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Geospatial Distribution of HIV/AIDS and Earliest awareness in Ethiopia - using Geographical Information System.

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Abstract*: Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome (HIV/AIDS) is one of the main perilous diseases across all over the humankind. This condition is a mainly significant community health problem in Ethiopia and is gradually increasing every year. The present study focuses on the estimation of HIV/AIDS distribution and the possible awareness system in Ethiopia using Geographical Information System (GIS) software tool. The characterization of the geospatial analyses of HIV prevalence in the country as well as description of the possible determination of HIV rate variation can direct surveillance efforts and assist in the development of HIV/AIDS control and prevention programs. The geospatial distribution of HIV prevalence for the periods of 2015, and 2016 were defined. Using GIS technology to georeferenced spatial maps and database was created. Included in the database were sentinel data, socio- economic, demographic data, yearly HIV affected and new infection population data collected from Ethiopia region health centers. Spatial Analysis such as Inverse Distance Weighted (IDW) techniques was used to demarcate HIV affected areas. The spatial distribution map indicates for the last five years HIV prevalence with urban and provincial region having higher awareness then rural areas. However there was an overall trend of decrease in HIV prevalence across the country, coinciding with protective sexual behavior campaigns operating in the country. The results of the HIV prevalence rates since 2015 and 2019 gradually decrease in awareness rates. These results indicate that HIV prevalence in Ethiopia is expected to stabilize or decrease further if current trends continue. The suggest that HIV control programs in the country would require an integrated approach combining HIV prevention messages as well as an understanding of social and cultural interactions between interdependent districts that produce behavioral diffusion of HIV prevalence rates.*

Key words: *Ethiopia, GIS, HIV/AIDS, Prevalence, Spatial distribution.*

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I. Introduction

The primary focus on this research to collect previous information about distribution of HIV and prevalence data, HIV modeling, use of HIV surveillance data and geo-statistics in HIV/AIDS research. There is indication that acknowledges current knowledge on HIV prevalence rates as critical in the estimation of current and future trends in the HIV/AIDS epidemic [1, 2].

Monitoring difficulties presents challenge in obtaining firm information about current HIV levels, spatial trends and the temporal course of the HIV/AIDS epidemic in the country resulting in the ongoing debate and validity of current HIV/AIDS estimates. Several modeling types have been developed for estimating HIV prevalence rates since its discovery two decades ago. The most commonly used approach in modeling HIV is the back-calculation or projection approach. Back-calculation has been used on United States data in many studies [3, 4, 5, 6, and 7] and on United Kingdom data by Isham (1989) to reconstruct past rates of HIV infection, estimate current prevalence of HIV infection, and predict future prevalence of AIDS [8]. These techniques depend on three key components: the assumed incubation period, the observed counts of AIDS diagnoses over time, and a model for distribution of infections [9]. Unfortunately, back-calculation techniques are known to be sensitive to the incubation period used [4] and assumes that adequate data are available for accurate estimation and that incubation does not contrast across populations [6,7]. In areas with rich reliable comprehensive HIV data, such techniques do provide good insight into past, current, and future HIV prevalence rates. However, in developing countries, monitoring difficulties united with inadequate assets often-present

challenges in obtaining consistent information on HIV/AIDS. As such, "traditional back-calculation methods cannot be used to model HIV epidemics in developing countries due to the paucity of reliable information on the incidence of HIV/AIDS [10].

A more direct technique to predicting AIDS cases into the future has been obtained by fitting a model to the incidence curve and extrapolating into the future [11, 12]. Extrapolation has been a good predictor of HIV/AIDS prevalence into the near future, but has not worked well for longer forecasts. Specifically, there have been clear changes in HIV/AIDS trends with a decreasing rate of growth being balanced by the number of deaths and HIV incidence has reached a plateau in some risk groups. A recent trend has been the use of HIV dynamic transmission models in trying to understand the importance of heterogeneity in risk behavior [13, 14], and patterns of sexual partner choice [15, 13, 16, 17]. Though, the models allow for heterogeneity in risky sex rates, they assume that sex partners are selected at random from a larger population [14, 1, 18, and 19]. Also "these models depend on critical but unverifiable assumptions and contain several unidentified parameters" [20]. Although these models have provided invaluable information pertaining to new infection rates in ce1iain groups and populations particularly in developed countries, the practical drawbacks of these approaches have prevented wide scale implementation mainly in mounting countries where HIV data acquisition still remain a challenge. As a result, not only has Sub-Saharan Africa remained an epicenter of the global AIDS epidemic, but we also know very little about current prevalence levels and trends in the outbreak due to lack of comprehensive epidemiological HIV/AIDS data. Furthermore, there has been little attempt to col1ect these models with geographical dimensions and HIV transmission, and how such linkages affect the efficacy of HIV prevention programs.

