Spatio-Temporal Analysis of Human Immunodeficiency Virus in MIMAROPA and Eastern Visayas (2010-2018)

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Abstract: Human Immunodeficiency Virus (HIV), a virus that targets the immune system of an infected individual, continues to spread in some countries in Asia and the Pacific despite the global decline of the infection. In the Philippines, the virus continues to spread among ages 25 to 34, males and females, in Region 4B (MIMAROPA) and Region 8 (Eastern Visayas). Using the relative risk, the global Moran's I values are computed and analyzed to study the presence of spatial autocorrelation. The expected values of the global Moran's I in each region are then used to identify the presence of positive and negative spatial autocorrelation. In Region 4B, there is a presence of negative spatial autocorrelation in 2015 and 2016 and positive spatial autocorrelation in Region 8 during 2012 and 2015. Provinces with relatively high or low local association are identified using the local Moran's I. Results showed that Palawan has clusters with high rates and is surrounded by clusters with low rates for Region 4B. In Region 8, Leyte was found to have clusters with high rates surrounded by clusters with low rates. The occurrence of HIV generally increased from 2010 to 2018.

Keywords: Human Immunodeficiency Virus; spatial autocorrelation; global Moran's I; local Moran's I

1. INTRODUCTION

The Human Immunodeficiency Virus (HIV) is a virus that weakens the immune system and is prevalent in many low to middle-income countries (Shao & Williamson, 2012). HIV targets the immune system by entering and eradicating the body's built in defense systems against diseases such as the white blood cells. As the person's immune system gets weaker, other diseases that normally do not trigger any illnesses can cause deadly effects to the body due to its inability to fend off germs. The immune system is heavily damaged when an HIV infection reaches its final stage. The infection advances to Acquired Immunodeficiency Syndrome (AIDS) (WHO, 2005).

In 2018, the Department of Health (DOH) released a report stating that there is a continuous rise of HIV in the Philippines despite a remarkable decline in other ASEAN countries (DOH, 2018). As a response, the Philippine government implemented the Philippine HIV and AIDS Policy Act of 2018 to mitigate the rapid spread of HIV. However, due to constraints in resources and time, creating effective policies poses difficulties for government agencies such as difficulties in the constant monitoring of the affected demographic groups and in the implementation of similar programs such as the Responsible Parenthood and Reproductive Health Act of 2012 (RH Law).

Many papers in the HIV literature utilized spatial analysis to detect significant patterns to improve the performance of prevention programs. An Ontario study used spatial analysis to detect spatial patterns in pneumonia and influenza from 9 years of aggregated hospitalization in its different counties. The analysis identified significant age-specific clusters of high values in multitude northern counties. Geographical illustrations of these clusters push the demand for focused prevention strategies and resources allocation. (Crighton et al., 2010). A similar study in China conducted spatial modelling and spatio-temporal analyses to detect any high-risk areas or an upsurge of HIV incidence, specifically transmission via men-to-men intercourse. While their analysis showed hotspots in municipalities, their spatial model also found significant positive correlation between various sociodemographic and HIV via men-to-men intercourse. This would further intensify the intervention planning of HIV in China with specific targeted sociodemographic in high risk areas (Qin et al., 2017).

This research explores the usage of spatial analysis in the Philippines, specifically the provinces of the two regions, MIMAROPA (Region 4B) and Eastern Visayas (Region 8). Its primary objective is to identify spatial patterns of HIV occurrence through time. Specifically, it aims to (1) present the trends of

HIV incidence by age and sex from 2010-2018 and (2) identify local clusters of HIV cases in the provinces of Region 4B and Region 8 from 2010-2018.

The results of this study will be helpful to the concerned organizations in Region 4B and Region 8 in formulating region-specific programs and laws for HIV prevention and awareness. Mapping HIV incidence and determining where it occurs densely may help policy makers and health organizations in these regions to regulate and prioritize areas with HIV incidence. With the information provided by this research, existing local programs may be revisited to assess their efficiency in targeting HIV. Moreover, this research may serve as a reference for future studies on HIV and disease mapping.

