American Journal of Public Health Research, 2017, Vol. 5, No. 4, 130-137
Available online at http://pubs.sciepub.com/ajphr/5/4/6
©Science and Education Publishing
DOI:10.12691/ajphr-5-4-6

Geographic Controls of Adult HIV/AIDS Prevalence and Their Determinants for Sub-Saharan Africa Countries

N. Kunene[1], M. Gella[2], T. Gala[1,*]

[1]Department of Geography, Chicago State University, Chicago, IL
[2]AHOPE Ethiopia, Mekanissa road, Addis Ababa, Ethiopia
*Corresponding author: tgala@csu.edu

Abstract More than 2/3 of global HIV/AIDS epidemics, as well as seven in ten of all HIV/AIDs death, are reported in Africa. The economic burden of the disease in terms of treatment and prevention for an already impoverished continent is enormous. Several international organizations are engaging Africa to alleviate the disease epidemics and its economic impacts. This study attempted to determine the geographical controls of HIV/AIDS prevalence rates and established a relationship with demographic, social and economic determinants. Accordingly, significant (I = 0.71; α = 0.5) geographical clustering of adult HIV/AIDS prevalence rates were detected, such that the higher rates are clustered in the southern African countries, while the west African countries have the clustering of the lowest rates. The demographic, social and economic factors such as literacy (female) rate, life expectancy at birth, contraceptive prevalence rate, education expenditure and percent Muslim population, significantly explained the variability of the Adult HIV/AIDS prevalence rates (R^2 = 0.81 – 0.84; α = 0.05) in Africa. This result highlights the need for geographically-resolved resource allocation, particularly in the areas of primary education and gender participation for the fight against HIV/AIDS.

Keywords: *HIV/AIDS, risk factors, spatial pattern analysis, spatial regression, Sub-Saharan Africa*

Cite This Article: N. Kunene, M. Gella, and T. Gala, "Geographic Controls of Adult HIV/AIDS Prevalence and Their Determinants for Sub-Saharan Africa Countries." *American Journal of Public Health Research*, vol. 5, no. 4 (2017): 130-137. doi: 10.12691/ajphr-5-4-6.

1. Introduction

Besides the human cost, HIV/AIDS is an enormous burden to an already impoverished African economy [4,5]. HIV/AIDS has shrunk the sub-Saharan countries' economic growth rate by 2 – 4% due to its impact on labor supply and productively [4]. For example, in South Africa, death from HIV/AIDS has reduced mine and transportation workers by about 27 and 22% [6]. The reduction in agricultural labor in rural Africa ranges from an estimated 2.9% in Cameroon to as much as 12.8% in Uganda. The disease is estimated to have reduced the size of the South African economy by 22% from the size it would have been without HIV/AIDS. There is also the additional costs of HIV/AIDS prevention and treatment for African families [7]. According to Kello [7], per capital cost of drug and test of HIV/AIDS in Ethiopia ranges from 38 – 62% of country's household income.

Several studies have noted various risk factors for HIV/AIDS infection in Sub-Saharan Africa [8-13]. For instances, in some African countries, polygamy, a cultural practice, which allows men to have multiple wives/affairs, have made the society vulnerable to the virus infection [10]. Additionally, increased male economic dependence on women in Swaziland and South Africa, have forced women to participate in sex work to support the family, risking their exposure to HIV virus [11]. A systematic review of relationship between male circumcision and risks to HIV infection has also shown that circumcision reduced HIV risk [8,9]. On the other hand, consuming alcohol in greater quantities increased risks of sexually transmitted infections (STI), including HIV/AIDS [13]. Moreover, for the young gay men vulnerability to HIV/AIDS was found to be contingent on race/ethnicity and sexual behavior, such that the risk is higher for Latino compared to White gay men and those with a number of sexual partners, and with a history of sexually transmitted diseases (STD) [14]. Urban dwellers experience higher HIV prevalence compared to rural inhabitants [15]. The disease's problems and risk factors are dependent on geographical scale, such that indicator/problem that stands out at individual scale may not stand once the data is aggregated at regional or national scale [15].

International organizations (i.e., WHO, UNICEF, UNAIDS etc.) are pouring resources into Africa, to reverse HIV/AIDS pandemics and control the risk factors. These organizations, alongside Millennium Development Goals (MDG), aim at eradicating poverty (HIV/AIDS) through improved primary education and gender participation. The efforts would be more effective if they were to be assisted with information that would help guide geographically-resolved resource allocation. Therefore, the objectives of this study are: a) to analyze the Spatial distribution of the Adult HIV/AIDS Prevalence Rates of Sub-Saharan Africa and literature supported relevant Risk Factors for the virus's infection; and b) to model the spatial relationships of the Adult HIV/AIDS Prevalence Rates and its demographic, social and economic determinants. Geographical information system (GIS) have various toolsets capable of resolving the patterns and relationships of spatial data, including the data of Adult HIV/AIDS Prevalence Rates and the risk factors to assist HIV/AID prevention as well as the allocation of treatment resources.

