HOTSPOT ANALYSIS OF HAND FOOT AND MOUTH DISEASE (HFMD) USING GIS IN KUCHING, SARAWAK, MALAYSIA

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Abstract

Purpose of the study: The main objective of this study was to identify the hotspot area of HFMD reported cases within two local councils, namely, Kuching North City Council and Kuching South City Council, by using Geographic Information System (GIS) technique.

Methodology: Two methods, namely, Getis-Ord GI* and Thiessen polygon, were used in this study. Getis-Ord GI* statistics was used to identify the hotspot areas and Thiessen polygon method was used to create an influencing boundary for each village. The analysis was conducted from 2014 to 2018 on the basis of the cases reported and registered with Sarawak Health Department by using ArcGIS Software.

Main Findings: The hotspot areas were confined to the Western area of Kuching North City Council, which is located at Rampangi Fasa II and Semariang Pinggir villages. Subsequently, in Kuching South City Council, there were two villages were identified as hotspot areas at Kampung Stampin and Kampung Stutong Baru.

Applications of this study: The findings from this study will help local authorities, public health officers, epidemiologists, and the public to identify the hotspot areas of HFMD occurrences and therefore, the information obtained in this study will be of a great help to them in coming up with the necessary mitigation plan to control this disease before it spreads to other locations.

Novelty/Originality of this study: Previous studies conducted in Sarawak on HFMD were based on divisional boundaries, which were too broad to be used as a guide for mitigation planning. Therefore, the outcome from this study, which was based on the village boundary, provides more information on the hotspot areas of HFMD at a micro level.

Keywords: GIS, HFMD, Hotspot, Spatial Analysis

INTRODUCTION

Hand, Foot, and Mouth Disease (HFMD) is a common disease infecting young children and infants. Although it is a common disease, it can cause dead if it is not properly treated. For example, in the year 2000, 3,790 patients were diagnosed with HFMD in Singapore (Kwai Peng, 2003). On the other hand, 6,049 reported cases with 22 deaths happened in China in 2008 (Yan Zhang, 2010). Similarly, in Malaysia, 51,147 recorded cases of HFMD were reported from January 2018 until August 2018 (Farhana Syed Nokman, 2019). Subsequently, in January 2019 alone, there were 615 cases of HFMD have been registered at Department of Health Sarawak, 2019.

This situation raises a question on the effectiveness of precautionary measure control in place. In 1997 for instance, there were 31 cases of fatality that linked to HFMD outbreak (Noraishah et al, 2016). Additionally, in 2006, there were 13 cases of fatality reported with 14,423 infected children (Felix Chuo Sing Tiing, 2008). Since HFMD can lead to fatality, proper mitigation plan needs to be developed and the identification of hotspot area of HFMD is crucial as the information of hotspot area is required for precautionary measures planning (Justin et al, 2017).

HFMD was caused by systemic infections of human enteroviruses such as genera rhinovirus, aphthovirus, cardiovirus, parechovirus and hepatovirus (Ministry of Health Malaysia, 2007) . On top of that, the Coxsackie virus groups A and B, enteroviruses 68-71, polioviruses and echoviruses were also contributed to HFMD infections. Figure 1 shows the symptoms and signs of HFMD.

In general, HFMD can be identified and detected if the respective patient has long fever, ulcers in several places, such as mouth, tongue, and throat, continuously having bad headache and sore throat as well as rashes with vesicles on hands, mouth, and feet. (Ministry of Health Singapore, 2015).

Figure 1. Signs and Symptoms of HFMD

Source: (Ministry of Health Singapore, 2015)

Due to the increasing number of HFMD patients, hence the objective of this study is to identify the hotspot areas of HFMD within two local councils namely Kuching North City Council and Kuching South City Council, which are located at Kuching Division of Sarawak. Therefore, GIS technique to identify hotspot area will be used in this study based on the data collected from Sarawak Health Department from the year 2014 to 2018. In term of population, the study area had a population of 763,900 with 63.91% being native (Department of Statictics Malaysia, 2017).

From the year 2014 to the year 2018, 525 cases were reported for Kuching divisions. Out of 525 cases, 349 cases were recorded at Kuching North City Council. As illustrated in Table 1, Kuching North City Council recorded 105 cases in the year 2014, which were 50% higher than Kuching South City Council. Similarly, the reported cases of HFMD from 2014 to 2018 also show that the recorded cases at Kuching North City Council were much higher than at Kuching South City Council.

