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Spatial Analysis of Malaria Cases in Palawan, Philippines

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Abstract

Palawan identifies malaria as one of the threats to its overall health care and development. Nearly 95 percent of malaria cases in the country in 2016 were recorded in Palawan alone – indicating that malaria cases are highly concentrated in the said province. The need to monitor and recognize geographical patterns of the disease is a great help in controlling malaria outbreak and in increasing awareness about the disease risk. Early action and detection of malaria epidemics are important to reduce the number of deaths and illnesses caused by malaria and to reduce its impact to the socioeconomic burden among barangays in Palawan. This study investigated malaria cases among the barangays in Palawan, and its spread across neighboring barangays. Spatial analysis was performed using different neighborhood criteria - queen's and rook's contiguity weight matrices, *k*-nearest neighbors weights matrices (*k* value set to 3, 4, 5), and distance-band weight matrices (a cutoff distance of 8, 9, and 10 km). Results showed that barangays in the southernmost part of Palawan which include Bunog, Iraan, Ransang, Campong Ulay, Culasian, Candawaga, Canipaan, Punta Baja, Bulalacao, Panaligaan, Malihud, Salogon, Marangas, Samareñana, Malis, Saraza, Mainit, Culandanum, Ipilan and Pangobilian were consistently classified as high-high cluster using the different weights matrices.

Keywords: Malaria; spatial analysis; spatial clustering.

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1. Introduction

Communicable disease is defined as a disease that is transmitted through contact with blood and fluids, through the air, or through insect bites [1]. Dengue, hepatitis A, B, C, salmonella, and malaria are some examples of this type of disease. Malaria, the main interest in this study, is transmitted through insect bites. *Plasmodium falciparum*, commonly known as the Anopheles mosquito, is an infective female parasite that primarily causes malaria. Malaria infection can be easily transmitted from one person to another if one is bitten by an anopheles mosquito that has been infected through a previous blood meal from another infected person. The infected person's red blood cells is the area where these parasites thrive; therefore, it is also possible for these parasites to be transmitted via blood transfusion, organ transplant, shared use of contaminated syringes and needles, and from an infected mother to her infant; but these circumstances happen rarely [2]. Due to its fast-spreading nature, malaria becomes one of the major health problems in the world. It is stated in the report by the World Health Organization that almost half of the world's population is at risk of [3]. The accounted deaths worldwide in 2013 and 2015 were 584,000 and 429,000, respectively. Similarly, Reference [4] stated that approximately 2.4 billion of the world's population found malaria as a threat to their overall health care and development. It was also stated that the most affected countries were from tropical and subtropical areas and the majority of these countries were from Latin America, Africa, and Asia. Moreover, Reference [5] stated that places where malaria incidences were high have been described as forested, swampy, hilly and mountainous. To some extent, geographical setting explains the malaria prevalence. In the Philippines, malaria is endemic in 58 of the 80 provinces [6]. Although there was a decline in malaria cases since 1990, Reference [5] claimed that malaria can still be considered as a serious public health issue in the country. It is reported that malaria places 9th in the highest cause of morbidity in the country in 2004 [7]. Among all the provinces in the country, Palawan's situation needs close attention. In fact, according to the report of the Field Health Service Information System (FHSIS) in 2016, nearly 95 percent of malaria cases in the country was recorded in Palawan alone – indicating that malaria cases are highly concentrated in the said province [8]. The fight for malaria eradication has always been a difficult task that led the government, health-related institutions and other private sectors such as Asia Pacific Malaria Elimination Network (APMEN), Philippine Malaria Network and Malaria Elimination Group (MEG) to intensively seek solution to this problem. The government conducted the Malaria Control Program which aimed to reduce the burden of malaria, and for the socioeconomic development of individuals and families in endemic areas not be affected by the disease [9]. Some of the concerns of the program were to determine areas that are high risk of the disease and to determine probable causes of it. This is to control malaria outbreak and to heighten awareness about the disease. Reference [7] also reported that health personnel in the MIMAROPA region launched programs to prevent the spread of the disease most especially to indigenous communities by sending health executives to test blood samples and perform deworming. It was also stated in the paper of Santos that DOH MIMAROPA during that time believes that poor knowledge about the disease causes the increase in malaria cases. It is deemed necessary to make use of the counts about the total number of malaria cases in the Philippines, particularly in Palawan to detect and quantify geographical patterns to help the aforementioned agencies to combat malaria. To do this, researchers can use spatial analysis that allows one to determine the location-oriented problems and to better understand the situation. Malaria has been found to have a significant spatial component in the several studies conducted [10, 11]. For this reason, this study will use different spatial techniques in analyzing malaria cases in the different barangays in Palawan, Philippines. Generally, the study aimed to analyze and investigate spatial patterns of malaria cases barangays in Palawan. The study described the spatial distribution of malaria cases across barangays in the province and identified malaria hot spots barangays. Wise and his colleagues [12] talked about the importance of spatial statistics in solving different health-related events. The authors stated that detecting and describing patterns in different locations such as prevalence of disease is done to provide explanations about the possible causes of high or low incidence of a certain disease. Nonetheless, it was also highlighted that spatial patterns can rarely provide direct evidence, but can suggest a certain mechanism about the event. Fast-spreading diseases like malaria which spreads through insect bites require rapid response as these are public health emergencies. As such, the results of this study may provide early precautions to residents and tourists planning to visit a certain area in Palawan by informing them malaria-prone areas, the number of population at risk and the severity of the disease's spread that will be useful in preparing on possible impacts of malaria. This is very essential since Palawan is one of the most visited provinces in the country. Palawan Provincial Tourism Office reported nearly 1.2 million domestic and foreign tourists in the province [13]. In this study, spatial analysis of malaria cases was done at the barangay level so that implementation of urgent programs and policies related to malaria cases will be more effective and efficient. According to [14], programs being implemented in small areas are better for them mobilizing services, foster the needs of the constituents, and make action happen. The Department of Health (DOH) budget has been increased to 167 billion in 2017 from 154 billion in 2016 [15]. Accordingly, one of their priorities is lowering the number of top health cases in the country like dengue and malaria. Hence, this study could help the government in properly allocating budgets, services, and facilities to specific barangays that need utmost attention. The generated clustering of malaria cases in this study were based only on the 2016 malaria counts from the Kilusan Ligtas Malaria Office in Palawan. The use of different data sources might come to different results. Moreover, because barangay was the considered domain of the study, most of the data that can be used as factors in spatial lag modelling were not available during the conduct of the study. Thus, the spatial lag modelling which can be useful in determining factors that may influence cases of malaria infections in Palawan was not done.

