# Two Dimensions Analysis of HIV Prevalence in Africa: From Geographical and Temporal Understanding

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**Abstract:** HIV/AIDS (Human Immunodeficiency Virus) / (acquired immunodeficiency syndrome) is one of the most common causes of illness and mortality in sub–Saharan Africa, accounting for about one-third of all cases. Over the years, there have been variations in the geographical distribution of HIV prevalence. High levels of poverty, civil and political turmoil, and a lack of education have all contributed to the deterioration of the public health infrastructure. In addition, there are significant geographic variances at the district level, as previously stated. In addition to a significant lack of age- and location-adjusted prevalence maps that could be used for targeting HIV educational programs and efficient resource allocation to higher risk groups, which is influenced by socioeconomic, environmental, and cultural factors, there is a significant lack of data on the prevalence of HIV.

## 1. Introduction

Since the early 1980s, the emergence and awfully spread of the human immunodeficiency virus (HIV) and acquired immune deficiency syndrome (AIDS) have caused alarming concern among populations from sexual and reproductive healthy aspects all over the world, particularly in sub-Saharan-Africa, which is home to 70% of the HIV-infected population worldwide. 1Southern Africa, and specifically the Southern African Development Community, is the most severely afflicted area in the world, according to the World Bank. [1] Sub-Saharan Africa is plagued by HIV/AIDS, which is the main cause of illness and death in the region. [2-3].

Since the mid-2100s, the use of antiretroviral therapy has increased rapidly and the mortality rate has decreased, resulting in 34% of infected people in East and Southern Africa, and 60% living with HIV in central and west Africa4 without treatment currently, and HIV/AIDS remains the leading cause of death in sub-Saharan-Africa.[2]

The world community has called for an end to the HIV pandemic on an almost constant basis. In the context of Millennium Development Goal (the battle against HIV/AIDS, malaria and other illnesses), the following aim was included: "Stop the spread of HIV/AIDS by 2015 and start working on reversing it." [4] More recently, Sustainable Development Goal [3] (SDG 3) was established (Ensure healthy lives and promote well-being for all at all ages) [6] expressly asks for the abolition of the pandemic by the year 2030. Fast-track plan for the Joint United Nations Programme on HIV/AIDS (UNAIDS) has established diagnostic and treatment targets [7] for 2020 and 2030, with the overall objective being to substantially reduce new HIV/AIDS cases and deaths by 2030. Despite these objectives, a recent analysis of the condition of HIV revealed that the world is still far from achieving its aim of eradicating the HIV pandemic. [8] Apart from that, global HIV expenditures in Sub-Saharan Africa reached their peak in 2013 and have subsequently dropped, [9] possibly compromising current HIV initiatives. To get the world back on track in terms of bringing HIV transmission under control, both in Sub-Saharan Africa and worldwide, renewed dedication and new instruments are necessary. Local statistics on the present prevalence of HIV are an example of such a tool since they allow for more effective targeting of resources and interventions.

## 2. HIV prevalence from temporal manner

According to UNAIDS estimates, from 2000 to 2017, 15 out of 47 countries had an increase in projected HIV prevalence (Figure 1a). Beginning in 2000 2017, they used the Accurate and Transparent Guidelines for Reporting Health Estimates (GATHER) to estimate HIV infection rates among adults aged 15-49 in five 5km grids in 47 countries in sub-Saharan Africa. The estimates are based on annual resolutions and are collected in accordance with collection guidelines. [10].

The spatially and temporally explicit generalized linear mixed-effects models are commonly used for estimating HIV prevalence.

$$Yi,\ t \sim \text{binomial}(pi,t,Ni,t) \quad \text{Yi,t}\sim\text{binomial(pi,t,Ni,t)} \tag{1}$$

$$\text{Logit}\ (pi,\ t)=\beta 0+\boldsymbol{\beta} 1Xi,t+\gamma c[i]+Zi,t+\epsilon i,t+(\beta 2+Ui)I\text{ANC} \quad \text{logit(pi,t)=β0+β1Xi,t+γc[i]+,t+ϵi,t+(β2+Ui)IANC} \tag{2}$$

$$\gamma c[i] \sim \text{normal}(0,\sigma 2\text{country}) \quad \gamma\text{c[i]}\sim\text{normal(0,σcountry2)} \tag{3}$$

$$Zi,t \sim \text{GP}(0,\Sigma\text{space}\otimes\Sigma\text{time}) \quad \text{Zi,t}\sim\text{GP(0,Σspace}\otimes\Sigma\text{time)} \tag{4}$$

$$\epsilon i,t \sim \text{normal}(0,\sigma 2\text{nugget}) \quad \epsilon\text{i,t}\sim\text{normal(0,σnugget2)} \tag{5}$$

