Spatial Epidemiological Pattern of HIV

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Abstract

This paper aims to explain the prevalence rate of Human Immunodeficiency Virus worldwide. The data matrix of CIA World Fact Book (2015) was used through new methodologies enclosed in fractal statistical analysis and data mining. After analyzing the data sets of different countries, a pattern was observed regarding the spatial epidemiological spread of HIV. Fractal statistical analysis revealed that the dynamic expansion of the virus is towards the northeastern hemisphere. Data mining further exposed that the spread of HIV follows the pathway along the coastal areas, specifically, following the trading system of the different countries. Moreover, being situated in the tropical environment can contribute directly and indirectly to the HIV prevalence through climate temperatures and agricultural productivity. Through these findings, it is then posited that the HIV incidence is not merely due to sexual activities rather it is also sensitive to the environmental characteristics of different countries.

Keywords: Human Immunodeficiency Virus (HIV), spatial epidemiology pattern, Nightingale's environmental theory, fractal statistical analysis, data mining.

Introduction

The number of HIV/AIDS fatality worldwide has caught the world's attention. It has affected over 78 million people and has caused 39 million deaths globally (Avert.org, 2015). This epidemic will continue to challenge most of the countries in their endeavor to reduce HIV impact. In fact, different studies were popularly funded by the different international organizations to understand the pathogenesis and the spread of the virus. In spite of this, there is still an increase in cases among youth and men (CDC, 2016). The increase of cases can be understood by reviewing the HIV epidemiological surveillance data at the global level.

Epidemiology is defined by CDC (2012) and WHO (n.d.) as the distribution and determinants of health-related states or events in specified populations. The National Institute of Allergy and Infectious Disease (2015) acknowledged the importance of epidemiologic tools as a means to understand the patterns of transmission. In application, Osmond (2003) observes that trends in the characteristics of HIV/AIDS cases provide significant information about how the epidemic is changing over time. Also, it is assumed that diseases do not occur randomly, but follow predictable patterns that can be studied (The John Hopkins and the International Federation of Red Cross and Red Crescent Societies, 2006). Thus, the epidemiological approach is a useful

tool in understanding diseases like HIV and how it is transmitted even if there is still no cure discovered.

Various studies have identified significant variables on the spread of HIV but only a few researches have explored on the hidden dimensions of the HIV cases. No attempt has been made to determine the deviations of HIV prevalence rates from its natural to fractal state. For the purpose of this paper, the natural state can be characterized as the concentration of HIV in the country of origin. Also, this is a state where environmental implementation and control exist. The fractal state, on the other hand, is described as the spread of HIV towards neighboring countries. In the fractal state, there is limited to no environmental measures such as migration policies, policies on sexual networks, poor health, and environmental condition.

This paper will explore the hidden dimensions of the HIV prevalence rates worldwide using datasets from CIA Fact Book. Specifically, this is limited to the use of new methodologies embedded in fractal statistical analysis and data mining. The spatial epidemiological pattern will be assessed by analyzing existing virtual data and connects bits of information to discover minute details on the increase of HIV cases globally.

Theoretical and Conceptual Framework

The study is anchored on the environmental theory of Florence Nightingale (Nightingale, 1859) and the Epidemiological Triangle of the Center for Disease Control (CDC, 2013).

Florence Nightingale's environmental theory believes that people are affected by their environment. Health hazards and type of surroundings can lead to poor health and disease. Nightingale also stressed that the environmental settings could be altered to improve conditions and to allow healing. Thus, health can be maintained by controlling the environmental factors to prevent diseases.

There are three types of environment as described by Florence Nightingale, namely physical, psychological, and social physical. In physical environment, physical elements such as the cleanliness and the temperature were considered to have an impact on the health of the person. Nightingale describes psychological environment as various activities that keep the patient's mind active (Wayne, 2014). While, social physical environment includes components of the physical environment such as clean air, clean water, proper drainage, which can influence an individual's exposure and susceptibility to diseases.

The Center for Disease Control in its epidemiological triangle model supports the theory of Nightingale. CDC described the epidemiologic triangle as a traditional model for infectious causation. The three components identified were an external agent, a susceptible host, and an environment that brings the host and agent together. In this model, the environment influences the agent, the host, and the route of transmission of the agent from a source to the host. CDC believed that a state of equilibrium between agent, host and environment must be maintained to achieve health. If this balance is disturbed, then disease will occur (CDC, 2013).