2. METHODOLOGY

2.1 Data

The datasets were obtained from the Department of Health-Regional Epidemiology Surveillance Unit (DOH-RESU) of MIMAROPA (Region 4B) and Eastern Visayas (Region 8). Each of the datasets reported annual HIV cases from 2010 to 2018, with demographic information limited to age, sex, and province where the cases were reported. The shape file map of these two regions were obtained from *PhilGIS.org*. The labeled map of Region 4B and Region 8, consisting of five and six provinces, respectively, are shown in Figures 1 and 2, respectively.

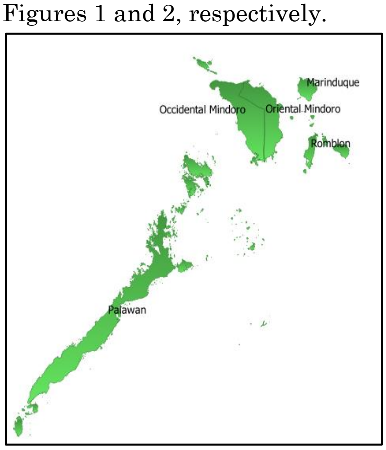

Figure 1. Labeled Map of Region 4B

Figure 2. Labeled Map of Region 8

The population size was based on the Census of Population and Housing Report from 2010 and 2015 by the Philippine Statistics Authority (PSA). Since this report updates every 5 years, population counts from the censuses in 2010 and 2015 were used to represent the population sizes of the provinces in the two regions from 2010 to 2014 and 2015 to 2018, respectively. The provincial counts of HIV cases are then converted into relative risk rates instead of crude rates to avoid the rounding off values to zero when applied to spatial data analysis software.

2.2 Statistical Models

2.2.1 Exploratory spatial data analysis

The shape files of Region 4B and Region 8 obtained from *PhilGIS.org* were edited and cropped using *QGIS 3.8.0* to convert the spatial units of the two regions into provincial levels. Each HIV count data for the years 2010 to 2018 was converted into relative risk rates. After which, the weights of the two regions were acquired for the purpose of Geographic Information System (GIS) mapping. Based on the max-min criterion, the distance band weight showed a distance threshold of 3.67 for Region 4B and 0.75 for Region 8. A higher distance threshold was generated for Region 4B due to the fact that Palawan does not share a border with the rest of the region. For this reason, it is appropriate to employ distance-based weights criteria to generate an adjacency matrix for borderless regions such as Region 4B. In the case of Region 8, a similar weights criteria was also utilized to take advantage of the versatility of a distance-based criteria; that is, other spatial weights criteria such as the contiguity-based weights would not count regions with small distances as neighbors as opposed to a distance-based criteria, where those regions are considered to be significant. Hence, a distance-based weights criteria would capture a more realistic adjacency matrix. Therefore, the weight matrices of the two regions are as follows:

$$w_{ij} = \begin{cases} 1, \ if \ d_{ij} \leq 3.67 \\ 0, \ if \ d_{ij} > 3.67 \end{cases}, \text{ for Region 4B}$$

and

$$w_{ij} = \begin{cases} 1, \ if \ d_{ij} \leq 0.75 \\ 0, \ if \ d_{ij} > 0.75 \end{cases}, \text{ for Region 8}$$

These weights were then utilized to generate the quantile maps of the HIV relative risk rates, and used to compute spatial autocorrelation.

2.2.2 Global and Local Indicator of Spatial Autocorrelation

The Global Moran's I is used to detect clustering of HIV incidence of the two regions by examining the location and similarity of the provinces. After converting the HIV incidence to relative risk rates, their resulting values were then used to compute for the values of the Global Moran's I using *GeoDa*. The Global Moran's I values of the two regions for each year were tested using the Monte Carlo permutation test with 999 permutations. Similarly, for the Local Moran's I, the relative risk rates were used to identify clusters in the two regions. The *GeoDa* software automatically shows the significant clusters of provinces with appropriate labels according to their significance. The Local Moran's I also uses the Monte Carlo permutation test with 999 permutations to test for significance.

