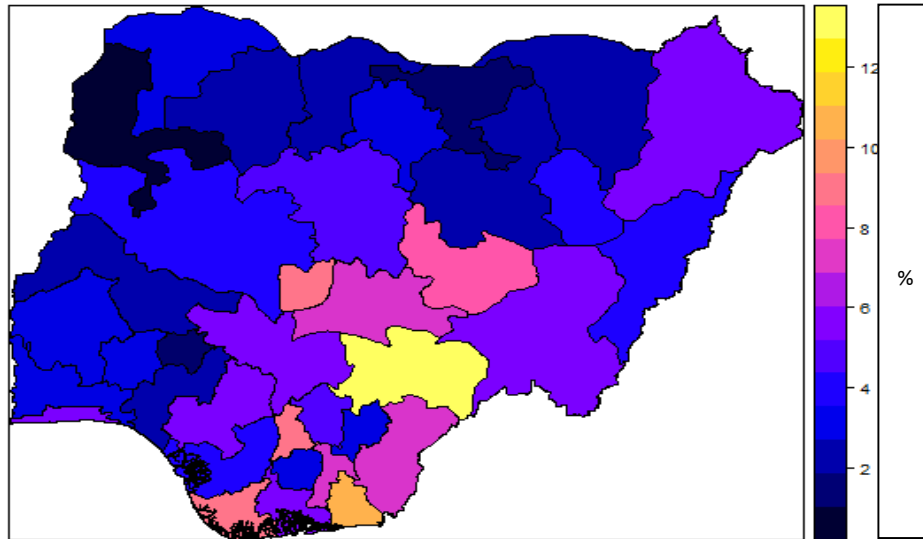
and normality and when the Monte Carlo simulation test was conducted. However there was a weak positive Global Moran test results in 2012 which was not statistically significant and showed that there was no global spatial clustering of HIV in the country in 2012.



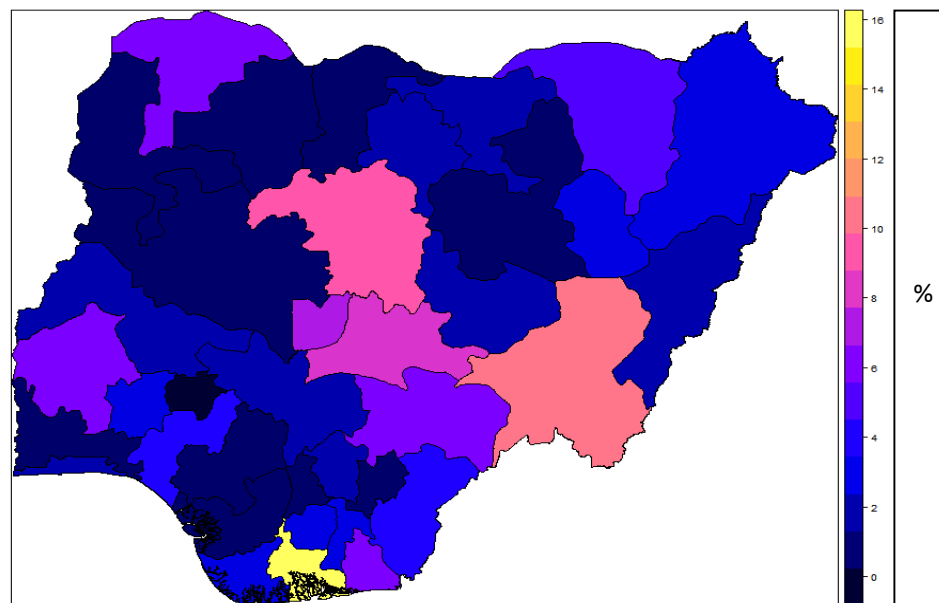
**Fig. 2. Trend of national HIV prevalence rate in Nigeria, 2008-2012**



**Fig. 3. HIV prevalence rate (%) in Nigeria by states in 2008**



**Fig. 4. HIV prevalence rate (%) in Nigeria by states in 2010**



**Fig. 5. HIV prevalence rate (%) in Nigeria by states in 2012**

Fig. 6 showed the adjusted false discovery rate (FDR) p values of the local Moran *I* test of the spatial distribution of HIV in Nigeria in 2008. The choropleth map identified significant clustering of HIV at  $p < 0.05$  in five states namely the Federal Capital Territory, Benue, Nasarawa, Akwa Ibom and Osun states. In 2010, significant clustering of HIV prevalence at  $p < 0.05$  were in three states namely Nasarawa, Benue and Akwa Ibom states as shown in Fig. 7. However in 2012, significant clustering of HIV prevalence rate in the country