Specifically, CDC (2013) identified the agent factors as the infectious microorganism (virus, bacterium, parasite or another microbe). These agents must be present for disease to occur. The hosts (humans) are intrinsic factors that can influence the individual's exposure, susceptibility, or response to a causative agent. Some of the host factors that can affect the person's likelihood of exposure are age, race, sex, socioeconomic status, and behaviors (smoking, drug abuse, lifestyle, sexual practices and contraception). While, age, genetic composition, nutritional and immunologic status, atomic structure, presence of disease or medications, and psychological makeup are some of the factors which can affect a person's response to an agent. Moreover, environmental factors are extrinsic factors which affect the agent and the opportunity for exposure.

The Nightingale's theory and CDC's epidemiological triangle have distinctly shown how the environment contributes to the spread

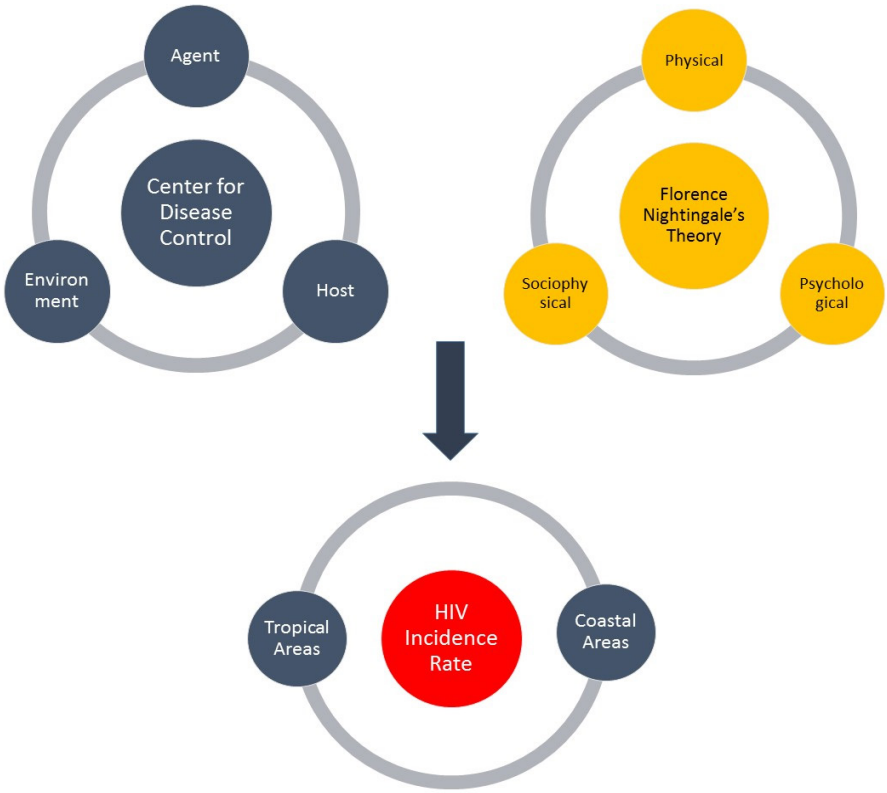

Figure 1. Schema of the framework of the present study.

of diseases. In the process, it is believed that environment plays an important factor in understanding the epidemiological pattern of HIV cases worldwide. Figure 1 illustrates the said phenomenon.

Objectives

This paper sought to investigate the epidemiological pattern of HIV incidences worldwide. Specifically, it intended to:

1. determine if the HIV incidence rates have deviated from their fractal state;
2. explain the deviation;
3. analyze the local characterization of fractal dimension; and
4. identify the factors that may contribute to the HIV incidence rate.

Methodology

This is a descriptive type of research, utilizing new methodologies of fractal statistical analysis and data mining. Specifically, it uses data sets from CIA World Fact Book (2015) on the global prevalence rate of Human Immunodeficiency Virus. Data showed 164 countries worldwide have HIV cases. These data were then analyzed, summarized and underwent fractal statistical analysis.

Fractal statistical analysis was used to explain if the data has deviated from its normal state. In testing the fractality of the data, the fundamental theorem for fractal statistics (Padua, 2015) was used. The theory state that "X is fractal if and only if $log\frac{x}{\theta}$ has an exponential distribution with rate parameter $\beta = \lambda - 1$." Thus, if the histogram of $y = log\frac{x}{\theta}$ is not exponential, then X is not fractal.