3. RESULTS AND DISCUSSION

3.1 HIV Incidence by Age and Sex

Figure 3 shows the annual cases of HIV in Region 4B and Region 8. Observe the drastic increase in the number of reported cases in the years 2015 to 2018. Note that Puerto Princesa, Palawan and Puerto Galera, Oriental Mindoro are top tourist destinations in Region 4B where a big percentage of transmission is reported (Magtubo, 2017).

Figure 4 shows that, in Region 4B, the increase in the number of cases in both sexes started from 2015 and continued up to 2018 with more HIV-infected females than males. On the other hand, in Region 8, there are more HIV-infected males than females as shown in Figure 5. The number of female cases in Region 8 remain considerably lower compared to the number of male cases. The incidence of HIV in males have increased remarkably from 2012 to 2018.

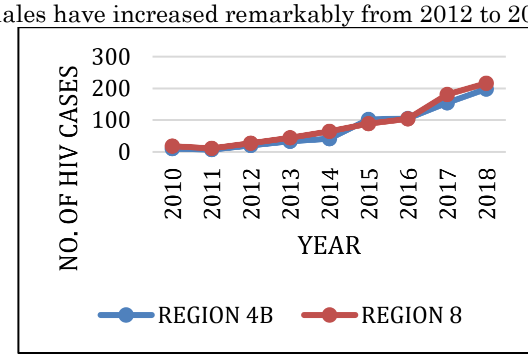

Figure 3. Annual HIV Count for Region 4B and Region 8 from 2010 to 2018

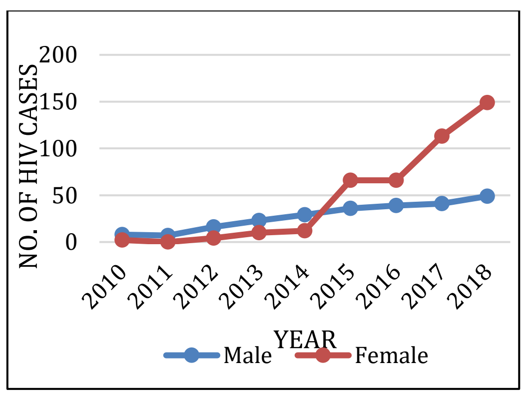

Figure 4. Annual HIV Count for Region 4B from 2010 to 2018 by Sex

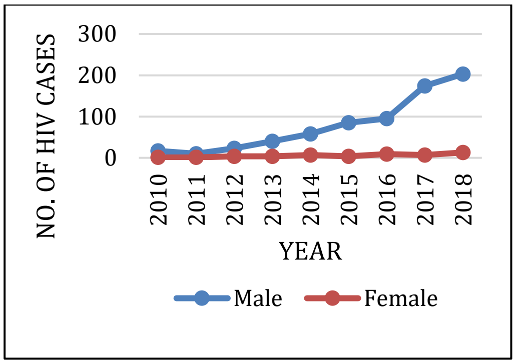

Figure 5. Annual HIV Count for Region 8 from 2010 to 2018 by Sex

In Figures 6 and 7, similar patterns of infection can be observed in Region 4B and Region 8. People aged 25 to 34 years old have the highest number of recorded cases. This age group is followed by 15- to 24-year-olds and 35- to 49-year-olds while HIV cases among people aged less than 15 and over 50 remain notably small.