2. Materials and Methods

2.1. Data Source

The official data on the number of confirmed malaria cases in Palawan from January 1 to December 31, 2016 was obtained from the Kilusan Ligtas Malaria (KLM) office of Palawan. KLM is under the Philippine Health Office of the Department of Health – a government office that promotes good public health decisions guided by strategic information to ensure best and sustainable outcomes. The Philippine map subdivided into provinces was obtained from the Philippine GIS Data Clearinghouse (PhilGIS). PhilGIS is a non-government organization that provides a simple and free portal of Philippine geospatial data that is used for educational and non-profit purposes.

2.2. Data Analysis

The percentile distribution of malaria cases of barangays across Palawan was plotted using GeoDa mapping software to determine barangays that have extreme cases. To describe the malaria status across barangays of Palawan, some appropriate descriptive statistics were computed and percentage distribution was constructed. Spatial autocorrelation was computed to determine if malaria incidence tends to cluster among nearby barangays. An analytical technique that considers occurrences distributed in space and includes physical dimensions such as proximity and location is spatial analysis. The spatial analysis' key concept is spatial autocorrelation. Lee [16] defines spatial autocorrelation as the measure on how much close the observational units are compared with other units. Moran's I index and Geary's C are the most commonly used measures of spatial autocorrelation. Between the two, it has been reported that Moran's I index is consistently more powerful than Geary's C [17]. Hence, the measure of spatial autocorrelation considered in this study was the Moran's global index.

Moran's I index was computed as $I = \frac{N}{\sum_i \sum_j W_{ij}} \frac{\sum_i \sum_j W_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2}$, where N is the total; X_i is the variable value at i^{th} location; X_j is the variable value at j^{th} location where $i \neq j$, $\bar{X}$ is the mean of the variable and W_{ij} is the weight applied to the comparison between location i and location j. Spatial weight, W is a $n \times n$ matrix that defines the degree of spatial proximity of n barangays with zeroes as the diagonal elements. Each element in W, denoted as w_{ij}, expresses the degree of spatial proximity between the barangay i and barangay j. If barangay j is adjacent to barangay i, the interaction will have 1 as weight and 0 otherwise. The result of Moran's I on the elements of W depends on different criteria. Contiguity weights matrix (queen and rook), k-nearest weights matrix (k=3, 4, 5), and distance-band weights matrix (cutoff distance = 8, 9, 10 km) were used to determine neighborhood of specific barangays. The Queen's and Rook's contiguity matrices criterion is analogous to the moves of such-named pieces on a chess board. The criterion of neighbors for Rook is defined by the existence of a common edge between two spatial units; while, the criterion of neighbors for Queen Contiguity matrix is said to be more encompassing, sharing a common edge or a common vertex between two spatial units [18]. The intention of using these two contiguity matrices is to compare if there will be a difference in their result, especially that the geographical profile of Palawan is narrow and elongated. Moreover, there is an assurance of no neighborless areas and each area will have an exactly the same number of neighbors if k-nearest neighbors weights matrix is employed. As the name of the method suggests, k is the number of nearest barangay from a reference point. Different values of k's were used as previously mentioned to give better options on what value of k will provide a higher spatial autocorrelation. Also, Palawan has areas that are isolated, hence distance–band weights matrix was also considered. Those barangays that fall within the pre-set cutoff distance will be classified as a neighbor of a specific barangay. Different cutoff distances were used to determine which among them has the highest spatial autocorrelation. The Moran's I global index provides a single statistic for Palawan. It shows the overall clustering of malaria cases in the entire province of Palawan. Moran's I global index can either be positive or negative. A positive Moran's I global index indicates that spatial clustering of similar values can either be low or high. This specifically tells that neighboring barangays tend to have a high or low number of malaria cases. Contrarily, a negative Moran's I global index indicates the occurrence of spatial clustering of dissimilar values. It implies that neighboring barangays tend to have a contrasting number of malaria cases. When a barangay has a high number of malaria cases, its neighboring barangays tend to have a low number of cases, or vice versa. There are cases wherein the result will show no global autocorrelation nor spatial clustering, or sometimes finding spatial autocorrelation at a local level is the main interest. In these instances, a global indicator of spatial autocorrelation can still be determined using the local indicator of spatial association (LISA). The sum of all the LISAs is equivalent to the Moran's I global index [18]. Unlike Moran's I global index, LISA indicates the significance of spatial clustering of similar values around the smaller domain of Palawan, barangay level per se. LISA is computed as: $I_i = z_i \sum_j w_{ij} z_j$, where z_i and z_j are deviations from the mean and the summation over j is referring only to the neighboring values that are included and W_{ij} is the weight applied to the comparison between location i and location j. The z_i standardized score is given by: $z_i = \frac{x_i - \bar{x}}{SD_x}$, where x_i is the observation in a spatial unit i; $\overline{x}$ is the mean observation; and SD_x is the standard deviation of the observations. The z_j refers to the z standardized scores of the neighboring spatial units and it is computed similar to z_i.Local Moran's I's interpretation is similar to that of Moran's I global index. A positive value of Local Moran's I means spatial clustering of similar values, whereas a negative value means spatial clustering of dissimilar values. Local clustering can be graphically visualized by Moran's scatter plot. Moran's scatter plot identifies specific types of clustering where a certain area and its neighbors belong. According to [18] "The classification of the spatial autocorrelation into four types begins to make the connection between *global* and *local* spatial autocorrelation. However, it is important to keep in mind that the classification as such does not imply significance." The clustering is divided into four quadrants as presented below:

Table 10

Quadrant 2: Low-High Clusters	Quadrant 1: High-High Clusters
Quadrant 3: Low-Low Clusters	Quadrant 4: High-Low Clusters

Wz=0

z=0

In the context of this study, the barangays plotted in Quadrant 1 belong to high-high clusters. This means that the reference barangay and its neighboring barangays tend to have a higher number of malaria cases than the overall average. In contrast, barangays plotted in Quadrant 3 belong to low-low clusters. This means that the reference barangay and its neighboring barangays have lower number of Malaria cases than the overall average. These two quadrants are the primary interests in the study. They are the ones that have positive local spatial autocorrelation. Furthermore, barangays plotted in Quadrant 2 belong to low-high clusters, wherein the reference barangay has low number of malaria cases while its neighboring barangays have high cases. Whereas, barangays plotted in Quadrant 4 belong to high-low clusters in which the reference barangay and neighboring barangays have high and low cases, respectively. Both Quadrant 2 and Quadrant 4 have negative local spatial autocorrelation. Significant barangays from high-high and low-low clusters can be identified using LISA Cluster Map. The barangays labeled red in the map are the significant barangays from the high-high clusters and termed as the hotspots of malaria. On the other hand, the barangays labeled blue in the map are the significant barangays from the low-low cluster and termed as coldspots of malaria.

3. Results

3.1. Overview of Malaria Status in Palawan

The map illustrates the percentile distribution of malaria cases in Palawan. The percentile score reflects the severity of cases in a certain barangay in comparison with other barangays. It can be observed that none of the barangays belong to the lower 1%, between 1% and 10%, and between 10% and 50% groups. Meanwhile, barangays Iraan, Ransang, Panalingaan, and Imulnod belong to the top 1% of the barangays – indicating that these barangays have the most extreme number of malaria cases in Palawan relative to the other barangays. Also, most of the barangays belonging in the top 10% lies in the southernmost part of Palawan.

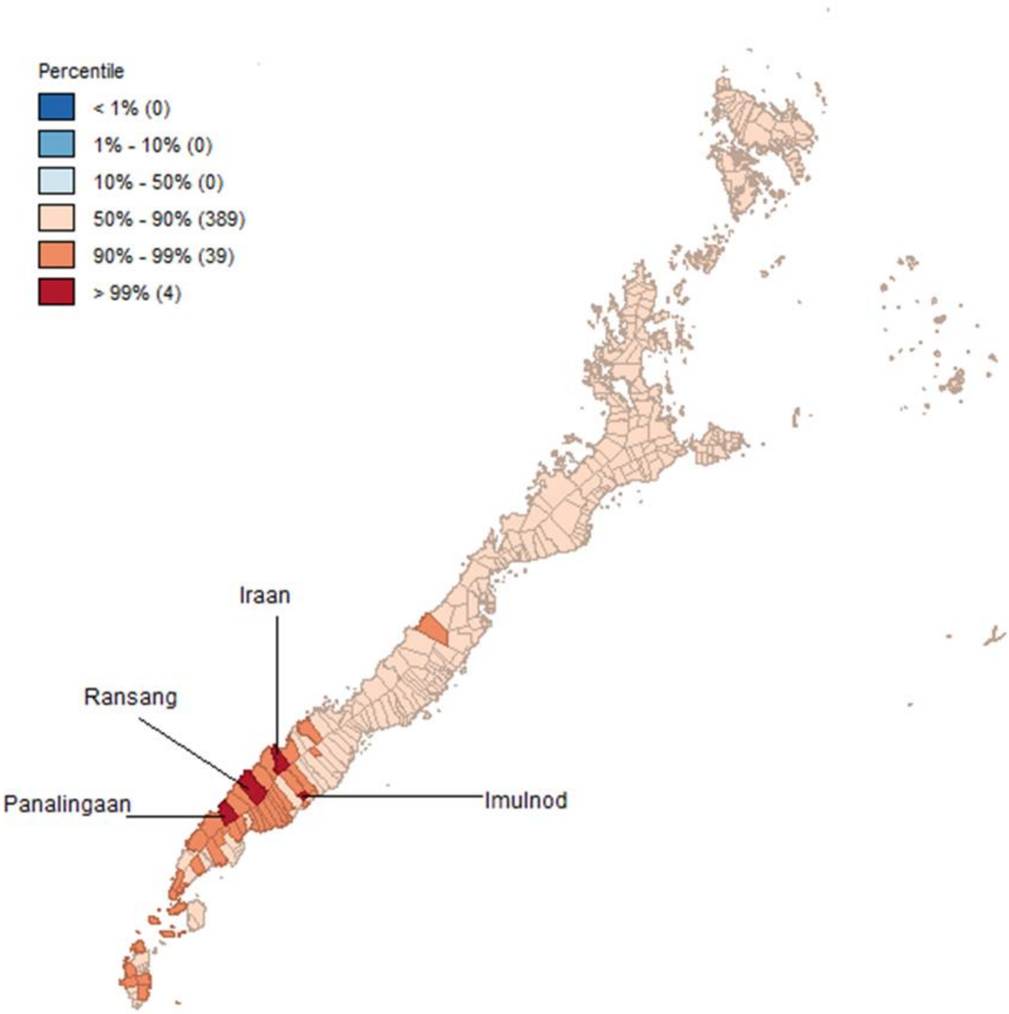

Figure 1: Percentile distribution of the number of reported malaria cases in Palawan

Palawan composed of 432 barangays with a population of 902,894 as of December 2016. There were a total of 6,324 malaria cases in the province, comprising 0.7% of the total population of the province in 2016. Albeit relatively small, Palawan recorded the highest number of malaria cases in the country during this year. This is consistent in 2015 wherein Palawan shared 90.7% of the total number of malaria cases in the country [19]. On the average, there were about 15 cases per barangay in the province. The number of malaria cases is dispersed across the barangays as indicated by its high standard deviation. There were very few barangays with extremely high numbers of cases, as indicated by positive coefficient of skewness. There were in fact barangays with no recorded cases and the highest number of cases recorded in a barangay was 556 – significantly larger than the average (Table 1). The barangay with the highest number of reported malaria cases is Ransang followed by Imulnod, Panalingan, and Iraan (Table 2). These barangays belong to the upper 1% as seen in Figure 1. All of the barangays in the top 5 highest barangays are situated in the municipality of Rizal except for Imulnod which is in Brooke's Point.