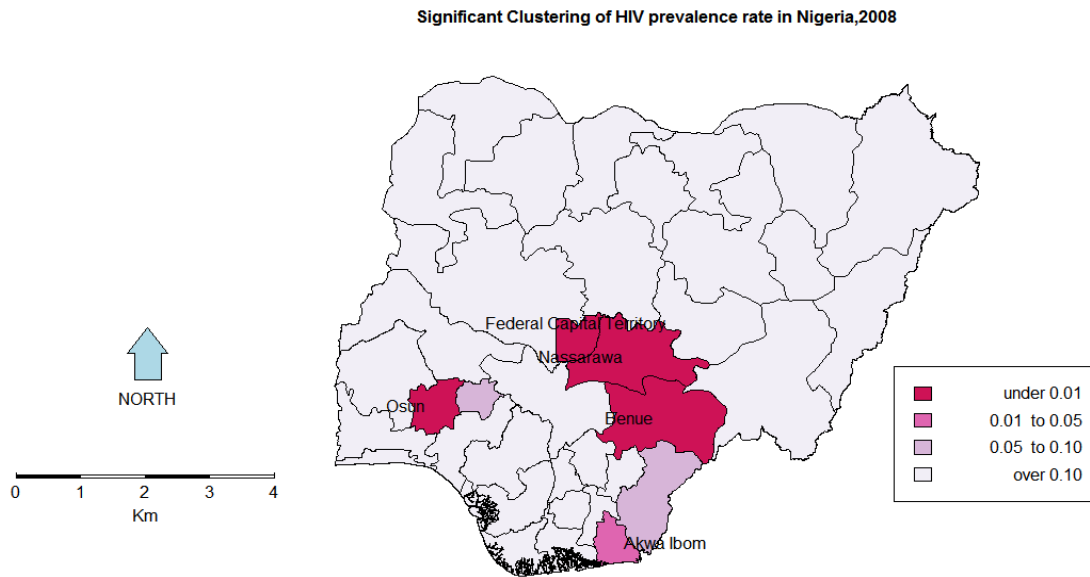
was found only in Nasarawa state as shown in Fig. 8.

#### 4. DISCUSSION

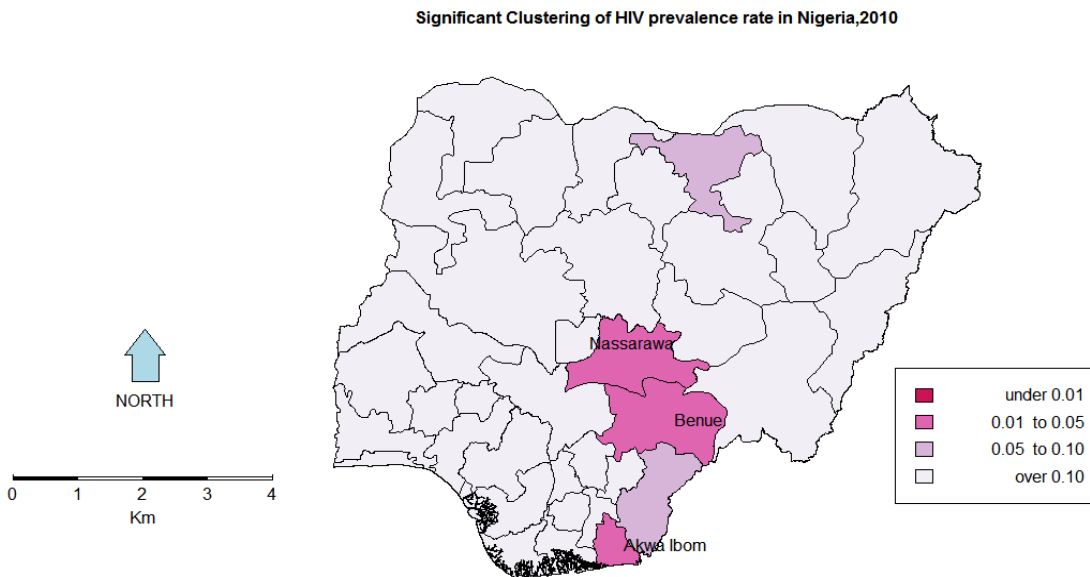
This study examined the spatial distribution of HIV in Nigeria between 2008 and 2012. The study builds on the previous studies on spatial analysis done by Obidoa and Cromley [5] who described the geographical analysis of HIV in Nigeria from 1991 to 2001 and Djukpen [6] who