Table 1: HFMD reported cases by Local Councils

Council / Year	2014	2015	2016	2017	2018
Kuching North City Council	105	41	62	61	80
Kuching South City Council	53	34	24	29	36
Total	158	75	86	90	116

Source: (Sarawak Health Department, 2018)

Based on the information provided by Sarawak Health Department as illustrated in Table 1, the hotspot area was identified. Hotspot area refers to an area that has high risk of infectious disease (Justin et al, 2017). On the other hand, it can also be considered as a location of statistically significant of clustering of disease occurred (Thomas Stopka, 2014). Concisely, hotspot analysis of HFMD is referring to the process of identification of more concentrated cases of HFMD as compared to other locations. Hotspot identification can be done in many ways. In this study, GIS was used as a tool for hotspot identification.

LITERATURE REVIEW

Although several researches have been conducted in other countries regarding HFMD, unfortunately only several studies were carried out in Sarawak pertaining to this subject. Hence, the strategic planning to control the spreading of HFMD becomes more challenging as the information of hotspot areas are very limited. Ratchaphon from Thailand has published a study on HFMD with the objective to identify the correlation between HFMD and weather condition from the year 2003 until 2012. His study identified that the case of HFMD increased during rainy and cold sessions (Ratchaphon Samphutthanon, 2014). Lin Zhu also conducted another study concerning HFMD in Shandong Province, China. GIS was used by Lin Zhu and their research team to examine the relationship between temperature conditions and HFMD reported cases. Their finding concluded that there was a statistically significant relationship between temperature conditions and the occurrences of HFMD in Shandong Province, China (Lin Zhu et al, 2015).

As for Sarawak, Ooi has used GIS to map HFMD reported cases for the whole of Sarawak. Thematic Map of HFMD based on division was later produced by him (C.H. Ooi, 2008). In 2014, Noraishah has conducted a temporal and spatial mapping of HFMD that covered 13 all divisions of Sarawak. Her studied focused on reported cased of HFMD from the year 2006 until 2012. She was further elaborated in her study that there was no significant clustering was detected (Noraishah Sham et al, 2014). Subsequently in the year 2016, Noraishah M. Sham conducted another study on HFMD, with the objective to identify the spatial spreading pattern of HFMD for urban divisions and non-urban divisions. Inverse Distance Weighted (IDW) was used by Noraishah M. Sham to interpolate the reported HFMD cases for the whole of Sarawak. Her study concluded that the high-risk pattern of HFDM was detected at urban divisions namely Kuching, Samarahan, Sibu, Bintulu and Miri (Noraishah et al, 2016).

Since the previous studies do not cover the hotspot area based on village boundary, it therefore does not answer clearly the location of settlement that has more concentration of HFMD. Ooi (2008) and Sham (2014 & 2016) only conducted the HFMD cases in Sarawak based on divisional boundaries which were too broad to be used for mitigation planning control of HFMD. Hence, this study will be focusing on the concentration of HFMD cases based on village boundary. Additionally, this study will examine the effectiveness of using GIS technique to generate the artificial boundary for each village within these two local councils. The artificial boundary will be created as there is no existing boundary available to separate each village.

