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HIV/AIDS PANDEMIC: MODELLING THE SPATIOTEMPORAL EFFECTS

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ABSTRACT
A possible decline in prevalence rates of HIV in Nigeria has been reported recently over the last few years (5.8% in 2001 to 5% in 2003 and 4.4% in 2005) FMOH (2006). Several factors may explain the observed decline including the effect of the ongoing intervention efforts, the increase in the number of rural survey sites, and death of those previously infected. The present study is aimed at evaluating the prevalence and incidence rates of HIV at map location indicating high and low risk areas in the North-Eastern States of Nigeria. A review was conducted of published reports and literature, raw and modeled. Two different data sets were used to get the invectives'. The prevalence rates from sentinel surveys were multiplied by the respective years of census figures. After the transformation the data was then tested for normality using MINITAB version 13 and STATGRAPHIC version 5.0. A generalized statistical model was also developed using R version 2.8.1 Statistical software. Where, years have been considered as time and locations as space. The risk maps were generated using ArcView GIS version 3.2a software. Observation was restricted to adult population among pregnant women aged 15-49years. Result show that there are significant changes in general. This was shown in figure 3, where Yobe is leading the increase followed by Bauchi, Taraba and Gombe States. However, Adamawa observed no changes in the prevalence rates of the HIV/AIDS pandemic. However, the model was able to explain about 76% of the variability indicating a better fit and location (states) contributes significantly to the spread of HIV than time.

KEYWORDS: Modeling, pandemic, spatiotemporal,

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INTRODUCTION.

An understanding of geographic variation of disease may provide potential explanation regarding possible proximal and distal contributions to not only AIDS mortality but also HIV infection. Knowing the geographic distribution of AIDS mortality can also inform and improve public health practice. A natural question to ask is whether or not the incidences of HIV/AIDS vary spatially. If there is some evidence of spatial variation, then knowledge of the characteristics of a particular state within the sub-region whose risk appears to be higher than the average may lead to new hypothesis regarding possible causal mechanism for the disease.

The severity of the AIDS epidemic in Nigeria and more especially North-East Sub-region is a formidable health and development issue; more broadly, the proliferation of HIV/AIDS is a universal problem and must be addressed at the global level. The far reaching social, economic and political effects of this epidemic call for examination by all fields of the social sciences rather than just the public health community. Violent conflict between states and countries in the neighborhood results in conditions that are favorable to the spread of HIV. The occurrence of war can affect the public health of the population in a myriad ways. In addition to combat-related casualties, war can encourage population movement, disrupt access to health care services, destroy or damage critical infrastructure, limit access to food and safe drinking water and leave population vulnerable to disease including AIDS. Moreover, migrant population and mobile soldiers act as vectors of disease (Ghobarah *et.al*. 2001).

Large number of mathematical models has been developed to simulate the impact of HIV/AIDS and the likely effect of prevention and treatment programmes. These models can be classified into three broad groups: individual-based stochastic simulation models, which randomly generate events such as infection and death for each individual in the population; and deterministic models, which typically divide the population into cohorts of individuals, and compute average numbers of events in each cohort on the assumption that all individuals in a cohort share the same characteristics. As well as the cartographic modeling that offers a procedural approach to the integration of map layers which allows the design of analysis of schema for spatial data. However, the ultimate aim of any modeling is to provide policy makers with an elicit decision to effectively and efficiently plan. The study is therefore aimed at using map location to identify high low risk areas, hence the choice of cartographic modeling. This is a generic way of expressing and organizing the methods by which spatial variables, and spatial operations, are selected and used to develop a GIS model and which is the focus of this study.

However, the emergence of HIV/AIDS has been a source of concern to human race. This epidemic has and continues to have devastating consequence in the decade to come, on virtually every sector of the society ranging from household and farms to growth of whole economy. In the last two decades, HIV/AIDS has emerged as one of the leading challenges for global public health, particularly in Sub-Saharan Africa, where the majority of HIV/AIDS cases have been recorded to be concentrated, and the epidemic continues to take an extraordinary human toll. This epidemic is undermining the possibility of achieving the millennium development goals adopted by the United Nations general assembly in 2000.