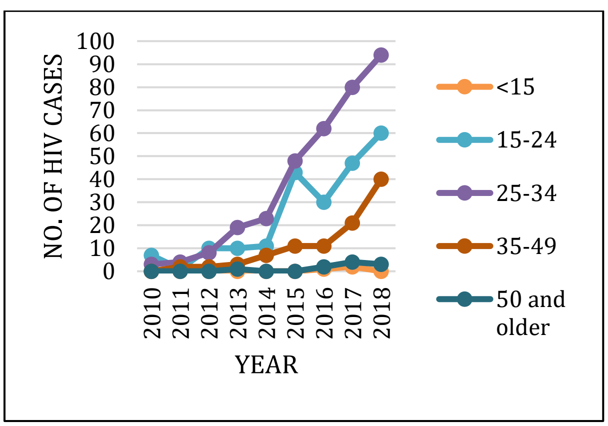

Figure 6. Annual HIV Count for Region 4B from 2010 to 2018 by Age Group

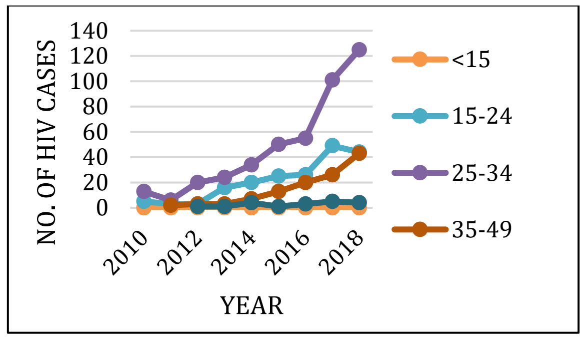

Figure 7. Annual HIV Count for Region 8 from 2010 to 2018 by Age Group

3.2 HIV Incidence and Global Spatial Autocorrelation in Region 4B and Region 8

From 2010 to 2018, there was a total of 670 HIV cases in Region 4B and 755 HIV cases in Region 8. Tables 1 and 2 show the years where Moran's I values were significant. In Region 4B, the years 2015 and 2016 have significant values ($p = 0.0490$; $p = 0.0970$). Meanwhile in Region 8, significant values were reflected in 2012 and 2015 ($p = 0.0870$; $p = 0.0100$). Thus, spatial clustering was present in these years. The expected values of the Global Moran's I were computed based on the number of provinces N in each region. Region 4B has 5 provinces, thus, the expected value of its Global Moran's I is -0.25 while Region 8 has 6 provinces, with an expected value equal to -0.20. In Region 4B, the Global Moran's I values in years 2015 and 2016 are less than -0.25, which implies a negative spatial autocorrelation among the provinces. Thus, the provinces in Region 4B have different relative risk rates of HIV. On the other hand, the Global Moran's I values in Region 8 indicated positive spatial autocorrelation. The corresponding statistics for the years 2012 and 2015 are greater than -0.20 implying a positive spatial autocorrelation and, therefore, the provinces in Region 8 have more closely valued relative risk rates.

Table 1. Global Moran's I for Region 4B

REGION 4B					
YEAR	GLOBAL MORAN'S I	P-VALUE	YEAR	GLOBAL MORAN'S I	P-VALUE
2010	-0.2817	0.4320	2015	-0.5770	0.0490**
2011	-0.3054	0.4790	2016	-0.5328	0.0970*
2012	-0.2554	0.4730	2017	-0.5031	0.1500
2013	-0.2231	0.3620	2018	-0.5323	0.0710
2014	-0.2500	0.4200			

*significant at $\alpha = 0.10$ **significant at $\alpha = 0.05$

Table 2. Global Moran's I for Region 8

REGION 8					
YEAR	GLOBAL MORAN'S I	P-VALUE	YEAR	GLOBAL MORAN'S I	P-VALUE
2010	-0.0919	0.3530	2015	0.6903	0.0100**
2011	-0.1202	0.4360	2016	-0.3679	0.3750
2012	0.3630	0.0870*	2017	0.4035	0.0780
2013	-0.5925	0.1730	2018	0.2437	0.1080
2014	-0.0980	0.3070			

*significant at $\alpha = 0.10$ **significant at $\alpha = 0.05$

Figure 8 illustrates the annual quantile maps for Region 4B. Complement to the results in Table 1, high and low relative risk rates are more dispersed among the provinces in the years 2015 and 2016. It can also be gathered from these maps that Palawan, Occidental Mindoro and Oriental Mindoro tend to have higher rates compared to Marinduque and Romblon. In 2018, it was reported that Palawan has the highest HIV cases in Region 4B which alarmed the city government of Puerto Princesa. The city government of Puerto Princesa is currently in partnership with UNAIDS to address the alarming rise of HIV cases in the city (Cimatu, 2018).