conducted exploratory spatial data analysis of HIV in Nigeria between 2001 and 2003. This study showed a decline of 26% in HIV prevalence rate in the country (from 4.6% in 2008 to 3.4% in 2012). Despite this decline, there is a wide variation in the HIV prevalence rate at the subnational (state) level. The study observed that about a third of the states mainly in the South West and North East geopolitical zones actually showed an increase in the HIV

prevalence rate during the period under review while states in the North central zone previously believed to be the epicenter of the disease [5], showed a decline in HIV prevalence rates between 2008 and 2012. The decline in the HIV prevalence rates in the North central geopolitical zone may be due to the implementation of targeted interventions in these states early on in the HIV epidemic in Nigeria to curb the spread of the disease [10].

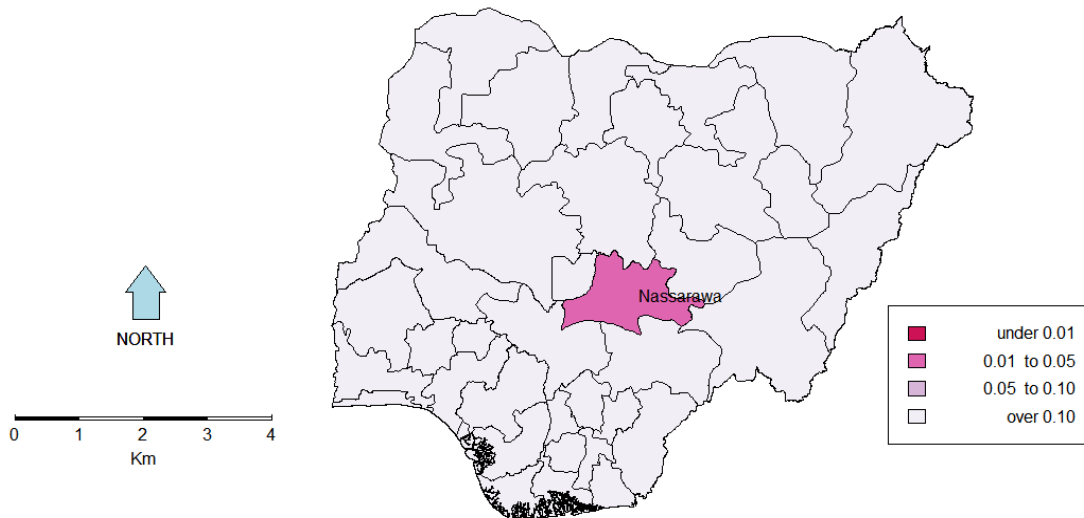


**Fig. 6. Significant spatial clustering of HIV prevalence rate in 2008**



**Fig. 7. Significant spatial clustering of HIV prevalence rate in 2010**

## Significant Clustering of HIV prevalence rate in Nigeria,2012



**Fig. 8. Significant spatial clustering of HIV prevalence rate in 2012**

This study also showed a decline in the number of significant clusters from four states in 2008 to one in 2012 and demonstrated the localization of the HIV epidemic to only one state in 2012. The four states (FCT, Nasarawa, Benue and Akwa Ibom) were identified with significant clustering for HIV in 2008 while in 2010, three states (Nasarawa, Benue and Akwa Ibom) had significant clustering of HIV infection and in 2012 only Nasarawa state was identified as a significant cluster for HIV in the country. In the previous studies carried out in Nigeria, significant clustering of HIV was observed in six states in 1999 (FCT, Benue, Nasarawa, Cross river, Ebonyi, Enugu), six states in 2001 but FCT was replaced with Borno state as a hotspot state and 6 states in 2003. In 2003, there emerged for the first time three states (Osun, Ondo and Oyo) in the south western geopolitical zone in addition to the traditional states of FCT and Nasarawa in the North central geopolitical zone [6]. Nasarawa state in the North central has remained consistently a hot spot for HIV infection since 1999 when all the 36 states and FCT were involved in the national HIV sentinel survey. This may suggest that Nasarawa state is the epicenter of HIV infection in Nigeria. A cursory look at some studies conducted in Nasarawa state on HIV showed common traditional practices that predispose to HIV infection such as polygamy, levirate marriage (a form of marriage where the brother of a deceased man is obliged to marry his brother's widow), female genital mutilation, early and child marriage [11].

