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RESEARCH

Hot-spots clusters of HIV infection in Cameroon : space-time analysis from the demographic and health surveys

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Abstract

Background: The Human Immunodeficiency Virus(HIV) infection prevalence in Cameroon has consecutively decreased from 5.28% in 2004 to 2.8% in 2018. However, this total decrease in prevalence may hide some disparities especially in terms of spatial or geographical pattern. Efficient control and fighting against HIV infection requires to target hotspot areas. This study was aimed to investigate whether there is a spatial pattern of HIV in Cameroon and to determine the hot-spots clusters.

Methods: HIV biomarkers data with Global Positioning System (GPS) location data were leveraged from the Cameroon 2004, 2011, and 2018 Demographic and Health Survey (DHS) after an approved request from the MEASURES Demographic and Health Survey Program. The spatial autocorrelation test was performed with the Moran *I* test through the R package "DCluster". The discrete Poisson model was fitted to scan and detect hot-spots clusters based on the Kulldorff test with the SaTScan software version 9.4, with purely spatial and space-time analysis respectively. Finally, the data and detected clusters were imported to QGIS software version 3.20.2 for maps manipulations.

Results: For the three considered periods of 2004, 2011, and 2018 respectively, there was a spatial autocorrelation of HIV infection in Cameroon. A total of 3, 5, and 2 significant hot-spots clusters were detected for the periods of 2004, 2011, and 2018 respectively. In the prospective space-time analysis, 2 significant clusters have been detected from 2004 to 2018. The relative-risk in the significant detected clusters were 2.72(p -value= 0.001) and 3.37(p -value=0.026) respectively. Cluster 1 included the following subdivisions : Mefou et Afamba, Nyong et So'o, Nyong et Mfoumou, Haute Sanaga, Mvila, Dja et lobo, Haut-Nyong, Boumba et Ngoko; Kadey, Lom et Djerem, and Mbere. The other cluster included : Nkam, Sanaga-Maritime, and Nyong-Ekele.

Conclusion: Despite the decrease of HIV epidemiology in Cameroon, the study revealed that there is a spatial pattern of HIV in Cameroon and the hot-spots clusters were detected. In its effort to eliminate HIV infection by 2030 in Cameroon, the public health policies should target more of the detected HIV hot-spots clusters in this study while maintaining effective control in other parts of the country which are cold-spots.

Keywords: Cameroon; Cluster; HIV; Hot-spots; Space; Space-time

Introduction

In recent years, the national and international communities had scaled up strategies to control HIV/AIDS. The Millennium Development Goal(MDG) of the United Nations had integrated the fight against HIV/AiDS in point 6. Many countries had adopted the MDG and as a result, according to World Health Organisation(WHO), HIV new infections declined by 38% between 2001 and 2013 worldwide[?]. In the Sustainable Development Goals(SDG), the fight against HIV was integrated into goal 3.3, where the main goal was to end the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases, and other communicable diseases by 2030. To reach this goal, the United Nations AIDS(UNAIDS) launched and advocated the 90-90-90 targets. These targets were to be reached by 2020 and consisted of : 90% of all the people living with HIV being able to know their HIV status, 90% of all people with diagnosed HIV infection will receive sustained antiretroviral therapy and 90% of all people receiving antiretroviral therapy will have viral suppression. With the efforts of most countries worldwide, new infections of HIV globally declined by about 17% between 2015 and 2020.

