



Faculty of Social Sciences and Humanities

**Data Analytics of Hand, Foot and Mouth Disease (HFMD) using
Geographic Information System (GIS) in Kuching Division, Sarawak**

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Data Analytics of Hand, Foot and Mouth Disease (HFMD) using Geographic
Information System (GIS) in Kuching Division, Sarawak

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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ABSTRACT

Hand, Foot and Mouth Disease (HFMD) is a common disease infecting young children and infants. Although it is a common disease, it can cause death if it is not treated at the early stage. Several studies have been conducted in relation to HFMD in Malaysia but the outcome of existing studies was too general to be used as a reference for mitigation planning. The high-risk area of HFMD at the residential area is yet to be revealed. As such, this study aims to identify the high-risk area of HFMD at the specified residential area in Kuching division. Kuching division has been chosen as a study area since it has recorded the highest number of HFMD within five years period (2014 to 2018) which was 7630 cases. In order to identify a high-risk area of HFMD, Geographic Information System (GIS) was used. To answer the research questions, several theories on disease transmission such as the epidemiological triangle, social determinants of health and Tobler's first law of geography have been applied. The findings show that the high-risk areas are concentrated in the central area of Kuching city, namely Kampung Semariang Pinggir, Kampung Sungai Luar, Taman Heng Hua, Kampung Tabuan Jaya, Kampung Gita, Kampung Tupong Batu, Kampung Pinang Jawa, Kampung Masjid, Kampung Stapok and Taman Desa Matang. The results of this study are very significant as it contributes to the knowledge of the high-risk area of HFMD and also spatial spreading pattern of this disease in Kuching division from 2014 to 2018.

Keywords: Hand, Foot and Mouth Disease, Geographic Information System, Data Analytics

***Analisis Data Penyakit Kaki, Tangan dan Mulut dengan Menggunakan Sistem
Maklumat Geografi (GIS) di Bahagian Kuching, Sarawak***

ABSTRAK

*Penyakit Tangan, Kaki dan Mulut (HFMD) adalah penyakit biasa yang menjangkiti kanak-kanak dan bayi. Walaupun penyakit ini lazim dijumpai, ia boleh menyebabkan kematian jika tidak dirawat pada tahap awal. Beberapa kajian telah dilakukan berkaitan dengan HFMD di Malaysia tetapi hasil kajian yang ada terlalu umum untuk dijadikan rujukan untuk perancangan mitigasi. Kawasan berisiko tinggi HFMD di kawasan kediaman masih belum diketahui. Oleh yang demikian, kajian ini bertujuan untuk mengenal pasti kawasan berisiko tinggi HFMD di kawasan kediaman di bahagian Kuching. Bahagian Kuching telah dipilih sebagai kawasan kajian kerana ia telah mencatat jumlah HFMD tertinggi dalam tempoh lima tahun (2014 hingga 2018) iaitu sebanyak 7630 kes. Untuk mengenal pasti kawasan berisiko tinggi HFMD, Sistem Maklumat Geografi (GIS) telah digunakan. Untuk menjawab persoalan kajian, beberapa teori mengenai penularan penyakit seperti **epidemiological triangle, social determinants of health dan Tobler's first law of geography** telah diadaptasi. Hasil kajian mendapati kawasan berisiko tinggi tertumpu di Kampung Semariang Pinggir, Kampung Sungai Luar, Taman Heng Hua, Kampung Tabuan Jaya, Kampung Gita, Kampung Tupong Batu, Kampung Pinang Jawa, Kampung Masjid, Kampung Stapok and Taman Desa Matang. Hasil kajian ini amat penting kerana ia dapat menyumbang kepada pengetahuan mengenai kawasan berisiko tinggi HFMD dan juga corak penyebaran ruangan penyakit tersebut di bahagian Kuching pada tahun 2014 sehingga 2018.*

Kata kunci: *Penyakit Kaki, Tangan dan Mulut, Sistem Maklumat Geografi, Analisis Data*

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LIST OF ABBREVIATIONS

ANN	Average Nearest Neighbour
DOS	Department of Statistics
ESRI	Environmental Survey Research Institute
GIS	Geographic Information System
GPS	Global Positioning System
HFMD	Hand, Foot and Mouth Disease
MOH	Ministry of Health
SA	South Australia Health
SSHD	Sarawak State Health Department
UAV	Unmanned Aerial Vehicle
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Study Background

Hand, Foot and Mouth Disease (HFMD) is a common disease infecting young children and infants. Although HFMD is a common disease, it may also cause fatality as it can develop severe complication to young infants and children such as meningitis, encephalitis and myocarditis, if they are not treated properly at the early stage (Zheng et al., 2017). According to World Health Organization (2018), 377629 cases of HFMD were reported in China, 59556 cases in Japan and 26252 cases in Singapore in 2018. In Malaysia, there were 21303 cases of HFMD reported in 2017 and 27296 cases reported in 2018 respectively (Ministry of Health Malaysia, 2018).

According to Ministry of Health Malaysia (2007), HFMD occurs due to systemic infections by human enteroviruses which consist of genera rhinovirus, aphthovirus, cardiovirus, parechovirus and hepatovirus. This includes Coxsackie virus groups A and B, Polioviruses, Echoviruses as well as Enterovirus 68-71. HFMD is transmitted to another human from direct contact, for example through nose or throat discharges and from the stool of HFMD's patient (Ministry of Health Malaysia, 2007).

Centers for Disease Control and Prevention (2019) further elaborated that enteroviruses spread from the infected person's saliva, nasal mucus, and sputum. Other activities such as hugging, kissing or sharing any personal belonging like cups, toothbrushes and foods too have higher chances of getting HFMD. Normally it takes three to seven days for anyone to develop symptoms when they are exposed to the HFMD viruses (Selner, 2018). It is noted that several studies have been conducted in relation to HFMD. However, it is also

observed that the conducted studies are focusing more on the macro level which are too general and broad to be used as a reference for precautionary measures planning. While the information of the current status of HFMD at the macro level such as the status of HFMD reported cases based on country and state are useful to provide an insight of the high-risk area of HFMD, it is however does not indicate clearly on which part of the study area that has more concentration of HFMD cases. Without this information, the operational plan to mitigate this disease can be very challenging as it does not precisely identify and locate the hotspot area of HFMD due to lack of information on the high-risk area of HFMD at the micro level.

Hence, it is important that the identification of high-risk area of HFMD can be revealed at the micro level (residential area) so that the mitigation plan can be prepared effectively. The map of the high-risk area of HFMD produced in this research can be used as a reference to any respective authorities such as Sarawak State Health Department and local authorities for their mitigation planning in future. The underlying theoretical frameworks to examine the HFMD occurrences will be based on epidemiological triangle (Stevens, 1960), social determinants of health (World Health Organization, 2005) and first law of geography (Tobler, 1970). These frameworks demonstrate how disease occurred due to the interaction with the surrounding factors.

Additionally, Geographic Information System (GIS) technology will be used to examine and identify the high-risk area of HFMD based on the framework used within the study area which is Kuching division from the year 2014 to 2018.

1.2 Problem Statement

HFMD is one of the biggest threats to infants and young children around the world. It can lead to serious complications and even more dangerous as it can cause death (Zheng

et al., 2017). It happens not only in developing countries such as Indonesia or Malaysia, it also happens in developed countries such as Japan, Singapore and China. This scenario proves that HFMD occurrences has no boundary and limit in term of the advancement of health care infrastructure. Japan and Singapore for example have been shortlisted as the top 10 countries in the world in terms of the best health care facilities (World Health Organization, 2000) and yet they are also struggling to control the occurrence of this disease.

In Malaysia, it became a hot topic in 1997 when it has recorded the first case in Sarawak. It has caused 29 young children died. In some cases, the infected young children died within hours after admission as a result of acute congestive heart failure (World Health Organization, 1997). From 2006 until 2012, there were 107941 cases of HFMD reported in Sarawak.

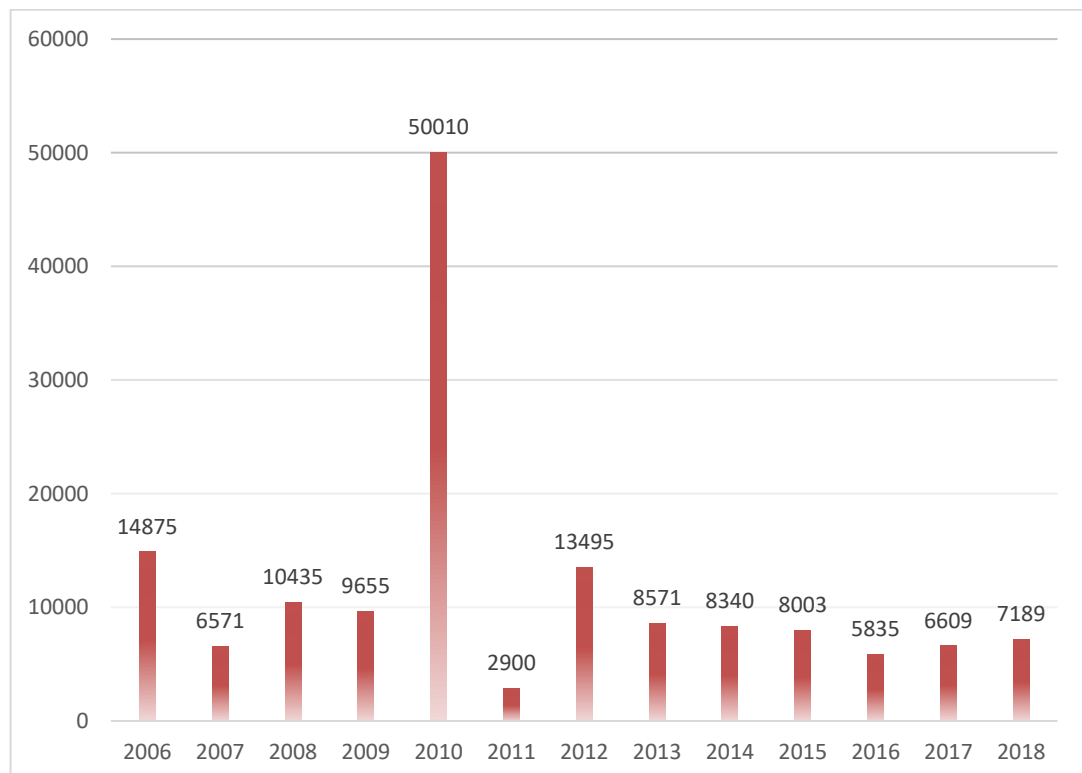


Figure 1.1: Reported HFMD cases, Sarawak

During this period, 50010 cases were reported in the year 2010, the highest ever

reported in Sarawak so far. Ironically, in the year 2011, the case dropped to almost 94% which was 2900 cases (Noraishah & Krishnarajah, 2016). However, there was another increase in the year 2012 where it had increased to 365% which was equivalent to 13495 cases. On top of that, in the year 2017 alone, there were 6609 cases reported and the number of cases increased to 7189 cases in the year 2018. Additionally, from 1 January 2019 to 19 January 2019, 615 cases were registered in Sarawak State Health Department.

The number of reported cases of HFMD in Sarawak shows that the existing precautionary measures are insufficient nor followed by both public and respective authorities. Moreover, the incidence rate of disease in Malaysia shows HFMD was the highest under the category of infectious diseases, which was 144.47 in the year 2016, as shown in Table 1.1 (Ministry of Health Malaysia, 2017).

Table 1.1: Incidence rate by disease category

Category	Incidence Rate
AIDS	3.86
Leprosy	0.65
Hepatitis C	8.35
HIV	10.73
Leptospirosis	16.69
Tuberculosis	81.3
Hand, Foot and Mouth Disease	144.47

Table 1.1 shows that HFMD is a common infectious disease among young infants and children. Young infants and children are highly vulnerable, and this situation may cause fatality. Moreover, 28% of the total 24398 cases registered in Malaysia in 2018 were cases of reported HFMD in Sarawak (Ministry of Health Malaysia, 2018). Inevitably, this percentage has triggered an alarm to the respective authorities on the effectiveness of

precautionary measures that have been implemented and applied in Sarawak.

While the danger of HFMD is recognized, the study and research to understand the current scenario and situation of HFMD are very limited and confined to a specific scale and boundaries (international or state). The conducted study by several researchers in Sarawak for instance were focusing more on the distribution of cases by divisions (Ooi, 2008; Noraishah et al., 2014; Noraishah & Khrisnarajah, 2016).

As a result of this, the understanding of HFMD situation at the micro level, which is at the residential area is yet to be identified. The unsolved problem due to unavailability of the information of the high-risk area of HFMD at the residential area has made the effort to prepare an effective precaution measures to control the transmission of HFMD becomes complicated.

Besides, the physical environmental features that contribute to the expand of HFMD transmission in Kuching division is yet to be addressed and understood. In response to this problem, this study proposes to identify and examine the high-risk area of HFMD in Kuching division with focus concentration at the residential area and to investigate the spatial relationship of environmental factor that has given an impact to HFMD occurrences. The environmental parameters which is water quality index shall be examined and analysed, particularly on how it contributes to the expand of HFMD disease in Kuching Division.

The focus area at the residential area in Kuching division has been chosen in this study so that the recommendation to mitigate the HFMD transmission can be prepared directly to the affected areas by the authorities. Hence, it will enhance the mitigation processes (Walia & Guleria, 2012). Kuching division has been chosen as a study area as it was the top division in Sarawak recording the highest number of cases of HFMD from 2014 to 2018 which was 7630 cases (Sarawak State Health Department, 2019).

1.3 Research Objectives

The aim of this research is to model a high-risk area of HFMD in Kuching division by using GIS. Subsequently, the following are the research objectives to be achieved in this study.

- i. To propose GIS data model that is needed for HFMD analysis.
- ii. To identify spatio-temporal spreading patterns of HFMD in Kuching division from the year 2014 until 2018.
- iii. To identify the relationship of environmental conditions with HFMD incidents from the year 2014 until 2018.

1.4 Research Questions

With the problem mentioned above, this study seeks to address the following research questions.

- i. What kind of GIS data model and attribute information required for HFMD spatial spreading analysis?
- ii. Where is the high-risk area of HFMD in Kuching division and what is the pattern of HFMD within the study area?
- iii. Are clustered, distributed and random pattern of HFMD associated with proximity of environmental factor and what is the correlation between them?

1.5 Scope of Study

The research study focuses on the ability of GIS to model the high risk area of HFMD in the residential area that covers five local councils namely Kuching North City Council, Kuching South City Council, Padawan Municipal Council, Bau District Council and Lundu District Council from the year 2014 to 2018. For spatial relationship assessment purposes between environment and HFMD, water quality index is the only environmental factor covered under this study.

1.6 Limitations

The limitations of this study are listed below.

- i. The study was conducted within Kuching division only.
- ii. GIS datasets used to represent residential locations on the map were obtained from GoogleMap and also from OpenStreetMap as updated in 2018.
- iii. The HFMD spatial distribution analysis was based on the data obtained from 2014 to 2018 only.
- iv. The spatial relationship analysis to analyse the correlation between environment factor with HFMD distribution was based on water quality index only.

1.7 Significance of the Study

Infectious disease like HFMD is a common disease infecting young children and infants (Moa et al., 2016; Guerra et al., 2018). These groups are highly vulnerable thus may lead to fatality. Although this disease is a common disease for young children and infant, the trends of the reported HFMD cases are increasing year by year as reported by the Ministry of Health Malaysia in 2018. The reported fatality cases that are linked to HFMD shows that the awareness of HFMD among public communities is still low. Public communities are

unaware of the personal hygiene and the danger of HFMD although the government through the Ministry of Health Malaysia has launched many strategies and programmes to educate them on the seriousness of this disease (Ministry of Health Malaysia, 2016). In view of this scenario, this study is quite significant in the sense of helping the authorities from various agencies such as local councils, Sarawak State Health Department and public community to identify the high risk area of HFMD in Kuching division. By knowing the high risk area of HFMD, it will be a great help for them to prepare a better plan to control HFMD transmission. A study conducted in Bangkok Thailand, indicated that the information on spatial spreading pattern does help the Department of Disease Control, Ministry of Public Health Thailand in their mitigation plan to control HFMD transmission (Chadsuthi & Wichapeng, 2018).

Moreover the outcome from this study can be used as a platform of public awareness as it generates a map indicating sensitive areas of HFMD and this will educate them to be alert on the current situation of HFMD transmission especially to improve the hygiene of their surrounding areas in order to minimise the risk of getting HFMD (Bernama, 2019). The Ministry of Education, Malaysia for example had launched the prevention of HFMD campaign in the year 2018, and that has seen a drop of HFMD cases reported in the country to 23%. This happened when the public is aware on the seriousness of HFMD cases within their areas (Rajaendran, 2018).

Subsequently this study introduces a GIS technique to generate an approximate boundary of residential areas within the study area. As there is no clear boundary between one residential area to another, this study will be using Thiessen polygon method to create an artificial boundary for each residential area. An artificial boundary is used due to the

unavailable current gazetted boundary. It is hoped that this technique can be used to overcome and solve the problem of not having the physical reference on the ground to indicate the administrative boundary of point of interest. For example, hospitals and clinics can use this technique to identify and describe their influencing area when serving the community.

The generated Thiessen polygon from this study can be used as a guide and reference for the authorities in coming up with their mitigation plan to control HFMD outbreaks based on the artificial boundary generated from this technique. This technique has been used by Patil et al. (2016) to generate river basin catchment area at Shakkar, India. On the other hand, Moise & Kalipeni (2011) in her study used Thiessen polygon to generate the boundary for each clinic that serve HIV patients.

1.8 Thesis Outline

This thesis contains five chapters as listed below.

- **Chapter 1: Introduction**

The review of HFMD cases in Sarawak and the strategy conducted in this research are discussed in Chapter 1. This includes the aim, objectives and questions to be addressed and answered, as well as the significance and the scope of the study.

- **Chapter 2: Literature Review**

In Chapter 2, the review of the published articles, research studies, theses will be presented here. The theory and framework used and explored regarding HFMD will be discussed. Additionally, the overview of GIS and how it was applied in the context of public health would be presented.

- **Chapter 3: Methods and Materials**

This chapter discusses the methodology adopted in order to achieve the stated objectives. It describes the techniques of the study such as point pattern analysis and correlation modelling between HFMD occurrences relationship with environmental factors.

- **Chapter 4: Results and Discussion**

The outcome of the conducted analysis and its discussion will be presented and discussed in this chapter.

- **Chapter 5: Conclusion and Recommendations**

This chapter concludes the findings from the research, highlights the issues and limitations as well as to recommend future topic to be explored in order to comprehend this research.

1.9 Chapter Summary

HFMD is a deadly disease and could lead to fatality if it is not treated systematically. As a result of this, the study of how HFMD transmitted to other areas is important as the information generated from this research can be used by the authorities in coming up with strategic planning to control the disease before it becomes critical or outbreak. Concurrently, the study on the relationship of HFMD incidents with environmental element is also essential as it can help the authorities to be more cautious if the environmental conditions at certain locations exceed the normal condition.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Geography and public health are interrelated disciplines as things that is happening around us does affect our health. Since geography and health are interrelated, the merge of these two disciplines into becoming health geography offers another way to view the issue of public health from geographic dimension. This was the approach that has been adopted by John Snow when cholera outbreaks happened in 1854 in which he had detected the cholera outbreaks occurred due to contaminated water supply in London (Johnson, 2006). Since then, more studies have been conducted to investigate public health problem from the geographic perspectives.

Generally, health geography focuses in two areas namely disease spreading patterns and provisional of health care centre (Dummer, 2008; Brown et al., 2009). In order to understand the disease spreading patterns, it is important to understand first how the disease is spreading to other location and this is where the human factors come into play (Lindahl & Grace, 2015). The occurrences of disease between space and time do not happen coincidently. It takes certain processes before it spreads to other locations. Furthermore, with the improvement of infrastructure mobilization, the spreading of diseases to other location and place can happen overnight. The Ebola and MERS-CoV diseases for instance were transmitted to other places when the carriers used air transportation during their mobilization (Mangili et al., 2015). The dissemination of infectious diseases like this can be understood by identifying the spreading process that happens over space and time. Therefore, it is crucial to understand how the disease spreads and infects other people.

This chapter is designed to address the following topic as listed below.

- **Hand, Foot and Mouth Disease (HFMD)**

This section discusses on an overview of the nature of HFMD. It addresses the root cause of HFMD, signs and symptoms and also the complications caused by HFMD.

- **Theoretical Framework of Epidemiological Triangle**

This section explains the theoretical framework of the epidemiological triangle that can be used to study the spreading pattern of HFMD. It depicts three pillars of the triangle namely host, agent and environment, social determinant of health and Tobler's first law of geography.

- **Geographic Information System (GIS)**

This paragraph discusses the overview of GIS and its components. It also highlighted the implementation and application of GIS generally in the area of public health and specifically on hand, foot and mouth disease.

2.2 Hand, Foot and Mouth Disease (HFMD)

HFMD is a disease caused by a microorganism which is Enterovirus. Among other family of Enterovirus, there are two main categories of viruses that caused HFMD, Coxsackie Virus A16 and Enterovirus-71 (EV71) (Ministry of Health Malaysia, 2007). These two viruses are harmful. Coxsackie Virus A16 was isolated for the first time in 1951 in Africa (Sickles et al., 1955). This virus is a member of Human Enterovirus, a species of Enterovirusgenus of Picornaviridae. Based on its size, it has a diameter within 30 µm and contains a single-stranded as well as positive sense genomic ribonucleic acid (RNA). Figure 2.1 shows the shape of the Ribonucleic acid of Coxsackie 17 (Centers for Disease Control and Prevention, 1981).

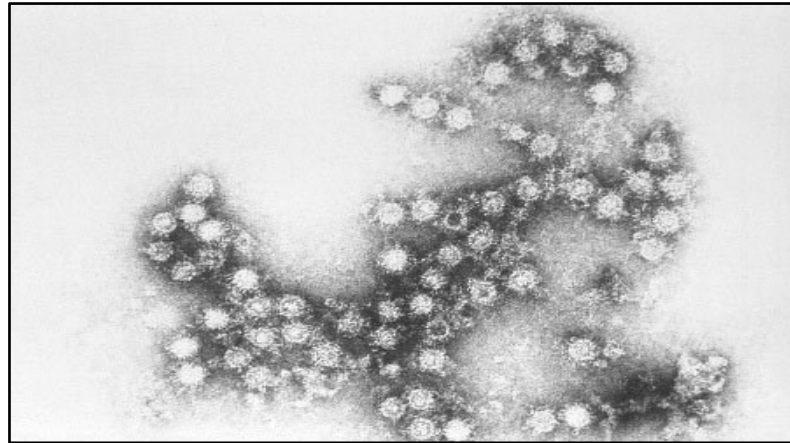


Figure 2.1: Ribonucleic acid of Coxsackie 17

Coxsackie viruses can be categorized into two categories namely A (CVA) and B (CVB). Each of these categories have different impact on human being especially young infants and children. For example, CVA can cause muscle injury, paralysis and even death too (Davis, 2018). On the other hand, CVB too can cause internal organ damage, however with less severe outcomes. In other words, CVB infects host cells in which will cause the host cells to break open.

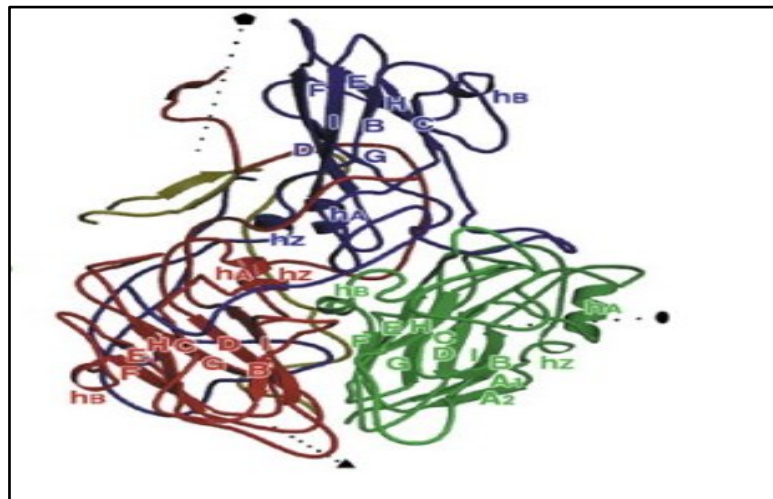


Figure 2.2: Structure of Coxsackie

CVB also contains viral proteins as shown in Figure 2.2 (Hendry et al., 1999). The viral proteins are represented in different colours, where viral protein 1 (VP1) in blue, viral

protein 2 (VP2) is represented in green and viral protein 3 (VP3) in red as well as yellow for viral protein 4 (VP4). In terms of habitat, Cocksackie viruses can be found in human digestive system (Boezem, 2017).

Similarly, for Enterovirus-71 (EV71), it was first detected in the year 1969 in California, America. It then spreaded to Europe where two countries experienced an outbreak namely Bulgaria and Hungary between 1975 and 1978. It does not stop in Europe, apparently it has transmitted to Asia too (Berkhout, 2019). EV71 is the same family with Cocksackie viruses which is Enterovirusgenus of Picornaviridae. It consists of genotype A, B and C (Sino Biological Incorporated, 2017).

The genotype B for example can be divided into 5 sub-categories ranging from B1 to B5 and the same case applies to genotype C which also consists of 5 sub- categories from C1 to C5 (Sino Biological Incorporated, 2017). EV71 also classified as positive-stranded genomic RNA. Both Cocksackie viruses and EV71 are genomic RNA which means it has high mutation rate with frequent recombination and low-fidelity replication (Liu et al., 2018). Figure 2.3 portrays the structure of EV71 (Yee & Poh, 2016).

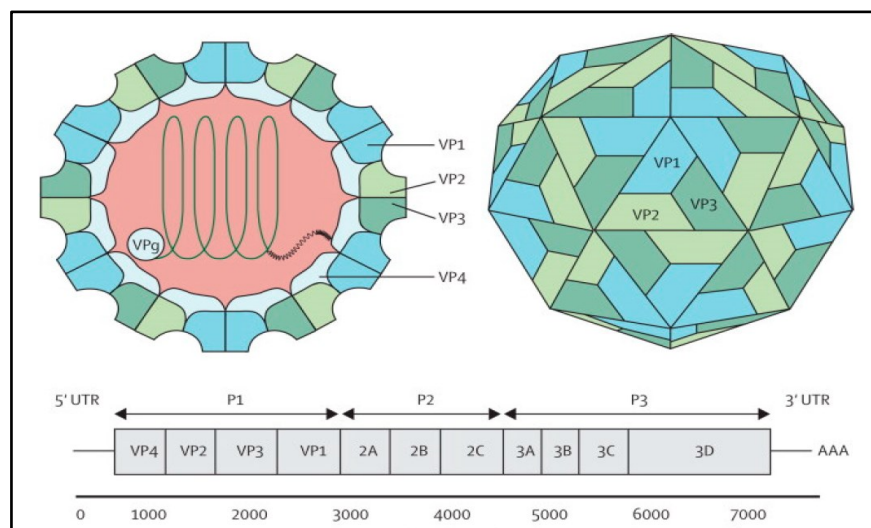


Figure 2.3: Structure of Enterovirus 71

As shown in Figure 2.3, Enterovirus 71 open reading frame (ORF) is divided into

three categories which are P1, P2 and P3. The viral proteins of VP1 until VP4 are grouped under P1 category which constitutes the viral capsid. On the other hand, the non-structural protein which are 2A to 2C and 3A to 3D are the categories that directly involved in virus replication within the infected cell (Yee & Poh, 2016).

Based on these two viruses, the next question to be asked would be who is the most vulnerable to get HFMD when these viruses infected human being. In general, this disease can infect anyone regardless of the ages, genders and locations. Whether they are young infants, teenagers or adults, all are exposed with HFMD (Ministry of Health Malaysia, 2019). Although it can infect any kind of age and gender, it gives high impact to young infants and children. This is due to the ability of young infants and children immunity system to protect themselves from Coxsackie and Enterovirus 71 (Centers for Disease Control and Prevention, 2019). Young infants and children do not have immunity against the viruses that can cause HFMD. Because of that, it will develop severe complications as a result of no immune system to protect them.

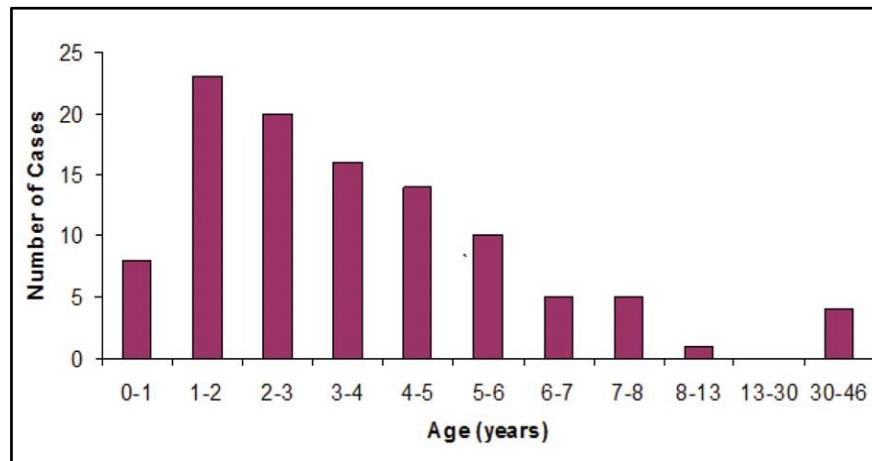


Figure 2.4: HFMD cases by age

In the year 2011 for example, there was a study of HFMD population in China conducted by Liu and the outcome of his study is shown in Figure 2.4 (Liu et al., 2011). The study conducted by Liu et al. (2011) as shown in Figure 2.4 clearly indicates that almost

95% of the recorded HFMD cases infected young infants and children below 8 years old.

It shows that HFMD itself does not give much impact to the teenagers and adults as these age groups have immune system to prevent them from developing any complications as a result of HFMD. In addition to that, the recent study conducted by Shuanbao Yu and others in Southern China in 2018 also detected the similar pattern as shown in Figure 2.5 (Yu et al., 2018).