Since the first AIDS case was reported in Nigeria in 1986, the epidemic has grown steadily, with the adult HIV prevalence increasing from 1.8% to 5.8% in 2001 (FMOH 2004). But in the subsequent HIV/AIDS Sentinel Surveillance Survey (HSSS) conducted in 2003 and 2005, there was an evidence of decline, 2003 with 5.9% and 2005 with 4.4% (FMOH 2006) in the prevalence of the disease in Nigeria.

Justification of study

Infectious diseases in general and HIV/AIDS in particular do not exist in a static, unchanging "natural" condition interrupted only by the activities of human population; it is rather a dynamic system of which humans are a part. Knowledge about changes of the epidemiology and the underlying processes that induce them has enormous impact on how society responds to them all, ultimately, the cost of responding to these changes. The continuous quest for such knowledge is therefore an obligation that cannot be overemphasized.

It is right to argue that, the impact of HIV/AIDS have been well documented for some time now (in case of the prevalence and incidence rates) these spatiotemporal effects are downplayed or even ignored. A study therefore of identifying at map locations the high and low risk areas of the disease in the North-Eastern Nigeria is no doubt imperative.

Limitations

One of the limitations of ANC sentinel surveillance is the fact that women attending public health facilities may not be representative of women in the general population since the latter include those who are using some form of contraception as well as those who are infertile. Moreover, pregnant women who choose to attend public health facilities may have characteristics different from all pregnant women; and, a substantial proportion of pregnant women, for various reasons, may not attend antenatal clinics. It is also known that men and women have different HIV-related risk behaviours and therefore may have different rates of infection. Sentinel sites were purposely selected on the basis of specific criteria and therefore may not be representative of all health facilities. Among the selected facilities, there may be policies and practices that may influence the pattern of attendance. However, studies in many countries have shown that HIV prevalence from pregnant women compares favourably with data from the general population.

MATERIAL AND METHODS

A common problem in environmental epidemiology is the estimation and mapping of spatial variation in disease risk. In this study, time and location data were extracted from the FMOH (2006) HSSS and National Bureau of

Statistics (2006) reports, for the North-Eastern states of Nigeria and four sentinel surveys from (1999-2005). The data was first subjected to a two way analysis of variance i.e. year (time) and location (space) using the R version 2.8.1 Statistical software. However, MINITAB version 13 and STATGRAPHIC version 5.0 were also used to test for normality and finally ArcView version 3.2a , a GIS and remote sensing software was used to generate risk maps

The different images were subjected to thresholdings – a process that involved using one standard deviation for demarcating real changes from minor variations. The different images contain pixels of negative and positive values, showing changes between two dates. A positive value shows a decrease in the difference image while a negative shows an increase in the difference image. However, every image pixels assumed to be normally distributed, where the mean is at the center and the standard deviation at the tails. The difference image too is assumed to be normal.

Test for normality

There are three (3) types of goodness of fit test. A chi-square testbased on an (empirical cumulative distribution function) ECDF test and a correlation based test. This plot shows the mean HIV patients for each level of States. It also shows an interval around each mean. The intervals currently displayed are based on Fisher's least significant difference (LSD) procedure. They are constructed in such a way that if two means are the same, their intervals will overlap 95.0% of the time. Any pair of interval that does not overlap vertically corresponds to a pair of means which have a statistically significant difference.