II. Study Area

Ethiopia is situated in the Horn of Africa Fig1. It is surrounded by Eritrea from the north, Djibouti and Somalia to the east, Sudan and South Sudan in the direction of the west, and Kenya toward the south. Ethiopia has a high innermost highland that varies from 1,290 to 3,000 m (4,232 to 9,843 ft) over sea point, with the utmost mountain reaching 4,533 m (14,872 ft).

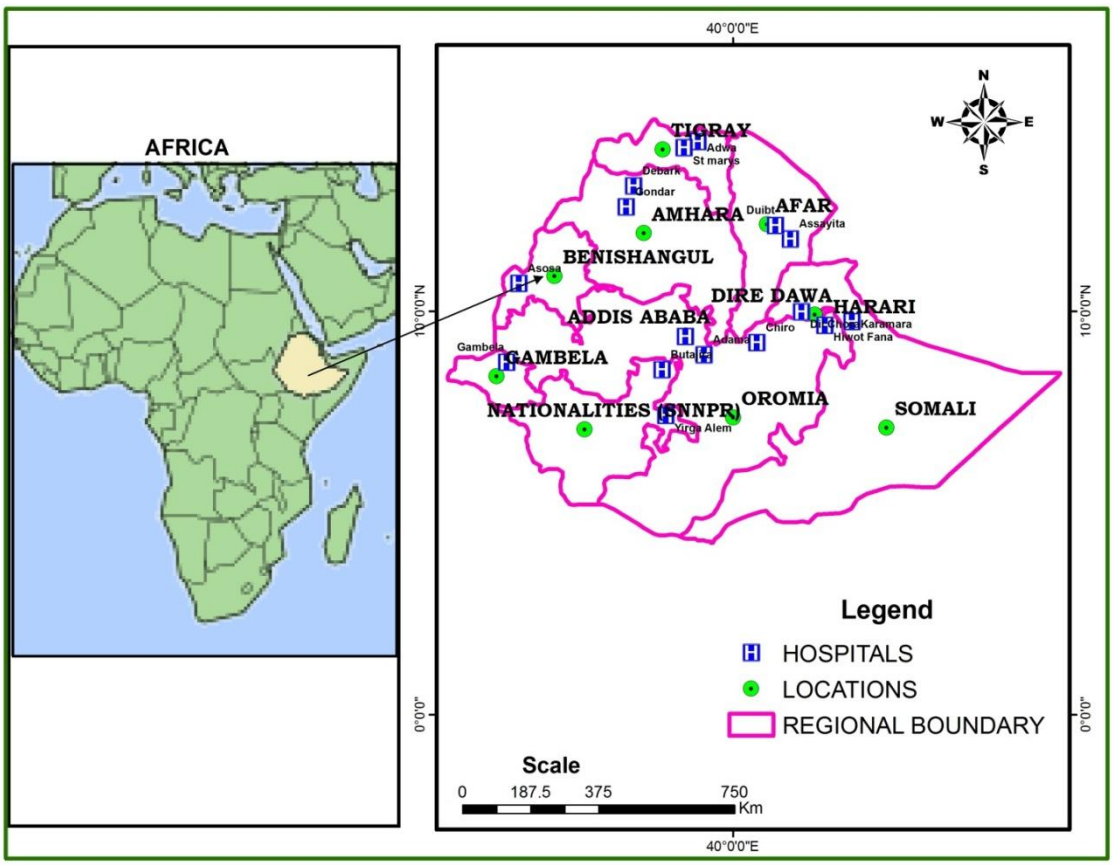

Fig. 1 Study Area Map

III. Methods

The methodology involved the application of Geographical Information System (GIS), spatial econometric models in GeoData and UNAIDS' Estimation and Projection Package (EPP) techniques to characterize the geographical distribution of HIV prevalence in Ethiopia, predict current and future HIV prevalence, and to examine spatial effects. First, interpolation of HIV prevalence and HIV mean estimates per year was undertaken using Arc info 9.2 software. A database was created that would allow for computation and visualization of patterns from the data. From this data, it was possible to produce a sequence of continuous smooth maps characterizing the spread of HIV as well as the production of mean HIV prevalence rates per year. Lastly, the related attributes in GIS were then imported to GeoData to determine whether the data exhibit spatial dependence.

When interpolating a surface from point coverage, Arc-Map provides three different methods of interpolation, Inverse Distance Weighting (IDW), kriging or Spline. In this study, a deterministic technique IDW and kriging: Arc-GIS 9.2 (ESRI, Redlands. CA) was used to interpolate point based HIV surveillance data into continuous smooth HIV prevalence maps for two years, 2011, and 2016 and projection 2021.Instead IDW calculates the constraint importance at an unmeasured point using a distance-weighted average of data points. It uses only the values of the known sample points to calculate approximately unknown points of interest. The weight consigned to a particular value reduces as distance from the prediction site increases, thus sample data adjoining to the unmeasured point contribute additional to the calculated average (Toblers' first law of geography). Additionally, using the squared distance also reduces the number of calculations making the IDW approach effective for reducing the amount of computation needed to produce an estimate. This is of particular importance in a study like ours that uses a tiny sample size of data. Consequently, IDW is an exact interpolator, which means theoretically it should produce the exact value given at a sample point.