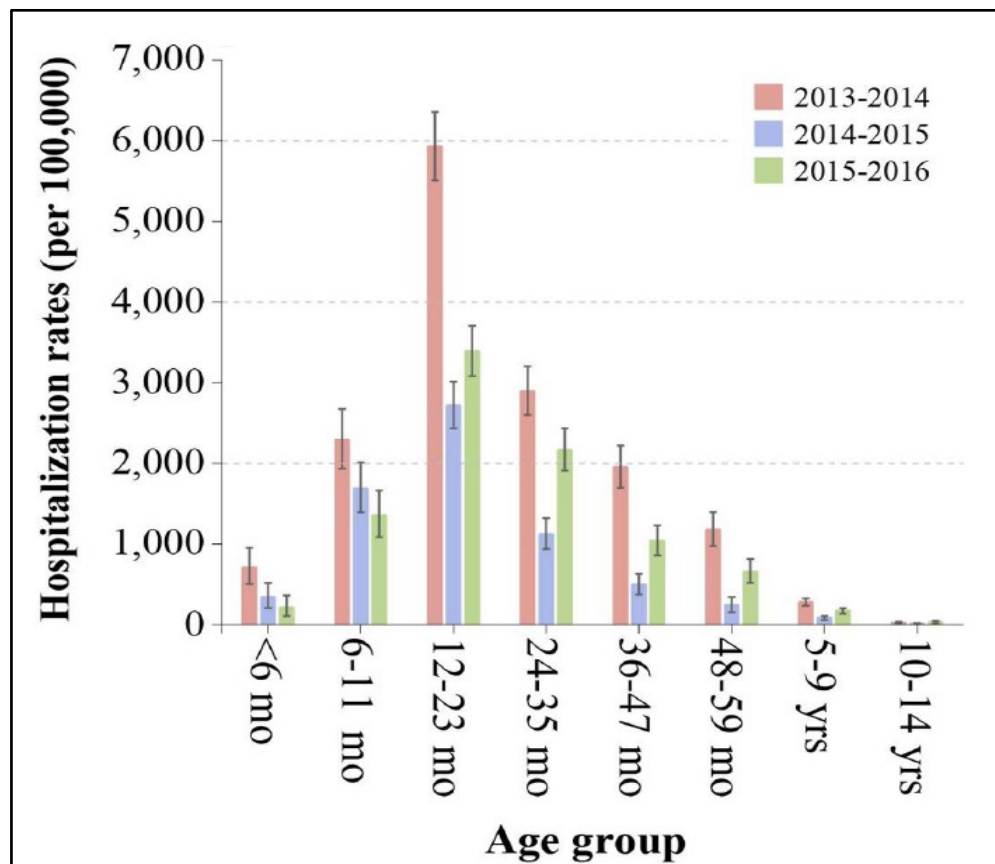


Figure 2.5: Hospitalization rates by age

The pattern and trend of HFMD distribution by age in Southern China proves that almost 95% of HFMD carrier is coming from the group of below 8 years old. Just like other diseases, HFMD is recognized from the signs and symptoms that a person is experiencing. However, not everyone infected with HFMD will develop any signs and symptoms. This is due to the antibody or immune system of each children and infant are having. Some may get

infected easily and some are not (Yang et al., 2011). In fact some people especially adults were detected to have HFMD without any signs or symptoms and yet are able to spread this disease to others (Centers for Disease Control and Prevention, 2017). Nevertheless, for those who are infected with this disease carrying the symptoms and signs of HFMD are easily recognized. Figure 2.6 shows the signs and symptoms of HFMD (Ministry of Health Singapore, 2019).



Figure 2.6: Signs of HFMD

The signs and symptoms of HFMD can be found and detected if rashes on the feet and mouth, as well as on the hands are present. The moment the children and young infant infected by Cocksackie or Enteroviruses 71, they will experience high fever and starts developing painful sores from their herpangina within one or two days after getting infected by the viruses.

A study conducted by Tu et al. (2007) in the year 2005 at Southern Thailand provides an interesting information on the signs and symptoms of infected HFMD patients. He has analyzed 13 signs and symptoms for all HFMD patients in 2005 and found out that the majority of the patients which is 60% of the patients who have been infected with Cocksackie virus and 68% for those who were infected by Enteroviruses 71 are experiencing fever. On

the other hand, 85% of HFMD patient caused by Coxsackie viruses have shown a symptom of mouth ulcer. Ironically there was no signs and symptoms of conjunctivitis and limb weakness detected from HFMD patient caused by Coxsackie viruses. Figure 2.7 shows the outcome from the study conducted by Tu et al. (2007).

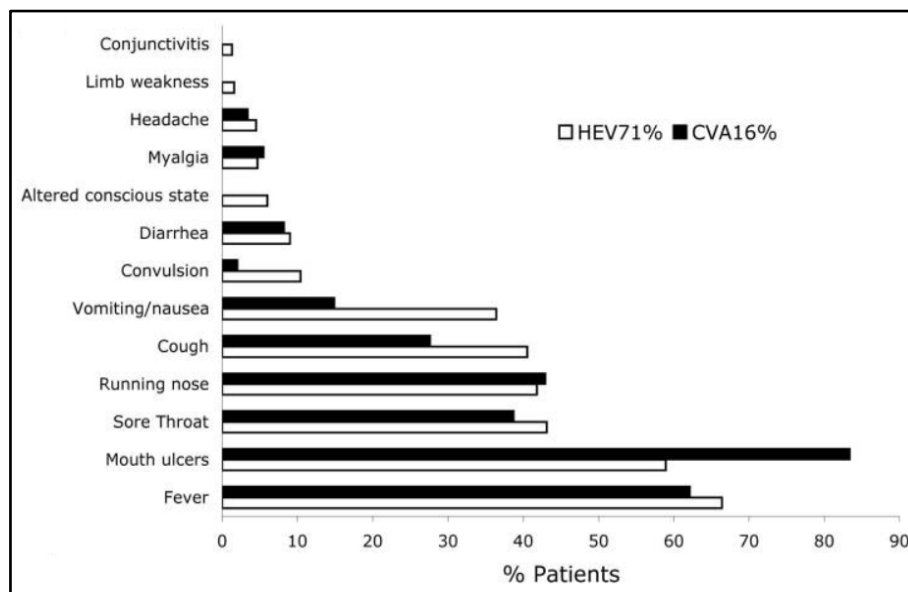


Figure 2.7: Symptoms of HFMD

Based on the Figure 2.7, it can be concluded that the signs and symptoms of a person getting HFMD depends very much with the virus that they are exposed to. It clearly indicates that the HFMD patients caused by Coxsackie and Enterovirus 71 develop different degree of signs and symptoms. Another study conducted by Gina C. Clementz in the year 2000 has found another symptoms and signs of HFMD which is nail matrix arrest. Nail matrix arrest is the situation of where fingernails and toenails become yellowish and fractured. Figure 2.8 shows the nail matrix arrest and outcome of the study conducted by Gina Clementz in year 2000. It shows that the fracture of the nails can be very serious as it can cause nails to rip.

The study conducted by her was based on the five patients of HFMD. This proves that nail matrix arrest is one of the symptoms of HFMD (Clementz, 2000). All of the five patients under her study showed a sign of nail matrix arrest.



Figure 2.8: Nail matrix arrest

Table 2.1 describes the outcome of the study conducted by her. It shows that almost all patients have experienced nail matrix arrest. From the study conducted by Clementz (2000), it can be observed that the occurrence of nail matrix arrest, be it at the fingers or toes are quite certain in the case of HFMD.

Table 2.1: Nail matrix arrest based on patient

	Patient				
	1	2*	3	4	5
Age (years)	4	3	2.5	1.9	2
Sex	M	M	F	M	F
Race	W	W	B	W	W
Time from HFMD to onset of nail changes (weeks)	4	4	3	8	3
Fever ^{max} with HFMD	none	none	39°C	40°C	39.5°C
HFMD exanthem					
Palms	+	+	+	+	+
Soles	+	+	+	+	+
Periungual lesions	–	–	–	–	–
Groin, buttocks	–	+	–	+	–
History of skin disease	–	–	–	–	AD
Medications	A, Ib, Amx	A, Ib, Amx	Ib	Ib	A
Nails					
Finger, affected	5	4	10	3	1
Finger, shed	5	0	4	0	1
Toe, affected	0	1	10	2	3
Toe, shed	0	0	2	2	3
Follow up	NR	NR	NR	NR	NF

*, Sibling of patient 1; AD, atopic dermatitis; A, acetaminophen; Ib, ibuprofen; Amx, amoxicillin for first 48 hours of HFMD; NR, normal regrowth; NF, no follow up available.

How does HFMD spreads from one person to another is also one of the areas that need to be discussed and highlighted. Coughing or sneezing from infected HFMD patient is one way on how HFMD can transmit the viruses to other people. When the patient of HFMD

coughs or sneezes, the Coxsackie or Enteroviruses 71 will be transmitted and released in a form of droplet. The droplet that contains the viruses will infect a new host (Centers for Disease Control and Prevention, 2016). The two main viruses of HFMD which are Coxsackie and Enteroviruses 71 that live in mucus and saliva will be transmitted within six feet radius from infected HFMD patient (Duda, 2018). In other words, the droplets can land on humans, animals and things while people will get infected if they breathe the droplet containing viruses or by touching anything that has droplets of HFMD viruses. Figure 2.9 depicts how HFMD is transmitted from aerosol (Afrose, 2017).

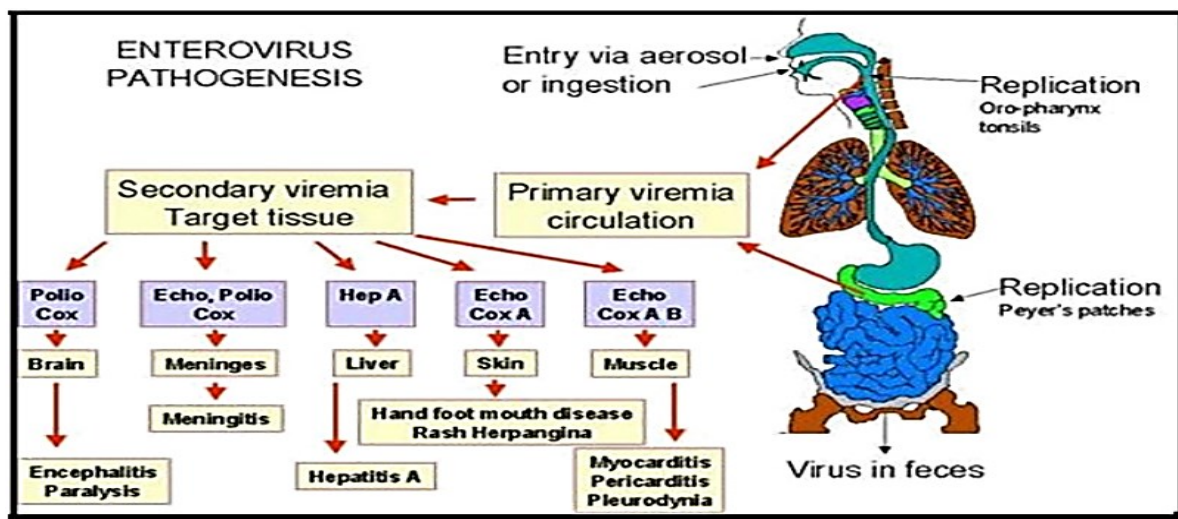


Figure 2.9: HFMD transmission from the air

As shown in Figure 2.9, the transmitted droplet containing HFMD viruses such as Coxsackie and Enterovirus 71 will enter human body during the breathing process. When the viruses get into the human body, it will replicate in mucosa of the oropharynx and at the small intestine as well as at the lymphoid (Afrose, 2017).

Secondly, HFMD can be transmitted to human being through the infection from the stool. This happens when a person accidentally touches the stool of an infected person and that is where the viruses spread. For example, a young infant and children playing with dirty

diapers of an infected HFMD patient will have high chances of getting infected. The stool that contains Coxsackie and Enteroviruses 71 viruses can find a new host easily whenever it is touched by another person and this normally happens at day care centres and homes too (South Australia Health Organisation, 2019). In addition to that, there was a study conducted in 1958 by Rubin to analyse the possibility of the existence of Coxsackie virus in stools as presented in Table 2.2 (Rubin et al., 1958).

Table 2.2: Frequency of isolation of Coxsackie virus

Specimen	No. of Specimens	No. Positive	Percentage Positive
Stool	135	82	61
Throat Washing	46	12	26
Cerebrospinal fluid	19	2	11

From 135 specimens taken from this study, it shows that almost 61% of the samples given contained Coxsackie virus from stool as compared to throat washing and cerebrospinal fluid (Rubin et al., 1958).

Thirdly, HFMD can be transmitted from infected patient to another person by sharing personal belongings such as fork and spoon, towel, toothbrush and others. The spread of the Coxsackie virus or Enterovirus 71 happens when sharing the personal belongings with HFMD infected patient. For example, sharing the fork and spoon of an infected young children with other children will expose them with HFMD. This always happens at childcare center or kindergarten where children share the forks and spoons while eating.

In 2015, there was a study conducted in Beijing by Lie and others. They have conducted a study on 51 kindergartens in Shijingshan district with 357 children involved. There were 56 cases of HFMD reported in these kindergartens. This study shows that sharing personal items are one of the factors that leads to HFMD outbreaks in Shijingshan district

(Lie et al., 2015). Sharing toothbrush can also cause danger to other family members. It has been reported that there are more than 100 million germs found in a toothbrush (Asmawati, 2011) and this microorganism can easily find a new host if the toothbrush is used by other family members. Cleaning toothbrush after use does not guarantee that it is free from microorganism as it is still there and will grow overnight. Ironically the microorganism on a toothbrush does not harm the owner of the toothbrush, however it will harm other users who use the same toothbrush. It will be worst if brushing of the teeth causes gum bleeding and brings along the bacteria to be transmitted to another person if they are using the same toothbrush.

Asmawati (2011) has conducted a study on the number of germs obtained from the used toothbrush as shown in Table 2.3.

Table 2.3: The average number of microorganisms

Duration	Average Number of Microorganisms	Percentage
< 3 Months	147.6	20.87
3-6 Months	269.8	38.16
> 6 Months	579.4	40.97

As presented in Table 2.3, the microorganism stays and sticks on a toothbrush that is unchanged for more than 6 months. If anyone is infected with HFMD, there is a high chance for other people to get infected too if there are using the same toothbrush. Therefore, sharing personal items or belongings with infected HFMD patients are not a good idea. The same principle applies to other personal belongings such as towel, soap and comb. Apart from that, HFMD can be spread to others when the personal belongings with HFMD has direct

contact with any objects such as door handles, chairs and tables. These objects will then have direct contact with another person and will have high chance to get infected too.

The Coxsackie and Enterovirus 71 viruses from the infected HFMD can be transmitted to any objects touched by them. This is where the spread of HFMD begins (World Health Organization, 2019).

Organisms	Elevator buttons (n = 48)	Biometric attendance devices (n = 24)	Door handles (n = 80)	Telephone sets (n = 30)	Railing (n = 20)	Water taps (n = 30)
<i>S. aureus</i>	11 (22.9%)	08 (33.3%)	13 (16.2%)	06 (20%)	03 (15%)	03 (10%)
<i>S. epidermidis</i>	10 (20.8%)	06 (25%)	11 (13.7%)	04 (13.3%)	01 (5%)	02 (6.6%)
<i>Enterococcus</i> species	04 (8.3%)	05 (20.8%)	08 (10%)	06 (20%)	02 (10%)	03 (10%)
<i>Diphtheroids</i>	05 (10.4%)	04 (16.6%)	07 (8.7%)	08 (26.6%)	04 (20%)	07 (23.3%)
<i>Micrococcus</i> species	07 (14.6%)	05 (20.8%)	08 (10%)	11 (36.6%)	02 (10%)	04 (13.3%)
<i>Escherichia coli</i>	03 (6.2%)	02 (8.3%)	04 (5%)	03 (10%)	01 (5%)	02 (6.6%)
<i>Pseudomonas</i> species	02 (4.1%)	03 (12.5%)	–	–	–	02 (6.6%)
<i>Acinetobacter</i> species	02 (4.1%)	03 (12.5%)	04 (5%)	05 (16.6%)	01 (5%)	04 (13.3%)
Total	44	36	55	43	14	27

Figure 2.10: Bacteria isolated from environmental surfaces

A study on how microorganisms can be transmitted by touching the object that has been touched by the infected person was conducted by Bhatta et al. (2018), in Nepal. He has conducted his study at Manipal Teaching Hospital, Nepal for the period of five months (Bhatta et al., 2018). Figure 2.10 shows that the microorganisms can be transmitted to whoever that touched elevator buttons, biometric attendance, door handles, telephone sets, railing and water taps. The study conducted by Bhatta et al. (2018) is quite significant to prove that the microorganisms is everywhere, and those harmful microorganisms can infect anyone who is in contact with the objects that contain the microorganisms.

When people get infected with HFMD, there are several complications that can be seen. These complications vary from one patient to another. Although HFMD is normally a mild condition that can recover naturally, it is however can cause serious complications and

death if it is not treated properly (Zheng et al., 2017). The following paragraphs discuss the complications caused by HFMD.

Dehydration is one of the complications that can be seen from the infected HFMD patients. Dehydration is a process of losing fluids from human body. It can only be classified as dehydration when human loses the fluids more than what human have been consumed (Josephson, 2017). Dehydration does not really give a serious matter for adults and teens, however it can give huge impact to young infants and children. When the body loses the amount of water that is needed, it will interfere the system in the body. In the case of HFMD patient, the sores that occur in the mouth and throat makes it difficult for the infected HFMD to drink, especially infants and children.



Figure 2.11: Ulcers in mouth

Figure 2.11 shows the example of existence of ulcers in the mouth of an infected HFMD patients (Crosta, 2017). They will refuse to drink as a result of ulcers in their mouth and throat making drinking becomes painful. The dehydration can be detected from the urine of HFMD patient. If their urine colour is clear, it means that their body has enough fluids, however if their urine is yellowish or dark in color, it shows that the HFMD patients are experiencing dehydration (Crosta, 2017). Not only their urine is coloured, they will get their

mouth dry and has ulcer, lack of energy (lethargy), dizziness and headache. The minimum water that is required by young children is 16 ounces and if they cannot meet this requirement, dehydration will occur. When that happen, there is tendency to get fever, low blood pressure, increase of heart rate and unconsciousness (Altmann & Fischman, 2018). Fatality may happen when low blood pressure is not managed properly as it reduces the amount of oxygen needed by the body (Crosta, 2017).

Another complication caused by HFMD is the viral meningitis which refers to an infection of membrane that covers the spinal cord and brain. The membrane itself is a tiny layer that protects and acts as outer boundary of our body. The outer boundary is named as plasma membrane (Rogers, 2019). The main function of membrane is to protect the body from toxic substances and allowing other molecules such as nutrients and ions to enter the body.

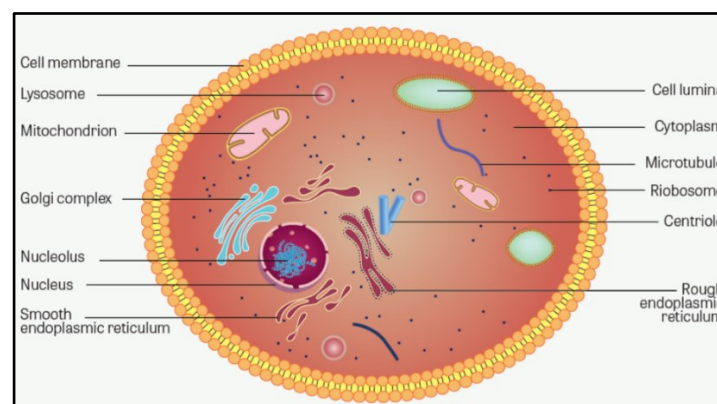


Figure 2.12: Membrane cell structure

The membrane cell as illustrated in Figure 2.12 (Rogers, 2019) acts as protector and shield the body from dangerous toxic substance such as polychlorinated biphenyls (PCBs) and dioxin which can be found from alcohol and cosmetics products (National Library of Medicine, 2019). When young infants and children are infected with HFMD, they have high chances of getting viral meningitis (Centers for Disease Control and Prevention, 2016) as a

result of weakened immune system. Figure 2.13 shows the infected membrane of brain (Venngage, 2019).

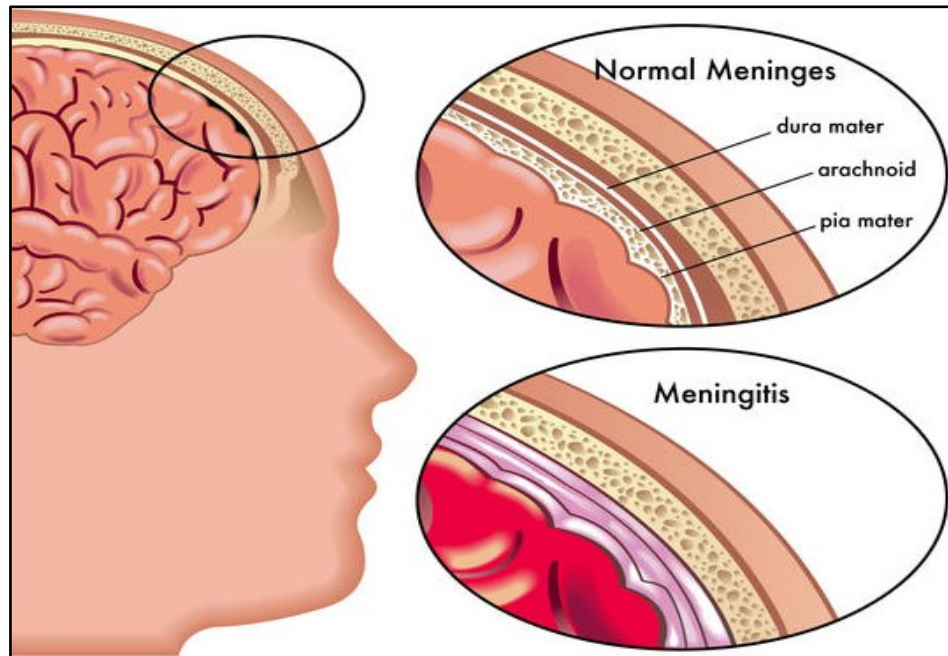


Figure 2.13: Infected membrane of brain

The viral meningitis caused by Enteroviruses 71 can lead to permanent brain damage if it is not treated properly and even can cause death (Columbia University Medical Center, 2019). In Finland, there are 219 of fatality from 100,000 population of young infants and children less than one year old due to viral meningitis (Rantakallio et al., 1986). This study proves that viral meningitis can cause death and permanent brain damage if serious attention is not given.

Encephalitis is also one of the complications caused by HFMD. If meningitis is an infection on the membranes that protect brain and spinal cord, Encephalitis on the other hand is the inflammation of the brain itself. Figure 2.14 shows the difference between meningitis and encephalitis (Modern Psych Encyclopaedia, 2019).

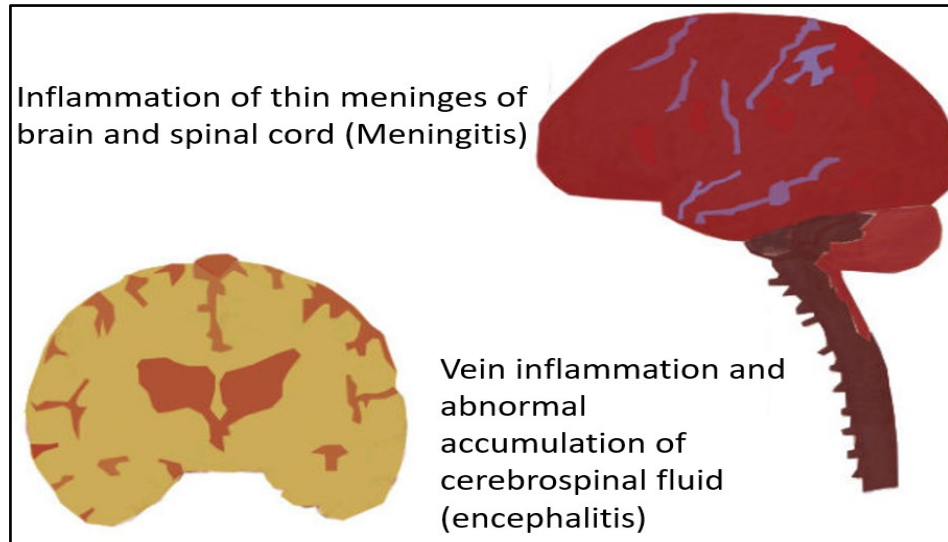


Figure 2.14: Meningitis Vs Encephalitis

Encephalitis can be divided into two categories namely primary encephalitis and secondary encephalitis. The primary encephalitis refers to a situation where Coxsackie and Enterovirus 71 infect the brain and spinal cord directly whereas the secondary encephalitis is referring to the attack of Coxsackie and Enterovirus from any part of the body to the brain. (Jayaraman et al., 2018).

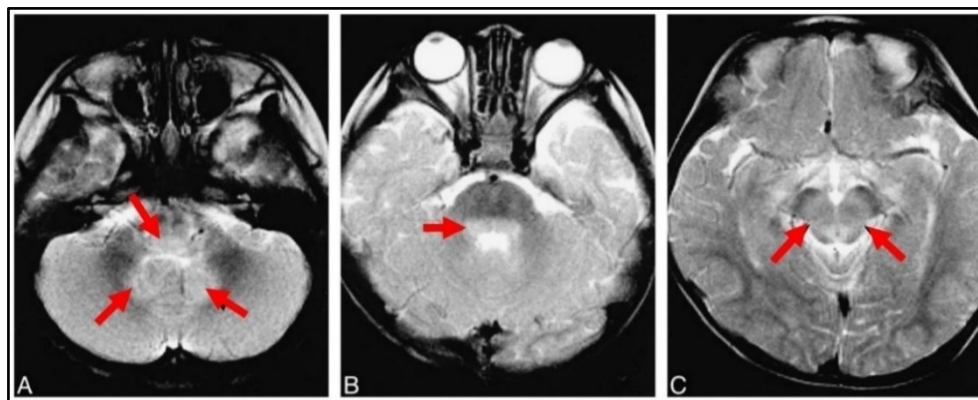


Figure 2.15: Magnetic Resonance Imaging (MRI) of Encephalitis

Figure 2.15 shows the MRI result of 4-year-old children conducted by Shen et al. (1999) in Taiwan. The image shows the presence of significant hyperintense lesions at medulla oblongata as a result from virus infection. In America, it has been estimated that

there are 19,000 hospitalizations with 230,000 hospital days and estimated cost of \$650 million as a result of encephalitis (Newman, 2017). The danger of encephalitis is that it can cause brain damage. When Coxsackie or Enterovirus 71 infected the brain, it gives little space for it to swell as the brain is covered and protected by the skull. By the time it swells, it gives pressure to the skull and if the pressure is significantly higher than the usual, it will damage the brain (Columbia University Medical Center, 2019). Loss of memory or even coma and paralyses are the complications caused by brain damage.

The next section discusses the theoretical framework adopted in this study.

2.3 Theoretical Framework

There are three theoretical frameworks adopted in this study. Each of this framework explains the concept of disease interaction with surrounding parameters and how it influences the spread of diseases. Details of each framework is discussed in the following section.

2.3.1 Epidemiological Triangle

The understanding on how the disease spreads through time and space can be very challenging, however, with the use of epidemiological triangle concept, this process can be simplified. This concept is used by the epidemiologist to investigate the source of organism that causes the occurrence of the disease and under what circumstances does it spreads to other locations (Stevens, 1960; Frost, 1976). The epidemiological triangle is represented with three components namely agent, host and environment. These three components are interrelated, and it needs each other to interact to make the disease to happen. Figure 2.16 shows the three components of epidemiological triangle namely host, agent and environmental (Stevens, 1960).

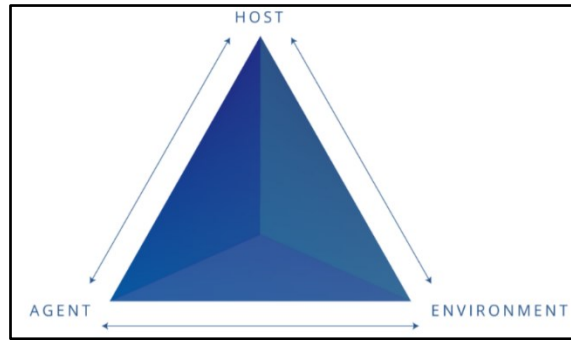


Figure 2.16: Epidemiological triangle concept

Many studies have been conducted abroad in the area of disease spreading pattern by using epidemiological triangle (Navalgund et al., 2019; Yusuf, 2019). For example, in 1987 there was a study conducted by Rivara F. P to assess the childhood injuries in America using epidemiological triangle framework. This study defines host as child itself, environment represented by socioeconomic of the child's family and agent refers to fireworks, firearms and other harmful equipment (Rivara, 1987).

In 2018, another study conducted by Qommaruddin in Yogyakarta, Indonesia is also adopting this framework to predict the outbreak of dengue from 2010 to 2016. He uses surveillance data such as rainfall, humidity and air temperature which is grouped under "environment" to identify the potential area of dengue by relating it with larva (agent) and mosquito (host). The outcome of his study shows that 76.4% of Sleman Regency, Yogyakarta was endemic areas in 2014, 70.6% in 2015 and had increased to 94.1% in 2016 (Qomaruddin, 2018).

Subsequently in 2019, Ellen et al. use this framework to study how climate change (environment) in North America affects and influences the rate of infectious disease and how it impacts the behavior of the agent and host. Her study reveals that there was a statistically significant relationship between environment, host and agent. The next paragraphs will depict in more details of these three components.

Agent

The first component of the epidemiological triangle is agent. Agent refers to the microorganism that causes the disease such as bacteria, virus, fungi and protozoa. Bacteria is single-celled organisms and in term of size, it is bigger than virus, however it is still cannot be seen by our naked eye (Vidyasagar, 2019). Their size normally measured within a few micrometer in length and it normally lives in ocean, soil and also human gut (Brazie, 2019). Figure 2.17 shows the difference types of bacteria. It clearly shows that the size of bacteria is within 0.5-2.0 μm (Aryal, 2018).

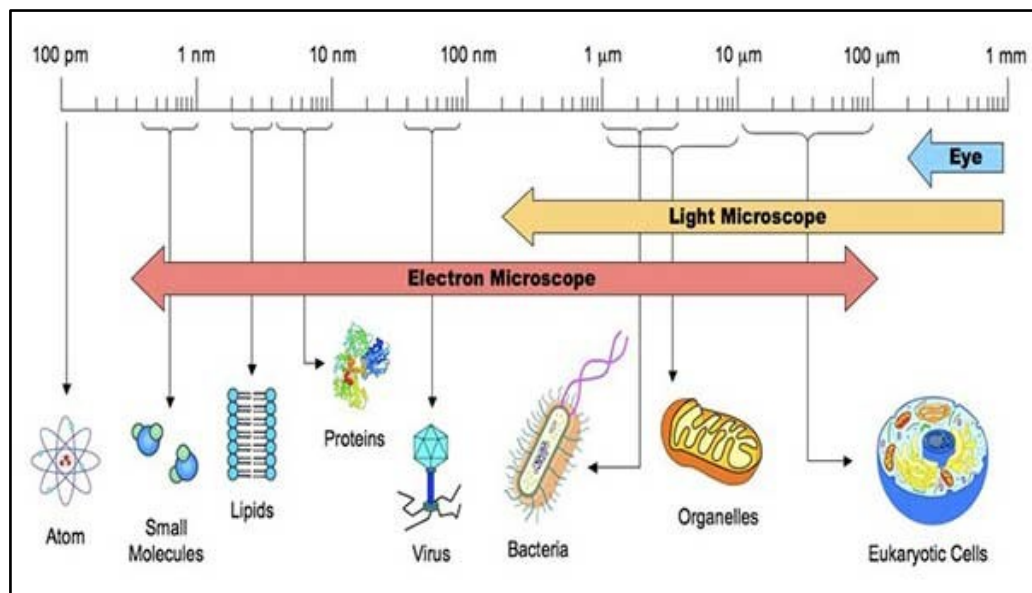


Figure 2.17: Size of bacteria

The bacteria stay together in communities of millions, for example a 40 million bacterial can be found in a gram of soil. It exists in various shapes such as in a form of spherical shaped, rod-shaped, spiral-shaped and comma shaped. Figure 2.18 shows the example of spherical shaped of bacteria. The staphylococcus aureus bacteria is shown in yellow (Bailey, 2018).