Similarly, Figure 9 displays the annual quantile maps for Region 8 and in conformity with the results in Table 2, provinces with high rates and low rates are seen together. Leyte and Southern Leyte bear higher rates in the region. A recent report from the Department of Health-Region 8 (DOH-8) confirmed that there is an alarmingly high number of HIV cases in the region and that 9 people died due to the infection in 2018. It was also noted that Leyte has the highest number of reported cases in Region 8 (Meniano, 2019).

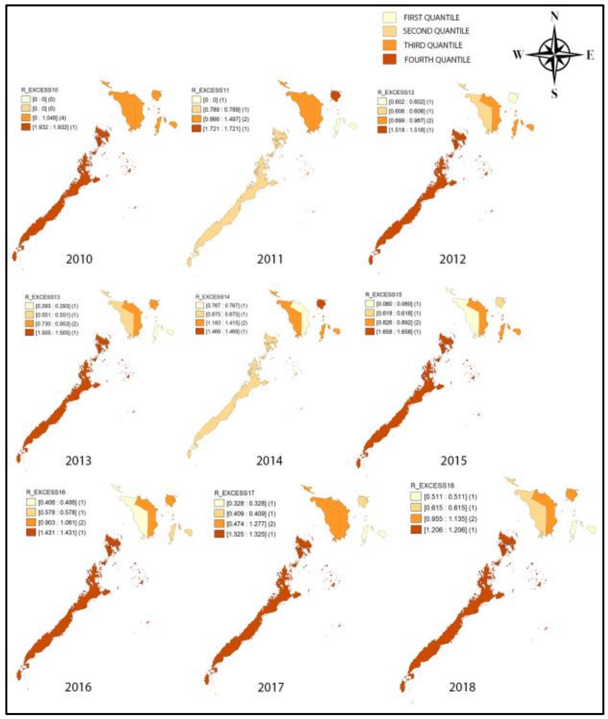

Figure 8. Quantile Maps of Region 4B

3.3 Local Moran's I

Figure 10 displays spatial autocorrelation using Local Moran's *I* in Region 4B. It can be inferred from the maps that there are no provinces with high rates surrounded by other provinces with high rates. Similarly, there are also no provinces with low rates encircled by other areas with low rates. However, Palawan has clusters of high rates surrounded by other provinces with low rates during the years 2010, 2015 and 2016. Oriental Mindoro has clusters with high rates surrounded by areas with low rates in 2010, 2013 and 2017. Marinduque and Romblon showed occasional clusters with high rates surrounded by low rates in 2012, 2015, 2016, and 2018. Additionally, Occidental Mindoro has clusters with low rates surrounded by provinces with high rates during the years 2011, 2012, 2015, 2016, and 2018.