Cameroon had also experienced a bright situation in terms of declination of HIV infection. In fact, from 2011 to 2018, the prevalence of HIV in Cameroon declined from 5.55% to 2.8%. However, there were persistent disparities in HIV infection in Cameroon(age, place of residence, regional and gender). Prevalence was higher in the female population(3.5%, versus 1.9% in male population), in urban area(2.9%, versus 2.4% in rural), and in adults aged 35-39 respectively. In terms of regional disparities, it was found that HIV infection was more prevalent in the South(5.8%), East(5.6%), Adamawa(4.1%), North-West(4.0%), and Center(3.5%) regions. These regions were defined in the 2018-2022 National Strategic Plan for HIV/AIDS and STIs as priority areas of intervention. Moreover, these regions were to be more targeted in the fighting against HIV infection in Cameroon[1]. However, regions are the first level of geographical and administrative division in Cameroon, they are generally very large with heterogeneous populations. For efficient interventions for HIV elimination, it would therefore be relevant to target hot-spots clusters, these are accurate spots areas where the infection gets to spread the most. This study aimed to identify the HIV infection hot-spots clusters in Cameroun for the periods, 2004, 2011, and 2018. Determining hot-spots clusters for diseases is important for public health authorities who should adopt them for better-targeted interventions. This has been done in other settings such as in Mongolia[2], Ethiopia[3], Brazil[4], Shanghai[5], Malawi[6] and Nigeria[7].

Methods

Study design and sample

Demographic and Health Surveys are on a nationwide scale, periodic, and generally based on similar methodologies in sampling surveys. In Cameroon, it has been performed for the periods 1991, 1998, 2004, 2011, and 2018. They were cross-sectional surveys, where individuals living in ordinary households were targeted. Basically, the Cameroun DHS was based on two-stage stratified random samplings. At stage 1, the enumeration areas(EA) from the general census of the population were sampled proportionally to the number of households in clusters after stratification in rural

and urban EA respectively. Then, at stage 2, the households were sampled within the sampled EA at stage 1 systematically and with equal probability. Finally, in the half of the total obtained in the sample, all 15-64 aged men and women were eligible for HIV screening tests. Table 1 shows the sample population for respective DHS periods in Cameroon. More details about the sample survey design of different Cameroon DHS could be obtained in reports[8, 9, 10].

Data sources and measurements

After an approved request from the DHS program, the GPS and HIV biomarkers data were downloaded from their website(<http://www.dhs program.com>). For the periods of 1991 and 1998, GPS and HIV biomarkers data were not collected. Therefore, in this study, only the periods of 2004, 2011, and 2018 were considered for the spatial and space-time HIV analysis in Cameroon. Blood samples were screened and double-checked for positive cases by a Pasteur Center of Cameroon. Then, for quality assessment, screened samples were re-screened externally by the Chantal Biya International Reference Center. A concordance of 98.96% was found between the outcomes of both centers. The primary endpoint of this study was confirmed HIV positivity cases of 15-64. Table 1 describes the HIV percentage for the respective periods.

An important feature among DHS surveys is the georeferenced data. Coordinates of clusters are observed on the field using GPS receivers. For confidential purposes, the positions of sampled locations were randomly displaced according to the type of area :

- In urban clusters, the displacement was done with a radius within 0 to 2 kilometers.
- In rural clusters, the displacement was done with a radius within 0 to 5 kilometers, with a further 1% of the rural clusters displaced a minimum of 0 and a maximum of 10 kilometers.

More details about, the GPS data collecting and processing in DHS can be found in[11].

Statistical methods and maps tools

Moran I test : Introduced by[12], the Moran I test is the global test most commonly used for spatial autocorrelation. The null hypothesis is that the spatial distribution of the studied phenomena is random versus the alternative hypothesis in which the studied phenomena were non-random : in this case, there is spatial autocorrelation. Moran I test is based on a neighborhood matrix that specified the links among spatial units. In this study, the k nearest neighbor matrix, which for each spatial unit determines the k nearest neighbors based on the distance between them. A significant Moran I test indicates that there is a presence of clusterings, but could not identify the hot or cold spots clusters. The R software version 4.1.0 and especially the package "Dcluster" was used for data manipulations and the Moran I test[13].

Kulldorff test : Kulldorff's test is the most applied test for hot-spot clusters detection. Basically, the detection consists for each location of determining an aggregation

of locations around the considered location with the most likely relative risks. A circular window containing all aggregated locations is defined, and the overall relative risk in this window is compared to those outside, if it is significantly higher, it therefore implies that the defined circular window is a hot-spot cluster. The Kull-dorf test could be used as well for a space-time analysis, where the hot-spot clusters over time are detected. The Satcan software version 9.4(<https://www.satscan.org/>) was used for spatial and prospective space-time analysis based on discrete Poisson models.