There is however need for future studies to better understand the drivers of the HIV epidemic in the state and therefore target the state with specific localized action to stem the tide of the epidemic and avoid diffusion of the HIV epidemic to contiguous states.

Though this study was not aimed at exploring the factors that may be responsible for the high HIV prevalence rate because of lack of data to compare across states, other studies have suggested other possible explanations why there is variation of HIV prevalence at the states. Samuels et al. [12] argued that though the country is still experiencing a generalized epidemic, there are concentrated pockets of areas in the country with a high rate of HIV infection especially where there is a large concentration of individuals that constitute high risk groups for HIV such as female sex workers (FSW), men who have sex with men and injection drug users who may be reservoir of infection to the general population. Other drivers of the epidemic identified includes low awareness of HIV/AIDS, stigma and discrimination, multiple sexual partners and low condom use, religion and cultural practices such as polygamy and "spouse-sharing" sharing practices with relatives among "Okun" people in North central geopolitical zone of Nigeria [13]. Another study suggests that poor and inequitable distribution of health infrastructure and gender/economic inequality that predispose individuals to transactional and intergenerational



sexual practices may be responsible for the unequal distribution of HIV in the country [14]. The complex interactions between these factors may be responsible for the geographical distribution of the disease in the country. There is need for further research to explore the contribution of these factors to the HIV epidemic in the country.

The reasons for the decline in the national HIV prevalence and the number of significant hot spot states in the country cannot be immediately ascertained. However, it may be attributed to the impact of interventions to reduce HIV prevalence in the country [10]. There has been considerable financial investment from both national and international donors in the fight against HIV in the country. The total funding to combat the HIV epidemic in Nigeria rose from USD 415,287,430 in 2009 to USD577, 432,903 in 2012 [10]. This funding was used to expand prevention services such as awareness creation, improving access to HIV counseling and testing services, prevention of mother to child transmission services and treatment and support services for people living with HIV/AIDS [15]. This may be responsible for the decline in the number of states with significant clustering from 2008 to 2012. Other studies have suggested that the decline in HIV prevalence may reflect the natural dynamics in HIV transmission in the general population from the epidemic threshold of sustainability [16,17], the variability on the host susceptibility to HIV infection [18], the changes in sexual risk behavior [19-21], the patterns of migration of high risk groups and the increased HIV associated mortality [22,23]. Further research will be required to assess the contribution of these factors to the decline in the national HIV prevalence rate in Nigeria.

## 5. LIMITATION OF STUDY

Disaggregation of the analysis of this study was at the state levels which are not homogeneous entities because of the large population. This is largely due to unavailability of HIV prevalence data at lower levels like the local government area (district). In addition, the government needs to make geographic and epidemiological data on HIV risk factors disaggregated by states accessible to aid comparison among states. In addition, there is need for government to strengthen epidemiological and geographical data generation and reporting at lower levels in the country especially at the local government areas to allow for more localized spatial analysis

that can provide detailed information to policy makers for effective decision making and strategic planning. The study suggests that subsequent studies should explore the determinants of HIV driving the epidemic in the identified hotspots/states

## 6. CONCLUSION

This study had built on the existing knowledge of the application of spatial analytic techniques in the study of the spatial distribution of HIV at the subnational level in Nigeria. The study has shown a decline in HIV prevalence rate at the national level and in some states. In addition, a decline in the number of significant clusters was observed between 2008 and 2012. There is therefore the need for policy makers to plan targeted action to the identified hot spots for HIV transmission in the country in order to effectively stem the tide of the epidemic in Nigeria.

## CONSENT

Patient consent was not required for this study. The study utilised is publicly available data on HIV prevalence rate in Nigeria with no personal identifiers.

## ETHICAL APPROVAL

Ethical approval was not obtained because the data utilised for this study is publicly available with no personal identifiers.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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