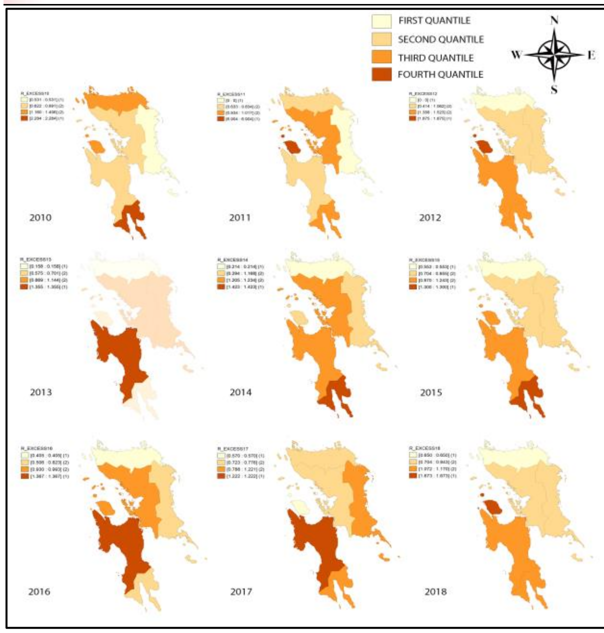

Figure 9. Quantile Maps of Region 8

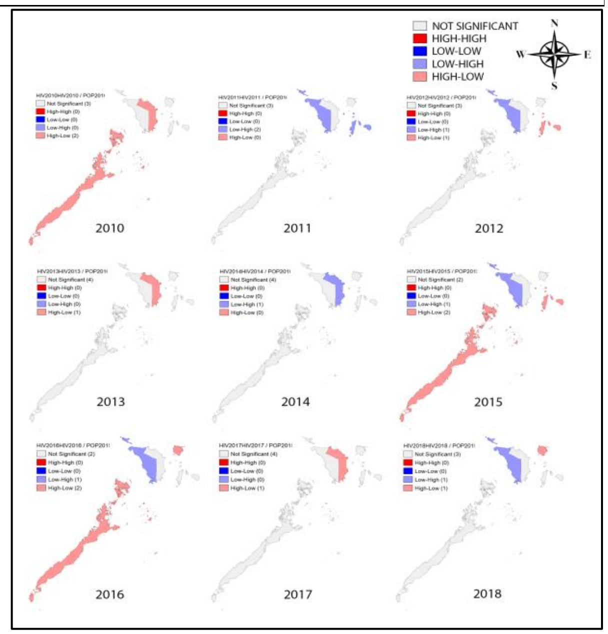

Figure 10. LISA Map of Region 4B

Figure 11 illustrates the spatial autocorrelation using Local Moran's *I* in Region 8. Leyte has clusters of high rates encircled by areas with high rates during 2012, 2015, and 2018. Northern Samar and Samar displayed clusters with high rates surrounded by areas with low rates in 2010 and 2014, respectively. In 2010, Leyte exhibited clusters with low rates surrounded by areas with high rates. Southern Leyte appeared to have clusters with low rates surrounded by areas with high rates during 2013 and 2016. During the years 2011 and 2017, there were no significant clusters in terms of rates.

3.4 Discussion

From the results generated by *GeoDa*, there is a negative spatial autocorrelation in Region 4B and positive spatial autocorrelation in Region 8. Negative spatial autocorrelation in Region 4B implies that some provinces in the region may have high rates of HIV occurrence while other neighboring provinces have low rates. Based on the quantile maps, Palawan consistently had the highest rates of HIV occurrence in the region, which is believed to be a result of the rise of tourism in the province (Santos, 2016). Tourism arrivals in Palawan was recorded at 1,162,439 foreign and local tourists in 2016, which increased by 15% in 2017, where most of the foreign tourists were American nationals (Formoso, 2017). In relation to the local spatial autocorrelation in Region 4B, Palawan has clusters of high rates surrounded by clusters with low rates during the years 2010, 2015, and 2016.

Positive spatial autocorrelation in Region 8 indicates that provinces with high rates of HIV occurrence also have neighboring provinces with high rates. Similarly, positive spatial autocorrelation may also entail that provinces with low rates of HIV incidence have neighboring provinces with low rates. Based on the quantile maps, Leyte and Southern Leyte have high rates of HIV incidence.

4. CONCLUSIONS

After analyzing the spatial and temporal trends of HIV occurrence in Region 4B and Region 8, it was observed that spatial autocorrelation is present in both regions based on the Global Moran's *I*. Negative spatial autocorrelation is present in Region 4B while positive spatial autocorrelation is present in