Minitab software was then used to create histograms out of the data gathered. Moreover, the exponential functions were evaluated to determine the outliers (countries). After identifying the outliers, the data were then grouped according to the continent it belongs.

The specific pattern was observed throughout the analysis of data. Also, data mining were utilized by extracting information from credible sources. This was done to determine the specific factors per country that may have contributed to the increase of HIV prevalence rate.

Results and Discussion

HIV Incidences Worldwide

The incidence of HIV cases varies per country and continent. The initial histograms revealed an exponential distribution of the data. Figure 2 illustrates that the HIV phenomenon is fractal by nature, based on the Principles of Fractals of Padua (2015). Moreover, it shows that there were 26 outliers among 164 countries with HIV worldwide. The majority of the outliers are countries from the continent of Africa, Asia, Europe and South America. It is interesting to note that about 50% of the people in South Africa have HIV compared to the number of cases in other countries. These findings can be attributed to the fact that the origin of HIV started from this country, and it spread out to different neighboring countries (Gallagher, 2014). Through fractal analysis, a thorough investigation on the spread of HIV was conducted.

An illustration map was then made to visualize clearly the outliers (26 countries) with a high incidence of HIV (as shown in Figure 3). The map illustrates the dynamic expansion of HIV cases worldwide. Interestingly, the HIV cases are spreading towards the northeastern hemisphere, except in Arabian countries. This deviation can be attributed to the underreported cases and absence of consistent and accurate surveys of HIV incidence (Alami, 2014; UNAIDS, 2014). To date, there has been no research, nor HIV prevention programs for sex workers and men who have sex with men (MSM) in UAE since these activities are considered illegal. Furthermore, Alami (2014) believes that the HIV rates in Arabian countries are still advancing/increasing. This scenario conforms to the assumption that HIV cases are spreading in numbers and follow the path identified by the researchers.

Moreover, the spread of HIV cases in the northeastern hemisphere is credited to different factors; one is the trading system of different countries. Figure 4 interestingly shows that South Africa and India were identified as the

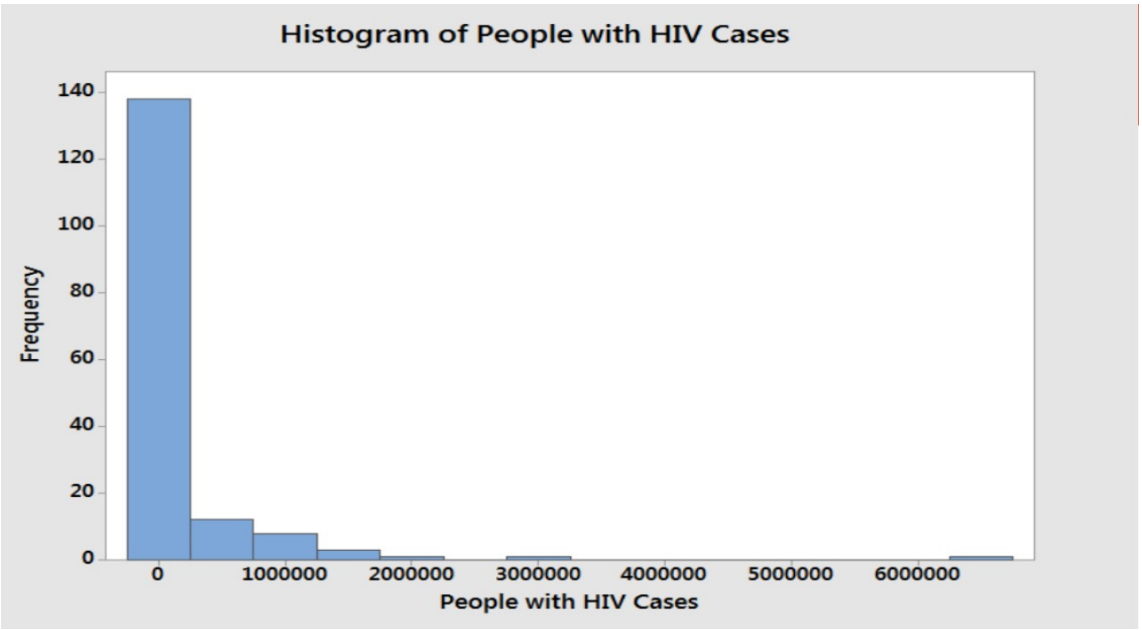

Figure 2: Exponential distribution of the data.