IV. Results and Discussion

HIV Spatial Distribution in 2011

From the geospatial analysis interpretation, the HIV distribution data of 2011 reports 25 % increased distribution in the regions of Addis Ababa, Tigray, Diredawa, Harari and Gambela, 15 -25 % in Oromia, SNNPR, Benishangul, Amhara and Afar regions and the least 0 – 5 % in Somali region the lowest among all the regions as revealed in Figure [21].

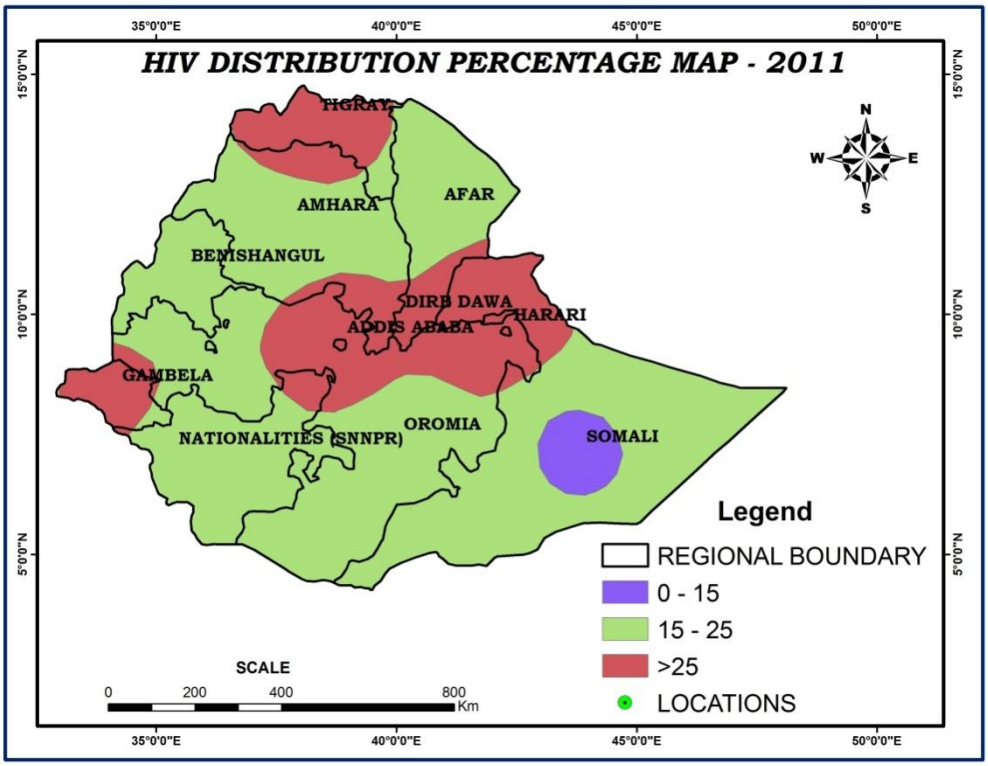

Fig 2. HIV Spatial Distribution Percentage Map 2011

This report presents the need for higher alert, awareness and protection measures among all the regions except Somali region. The possible reasons for the results could be due to the effect of truck routes/drivers on

HIV prevalence as per recent studies [23, 24]. A chance of contracting HIV is largely affected by Truck driving instances. The reasons are due to the prolonged nonexistence from home and families increasing the chances of indulging in risky behavior. The more likelihood of passing by is through truck drivers through major stops where the operating hours of female sex workers. This action leads to contraction of disease leading to passing it home to their life partners or other female companions. Added to this there is absence of information on HIV/AIDS and non-usage of condom which is common among sex workers and truck drivers [24,25].Although there is a sharp increase in the percentage of people on usage of condom without knowledge and increase in access, the decrease in number of people using condoms is indicated in 2011.

HIV Spatial Distribution in 2016

The HIV distribution 2016 data from geospatial interpretation reports that there is more than 15 % reduction rates in the regions of Oromia, SNNPR and Amhara, in the range of 10-15 % in Somali, Harari, Addis Ababa, Gambela and Benishangulthe and the lowest range is covered in Tigray and around villages when compared to other regions as exposed in Figure 3. Also in the same year, a substantial geographical variation in the prevalence of HIV is cautioned in Ethiopia. More prevalence rates were observed in urban areas than rural.