2. Material and Methods

2.1. Study Area

Africa, with a total population of over 1.1 billion people i.e., 15% of the world population, is the second populous continent of the world. It also has the youngest population, with a median age of 19.7 when compared to the world's median age of 30.4 in 2012 [16]. Africa has large diversity in terms of ethnicity and cultures (Figure 1). There are estimated to be over 1,000 languages spoken in Africa, which are grouped in to four major categories i.e., Afroasiatic, Nilo-Saharan, Niger-Congo and Khoisan language families [17]. The majority of Africans are believers of Abrahamic religion, especially Christian (45%) and Muslim (40%); only a small number of Africans (less than 5%) follow Hindu, Buddist, Baha and etc.

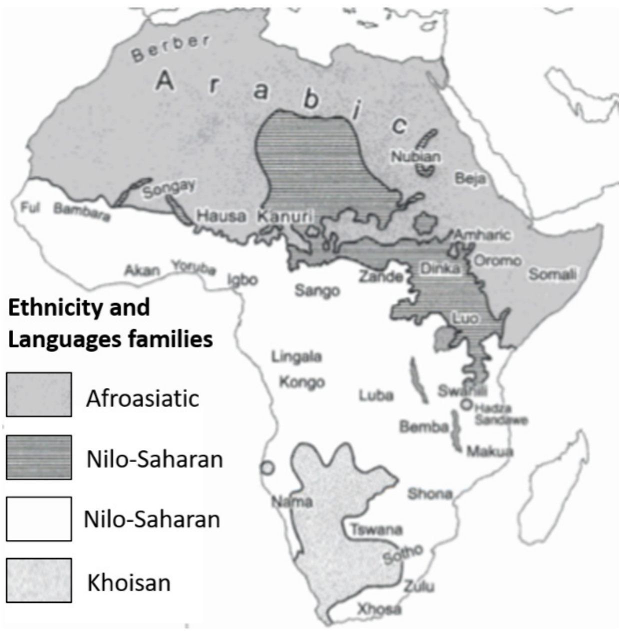


Figure 1. Cultural diversity and ethno-linguistic landscape of Africa Source: Map courtesy of Mark Dingemanse and Pmx

The African continent has Fifty-four independent countries, out of which, 48 countries are found on the mainland while the remaining 6 are islands. The entire continent of is divided into five regions Southern Africa, Central Africa, West Africa, East Africa and North. The division is based on factors including geographic, political and/or predefined boundaries by international organization such as UNICEF, WHO, CDC etc. This study excluded the Northern region of Africa, and island states owing to distinct cultural composition, lack of data and/or very low HIV/AIDS prevalence rates. The remaining four regions, Southern Africa, Central Africa, West Africa, and East Africa, also known as sub-Saharan Africa, are included.

2.2. Research Data

The data considered for this study are countries statistics of Urban Population, Literacy, Unemployment, Infant mortality and contraceptive prevalence rates. Additionally, the data had statistics of countries' GDP - per capita (PPP), health expenditures and education expenditures as a percentage of GDP. Moreover, countries' Muslim population (i.e., percentage of countries population that follows Islam faith) and life expectancy at birth were also taken into account. Urban population expressed as percentage of total population living in urban areas to describe countries' degree of urbanization; whereas literacy rate implies not the absolute educational achievement but just percentages of countries' population with the ability to read and write. While unemployment rate represents the percent of the labor force without job; infant mortality and life expectance at birth imply the number of deaths of children below one year in a given year per 1000 live birth in the same year and the average number of years to be lived by a group of people born in the same year. Both infant mortality and life expectance at birth are often used as indicators of overall quality of life and health in a country. On the other hand, contraceptive prevalence rate is an indicator of health services and awareness presented as a percentage of reproductive women (15-49 age) using a method of contraception; while health and educational expenditures are total expenses on health and education as a percentage of countries' GDP. Adult HIV/AIDS prevalence rate is an estimate of adults (aged 15 – 19) living with the disease.

The statistics of the adult HIV/AIDS prevalence rates and the risk factors were drawn from the UNAIDS Global Report, World Reference Database [18], United Nation Development Program (UNDP) and World Health Organization (WHO). Through its periodically released global report, UNAIDS accumulated research data of socio-economic and health condition indicators. Similarly, the Human Development Report of the UNDP and World Health Statistical series compile the Human Development Index (HDI), health and health related indictor data used data for international Sustainable Development Goals (SDGs) and associated targets [3,19,20]. These statistics are com piled by the collaborations of these organizations in close partnership with member states and surveys available on public domain for agencies and/or researchers use. Efforts were made to acquire the statistics of particular indicator from the same data source so as to apply consistent measures of data compilation per entry.

Finally, a base map for African continent was obtained from Environmental Systems Research Institute (ESRI). Founded in 1969, ESRI is the organization that has grown to be a leader of geographic analytics and providing spatial data. With high technical partners such as Amazon Web Services, Citrix, IBM, Microsoft, Oracle, SAP, SAS, and others, ESRI manages to stay up to date with software and optimally qualified spatial data.