Figure 3: The illustration map of 26 outliers (countries).

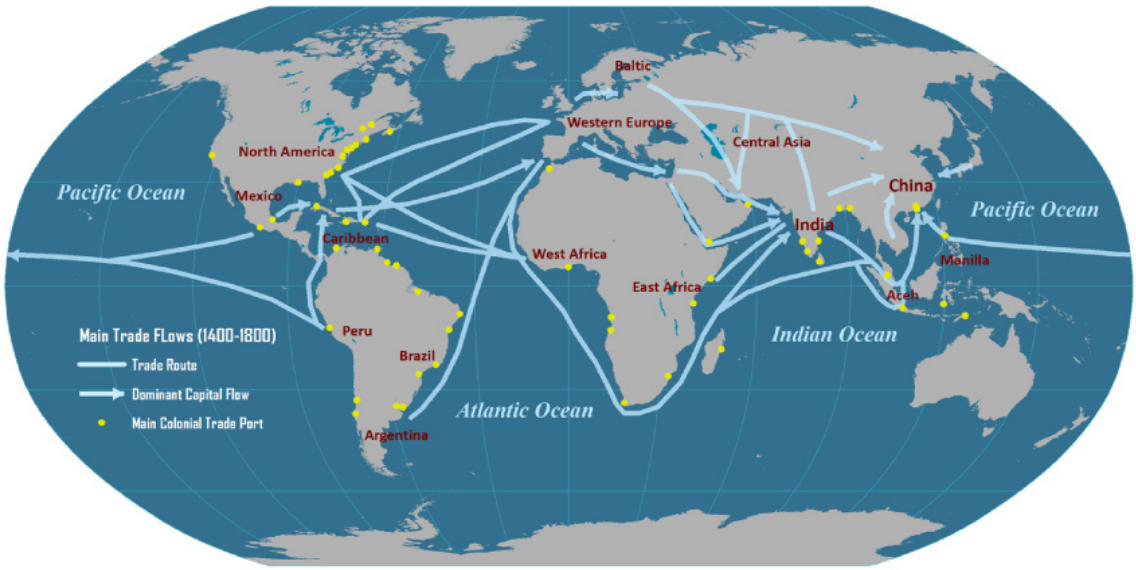

Figure 4: Major global trade routes.

origin or source of trade force, not to mention that these two countries are known to have a high incidence of HIV (InfoChange News & Features, 2008). It also shows that the major global trade routes of these countries follow the pathway along the coastal areas. Data mining revealed that the trading activities are not only concentrated on goods alone, but also on human trafficking for labor and sex exploitation. An estimated 300,000 to 450,000 people were trafficked within Asia each year (UNDP, 2007), and about 30,000 African children have been trafficked annually as part of the sex trade (Watt, 2015). This activity increases the risk of HIV transmission to other countries.

This finding is strengthened by a study conducted by Mbirimtengerenji (2007) showing that sexual trade, migration and cultural