METHODOLOGY

Study Area

The study area is located in Kuching division, which has an area of 4200 square km. Figure 1 illustrates the location of study area. It comprises of two local councils, namely, Kuching North City Council and Kuching South City Council.
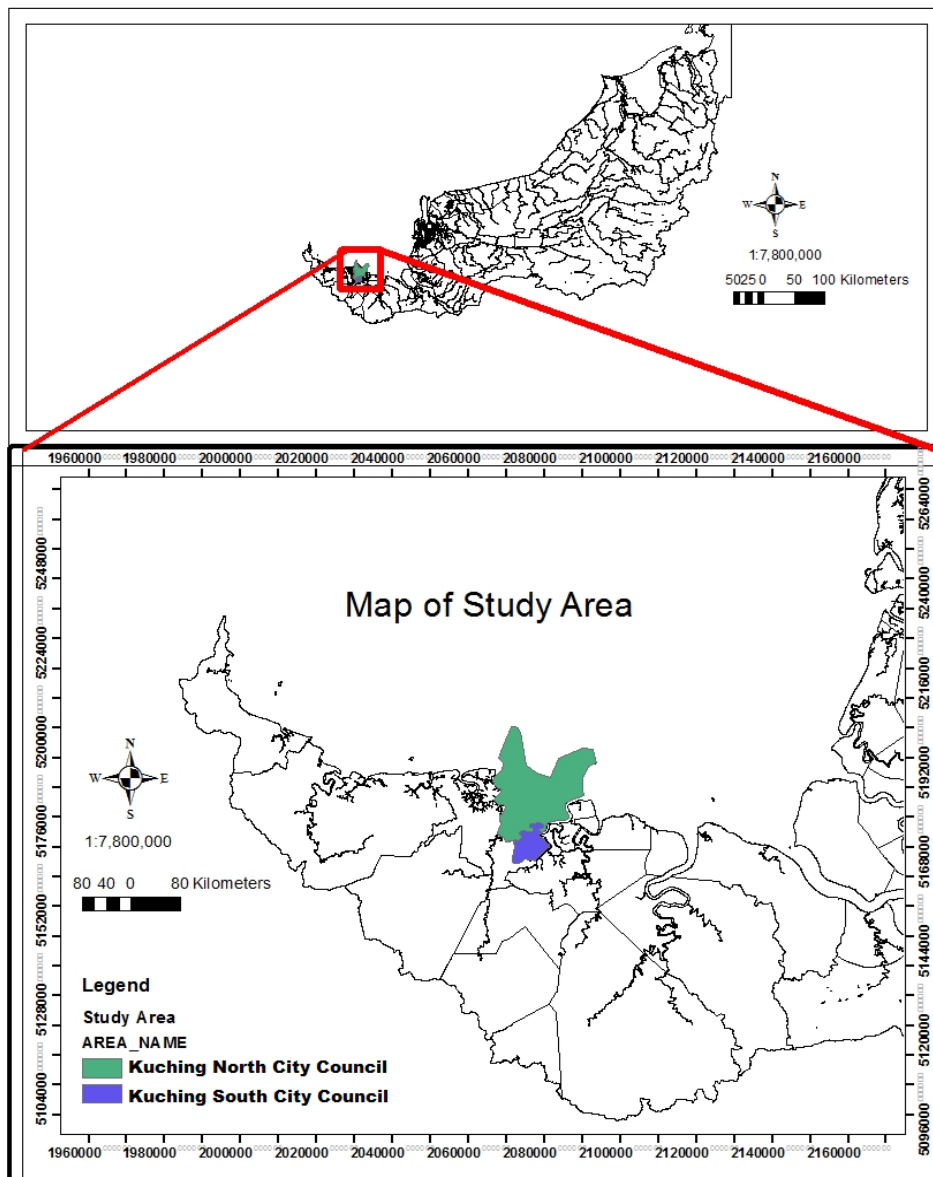

Figure 1. Map of Study Area

Data Acquisition

The data on reported HFMD cases in this study were obtained from Sarawak Health Department from the year 2014 to the year 2018. The collected data was geocoded on the basis of its location on the ground. The boundary for each village was generated by using the Thiessen Polygon Method due to non-existing boundary available for each village. This can be assessed from the unrestricted map produced by the Department of Survey and Mapping Malaysia (JUPEM) in 2018,

where no village boundary was generated. Since there is no boundary to mark each village, the Thiessen polygon method was introduced as a reference and guide to indicate the concentration of HFMD cases by villages. Thiessen polygon also known as Voronoi is a method to understand the influence of any reference points (Zaria Tatalovich, 2008). The distance of connected triangulation for each village will be divided equally and from there, a polygon was formed. Figure 2 below shows the steps of creating Thiessen Polygon and Figure 3 illustrates the generated artificial boundary of each village.
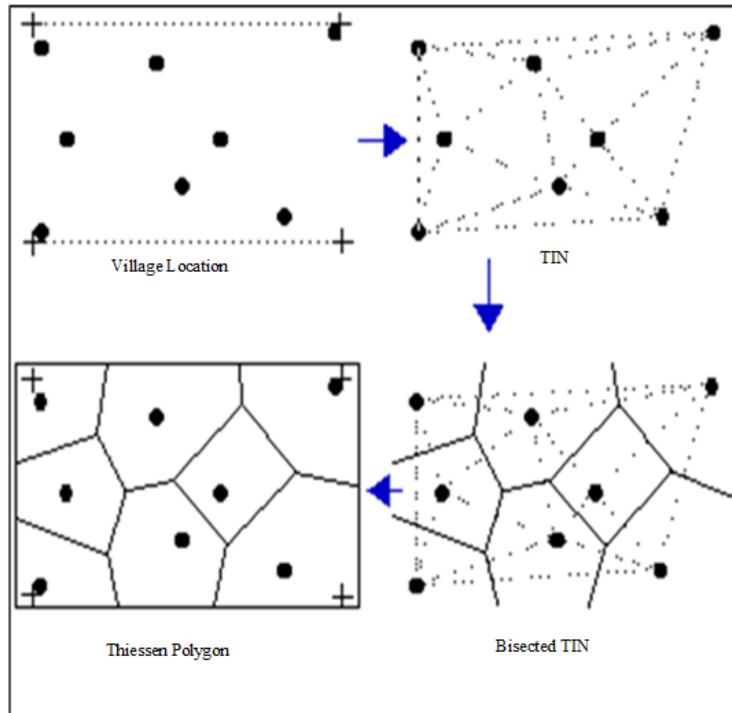