Maps manipulations : All the spatial data were imported to QGIS software version 3.20.2(<https://www.qgis.org/fr/site/>) for maps representations.

Results

Table 1 shows the HIV prevalence in Cameroon for respective periods. Basically, the HIV prevalence in Cameroon was 5.28%, 5.55% and 2.80% for the periods of 2004, 2011 and 2018 respectively. From 2004 to 2011, there was a relative increase of 5.11%, and from 2011 to 2018, the epidemiology of HIV infection decreased by 49.55%.

Spatial auto-correlation of HIV in Cameroon

Based on the k-nearest neighbor, the spatial auto-correlation test results were displayed in Table 2. Considering all those periods, the spatial autocorrelation test was significant at 1% level. In 2004, 2011, and 2018, the number of nearest neighbors considered enough for significance was $k = 1, 3,$ and 1 respectively.

Significant hot-spots clusters of HIV in Cameroon in the purely spatial analysis

The tables 3, 4, and 5 displayed the coordinates, the relative-risks estimates and the subdivisions for detected hot-spots of HIV in Cameroon for the periods of 2004, 2011 and 2018 respectively. While this detected hot-spots clusters were mapped in figure 1, 2, and 3 respectively.

In 2004, three significant hot-spots clusters were detected. The most significant hot-spot cluster was centered in the Adamawa region and included the following subdivisions :

- Partly : Benoué, Mayo Rey, Menchun, Mezam, Menoua, Haut-NKam, Mfoundi, Mefou et Afamba, Nyong et Mfoumou, Haut-Nyong and Kadey.
- Totally : Faro, Faro et Deo, Vina, Donga Mantung, Mayo Banyo, Djérem, Mbéré, Lom et Djerem, Boyo, Bui, Ngo-Ketunjia, Bamboutos, Noun, Mifi, Koung-Khi, Haut-plateaux, Ndé, Mbam et Inoubou, Lekié, Mbam et Kim, Haute Sanaga.

The second cluster was centered in the East region and included :

- Partly: Mayo-Rey, Mayo Banyo, Faro et Déo, Mfoundi, Lekié, Nyong et So'o, Dja et Lobo,
- Totally : Vina, Djerem, Mbere, Mbam et Kim, Lom et Djerem, Haute Sanaga, Mefou et Afamba, Nyong et Mfoumou, Haut Nyong, Boumba et Ngoko and Kadey.

The last hot-spot cluster is centered in the North-West region and mostly contains the Mezam subdivision and a little part Momo and Ngo Ketunjia respectively.

In 2011, there were five significant HIV hot-spots clusters detected in Cameroon. The first is centered in the South region and included the following subdivisions

- Partly : Fako, Meme, Moungo, Haut-Nkam, Haut-plateaux, Koung-Khi, Noun, Bam et Kim, Lom et Djerem, Kadey and Boumba et Ngoko
- Totally : Wouri, Nkam, Ndé, Sanaga-Maritime, Ocean, Valle du Ntem, Mvila, Dja et Lobo, Haut-Nyong, Nyong et So'o, Nyong Ekele, Mefou et Akono, Mfoundi, Mefou et Afamba, Nyog et Mfoumou, Haute Sanaga and Mbam et Inoubou.

The second hot-spot cluster was centered in the East region and included :

- Partly : Ocean, Valle du Ntem, Mvila, Sanaga Maritime, Nyong et Ekele, Mbam et Inoubou, Mbam et Kim, Djerem, Vina, and Mayo-Rey.
- Totally : Mbere, Lom et Djerem, Kadey, Boumba et Ngo, Haut Nyong, Dja et Lobo, Haut Nyong, Nyong et So'o, Nyong et Mfoumou, Mefou et Afamba, Mfoundi, Lekie and Haute Sanaga.

The third hot-spot cluster was centered in the South-West region and included :

- Partly : Wouri, Moungo, Kupe Manengumba, Meme and Ndian.
- Totally, there was only Fako subdivisions.

The fourth hot-spot cluster was centered in the Adamaoua region and was mostly constituted of Djerem, Vina and Mbéré.