$$Ui \sim \text{GP}(0,\Sigma\text{space}) \quad \text{Ui}\sim\text{GP(0,Σspace)} \tag{6}$$

where ~ means "distributed". We use binomial variables to express the number of HIV-positive people (Yi,t) in the sample (Ni,t) for a given position I and year (t) as binary variables. In this model, logit-converted HIV prevalence (pi,t) is described as regional intercept (0), covariate effect (Xi,t), national random effect (c [I]), geographically and time-dependent linear combinatorial random effect (Zi,t), and uncorrelated error terms or nugget effect (I, t)(I, t). ANC sentinel surveillance is considered a bias in measuring HIV prevalence in the wider adult population, as it includes only pregnant women participating in ANC, not all adult males and females [11-12]. In the case where the data included in our model are obtained by ANC sentinel monitoring (IANC = 1), we include a fixed term (2) representing the average deviation over time and a spatial variation term (Ui) recording the change in the amplitude of the different position deviations. In this model, the spatial and time-dependent random effects (Zi,t) are modeled as a Gaussian process with a mean of 0 and a covariance of m, atrix given by the Kronecker product of the spatial matrix covariance function (space) and the temporal first-order autoregressive covariance function (time) and the spatial matrix covariance function (space). Ui is modeled as a Gaussian process with a mean of zero and a spatial parameter covariance (space) with a mean of zero. A sensitivity analysis was performed to determine the sensitivity of the model to the hyper-prior specification. The results of these analyses are detailed in Section 4.2 of the Supplementary Information.

To estimate the continuous spatial and spatio-temporal Gaussian random fields with more reliability, model described above was modified to fitted in R-INLA [13] using the stochastic partial differential equation [14] technique (Ui and Zi,t, respectively). A unique model was fitted for each of the four areas due to computational limitations and to account for regional variations in the association between the variables and HIV prevalence as well as changes in the temporal and geographical autocorrelation in HIV prevalence. We created 1,000 draws from the estimated joint posterior distribution of all model parameters for each fitted model, and we used these to build 1,000 draws of pi,t, with IANC set to zero, for each fitted model. In order to examine model performance and to compare among a number of different models that employ variables, ANC data, and polygon data in a variety of ways, fivefold cross-validation was performed on the data.

A rise in HIV prevalence was found in 22.9 percent of first-level administrative subdivisions (located in 24 countries) and 25.0 percent of second-level administrative subdivisions (located in 28 countries) in sub-Saharan Africa, according to the group's estimates at the subnational and local levels (Fig. 1b, c; the posterior probability of an increase). However, broad regional trends were evident, even as the presence of local heterogeneity; the largest increases were found primarily in coastal countries in southern Sub-Saharan Africa, while the largest decreases were found primarily in a band stretching from Botswana to Kenya and in the Central African Republic. Although the direction and change rate from opposite sides of international borders differed significantly in some places (for example, between Botswana and South-Africa), transnational patterns were also evident; for example, the region that encompassed eastern South Africa and southern Mozambique, in other places, transnational patterns were not apparent.

It is estimated that HIV prevalence is increasing or decreasing in 16 countries (34 percent) in first-level administrative subdivisions, whereas HIV prevalence is estimated to be decreasing or increasing in the remaining countries (the remaining countries are in second-level administrative subdivisions) (figure 1b). At the second administrative level, this is true for 20 nations (42.6 percent), and at the grid cell level, this is true for 28 countries (59.6 percent) (Figure 1c, d). In some of them, the disparity is significant in magnitude. According to the World Health Organization, the HIV prevalence rate in Mozambique's Manica district declined by 5.8 percentage points (0.2-11.4 percentage points), however the HIV infection rate in the Guija district grew by 17.2 percentage points (0.2-11.4 percentage points) (9.3-21.1 percentage points). Prevalence reduced by 14.3 percentage points (10.3-18.2 percentage points) in Zimbabwe's Chegutu area, whereas the prevalence grew by 0.6 percentage points (4. 1 to 5.0 percentage points) in the Beitbridge region, according to the same study.