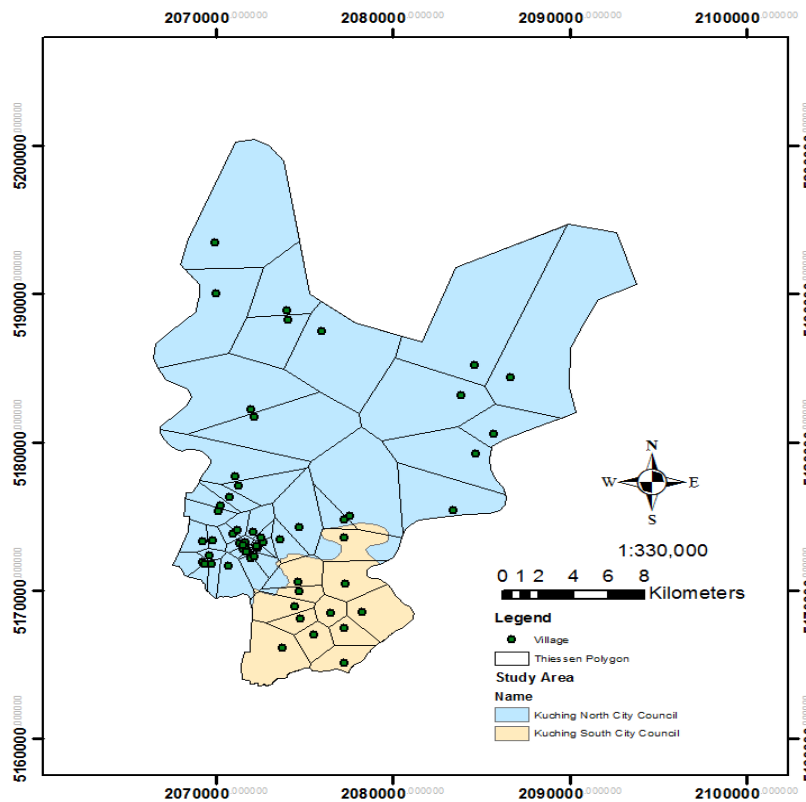Figure 2. Thiessen Polygon

Source: ESRI, 2018

Figure 3. Village boundary based on Thiessen Polygon

Hotspot Analysis

Getis Ord GI* technique was used in this study to identify the hotspot area of HFMD distributions within two local councils, that is in Kuching South City Council and Kuching North City Council. New GIS layer used to represent the concentration of HFMD was created by using this technique. Equation 1 below illustrates the formula of Getis Ord GI* that has been used in this study.

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \overline{X} \sum_{j=1}^{n} w_{i,j}}{s \sqrt{\dfrac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2 \right]}{n-1}}}$$

$$\overline{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\overline{X} \right)^2}$$

Equation 1: Getis Ord GI*

Source: (ESRI, 2018)

In this statistical analysis, xj refers to attribute value of feature j, which is HFMD locations whereby wij refers to spatial weight in between feature i and j. While n refers to the number of HFMD locations (ESRI, 2018). The output from this analysis, especially the z scores and p-values, will determine if HFDM distributions on the ground are hotspot or coldspot areas. If the z-value is positive, it tends to be a hotspot area and if z-value is negative, it tends to be a coldspot area. Figure 4 shows the methodology adopted in this study.
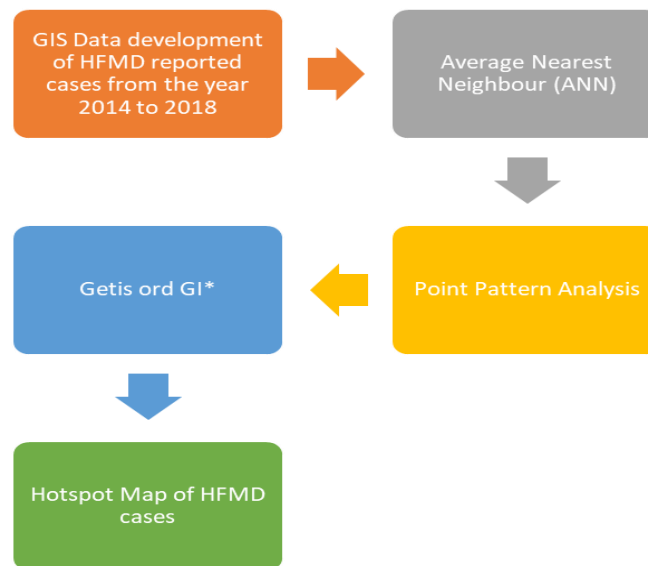

Figure 4. Adopted Methodology of Hotspot Analysis using GIS

All reported cases of HFMD will be converted into GIS format and each of the cases will be given a coordinate system on where it was reported on the basis of its location on the ground. Subsequently, point pattern analysis will be conducted to identify the distribution of HFMD cases between Kuching North City Council and Kuching South City Council. This is to identify whether it is clustered, dispersed, or randomly distributed. Lastly, the outcome from Average Nearest Neighbor Analysis will be used as an input for Getis Ord GI* for Hotspot Map analysis.