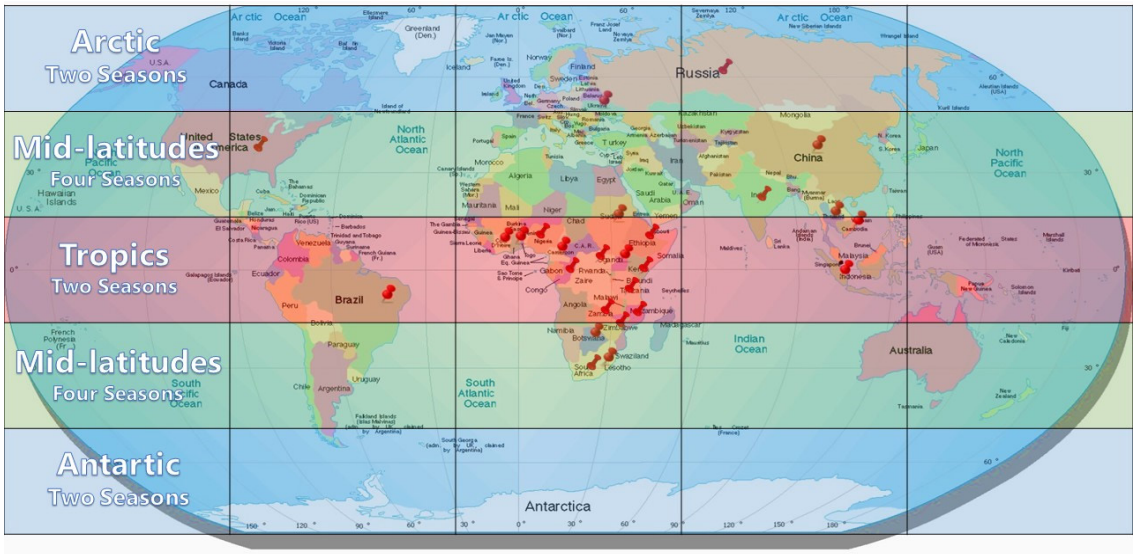

Figure 5: Maps of 26 countries with HIV on tropical areas.

practices in the Sub-Saharan region exacerbate the prevalence of HIV/AIDS. It is surmised that the key factor in the northeastern expansion of HIV is the coastal trading activities. This finding has implications for the health policies, specifically on HIV screening test of incoming tourists and workers of different countries along its entry points.

In a similar study related to coastal areas, Zafar et al. (2014) reported that fishermen are at higher risk of transmitting HIV/AIDS due to their linkages and movement to various sites and regional markets. FOA (2007) confirms the frequent mobility and high levels of alcohol use among fishermen before and during sexual encounters may be a factor of unsafe sexual practices contributing to the incidence of HIV. Besides, the United Nations' FOA (2014) estimated 12.3 million people in African countries and 14.5 million people in India are fishermen; hypothetically, if these number of fisherman engage in unsafe sexual practices, then an extensive number of HIV cases and the spread along the coastal areas is possible.

Another enthralling fact observed in the epidemiological pattern of HIV is the location of countries in tropical areas. Figure 5 illustrates the map of 26 countries with high HIV cases along the tropical line. Being situated in the tropical environment can contribute directly and indirectly to the increase of HIV. The two important factors attributed to this phenomenon are climate temperature and agricultural productivity.

The location of countries in this study is noted as an appropriate environment for transmitting and acquiring HIV. Specifically, warm and humid environment are good mediums for the occurrence of tropical diseases that are prevalent and unique in tropical and subtropical regions. Somani et al. (2010) revealed that higher temperatures in tropical countries may favor the replication of pathogenic agents both inside and outside biological organisms. Also, tropical infections may facilitate the transmission of HIV and accelerate progression from asymptomatic HIV infection to AIDS (Harms & Feldmeier, 2005). The finding is further supported by Skolnik et al. (2013) stating that tropical diseases like Lymphogranuloma Venereum (commonly occurs in tropical countries) increases the risk of acquiring HIV.

Moreover, Mistry (2013) explained how tropical diseases contribute to the incidence of HIV. He noted that tropical diseases like tuberculosis, malaria, schistosomiasis and the like weakened the human immune system,

making it more likely for an individual to be susceptible to HIV. Thus, HIV and tropical diseases mutually affect each other.

Furthermore, it is noted that majority of tropical countries with higher HIV cases were also underdeveloped countries, as shown in Figure 6. It is interesting to note that the unique characteristics of these tropical countries directly contributed to its underdevelopment and indirectly associated with the increased risk of HIV infection. The agriculture productivity of tropical countries can be attributed to the said scenario.

Somani et al. (2010) revealed that climate indirectly makes disease in tropical regions more severe by reducing agricultural production, which increases the risk of malnutrition. Furthermore, Diamond (2012) observed that the agricultural productivity of tropical areas is lower compared to the temperate areas, for several reasons. First, temperate plants store more energy than tropical plants. Second, diseases borne by insects and other pests reduce crop yields more in the tropics than in the temperate zones, because the pests are more diverse and survive better year-round in tropical than in temperate areas. Lastly, glaciers repeatedly advanced and retreated over temperate areas, creating young nutrient-rich soils. These factors were known to contribute to poor agricultural productivity (Acemoglu & Robinson, 2012).