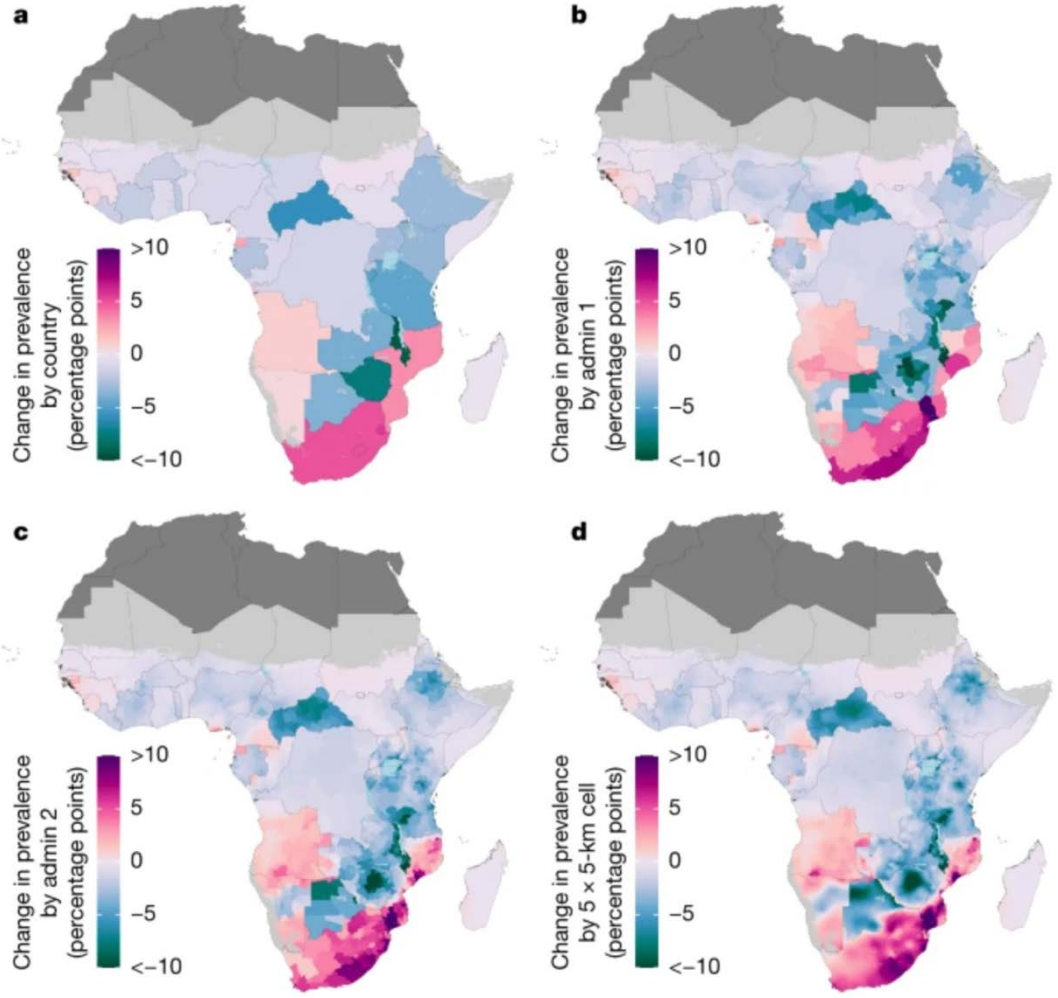


Figure 1. Change in HIV prevalence in adults aged 15–49 from 2000 to 2017.

Changes in HIV prevalence in any one region between 2000 and 2017 are seldom linear or necessarily continuous in the same direction over time.

## 3. Geographical changes in HIV prevalence

A considerable rising trend in the rate of human immunodeficiency virus (HIV) infection has been seen in South Africa over the last many years. A large number of studies have shown that young individuals, especially young women, are more vulnerable to infection. [17-21] According to the formal study, data from the National Household Survey on HIV Infection and Sexuality Among Young People Aged 15-24 years, which was performed in 2003, was used to compile the findings.[5] A total of 714 enumerated areas (EAs) were randomly chosen and stratified by province and enumerated regional type, with the 2001 National Population Census serving as a basis for sample selection. In each EA, one eligible youngster is chosen at random from among the families that have been sampled. Some participants will be asked to answer questions about HIV-related risk behaviors and to submit oral fluid samples for testing for anti-HIV antibodies. Others will be asked to provide blood samples for testing. [18] All HIV tests were performed in an anonymous manner; however, they were linked to the questionnaires. Earlier this year, a more in-depth study was published on the methods and findings of this inquiry. [19].

A survey was conducted on the following census variables: the proportion of black African residents, the proportion of urban areas, the proportion of unemployed persons aged 1720-64 years, population density, the proportion of informal households, the proportion of non-schooling population aged 19-24, the proportion of households without electricity, the proportion of people aged 20-24 who did not live with their partners, the proportion of heads of household under 19 years of age, and the proportion of people aged 21-25 who did not live with their partners. Because of the low number of factors available in the census, all variables that were found to be linked with HIV infection in the survey were chosen from other research or speculatively as prospective explanatory variables, given the small number of variables available in the census.