2.3. Methodology

2.3.1. Analyzing the Spatial Patterns of Adult HIV/AIDS Prevalence Rates and the Risk Factors

Both global as well as local spatial autocorrelation tools in GIS were used for understanding how adult HIV/AIDS prevalence rates and the risk factors behave over geographical regions of Sub-Saharan African countries. The tools are exploratory spatial statistics that quantifies specific patterns of these values, arrangements of corresponding extreme values or outliers, and spots of their specific geographical homogeneity. Global spatial autocorrelation, which measures the overall strength of the correlation between values and the distance separating, was estimated by Moran's I index [21] as:

$$I = \frac{n}{S_o} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} Z_i Z_j}{\sum_{i=1}^{n} Z_i^2} \tag{1}$$

Where: Zi is the deviation of an attribute for feature I from its mean $(x - \bar{x})$, Wi,j is the spatial weight between features I and j , n is equal to the total number of features, and So is the aggregate of all spatial weight:

$$S_o = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j}. \tag{2}$$

The ZI-score for the statistic is computed as:

$$Z_I = \sqrt{\frac{I - E[I]}{V[I]}} \tag{3}$$

Where:

$$E[I] = -1/(n-1) \tag{4}$$

$$V[I] = E\left[I^2\right] - E[I]^2 \tag{5}$$

$$E\left[I^2\right] = \frac{A - B}{C} \tag{6}$$

$$A = n\left(n^2 - 3n + 3)S_1 - nS_2 + 3S_0^2\right). \tag{7}$$

$$B = D\left[\left(n^2 - n\right)S_1 - 2nS_2 + 6S_0^2\right] \tag{8}$$

$$C = (n-1)(n-2)(n-3)S_0^2 \tag{9}$$

$$D = \frac{\sum_{i=i}^{n} Z_i^4}{\left(\sum_{i=i}^{n} Z_i^2\right)^2} \tag{10}$$

$$S_1 = (1/2) \sum_{i=1}^{n} \sum_{j=1}^{n} \left(w_{i,j} + w_{j,i}\right)^2. \tag{11}$$

On the other hand, the local indicator of spatial association identifies local variations in a specific region where values of the variables are clustered, extreme (outlier) and geographically homogeneous. This index, in addition to global Moran's I, was helpful in detecting pockets of localities (hotspots or cold spots) that are exhibiting homogeneous values that do not follow the global trend [21]. The standard tool used for examining local autocorrelation is Anselin Local Moran's (I) and expressed as:

$$I_i = \frac{X_i - \bar{X}}{S_i^2} \sum_{j=1, j \neq i}^{n} W_{i,j} \left(x_i - \bar{X}\right) \tag{12}$$

Where: Xi is an attribute for feature i, $\bar{X}$ is the mean of the corresponding attribute, Wi,j, is spatial weight between feature i and j and:

$$S_i^2 = \frac{\sum_{j=1, j \neq i}^{n} W_{ij}}{n-1} - \bar{X}^2 \tag{13}$$

With n equating to the total number of features.

The Z_{ii} – score for the statistics were computed as:

$$Z_{Ii} = \frac{I_i - E[I_i]}{\sqrt{V[I_i]}} \tag{14}$$

Where:

$$E[I_i] = -\frac{\sum_{j=1, j \neq i}^{n}}{n-1} \tag{15}$$

$$V[I_i] = E\left[I_i^2\right] - E[I_i]^2 \tag{16}$$

$$E\left[I^2\right] = A - B \tag{17}$$

$$A = \frac{(n - b_{2i}) \sum_{j=1, j \neq i}^{n} W_{i,j}^2}{n-1} \tag{18}$$

$$B = \frac{(2b_{2i} - n) \sum_{k=1, k \neq i}^{n} \sum_{h=1, h \neq i} W_{i,k} W_{i,h}}{(n-1)(n-2)} \tag{19}$$

$$b_{2i} = \frac{\sum_{i=1, j \neq j}^{n} \left(x_i - \bar{X}\right)^4}{\left(\sum_{i=1, j \neq j}^{n} \left(x_i - \bar{X}\right)^2\right)^2}. \tag{20}$$

2.3.2. Modelling Spatial Relationships of Demographic, Social and Economic Risk Factors of HIV/AIDS

Spatial regression was utilized to find a relationship between the prevalence rates of adult HIV/AIDS and indicator values of various demographic and socio-economic risk factors of countries in the Sub-Saharan Africa. Before applying spatial regression, tests were conducted to see if the data does not satisfy the assumptions of Ordinary Least Square (OLS) estimation. For a linear regression, represented in the equation (1), the underlying assumptions are that the terms of random error has mean zero, normal distribution and constant variance. Under certain circumstances, as hypothesized in this study, data fail to satisfy these assumptions. Adult HIV/AIDS prevalence rates and values demographic, and socio-economic risk factors are dependent on geographical locations (i.e., spatial dependence) thereby making location and distance the important components of modeling relationships between dependent and explanatory variables.

$$Y = \beta_o + \beta_1 X_1 + \varepsilon \quad (21)$$

Where: The vector parameters (β), denote the direction of the relationship (positive, negative or neutral); The independent variables (X), which were values of demographic and socio-economic indicators of Sub-Saharan African countries (HIV/AIDS risk factors); and the dependent variable (Y), is prevalence rates of adult HIV/AIDS.