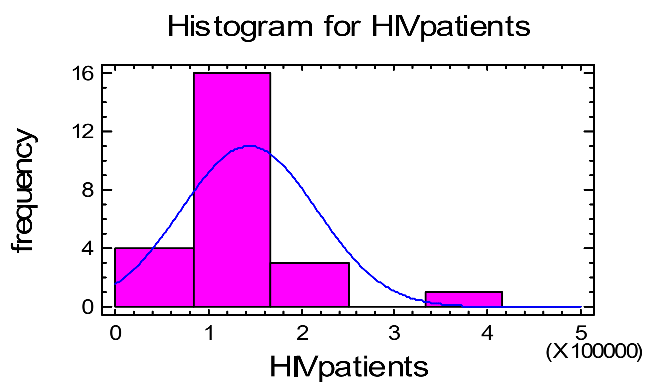

Figure 1a. Showing a histogram of a normal distribution plot

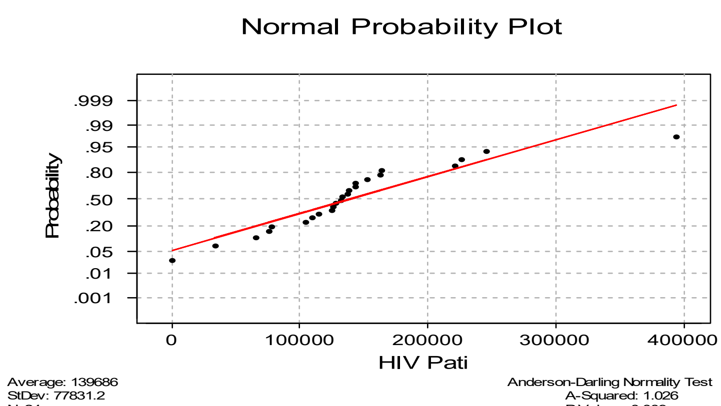

Figure 1b. Showing normality test for Andeson-Darling

Schematic presentation of infective transmission state

AIDS is officially diagnosed by the presence of one or more defining conditions. In order to monitor the progress of HIV within the body a marker path is to describe the incubation period, where markers are a consequence of disease. One of the most commonly used markers for this purpose is CD_4 cell count. In general, the lower the CD_4 cell count, the worse the condition of the immune system and hence the severity of the illness. Markers have proved to be of great importance in monitoring the effect of therapy; in particular, measurements of CD_4 can give an indication as to whether HIV has become resistant to the current treatments available (Griffiths *et al.*2005).

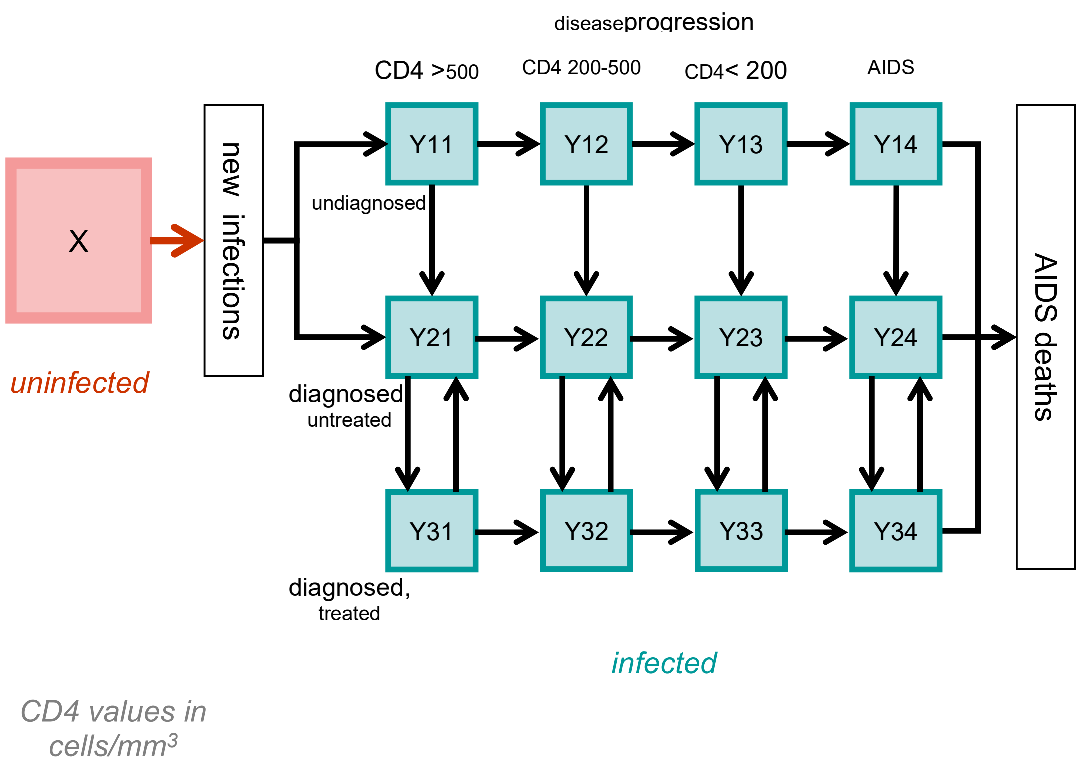

Figure 1e. Showing infective transition states
Source: Karina *et.al* (2006).