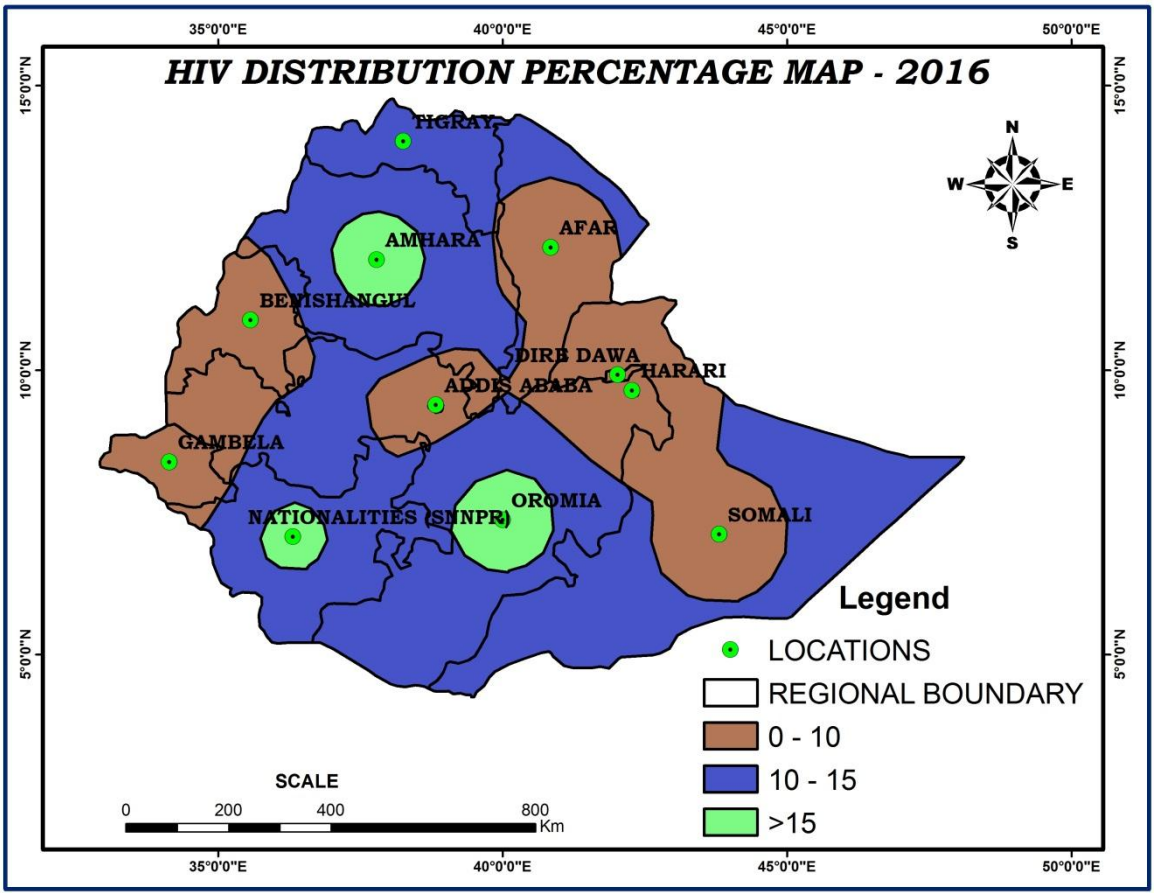

Figure3. HIV Spatial distribution percentage Map 2016

HIV Prevalence

The prevalence of HIV is highest in 2011(Figure 4) compared to rural areas there is more distinct prevalence in town areas and in provincial headquarters regions. Although there was slight lowering in 2016 with clusters decreasing to 0-1 percentage covered by Somali, Sothern Oromia and Northwestern Tigray regions, the size of clusters seems to have increased especially in Central Amhara, Oromia and SNNPR. The continuous decline in prevalence rates was observed between2011 and 2016. There is a higher prevalence of HIV in 2011 in Western, Central and two Eastern districts forming a new cluster in Luapula's provincial district of Mansa. More pronounced decrease by 2016 is recorded both countryside and town areas. Compared to 2011 data there is more prevailing among Copper belt district and also increasing trend was observed Figure. 5. [21].