The last hot-spot cluster was centered in the North-West region, and included : Bui, Boyo, Ngo-Ketunjia, and partly Mezam, Menchum, and Dounga-Mantung.

In 2018, there were 2 significant hot-spots clusters. the first was very large and centered in the East region. It included :

- Partly : Mvilla, Nyong et So'o, Mefou et Afamba, Mbam et Kim, Djerem, Vina, Mayo-Rey and Mbere.
- Totally : Lom et Djerem, Haute Sanaga, Nyong et Mfoumou, Dja et Lobo, Haut-Nyong, Kadey and Bouba et Ngoko.

The second was centered in the Litoral region, and included : Nkam, Sanaga Maritime, and Nyong et Ekele.

Significant hot-spots clusters of HIV in Cameroon in the space-time analysis

The prospective space-time analysis allowed the identification of significant hot-spots clusters over time for the three considered periods. The results of the space-time analysis of HIV in Cameroon for the periods of 2004, 2011, and 2018 were summarized in table 6 and figure 4. As a whole, from 2004 to 2018 there were 2 HIV hot-spots clusters in Cameroon which remained significant. The significant hot-spots clusters were similar to those detected in 2018, the only difference was in the first cluster, where the Mayo-Rey subdivision was not included.

Discussion

This study has provided a precise space-time analysis of HIV infection in Cameroon for the periods of 2004, 2011, and 2018, which determined the hot-spot clusters over

time. These analyses go beyond the regional analysis which is commonly adopted by public health policies in Cameroon. In fact, in the recent document of the National Strategic Plan for HIV/AIDS, 5 regions, which were the : East, Center, Adamaoua, North-West, and South were defined as priority areas of intervention[1]. A study by[14] revealed that HIV risk among pregnant women in Cameroon was higher in the East, North-West, and South-West regions. However, the accurate localities or subdivisions in these regions were not identified. In such a way, the interventions on a large division scale such as regions may not be efficient. The space-time analysis of this study identified two significant hot-spots clusters of HIV infection for the periods of 2004, 2011, and 2018, with the included localities. Cluster 1 is constituted of some localities of the regions of East, Center, and South. While, the other cluster is composed of some localities of the Littoral region. Even if the clusters identified were overlapped with the targeted regions in the strategic document for the fight against AIDS in Cameroon, our study identified accurately the hot-spots subdivisions of HIV infection in Cameroon which were finer than regions.

Some of the subdivisions of Cluster 1(Nyong et Mfoumou, Haute Sanaga, Lom et Djerem) were found on the mid-way of the corridor Douala-Bangui. This route is among the longest and the most trafficked road in the country which goes up to the capital city of Central Africa Republic(CAR). Cities and towns within these subdivisions constitute of truck stops and rest-spots for truck drivers. Therefore these subdivisions on the corridor are hot-spots clusters of HIV infection as found in other settings[7, 6, 3]. In fact, truck drivers generally have high sexual risk behaviors, they practice unprotected sexual intercourse with multiple partners living in rest-spots cities[15, 16, 17, 18]. Another characteristic of cluster 1 was that most of its subdivisions were found on the cross-borders of Cameroon with CAR(Mbere, Lom et Djerem, Kadey, Boumba et Ngoko) and Congo(Haut-Nyong, Dja et Lobo and Mvila) respectively. Some studies revealed that borders areas are generally subjected to a high rate of unsafe sex practice and a low level of HIV-related knowledge, attitudes, and practices[19, 20, 21]. This may explain the high risk of HIV infection in these subdivisions on the borders where there is high human mobility in and out.

The other space-time HIV infection hot-spot cluster for the period 2004-2018 was located in the Littoral region. It was a small area, with cover a radius of 68.54 km, and included Nkam, Nyong et kelle and Sanaga-Maritime subdivisions. Populations of these subdivisions would have sexual risk behaviors especially in terms of condom non-use. A study on adolescents in Edéa(Capital city of Sanaga-Maritime) found that adolescents both males and females had poor condom use perception[22]. The socio-cultural habits of individuals of these subdivisions which are mostly Bassa could favor other sexual risk behaviors[23]. Other contextual factors of these subdivisions which could increase the rate of HIV transmission in these localities need to be more investigated in further studies.