Modeling spatial relationship was accomplished by creating spatial weights and applying spatial models. Spatial weights were created to define a structure by which spatial relationship are modeled. This study used a contiguity spatial weighting structure, which assigns a weight 1 and 0; where 1 is given for the neighboring countries and 0 to all other countries that do not share the boundary in that the estimate is influenced by only countries that are sharing edge. Two sets of spatial models were used for predicting spatial relationships i.e., spatial error and spatial lag [21]. While spatial error estimated based on the behavior of the error terms across space, the spatial lag estimated in the account of a country's Adult HIV/AIDS prevalence rates as influenced by values of demographic, and socio-economic risk factors in that country and adjacent neighbors. This study used both modeling approaches and presented results are those produced by the best unbiased regression estimates.

2.3.3. Validation Methods

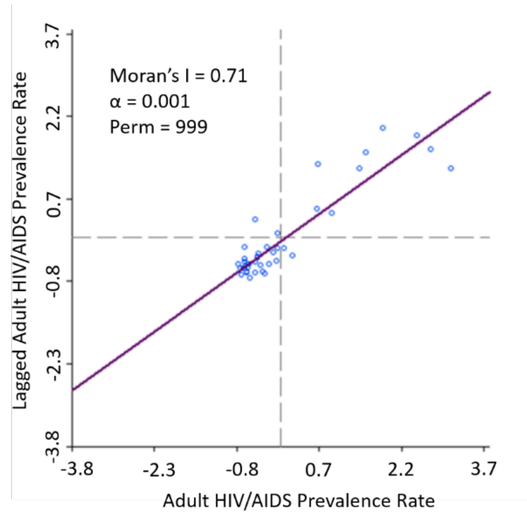
The global and local spatial patterns of adult HIV/AIDS prevalence rates and the risk factors data is verified by the values of Moran's I Index and corresponding p-value. Generally, while +1 Moran's Index value indicates spatial autocorrelation (dependency) of the data, the index value near -1.0 indicates dispersion. P-values ascertain statistical significance of the observed patterns in the data. Simple regression was implemented to establish relationship between Countries HIV/AIDS prevalence rate and risk factors of higher HIV prevalence rates. While The relative strength of the relationships evaluated with regression parameters (i.e. calculate coefficient of determination (r^2), Root Mean Square Error (RMSE) and statistical significances (α).

3. Results and Discussion

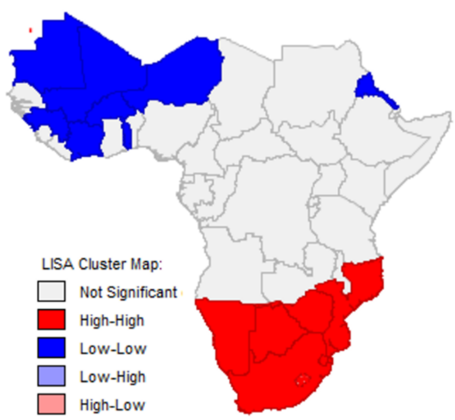
3.1. Geographical Distribution of Adult HIV/AIDS Infection Rates in Sub-Saharan Africa

Figure 2 shows global and local spatial correlation of adult HIV/AIDS prevalence rates for countries in Sub-Saharan African countries. Accordingly, there is a significant spatial dependency (i.e., geographic controls) of the prevalence rates (Figure a; I = 0.71; α = 0.5). Additionally a LIZA cluster map of local autocorrelation also found significant clustering of both higher (i.e., hotspot) and lower (i.e., cold spot) of adult HIV/AIDS prevalence rates. The cluster analysis further confirms the disease's burden and severity of HIV/AIDS prevalence in the southern region. Seven countries, namely Swaziland, Lesotho, South Africa, Mozambique, Namibia, Zimbabwe and Botswana had significant (α = 0.05) clusters of higher HIV/AIDS prevalence rates (i.e., hotspot); while, Zambia and Malawi are a significant cluster of higher adult HIV/AIDS prevalence rates (i.e., hotspot) at α = 0.1.

The adult HIV/AIDS prevalence rates of all the countries in the eastern (i.e., except Eritrea) and central region of sub-Saharan Africa do not show significant clustering of the rates (α = 0.05). Furthermore, six countries in the western region namely Nigeria, Benin, Ghana, Senegal, Sierra Leone, Chad and Gambia show no significance clustering of adult HIV/AIDS prevalence rates (α = 0.05). On the contrary, the majority of the western African countries are significant cluster of lower HIV/AIDS prevalence rates (i.e., cold spot) (α = 0.05). These are Niger, Mali, Mauritania, Burkina Faso, Togo, Guinea-Bissau, Côte d'Ivoire, and Guinea. In general, the southern sub-Saharan African countries are hotspots of adult HIV/AIDS; while the western countries are the cold spots indicating a clear geographical controls of adult HIV/AIDS prevalence rates in Africa.



a)



b)

Figure 2. Spatial autocorrelation of HIV/AIDS Prevalence rates for Sub Saharan Africa countries: a) Global autocorrelation and b) local autocorrelation

Several, studies have reported similar regional variability adult HIV/AIDS infection rates in Africa [3,22,23,24]. The study [22] investigated risk HIV/AIDS infection rates in four urban populations of sub-Saharan Africa and reported significant variations among the population. Similarly, [3] and [24] also documented similar geographical variability of infection rates. Asamoah-Ode [23] documented the relative higher adult HIV/AIDS prevalence rate for southern African countries (South Africa and Botswana) vis-à-vis the west African; while the [3] reports indicated infection rates in the order of 20% for southern African countries and as low as 0.5% in Western African countries.