Table 1: Descriptive statistics on the number of reported malaria cases in Palawan.

Population	Malaria Cases	Number of Barangays	Average per Barangay	Standard Deviation	Min	Max	Skewness
902,894	6,324	432	14.6	51.5	0	556	0.85

Table 2: Top 5 barangays with the highest number of reported malaria cases.

Barangays	Frequency (Percentage)
Ransang	556 (8.79%)
Imulnod	448 (7.08%)
Panalingaan	325 (5.14%)
Iraan	318 (5.03%)
Punta Baja	291 (4.60%)

3.2. Mapping of Malaria Cases in Barangay Level

The number of malaria cases in each barangay was analyzed using different weight matrices, namely contiguity weight matrices (queen and rook), *k*-nearest neighbors weights matrices (*k*=3, 4, and 5), distance-band weight matrices (cutoff distance = 8, 9 and 10 km). Only the weight matrix which yielded the highest spatial autocorrelation from each type of spatial weights was discussed. Using queen's contiguity and rook's weight matrix, the spatial autocorrelation represented by Moran's I is positive with a magnitude of 0.4504 and 0.4483, respectively, implying that neighboring barangays tend to have high or low malaria cases. Likewise, the spatial autocorrelation was found statistically significant for both matrices (*p-value*=0.0010), providing an evidence that malaria cases in the province tend to cluster together. The Queen Contiguity matrix is more encompassing that is the reason why it obtained higher spatial autocorrelation. The number of neighbors based on the Queen criterion will always be at least as large as for the Rook criterion.

Table 3: Spatial statistics using contiguity weight matrices.

Spatial Matrix	Weights	Moran's I	Mean	Standard Deviation	Z-value	*p*-value*
Queen's		0.4504	-0.0017	0.0313	14.4585	0.0010
Rook's		0.4483	-0.0020	0.0327	13.7780	0.0010

*significant at *p*-value <0.05

Many of the barangays belong to high-high cluster, indicating high cases among these barangays and their neighboring barangays (Figure 2). Out of all the barangays in Palawan, there are 29 that significantly belong to high-high clustering, namely: Bunog, Iraan, Punta Baja, Campong Ulay, Ransang, Candawaga, Culasian, Taburi, Panaligaan, Canipaan, Tagolango, Culandanum, Rio Tuba, Tarusan, Bulalacao, Malihud, Bono-Bono, Marangas, Inogbong, Malis, Salogon, Pangobilian, Ipilan, Samareñana, Saraza, Amas, Imulnod, Mainit, and Aribungos (Figure 3). These barangays are from the municipality of Bataraza, Brooke's Point and Rizal which are known to have the largest tree covers according with 58%, 60%, and 70% tree cover, respectively [20]. The extent of a tree cover is defined by having greater than 30% of canopy tree which strengthen the idea that high malaria cases are indeed found in areas that are forested. Barangays that belong to low-low clustering barangays are not clearly seen in the plot since their points tend to overlap and near the origin (Figure 2). Nevertheless, these barangays and their neighboring barangays tend to have low cases of malaria. Malaking Pata, Bangcal, Model, Princesa, Madoldolon, Santo Niño, Taloto, Barangay VI, San Nicholas, Tagumpay (Coron), Santo Tomas, Igabas, Kalipay, Magkakaibigan, Maligaya, Masipag, Tagumpay (Puerto Princesa), Dumarao, and Cataban significantly belong to low-low clustering (Figure 3). Nonetheless, 79% of the barangays were not significant, which means that these barangays neither belong to any clusters nor come without neighboring barangays. This also indicates that only 21% of the provinces indeed cluster together. Furthermore, 9% of the barangays appeared to have no neighboring barangays (Table 4).

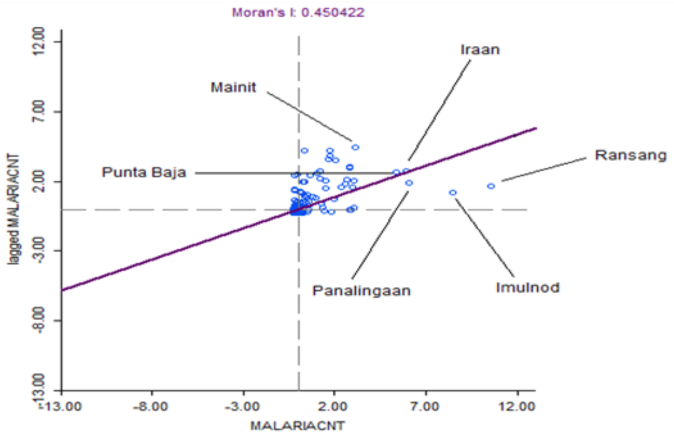

Figure 2: Moran's scatter plot of malaria cases using queen's contiguity weights

The criterion using *k*-nearest neighbor weight matrices is considered to ensure that none of the municipalities will be neighborless. This study considered setting *k* into 3, 4 and 5. Among the set values, *k*-nearest neighbors weight matrix with *k*= 4 gave the highest Moran's I of 0.4542 which is slightly higher than that of contiguity matrices. Similarly, positive spatial correlations were generated for *k*=3 and *k*=5 with Moran's I of 0.4441 and 0.4394, respectively. These results indicate that neighboring barangays tend to have a high or low number of malaria cases. All spatial autocorrelations were significant signifying that malaria cases in Palawan tend to cluster together. A positively high spatial autocorrelation, provided by *k*=4, indicates a strong clustering among high or low malaria cases.