PRESENTATION OF IMAGES

This section attempted to present the images generated from ARCVIEW version 3.2a GIS and Remote Sensing Software. The images provide the spatial distribution of HIV patients' for the study period. While the bar diagram provides the percentage changes of the prevalence rates with respect to time and location. However, these images were used to identify high or low risk areas. The output was discussed extensively in the subsequent section.

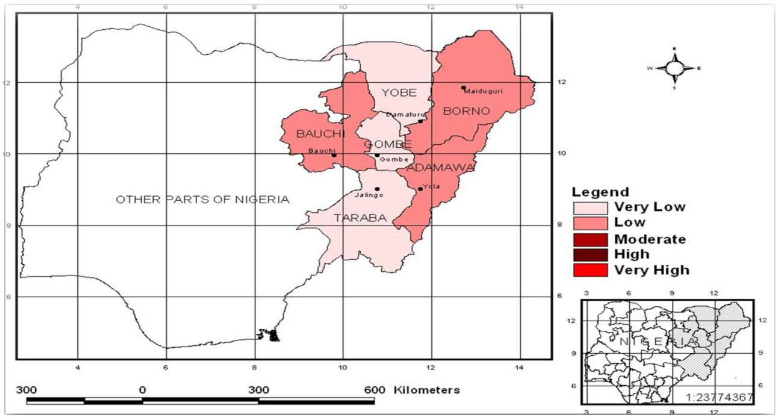

Figure 2a: Spatial Distribution of HIV Patients in the North Eastern Nigeria -1999

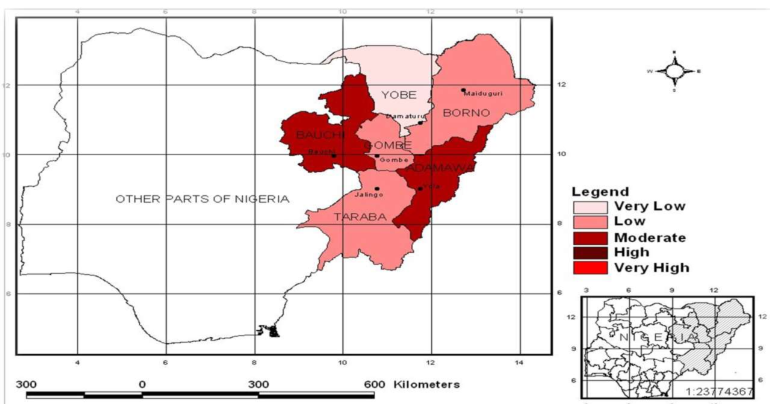

Figure 2c: Spatial Distribution of HIV Patients in the North Eastern Nigeria -2003

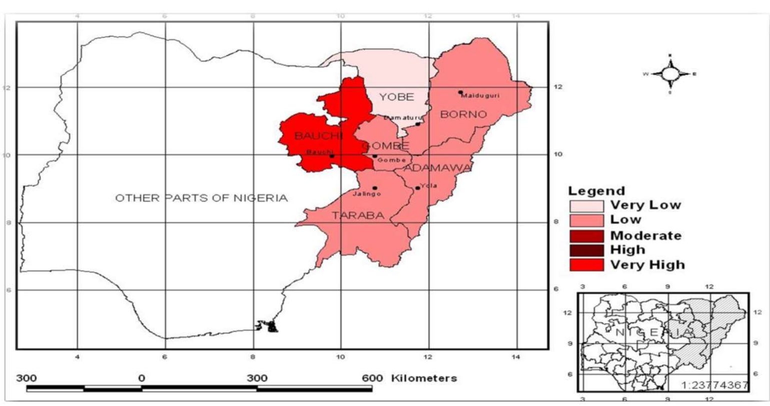

Figure 2b: Spatial Distribution of HIV Patients in the North Eastern Nigeria -2001