Geographical variability of the adult HIV/AIDS prevalence rates are perhaps attributed to regions' or countries' exposure to varying risk factors. For instance, studies shown that countries with polygamous culture [25], unequal participation and service opportunities for women [26], scarce ART treatment [27]; and transnational economic migration [28] were found to have higher HIV prevalence rates. Additionally, in the countries with culturally motivated gender inequality characterized by lesser control of women over their sexual and reproductive health, increased economic dependence on men and violent relationships risk higher HIV/AIDS prevalence rate occurred [29].

3.2. Spatial Pattern of HIV/AIDS Risk Factors in Sub-Saharan Africa

Table 1 shows the variables that have shown significance of spatial controls of indicators of demographic, cultural and socioeconomic variables for Sub-Saharan African country, just as adult HIV/AIDS prevalence rate. With the exception of urban population, all other variables have shown significant spatial dependency (α<0.05). While countries' literacy, Contraceptive prevalence, and percent Muslim population have demonstrated strong spatial dependency at α < = 0.001; countries' health expenditures also shown spatial dependency at α < = 0.01 significant level. The remaining variables shown significant spatial dependency at I = 0.05 – 0.01. Similar varying strengths of spatial dependency were also noted with Moron's coefficient. Countries Literacy rate (Total and female), prevalence of contraceptives and percent Muslim population have registered strong Moron's coefficient (i.e., I > 0.5). On the other hand, the coefficients of Male literacy rate, health expenditures and GDP - per capita (PPP) have shown moderate Moron's coefficient (I) (0.2 – 0.5); while the remaining variables were I < 0.

The spatial dependencies of indicators of demographic, cultural and socioeconomic variables for Sub-Saharan African country ratifies essence of regional division of sub-Saharan African countries. Sub-Saharan African countries are regionalized into four regions, based on factors such as social-cultural, geographical and political similarities [30]; which the spatial autocorrelations of the indicators have attested. Additionally, the dual spatial dependence of the indicators and adult HIV/AIDS prevalence rates also triggers a hypothesis that stipulates underlying associations. This is significant because, if in fact this association can be established, countries will have additional tools available in their fight against HIV/AIDS pandemics in Sub-Saharan Africa.

Table 1. Moron's Coefficient (I) and corresponding level of statistical significance (α) to demonstrate spatial dependency for indicators of demographic, cultural and socio-economic variables of Sub-Saharan African countries

	Variables	Moron's I	α (999 Permutation)
1	Urban Population	0.15	0.056
2	Total Literacy	0.50	0.001*
3	Female Literacy	0.51	0.001*
4	Male Literacy	0.37	0.001*
5	Unemployment rate	0.17	0.033*
6	GDP - per capita (PPP)	0.33	0.003*
7	Infant mortality rate	0.19	0.024*
8	Life expectancy at birth	0.18	0.028*
9	Contraceptive prevalence rate	0.50	0.001*
10	Health expenditures	0.24	0.010
11	Education expenditur	0.18	0.035*
12	Percent Muslim Population	0.60	0.001*

Table 2. Coefficient of determination (R^2), beta (β) and corresponding level of statistical significance (α) for spatial relationships of Adult HIV/AIDS prevalence rates with indicators of demographic, cultural and socio-economic variables of Sub-Saharan African countries

	Variables	R^2	β	α
1	Urban Population	0.01	-0.012	0.754
2	Total Literacy	0.81	0.063	0.018*
3	Female Literacy	0.81	0.064	0.004*
4	Male Literacy	0.80	0.040	0.166
5	Unemployment rate	0.80	0.063	0.179
6	GDP - per capita (PPP)	0.80	0.000	0.091
7	Infant mortality rate	0.80	-0.046	0.073
8	Life expectancy at birth	0.83	-0.319	0.000*
9	Contraceptive prevalence rate	0.84	0.137	0.000*
10	Health expenditures	0.80	0.299	0.152
11	Education expenditures	0.81	0.567	0.003*
12	Percent Muslim Population	0.80	-0.029	0.049*

The spatial lag modeling is used to establishthe relationships between demographic and socio-economic indicators of Sub-Saharan African countries and their corresponding adult HIV/AIDs prevalence rate. With the exception of percent urban population, which demonstrated a very weak relationship (R2 = 0.01), the remaining indicators have registered strong relationships (R2 = 0.84). Countries' contraceptive prevalence rates and life expectancy at birth are the strongest determinants of Adult HIV/AIDs prevalence rate followed by literacy rates (total and female) and education expenditure as a percentage of GDP (R2 = 0.81). The remaining indicators also documented a strong relationship (R2= 0.80). However, despite the detected strength of the relationships, only the relations with countries percent Muslim population, life expectancy at birth, education expenditure as percentage of GDP, contraceptive prevalence rate, and literacy (Total and Female) were significant (α <0.05). Significant positive relationships (β) were documented for education expenditure as percentage of GDP, contraceptive prevalence rate, and literacy (Total and Female) whereas the relationships were significantly negative (β) for Muslim population and life expectance at birth.