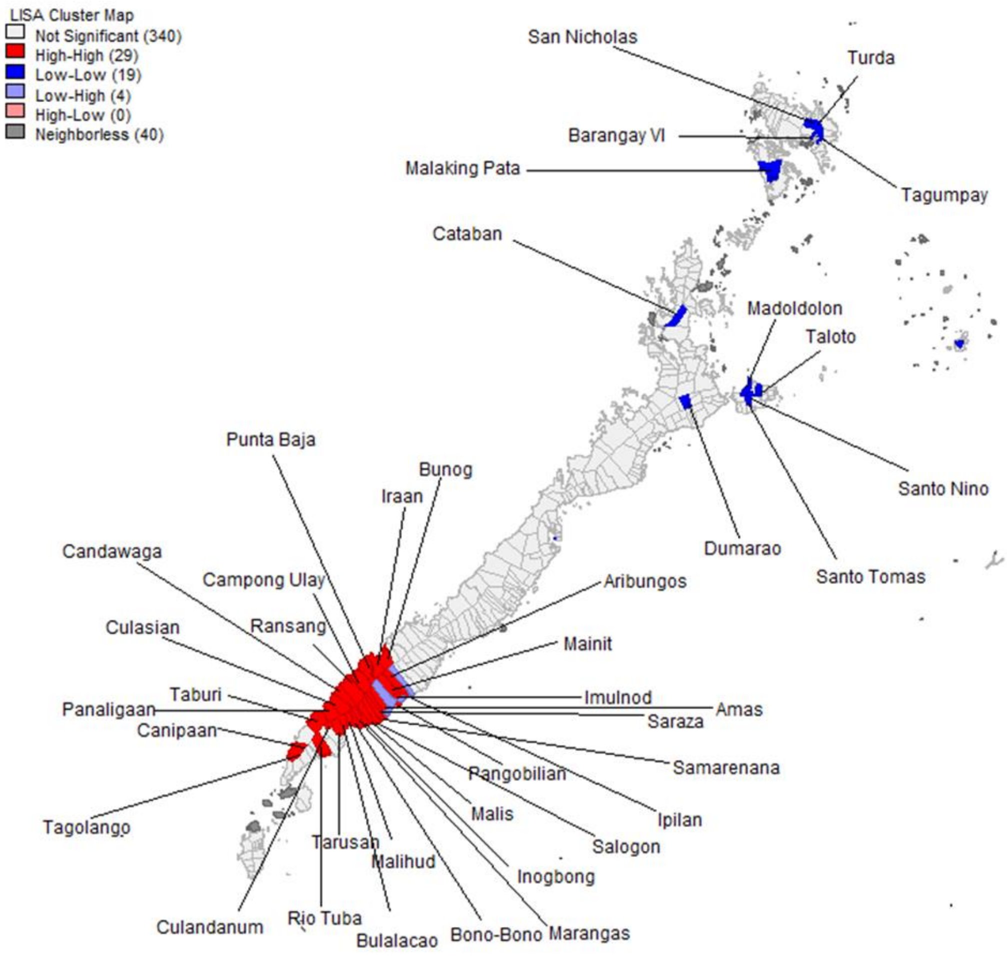

Figure 3: LISA cluster map of malaria cases using queen's contiguity weights

Table 4: Percentage distribution of clustering of the barangays using queen's contiguity matrix

Contiguity Matrices	Not Significant Barangays	High-High Barangays	Low-Low Barangays	Low-High Barangays	High-Low Barangays	Neighborless Baranagys
Queen's	340 (79%)	29 (7%)	19 (4%)	4 (1%)	0 (0%)	40 (9%)

Table 5: Spatial statistics using *k*-nearest neighbors weight matrices.

k-nearest neighbors weights matrix	Moran's I	Mean	Standard Deviation	Z-value	*p*-value*
k=3	0.4441	-0.0024	0.0343	13.0357	0.0010
k=4	0.4542	-0.0018	0.0297	15.3710	0.0010
k=5	0.4394	-0.0019	0.0268	16.4618	0.0010

*significant at p-value <0.05

Ransang, Imulnod, Pangalingaan, Iraan, Punta Baja, Campong Ulay and Candawaga are some of the barangays municipalities that belong to high-high cluster using *k*-nearest neighbors weights matrix (*k*=4) (Figure 4). These barangays within high-high cluster and their neighboring barangays tend to have high cases of malaria. Moran's scatter plots of *k*-nearest neighbors weights matrix (*k*=4), on the other hand do not clearly specify the point for a certain barangay because similar to that of queen's method, points tend to overlap and are near the origin. But certainly, a minority of the barangays in Palawan belong to low-low clustering, and these barangays and their neighboring barangays tend to have low cases of malaria (Figure 4). Using the *k*- nearest neighbors weights matrix (*k*= 4), 6% of the 432 barangays significantly belong to high-high clustering – all of these can be found in Brooke's Point, Bataraza, Rizal and Balabac (Table 6). Barangays in this cluster include Bunog, Iraan, Punta Baja, Campong Ulay, Ransang, Candawaga, Culasian, Taburi, Panaligaan, Canipaan, Buliluyan, Bancalaan, Culandanum, Bulalacao, Malihud, Marangas, Malis, Salogon, Pangobilian, Ipilan, Samareñana, Saraza, Mainit, and Aribungos (Figure 5). Del Monte Arabia rented 6,000 hectares of land that go across three towns in the southern part of Palawan including Brooke's Point, Rizal and Bataraza to operate a plantation [21]. These areas are described as an ideal place for pineapple and banana plantations because they have the same latitude as Davao, and similar to the study of Krefil and his colleagues [22], banana or plantain production was emphasized to triple the risk of malaria. On the other hand, none of the barangays significantly belong to low-low cluster. It can be concluded none of the points seen in the Quadrant 3 are significant (Table 6).