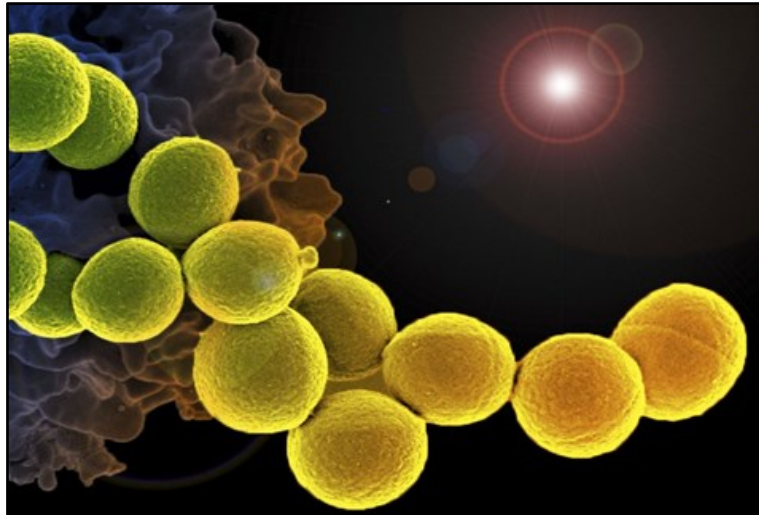


Figure 2.18: Spherical shaped of bacteria

The example of the spherical shaped of bacteria is *Streptococcus pyogenes* and *Staphylococcus epidermidis*. On the other hand, *Escherichia coli* also known as E.coli is grouped under the rod-shaped bacteria. Figure 2.19 shows the rod-shaped bacteria (Bailey, 2018).



Figure 2.19: Rod shaped bacteria

The rod-shaped bacteria as shown in Figure 2.19 is harmful to animals, humans and plants too. The *Bacillus cereus* for example can cause food poisoning (Rogers, 2019). The arrangement of rod-shaped bacteria can be grouped based on how it is structured.

Monobacillus refers to the cell that remain as a single rod-shaped after the dividing process whereby the Diplobacilli will remain in pairs after dividing. Similarly, Streptobacilli bacteria will remain in chain after dividing (Bailey, 2018).

The next category is spiral-shaped bacteria. This type of bacteria consists of two types of spiral cells namely spirillum and spirochete. An example of spiral shaped bacteria is *Leptospira* that causes leptospirosis and *Treponema* that causes treponematoses. Figure 2.20 shows the shape of spiral bacteria (Cameron, 2019).

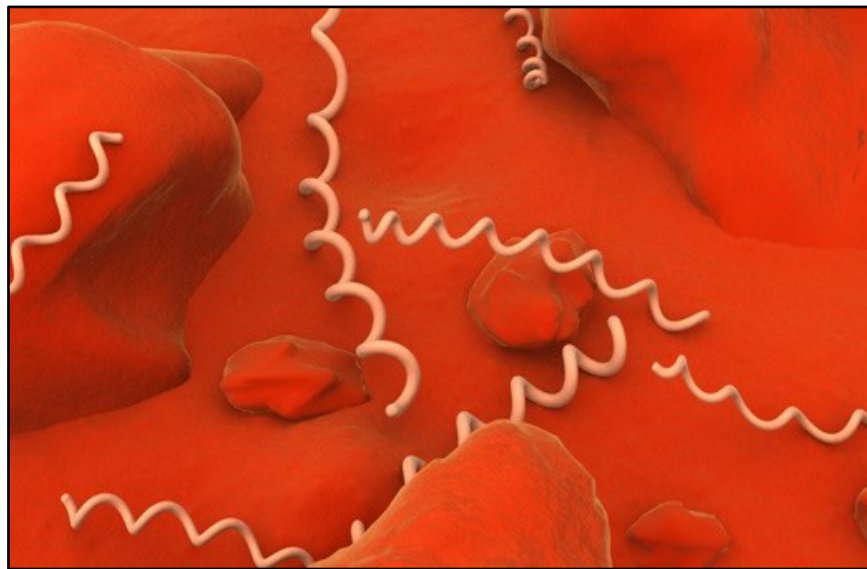


Figure 2.20: Spiral-shaped bacteria

Spiral-shaped bacteria looks like a spring. When it rotates, its wings move like a spiral. In terms of size, this type of bacteria has a diameter of 1.4 to 1.7 μm and in terms of length, it can go up to 60 μm (Bailey, 2018). Similarly, like bacteria, virus is also harmful and dangerous to humans and animals. Virus is the thinnest among other microorganisms. It can only be seen by using electron microscope. It does not eat, excrete and breathe as well as living in another organism (host). Similar to bacteria, virus also existed in various shapes such as rod-shaped, tadpole-shaped and spherical-shaped. Figure 2.21 shows the sample of virus shapes (Trisha, 2019).

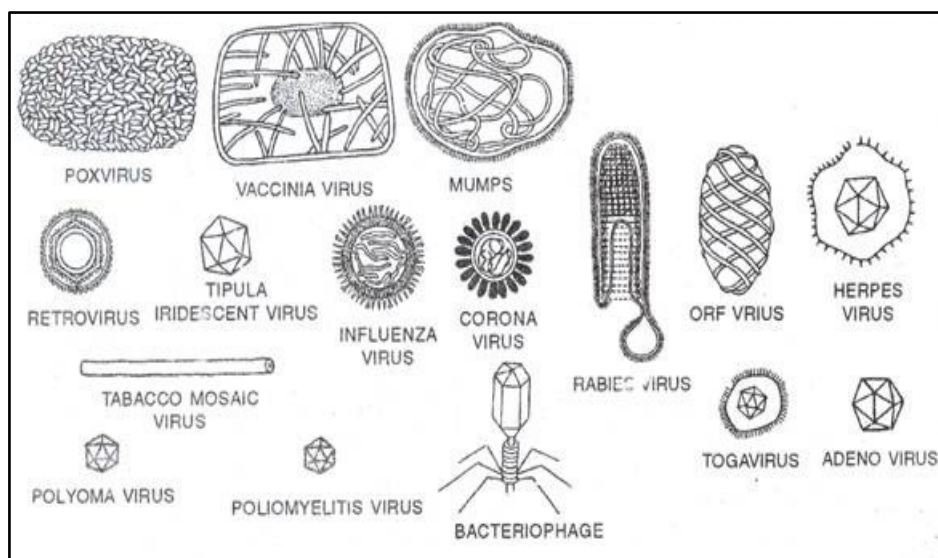


Figure 2.21: Size and shape of viruses

Each virus shown in Figure 2.21 has different types of shapes and size. The smallest virus is Tobacco virus which is $17\ \mu\text{m}$ and the largest virus will be Poxvirus with the size of $350 \times 250 \times 100\ \mu\text{m}$. The virus normally spreads and transmits in many ways such as from human to human or from blood sucking insects. When it is transmitted to another humans or animals, it will create new cell and multiply its cell to another new host.

Another microorganism that falls under agent is fungi. Just like other agent, fungi can be found as a single celled and sometimes it can be very complex. Fungi normally lives on land such as in soil and any plant. It seldom stays in the sea or even fresh water (Microbiologyonline, 2019). An example of fungi are moulds, yeasts and mushrooms.

The skin disease caused by fungi can happen in any part of the human bodies and animals such as hand and foot. For example, yeasts or molds can cause nail infection, ringworm or the medical terms known as tinea also caused by fungi. On the other hand, Aspergillosis disease is caused by Aspergillus, another type of fungi (Centers for Disease Control and Prevention, 2019). Figure 2.22 demonstrates the danger of fungi that causes skin disease (Khan, 2015).



Figure 2.22: Skin disease from fungus infection

In the case of HFMD, the element of agent is caused by two main viruses namely **Enterovirus 71 (EV71)** and **Coxsackievirus A16 (CVA16)**. The Enterovirus 71 (EV71) is a virus under the family of Picornaviridae virus. The size of this virus is within 20 to 30 μm . Since it is neurotropic virus, it can be very severe and can cause complications such as myocarditis and even can cause fatality too (Solomon et al., 2010). Figure 2.23 shows the structure of Enterovirus 71 (EV71).

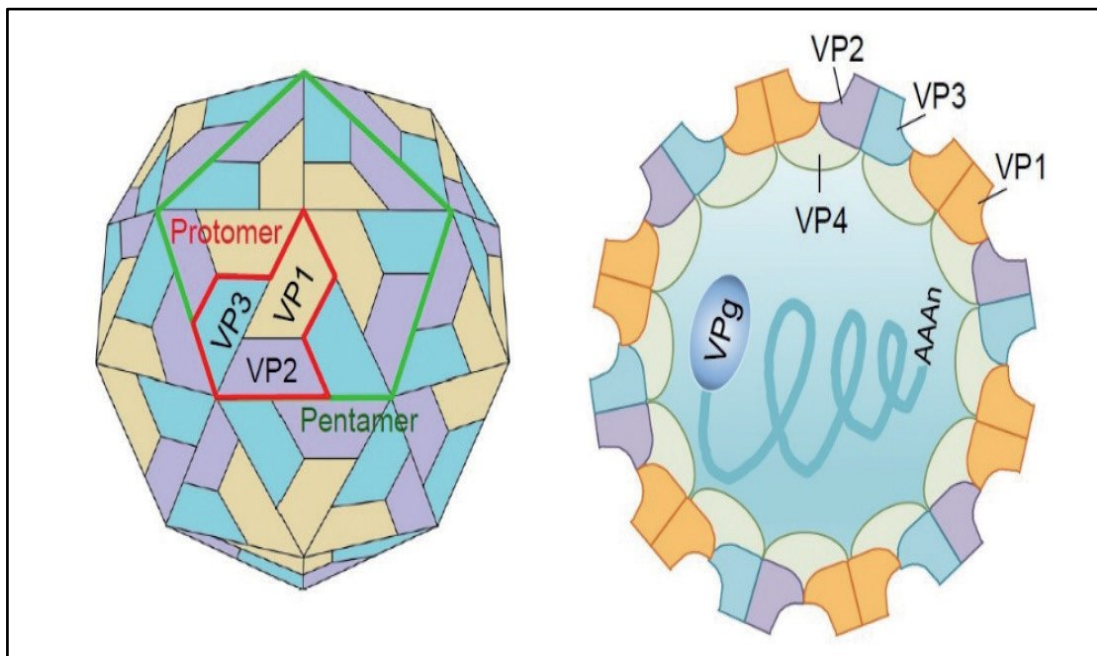


Figure 2.23: Enterovirus 71 (EV71)

As shown in Figure 2.23, EV71 capsid has four different proteins namely VP1, VP2, VP3 and VP4 (Solomon et al., 2016). These four proteins merged to form a protomer and the protomer will form a pentamer. Coxsackievirus A16 (CVA16) on the other hand is a virus that can survive with dry and cool season. It is also a harmful virus as the infected humans will feel the pain within 3 to 5 days. Similar to EV71, it can cause complications such as heart inflammation and thus can cause death too. The CVA16 and EV71 are the primary agent of HFMD infections (Wang et al., 2018).

Host

Based on the epidemiological triangle, host is referring to the organism that can be represented as humans and animals. Any infected humans and animals will harbour the disease caused by the “agent” (Rivier University Online, 2017). For example, humans who are exposed with bacteria (*Mycobacterium tuberculosis*) will most likely to get tuberculosis (Mayo Clinic, 2019). Figure 2.24 shows how disease is transmitted to humans and animals (Smith, 2019).

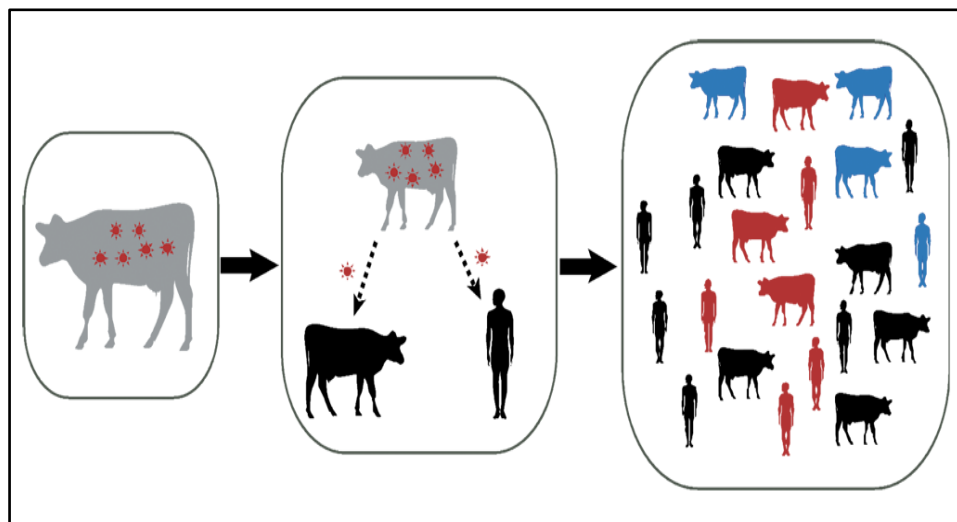


Figure 2.24: Disease transmission to humans and animals

Humans and animals can transmit the disease that they carried to other humans. It can be from human to human or from animals to humans. For human-to-human infection, the Human Immunodeficiency Virus (HIV) can be transmitted to other people from sexual activities. Leptospirosis is another example on how animal can transmit the disease to human through their urine. Sometimes the host may not be aware that they carry the disease until it is detected from the signs and symptoms of the diseases. The carrier of Hepatitis B will only realize that they carried Hepatitis B when their skin is yellowish (World Health Organization, 2018).

In the context for HFMD, humans and animals are the host of this disease. In Malaysia, 51,147 people have been infected by HFMD in 2018 (Farhana, 2018). In the case of Sarawak, 553 pupils have been infected from January to April 2019 (Norsyazwani, 2019). Similarly, in 2001, United Kingdom and Netherlands have recorded 6.5 million infected animals of foot, mouth disease (FMD) (Scudamore et al., 2002) and in 2011, Japan has recorded 290 thousand infected animals of FMD (Hayama et al., 2015). Based on this information, it shows that the “host” of HFMD can be transmitted from either human to human or from animal to human.

Environment

The last component in epidemiological triangle is environment. It is an external factor, apart from the “agent” and “host” that will influence the rate of disease transmission to other places. Some disease can be transmitted easily to other human as a result of environmental factor. The environment factor here does not necessarily refers to geographical condition or physical environment, but also refers to other component such as socio-economy, public health activities and human behaviour (Centers for Disease Control and Prevention, 2012).

In the case of geographical condition and physical environment, some disease can be transmitted easily with the help of physical condition such as temperature and humidity level. It has an impact on the agent's ability to transmit the disease to another host (Chowdhury et al., 2018). The infectious diseases such as malaria, diarrhea and pneumonia have statistically significant relationship between the number of disease cases with temperature and humidity (Chowdhury et al., 2018). For example, flu virus is more dangerous and active during cold winter temperatures as compared to warmer temperatures as a result of interaction between human body with cold weather condition that makes the virus becomes liquid and has the ability to find new host (National Institute of Child Health, 2008). As opposed to flu viruses, mosquitoes will be more aggressive to transmit dengue, west Nile virus, Zika and Chikungunya during warmer temperatures especially if temperature is above 25 degrees Celsius (Jordan, 2019).

In addition to that, another study was conducted in 2019 by Yi et al. in South China concerning the influence of climate to the spread of infectious diseases in the study area. Based on their finding, it was observed that for one degree Celsius increase of temperature will lead to 3.6% to 14.8% of the occurrences of bacillary dysentery disease. The same scenario happened to HFMD in which they found out that the increase of 1 degree Celsius of temperature will lead to 1.8% to 5.9% of HFMD.

Esmailnejad et al. (2018) also conducted the same study in South Khorasan, Iran where he studied the relationship of temperature and zoonotic disease. Figure 2.25 shows the relationship of temperatures and the occurrences of Zoonotic disease in South Khorasan, Iran that he has observed (Esmailnejad et al., 2018). Figure 2.25 clearly indicates that zoonotic disease reaches 500 cases when the temperature is 21 degrees Celsius. Similarly, the zoonotic disease is at 350 cases when the temperature is 19.6 degree Celsius

(Esmacilnejad et al., 2018).

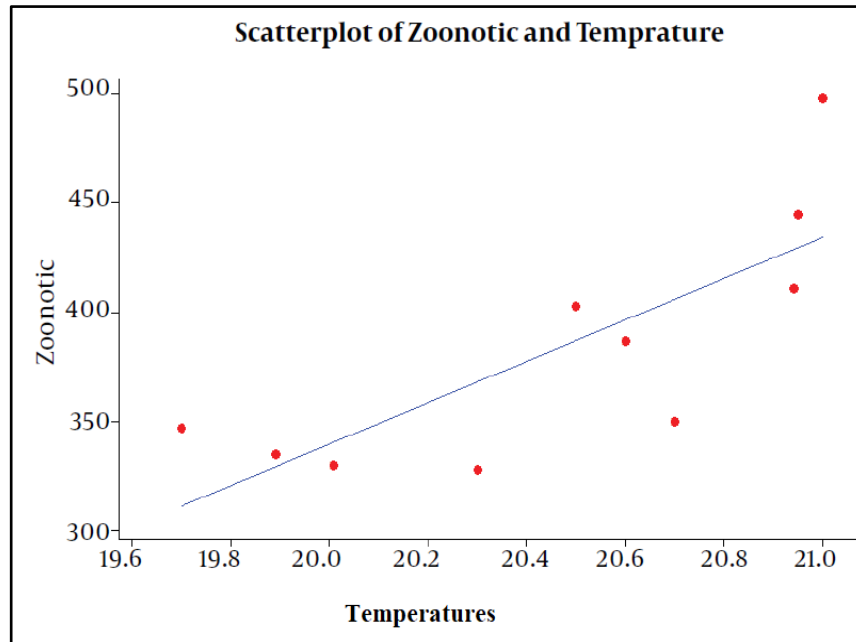


Figure 2.25: Zoonotic disease and temperatures

Apart from climate, the physical condition of geographical area does affect and influence the spread of disease. Take air pollution as an example, the air pollution brings harmful substance such as dangerous particles, molecules and gases and these items will go directly to our lungs when we breath and that will cause problem to our health. The fine particles such as black carbon, mercury and sulphur dioxide can contribute to asthma disease and those people who are living in the same area have high tendency to get the similar disease (Perera, 2017).

In 2018 for example, there was another study conducted in China by Liu et al. to investigate the impact of air pollution to the disease occurrences in China from 2013 to 2015. It was discovered that there was positive connection between influenza activities with the occurrences of infectious diseases in China (Liu et al., 2018). Figure 2.26 shows the lung of emphysema disease patient as a result of air pollution (Smith, 2019).

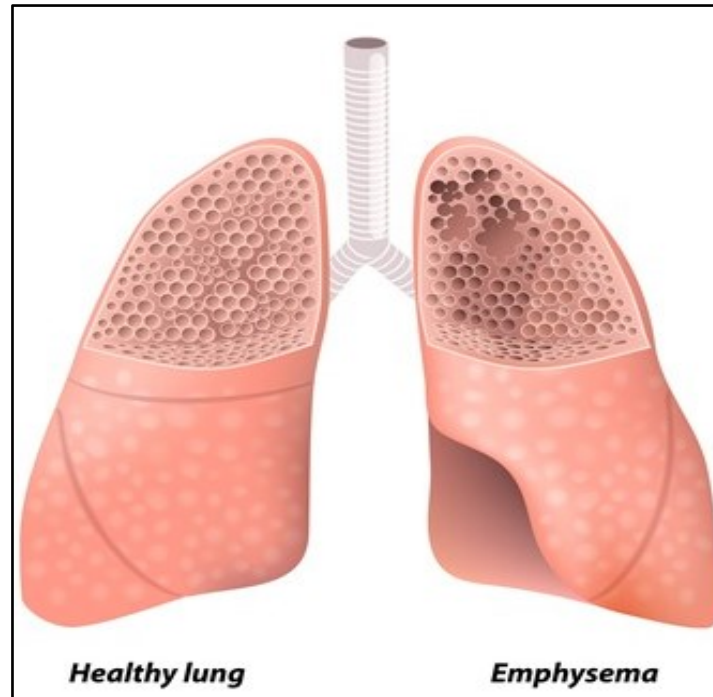


Figure 2.26: Lung condition of emphysema patient

Figure 2.26 shows that the lung tissue of emphysema patient has been damaged from the exposure of air pollution. Similarly, water pollution could also contribute to the spread of diseases at the large scale. John Snow in 1855 has detected the cholera outbreaks in London which caused 10,000 died as a result of drinking contaminated water (Snow, 1855).

As mentioned earlier, the environmental factor is not the only factor that contributes to disease outbreak. The socio economical condition also plays a significant role to disease outbreak. According to Clark (2009), the socioeconomic status refers to an individual's social position as compared to other people in the community. His study suggested that the low-income people has high potential to get cardiovascular disease (Clark, 2009). In Iran for example, the lower socio-economy group has high possibility to get coronary artery disease as compared to high income group due to lack of self-awareness pertaining to health condition (Janati et al., 2011).

On the other hand, the ability to have access to healthcare facility also contributes to the speed of disease transmissions. In principle, any location that is near to the health care facility will have low risk to have disease outbreak. This is due to accessibility of patient receiving treatment at the early stage as compared to locations that are far away from healthcare centre. A study conducted in Northern America, Western Europe, Australia and New Zealand show that patients living further from any health care centres had worse health conditions (Kelly et al., 2016). From 108 respondents, 77% were identified having bad health conditions as a result of living further from health care centres. Some of the respondents opted not to undergo follow-up session with respective health care centres as it would take some time and distance for them to reach the nearest healthcare centres.

In a nutshell, the interaction of agent, host and environment are interrelated as each of them need each other to accelerate. Agent will not grow and transmit the disease without the help of environmental factor that allows them to act actively. Host will not transmit the disease or receive the diseases if the host immunization is strong and able to protect themselves from the disease. In the context of this study, focus is given to examine how water quality index influence the rate of HFMD distribution in Kuching Division.

2.3.2 Social Determinants of Health

The social determinants of health are another framework that can be used to understand the transmission of diseases. It was introduced by World Health Organization in 2008 with the mission to close the gap of health-related issues among all countries. To what extent this factor influences the spread of the disease depends on the scale and level of in situ conditions. Take life of expectancy as an example, in Singapore it was recorded that the life of expectancy is 83.608 years as compared to Nigeria which is 53.62 years (World Health Organization, 2017).

This scenario proves that the level of health facilities has an impact on the condition of health of an individual depending on their location. Singapore has better infrastructure in terms of health facilities as compared to Nigeria (Martin, 2019). As a result of poor health service facilities, the possibility of disease to become an outbreak is very high (Vecchio et al., 2018).

Another example on how social determinants of health has an impact on human health is that there are 170 children died for every 1000 newborn baby in Sub-Saharan Africa as compared to the developed countries which was less than 10 as a result of good health care accessibility where the infected diseases can be treated and cured at the early stage (Rutherford et al., 2009). In China, the improvement of health care accessibility has led to a reduction of infant mortality from 29 in year 2000 to 16 per 1000 cases in the year 2011 (Zeng et al., 2013). Figure 2.27 shows the element of social determinants of health that has significant impact on human health (Russell, 2016).

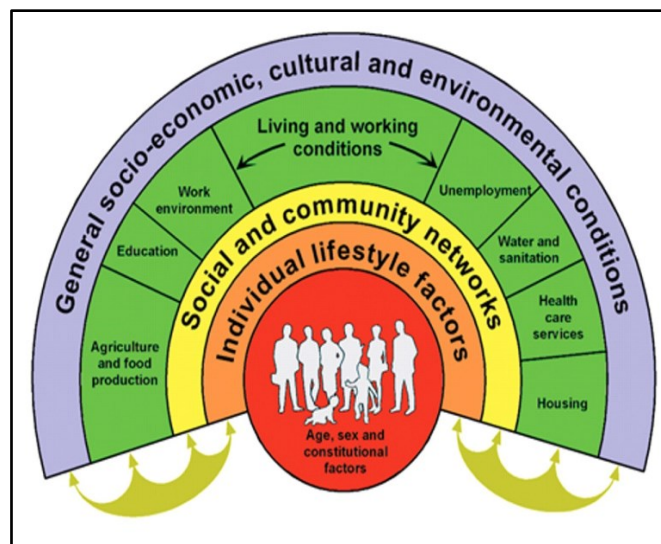


Figure 2.27: Social determinants of health

Social status also has a significant influence of how disease spreads to other area. The population that has high income, education and occupation has better health condition

and is more alert with the disease outbreak that happens surrounding them. The level of health conscious and awareness is very high and therefore any symptom of getting sick is managed at the early stage. This prevents the disease to become an outbreak. A study done by Sharon Friel in 2014 in Australia found out that people in high-class category can live six years longer than the low-class community (Friel, 2014).

Similarly, physical environmental features also contribute to the level of disease spreading rate. This can be seen from physical exposure of air pollution that affects large area (Brook et al., 2010). According to Brook et al. (2010) the exposure of particulate matter (PM) for several hours and weeks has the potential to trigger cardiovascular disease. Long term exposure of ambient air pollution has caused diabetes type 2 in Europe, North America, and China (Puett et al., 2019). On the other hand, 1400 people died everyday as a result of water pollution around the world (Khan et al., 2018). This shows that physical environmental features have significant impact on the health condition of each area.

2.3.3 Tobler's First Law of Geography

While the epidemiological triangle and social determinants of health focus on potential factor contributing to disease transmission, Tobler's first law of geography theory on the other hand emphasizes on how location, space and distance can influence the surrounding environment. Tobler said that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). In his article, Tobler presented the simulation model of urban growth in Detroit from 1910 to 2000 as shown in Figure 2.28 (Tobler, 1970).

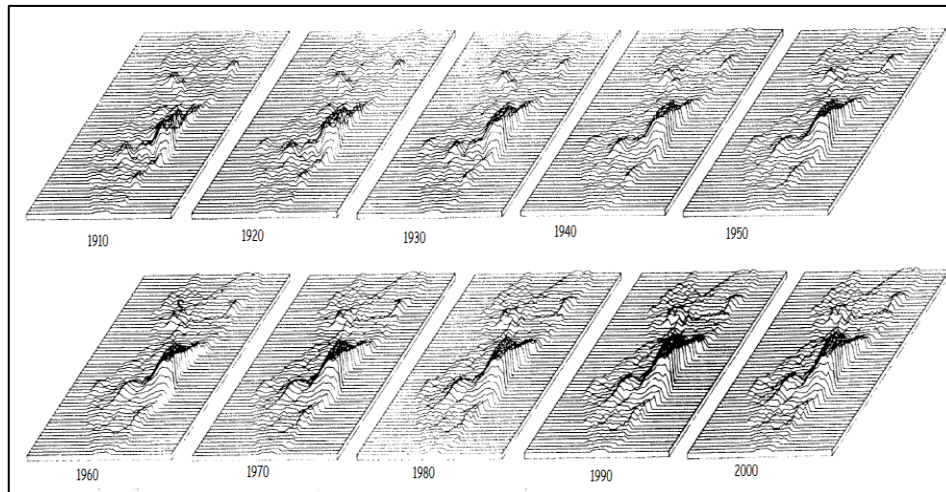


Figure 2.28: Simulation model of urban growth in Detroit

The simulation model of urban growth in Detroit as shown in Figure 2.28 has taken into consideration of the spatial autocorrelation in what Tobler described as “everything is related to everything else”. Based on that philosophy, he created 1150 grid cells in his urban growth model and used the adjacent or neighbouring cells to influence the growth of population in Detroit (Tobler, 1970). His model shows that the urban growth in Detroit from 1910 until 2000 were influenced by spatial distribution of population. Figure 2.29 explains in detail on how Tobler’s first law of geography can be applied in anything (Dempsey, 2014).

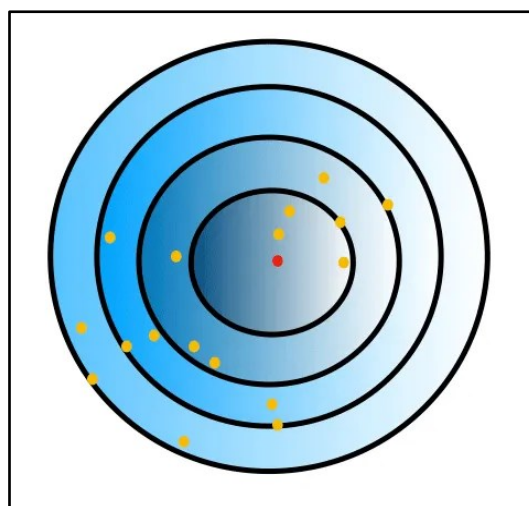


Figure 2.29: Tobler's first law of geography

As shown in Figure 2.29, the points of interest represented in orange that are closest to red are more likely related to what is happening to red as compared to others that are further away from it (Dempsey, 2014). The element of distance and space as introduced by Tobler has become popular since it was first introduced. In 2014 for example, a study to evaluate the spatial autocorrelation of influenza epidemic in Vellore, India based on Tobler's theory detected that the influenza epidemic was localised and clustered. Indirectly, its confirmed that everything is related to everything else, but near things are more related.

2.3.4 Assessment of Chosen Theoretical Framework

As discussed in the previous section, there are three theoretical frameworks to be adopted in this study namely epidemiological triangle, social determinants of health and Tobler's first law of geography. Venn diagram as shown in Figure 2.30 describes the intersection of three theories.