DISCUSSION / ANALYSIS

The number of HFMD reported cases was 525 for five years (from 2014 to 2018), out of which 66% of HFMD cases were located in Kuching North City Council. As illustrated in Figure 5, Kuching North City Council received the highest number of HFMD cases (105 cases) in the year 2014. Within five years of this study, 41 cases were reported in Kuching North City Council in 2015, as compared to 24 cases in 2016.
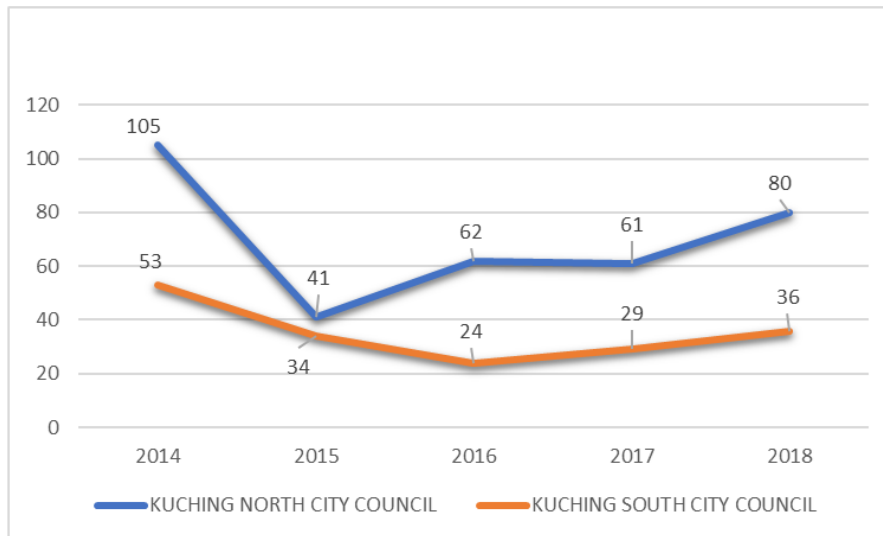
Figure 5. Reported cases of HFMD from the year 2014 until 2018

In Kuching South City Council, the highest number of cases (53 cases) was recorded in 2014 and the lowest number of cases (24 cases) was recorded in 2016. It was observed that the reported cases of HFMD had decreased in the year 2015 as compared to 2014. It decreased to 60.95% and 35.85% for Kuching North City Council and Kuching South City Council, respectively. Although the number of HMFD cases reduced in the year 2015, it slowly increased in the subsequent years. Figure 6 illustrates the distribution of HFMD cases that cover Kuching North City Council and Kuching South City Council. It was found out that the spatial distribution of the highest reported cases of HFMD within the period of five years occurred almost at the same area, which was at block V6. This block refers to Rampangi village, which was under the administration of Kuching North City Council. In 2017 and 2018, it was detected that Rampangi village received 10 to 20 cases of HFMD (Figure 6). The consistency of the number of reported cases of HFMD for this area has raised concern on the effectiveness of disease control that has been carried out. Similarly, the area of V17, which is referring to Tabuan Tengah village, has reported the cases of HFMD between seven and nine cases from 2014 to 2018.