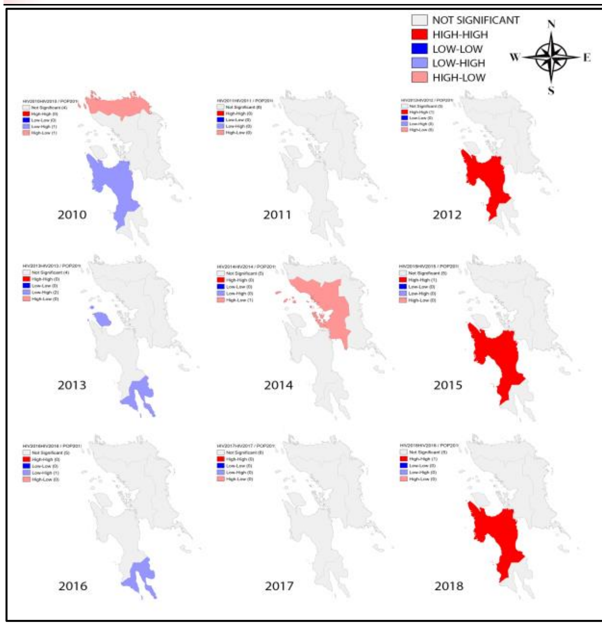

Figure 11. LISA Map of Region 8

Region 8. Based on the local Moran's *I*, Palawan has the highest rate of HIV incidence Region 4B, which can be attributed to the increase in its tourism rates. Meanwhile, in Region 8, the increase in the rates of HIV occurrence can be related to the low HIV awareness in the region, especially among males and the youth. The local government and concerned organizations in these regions may utilize this information to formulate specific programs to combat the spread of HIV in these regions, as well as to target the underlying causes of transmission.

Hence, the following recommendations may be considered for future research: (1) include all the provinces in the Philippines to increase the number of spatial units; if possible, city or barangay level data should be used to better illustrate clustering among the units, (2) generate spatial scan statistics to compare clusters of different sizes, and (3) consider other demographic factors such as ways of transmitting the disease and poverty to contribute more comprehensive information about the spread of HIV to concerned organizations. Additionally, public health officers in Region 4B and Region 8 may utilize this research to prioritize younger age groups for programs addressing HIV such as testing and screening, counseling, and treatment.

5. ACKNOWLEDGMENT

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6. REFERENCES

Anselin L. (1995). Local Indicators of Spatial Autocorrelation - LISA. *The Ohio State University*, 27, 93-115. doi.org/10.1111/j.1538-4632.1995.tb00338.x

Anselin, L. and Rey, S. J. (2014). *Modern spatial econometrics in practice: A guide to GeoDa, GeoDaSpace and PySAL*. Chicago, IL: GeoDa Press LLC.

Cimatu, F. (2018, September 20). *Puerto Princesa commits to end HIV epidemic by 2030*. Rappler. Retrieved from https://www.rappler.com/science-nature/life-health/212442-puertoprincesa-palawan-commits-end-hiv-epidemic-2030

Formoso, C. (2017, June 17). Palawan tourist arrivals up 15 percent. Palawan News. Retrieved from https://palawan-news.com/palawan-tourist-arrivals-15-percent/

Magtubo, C.A. (2017, April 22). DOH conducts HIV/AIDS awareness drive in popular tourist spot. *MIMS Today*. Retrieved from https://today.mims.com/doh-conducts-hiv-aidsawareness-drive-in-popular-tourist-spot

Meniano, S. (2019, February 15). DOH-8 reports 204 new HIV/AIDS cases in 2018. *Philippine News Agency*. Retrieved from https://www.pna.gov.ph/articles/1061965

Punay, E. (2013, July 17). SC votes 8-7 to extend suspension of RH Law. *The Philippine Star*. Retrieved from https://www.philstar.com/headlines/2013/07/17/979441/sc-votes-8-7extend-suspension-rh-law#Ux38hBbu16uLoDDi.99

Santos, C. (2016, March 11). Rising HIV cases in Palawan due to tourist influx. *Palawan News*. Retrieved from https://palawan-news.com/rising-hiv-cases-palawan-due-tourist-influx/

The Joint United Nations Programme on HIV/AIDS (2018). *UNAIDS DATA 2018*. Retrieved from http://www.unaids.org/sites/default/files/media_asset/unaids-data-2018_en.pdf

World Health Organization (2005). *Module 1: Overview of HIV Infection*. Retrieved from: https://www.who.int/diagnostics_laboratory/documents/guidance/pm_module1.pdf