Conclusions

HIV infection has significantly decreased in Cameroon from 2011 to 2018. However, a prospective space-time analysis in this study has indicated that there remained

persistent hot-spot clusters. This study has provided mappings of these hot-spots clusters. Cameroonian public health authorities usually based their policies on regional disparities analysis. Beyond these regional analyses, this study performed a finer analysis with accurate geographical coordinates of identified hot-spots clusters. Therefore, accurate subdivisions and localities which need more attention are now identified. For an efficient fight against HIV infection in Cameroon, public health policies should target more on the identified hot-spots clusters with adapted interventions. However, the surveillance and control in other areas which were not identified as hot-spot clusters should continue.

List of Abbreviation

HIV : Human Immunodeficiency Virus; AIDS : Acquired Immuno Deficiency Syndrome; EA : Enumeration Area; DHS : Demographic and Health Survey; GPS : Global Positioning System; STI : Sexually Transmitted Infection; WHO : World Health Organization; UNAIDS : United Nations Programme on HIV/AIDS; CAR : Central Africa Republic. The datasets used and analyzed during the current study are available from the corresponding author on reasonable request. Or alternatively directly from the DHS program on a request.

Declaration

Ethical Approval and Consent to participate

Not applicable.

Consent for publication

Not applicable. The manuscript does not contain any individual personal data in any form (individual details, images, or videos). The authors have delegated all authority to submit and publish the article to the corresponding author.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request. Or alternatively directly from the DHS program on a request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

ABS, JBTM and AENN conceptualized and designed the study. ABS did the data extraction, data analysis, maps manipulations, and manuscript preparation. JBTM reviewed and edit the manuscript. AENN reviewed and edit the manuscript. All co-authors has read and approved the manuscript.

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Figures

Figure 1 Spatial distribution of HIV in Cameroon and hot-spots clusters 2004

Figure 2 Spatial distribution of HIV in Cameroon and hot-spots clusters 2011

Figure 3 Spatial distribution of HIV in Cameroon and hot-spots clusters 2018

Figure 4 Space-time of HIV in Cameroon for the periods 2004, 2011 and 2018

Tables

Table 1 Sample sizes and HIV prevalences for 2004, 2011 and 2018

Periods	Sample sizes	Prevalence
2004	10194	5.28%
2011	14442	5.55%
2011	14085	2.80%

Table 2 HIV spatial auto-correlation test for 2004, 2011 and 2018 in Cameroon

Periods	<i>k</i>	I statistic	p-value
2004	1	0.002	0.004
2011	3	0.0009	0.005
2018	1	0.003	< 0.001

Table 3 Significant hot-spots clusters detected in 2004

Clusters	Coordinates / radius	Relative-risk	p-value
1	(6.278971 N, 12.809584 E) / 305.61 km	1.84	< 0.001
2	(4.888288 N, 14.235064 E) / 324.43 km	1.82	< 0.001
3	(5.948502 N, 10.164662 E) / 26.76 km	2.41	0.002

Table 4 Significant hot-spots clusters detected in 2011

Clusters	Coordinates / radius	Relative-risk	p-value
1	(2.436196 N, 11.973725 E) / 371.61 km	2.03	< 0.001
2	(3.452346 N, 15.429731 E) / 516.46 km	1.97	< 0.001
3	(4.400003 N, 9.275178 E) / 64.67 km	1.72	< 0.001
4	(6.564006 N, 12.996895 E) / 86.78 km	3.50	< 0.001
5	(6.297939 N, 10.552934 E) / 55.26 km	1.87	< 0.001

Table 5 Significant hot-spots clusters detected in 2018

Clusters	Coordinates / radius	Relative-risk	p-value
1	(2.621281 N, 16.066787 E) / 519.90 km	2.66	< 0.001
2	(4.127710 N, 10.412338 E) / 68.54 km	3.18	0.018