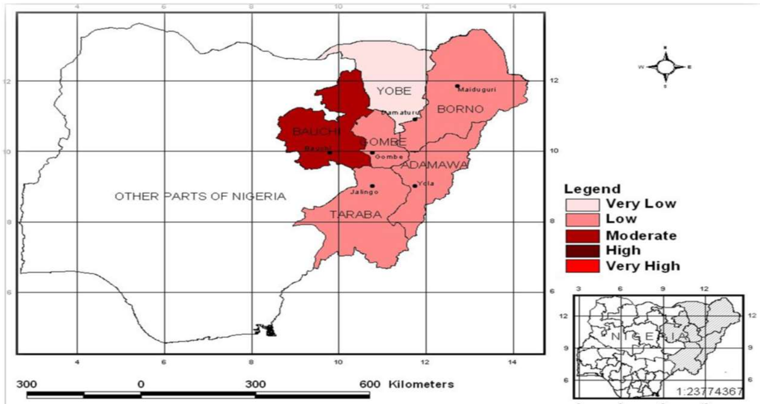

Figure 2d: Spatial Distribution of HIV Patients in the North Eastern Nigeria -2005

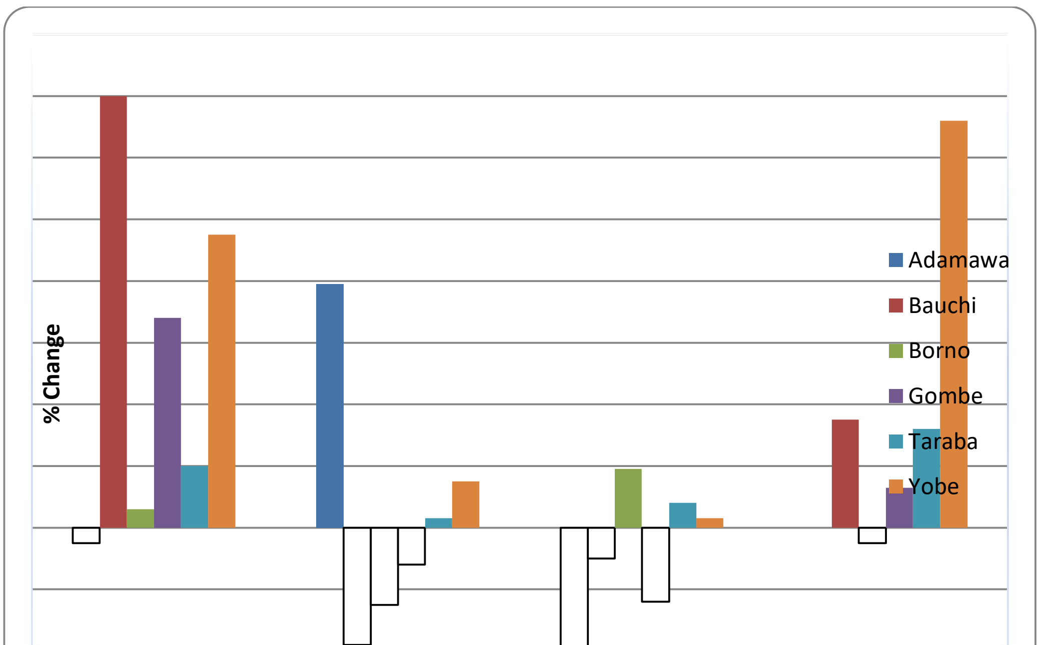

Figure 3: Percentage Change in HIV Prevelence from 1999-2005 in the North Eastern Nigeria

DISCUSSION

Some values are said to be significant changes on the images generated while others are not referred to be changes. It is on this note that the study need to differentiate (isolate) real changes from minor variation. In doing this the study used descriptive statistics such as the mean and standard deviation which were explored for thresholds. i. e. $\mu \pm \sigma,\ \mu \pm 2\sigma,\ \mu \pm 3\sigma$

However, $\mu \pm \sigma$ was selected to force some changes to appear on the image generated. This is because the smaller the standard deviation the more likely of some images appearing and the larger the standard deviation the less likely images are appearing. Therefore, the lower and the upper thresholds were set with $\mu - \sigma$ and $\mu + \sigma$ respectively. It was against this background that decision was made. Areas having changes negatively are those that fall below $\sigma\sigma$ to the mean while those that are above σ to the mean are those areas having changes positively. Finally those pixels (values) that fall between those thresholds did not have changes. In the classification of images the negative values are designated as having changes positively. While the positive values are having changes negative. For example, if 5 is a pixel value in an earlier image and 7 in a latter image, it means the value has increased from 5 to 7 by +2 this means the result will be given as -2 in the difference image. This mathematically confirms that taking a larger number from a smaller one the result is a negative number.