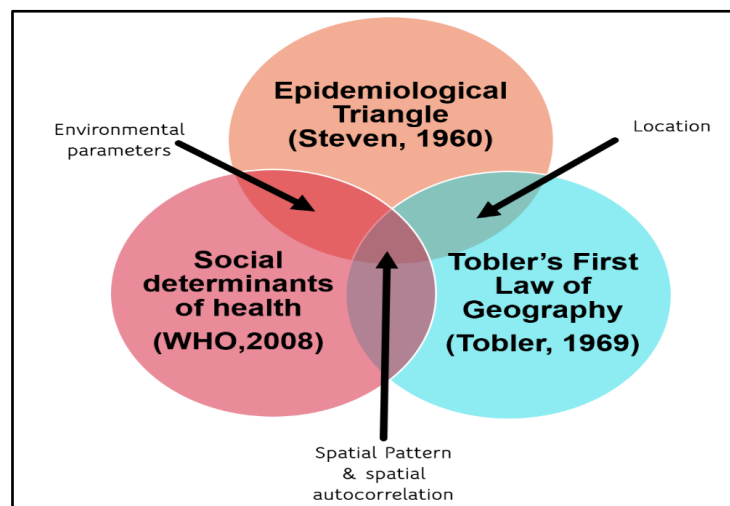


Figure 2.30: Venn diagram of adopted theoretical frameworks

The epidemiological triangle covers three parameters which are agent, host and environment. The environment parameter in epidemiological triangle is the main topic that covers the social determinants of health theory introduced by World Health Organization in

2008. To quantify these models in analysing the HFMD transmission in Kuching division, an element of spatial location needs to be taken into consideration, and this is where Tobler's first law of geography theory comes in. By identifying the spatial pattern and spatial autocorrelation, the in-situ variables that influence the transmission of HFMD can be evaluated and examined.

2.4 Geographic Information System (GIS)

Geographic Information System (GIS) is not a new technology. It has been around for many decades. The usage of it has also extended from not being used only for mapping operation and spatial data storage but to a more advanced analytic modelling (Mohammad, 2016). Besides, it is no longer exclusive and confined to a specific group as the users now comprises all industries that require spatial data to support their business operations.

Its capabilities to store and manage spatial data have helped decision makers, planners and analysts in many ways. This statement is proved by reviewing articles, journals and reports that mentioned the success story of GIS utilization in many fields. In 1968, Geographic Information System (GIS) had gotten its name when Roger Tomlinson used it (Thomlison, 1968). Since then, this term has been widely used until now.

So what exactly is GIS? GIS is a tool for working with geographic information (Huisman, 2009). Aronoff (1989) further elaborated that GIS is a computer-based system that provides specific functions namely data capturing, data management, data manipulation, data analysis and data presentation of spatial data. This definition is interesting as it covers all aspects of GIS life cycle system, from data capturing processes up to data presentation and visualization. According to Ruslan (1998), GIS is a system that has the capability to perform data entry, data editing, data manipulation, data analysis and data presentation of spatial data and non-spatial data. The non-spatial data refers to the information that is linked

to and integrated with locational information.

Besides Ruslan (1998), Environmental Systems Research Institute (ESRI) defines GIS as a framework for gathering, managing and analyzing data (ESRI, 2018). On the other hand, Tarmiji (2015) refers GIS as a system that uses geographic data and information for the decision-making process. Based on the above definition, it can be summarized that GIS is a system that manages all data with geography, space and locational information as well as a tool for data manipulation, editing and analysis.

Figure 2.31 shows the example of GIS system indicating Sarawak administrative boundary with the names of all division that is used to symbolise the map by assigning the respective divisions with specific colours. The information of every division is kept as an attribute in Sarawak administrative boundary layer.

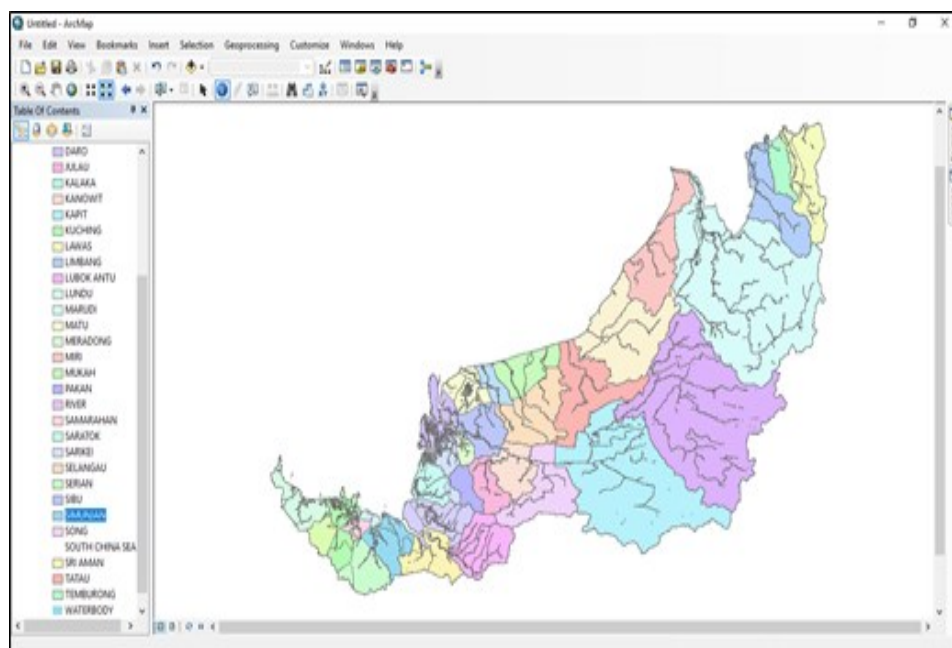


Figure 2.31: Graphical user interface of ArcGIS Software

Since GIS system has the capabilities to generate map that tailors to the user's need, users have the option to change any colour or symbology that meet their requirements. This cartographic skill varies from one person to another and depends solely on the experience of

the GIS specialist itself. Nonetheless certain department and agencies have their own standard colour scheme and symbology to be followed by their GIS users.

This is to ensure the map they generate is consistence in terms of the symbology and colour used to represent any feature on the ground into GIS system. Jabatan Ukur dan Pemetaan Malaysia also known as JUPEM for instance has released their standard guideline for mapping to be followed by GIS data providers (Jabatan Ukur Pemetaan Malaysia, 2006).

GIS Component

The success of GIS implementation and utilization rely very much on the availability of five GIS essential components in any organization. Techclopedia (2012) describes the component as one or more logical tasks that works with one another and make the system functions. With respect to GIS, these components are the important element that makes GIS utilization a success. According to ESRI (2019), GIS component comprises of hardware, software, data, people and procedure as shown in Figure 2.32.

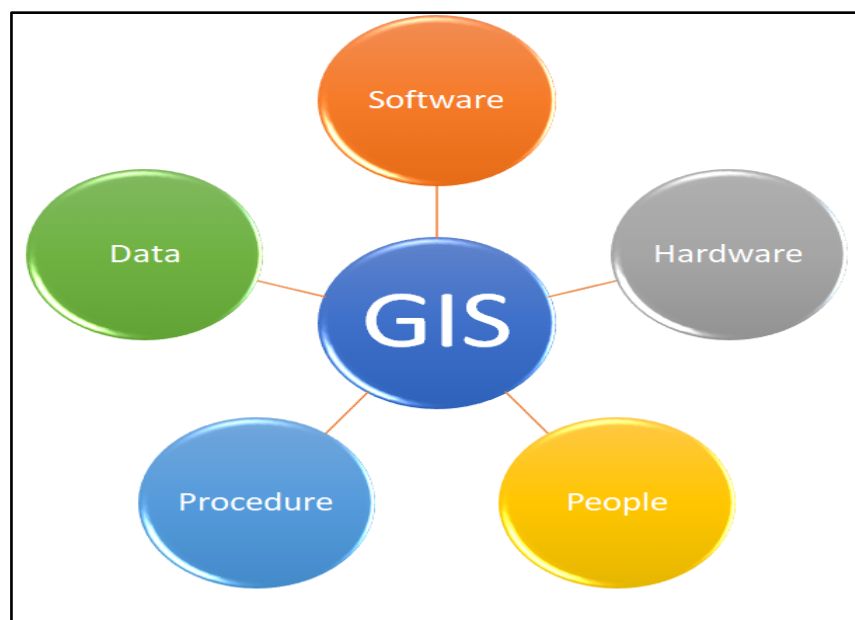


Figure 2.32: Basic GIS components

There are five main components that support each other namely hardware, software,

data, procedure and people. Without any of these five components, GIS implementation may not work as per expectation. Some organization may have all components except procedure and that can create an issue when GIS operations are not utilized in a proper manner. Although each organization may have their own procedures to be used and adopted, it might not be able to be used correctly as a result of poor understanding of how GIS or spatial technology is used in decision making process.

Therefore, it is important to ensure the investment of GIS technology in any organizations are taken into consideration of each component as shown in Figure 2.32. Software relies on hardware to process GIS operations and GIS operations need data for recommendation. Ironically, the whole process of GIS requires a set of procedure which will be operated by the people, as in the GIS user itself. The next section will discuss further on each of GIS components.

Hardware

Hardware refers to the physical parts of a computer and related devices. It includes devices such as motherboards, random access memory (RAM), hard drives, monitors, mouse, printers, keyboards and scanners (Techterms, 2018). In the context of GIS, hardware requirements also refer to other devices such as Global Positioning System (GPS) equipment, Unmanned Aerial Vehicle (UAV) and plotter.

The selection of hardware to be invested in any organization is crucial as it determines how effective and efficient the hardware in processing GIS data and GIS software functions. Software vendor such as ESRI has recommended the minimum requirements of hardware specifications for the end user to consider before they can use their technology. This is to ensure that the hardware specification can support the processing requirements of GIS. Some of the GIS functions such as 3D modeling and raster visualization are indeed

required high-end graphics adapter for a better visualization and processing (Dempsey, 2014).

Table 2.4: Hardware requirements

Item	Supported and Recommended
CPU speed	2.2 GHz minimum; Hyper-threading (HHT) or Multi-core recommended
Platform	x86 or x64 with SSE2 extensions
Memory/RAM	Minimum: 4 GB
Display properties	24-bit color depth
Screen resolution	1024x768 recommended minimum at normal size (96 dpi)
Disk space	Minimum: 4 GB
	Recommended: 6 GB or higher
	ArcGlobe creates cache files when used. If using ArcGlobe, additional disk space may be required.
Video/Graphics adapter	64 MB RAM minimum; 256 MB RAM or higher recommended. NVIDIA, ATI, and Intel chipsets supported.
	24-bit capable graphics accelerator
	OpenGL version 2.0 runtime minimum is required, and Shader Model 3.0 or higher is recommended.
	Be sure to use the latest available drivers.

Listed in Table 2.4 is the minimum requirements of ArcGIS running in any machine (ESRI, 2018). It specifies that the minimum CPU speed is 2.2 GHz with the platform of x86 or x64. This is to ensure the processing power of GIS is enough to process GIS data which is bigger in nature.

The other important specification of hardware is the memory capacity. According to Zlatanov (2016), random access memory (RAM) captures data for system to process the information. Bigger RAM allocation of memory assigned to the application will improve the speed of processing. Although the minimum RAM is 4GB, but it is recommended that the

hardware should have 8GB memory for the best performance and processing.

An Open Source GIS software such as QuantumGIS (QGIS) has its own hardware requirements. Boundless Spatial Incorporation (Boundless) has released the minimum requirements and recommendations of hardware specification of QGIS in 2017 as specified in Table 2.5 (Boundless, 2017).

Table 2.5: QGIS hardware requirements

Minimum	Recommended
OS: 64-bit Windows 7 (SP1) or Server 2008 R2	OS: 64-bit Windows 10 or higher
CPU: Hyperthreaded dual core	CPU: Quad core or better
RAM for Desktop: 1 GB	RAM for Desktop: 2 GB or higher
Screen resolution: 1280x800 at standard dpi	Screen resolution: 1440x900 or higher at standard dpi
Screen color depth: 32-bit	Screen color depth: 32-bit
Video RAM for Desktop: 256 MB or higher	Video RAM for Desktop: 512 MB or higher
Graphics card: DirectX 9 (OpenGL 2.0)	Graphics card: DirectX 11 (OpenGL 3.2) or better
Disk space for Desktop (and data): 3 (10) GB	Disk space for Desktop (and data): 3 (40) GB or higher

In Table 2.5, it appears that QGIS has less hardware memory requirement as compared to proprietary software like ESRI. Although it indicates that the memory requirement is 2GB, it is still recommended that the hardware RAM specification is to be at least 8GB for the best processing and performance. For better GIS hardware processing, QGIS recommends to have at least 64-bit Windows Operating system. Additionally, Quad Core processor is suggested as it will improve the speed of processing GIS data and GIS operations.

Software

The selection of software to be implemented and used in any organization is worth serious attention as it draws a line of GIS functions capabilities in supporting organization in their business operations. There are two categories of GIS software available in the market, namely an open source GIS software and propriety GIS software. Although propriety GIS software is better in terms of functionalities and capabilities as well as stability, it does not mean that open source GIS is way behind propriety software. Each of this software has its own advantages and disadvantages.

According to a report produced by SpendEdge, ESRI software was nominated as a leader in the GIS industry (SpendEdge, 2017) and had earned \$1.1 billion in 2016. Other than ESRI, there are other popular GIS software among the GIS users such as Map Info, SuperMap GIS, Autodesk Map and SmallWorld GIS. GIS software can be classified and grouped into three categories, namely GIS Desktop, GIS web and GIS mobile. GIS desktop covers the operation use of software to process GIS data and functions within desktop environment.

On the other hand, GIS for web uses the internet infrastructure to disseminate GIS data and operation to wider audience which is internet community. Similarly, GIS for mobile is designed for onsite operation which includes GIS data collection on the field. The requirement for GIS user to use GIS for desktop, GIS for web and GIS for mobile depend very much on their needs.

In the area of open source GIS, Quantum GIS, also known as QGIS is the most popular software among the other open source software. (Newcom et al., 2017). Table 2.6 lists the general functionalities required by any GIS software.

Table 2.6: Standard GIS functions

No	GIS Functions
1	Data Creation
2	Data Editing
3	Data Manipulation
4	Data Analysis
5	Spatial Modeling and advanced analysis
6	Map Composition and Layout Design

Data creation refers to a process of developing spatial data into the system where data editing function allow GIS user to amend and alter the converted data to become meaningful information. On the other hand, data manipulation and data analysis functions provide GIS user with the capabilities of GIS to solve their business operation by using spatial analysis functionality. Additionally, map composition and layout design functions help GIS user to generate map and support their cartographic requirements.

As software investment can be very costly in term of licensing and upskilling program, an organization are recommended to conduct situational review of their GIS needs. The identification of GIS software to be used shall be conducted by external GIS consultant that has no conflict of interest with any preferred GIS technology.

Data

Data plays a significant role in any GIS implementation as it is used to support the current business operation in the decision-making process and planning. GIS data model comprises of two formats namely the vector model and raster model.

In a nutshell, vector model is used to represent geographical features on the ground in the form of point, line and polygon. Each of the features has X and Y that coordinates information and these coordinates will be used as a reference to the feature on the ground.

According to Aronoff (1989), the associated X and Y coordinate pairs are used to represent the vertices of geographical features on the ground. Figure 2.33 shows the example of vector model representation for points, lines and polygon feature.



Figure 2.33: GIS vector model representation

In Figure 2.33, three layers were combined into one view and these layers were street lighting which was represented in point, road layer as a line feature and building layer as in polygon feature. The representation of geographical features whether it is in point, line and polygon are very much depending on the scale and the accuracy required by GIS users. For that matter, a house can be represented as a point on a map of 1:50000 or a polygon at the scale of 1:1000.

As opposed to vector data model, raster data model is a cell-based way of representing geographic features. Each cell in raster format will be assigned with a unique value to what it is represented. According to ESRI (2019), raster data model is the model that uses pixels to represent the geographic features and organized it based on rows and columns. The size of each cell is known as resolution. Resolution refers to spatial details that can be captured (Netele, 2008).

Figure 2.34 shows the comparison between vector model and raster model of GIS feature representation (ESRI, 2016).

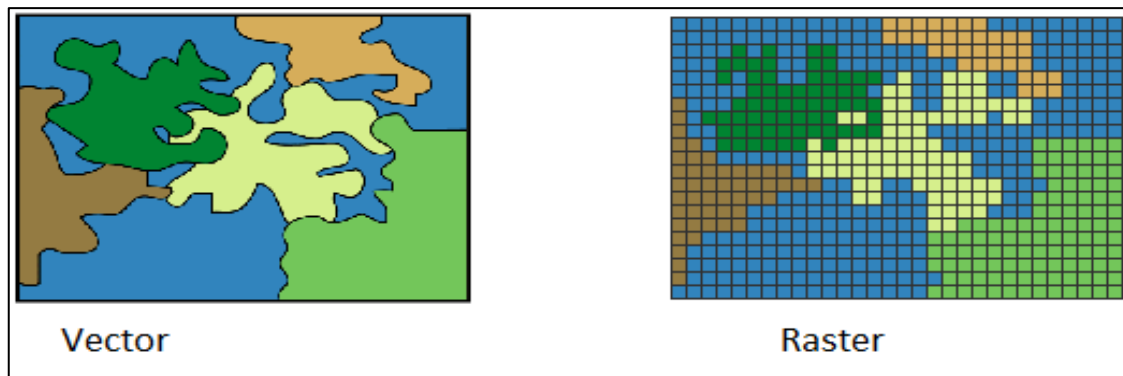


Figure 2.34: GIS vector and raster data model

Vector layer uses vertices to represent the feature into GIS system and it normally represent feature either in point, line and polygon. Raster however uses grid cell to represent any feature and each of the grid cell will be assigned to any number. The size of the grid cell in raster format represents the level of details of the feature that is represented. Both vector and raster have its own advantages and disadvantages. The selection of these data formats are also depending on the specific application.

People

Likewise, data, people also tremendously affect the success of GIS implementation in any organization. Having a dedicated team or human resource to manage GIS operations does not guarantee the objective of having GIS system to support organizational business operation is achievable. It has to be a person who has a domain knowledge in GIS and knows how to use the tool to support their application. For instance, an organization can't hire a person without any experience in GIS to manage GIS operations as their view or opinion may not help them to use GIS technique efficiently. In addition to that, a dedicated team must be willing to adopt and adapt GIS as part of their decision-making process. To ensure

the return of investment in GIS is justifiable to the organization, suggested skills needed for GIS personal is presented in Table 2.7 (Dibiase et al., 2006).

Table 2.7: GIS skillset requirements

No	Category	Sub-category
1	Analytical Methods	Academic and analytical origins
		Query operations and Query
		Geometric measures
		Basic analytical operations
		Basic analytical methods
		Analysis of surfaces
		Spatial statistics
		Geostatistics
		Spatial regression and econometrics
		Data Mining
		Network Analysis
		Optimization and location-allocation modeling
2	Conceptual Foundations	Philosophical foundations
		Cognitive and social foundations
		Domains of geographic information
		Elements of geographic information
		Relationships
		Imperfections in geographic information
3	Cartography and visualization	History and trends
		Data considerations
		Principles of map design
		Graphic representation techniques
		Map production
		Map use and evaluation
4	Design Aspects	GIS system design
		Project definition
		Resource planning

Table 2.7 continued

No	Category	Sub-category
	Design Aspects	Database Design
		Analysis Design
5	Data Modeling	Basic storage and retrieval structures
		Database Management systems
		Tessellation data models
		Vector and object data models
		Modeling 3D, uncertain and temporal phenomena

As shown in Table 2.7, analytical method is one of the skills required for anyone who wants to be a GIS analyst or consultant. A person who has the GIS analytical skill would be able to interpret and analyse GIS data and able to get an insight out of it. GIS shall not be used mainly for mapping only, but it is beyond mapping and because of that, the person who is responsible to lead GIS must have analytics skill and have a very good conceptual foundation on GIS.

It is compulsory to know the geodesy concept so that the converted GIS data is accurate in terms of its position on the ground. Moreover, the cartographic skill will enable their map to be more presentable and easier to understand. Subsequently, design aspect skill is also needed so that any GIS system to be developed are going through several phases and meet their actual requirement. Lastly, data modelling is required as it draws the overall data development requirement of GIS datasets.

Procedure

The implementation of GIS in any organization may not meet their goals and objectives if there are no proper procedures in place. Because of this, it is vital that every

agency know their exact requirements and how GIS is used to support their current business operations. As an evidence, 85% of GIS projects fail to meet their business objective (Ghamdan & Ammar, 2012). This scenario happened due to lack of procedures and processes in defining GIS and how it can be used to support their operations.

Procedure plays an essential role as it outlines the procedure of how an organization will be using GIS to support their business operations. The procedure starts with GIS data creation, data manipulation, data analytics and data presentation. These steps are crucial to be followed by GIS users. Typically, the method and procedure of how GIS is used, are identified during GIS needs assessment. The outcome of GIS needs assessment will determine the range and type of GIS solutions and applications which are required by the organization (FountainSpatial, 2008) and therefore the acquisition of GIS software and hardware shall be based on these requirements.

Moreover, by proper organizational operation, GIS investment return is justifiable. Thus, it is recommended that all procedures and processes to be used are properly documented and shared among GIS users within the organization. This is to ensure the consistency of GIS in terms of the data format, policies and legislation are made known to everyone concern. The standard operating procedure (SOP) must be developed and monitored closely so that all GIS users in the organization follow similar steps and standards.

In addition to this, a dedicated committee can be formed to monitor all GIS procedures are to be followed by GIS users. It is essential that this committee is represented by someone that has vast knowledge in GIS and thus able to operate and use GIS effectively. The chances of getting the right methods and procedures while using GIS to support business operation in the organization is very high if it is handled by GIS professional. Besides, the critical success factor of GIS implementation is also due to the human capital who is being

assigned to manage GIS operation (Eldrandaly et al., 2015). The person that is appointed to lead GIS must be able to prepare a strategic plan and implementation programs that guides the organization to achieve their goal. The prepared plan shall be scalable and dynamic enough to meet current and future GIS requirements.

GIS was used for the first time in the area of public health and epidemiology in 1854 to solve the mystery of cholera outbreaks in London. From the year 1831 until 1854, 10,000 people died because of Cholera. John Snow, an epidemiologist in London has conducted GIS mapping of cholera distribution in 1854 in order to identify why was cholera disease happened in London. During his mapping, he has developed GIS data model that consists of three main geodatasets namely road (line feature), cholera disease locations (point feature) and water pump locations (point feature) as illustrated in Figure 2.35.

Figure 2.35: Cholera incident in London

cases were happening nearby water pump location.

As shown in Figure 2.35, the red dots that represent the cholera disease locations were clustered to each other within nearby water pump locations. The concentration of cholera incident shows some significant relationship between the distribution of cholera incident with water pump locations that were contaminated with bacteria. With GIS map generated by John Snow, he concluded that cholera outbreak was due to the contaminated water supply from the pump as most of the clustered cases reported were people that lived nearby the water pump (Snow, 1855) as shown in Figure 2.35. Since then, GIS has gained its popularity in helping epidemiologist in solving public health related issues and many epidemiologists have used the state of the art of GIS technology to help them to understand health problems and identify the correlation between these diseases.

In 2015, Susan van Rheenen has conducted her research on Stroke disease in Canada by using GIS. She has conducted her study on stroke disease for the period of six years starting from 2003 until 2008. There were 3673 cases of stroke registered in Canada in 2003, 3678 cases in 2004, 3724 cases in 2006, 3619 cases in 2006 and 3665 cases in 2007 as well as 3527 cases in 2008. Stroke disease is not distributed randomly among society and population, in fact it is distributed closely in relation to environmental parameter. Based on this principle, she uses GIS to model the stroke distribution in Canada. The main objective of her research was to examine the spatial clustering and hotspot of stroke disease in Alberta, Canada.

To do that, she has developed a GIS data model that consists of several geodatasets namely Administrative boundary (polygon feature), health care facilities (point feature), and

stroke patient's locations (point feature). By using hotspot analysis based on Getis ord GI model, a map of hotspot of stroke disease in Alberta was generated.

Based on Figure 2.36, it shows that the hotspot areas were clustered at the eastern area of Alberta for ischemic type of stroke. As opposed to hotspot areas, the coldspot areas were detected at Northern part of Alberta, Canada. By using GIS technique to identify the hotspot area of stroke disease and linked that information with health data of each stroke cases, Susan has concluded that ischemic stroke and transient ischemic attack hotspot in Alberta, Canada had lower proportion of stroke from diabetes mellitus as compared to outside of hotspot area. According to Rheenen (2015), the finding from her study serves as a reference for the authorities to plan for primary prevention.

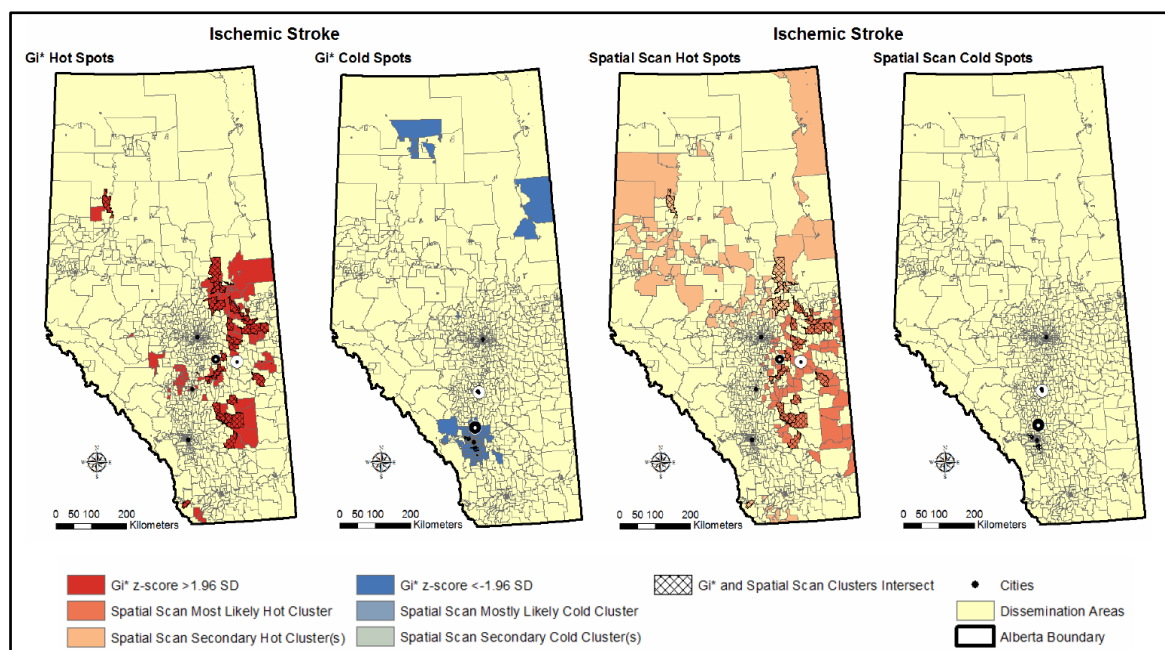


Figure 2.36: Hotspot analysis of stroke in Alberta Canada

In the meantime, Stopka et al. (2017) has conducted a study on Hepatitis C by identifying the hotspot areas of this disease by using GIS technique in 2017. It was observed that in his study, he had developed GIS data model consists of Hepatitis C case locations

which was 99,780 cases from 2002 until 2013. The data was collected from Massachusetts Department of Public Health. Other variables such as year of cases, gender, mode of transmissions, address and ethnicity were linked to Hepatitis C case locations.

On top of that, population data and socio-economic data were developed too. By using Getis-Ord Gi* model to generate the hotspot map, the pattern of Hepatitis C was developed as illustrated in Figure 2.37.

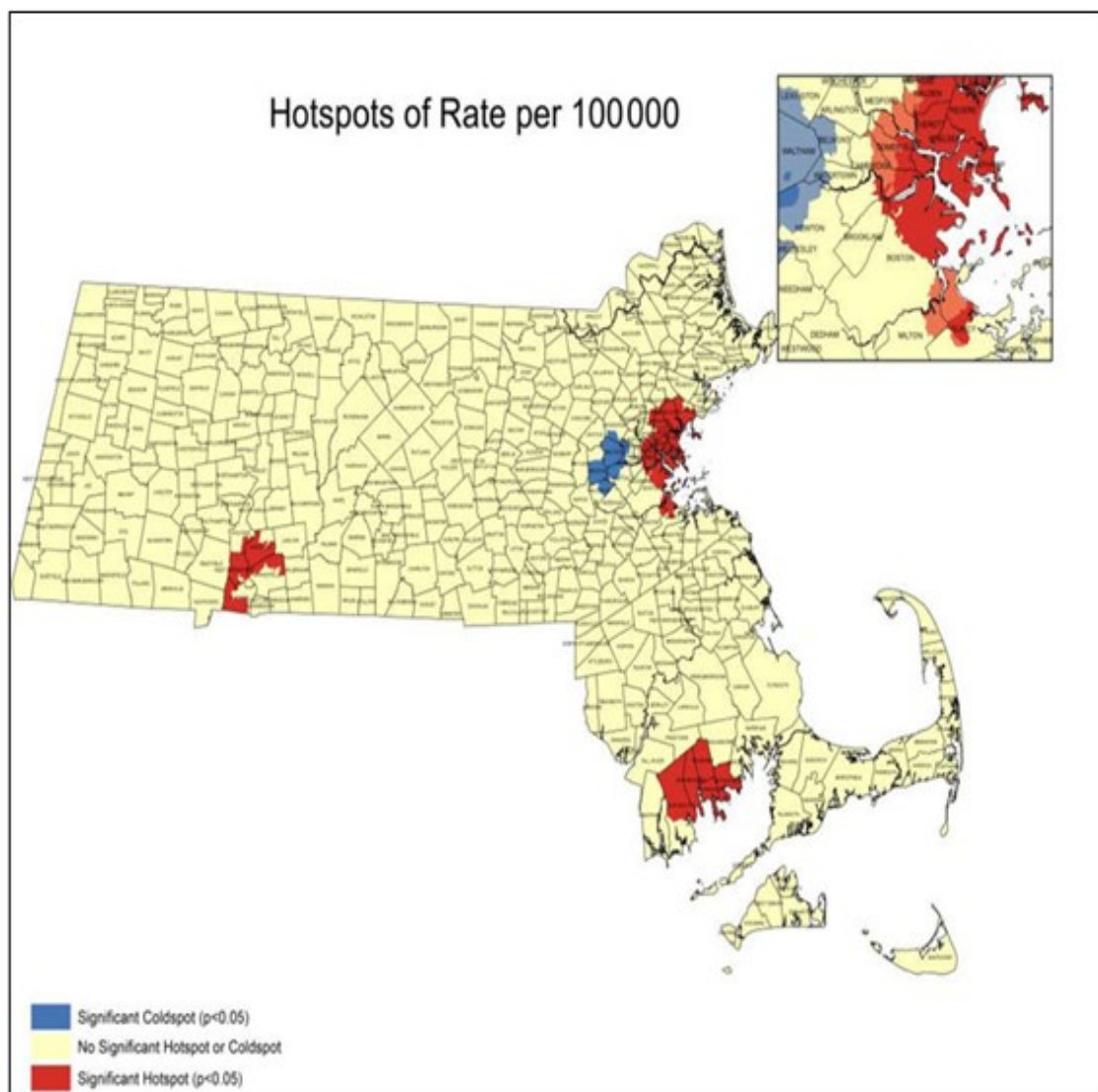


Figure 2.37: Hotspot analysis of Massachusetts, US

As shown in Figure 2.37, Stopka et al. (2017) found out that the hotspot areas were concentrated at the three main areas, namely Boston, New Bedford and Springfield. The

outcome from hotspot analysis is very important as it confirms the pattern of clustering. Furthermore, it indicates the high-risk area of hepatitis disease in Massachusetts which can be used to support mitigation planning.