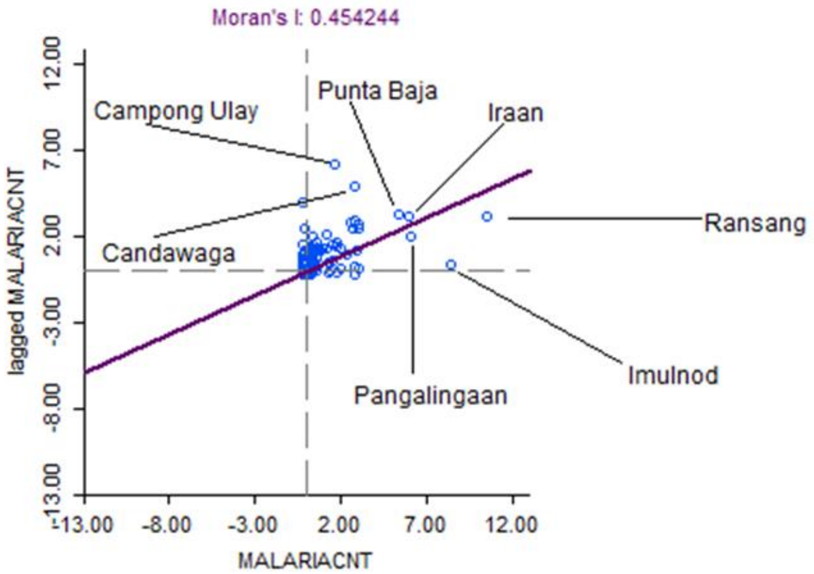

Figure 4: Moran's scatter plot of Malaria cases using k-nearest neighbors weights matrix (k=4)

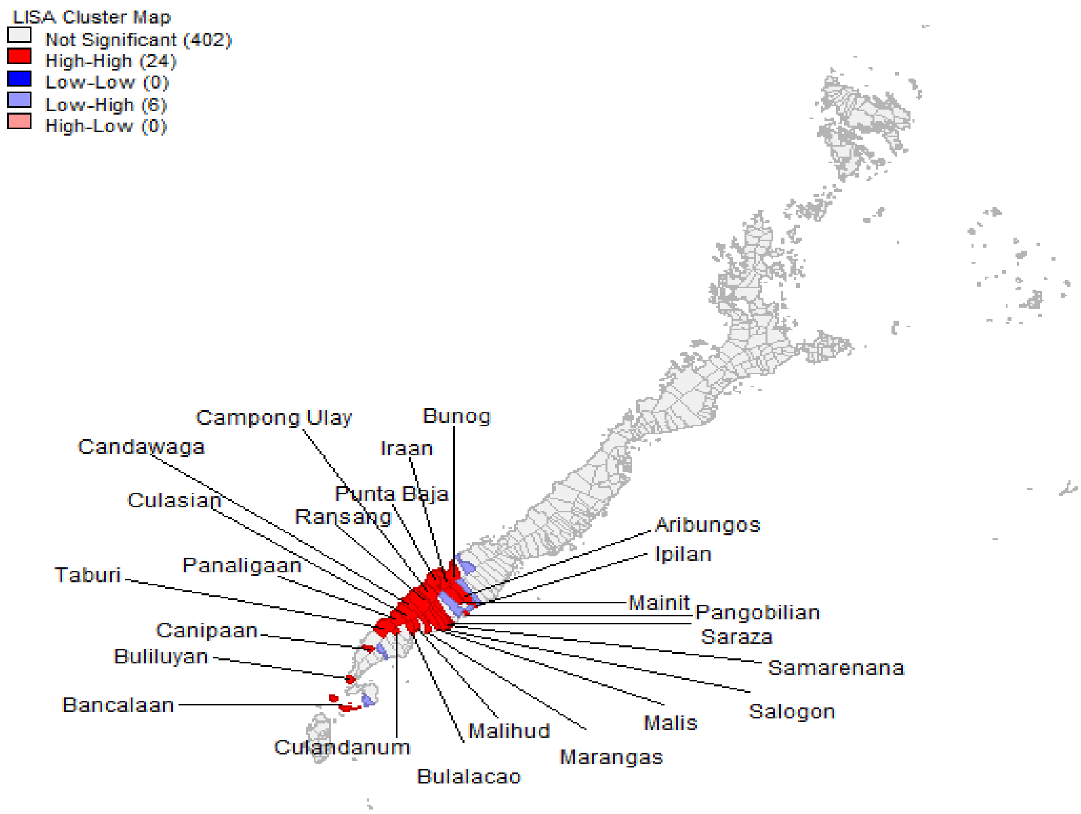

Figure 5: LISA Cluster Map of Malaria cases using k-nearest neighbor weight matrix (k=4)

Table 6: Percentage distribution of clustering of the barangays using k-nearest neighbors weight matrix (*k*=4).

Not Significant Barangays	High-High Barangays	Low-Low Barangays	Low-High Barangays	High-Low Barangays	Neighborless Barangays
402 (93%)	24 (6%)	0 (0%)	6 (1%)	0 (0%)	0 (0%)

Distance-band weights using 8, 9, and 10 kilometers are the cutoff distances that were used in the study. Neighborless barangays are expected in this method, especially if there are isolated or secluded areas. The minimum cutoff distance in order to have a non-neighborless municipality in the context of this study is 46.5617 kilometers. This is because there are barangays such as Magsaysay and Mangsee whose topographical location is far-stretched to other barangays. Results for greater than or equal the minimum cutoff distance is not presented due to a low spatial autocorrelation. The distance-band weights matrix with a cutoff distance of 8 km generated spatial autocorrelation of 0.4897. This is fairly higher compared to that of the contiguity weights matrices and *k*-nearest weight matrices. The positive spatial autocorrelation, once again, indicates a similar situation (either low or high cases) of neighboring barangays. Likewise, spatial autocorrelation is statistically significant (*p-value*=0.0010) implying that malaria cases in Palawan indeed tend to cluster together. Meanwhile, the spatial autocorrelation computed using a cutoff distance of 10 km is 0.4664. The one kilometer addition to the cut-off distance lowered the strength of the clustering of malaria cases by 0.0233 and remained statistically significant (*p-value* =0.0010). Lastly, a cutoff distance of 9 km obtained a spatial autocorrelation of 0.4622, the lowest among all distances-band weight matrices used and yet still significant (*p-value*=0.0010) (Table 7).

Table 7: Spatial statistics using distance-band weight matrices.