Sachs (2015) observed that the soil formation and erosion, pest and parasites, and the effects of tropical climates on plant respiration can lead to reduced agricultural productivity and the possible cause of poor nutrition. It is noted that with poor nutrition, HIV transmission is highly possible. A related study was conducted by Egal and Valstar (1998) confirming that the chance of infection with the HIV is reduced in individuals who have good nutritional status, with micronutrients and, especially vitamin A playing significant roles. The findings suggest that HIV transmission is not only dependent on its host and agent, rather

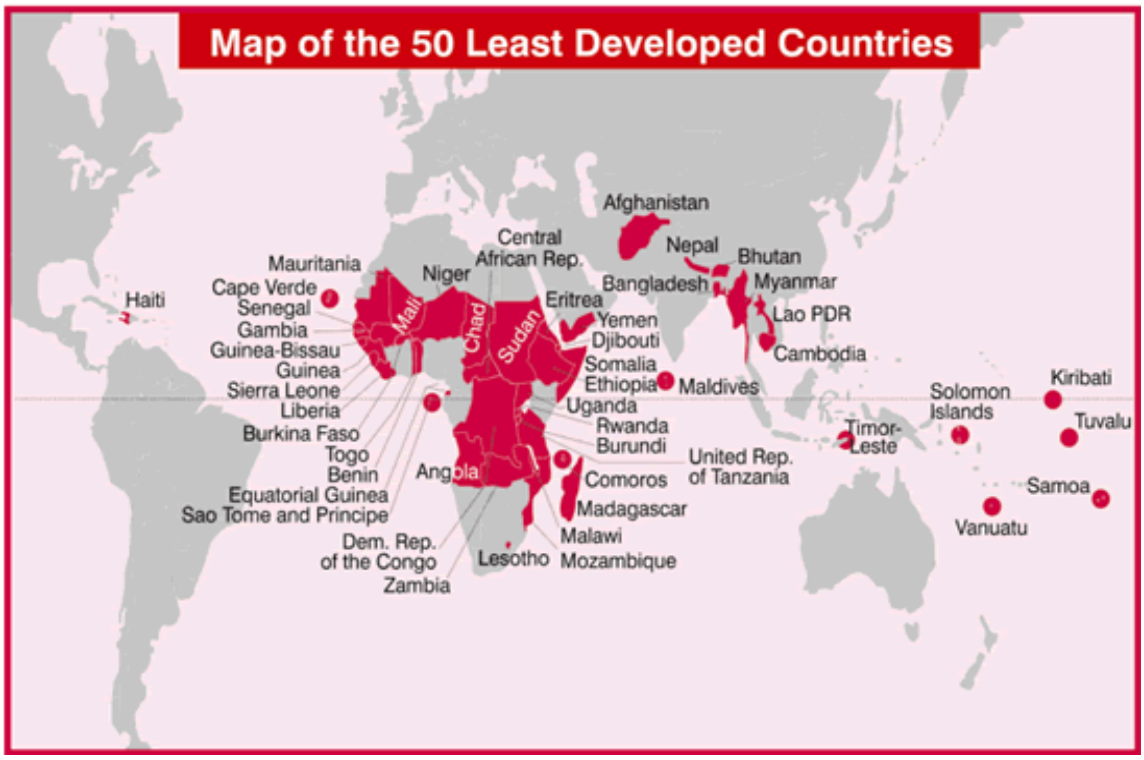

Figure 6: Map of the 50 least developed countries.

it is affected by the countries' environmental climate.

In sum, the study showed the possibility of environmental factors contributing to HIV spread. Different health organizations may look into the environmental characteristics of different countries that may have led to some HIV spread. By strengthening environmental measures such as migration policies, sexual networks, and health conditions, HIV spread may be addressed, and hopefully, HIV prevalence may decrease.

Conclusion

In line with the findings of the study, the following conclusions were drawn:

1) that new methodologies like fractal analysis and data mining can be used as a starting point in the hidden dimension of HIV;
2) that the incidence of HIV is also sensitive to the environmental characteristics of different countries; and
3) that the hidden dimension is categorized according to tropical location of countries, and pattern of HIV spread. Regarding location, countries located in the tropical hemisphere are prone to HIV spread. This is due to sexual trading practices in coastal areas, climate temperature, and poor environmental conditions. Also, a pattern was observed that HIV defuses following the northeastern pathway, starting from its source (South Africa) to its neighboring countries.

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