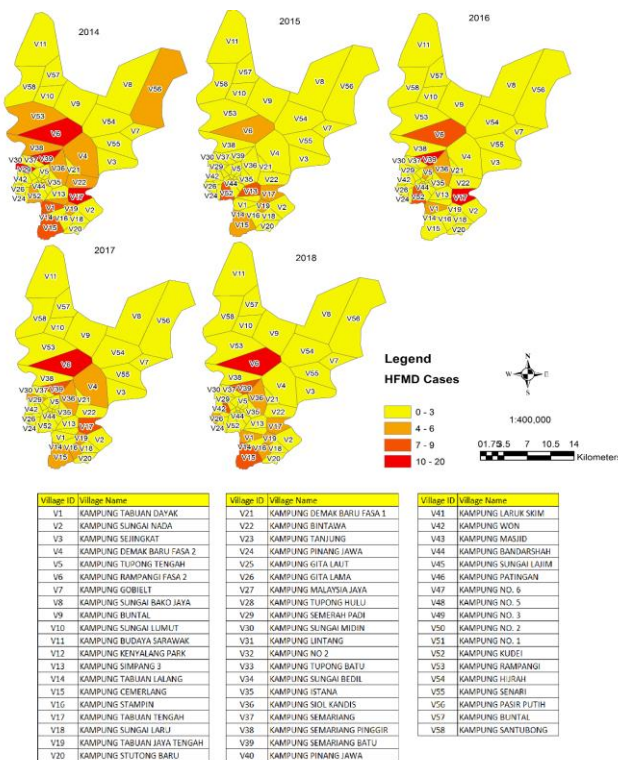| Village ID	Village Name	Village ID	Village Name	Village ID	Village Name
V1	KAMPUNG TABUAN DAYAK	V21	KAMPUNG DEMAK BARU FASA 1	V41	KAMPUNG LARUK SKIM
V2	KAMPUNG SUNGAI NADA	V22	KAMPUNG BINTAWA	V42	KAMPUNG WON
V3	KAMPUNG SEJINGKAT	V23	KAMPUNG TANJUNG	V43	KAMPUNG MASJID
V4	KAMPUNG DEMAK BARU FASA 2	V24	KAMPUNG PINANG JAWA	V44	KAMPUNG BANDARSHAH
V5	KAMPUNG TUPONG TENGAH	V25	KAMPUNG GITA LAUT	V45	KAMPUNG SUNGAI LAJIM
V6	KAMPUNG RAMPANGI FASA 2	V26	KAMPUNG GITA LAMA	V46	KAMPUNG PATINGAN
V7	KAMPUNG GOBIELT	V27	KAMPUNG MALAYSIA JAYA	V47	KAMPUNG NO. 6
V8	KAMPUNG SUNGAI BAKO JAYA	V28	KAMPUNG TUPONG HULU	V48	KAMPUNG NO. 5
V9	KAMPUNG BUNTAL	V29	KAMPUNG SEMERAH PADI	V49	KAMPUNG NO. 3
V10	KAMPUNG SUNGAI LUMUT	V30	KAMPUNG SUNGAI MIDIN	V50	KAMPUNG NO. 2
V11	KAMPUNG BUDAYA SARAWAK	V31	KAMPUNG LINTANG	V51	KAMPUNG NO. 1
V12	KAMPUNG KENYALANG PARK	V32	KAMPUNG NO 2	V52	KAMPUNG KUDEI
V13	KAMPUNG SIMPANG 3	V33	KAMPUNG TUPONG BATU	V53	KAMPUNG RAMPANGI
V14	KAMPUNG TABUAN LALANG	V34	KAMPUNG SUNGAI BEDIL	V54	KAMPUNG HIJRAH
V15	KAMPUNG CEMERLANG	V35	KAMPUNG ISTANA	V55	KAMPUNG SENARI
V16	KAMPUNG STAMPIN	V36	KAMPUNG SIOL KANDIS	V56	KAMPUNG PASIR PUTIH
V17	KAMPUNG TABUAN TENGAH	V37	KAMPUNG SEMARIANG	V57	KAMPUNG BUNTAL
V18	KAMPUNG SUNGAI LARU	V38	KAMPUNG SEMARIANG PINGGIR	V58	KAMPUNG SANTUBONG
V19	KAMPUNG TABUAN JAYA TENGAH	V39	KAMPUNG SEMARIANG BATU		
V20	KAMPUNG STUTONG BARU	V40	KAMPUNG PINANG JAWA		