In 2018, another study using GIS was conducted by Rajabi et al. (2018) on spatial pattern of cardiovascular disease. The understanding of spatial pattern and distribution over space and time are indeed very important as this disease is one of the major diseases that causes mortality in adults around the world. The period of ten years from the year 2000 until 2010 were selected by the researchers with Sweden as the study area. In this study, researchers have developed GIS data model comprising several geodataset namely cardiovascular disease locations (point feature), hospital administrative boundary (polygon feature) and residential areas (polygon feature). These GIS layers were linked with textual information collected from Swedish National Board of Health and Welfare such as gender, age and date of admission. The purpose of developing this GIS data model was to model the spatial distribution of cardiovascular and also to identify the hotspot and coldspot areas of this disease.

In order to identify the hotspot and coldspot areas, Rajabi et al. (2018) used Getis-Ord G_i^* technique using the hospital administrative boundary (polygon feature) that was linked to textual data of number of cardiovascular cases. The interesting element of this study is the use of hospital administrative boundary as a reference for hotspot identification instead of an individual level instead of jurisdiction boundary. As mentioned by the researcher, the rationale of using hospital administrative boundary for hotspot and coldspot identification was driven by the objective of study to examine the health care services in Sweden instead of assessing the distribution of cardiovascular disease at jurisdiction level.

Figure 2.38 shows the hotspot areas and coldspot areas within the study area

generated by the researcher. Based on the study conducted by Rajabi et al. (2018), it was detected that the spatial pattern of Cardiovascular disease in Sweden as clustered. It was found out that the hotspot areas were located at Southern part of Sweden namely Skane, Smaland and Varmland. It was concluded by the research team that the information of hotspot and coldspot areas generated from their research can be used as a reference for Cardiovascular mitigation plan.

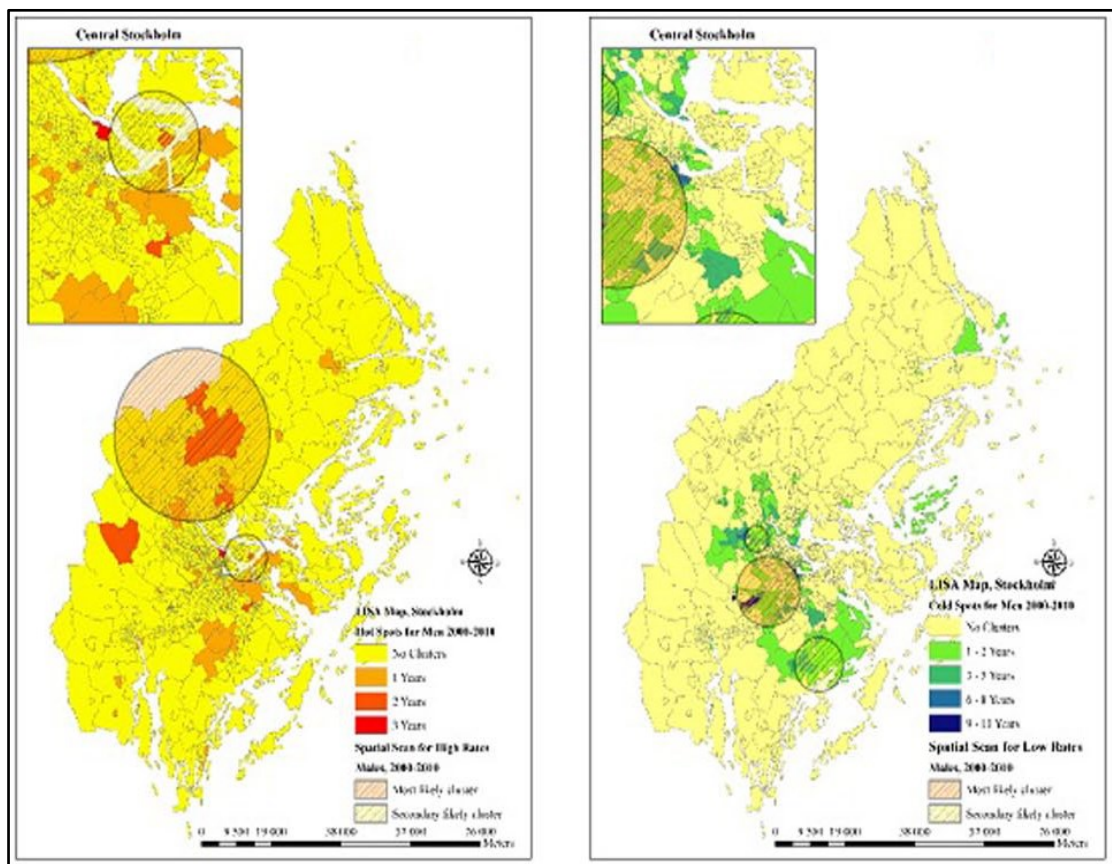


Figure 2.38: Hotspot and coldspot map of Sweden

Based on the study conducted by Rajabi et al. (2018), it was detected that the spatial pattern of cardiovascular disease in Sweden as clustered. It was found out that the hotspot areas were located at southern part of Sweden namely Skane, Smaland and Varmland. It was concluded by the research team that the information of hotspot and coldspot areas generated from their research can be used as a reference for cardiovascular mitigation plan.

As noted above, on the previous studies conducted by epidemiologists and public health officers, GIS has been found useful in helping them to analyse various types of diseases (Snow, 1854; Rheenen, 2015; Stopka et al., 2017; Rajabi et al., 2018) particularly in helping them to understand the spatial spreading pattern and hotspot analysis of the diseases. Snow (1854) successfully connects cholera outbreaks with the contaminated water supply in London by plotting out cholera incidents on the map.

On the other hand, Rheenen (2015), Stopka et al. (2017) and Rajabi et al. (2018) had used Average Nearest Neighbour (ANN), Spatial autocorrelation Moran's Index and Getis Ord GI* techniques, a popular GIS technique to study the spatial spreading patterns and hotspot analysis within their study area. The next paragraphs will elucidate the application of GIS specifically for Hand, Foot and Mouth Disease (HFMD).

2.6 GIS in Hand, Foot and Mouth Disease (HFMD)

As mentioned in earlier paragraphs, GIS has been found useful in assisting decision makers and health planners. These can be seen from the studies conducted involving HFMD. The ability of GIS to locate the incident locations on the ground have helped the respective authorities to quickly identify the location at risk. The conducted studies are not confined to disease mapping but extended to mapping operations.

Several new techniques have been used and implemented such as spatial statistics to study the correlation of HFMD with other associated factor, spatial autocorrelation to study the strength of disease distribution as well as spatial analysis to predict the occurrences of a disease in future (Centers for Disease Control and Prevention, 2016).

In the year 2014 for example, Ratchaphon Samphutthanon has conducted a study on HFMD in Thailand. The main objective of his study was to detect the spatial temporal of

HFMD (Samphutthanon, 2014). The study was conducted to evaluate the distribution of HFMD in Thailand from the year 2003 to 2012 and at the same time to examine the correlation between HFMD incident with environmental factor such as humidity and temperature. Figure 2.39 shows the maps produced in this study (Samphutthanon, 2014).

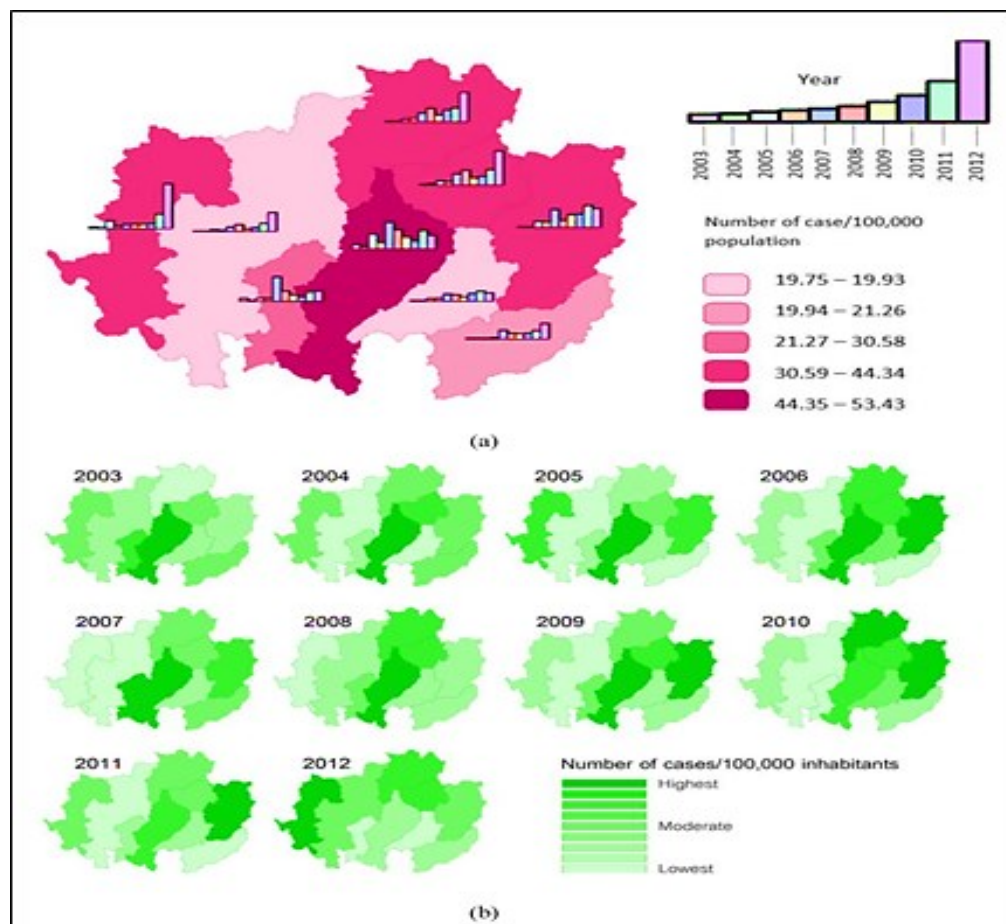


Figure 2.39: Temporal spatial pattern from 2003 to 2012

Samphutthanon (2014) had used spatial statistics and spatial-temporal analysis in examining the distribution of HFMD cases in Northern Thailand for ten years, from 2003 until 2012. A map of distribution pattern and other statistical maps such as standard deviation ellipse and hotspots from the outbreak locations were produced. Other than that, Samphutthanon (2014) also found out that the occurrences of HFMD in Northern Thailand increased during rainy and cold seasons.

In 2018, another research on HFMD using GIS had been conducted by Xu et al. (2018), in Qinghai, China. The research study entitled “Epidemiological features and spatial clusters of hand, foot, and mouth disease in Qinghai Province, China, 2009–2015” was conducted with the objective to study the epidemiological characteristic of HFMD and also to identify the patterns of HFMD distribution in Qinghai Province from year 2009 until 2015 (Xu et al., 2018) as shown in Figure 2.40.

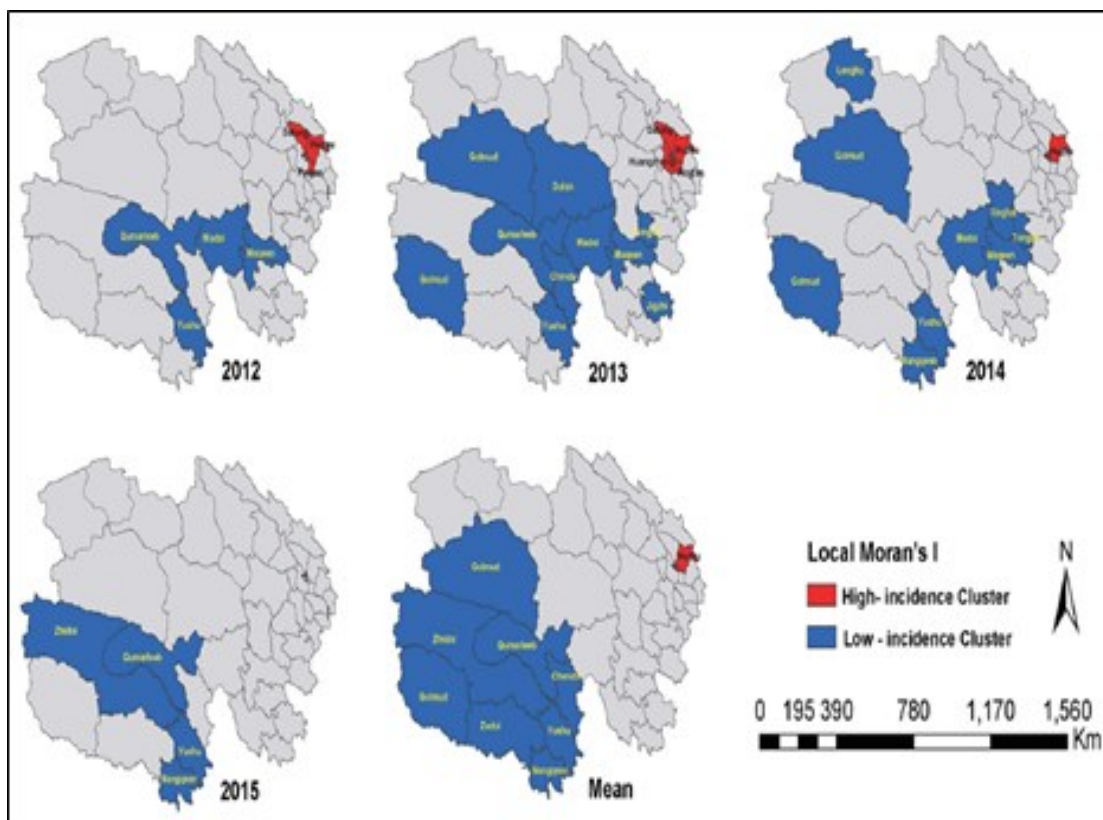


Figure 2.40: Spatial autocorrelation map of Qinghai province China

It was reported that there were 14,480 cases of HFMD in Qinghai province during the study period. On top of that, the researchers had explored and ranked the reported cases based on age and identified that 89% of the patients were from the age of 5 years and less. The spatial statistic was used in this study to examine the level of clustering of reported HFMD in Qinghai Province.

In the context of Sarawak, at present, there are not many studies conducted in

Sarawak concerning the problem of HFMD using GIS technique. In the year 2008, GIS was used by Sarawak Health Department to generate a map of HFMD distribution by the division for the whole of Sarawak (Ooi, 2008).

In the study of “Temporal and spatial mapping of hand, foot and mouth disease in Sarawak, Malaysia” conducted by Noraishah M. Sham in 2014, GIS was used to examine the distribution of HFMD reported cases throughout Sarawak. This study focuses on the reported cases of HFMD from the year 2006 to 2012. In 2006 alone, there were 14,875 HFMD cases reported in Sarawak and that was the highest reported case in Malaysia (Noraishah et al., 2014). Thematic Map of HFMD reported cases in eleven divisions of Sarawak was created from the year 2006 until 2012 as shown in Figure 2.41.

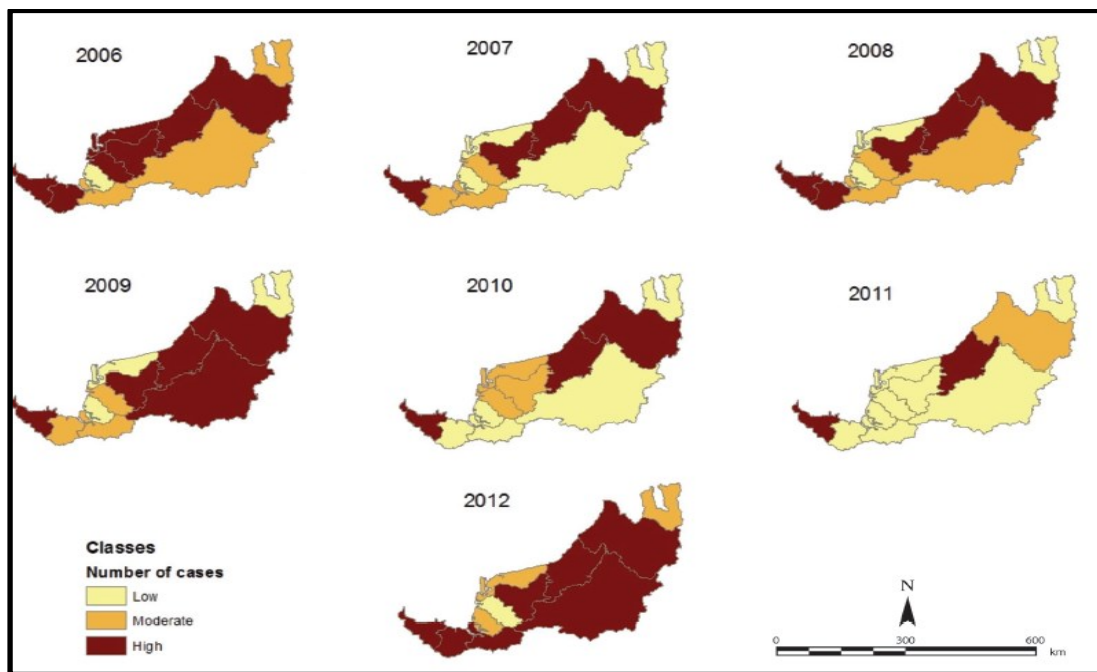


Figure 2.41: Number of HFMD cases based on the categorization by district

Based on their research and analysis, it was found that there was no significant clustering pattern from the year 2006 to 2011. In the year 2012, it was observed that the P value of spatial autocorrelation was 0.068 which shows some signs of clustering. This analysis was done using *Moran's I* statistics.

As shown in Figure 2.41, Kuching division is consistently classified as high based on the number of HFMD recorded from the year 2006 until 2012. Although Kapit division was ranked as low in 2006, it was then ranked as high category of number of cases in 2012.

In 2016, Noraishah and others continued their study and published another article entitled "Use of GIS Mapping for HFMD Cases in Sarawak" which was published in International Journal of Advanced Remote Sensing and GIS. In this study, Noraishah and others had extended their research to analyze the spatial pattern of HFMD to eleven divisions of Sarawak from the year 2006 to 2013. This time around, they were analyzing the possibility of HFMD spreading patterns in the urban division and non-urban division. Figure 2.42 shows the outcome of the study (Noraishah & Krishnarajah, 2016).

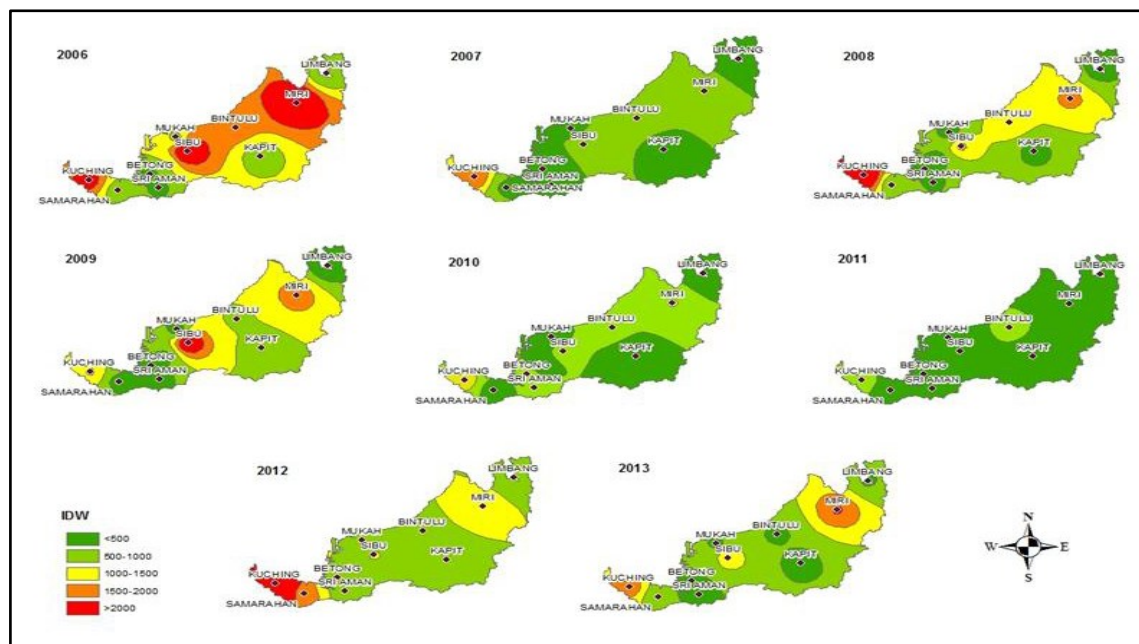


Figure 2.42: IDW interpolation from 2006 to 2013

An inverse Distance Weighted (IDW) technique was used for spatial interpolation and again *Moran's I* statistics was used to study the spatial autocorrelation of HFMD cases for the urban division and non-urban division. It was detected that a high-risk pattern of HFMD was identified in all urban divisions as compared to the non-urban divisions. The

study team proposed the classification of urban division and non-urban division based on the number of population for each division. The division that has more than 10,000 people was classified as urban division and division that has less than 10,000 people was grouped under non-urban division. As a result, the divisions such as Kuching, Samarahan, Sibu, Bintulu and Miri were grouped under urban division and the rest were under non-urban division.

Based on the above literature review, it can be concluded that GIS has been found useful in helping epidemiologist in understanding the spatial distribution of HFMD cases. While the scope of the studies conducted by Ooi in the year 2008 and Noriashah et al. in 2014 and 2016 in Sarawak were only based on divisions which were too broad and general, therefore it may not be appropriate to represent the model of spatial distribution of HFMD. The maps generated by them were based on centroid point of each division to represent the spatial distribution of HFMD in Sarawak. Using this method it might not be able to provide details of understanding on the spatial distribution of HFMD within the division itself. For example, Naraishah & Krishnarajah (2016) classified Kuching division as red zone with recorded cases of HFMD exceeding 2000 cases in 2016. With the total area of 4,560 km², it is difficult to see the trend of spatial distribution of HFMD in Kuching division. Therefore this study will model the spatial distribution of HFMD at the residential areas in Kuching division by using GIS technique.

Similarly, previous studies by Ooi (2008) and Noriashah et al. (2014) do not recommend any GIS data model to be adopted for GIS analysis in the area of HFMD study. GIS data model has not been defined clearly nor addressed properly by the previous researchers on HFMD cases in Sarawak. Without proper GIS data model to be used, it will limit the capability of GIS data to be shared among GIS community. GIS Metadata, feature type, attribute and coordinate systems are among other issues that needs to be addressed

when it comes to GIS Data model development (Gelagya, 2017).

In order to develop standard GIS data model for HFMD, the assessment will be conducted based on the generated maps produced in the previous studies. The GIS basemap layer and the supporting GIS layers will be examined including the message or information to be displayed on the map. From there, the generic GIS data model can be developed.

In 2002, Ministry of Water, Land and Natural Resources Malaysia had setup the Malaysian Centre for Geospatial Data Infrastructure (MaCGDI) with the objective to promote GIS data sharing among GIS community through common data framework. In view to this scenario and the criticality to have a standard and common GIS data model, this study shall propose the GIS data model that can be used by an epidemiologist in supporting their analysis from GIS perspective in future.

Lastly, there is not much study being conducted to review and identify the temporal patterns of HFMD using GIS technique at the residential area. By using GIS, an epidemiologist would be able to analyse if the occurrences of certain diseases at particular locations show any signs of recurring every year or only happen once (Longley et al., 2005). This topic is yet to be revealed from the previous study especially in Sarawak as it only covers at the divisional level. Therefore, the main objective of this study is to identify the high risk area of HFMD distribution at the micro-level, specifically at the residential area. By using residential area as a reference point, it is hoped that the outcome from this study can be used by Sarawak State Health Department to identify and locate the “sensitive” area of HFMD precisely and at the same time, the temporal patterns of HFMD in Kuching division from the year 2013 until the year 2018 can be revealed too.

2.7 Water Quality Index and HFMD

In the epidemiological triangle, an environmental factor plays a significant role in

determining the disease transmission (Stevens, 1960). Based on this theoretical framework, several studies have been conducted in evaluating the relationship between the environmental factor with the transmission of disease. According to Joshi et al. (2018), who have conducted their study in Korea from 2010 to 2015 have concluded that drinking water quality is one of the major determinants of HFMD transmission. Joshi et al. (2018) have collected the HFMD data from seven major cities in Korea namely Incheon, Seoul, Daejeon, Gwangju, Daegu, Ulsan and Busan. Figure 2.43 shows the location of the study area.

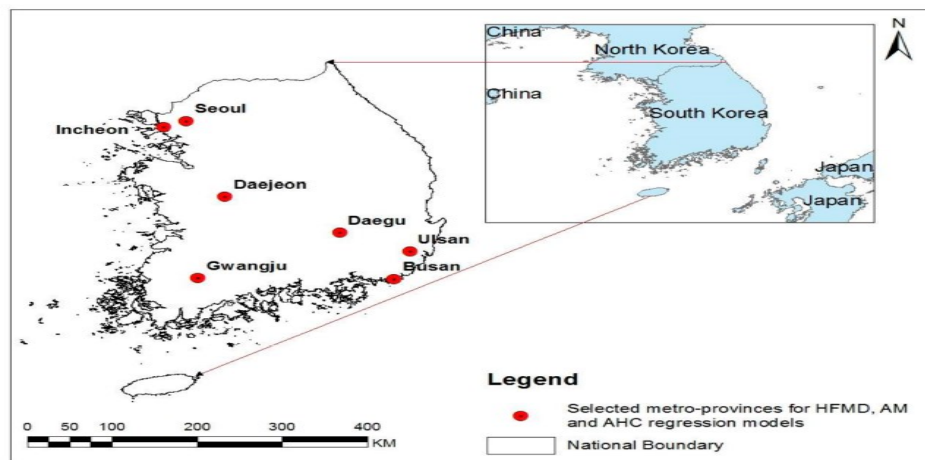


Figure 2.43: Location of study area conducted by Joshi et al. (2018)

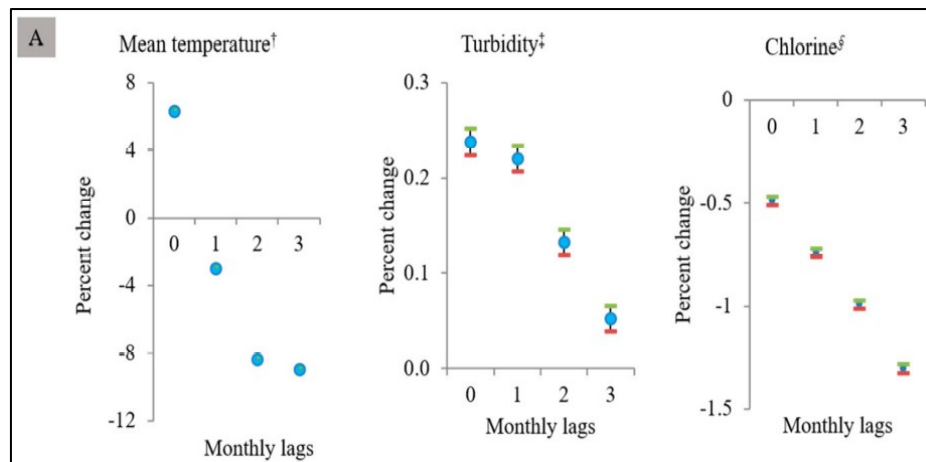


Figure 2.44: Association of water quality index and HFMD case

A Poisson regression analysis was used by Joshi et al. (2018) in their study and based on the correlation analysis, it was observed that the HFMD transmission in Korea was

statistically significant with the quality of the water used in Korea. As illustrated in Figure 2.44, the water quality parameters, turbidity and chlorine, were closely associated with HFMD cases. An increase of 1 Nephelometric Turbidity Unit (NTU) has caused a rise of 0.24% in HFMD cases.

Characteristics within 1 month prior to admission	NEVD* controls No. (%)	AM† cases No. (%)	OR (95% CI)‡,§	HFMD‡ cases No. (%)	OR (95% CI)‡,§
Boiling of drinking water					
Always	131 (77.1)	113 (55.1)	1.00	65 (56.0)	1.00
Sometimes or never	39 (22.9)	92 (44.9)	2.83 (1.44-5.59)	51 (44.0)	3.34 (1.59-6.99)
Use of water purifier					
Yes	84 (49.4)	96 (46.8)	1.00	57 (49.1)	1.00
No	86 (50.6)	109 (53.2)	2.90 (1.52-5.54)	59 (50.9)	1.47 (0.72-2.99)
Drinking water supply					
Tap water	141 (82.9)	160 (78.1)	1.00	91 (78.5)	1.00
Water from well or underground; commercial mineral water	29 (17.1)	45 (21.9)	0.85 (0.30-2.42)	25 (21.5)	0.67 (0.22-2.06)
Water used in cooking					
Tap water	148 (87.1)	180 (87.8)	1.00	102 (87.9)	1.00
Water from well or underground; commercial mineral water	22 (12.9)	25 (12.2)	0.71 (0.22-2.25)	14 (12.1)	1.32 (0.38-4.56)
Type of toilet					
Flush, individual, and inside the house	155 (91.2)	189 (92.2)	1.00	98 (84.5)	1.00
Traditional, communal, or outside the house	15 (8.8)	16 (7.8)	0.81 (0.34-1.97)	18 (12.5)	2.77 (1.14-6.74)
Eating shellfish					
No	151 (88.8)	182 (88.8)	1.00	100 (86.2)	1.00
Yes	19 (11.1)	23 (11.2)	0.50 (0.23-1.09)	16 (13.8)	1.05 (0.42-2.65)
Changes in water quality					
No	165 (97.1)	187 (91.2)	1.00	100 (86.2)	1.00
Yes	5 (2.9)	18 (8.8)	4.56 (1.38-15.09)	16 (13.8)	6.93 (2.17-22.15)
Contact with AM patients					
No	168 (98.8)	182 (88.8)	1.00	115 (99.1)	1.00
Yes	2 (1.2)	23 (11.2)	10.93 (2.04-52.00)	1 (0.9)	0.87 (0.04-18.18)
Contact with HFMD patients					
No	166 (97.7)	199 (97.1)	1.00	102 (87.9)	1.00
Yes	4 (2.3)	6 (2.9)	1.11 (0.24-5.20)	14 (12.1)	4.96 (1.39-17.67)
Contact with URI** patients					
No	158 (92.9)	191 (93.2)	1.00	102 (87.9)	1.00
Yes	14 (12.1)	14 (6.8)	1.33 (0.49-3.61)	14 (12.1)	1.52 (0.52-4.38)
MMR†† vaccination within past 2 months					
No	165 (97.1)	199 (97.1)	1.00	108 (93.1)	1.00
Yes	5 (2.9)	6 (2.9)	1.15 (0.26-5.13)	8 (6.9)	3.35 (0.90-12.44)

Figure 2.45: The association between HFMD and mode of transmission

Another study conducted by Park et al. in 2010 concluded that HFMD cases were associated with water quality in Korea. They have collected HFMD data from three general hospitals in Gyeongju, Pohang and Seoul from 2002 until 2003. There were 116 HFMD cases that they have analyzed. Using the logistic regression model, the study revealed that the

changes in water quality had a significant higher risk of getting HFMD. As illustrated in Figure 2.45, Park et al. (2010) concluded that the odds ratio of getting HFMD is due to the changing water quality which is 6.93 compared to the odds ratio of 1 when water quality has not changed. This shows that the HFMD transmissions is associated with the quality of water consumed by human.