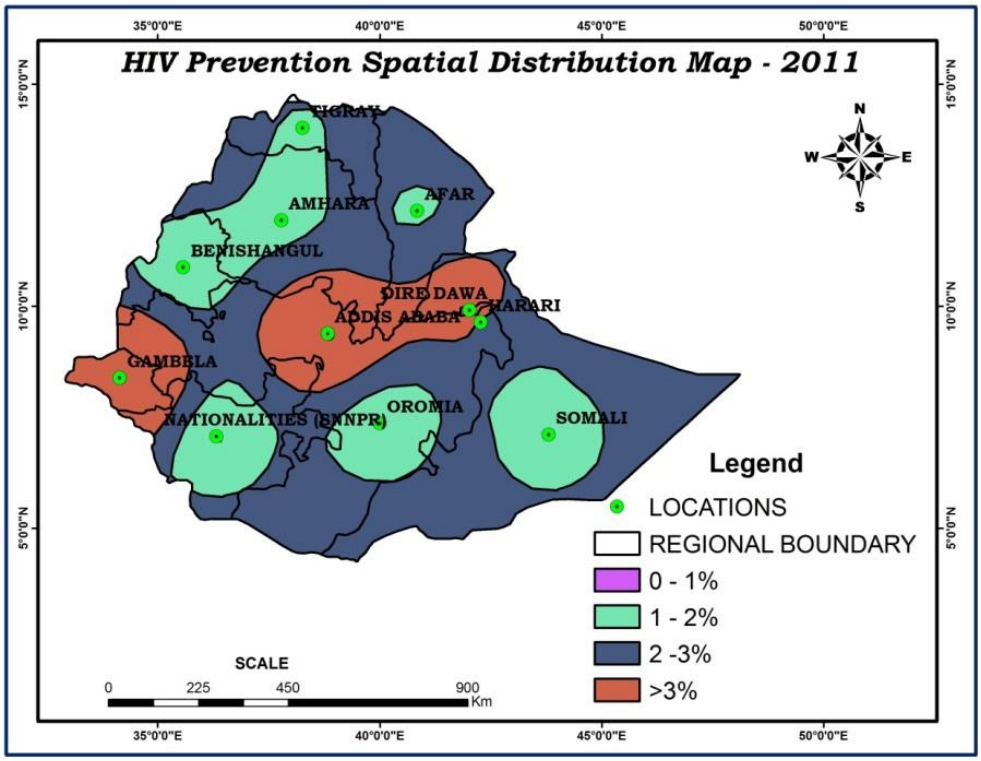

Fig. 4 HIV Prevention Spatial Distribution Percentage Map 2011

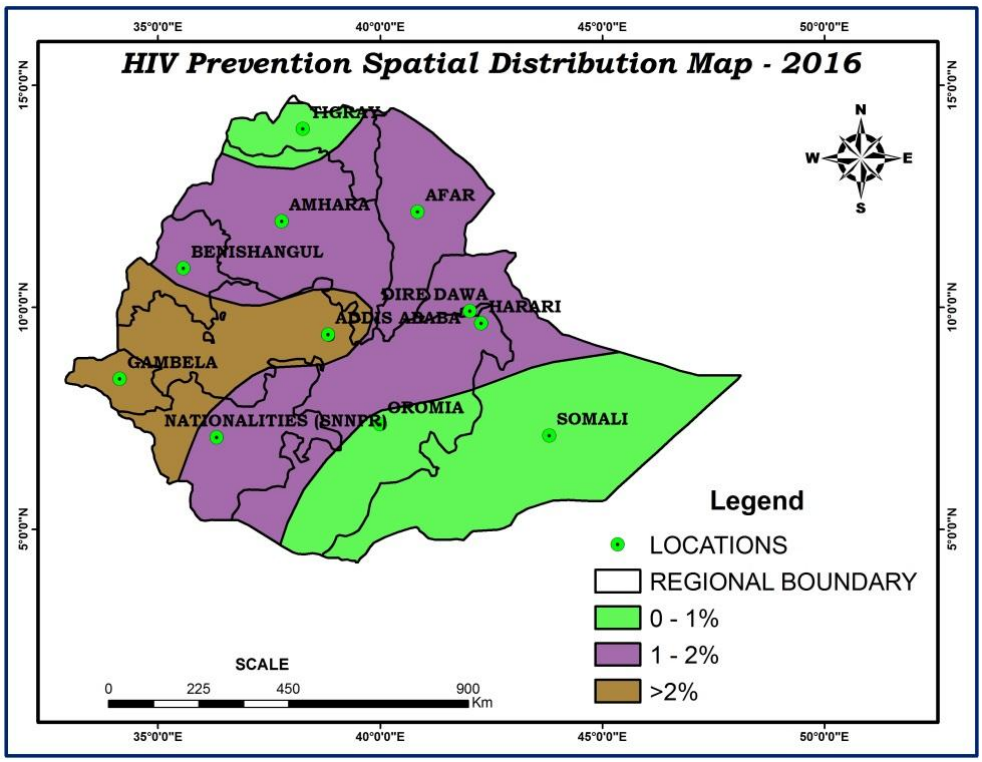

Fig. 5 HIV Prevention Spatial Distribution Percentage Map 2016

In summary, there is a substantial geographical variation in HIV prevalence in Ethiopia. Urban areas are more prone to HIV than rural areas have high prevalence rates. In spite of this, I-III prevalence is declining across the country. The decline is more prominent in urban areas than in rural areas.