Distance-band Weight Matrix	Moran's I	Mean	Standard Deviation	Z-value	*p*-value*
cutoff distance of 8 km	0.4897	-0.0031	0.0332	14.8238	0.0010
cutoff distance of 9 km	0.4622	-0.0028	0.0325	14.3169	0.0010
cutoff distance of 10 km	0.4664	-0.0022	0.0320	14.6305	0.0010

*significant at p-value <0.05

Some obvious barangays that lies inside the high-high cluster using a cutoff distance of 8 kilometers includes Iraan, Ransang, Imulnod, Panalingaan, Bunog, Ipilan, Culasian, Candawaga, Campong Ulay and Punta Baja (Figure 6). Each of these barangays exhibited a high number of malaria cases and also tend to have neighbors with high malaria cases as well. In contrast, the relatively larger portion of the barangays (24%) was significantly classified in the low-low cluster, indicating that each of these barangays and their neighboring barangays tend to have a low number of malaria cases (Table 8). Moreover, using the LISA Cluster Map with a cutoff distance of 8 kilometers, only 6% of the barangays have significantly high-high clustering (Table 8 and Figure 7). The result seems reasonable since 8 kilometers might only cover a few numbers of barangays as neighbors. In fact, Palawan stretch measures an approximate 450 kilometers long and 50 kilometers wide. Quinlogan, Bunog, Iraan, Punta Baja, Campong Ulay, Ransang, Candawaga, Culasian, Panaligaan, Canipaan, Tagolango, Malitub, Buliluyan, Puring, Culandanum, Bulalacao, Malihud, Bono-Bono, Marangas, Inogbong, Malis, Salogon, Samareñana, Saraza, Pangobilian, Ipilan, Amas, and Mainit are the barangays that significantly belong to high-high clustering (Figure 7). Majority of these barangays are sheltered along Mt. Mantalingajan, the highest mountain in Palawan. It covers a total area of 120,457 hectares [23]. Mt. Mantalingajan has a rich ultramafic forest, unique fauna and flora, and different vegetative cover types within the area, including mossy, mangrove, brushland, and different plantations [24]. High Malaria cases have been described to occur in mountainous areas. Furthermore, only 43% of the barangays indeed cluster together and 12% of the barangays classified to have no neighboring barangays (Table 8).

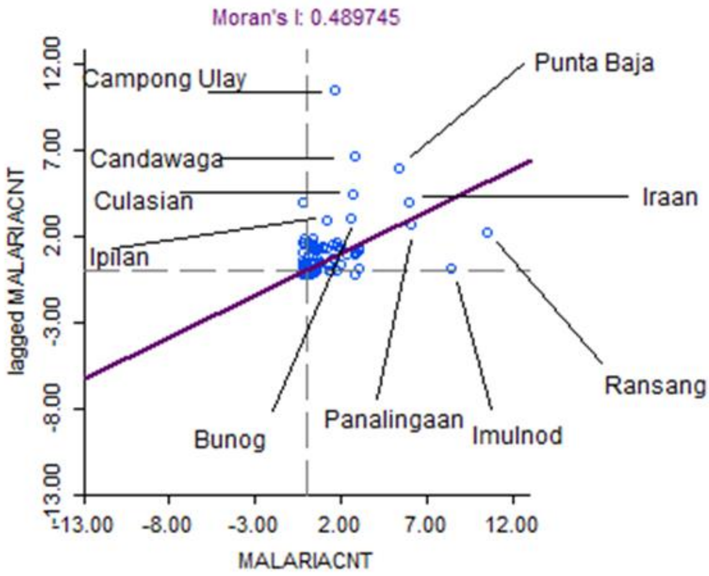

Figure 6: Moran's scatter plot of malaria cases using distance-band weight matrix with a cutoff distance of 8 km