The selection of models dealt with here was motivated by the general nature of HIV in Nigeria and dynamical modeling initiatives, and is not by a desire to present a comprehensive account of mathematical models available till date. There is an urgent need for extensive mathematical models of AIDS incidence and spread so as to enable informed and efficient investments in preventive therapeutic measures. This study concentrates on models of spread.

RESULTS

The study begins with an assessment of the extent of HIV/AIDS infection rates in the study area over the past half-decade. The data on HIV/AIDS prevalence rates were provided by the FMOH 2006 HSSS reports for each state of the study area. These rates were used as an area pattern since it represent each state, the prevalence rates were transformed by multiplying it with the population figures for the four sentinel surveys in the respective states. After which the total infected for various states under the study area were established.

The data was first subjected to a two way analysis of variance i.e. years considered as time and location as space using R version 2.8.1 Statistical software. However, MINITAB version 13 and STATGRAPHIC version 5.0 were also used to test for normality and finally ARCVIEW version 3.2a a GIS and remote sensing software was in addition used to generate at map location the high and low risk areas within the study. Percentage changes are also shown in figure 3 to see the trend of the infection. The focus of the study is on the prevalence rates, that is the percentage of the population testing positive for HIV virus.

Tables 1a.and 1b. Summarize the result of fitting a general linear statistical model relating HIV patients to two predictive factors. Since the P-value in the first ANOVA table for HIV patients is less than 0.01, there is a statistically significant relationship between HIV patients and the predictor variables at the 99% confidence level. The second ANOVA table for HIV patients tests the statistical significance of each of the factors as it was entered into the model. The study observed that the highest P-value is 0.1654, belonging to years. Since the P-value is greater or equal to 0.10, that term is not statistically significant at the 90% or higher confidence level. Consequently, you should consider removing years which is time from the model. The R-Squared statistic indicates that the model as fitted explains 75.592% of the variability in HIV patients which suggest a better fit. The generalized statistical linear model for the study is as given below.

$Y=174147+X_1 102676-X_2 17720-X_3 26390-X_4 30484–X_5 106249-X_6 5104–X_7 25085-X_8 48757$
Where X_1 is Bauchi, X_2 is Borno, X_3 is Gombe, X_4 is Taraba, X_5 is Yobe, X6 is 2003, X_7 is 2005, X_8 is 1999 and Y is the response variable. i.e. HIV patients

As a result of migration occasion by push and pull factors a person can be infected since he/she is exposed to a high prevalence area. These factors might be conflicts, wars, civil unrest or people seeking for employment. While time do not contribute to the spread of the disease (HIV/AIDS). After acknowledging that location contributes significantly, a post-hoc test is conducted to identify which of the locations contributes most. However, the result is displayed in table 2, where Yobe-Bauchi and Taraba-Bauchi are significantly contributing to the spread at ($p < 0.01$) as well as. Borno - Bauchi and Gombe - Bauchi has contributions significantly at ($p < 0.05$) to the spread of the disease. The correlation matrix of locations is shown in table 3, Result shows that Yobe and Taraba has the strongest relationship of 0.965 followed by Gombe and Yobe with 0.849 as correlation coefficient.

Figures 1a and 1b shows the probability plots of the normality test. The tests are that of Anderson-Darling which is based on empirical cumulative distribution function, Ryan-Joiner based on correlation and Kolmogorov-Smirnov which is based on the chi-square test. The grid on the graph resembles the grids found on normal probability paper. The vertical axis has a probability scale. The horizontal axis, a data scale. Least square line fit to the plotted points was drawn on the plots for references. The line forms an estimate of the cumulative distribution function for the population from which data are drawn. Numerical estimates of the population parameters μ and σ are displayed together with the plots.