Table 6 Significant hot-spots clusters detected within periods 2004, 2011 and 2018(Space-time analysis)

Clusters	Coordinates / radius	Relative-risk	p-value
1	(2.621281 N, 16.066787 E) / 515.20 km	2.72	< 0.001
2	(4.127710 N, 10.412338 E) / 68.54 km	3.37	0.026

Figures

Relative-risk distribution of HIV in Cameroon in 2004 and its significant clusters

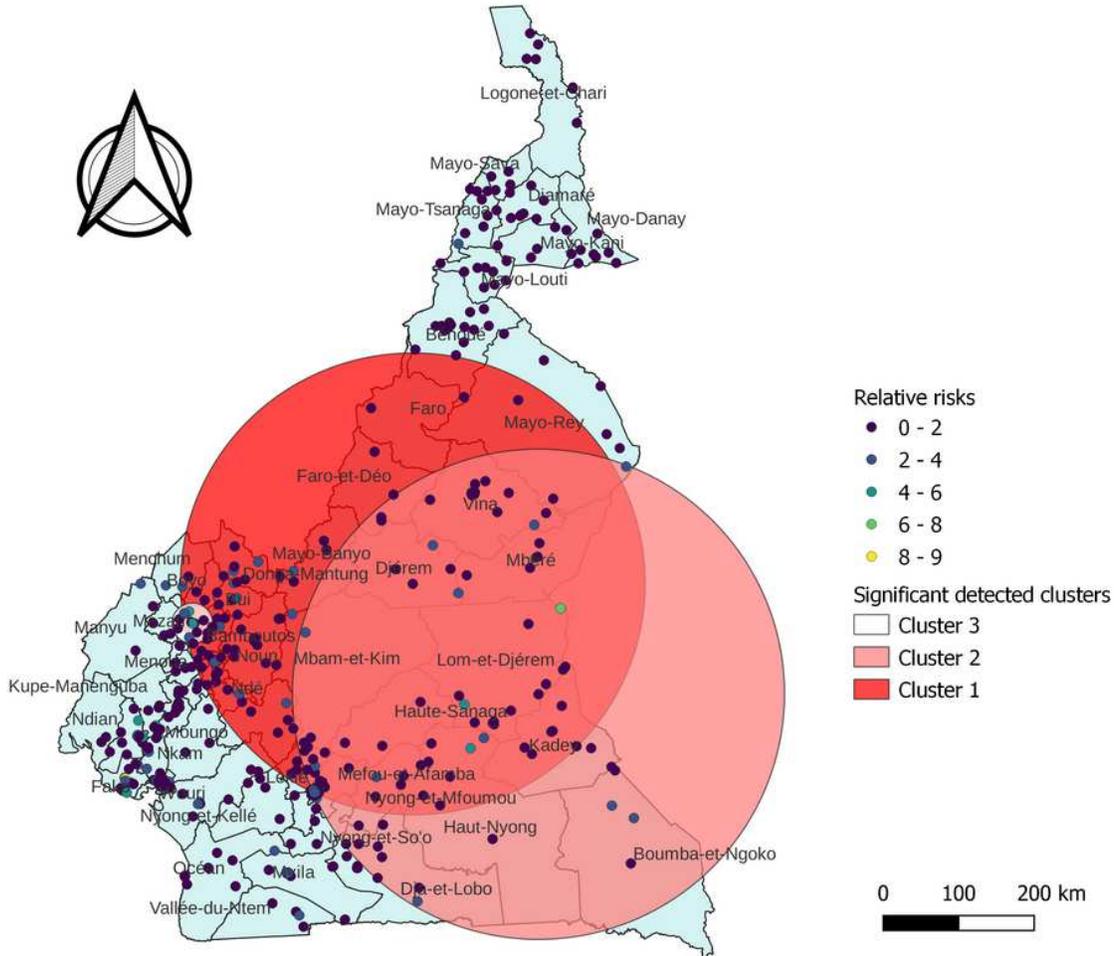


Figure 1

Spatial distribution of HIV in Cameroon and hot-spots clusters 2004

Relative-risk distribution of HIV in Cameroon in 2011 and its significant clusters