Figure 6. Number of reported cases of HFMD by villages from 2014 to 2018

The distribution of reported HFMD cases shows that it was clustered from 2014 to 2018, as illustrated in Figure 7.
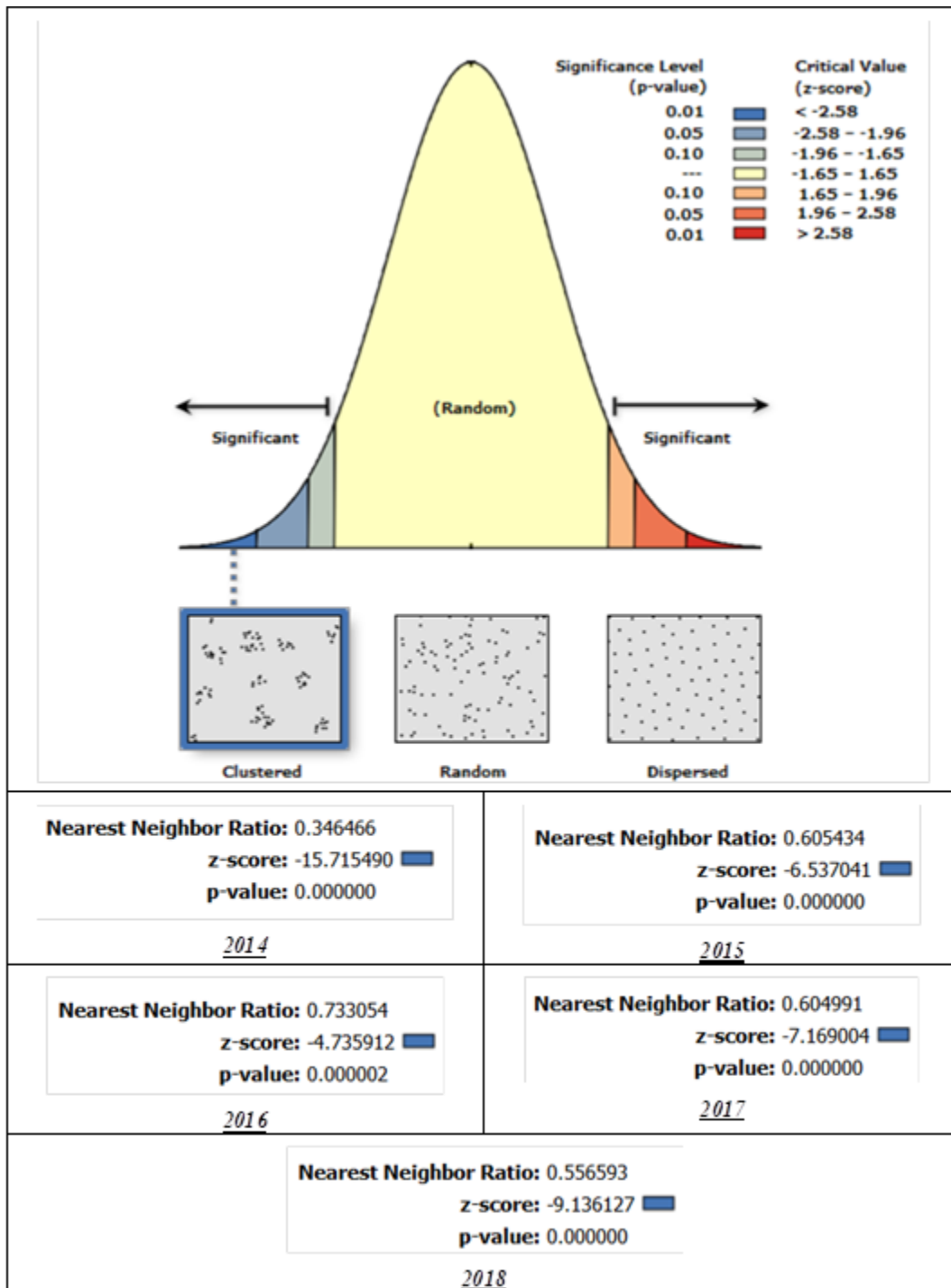