The significant negative relationship (-β, and α <0.05) between Adult HIV/AIDS prevalence rates and countries' life expectance implies that people have shorter lives in the countries where HIV/AIDS prevalence rates are high. Additionally, countries with the higher percent of Muslim population, tend to have lower Adult HIV/AIDS prevalence rates. This finding corroborates with other studies, which reported that HIV/AIDS is among the top most killing diseases in Africa [31,32]. It also corroborates with reports indicating a strong impact of Islamic faith against HIV/AIDS infection in some regions Africa [33,34]. According to these studies [32] and [33], Islam faith has strong influence on local values, morals, and government policies that it has sustained infection rates, in these countries, at a negligible level. This is attributed to the strong social taboo of pre-marital [33] and extra-marital [34] sexual relations in Muslim communities.

On the other hand, a significant positive relationship (-β, and α <0.05) between Adult HIV/AIDS prevalence rates and countries' education expenditure and literacy rate invoke a closer look at the data. According to this result, countries, which incur higher expenses on education and therein has literacy rate exhibited higher HIV prevalence rates. This contradicts with several studies which have attributed declining HIV/AIDS prevalence rates to improving education [35,36,37,38] (Fylkesnes et al, 2001; Baker et al., 2011; Fortson, 2011; and Brent 2014). Fylkesnes [35] indicated declining adult HIV/AIDS prevalence rate with increasing educational status of childbearing women of Zambia; while [36,37,38] illustrated a trend of declining adult HIV/AIDS incidence and prevalence rates due to education's ability to bring about behavioral changes, improved cognitive skills, and informed decision making and risk assessment skills among the population. Obviously, education through its influence on decision making and empowerment, remains a key intervention strategy of HIV/AIDS pandemics in Africa. However, the inability of the model to reveal this fact at national scale is maybe attributed to the model's sensitivity to other tenacious factors or the scale of the investigation. For example, west African and Sahelian countries such as Niger (19.1%), Guinea (30.4%), Burkina Faso (36%), Benin (36%) and Mali (38%) have the lowest literacy rate in the continent, while also having the lowest adult HIV/AIDS prevalence rates (< 2.5%) [18]. On contrary, with the continent's highest literacy rates like Zimbabwe (86.5%), Swaziland (87.5%), Botswana (88.5%), and South Africa (94.3%) also exhibited the highest adult HIV/AIDS prevalence rates (>16.7%) [18]. Therefore, it could be possible the model became more respondent to the impacts of Islamic culture on HIV/AIDS infection than the literacy rates. Regionally or nationally disaggregated investigation on this factor could uncover the underlying role of education on HIV/AIDS intervention.

Similarly, the relative higher rate of contraceptive prevalence and health expenditures as percentage of GDP, in the countries with higher adult HIV/AIDS prevalence rates invoke scrutiny. Because, under normal circumstances higher contraceptive prevalence rate should mean greater control on the disease's prevalence. However, in sub-Saharan African countries adult HIV/AIDS prevalence rates is heightened in response to socio-cultural practices of multiple partners and promiscuity especially for males, polygamous relationships, commercial sex and sexual networking [34,39,40]. Therefore, the higher contraceptive prevalence rates in the countries with higher adult HIV/AIDS prevalence rates indicate countries' preventive reaction to pandemics and the overall disease's economic burden.

4. Conclusion

The adult HIV/AIDS prevalence rates for countries in Sub-Saharan African countries has shown global and local spatial clustering. While significant clustering for higher prevalence rates were concentrated in the southern African countries, the West African countries show a cluster of lower HIV/AIDS prevalence rates. Most central and eastern African countries did not show any significant clustering of the adult HIV/AIDS prevalence rates. Consequently, the international organizations' (i.e., WHO, UNICEF, UNAIDS etc.) funding to eradicate HIV/AIDS in Africa must gauge their resources towards southern African countries (Swaziland, Mozambique, Zimbabwe, Namibia, South Africa, Lesotho, and Botswana), despite the fact that these countries would not attract foreign aid. Most southern African countries are economically better-off compared to most western, central and eastern African countries.

The regional variability of the epidemics is demonstrated to have been conditioned by literature supported HIV/AIDS risk factors. With the exception of urbanization, all other demographic, cultural and socioeconomic risk factors have shown the geographical control of various strengths. A strong geographical control was observed with the countries' literacy rates, contraceptive prevalence rates, and percent Muslim population; whereas moderate controls was found with countries' health expenditures. Other outstanding risk factors i.e., unemployment, Infant mortality, GDP - per capita (PPP), health expenditures and education expenditures and life expectancy at birth show, relatively weaker geographical control. Of the factors, however, only Literacy (female), life expectancy at birth, contraceptive prevalence rate, education expenditure and percent Muslim population have shown significant degree of spatial relationship with the adult HIV/AIDs prevalence rates, indicating the need for improved primary education and gender participation in combatting HIV/AIDS in Africa. Geographical location is very much a component of HIV/AIDS risk and that funds should be diverted to match the regions identified greatest need.