2.8 Chapter Summary

Undoubtedly, GIS has improved the way epidemiologists and public health officers in assisting their work to understand the distribution of disease geographically. This can be seen when several studies have been conducted in relation to how GIS can help in the area of public health and epidemiology. The outcome from the previous studies also concluded that GIS is found useful for them to identify and understand better on the characteristic of disease distribution within space and time. Additionally, GIS also offers a new way to analyse the disease incident spatially. With spatial statistics that comprehend the traditional statistics, epidemiologists and public health officers no longer lock down their views from textual perspective as the map presentation is now available for them to visualise spatially.

This shall improve their understanding as the map can be used as supporting tool for their analysis. Although the benefits of using GIS in the previous studies are recognised, some gap of knowledge were identified and therefore it is hoped that the outcome from this study can be used by the authorities to address the issue of HFMD in Kuching division specifically and subsequently can be used as a reference for their precautionary measures planning.

CHAPTER 3

METHODS AND MATERIALS

3.1 Introduction

This chapter discusses and describes the methodology to be taken and adopted in identifying the high risk area of HFMD from spatio-temporal perspectives such as spatial spreading pattern and distribution, hotspot and coldspot pattern as well as temporal pattern from the year 2014 to 2018. The methods and techniques discussed in this chapter shall walkthrough the processes to be executed in order to achieve the set objectives as specified in Chapter 1.

The discussion begins with the introduction of the research area and the rational of selecting the location of the study area. The conceptual framework will be presented and discussed in this chapter too. It shows the steps and operations to be taken in order to achieve the objectives. Then it is followed by the discussion on how to collect and gather data from various agencies and the identification of the required attributes needed for the study. The last topic to be addressed in this chapter is research technique and method to be used in analyzing the data. It discusses the selection of the methods and why those methods were chosen in this study.

3.2 Research Area

The proposed study area is located in Kuching division, Sarawak. Kuching division consists of five local councils namely Kuching South City Council, Kuching North City Council, Padawan Municipal Council, Bau District Council, and Lundu District Council as shown in Figure 3.1. It covers approximately 4200 km square with the population in 2019 is 802,900 people (Department of Statistics, 2020).

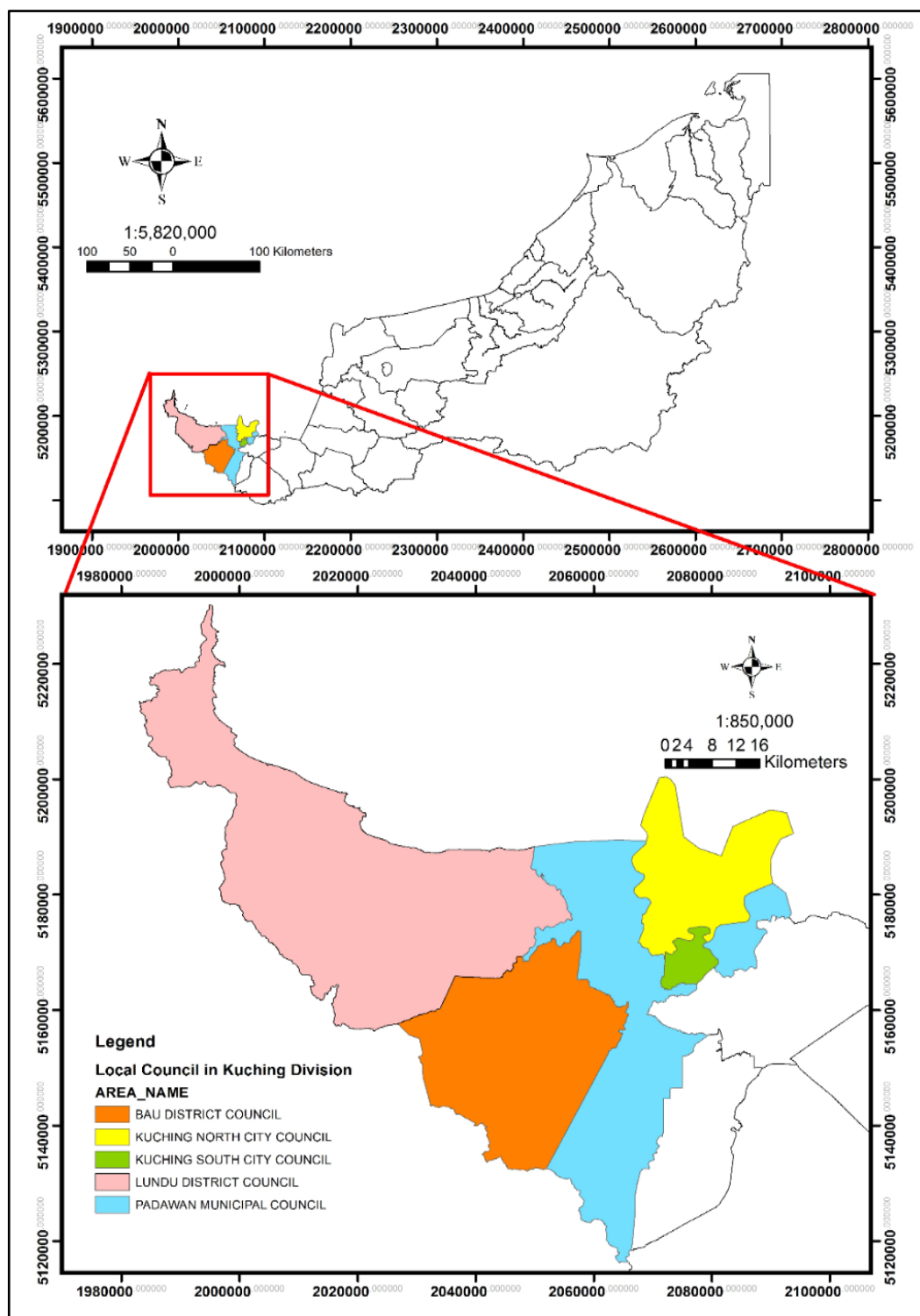


Figure 3.1: Kuching division

In terms of population distribution, 515,100 are Bumiputera, 263,000 are Chinese, 5600 are others and lastly 19000 of the population are non-Malaysian citizens as of in 2019

(Department of Statistics, 2020). Out of five local councils, Lundu District Council has the biggest administrative area which is 4559.5 km². The smallest Local council located at Kuching division is Kuching South City Council with the size of administration is 61.53 km². Kuching division is located at 1°33'23.7" to the North and 110°19'59.0" to the East. The HFMD reported incidents shall be collected within Kuching division.

3.3 Conceptual Framework

The proposed research study is aimed to identify the high risk area of HFMD in Kuching division from the year of 2014 until 2018 and also to understand the relationship of water quality index of Kuching division with the spreading pattern of HFMD. With that aim in mind, the analysis to be carried out must be able to answer and address the issues related to HFMD as well as how space and time factors can be used to identify and understand the distribution of HFMD.

This study uses quantitative approach to analyze HFMD data. Quantitative approach refers to technique that uses statistical and mathematical model of collected data by analyzing it and then make a conclusion based on the measured data. This method emphasizes on numerical data and generalizing it to make sense out of it. The collected data can be based on group of people, diseases, locations or anything that is needed to be revealed. Subsequently, the GIS system shall be used as a tool to perform spatial analysis.

The GIS system will also be used for converting HFMD reported cases into GIS format. The HFMD reported cases shall be collected from Sarawak State Health Department. Figure 3.2 shows the conceptual framework undertaken in this study. It illustrates the steps and processes to be taken in this study.

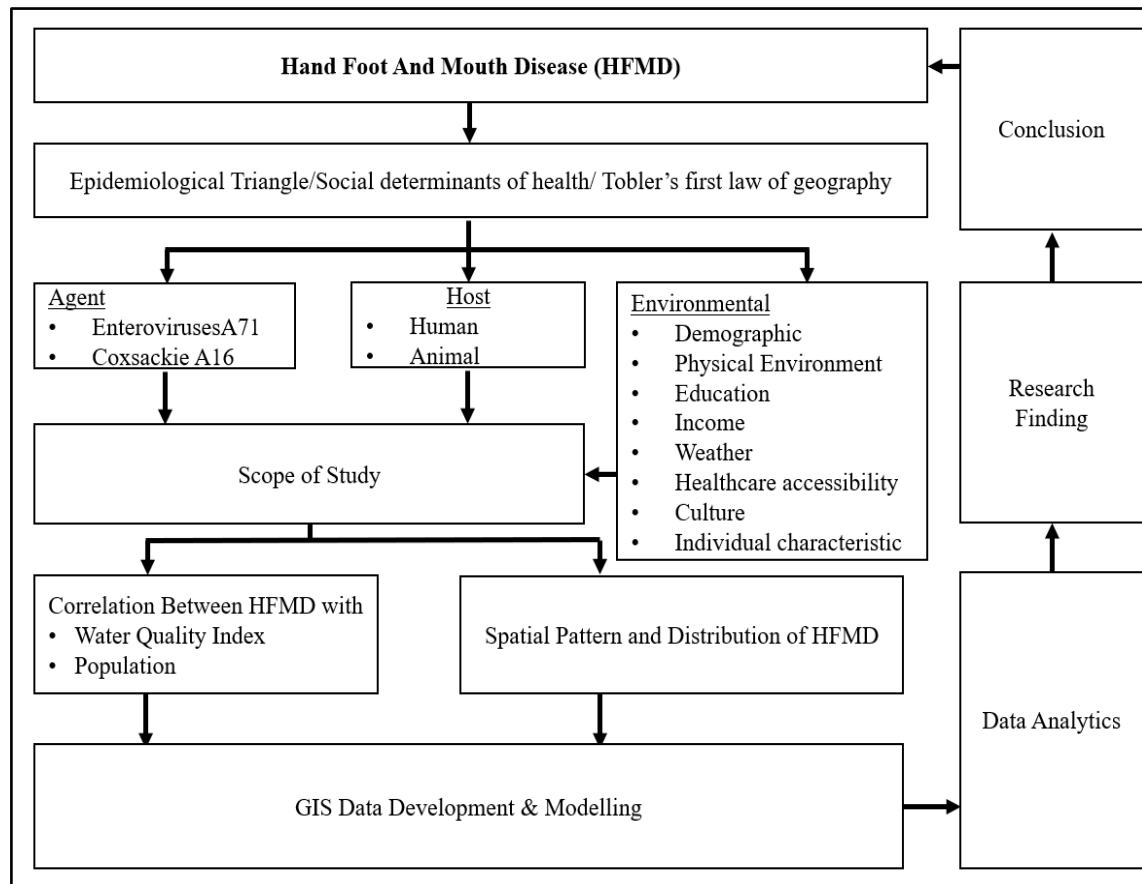


Figure 3.2: Conceptual framework

This study uses epidemiological triangle theory, social determinants of health and Tobler's first law of geography in order to identify the high risk area of HFMD and at the same time to understand the influencing factor of HFMD cases in Kuching division. The component of agent, host and environment will be assessed based on the epidemiological triangle framework. The epidemiological triangle and social determinants of health, as discussed in Chapter 2 are the common frameworks to be used in analyzing the distribution of diseases and how other factors influence each other in determining the spreading pattern of the disease.

Although there are several factors and components involved in epidemiological triangle and social determinants of health theories, the scope of the study shall be focusing

on the environmental component, which is water quality index. The water quality index will be used to examine the level of correlation between HFMD reported cases within the study area. The collected data of reported HFMD cases from Sarawak State Health Department will be analyzed in order to examine the pattern of HFMD within the study area. On the other hand, the collected data of water quality index from the Natural Resources Environmental Board (NREB) will be analyzed pertaining to how it influences the spread of HFMD. Figure 3.3 describes the research methodology to be taken in this study.

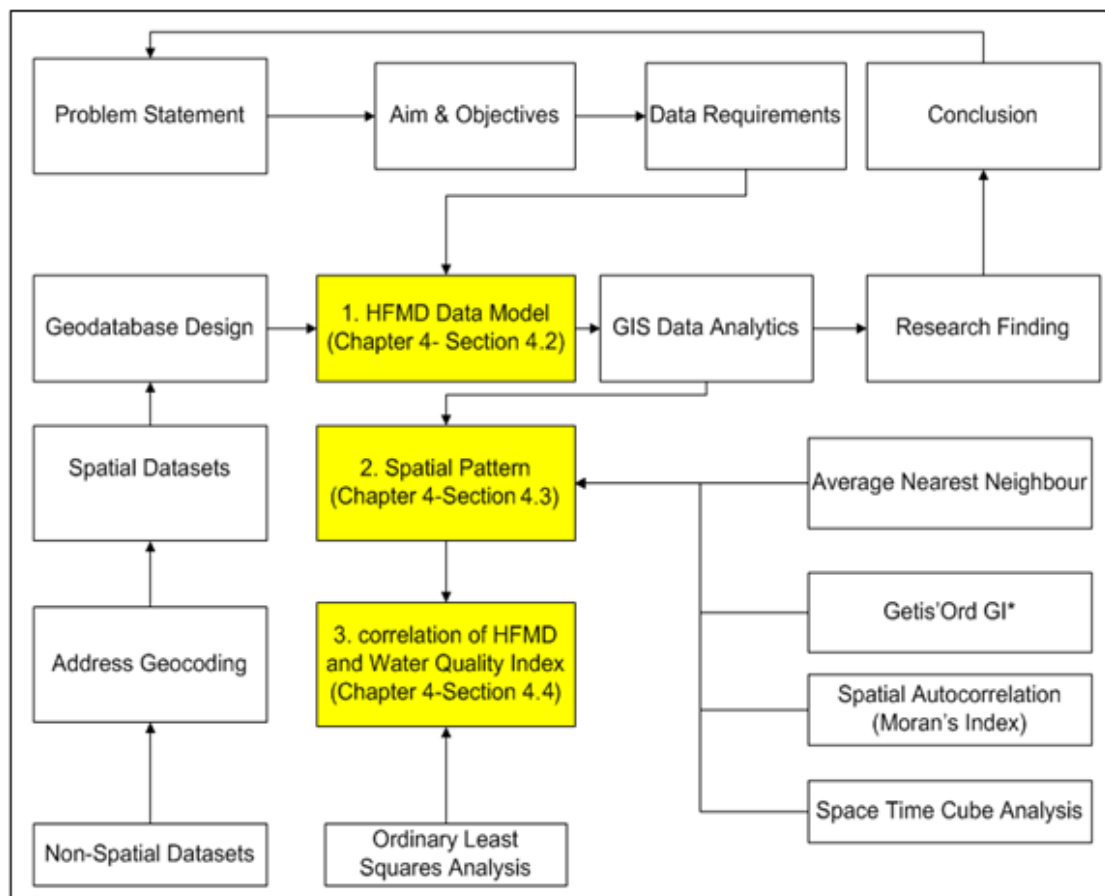


Figure 3.3: Methodology

The methodology adopted will be guided by three objectives of this study namely the development of HFMD GIS data model, spatio-temporal pattern of HFMD and correlation of HFMD with water quality index.

3.4 Data Collection

Two main categories of data were used in this study namely primary data and secondary data. The primary data was collected from the interview conducted with respective officers in-charge in Sarawak State Health Department. The secondary data in this study refers to the data of HFMD cases from Sarawak State Health Department. Although the secondary data obtained from Sarawak State Health Department is the primary source of data for analysis, in depth interview was conducted in order to quantify, verify as well as to seek an advice and opinion from Sarawak State Health Department officers.

The assessment on the condition of the data collected from Sarawak State Health Department was carried out to identify the availability of the coordinate system of the reported HFMD incident based on the data obtained from Sarawak State Health Department. If the coordinates are available, it will then be used for georeferencing. Table 3.1 below shows the listed data required for this study.

Table 3.1: List of GIS dataset required

NO	Layer Name	Data provider/Source of data
1	HFMD cases in Kuching division	Sarawak State Health Department
2	Administrative boundary	GoogleMap and OpenstreetMap
3	Residential locations	GoogleMap and OpenstreetMap
4	Water quality sampling stations	Natural Resource Environmental Board
5	Kuching South City Council boundary	Kuching South City Council
6	Kuching North City Council boundary	Kuching North City Council
7	Padawan Municipal Council boundary	Padawan Municipal Council
8	Bau District Council boundary	Bau District Council
9	Lundu District Council boundary	Lundu District Council

3.5 Technique

Several GIS techniques was used in this study in order to achieve the set objectives. GIS has been chosen in this study as it has been proven to be the best tool used in analysing spatial oriented data (Samphutthanon, 2004; Ooi, 2008; Rezaeian et al., 2017). Based on the epidemiological triangle framework and social determinants of health theory, the spatial pattern and spatial autocorrelation of environment factor of disease incident were examined by using the following techniques namely average nearest neighbour, spatial autocorrelation using Moran's Index and Getis ord GI* for hotspot and coldspot analysis. These techniques address the Tobler's first law of geography where near things are more influence than distant things. The details of the adopted techniques used as listed below are organized based on the set objectives specified in Chapter 1.

3.5.1 Technique to Achieve Objective 1: GIS data model

The development of GIS data model is crucial for any GIS applications. Failure to identify the right data model from the beginning will only increase the operational cost to convert the identified data. Therefore, proper process to develop GIS data model is required so that the creation of GIS data model to support the HFMD analysis is met. To do that, standard data modelling process was adopted in this study to propose GIS data model that is required for HFMD spatial spreading pattern study. There is no difference between textual data model and GIS data model in terms of the modelling process.

The only difference between them is the way it is represented. In the case of textual data model, the representation of information will be done through table format whereby GIS data model will be represented based on how the feature is being design, such as in

point, polyline and polygon formats. Figure 3.4 (Teorey et al., 2008) shows the example of representation of textual data model and Figure 3.5 on the other hand shows GIS data model representation (Bernhardsen, 1999).

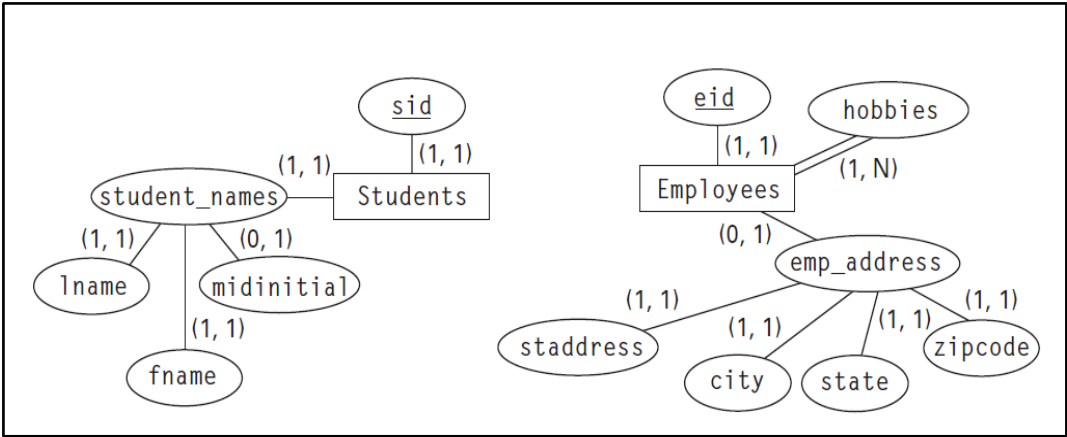


Figure 3.4: ER diagram of textual data model

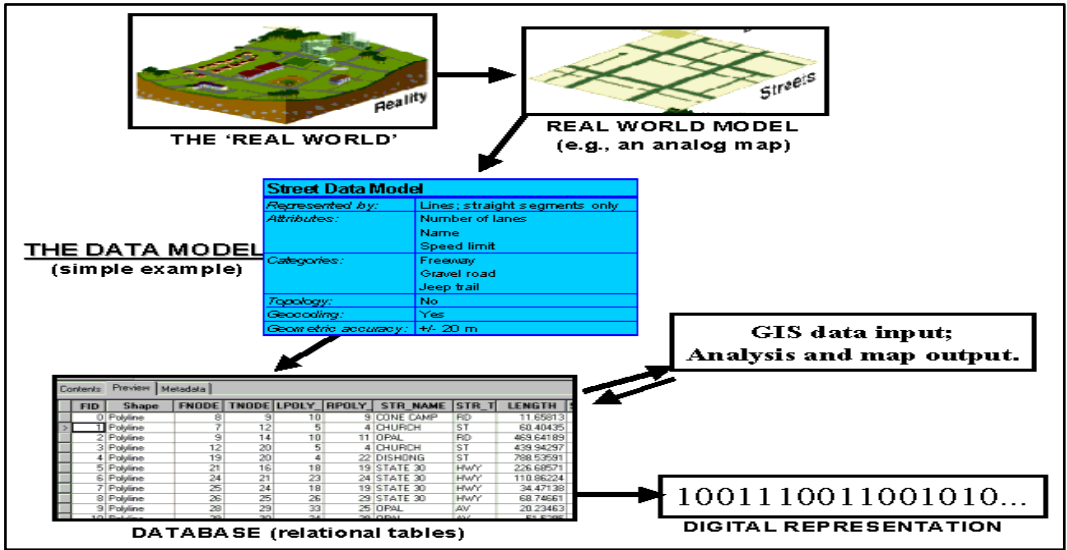


Figure 3.5: GIS data model

For the purpose of developing HFMD GIS data model, typical database modelling process is adopted. Figure 3.6 shows the data modelling processes to be undertaken in this study.

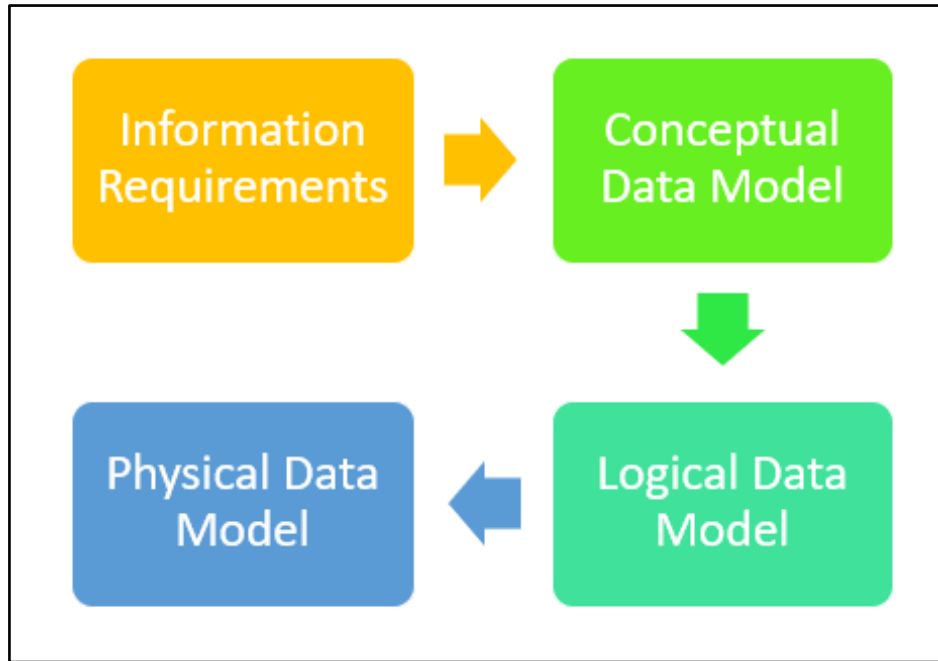


Figure 3.6: Database modelling processes

Information requirements cover the identifying the data required to support the aim and objectives of the analysis. The information requirements were collected and assessed from the conducted interview session with the respective officers from Sarawak State Health Department and Natural Resources Environmental Board.

After information requirements were gathered, the conceptual data model was developed which specified the GIS data layers together with its attribution information. In logical data model stage, the conceptual data model was further defined with its feature types (point, line & polygon) together with spatial reference system required whereby in physical data model, the details of attribution information such as size and type of column were identified.

3.5.2 Technique to Achieve Objective 2: Spatio-Temporal Analysis

Average Nearest Neighbour

According to Tarmiji (2015), Average Nearest Neighbour measures the distance of each point of interest on the ground and how it is related to each other in term of distance. The average of each distance will be calculated to determine if the distribution point of interests are clustered, dispersed or randomly distributed. Gimond (2019) further elaborated that Average Nearest Neighbour measures the average distance from each point within the focus area to its nearest point. In short, Average Nearest Neighbour takes all the points within the study area and measures the distance of every single point and average it out. Equation 3.1 shows how the Average Nearest Neighbour is calculated (ESRI, 2018)

$$ANN = \frac{\bar{D}_O}{\bar{D}_E}$$

Equation 3.1: Average nearest neighbour

Value $\bar{D}_O$ represents observed mean distance of every point in comparison with its nearest neighbor.

$$\bar{D}_O = \frac{\sum_{i=1}^n d_i}{n}$$

Equation 3.2: Observed mean distance

In the case $\bar{D}_E$, it is a representation of expected mean distance for all points in a random pattern.

$$\bar{D}_E = \frac{0.5}{\sqrt{n/A}}$$

Equation 3.3: Expected mean distance

As shown in Equation 3.2, d_i is equal to the distance between point i and its nearest

neighboring feature whereby n refers to the number of point i . Also, A applies to the minimum area that covers all points within the rectangle. Subsequently, the average nearest neighbor Z-score can be calculated as the Equation 3.4.

$$z = \frac{\bar{D}_O - \bar{D}_E}{SE}$$

where:

$$SE = \frac{0.26136}{\sqrt{n^2/A}}$$

Equation 3.4: Z-Score

The ANN technique calculates the distance of each incident and average it out by comparing the distance with other neighbouring incidents. The outcome of this technique produces the ratio of the calculated distance. If the ratio is less than 1, it indicates the clustering distribution and if it is greater than 1, the pattern is towards dispersion. This technique was used in this study to identify the distribution of HFMD cases and how it relates to the environmental factor in epidemiological triangle and social determinants of health frameworks which is water quality index based on the locational distribution of HFMD. The location of each HFMD cases that were represented as a point layer in GIS format were analyzed using ANN technique.

The pattern of HFMD distribution was measured based on the ratio and index produced and generated by ANN test. If the result of ANN is less than 1, it means that the distribution of HFMD cases are clustering and if the ANN result is greater than 1, it means that the pattern is dispersion. By understanding the pattern of HFMD distribution based on

ANN, it will help to answer the objective of this study which is to identify the spatial pattern of HFMD distribution from 2014 to 2018.

Moran's I

“Everything is related to everything else, but near things are more related than distant things” is the popular theory introduced by Tobler (1970). This concept has become a guideline in spatial autocorrelation analysis. This analysis was used in this study in order to evaluate the strength of concentration of HFMD reported cases and how near things is more related than distant thing and how it is associated one after the other (Rezaeian et al., 2007; Griffith et al., 2017). Moreover, this technique is also quite popular among researchers in identifying the correlation of variables from a geographic perspective (ESRI, 2018).

In the context of epidemiology, Samphutthanon (2014) uses spatial autocorrelation technique to evaluate the correlation of HFMD cases and how the settlement was clustered in Thailand. On the other hand, Guelat & Kery use this model to study the correlation of species distribution in ecology (Guélat & Kery, 2018). Undoubtedly this technique allows the researcher to understand better on the concentration of distribution of any feature of interest. Since the proposed study will be using ESRI technology, the *Moran's i* algorithm will be based on the algorithm developed and used by ArcGIS.

Spatial Autocorrelation does take into consideration the attribute values of each features it represented as compared to Average Nearest Neighbour that counts the distribution point of incidents from every points. Equation 3.5 shows the algorithm used by this ArcGIS software where the value of Z_i refers to the deviation of calculated mean of the attribute of feature i (ESRI, 2018).

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{i,j} z_i z_j}{S_0 \sum_{i=1}^n z_i^2}$$

Equation 3.5: Moran's i

On the other hand, $w_{i,j}$ is referring to the spatial weight of feature i and j with n is representating the total number of features and S_0 is representing the aggregate of total of spatial weight. The key important element of Moran's i index is the outcome of the calculated index. If the Moran's i index is close to +1, which is a positive value, it indicates the values are clustered to each other. However, if the index value is negative which is close to -1, it means that the values are dispersed.

Obviously, this technique offers an understanding on how strong the distribution of HFMD as compared to other reported cases of HFMD in different locations. If the locations of HFMD incidents are nearer to each other in terms of the number of cases registered represented by the HFMD incident location, it tends to be clustered and this can be calculated using Moran's i index. By using this technique, it can explain how in-situ condition which is the environmental component of epidemiological triangle can influence the spreading of HFMD.

Thiessen polygon

Thiessen polygon method is introduced in this study as a result of no clear boundary of residential area. In reality, people tend to go to the nearest hospital although their designated area is at other location and this is where the distance play a major role in influencing the movement of people. Therefore, Thiessen polygon can be useful in this case

as it takes the average distance of another point and estimate the area of influence of these points by generating a boundary. This boundary can be used as a reference of influencing area. Thiessen polygon is sometimes referred to as Voronoi, a technique in GIS to interpolate the influence of the point of interest as compared to other points (Tatalovich, 2008). This technique generates the boundary that is created from the triangulation method by connecting the adjacent points. Figure 3.7 shows the created Thiessen polygon from point locations (ESRI, 2018).