The spatial distribution of HIV patients in the study area was displayed on figures 2a, 2b, 2c and 2d with high prevalence at Bauchi and low prevalence at Damaturu throughout the study period. Looking at Figure 2a, Maiduguri, Yola, Damaturu, Jalingo and Gombe are classified as low risk states, where as Bauchi is identified as high risk area. While Figure 2b shows that Yola is the only high risk area while other states are identified to be low risk areas. Figure 2c shows that Maiduguri, Damaturu and Jalingo are classified as high risk areas where as Yola, Bauchi and Gombe are identified as low risk areas.

The percentage changes in HIV prevalence from 1999-2005 was displayed on figure 3. These Changes were observed between two sentinel surveys. However, it was later generalized to see the overall changes within the study period. Efforts were also made to compare these sentinel surveys. The result show that between 1999 to 2001 Adamawa had a decrease with a corresponding increase at Bauchi, Gombe, Yobe, Taraba and Borno States. The change from 2001 to 2003 was a progressive one. As depicted by the bar diagram, which had Adamawa leading the increase, followed by Yobe, and Taraba States. Meanwhile, Bauchi, Borno, and Gombe States had a corresponding decrease in the percentage change of HIV/AIDS prevalence rates. The changes seem to be fluctuating from 2003 to 2005. This might be probably attributed to government efforts toward advocacy about the dangers of the scourge. The period had Adamawa maintaining the lead of decrease followed by Gombe and Bauchi States. While, Borno lead the increase, followed by Taraba and Yobe States. Considering the four sentinel surveys i.e. 1999-2005 the period under study observed significant changes in general. This was shown in the figure 3 where Yobe is leading the increase followed by Bauchi, Taraba and Gombe States. However, Adamawa observed no changes in the prevalence rates of the HIV/AIDS pandemic.

Over the four sentinel periods under review the study examines, and shows the distribution of HIV prevalence rates at map location in the study area. However, it was observed that there rates show general increase. This increase varies significantly among states in the region. On the surface, it is not immediately obvious that states experiencing conflicts, migration, unemployment, poverty, illiteracy rates are higher. While states where prevalence rates were reported to be decreasing which have to be attributed to social institutions being less effective, law and order breakdown, and public health provisions make a steady move to the bottom of the government's priority list. The violence and chaos resulting from civil unrest in Plateau, Benue and Bauchi led to unprecedented levels of HIV prevalence due to rampant rapes and movement of people from urban to rural areas and vice versa.

In addition to rape observation from informal interviews elucidate that tertiary institution students move out to urban cities like Abuja and engage in sexual relations out of a need for food or shelter. However, HIV transmission rates go up due to conflict as poverty and desperation force women and girls to become commercial sex workers. At a time when public health facilities are not optimally operative and sexual health education is not widely available the plight of women can have serious repercussions in the form of disease transmission.

CONCLUSION

A possible and fruitful direction of inquiry in this regard is the use of an estimating equations approach (e.g. Liang and Zeger 1986; Zorn 2001) in a spatial context. Recently, some scholars in the field as diverse as biology (Pebesma *et.al.*2000; Mugglestone and Kenward 2002), Biostatistics (Albert and McShane 1995; Yusai and Lele 1997) and Forestry (Baumler 1995) have adopted spatial generalized estimating equations methods to model the spatial and/or spatio-temporal correlation among their data. Such an approach has the advantage of avoiding more-or-less arbitrary decisions about the proper specification of the spatial weights matrix W, and would also allow for consistent estimation of covariate effects on the first moment in the presence of misclassification of the spatial relationship. The study attempts to investigate this approach further in future work.

The universal concern for the rapidly spreading HIV/AIDS epidemic has made it immensely important for scholars and professionals in the medical and health communities, development economists, sociologists, and political scientists to examine the factors related to the causes and effects of HIV prevalence in the world. Multilateral, regional, and humanitarian organizations are engaged in incessant efforts to prevent further spread of the disease. However, the threat of HIV/AIDS is not on the retreat, particularly in the conflict-ridden parts of Africa. The HIV/AIDS menace to the global society cannot fully be understood unless all the pertinent medical, political, social, and economic dimensions to the issue are assessed at the states and national levels.