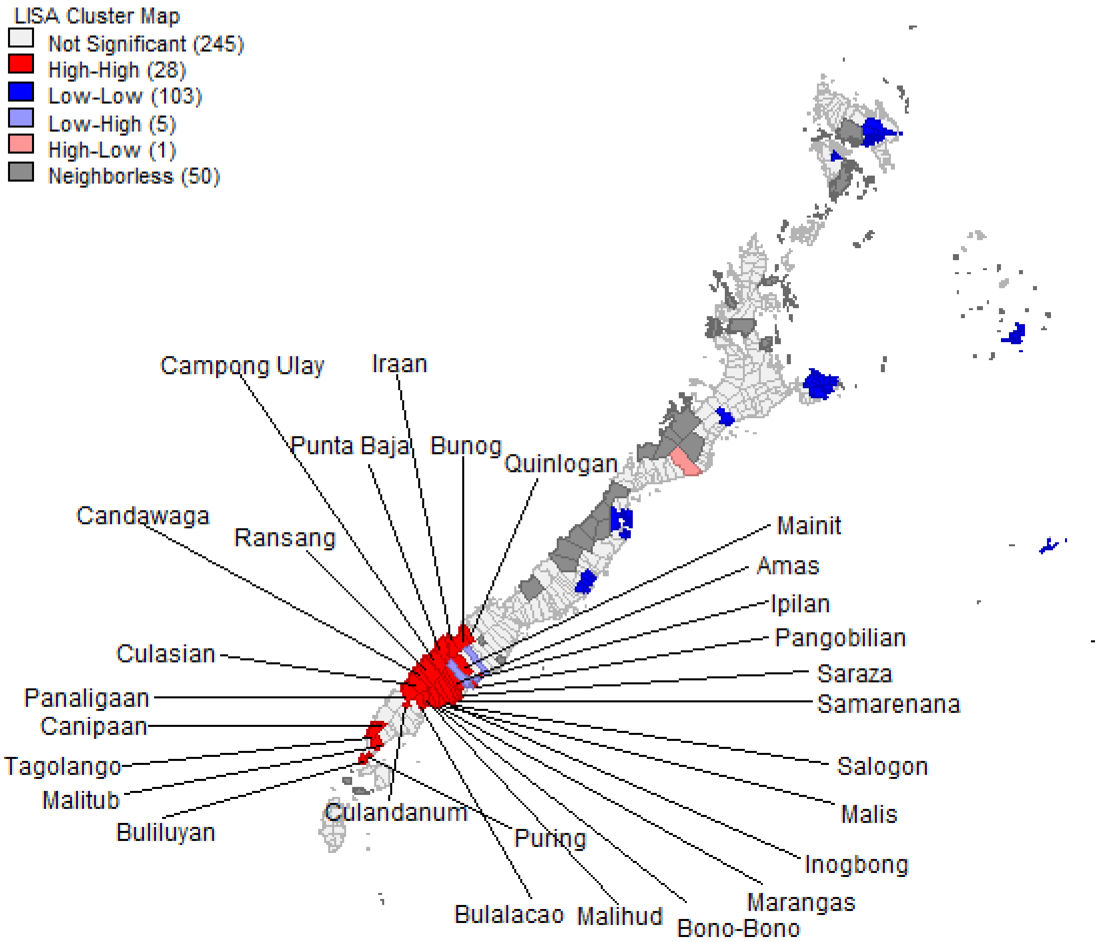

Figure 7: LISA Cluster Map of Malaria cases using distance-band weight matrix with a cutoff distance of 8 km

Table 8: Percentage distribution of clustering of the municipalities using distance-band weight matrices (cutoff=8km).

Not Significant Barangays	High-High Barangays	Low-Low Barangays	Low-High Barangays	High-Low Barangays	Neighborless Barangays
245 (57%)	28 (6%)	103 (24%)	5 (1%)	1 (0%)	50(12%)

4. Conclusion

This study conducted a spatial analysis to analyze the spatial pattern of malaria cases across all barangays in Palawan, Philippines. Distribution of malaria cases in the province was presented through descriptive statistics and percentile map. Barangay Ransang recorded the highest number of malaria cases in the province. Alongside Ransang, Imulnod, Panalingaan and Iraan barangays also have the most extreme malaria infections. The number of malaria cases of each barangay was analyzed using different weight matrices, including contiguity weight matrices (queen and rook), *k*-nearest neighbor weight matrices (*k*=3, 4, and 5), distance-band weight matrices (a cutoff distance of 8, 9 and 10 km). Moran's I was computed for all weight matrices. For each method, the one with the highest spatial autocorrelation were considered in the classification of barangays. All of the neighborhood criteria obtained significant positive spatial autocorrelation – indicating that neighboring barangays tend to have either high or low number of malaria cases. There are 20 barangays in Palawan that constantly included in high-high cluster using the different spatial weight matrices. Barangays of Bunog, Iraan, Ransang, Campong Ulay, Culasian, Candawaga, Canipaan, Punta Baja, Bulalacao, Panaligaan, Malihud, Salogon, Marangas, Samareñana, Malis, Saraza, Mainit, Culandanum, Ipilan and Pangobilian are indeed hotspots of malaria cases (Table 9). Tau't Bata IP Community resides in Singnapan Valley, a remote area in Ransang where people are mostly sheltered in large caves [25]. Attributable to the area's distance from the town proper, residents living there have limited access to medical facilities. The nature of their shelters is vulnerable because they have limited protection to mosquitoes. Similar situations can be seen for the Palaw'an tribe in Iraan, Afutayen tribe in Ipilan and Molbog tribe across barangays in Balabac and Bataraza. Mt. Mantalingahan Protected Landscape covers areas across all barangays in the municipality of Rizal which includes Bunog, Campong Ulay, Candawaga, Culasian, Iraan, Panaligaan, Punta Baja and Ransang. Malihud in Bataraza and Mainit in Brooke's Point are also included in the area range set by the organization [26]. All of the barangays mentioned are hotspots of malaria infections. Mt. Mantalingahan is not only a sanctuary of forest districts and refuge of different plant species contributes to high malaria cases, but also serves as a home to many indigenous groups.

Table 9: Summary of clustering of significant barangays using the different spatial weight matrices**.**

Queen's		***k*-nearest neighbors (k=4)**		**Distance based (8 km)**	
High-high		**High-high**		**High-high**	
Bunog	*Iraan*	*Bunog*	*Iraan*	*Bunog*	*Iraan*
Ransang	*Campong Ulay*	*Ransang*	*Campong Ulay*	*Ransang*	*Campong Ulay*
Culasian	*Candawaga*	*Culasian*	*Candawaga*	*Culasian*	*Candawaga*
Canipaan	*Punta Baja*	*Canipaan*	*Punta Baja*	*Canipaan*	*Punta Baja*
Bulalacao	*Panaligaan*	*Bulalacao*	*Panaligaan*	*Bulalacao*	*Panaligaan*
Malihud	*Salogon*	*Malihud*	*Salogon*	*Malihud*	*Salogon*
Marangas	*Samareñana*	*Marangas*	*Samareñana*	*Marangas*	*Samareñana*
Malis	*Saraza*	*Malis*	*Saraza*	*Malis*	*Saraza*
Mainit	*Culandanum*	*Mainit*	*Culandanum*	*Mainit*	*Culandanum*
Ipilan	*Pangobilian*	*Ipilan*	*Pangobilian*	*Ipilan*	*Pangobilian*
Tagolango	Aribungos	Aribungos	Buliluyan	Inogbong	Tagolango
Rio Tuba	Taburi	Taburi	Bancalaan	Amas	Buliluyan
Bono-Bono	Amas			Malitub	Bono-Bono
Inogbong	Tarusan			Puring	Quinlogan
Imulnod					

5. Recommendation

This study recommends the concerned institutions such as the Kilusan Ligtas Malaria Office to prioritize those identified hotspots barangays in Palawan in terms of the conduct of disease controlling activities and the allocation of medical supplies and equipment among the health facilities in the province. This will help KLM in expediting strategic spraying or misting operations and acquiring of hygiene kits to be distributed. Correspondingly, conducting anti-malaria tests such as blood smear test, deworming, ICT (Immunochroatographic Test for Filariasis) and RDT (Rapid Diagnostic Test) can be easily facilitated. Moreover, this study can be used to further assess specific barangays that need additional rural health units and workers. It is also recommended for the future studies on the same topic to consider spatial lag modelling. Spatial lag models can be used to predict the number of malaria cases per barangay. The results of spatial lag modelling will be useful in determining factors that may influence cases of malaria infections.

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