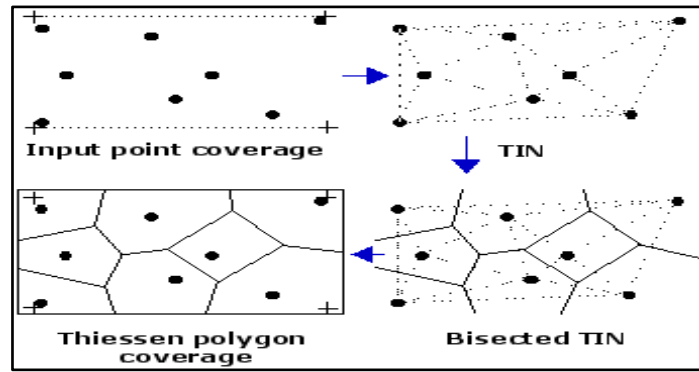


Figure 3.7: Thiessen polygon

The fundamental theory of Thiessen polygon is to divide the connected triangulation into several polygons. Each of these polygons shows the area of influence of every single point. In the case of HFMD, the point location of settlement (residential) can be used as a basis for calculating the influencing areas. By connecting each settlement points, the influencing boundary was created based on the formula in Equation 3.6 (ESRI, 2018).

$$T = \frac{P_1 A_1 + P_2 A_2 + P_3 A_3 + \dots + P_n A_n}{A_1 + A_2 + A_3 + \dots + A_n} = \frac{\sum_{i=1}^n P_i A_i}{\sum_{i=1}^n A_i}$$

Equation 3.6: Thiessen method

As shown in Equation 3.6, T refers to the weighted average, P's are the measured distance and A's refer to the size of each polygon (area). Thiessen Polygon method was used in this study because of no official gazetted boundary from the authority pertaining to the residential boundaries. By using Thiessen polygon method, the boundary of each residential areas can be derived and these boundaries were used as a basis to map the high risk area of HFMD.

Getis ord GI*

The next technique applied in this research is Getis Ord Gi* which is commonly used to analyse and identify hotspot and coldspot area. This method uses vector layer and attribute field information to calculate and identify the hotspot and coldspot area. The outcome and result from this analysis will be displayed in polygon feature. Hotspot area in the context of HFMD incident is referring to the high risk area of HFMD (Lessler et al., 2017). Similarly, it can also refer to a location of statistically significant of clustering of HFMD (Stopka et al., 2014). Equation 3.7 describes the formula of Getis Ord Gi* (ESRI, 2018).

$$G_i^* = \frac{\sum_{j=1}^n w_{ij}x_j - \bar{X} \sum_{j=1}^n w_{ij}}{s \sqrt{\frac{n \sum_{j=1}^n w_{ij}^2 - \left(\sum_{j=1}^n w_{ij}\right)^2}{n-1}}} \quad (1)$$

$$\bar{X} = \frac{\sum_{j=1}^n x_j}{n} \quad (2)$$

$$s = \sqrt{\frac{\sum_{j=1}^n x_j^2}{n} - (\bar{X})^2} \quad (3)$$

Equation 3.6: Getis Ord GI*

Where x_j is referred to the value of an attribute for feature j , w_{ij} is the spatial weight between feature i and j , while n is equal to the number of feature (Jana & Sar, 2016). The important information of this method is Z score and P values from the generated value. The Z score here is referring to the standard deviations and P value, on the other hand is representing the probability value. If Z score value is high and P value is small, it indicates

that a significant hotspot is detected. However, if Z score value is negative and P value is small, it indicates the coldspot area. When the Z Score value is ranging from -1.65 to 1.165 with P value is less than 0.10, it describes the confidence level of 90% of hotspot area occurrences whereby if the Z score value is within -1.96 to 1.96 with P value less than 0.05, it refers to 95% confidence level of hotspot area and lastly if the Z score value is -2.58 to 2.58 with P value less than 0.01, the confidence level of hotspot will be 99% (ESRI, 2018).

This technique was selected in this study in order to identify the hotspot and coldspot areas of HFMD. The polygon layer that represents each residential area is equipped with attribute information of number of cases of HFMD obtained by respective residential. These attributes were then used to determine the hotspot and coldspot areas of HFMD based on the P value and Z value computed by ArcGIS software.

3.5.3 Technique to Achieve Objective 3: Spatial relationship

Ordinary least squares

The last technique used in this study is Ordinary Least Squares (OLS). The OLS analysis is one of the regression techniques that will answer “Why” the incident is happening. For example, why certain number of HFMD cases is high at certain locations and what caused that to happen. On the other hand, OLS can also be used to predict the likelihood of the incident to happen at particular places and also to examine the relationship between several parameters (ESRI, 2018). This technique is expected to provide a better understanding on the relationship of water quality index in Kuching division with the occurrence of HFMD cases. Equation 3.7 shows the formula used in OLS analysis (ESRI, 2018).

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n + \epsilon$$

Equation 3.7: Ordinary least square

Dependent Variable which is represented as **Y** refers to a model or prediction that is going to be carried out. The explanatory variable which is **X** refers to the parameters that are believed to influence the dependent Variable (**Y**). The coefficients (**β**) on the other hand refers to values that indicate the relationship and strength of each explanatory variable (**X**). The residual (**ε**) explains the deviation between predicted value and observed value. The outcome from this regression model shall be used to determine if there is any positive or negative relationship of each explanatory variable. In order to assess the positive or negative relationship between dependent variable and exploratory variable, the scatterplot graph generated from OLS will be examined.

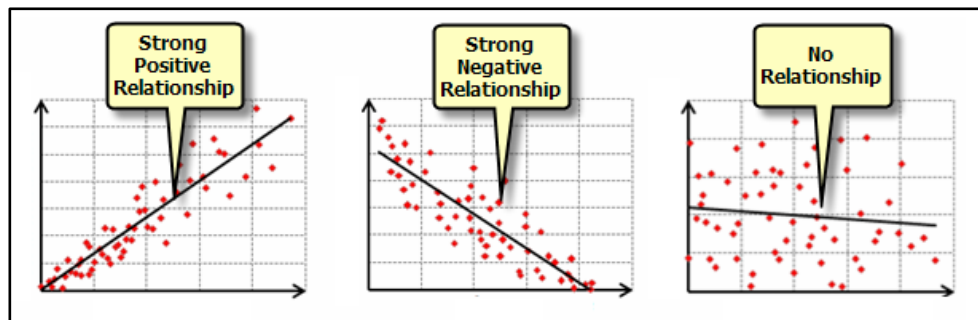


Figure 3.8: Positive and negative relationship

Figure 3.8 shows the example of linear relationship generated from OLS scatterplot graph. The positive relationship of dependent and exploratory variables can be concluded if the number of dependent variable (y-axis) increases together with exploratory variable (x-axis) from the generated OLS scatterplot graph. In other words, the explanatory variable is statistically significant positive relationship with dependent variable. For example, if the

outcome from OLS scatterplot is positive between disease cases and the quality of life, it can be interpreted that the number of recorded diseases is statistically significant with the quality of life. In the case of negative coefficient result, the scatterplot graph will show the dependent variable (y-axis) increased but the exploratory variable decreases (x-axis).

For the purpose of achieving objective three of this study, which is to model the spatial relationship of HFMD cases with environmental factor, the dependent variable is represented by the total number of HFMD cases in Kuching division, whereby the explanatory variable is referring to the water quality index (WQI) produced by Natural Resources Environmental Board (NREB) that covers Kuching division from the year 2014 until 2018. Table 3.2 shows the location of water quality sampling stations under the supervision of NREB.

Table 3.2: Water quality sampling stations in Kuching division

No.	ID	LOCATION	2014	2015	2016	2017	2018
1	SW1	Satok Bridge	75	78	77	75	76
2	SW3	Holiday Inn (Near to discharge point)	69	66	73	75	72
3	SW6	Bintawa Causeway	69	75	70	68	72
4	SW2	Confluence of Sg. Bintangor	60	57	60	65	68
5	SW4	Confluence of Sg. Padungan	56	62	68	66	64
6	SW5	Confluence of Sg. Sekama	57	58	53	44	47
7	SW7	Downstream Barrage (Seawards Side)	65	66	62	61	64
8	SW8	Upstream Barrage (Inland Side)	70	78	67	72	74
9	SW9	Bako Causeway	65	76	72	71	74
10	SN1	Batu 3, Jalan Bormill Estate	57	55	44	49	60
11	SN2	Jalan Keretapi	49	54	43	46	55
12	SN3	Metro Park	59	59	41	50	53
13	SN4	Jalan Stapok	58	58	49	51	57

Table 3.2 continued

No.	ID	LOCATION	2014	2015	2016	2017	2018
14	SN5	Kim Hin Industries	39	48	35	39	62
15	SN6	Desa Ria Fasa II Batu Kawa	51	62	44	47	59
16	SN7	Sg. Maong Kiri & Kanan	58	67	54	53	65
17	SQ1	Kampung Buta	92	93	89	75	89
18	SQ2	Wind Cave, Bau	88	91	87	72	87
19	SQ3	Bau Water Intake Point	91	93	87	71	88
20	SQ5	Siniawan Jetty	80	70	63	56	75
21	SS2	Batu Kitang Weir	88	90	85	72	87
22	SS3	Kampung Landeh	88	90	87	72	85
23	SS4	Kampung Semadang	87	93	89	70	89
24	SS1	Batu Kitang	89	90	85	72	84
25	SZ1	KPA Wharf	64	63	59	67	76
26	SZ2	Jetty Kpg. Muhibbah	66	51	53	62	65
27	SZ4	Sg. Kuap Bridge	62	55	44	68	74
28	ST5	Sg. Tabuan Bridge	52	42	60	54	60
29	ST4	SK Sg. Apong Jetty	54	42	40	44	59
30	ST2	Tabuan Jaya Bridge	43	35	44	46	54
31	ST3	Jalan Foochow Bridge	44	41	41	47	56
32	ST1	Tabuan Dayak Bridge	34	29	41	44	42
33	SK1	Jambatan Ulu Batang Kayan	76	80	82	77	76
34	SK2	Kampung Selampit Jetty	64	79	77	71	77
35	SK3	Lundu Ferry Ram	64	74	72	66	70
36	SK4	Kampung Seling Jetty	64	75	74	68	65

Each of the station captured the water quality index that spelled out the condition of the water quality within that area. The classification of the water quality index was based on the national water quality standard of Malaysia from Department of Environmental Malaysia (2012) as illustrated in Table 3.3.

Table 3.3: Water quality index categorization

Parameter	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	-0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 – 3	06-Mar	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	05-Mar	03-Jan	< 1
pH	-	> 7	07-Jun	06-May	< 5	> 5
Total Suspended Solid	mg/l	< 25	25 - 50	50 - 150	150 - 300	> 300
Water Quality Index (WQI)	-	> 92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	< 31.0

The water quality index is further divided into several classes based on the recommended usage of the water. For WQI that is less than 31.0, it is only suitable for class V, 31.0 until 51.9 is recommended for class IV and 51.9 until 76.5 is mainly for class III. If the WQI is between 76.5 until 92.7, it is suitable for class II and if the WQI is more than 92.7, it is recommended for class I. Table 3.4 shows the proposed use of water quality based on classification released by Department of Environment Malaysia in 2012.

Table 3.4: Proposed water usage by Department of Environment Malaysia, 2012

Class	Uses
Class I	Conservation of natural environment.
	Water Supply I - Practically no treatment necessary.
	Fishery I - Very sensitive aquatic species
Class IIA	Water Supply II - Conventional treatment.
Class IIB	Fishery II - Sensitive aquatic species.
	Recreational use body contact.
Class III	Water Supply III - Extensive treatment required.

Table 3.4 continued

Class	Uses
Class III	Fishery III – Common for economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above

By using ArcGIS software, the water sampling station locations will be interpolated into surface layer using Inverse Distance Weighted (IDW) method. The surface layer of water quality index will be used as exploratory variable layer in ArcGIS Ordinary Least Squares analysis. The interpolation technique to convert water sampling point into surface layer is not something new in GIS.

For example in 2019, Li et al. (2019) have conducted a study in Shandong province, China. The objective of their study was to model the water quality index in Shandong province and had used GIS interpolation technique which was Kriging interpolation method to fill in the gap between data collected on the ground and data needed for analysis. To develop a WQI surface layer, the observed values of WQI was obtained from WQI sampling stations. The observed value will then be used to predict the value of WQI for the nearby area using Kriging interpolation method. Figure 3.9 shows the location of WQI sampling stations and Figure 3.10 shows the outcome of Kriging interpolation technique.

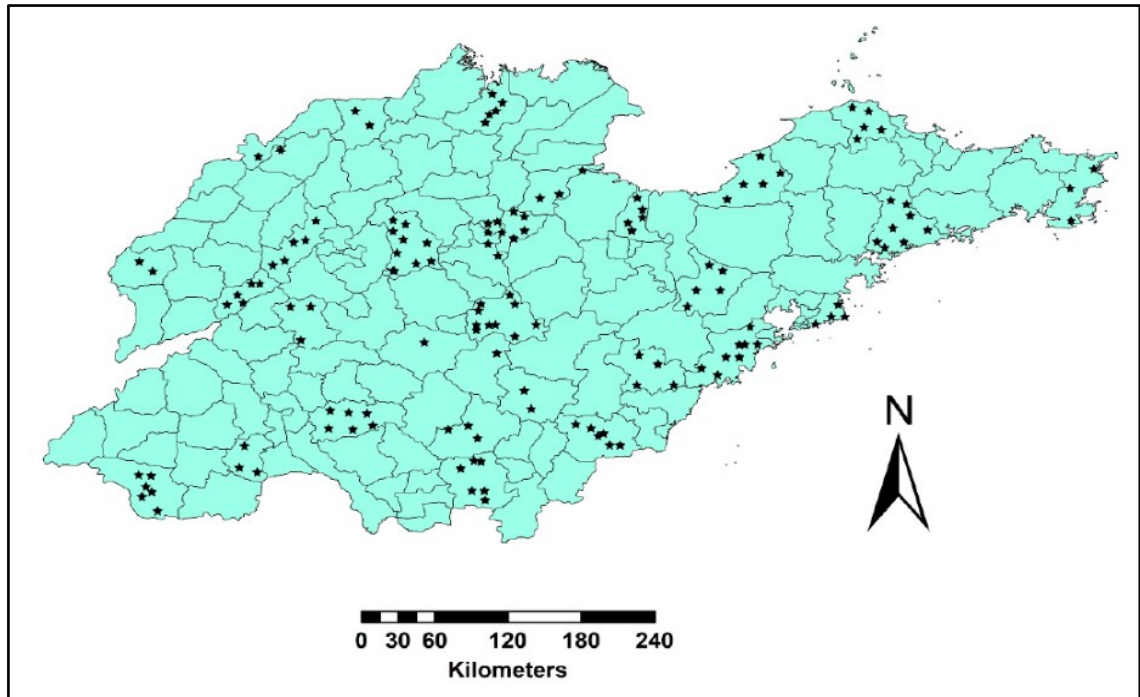


Figure 3.9: WQI sampling stations of Shandong province, China

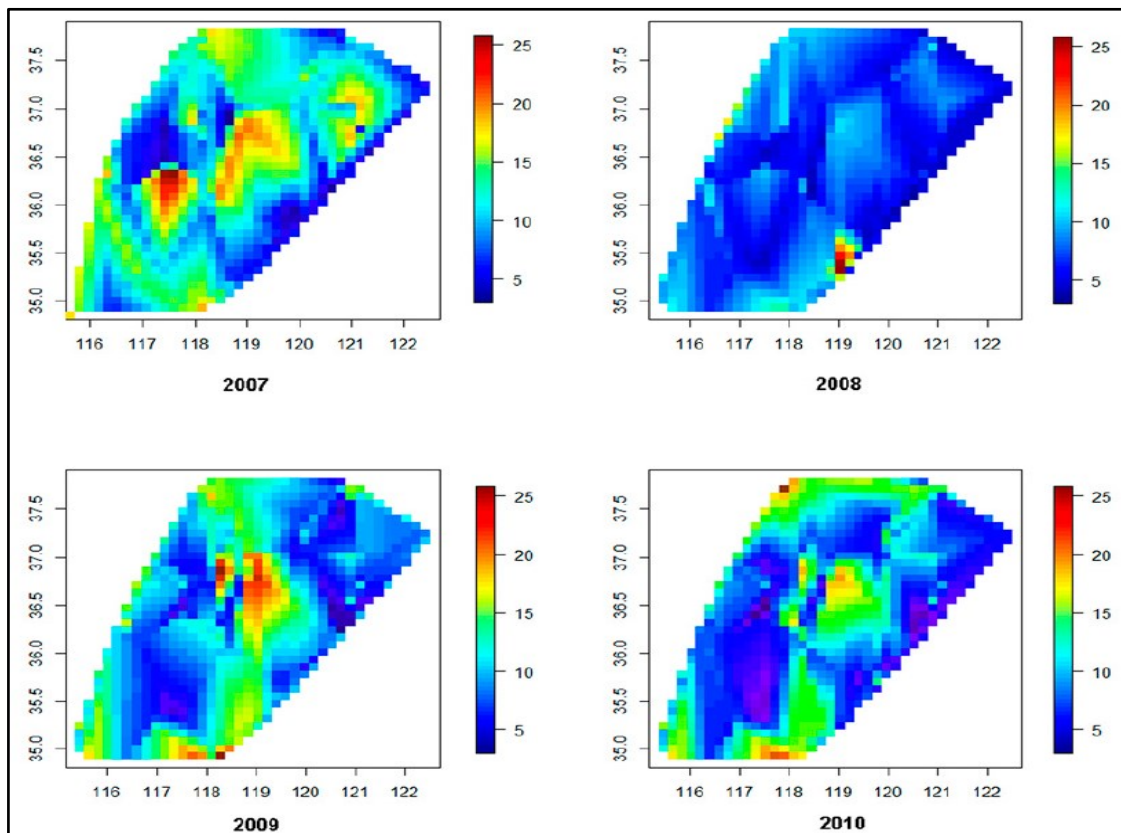


Figure 3.10: Map of WQI generated from Kriging interpolation technique

According to Li et al. (2019), the map of WQI generated by using Kriging interpolation technique can be used to describe the spatial and temporal distribution of WQI in Shandong province, China. Similarly, in 2018, another research conducted in Nigeria by Ogbozige et al. (2018) have used another GIS interpolation technique, which is known as Inverse Distance Weighted (IDW) to develop WQI map based on water sampling collected at River Karuna, Nigeria.

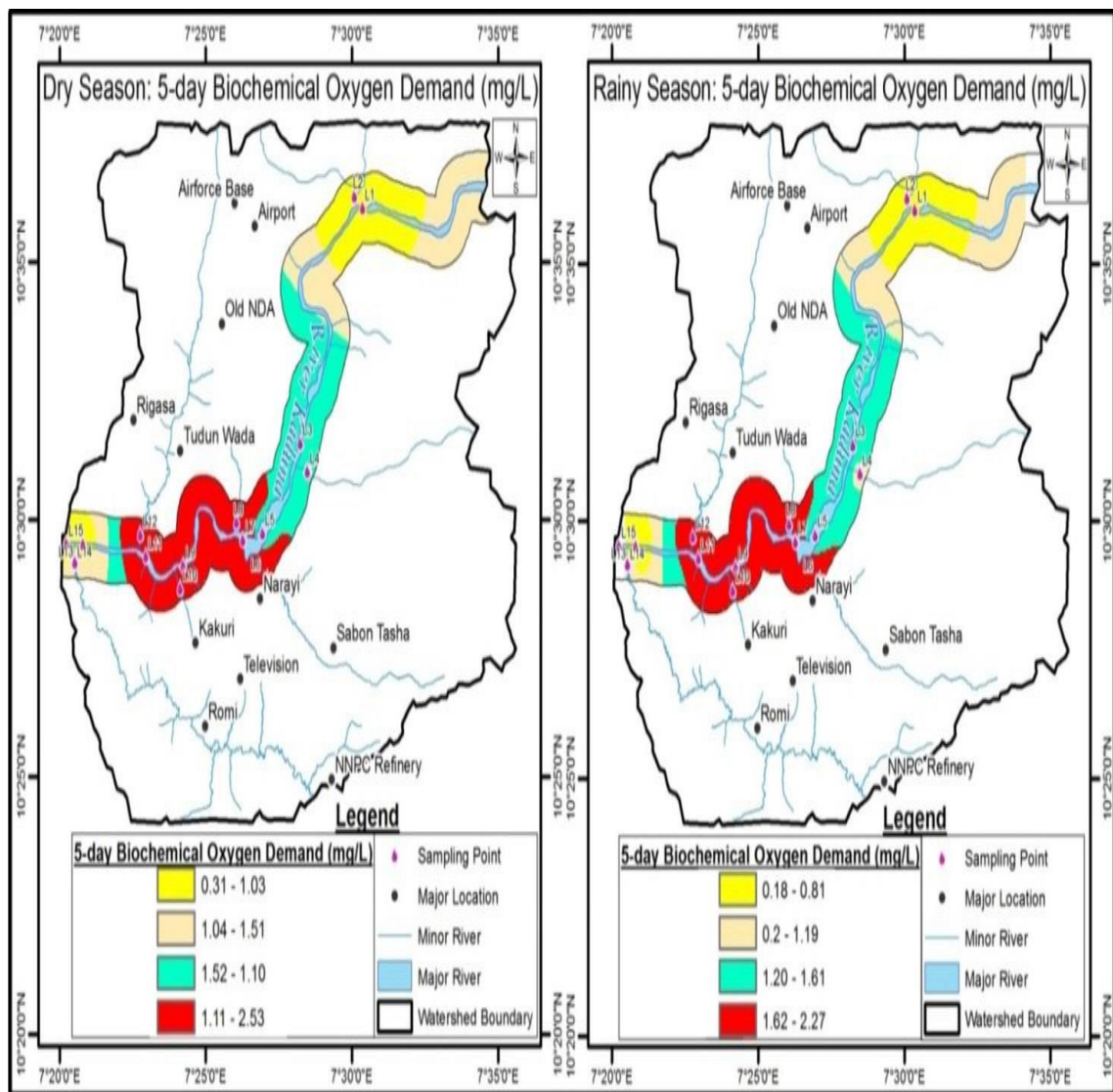


Figure 3.11: Map of WQI generated from IDW interpolation technique

There were 15 sampling locations that have been identified and used by Ogbozige et al. (2018) in his study. Figure 3.11 shows the WQI Map generated from IDW technique conducted by Ogbozige et al. (2018). Based on the WQI map generated from IDW technique, Ogbozige et al. (2018) concluded that Biochemical Oxygen Demand (BOD) concentrations during the dry season were higher than the permissible limit as compared to the rainy season.

3.6 Chapter Summary

The selection of Kuching division as a study area in this research is based on the assessment that was done on the occurrences of HFMD from the year 2014 to 2018. It appears that Kuching division has received 1093 cases out of the total recorded HFMD cases for the whole Sarawak which was 4015 cases in 2019 (Sarawak State Health Department, 2019). This represents 28% of HFMD cases throughout 11 divisions in Sarawak (Sarawak State Health Department, 2019). GIS has been chosen as a primary instrument in this study as it has the ability to process and visualize HFMD incidents spatially and with GIS spatial statistic functionalities, the pattern of HFMD from spatial distribution to temporal pattern of HFMD can be modelled and detected. The selection of various techniques in this research such as Average Nearest Neighbour, Moran's index, Thiessen polygon and Getis Ord GI* are based on its popularity and were used globally in the area of spatial pattern analysis.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the outcome of the conducted analysis and discussions of the derived output. It started with the presentation of the proposed GIS data model of HFMD application. It was then followed by the analysis of the spatial patterns of HFMD occurrences within the study area. After that, result of the spatial temporal analysis will be presented. Both spatial pattern and temporal analysis are important elements for the identification process of the high risk area of HFMD. Lastly, the correlation analysis between HFMD reported cases and water quality index are presented. Based on the above sequences, the discussion on “how” and “why” will be discussed and presented.

4.2 Objective One: GIS data model

The number one objective of this study is to propose the GIS data model that can be used as a guideline and reference for any study pertaining to public health in general and HFMD to be specific. By using the proposed GIS data model, it will become a jump start for any researchers to use GIS in their analysis. GIS data model is a representation of entities that are needed to support various applications (Dueker, 1997). The requirements of developing a GIS data model is vary and depends very much on the goals and objectives that is needed to be achieved (Frank, 2005). In the context of this study, the proposed data model shall consists of representation of information based on the epidemiological triangle and social determinants of health frameworks that would be able to address and answer the issue of HFMD occurrences in Kuching division. The epidemiological triangle represented by

three pillars namely agent, host and environment has its own attribute (Stevens, 1960) and therefore the proposed data model must be dynamic and scalable enough to be fitted with new information for future use. Figure 4.1 shows the proposed GIS data model for HFMD application.

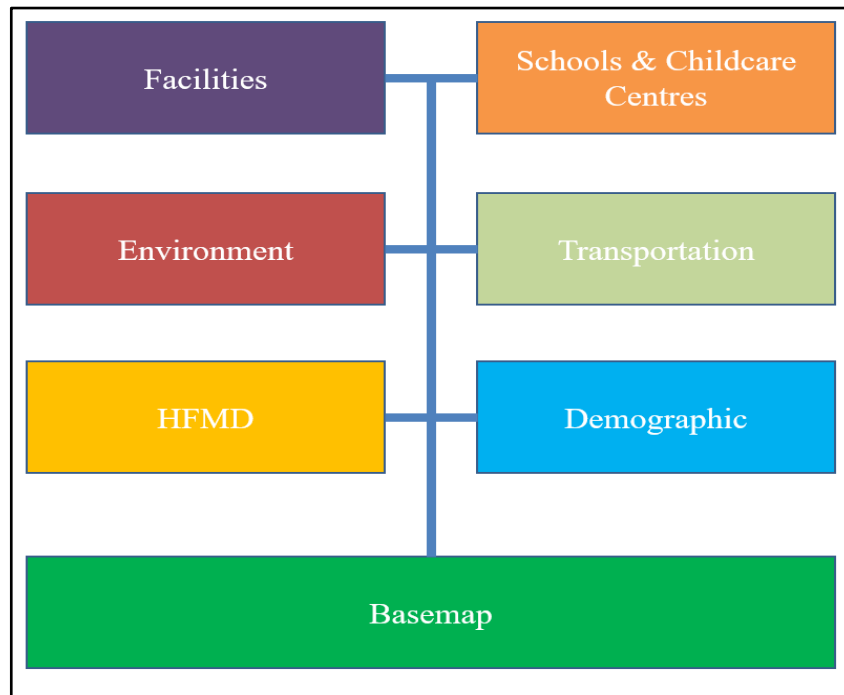


Figure 4.1: Proposed HFMD GIS data model

There were seven main categories of HFMD GIS data model proposed namely basemap, HFMD, demographic, transportation, environment, facilities, school and childcare centres. Basemap refers to the background layer to be used to provide general information of the area. It can be in the form of administrative boundary and land parcel. The requirement of each basemap is different from one use case to another. For example, the basemap layer for land management is totally different from the basemap of hydrological application. This is due to the nature of the application requirements itself. In the case of HFMD GIS data model, the basemap layer here refers to the underlying background information that is used to depict the study area. Figure 4.2 shows the basemap layers that were used in this study. It

consists of several layers and attribute information needed to support the analysis of HFMD disease within the study area.

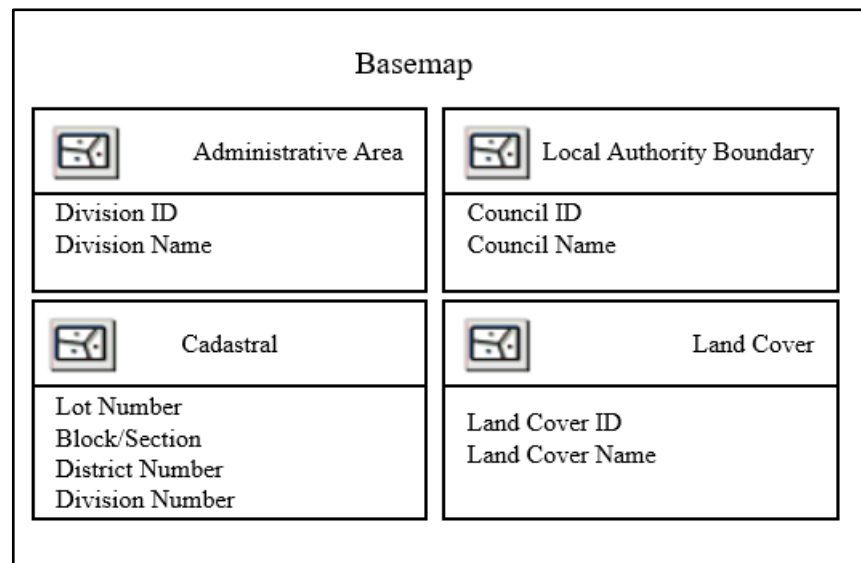


Figure 4.2: Proposed basemap layer

The administrative area refers to Sarawak state administrative boundary which has the information of Division ID and Division Name. Local authority boundary on the other hand indicates the administrative boundary of each local council such as Kuching North City Council, Kuching South City Council, Bau District Council, Lundu District Council and Padawan Municipal Council. The cadastral layer and land cover layer are not being developed and obtained from Land and Survey Sarawak as it is beyond the scope of the study. Nevertheless, the proposed data model for both cadastral layer and land cover layer were presented for future reference.

The next category of data model used in this study was HFMD layer. This was a prime layer developed for the purpose of supporting the analysis in this research. The information received from Sarawak State Health Department was converted into GIS format and has been geocoded on the ground based on its addresses. The development of GIS data model representing HFMD cases must consider the information in detail that can be used to

analyze the spatio-temporal of the HFMD occurrences. The information of the location of the HFMD's incident alone is not sufficient to support the objective of this study which is to identify and examine the pattern and trend of HFMD disease in Kuching division. It needs to include other parameters. Figure 4.3 shows the data model adopted to represent HFMD incident.

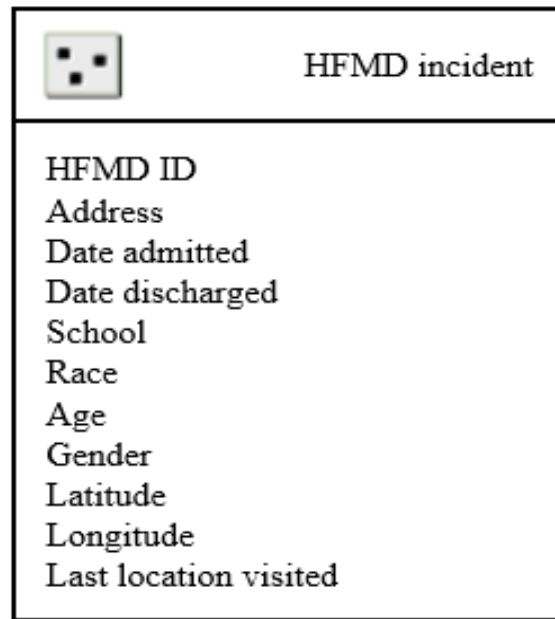


Figure 4.3: HFMD proposed data model

The address information is critical for HFMD layer as it provides the locational positioning of patient on the ground. Without the address information, the pattern of HFMD distribution cannot be modelled and detected. Additionally, the information of date admitted and discharged was also needed for HFMD analysis. Date of admission and discharged provide an understanding on when was the case recorded and recovered. This information can be used to study the temporal situation of HFMD incident by using the date of admission to model the HFMD disease in Kuching division. It can be modelled based on daily, weekly and monthly as well as yearly. On the other hand, the information of ethnic, age and gender

were also captured and entered into HFMD layer. Information of ethnic, age and gender provide a great insight of the pattern and trend according to the ethnic, age and gender.