Acknowledgements

The article is extracted from a thesis of Ms. N. Kunene. The authors are grateful to Professor Daniel Block (PhD) and Professor Williams Ebomoyi (PhD) of Chicago State University, who reviewed the thesis as examiners and other anonymous reviewers. Additionally, the authors are grateful to the following institutions for providing the main and ancillary data for this study: U.S. Central Intelligence Agency (CIA) World Factbook, United States Agency for International Development (USAID), Environmental Systems Research Institute (ESRI) and Chicago State University (CSU). The authors are indebted to thank CSU's GIS laboratory for software provision and some technical supports.

References

[1] AVERT. "HIV and AIDS in East and Southern Africa." HIV and AIDS information and resources. Available: https://www.avert.org/professionals/hiv-around-world/sub-saharan-africa. [Accessed April 15, 2017].

[2] Lamptey, PR., Johnson, J L., & Khan, M. (2006). The global challenge of HIV and AIDS. *Population Bulletin,* 61(1): 1- 24.

[3] UNAIDS (2015) *How AIDS Changed Everything* IN: Fact sheet 2014 statistics, World Health Organization (WHO), Geneva, Switzerland.

[4] Dixon, S., McDonald, S., & Roberts, J. (2002). The impact of HIV and AIDS on Africa's economic development. BMJ: British Medical Journal, 324(7331), 232-234.

[5] Bell, Clive and Devarajan, Shantayanan and Gersbach, Hans, The Long-Run Economic Costs of AIDS: Theory and an Application to South Africa (October 2003). World Bank Policy Research Working Paper No. 3152. Available at SSRN: https://ssrn.com/abstract=636571.

[6] Drimie S (2002) The Impact of HIV/AIDS on Rural Households and Land Issues in Southern and Eastern Africa, Integrated Rural & Regional Development, Human Sciences Research Council, Private Bag X41, Pretoria, South Africa. Available: from ftp://ftp.fao.org/docrep/nonfao/ad696e/ad696e00.pdf. [Accessed on July 2017].

[7] Kello, A. B. (2017). Impact of AIDS on the economy and health care services in Ethiopia. *The Ethiopian Journal of Health Development (EJHD)*, 12(3): 1-12.

[8] Weiss, H. A., Quigley, M. A., & Hayes, R. J. (2000). Male circumcision and risk of HIV infection in sub-Saharan Africa: a systematic review and meta-analysis. *Aids,* 14(15), 2361-2370.

[9] Westercamp, N., & Bailey, R. (2007). Acceptability of male circumcision for prevention of HIV/AIDS in sub-Saharan Africa: a review. *AIDS and Behavior,* 11(3), 341-355.

[10] Mah, TL., & Halperin, DT. (2010). Concurrent sexual partnerships and the HIV epidemics in Africa: evidence to move forward. *AIDS and Behavior*, 14(1), 11-16.

[11] Kalichman, S. C., Simbayi, L. C., Kaufman, M., Cain, D., & Jooste, S. (2007). Alcohol use and sexual risks for HIV/AIDS in sub-Saharan Africa: systematic review of empirical findings. *Prevention science*, 8(2): 141-151.

[12] Scorgie, F., Chersich, M. F., Ntaganira, I., Gerbase, A., Lule, F., & Lo, Y. R. (2012). Socio-demographic characteristics and behavioral risk factors of female sex workers in sub-Saharan Africa: a systematic review. *AIDS and Behavior,* 16(4): 920-933.

[13] Bicego, G. T., Nkambule, R., Peterson, I., Reed, J., Donnell, D., Ginindza, H., . . . Philip, N. (2013). Recent patterns in population-based HIV prevalence in Swaziland. *PLoS ONE,* 8(10): e77101-10.1371/journal.pone.0077101.

[14] Scott, H. M., Vittinghoff, E., Irvin, R., Sachdev, D., Liu, A., Gurwith, M., & Buchbinder, S. P. (2014). Age, Race/Ethnicity, and Behavioral Risk Factors Associated with Per-Contact Risk of HIV Infection Among Men Who Have Sex with Men in the United States. *Journal of acquired immune deficiency syndromes* 65(1):115-121.

[15] Rezaeian, M., Dunn, G., St Leger, S., & Appleby, L. (2007). Geographical epidemiology, spatial analysis and geographical information systems: a multidisciplinary glossary. *Journal of Epidemiology & Community Health,* 61(2): 98-102.

[16] Abdoulie, J. (2012). *Forty-fifth session of the commission on population and development" item, 4 of the provisional agenda– General debate on national experience in population matters: adolescents and youth*. United Nations Economic Commission for Africa. Addis Ababa, Ethiopia.

[17] Heine, B., & Nurse, D. (Eds.). (2000). *African languages: An introduction*. Cambridge University Press

[18] The World Factbook (2016). Washington, DC: Central Intelligence Agency. Available: https://www.cia.gov/library/publications/the-world-factbook/index.html.

[19] WHO & UNICEF (2013). *Statistical annex explanatory notes* IN: The World Health Report 2004. Geneva, Switzerland: retrieved from http://www.who.int/whr/2004/annex/en/whr04_annex_notes.pdf?ua=1.