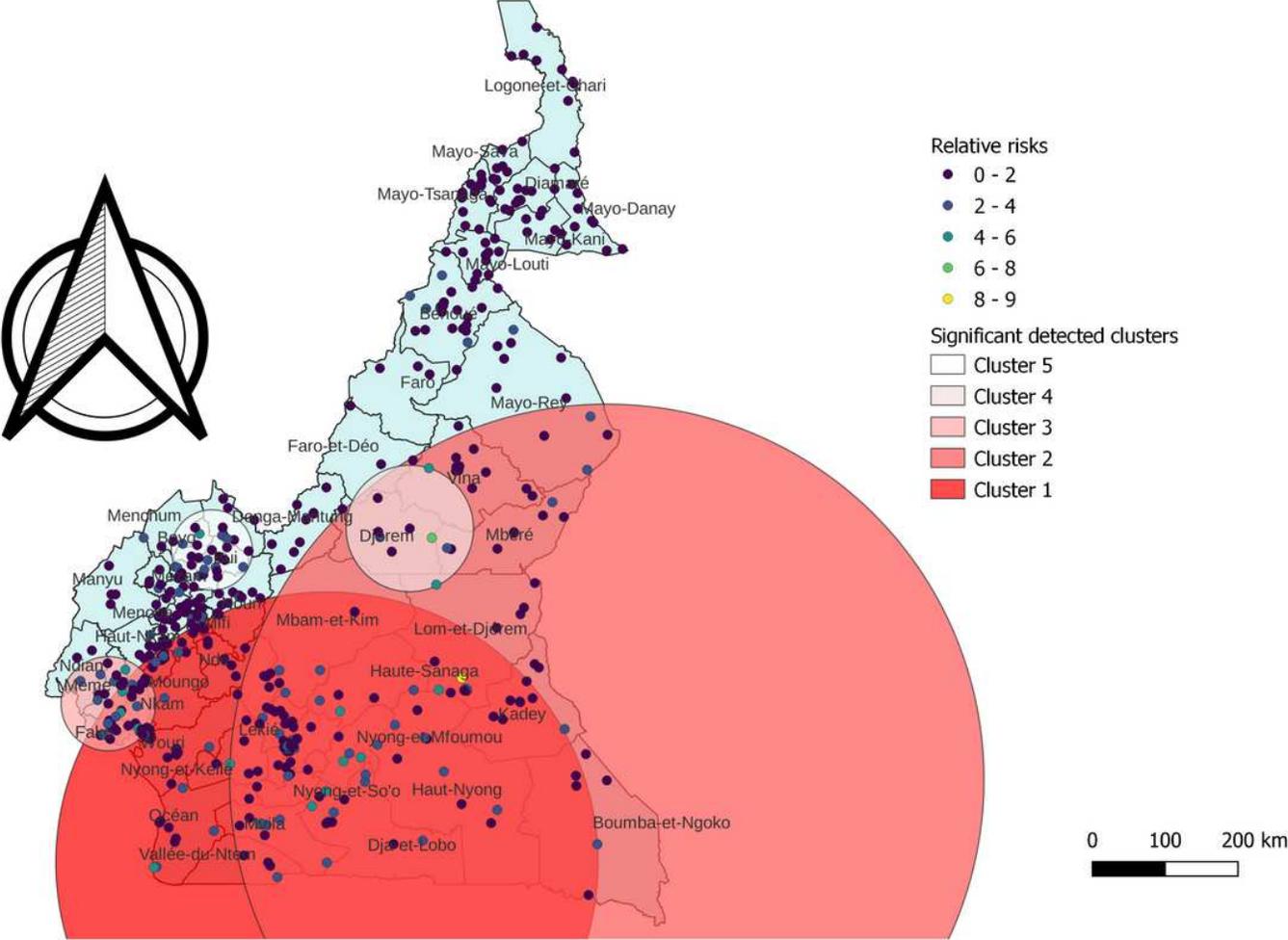


Figure 2

Spatial distribution of HIV in Cameroon and hot-spots clusters 2011