The Women and Men HIV ratio

The analysis of men and women average HIV distribution rates still show evidence of clusters in urban areas Figure. 6 and 7. This result holds good whether the spatial pattern is assessed by the interpolated IDW maps or with mean averages obtained from zonal statistics. It can be observed from the maps that the spatial pattern for 2016 is spread across the country with a more distinct west-east and north-central trend. Then compare with women and men HIV ratio is higher in 2016[26].

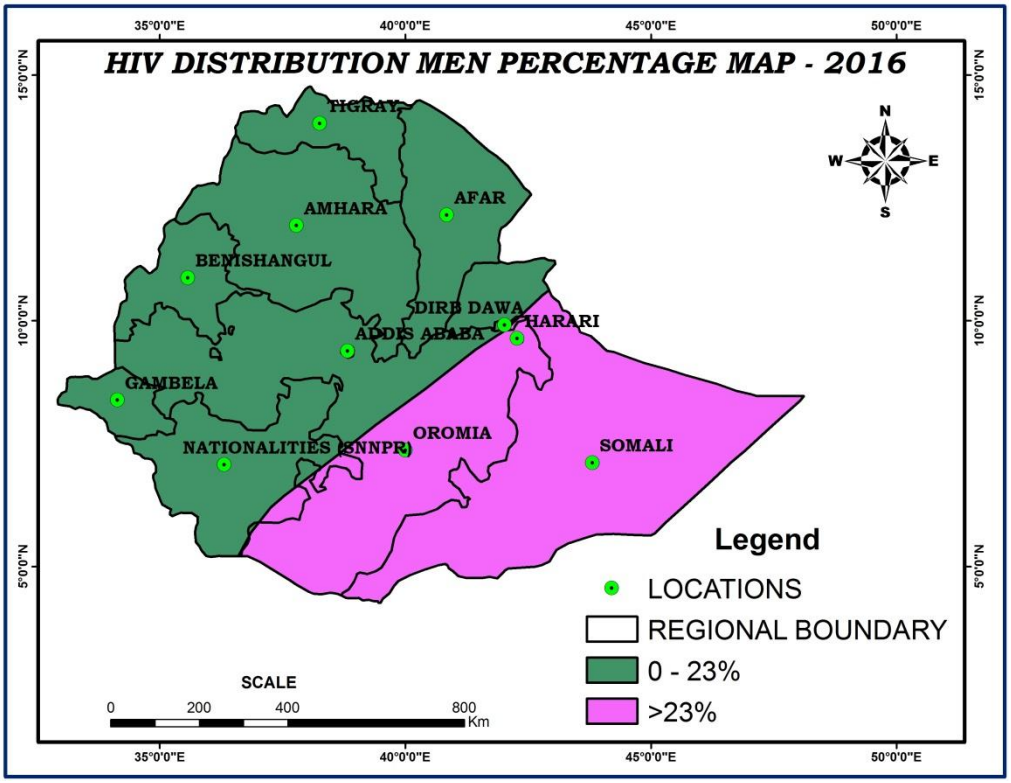

Fig. 6 HIV Men Spatial Distribution Percentage Map 2016

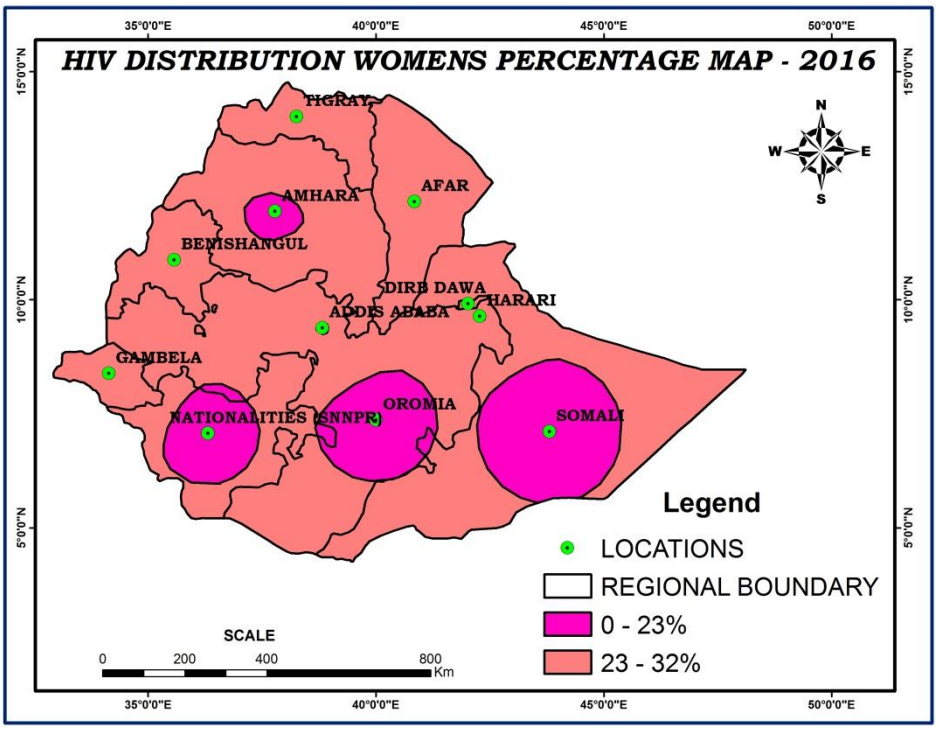

Fig. 7 HIV Women Spatial Distribution Percentage Map 2016

HIV/AIDS-Related Knowledge

As of 2016, almost all women and men in Ethiopia had heard of HIV/AIDS. Women's knowledge of AIDS has increased since 2011 when only 90% women age 15-49 had ever heard of HIV. Knowledge of AIDS avoidance methods is not as high. Presently only 56% of women know that AIDS can be not permitted by using condoms and only 65% know that AIDS can be prevented by restricting sex to one uninfected partner. Men's awareness of the two main avoidance methods is much higher; 82% of man knows about using condoms and 74% of man knows about restricting sex to one spouse. Knowledge of AIDS prevention methods is uppermost among women and men in town areas, those with secondary or higher education, and those from the richest household. Women and man existing in Tigray are for the most part expected to know the two prevention methods, whereas those in Somali are slightest knowledgeable and the AIDS knowledge map shown in Figure. 8 and 9[26].