Figure 7. Average Nearest Neighbor Analysis

In Figure 7, the Nearest Neighbor Ratio from the year 2014 until 2018 was less than 1. This indicates that the pattern of HFMD distributions was clustered within these five years. On the other hand, the Z-Score value within this time frame was also less than -2.58; therefore, the null hypothesis was rejected with the confident level of 99% that the cases were clustered and 1% confident level that the cases were randomly distributed.
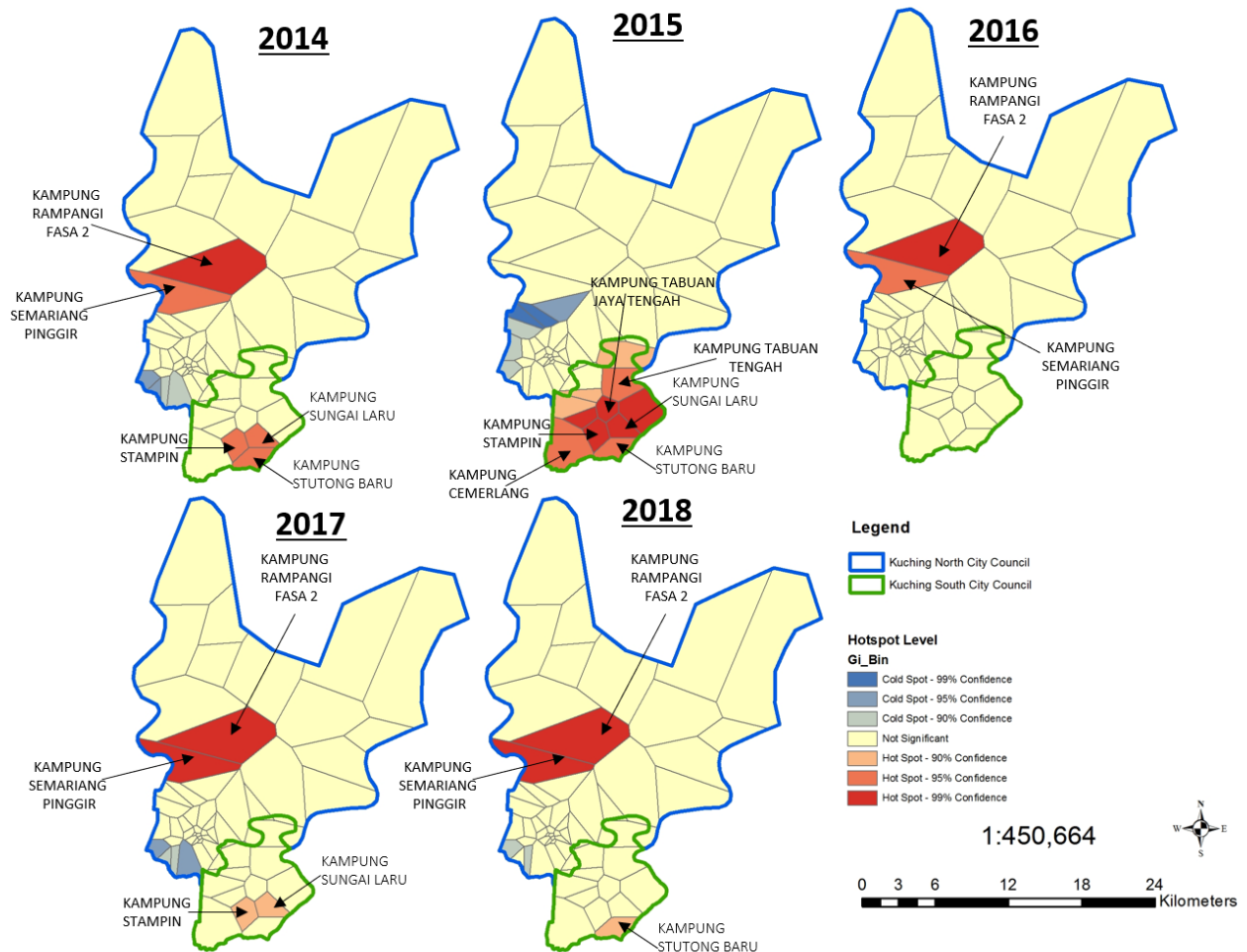
Figure 8. Hotspot Analysis for confidence level from the year 2014 to 2018

As illustrated in Figure 8, it was detected that there were several areas that has been classified to have statistically significant positive z-scores which indicates the high clustering at Sg. Laru, Semariang Pinggir, Stutong Baru, and Rampangi Fasa II in the year 2014. Then, it tremendously increased in the year 2015 where several new areas were identified at Kpg Cemerlang, Kampung Tabuan Jaya Tengah, and Kampung Tabuan Tengah. Ironically, Kampung Sungai Laru, Stutong Baru, and Rampangi Fasa II were classified as statistically non-significant in the year 2015.

However, in the year 2016, the same locations in 2014, which were Rampangi Fasa II and Semariang Pinggir, had been included again as hotspot areas with the positive Z-Scores values of more than 2.58. Although new areas had been identified to have high clustering of HFMD cases in the year 2017, the same locations of hotspot areas, namely, Rampangi Fasa II and Semariang Pinggir still exists and it also appeared in the year 2018. In the year 2018, Kampung Stutong Baru, which was under the administration of Kuching South City Council, was included as one of the hotspot areas although its neighbors, Kampung Stampin and Kampung Sungai Laru, did not record any trend of HFMD concentration.

Based on the conducted analysis from the year 2014 until 2018, it shows that the hotspot areas of HFMD were confined to the western area of Kuching North City Council namely at Rampangi Fasa II and Semariang Pinggir. For Kuching South City Council, the hotspot areas of HFMD were identified at Kampung Stampin and Kampung Stutong Baru. The trend of HFMD occurrences were confined to these villages from the year 2014 until 2018. Additionally, in the 2016, Kuching South City Council does not have any HFMD cases that can be classified as hotspot as compared to Kuching North City Council.

CONCLUSION

HFMD is a very dangerous disease as it can cause death. Hence, the precautionary measures and planning is necessary to prevent it from spreading to other areas.The authorities will be able to identify the hotspot areas of HFMD occurrences

with the help of GIS and the information obtained from GIS will help the authorities to come up with the necessary mitigation plan to control this disease.

LIMITATIONS AND FUTURE STUDY

The hotspot analysis of HFMD conducted in this study was based on the data collected for Kuching Division of Sarawak. Hence, it was not clearly indicating the overall status of HFMD occurrences for Sarawak state. Therefore, it is recommended that future studies be extended to other divisions of Sarawak.

ACKNOWLEDGEMENT

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