A extended geostatistical spatial model based on the Markov Chain Monte Carlo (MCMC) simulation was used to estimate HIV prevalence at sampling sites (EAs) in order to identify relevant covariates in the census, which was then used to identify important covariates in the census. Bayesian kriging was used to make spatial predictions of HIV prevalence in a grid of all cartographic locations (pixels) in a grid of all cartographic locations (pixels). Detailed information on this technique may be found in the Annex. Spatial modeling and spatial prediction were carried out with the help of the software package Geographic Rglm, which is part of the statistical software program R. [25]

The incidence of HIV varies greatly from one region to the next. Compared to other provinces, the Western Cape has the lowest rural inland areas, with much higher levels in the north-west of KwaZulu Natal, the southern Mpumalanga province, and the eastern Free State province.

## 4. Discussion

The relationship between HIV risk and various socio-economic factors may have varied consequences and causes depending on the indicator. On an individual level, those with a lower work position, for example, may be denied access to protections and health care. At the same time, highly educated professionals may have more understanding about health promotion and improved adherence to preventative strategies — while higher-earning professionals may be at greater risk of HIV infection as a result of participating in risky sex practices.

Several variables, notably the high amount of cross-border commerce trafficking and the large number of licensed and undocumented migrants, may be attributed to the comparatively high prevalence of HIV infection in the country. When compared to prior years, the results of Survey [9] in 2004 revealed an increase in AIDS awareness in Francistown and Maharapi. The usage of condoms, on the other hand, is greater in the southern hemisphere than in the northern hemisphere. It should come as no surprise that the prevalence of sexually transmitted diseases (STIs) in the southern region

of Botswana is lower than in the northern region. However, according to the survey, the consistent use of condoms by frequent partners is often lower than the use of condoms by short-term or temporary partners.

There are two halves to South Africa: the eastern half has a high prevalence of HIV/AIDS and the western half has a low incidence of HIV/AIDS. Women in western KwaZulu Natal, areas of southern Mpumalanga, and the outskirts of Durban have much greater rates of lesotho and Eswatini than in the rest of the country. Males are more likely than women to be affected by HIV in urban and coastal regions of KwaZulu Natal, although the incidence is much lower among men than among women. It is unknown why the prevalence of men and women in this age group varies so much in locations where the prevalence of men and women is at its highest. One reason for this could be that the average male partner of the female partners surveyed was four years older than the female partners surveyed and thus frequently fell outside the age range of the survey, or that many of their partners were migrant workers who worked in areas with better job prospects than their home country.[10]

In general, young women are about three times more likely than young males to be at risk of developing HIV than young men. [10,17]

## 5. Limitations

Africa is covered by a tropical rainforest, which fosters the growth of germs. Viruses that occur in other creatures will infect humans after being hunted by locals. This is particularly true for certain Africans who consume raw meat. Among Africa, the HIV virus is prevalent in monkeys. Africans chase monkeys because to a lack of awareness or a lack of idea of poultry. They are particularly prone to HIV infection. Simultaneously, Africa is geographically vast, and when HIV spreads across several avenues, it has a significant impact.

### 5.1 Impoverished

Regarding Africa, our most subjective image is one of poverty and backwardness. Because some individuals did not get gender education as children, along with a lack of hygienic awareness, there was no guarantee of safety while living as a couple. Additionally, their surroundings are very unclean and untidy from the moment they are born, which is perfectly logical in their minds, and they are unaware that such an environment would also result in the proliferation of certain illnesses. Additionally, there is a shortage of medical care and medication, as well as an inability to purchase pharmaceuticals, which will contribute to the spread of AIDS. Even though international assistance is now available, local health conditions and hospital facilities remain inadequate, and thus there are still many people who do not pay close attention to hygiene habits, such as eating raw meat, pilaf, and other living habits, which introduce a large number of bacteria into the body, plus some parts of Africa after death, the body is directly placed on the open ground until it rots, plus the local flora and fauna. The second is that Africans' private lives are more chaotic; they not only regularly change partners, but also search for sex workers, and the most concerning aspect is that there is no protection whatsoever while interacting with these sex workers, which facilitates the spread of AIDS.

### 5.2 Private life is disorganized

In AIDS-affected areas of Africa, local people, men and women alike, have multiple sexual partners; the average number of sexual partners per person is even seven; and even some African men and women, even if they are unaware, will engage in sexual relations during casual conversation; and even if they are aware that they are infected with AIDS, they are not concerned, because the disease is not imminent; as long as effective treatment is taken, they can continue to live for a long time. It is exactly because of this chaotic lifestyle and lack of attention that AIDS is not adequately managed in the local region.

As far as we know, there is no complete and comparable set of estimates of HIV prevalence at sub-levels in sub-Saharan Africa. Furthermore, for most countries, the available estimates are one year and use a single source of data.

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