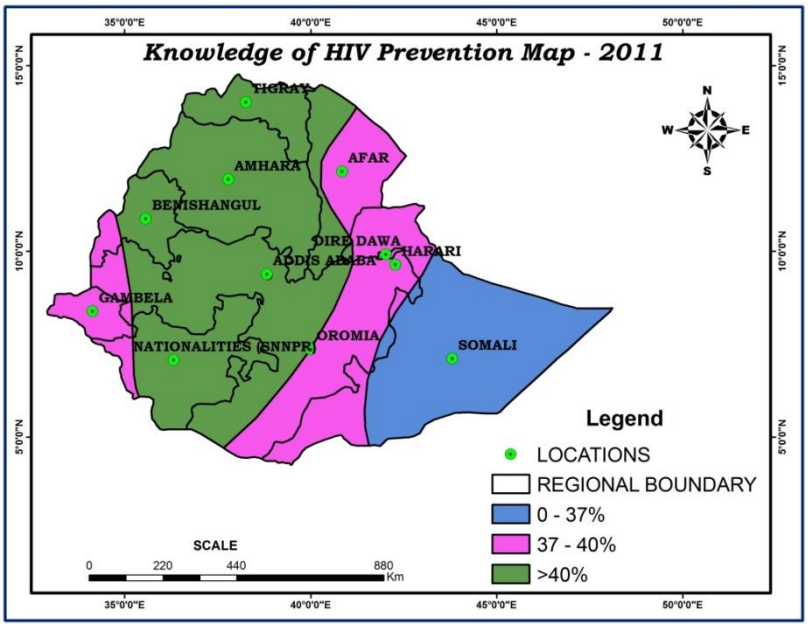

Fig. 8 HIV Knowledge Spatial Distribution Percentage Map 2011

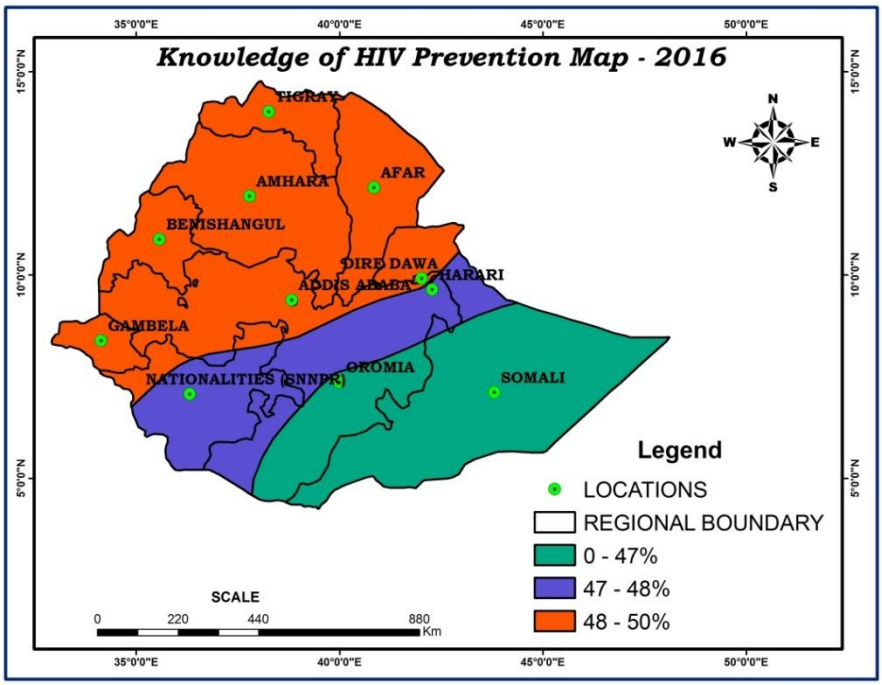

Fig. 9 HIV Knowledge Spatial Distribution Percentage Map 2016

The nature of the observed spatial patterns (declining rates) is reflective of protective sexual behavior campaigns that are operating in the country. This could also be an indication of the fact that there are fewer new infections than the number of people who are dying from AIDS. Similarly, HIV/AIDS education and prevention programs are predominantly located in urban areas than rural areas especially in region around the Amhara. Urban areas have more sentinel clinics that often are well staffed and equipped than rural areas making sentinel surveillance in urban areas a little better than that of rural clinics.

Furthermore, in both rural and urban areas, HIV/AIDS programs in the country have been reported not to target the high-risk and vulnerable populations such as women and young girls. Most HIV/AIDS programs offer to provide HIV/AIDS education, treatment and care to all. Since programs are not designed for specific groups, gender or age, that in need who may seek to benefit or participate may otherwise be excluded. This could be the reason behind the high prevalence rates among women and young girls (18%). This is further compounded by low literacy rates among females, poverty levels and fear of stigmatization [26].

Results from spatial regression models and maps generated with inverse distance weighted interpolation show that only four years were used in the study: 2011 and 2016. Since there was considerable variation in the number of data that were replied for each consecutive year at each clinic from 2005, 2011 to 2006 only the three years were selected for further analysis. There is a body of literature pointing to the fact that datasets with a lot of missing values have problems that make inclusion of such datasets in a GIS or Spatial regression model inappropriate. While it is possible to predict and forecast HIV prevalence using interpolation, the conditions under which interpolation will produce efficient predictive and forecasting power of HIV prevalence are quite limited and are unlikely to be met in practice. One peculiar problem is that HIV is still not a reportable condition in Ethiopia as well as other Sub-Saharan countries [26].

V. Conclusion