[20] United Nation Development Program (UNDP) (2015) *Human Development Report*. New York, United Nation. Available: http://hdr.undp.org/en/data.

[21] Mitchell, A (2005) The ESRI Guide to GIS Analysis, Volume 2. ESRI Press.

[22] Auvert, B., Buvé, A., Ferry, B., Caraël, M., Morison, L., Lagarde, E., . . . Rutenberg, N. (2001). Ecological and individual level analysis of risk factors for HIV infection in four urban populations in sub-Saharan Africa with different levels of HIV infection. *Aids,* 15: S15-S30.

[23] Asamoah-Odei, E., Calleja, J. M. G., & Boerma, J. T. (2004). HIV prevalence and trends in sub-Saharan Africa: no decline and large subregional differences. *The Lancet,* 364(9428): 35-40.

[24] Mishra, V., Bignami-Van Assche, S., Greener, R., Vaessen, M., Hong, R., Ghys, P. D., . . . Rutstein, S. (2007). HIV infection does not disproportionately affect the poorer in sub-Saharan Africa. *Aids,* 21: S17-S28.

[25] Auerbach, J. D., Parkhurst, J. O., & Cáceres, C. F. (2011). Addressing social drivers of HIV/AIDS for the long-term response: conceptual and methodological considerations. *Global Public Health,* 6(sup3): S293-S309.

[26] Buseh, A. G., Glass, L. K., & McElmurry, B. J. (2002). Cultural and gender issues related to HIV/AIDS prevention in rural Swaziland: a focus group analysis. *Health care for women international*, 23(2): 173-184.

[27] Williams Brian G. , Eleanor Gouws, Pierre Somse, Mpho Mmelesi, Chibwe Lwamba, Trouble Chikoko, Erika Fazito, Mohamed Turay, Eva Kiwango, Pepukai Chikukwa, Henry Damisoni, Michael GbounShow (2015), Epidemiological Trends for HIV in Southern Africa: Implications for Reaching the Elimination Targets. *Current HIV/AIDS Reports* 12(2): 196-206.

[28] Voeten, H. A., Vissers, D. C., Gregson, S., Zaba, B., White, R. G., de Vlas, S. J., & Habbema, J. D. F. (2010). Strong association between in-migration and HIV prevalence in urban sub-Saharan Africa. *Sexually transmitted diseases,* 37(4), 240.

[29] Shannon, K., Leiter, K., Phaladze, N., Hlanze, Z., Tsai, A. C., Heisler, M., . . . Weiser, S. D. (2012). Gender inequity norms are associated with increased male-perpetrated rape and sexual risks for HIV infection in Botswana and Swaziland. PLoS ONE, 7(1), e28739.

[30] Oxfam, & AfriMAP. (Eds.). (2010). *Strengthening Popular Participation in the African Union: A Guide to AU Structures and Processes*. African Books Collective.

[31] Mathers, C. D., Boerma, T., & Ma Fat, D. (2009). Global and regional causes of death. *British medical bulletin*, 92(1), 7-32.

[32] Jayaraman S., Johns N., McAnulty J.H., McDermott M.M., McGrath J., Mensah G.A., Merriman T.R., (...), Jasrasaria R. (2012). Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet,* 380(9859): 2095-2128.

[33] Elemo, Ibrahim (2005). *HIV/AIDS, Gender and Reproductive Health Promotion, the Roles of Traditional Institutions among The Borana Oromo Southern Ethiopia*, Addis Ababa Ethiopia.

[34] Medwiser, (2013) *AIDS in Africa - Statistics and facts about HIV in Africa*. Available: http://www.medwiser.org/hiv-aids/around-the-world/aids-in-africa/ [Accessed on August 2017].

[35] Fylkesnes, K., Musonda, R. M., Sichone, M., Ndhlovu, Z., Tembo, F., & Monze, M. (2001). Declining HIV prevalence and risk behaviours in Zambia: evidence from surveillance and population-based surveys. *Aids,* 15(7): 907-916.

[36] Baker J, Quick H, Hullsiek KH, Tracy R, Duprez D, Henry K, Neaton JD. (2011) Interleukin-6 and d-dimer levels are associated with vascular dysfunction in patients with untreated HIV infection. *HIV Med.* 11:608-609.

[37] Fortson, J. G. (2011). Mortality risk and human capital investment: The Impact of HIV/AIDS in Sub-Saharan Africa. *The Review of Economics and Statistics*, 93(1): 1-15.

[38] Brent, R. J. (2013). The economic value of reducing the stigma of HIV/AIDS. Expert Review of Pharmacoeconomics & Outcomes Research 13(5): 561-563.

[39] Weiser, SD., Leiter, K., Bangsberg, D. R., Butler, L. M., Percy-de Korte, F., Hlanze, Z., . . . Heisler, M. (2007). Food insufficiency is associated with high-risk sexual behavior among women in Botswana and Swaziland. *PLoS medicine,* 4(10), e260.

[40] Baral S., Beyrer C., Muessig K., Poteat T., Wirtz A.L., Decker M.R., Sherman S.G., Kerrigan D. (2012) Burden of HIV among female sex workers in low-income and middle-income countries: A systematic review and meta-analysis. *The Lancet Infectious Diseases,* 12 (7):538-549.