The present study critically discussed some risk areas of AIDS incidence with the aim of understanding how such estimates are interpreted by the general public and exploring possible improvements in policy making. It should be emphasized that ignoring how a disease spreads, and related assumptions, as well as neglecting key input information could lead to wrong policy direction. The need for appropriate assessment and improvement of specific modeling purposes, and explicit listing of limitations and parameter inputs as well as possible solution to aid relevant policy formulation was therefore highlighted.

RECOMMENDATIONS

- Understanding the relationship between location and health can greatly assist us in understanding, controlling and preventing disease, and in better healthcare planning, with more efficient and effective resource utilisation. This should ultimately lead to better healthcare outcomes and improved health for everyone.

- However, for geographic informatics to become one day a mainstream technology in the health sector like today's spreadsheet and database packages, we still need to combat many data availability/quality barriers, as well as cultural and organisational barriers, including "spatial illiteracy" among healthcare workers, while making the tools cheaper and much easier to learn and use.

- Professional education and hands-on training courses in geographic informatics are extremely important in achieving this goal.

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Table 1a. Analysis of Variance for HIV patients’ model

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	9.16749E10	8	1.14594E10	5.81	0.0017
Residual	2.9601E10	15	1.9734E9		

Table 1b. Showing analysis of Variance for HIV patients with respect to time and location

Source	df	Sum Sq	Mean Sq	F value	Pr (>F)
state	5	8.0146e+10	1.6029e+10	8.1226	0.0006982 ***
year	3	1.1529e+10	3.8430e+09	1.9474	0.1653592
Residuals	15	2.9601e+10	1.9734e+09		

Significance. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 2a. Showing the estimated coefficients of the model

Coefficients	Estimate	Std. Error	t value	Pr (>|t|)
(Intercept)	174147	29383	5.927	2.78e-05 ***
statebau	102676	33928	3.026	0.00851 **
statebor	-17720	33928	-0.522	0.60910
stategom	-26390	33928	-0.778	0.44878
statetar	-30484	33928	-0.898	0.38313
stateyob	-106249	33928	-3.132	0.00686 **
year03	-5104	27702	-0.184	0.85630
year05	-25085	27702	-0.906	0.37951
year99	-48757	27702	-1.760	0.09877 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 2302267085)
Null deviance: 1.3439e+11 on 23 degrees of freedom
Residual deviance: 3.4534e+10 on 15 degrees of freedom
AIC: 594.2

Table 2b. Showing the mean contrast of location

States	diff erence	lwr	upr	p adj
bau-ada	101976.25	-79.61953	204032.12	0.0502347
bor-ada	-17720.00	-119775.86953	84335.87	0.9919937
gom-ada	-26389.75	-128445.61953	75666.12	0.9549232
tar-ada	-30484.00	-132539.86953	71571.87	0.9203954
yob-ada	-91565.25	-193621.11953	10490.62	0.0915624
bor-bau	-119696.25	-221752.11953	-17640.38	0.0173442
gom-bau	-128366.00	-230421.86953	-26310.13	0.0102236
tar-bau	-132460.25	-234516.11953	-30404.38	0.0079627
yob-bau	-193541.50	-295597.36953	-91485.63	0.0002180
gom-bor	-8669.75	-110725.61953	93386.12	0.9997331
tar-bor	-12764.00	-114819.86953	89291.87	0.9982690
yob-bor	-73845.25	-175901.11953	28210.62	0.2340883
tar-gom	-4094.25	-106150.11953	97961.62	0.9999935
yob-gom	-65175.50	-167231.36953	36880.37	0.3495157
yob-tar	-61081.25	-163137.11953	40974.62	0.4148847

Table 3. Showing correlation Matrix of location

Adamawa	Bauchi	Borno	Gombe	Taraba	Yobe	
Adamawa	1.0000000	-0.1293422	-0.9404040	0.3192019	0.1943965	0.3904386
Bauchi	-0.1293422	1.0000000	0.3674977	0.8007762	0.3342089	0.4032443
Borno	-0.9404040	0.3674977	1.0000000	-0.1875295	-0.3050948	0.4396296
Gombe	0.3192019	0.8007762	-0.1875295	1.0000000	0.7532635	0.8492783
Taraba	0.1943965	0.3342089	-0.3050948	0.7532635	1.0000000	0.9699058
Yobe	0.3904386	0.4032443	-0.4396296	0.8492783	0.9699058	1.0000000