Analysis of spatial patterns of HIV for the four years under study 2011 and 2016 reveal a gradual declining trend in HIV prevalence across the country. This result holds whether spatial pattern is assessed using inverse distance weighting or by mean HIV prevalence obtained from zonal statistics as illustrated by Figures 2 and 3. It can be seen from both IDW and mean HIV prevalence maps that HIV prevalence is highest in 2011 and is more pronounced in urban areas and in provincial headquarter districts than in rural areas. One possible explanation of the observed high prevalence in urban and provincial regions could be due to high population density in these areas as well as existence of most services. The result has been a rural/urban drift coupled with high unemployment and perhaps indicating higher levels of risk sexual behaviors. The high rate of urban drift may have contributed to high HIV prevalence rates in these areas since urban areas have the highest prevalence rates. Unfortunately, the patterns and number of those moving to cities is unknown. Nevertheless, results suggest that responsible sexual behavior messages should be targeted to both rural and urban residents so that as people migrate from rural to urban areas, they would already have had the information needed to protect them from contracting the deadly disease.

Provincial regions exhibiting high prevalence rates are points of interest and they include, Oromia and Amharain Central province. These areas provide an opportunity to examine the role played by social amenities that exist in urban areas versus rural areas. Clearly, most socio-economic exchanges in Ethiopia take place in provincial regions. Provincial regions tend to have political influence, good infrastructure as well as social amenities such as night clubs, hospitals and banks. As a result, people from other districts come to these areas every month-end to collect their salaries giving them an opportunity to engage in more leisure activities including drinking, bar hopping and sexual relations. Thus, high prevalence rates in these areas may have resulted from exchanges among humans and the provincial districts. Finally, the conclusions regarding the spatial patterns of HIV prevalence in Ethiopia were drawn using sentinel data that were obtained from testing pregnant women attending designated clinics from years: 2011 and 2006. It is necessary to validate these conclusions with data obtained from demographic health surveys. Particularly, data on prevalence among different age groups as well as locales as it would provide further evidence to validate the conclusions above. In addition to investigating prevalence in different sub-populations, it would be useful to evaluate the role of human migration within and between regions. Analysis of the patterns of human migration in relation to HIV transmission would assist in explaining the high prevalence rates in urban and provincial districts. Specifically, the nature and scale of clustering of prevalence rates around border districts would better be explained using both international and country migration patterns.

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