Although the information of last location visited was not provided and captured by the Sarawak State Health Department, this information, however, can be used for forensic analysis based on location. By identifying the location of last visited location, the responsible authorities will have a better understanding on the origin of the disease started to spread. Since the location of recorded HFMD patient is important, the coordinate of the patient's house need to be entered into the system.

The coordinate system which is longitude and latitude of the patient's house were recorded based on the address received from Sarawak State Health Department in HFMD layer. As for the current practice, the coordinate system of HFMD cases will be recorded if the case was clustered. This standard operating procedure (SOP) limits the capability of information to be used for future analysis. Without coordinate information (longitude and latitude) of HFMD cases, it will be difficult to view the distribution of the HFMD cases on the ground.

Map of distribution of HFMD cases is crucial as it can help respective officers concerned to identify the high risk area of HFMD by looking at the distribution of HFMD cases on the ground. Therefore, it is strongly recommended that each of HFMD registered cases should also record the coordinate of the incident for future references. In view to privacy and confidentiality, the patient's details such as Name and Identify Card (IC) number were not recorded.

For the purpose of analyzing the socio-cultural and socio-economy factors influencing the spread of HFMD, the demographic information is required to be captured and modelled. Although the socio-economy and socio-cultural were not part of the scope of

the study, the data model to represent this category was developed as shown in Figure 4.4. Demographic data is one of the important elements under epidemiological triangle and social determinants of health.

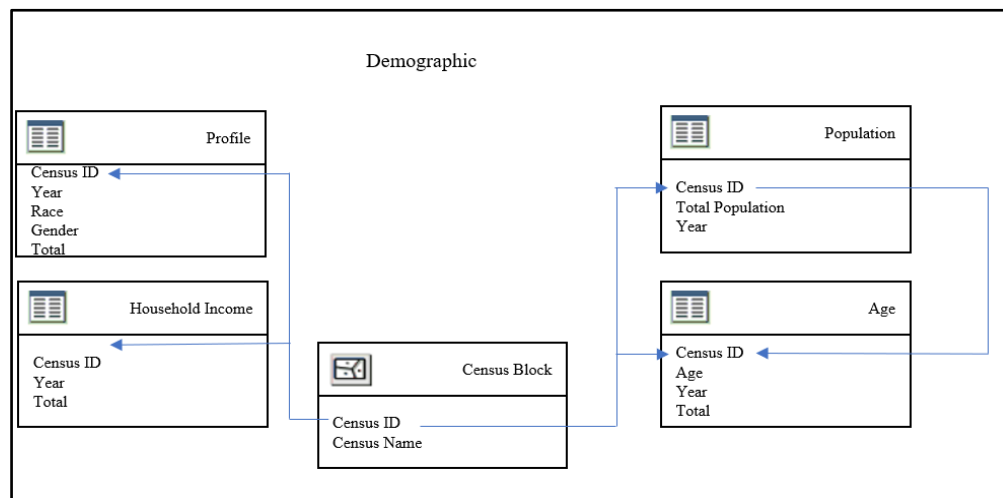


Figure 4.4: Demographic data model

The presented data model of demographic category as shown in Figure 4.4 can be used as a reference for future analysis. The proposed data model for demographic category can be changed and amended to meet future requirements. Basic information such as total number of populations based on ethnic, age and gender were included in this data model. This information provides an insight of how demographic distribution can influence the spread of HFMD outbreak.

The next category of the proposed data model for HFMD application was environment. The environment data model solely refers to geographical condition and physical of study area. The environmental factor indeed has some bearing to determine the rate of HFMD disease outbreak. Therefore, it is important to take into consideration on how in-situ condition can give impact to the rate of disease outbreak (Talmud, 2007). Figure 4.5 presented basic environmental data model to be used for HFMD disease analysis. This data

model can be expanded to include other environmental criteria that is required for certain diseases.

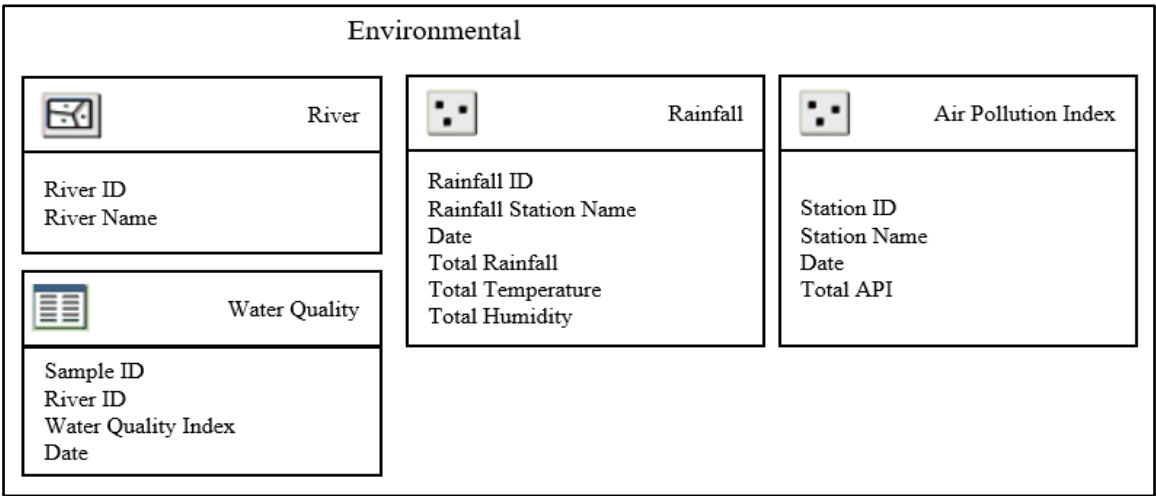


Figure 4.5: Environment data model

The location of river together with water quality index of each river are extremely important for HFMD. As discussed in Chapter 2, microorganism such as Enterovirus 71 and Coxsackie can live in contaminated river and therefore it is important to know the locations of polluted rivers as microorganisms are the root cause of HFMD (Ji et al., 2012). Water quality index was collected from Natural Resources Environmental Board (NREB) Sarawak and was used in this study. Rainfall and air pollution index also have some significant impact on the HFMD outbreak (Samphutthanon, 2014). However, both datasets are not collected and it is beyond the scope of the study. Nevertheless, the presented data model as shown in Figure 4.5 does cover the requirements of having rainfall and air pollution datasets for future study.

Transportation also contributes to the expand of HFMD disease. The improvement of transportation system such as air transportation and land transportation have made it possible for disease to be transmitted to other places. The infected HFMD patient in Kuching division can transmit the same disease in Sibul division if the infected HFMD person is

mobilizing to Sibu division by using air transportation. A study by Mangili & Gendreau (2005) concluded that Ebola virus and MERS-CoV outbreak in United States were due to mobilization of people to United States via air transportation. In the context of Sarawak, it is necessary to have a layer of transportation so that the ability to model the disease outbreak can be realized. Figure 4.6 shows the proposed data model of transportation.

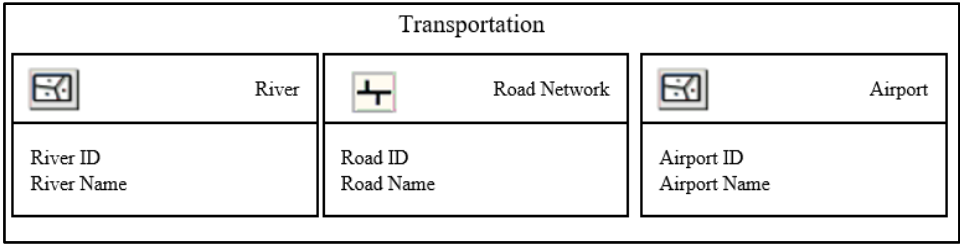


Figure 4.6: Transportation data model

The HFMD outbreaks can be simulated by keeping track the movement of HFMD patient from the first day HFMD symptom was detected. By identifying the mode of transportation used, it will help the respective authorities concern especially public health department to identify the potential high-risk area of HFMD by studying the movement of HFMD patient in terms of places visited. Besides transportation, facilities layer also influences the speed of HFMD outbreak.

The facilities layer represented by hospitals, clinics and health care facilities are important information to be collected. This is due to the services that they provide to the community. If the health care facilities are too far reachable by the community, it has significant impact on the HFMD outbreaks. A study conducted in Zambia shows that the distance of HIV health care facilities contributed to the fatality of HIV patient. It was observed in Zambia that the distance of HIV health care centers was 50km away for 52% of the Zambia’s population (Moise et al., 2011). Another study conducted in Bangladesh confirming the distance of health care facilities from home had high hypertensive as

compared to people who stay nearby from health care facilities which was low (Biswas, 2017).

Since the distance of health care facilities are equally important in order to control HFMD cases, an appropriate information pertaining to the distance of health care facilities need to be developed. Therefore, presented in Figure 4.7 shows the proposed data model of facilities layer for HFMD analysis.

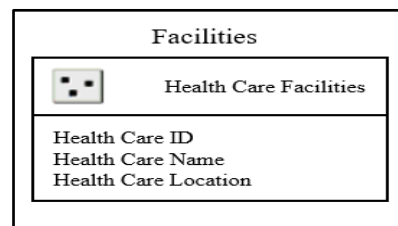


Figure 4.7: Proposed data model of facilities layer

The location and name of the health care facilities are required to be entered into GIS system. This information would be able to be used in identifying the distance of infected HFMD patient from health care facilities layer. The coordinates of the location for each health care facilities shall be recorded and kept into the GIS system. The coordinates can be in World Geodetic System 1984 (WGS1984) or Borneo Rectified Skew Orthomorphic (BRSO). By having the coordinates information of each health care facilities, GIS operation such as Thiessen polygon to identify the artificial boundary of health care facilities areas or buffering to measure the distance of health care facilities in relation to the house of infected HFMD patient can be performed. This information shall provide an specific pattern on how the distance in getting treatment of HFMD can influence the rate of HFMD outbreaks.

The last category of proposed HFMD data model was schools and child care centres. Most of the HFMD cases were recorded and spread from the schools and child care centres

(Huang et al., 2012). Figure 4.8 presents the proposed data model of schools and child care centres category.

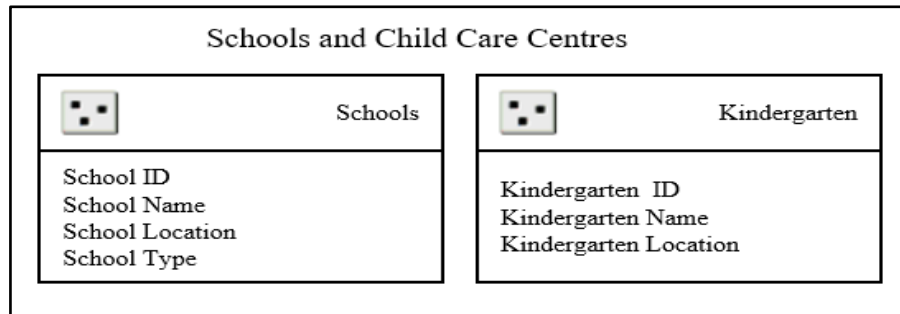


Figure 4.8: Proposed data model of schools and child care centers

The name of schools and kindergartens are quite important as it provides the information of where the HFMD cases is recorded and detected. By having this information, it will enable the authorities to quarantine the affected school whenever the case of HFMD is recorded. Precautionary measures shall be taken and the process of isolating and quarantine the infected HFMD pupils would be much easier as a result of having a good database of schools and kindergartens inventories.

There is other element of GIS data model that has been identified namely the spatial referencing system. For the purpose of having consistency of spatial referencing system, it is recommended that all data to be georeferenced based on Borneo Rectified Skew Orthomorphic (BRSO) or World Geodetic System 1984.

4.3 Objective Two: Spatio-Temporal

This section presents the outcome of spatio-temporal analysis of HFMD. In order to understand the HFMD spreading patterns, it was decided that the distribution of HFMD cases in Kuching division shall be included and the outcome from this analysis provides an

overview of how HFMD disease was distributed. After distribution analysis was conducted, the analysis of pattern and trend of HFMD from 2014 to 2018 were analysed.

The HFMD distribution analysis was conducted to derive the statistical information of the occurrences of HFMD from the year 2014 to 2018. The minimum and maximum number of cases as well as median, standard deviation and mean of HFMD cases were identified. As mentioned in Chapter 3, the study area of this study, which is Kuching division covers five local councils namely Kuching North City Council, Kuching South City Council, Padawan Municipal Council, Bau District Council and lastly Lundu District Council. The data collected from Sarawak State Health Department was used in this analysis.

Table 4.1: HFMD cases from 2014 to 2018

Local Council	2014	2015	2016	2017	2018	Total
Kuching North City Council	660	708	471	375	375	2589
Kuching South City Council	311	277	268	340	86	1282
Padawan Municipal Council	350	262	652	943	344	2343
Bau District Council	498	34	24	21	37	720
Lundu District Council	184	35	228	127	20	574

As shown in Table 4.1, Kuching North City Council receives the highest number of cases which is 2589 cases as compared to other local councils from 2014 to 2018 (Sarawak State Health Department, 2019). It is also noted that the highest number of recorded HFMD cases was in the year 2015 which was 708 cases. Although the total number of cases registered in Kuching division decreased in 2015, which was 34.3% of the total number of

cases in 2014, it then increased back to 1643 cases in 2016 and 1806 cases in 2017 and decreased to 862 cases in the year 2018.

It is also noted that Bau District Council has recorded the second highest number of HFMD cases in Kuching division in the year 2014 where it has recorded 498 cases. Ironically, it has dropped tremendously in the year 2015 which was 34 cases only, equivalent to 93% of total cases in the year 2014. Figure 4.9 shows the trend of recorded HFMD cases in Kuching division from the year 2014 to 2018.

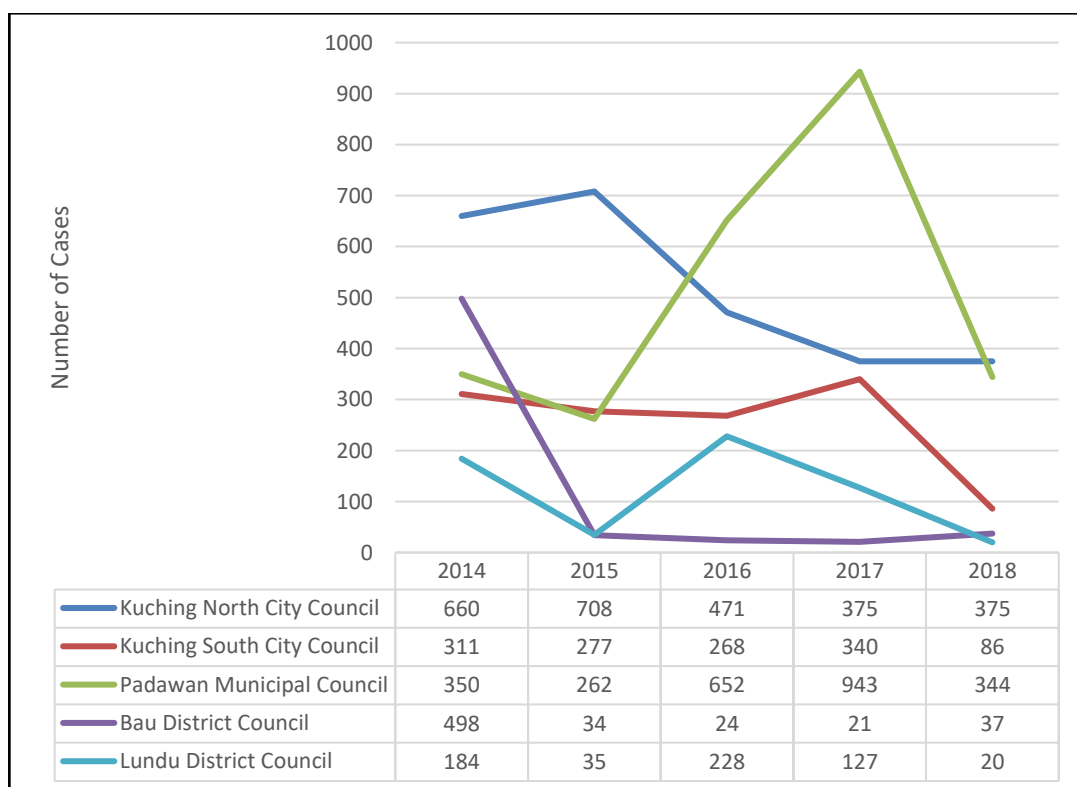


Figure 4.9: Total number of HFMD cases in Kuching division

As shown in Figure 4.9, almost all local councils had shown a decrease of number of recorded HFMD cases in 2015, except for Kuching North City Council where it has recorded an increase by 7% in 2015. Ironically Padawan Municipal Council shows an exponential increase of HFMD cases from 2015 to 2017. It started with 262 of HFMD cases in 2015 to 652 in the year 2016 and 943 cases in the year 2017.

Figure 4.10 shows the visual distribution of HFMD cases for Kuching division from the year 2014 to 2018 on the map. The distribution map of HFMD was categorised based on distribution of HFMD cases in five local councils in Kuching division.

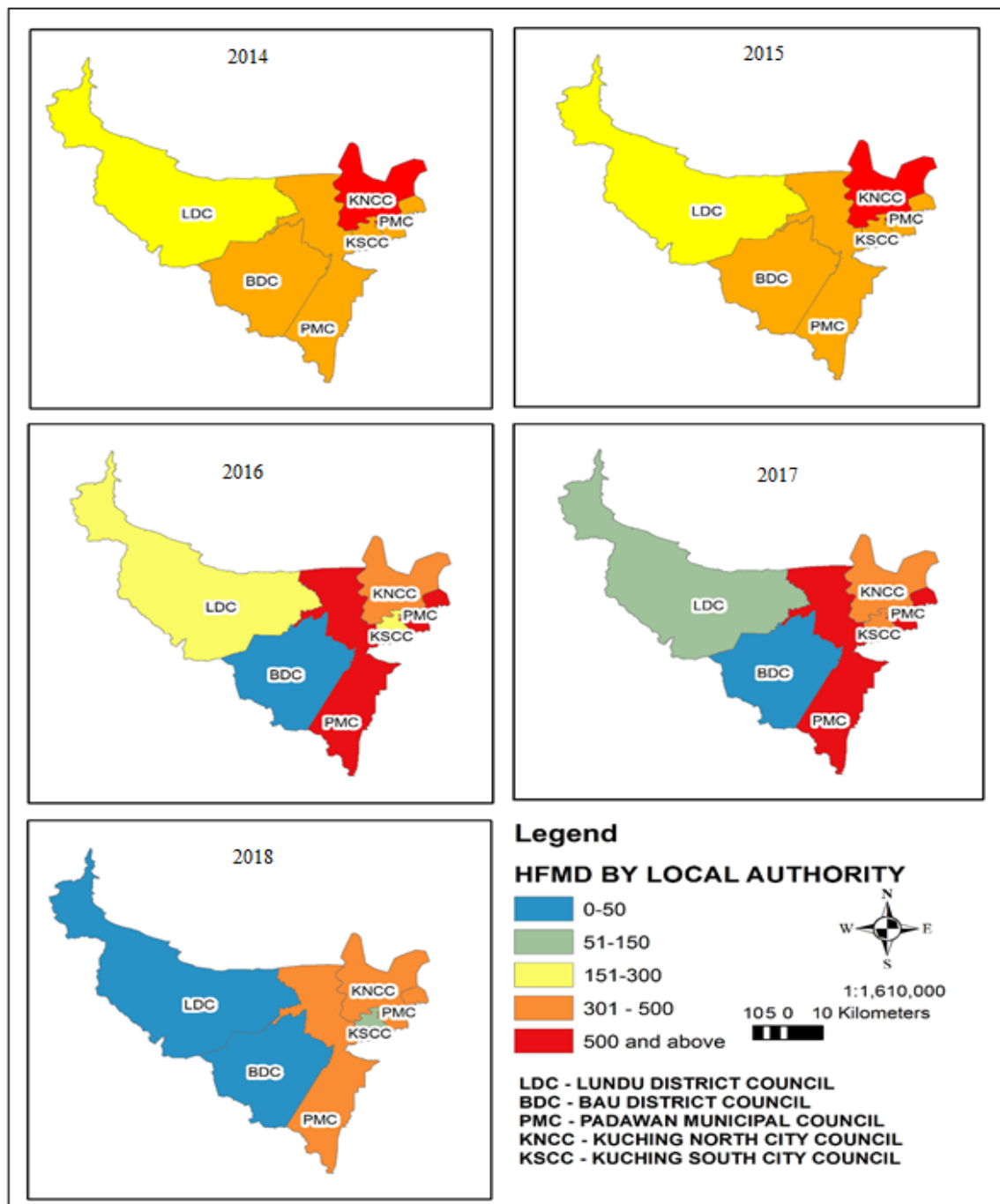


Figure 4.10: HFMD by number of cases

In the year 2014, it is observed that there are three local councils that have been classified under the category of 301-500 cases. These local councils are Kuching South City Council, Padawan Municipal Council and Bau District Council. Kuching North City Council is the only council that recorded the case of more than 500 cases. Similar pattern has been detected in 2015.

Kuching North City Council (KNCC) has consistently received the number of HFMD above 500 cases from 2014 to 2016. However, it was then dropped under the category of 301 to 500 cases in the year 2017 and 2018. The only area that managed to decrease the number of HFMD cases was Bau District Council. It was in Red Zone (501 and above) in the year 2014 but slowly grouped under the category of green zone (0-50) in the year 2017 and 2018. Based on the map shown in Figure 4.10, it can be concluded that the HFMD cases were distributed heavily in Kuching North City Council, Kuching South City Council and Padawan Municipal Council where the case registered was above 300 cases as compared to Lundu District Council and Bau District Council which were less than 300 cases from 2014 to 2018.

For the purpose of presenting the outcome of the analysis in the form of map presentation at the residential level, please refer to Figure 4.11 as it shows the reference number of each polygon. Each polygon represents each settlement or residential area. As discussed in Chapter 3, the GIS technique adopted in this study to create an artificial boundary was based on Thiessen polygon method. The Thiessen polygon method was used as a result of no official boundary to represent the boundary of each residential area. This is due to unavailability of official boundary to represent settlement boundary generated by the authorities such as from local council and Land and Survey, Sarawak. Hence, the boundary created from Thiessen polygon method was deployed.

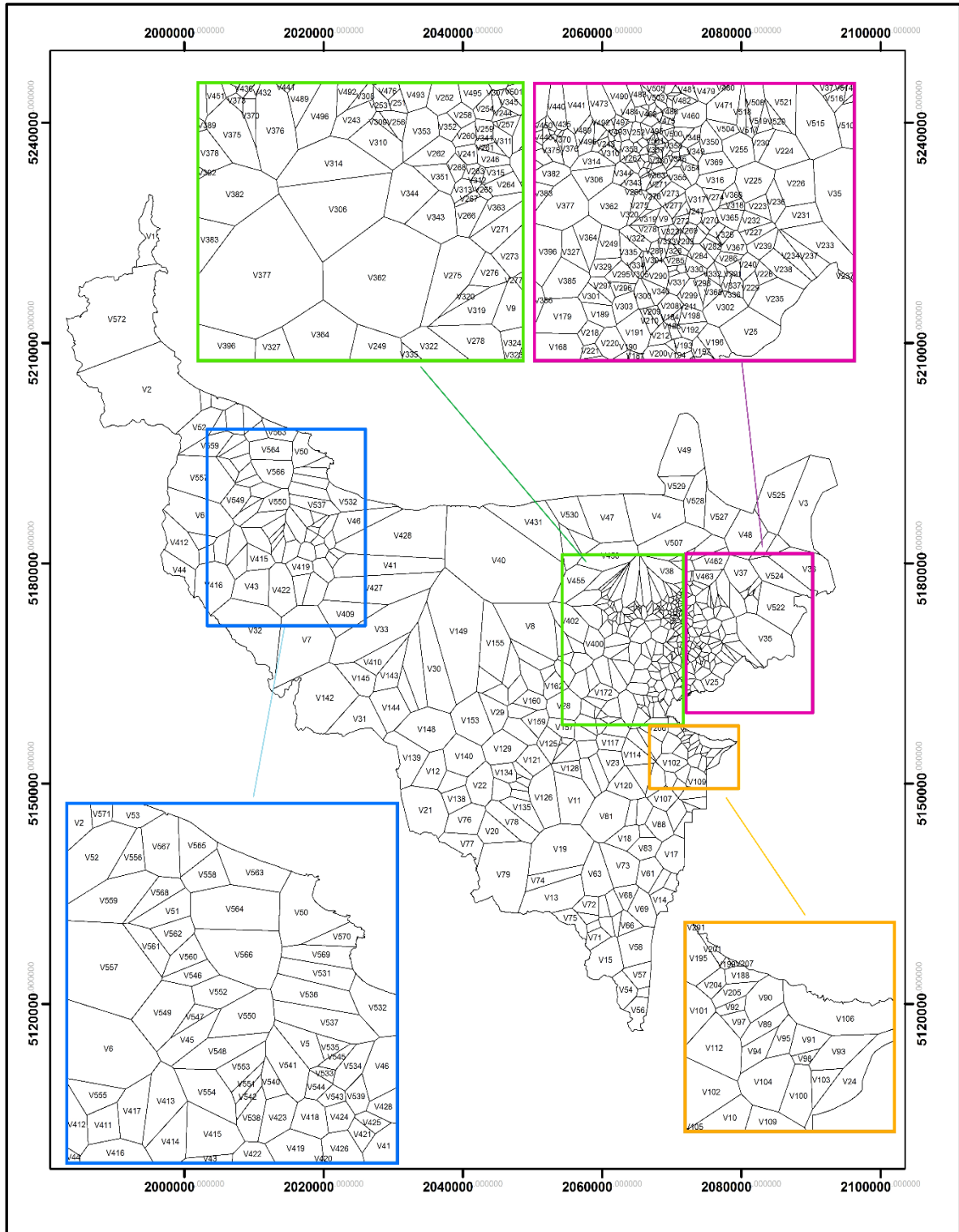


Figure 4.11: Reference ID for each polygon

The reference number that was used to label each polygon was referred to residential area. The details of each residential area's name was presented in Table 4.2.

Table 4.2: Reference ID based on residential name

ID	Residential Name		ID	Residential Name
V1	Kampung Telok Melano		V41	Kampung Gerunggang
V2	Kampung Pueh		V42	Kampung Sebandi Hilir
V3	Kampung Pasir Putih		V43	Kampung Bukit Batu
V4	Kampung Pasir Pandak		V44	Kampung Biawak
V5	Taman Lundu Jaya		V45	Kampung Tebaro
V6	Kampung Buang		V46	Kampung Temelan Dayak
V7	Kampung Selampit		V47	Kampung Sungai Aur
V8	Kampung Segong		V48	Bako Bazaar
V9	Taman Excella Jalan Stapok		V49	Kampung Budaya Sarawak
V10	Kampung Sibatuh		V50	Kampung Pandan
V11	Kampung Seropak		V51	Kampung Paon
V12	Kampung Sibobog		V52	Kampung Sebat Baru
V13	Kampung Semban		V53	Kampung Siru Melayu
V14	Kampung Bidak		V54	Kampung Annah Semuti
V15	Taman Borneo Heights		V55	Kampung Sebuang
V16	Kampung Nusantara Maras		V56	Kampung Sibakar
V17	Kampung Jambu		V57	Kampung Sadir
V18	Kampung Semadang		V58	Kampung Annah Rais
V19	Kampung Rejoi		V59	Kampung Sigandar
V20	Kampung Pedau Bawah		V60	Kampung Payang
V21	Kampung Jagoi Serikin		V61	Kampung Bayur
V22	Kampung Bogag		V62	Kampung Abang
V23	Kampung Segubang		V63	Kampung Bojong Sting
V24	Kampung Seratau		V64	Kampung Kamas
V25	Kampung Sungai Tapang		V65	Kampung Assum
V26	Taman Mei Jalan Stakan		V66	Pangkalan Ampat
V27	Kampung Siniawan Lot Melayu		V67	Kampung Kakas
V28	Kampung Buso		V68	Kampung Jabir
V29	Kampung Rumih		V69	Kampung Timurang
V31	Kampung Raso Ii		V71	Kampung Parang
V32	Kampung Kendaie		V72	Kampung Kiding
V33	Kampung Siluk		V73	Kampung Bengoh
V34	Taman Synergy		V74	Kampung Rejoi Nyegol
V35	Taman Muara Tabuan		V75	Kampung Sapit

Table 4.2 continued

ID	Residential Name		ID	Residential Name
V36	Kampung Gobielt		V76	Kampung Padang Pan
V37	Taman Sepakat Jaya		V77	Kampung Gumbang
V38	Kampung Semariang Pinggir		V78	Plaman Monggok
V39	Taman Rose		V79	Kampung Tringgus Tabak Rotan
V40	Kampung Jaya Bakti		V80	Kampung Giam
V81	Bengoh Resettlement Scheme		V138	Kampung Duyoh
V82	Kampung Garung		V139	Kampung Stass
V83	Kampung Karu		V140	Kampung Serasot
V84	Kampung Giam Baru		V141	Kampung Jagoi Gunong
V85	Kampung Petag		V142	Kampung Raso I
V86	Kampung Sitaang		V143	Kampung Stungkor Baru
V87	Kampung Bangau		V144	Kampung Tugag Oma
V88	Kampung Benuk		V145	Kampung Bokah
V89	Taman Inling		V146	Kampung Stom Muda
V90	Taman Eden Feild		V147	Kampung Stum Muda
V91	Taman Beverly Hills		V148	Kampung Skibang
V92	Taman Lai Lai		V149	Kampung Stenggang
V93	Taman Lavender Hills		V150	Kampung Stanggang
V94	Taman Millenium		V151	Kampung Tembawang Baru
V95	Taman Cavery		V152	Kampung Nowang
V96	Taman Perwira Landeh		V153	Kampung Opar
V97	Taman Penrissen		V154	Kampung Suba Bau
V98	Taman Siburan Baru		V155	Kampung Jugan
V99	Kampung Bratan Asah		V156	Kampung Tembawang Sauh
V100	Kampung Pengiran		V157	Kampung Skiat Lama
V101	Kampung Sri Arjuna		V158	Kampung Grogo
V102	Kampung Sinar Baru		V159	Kampung Suba Bandar
V103	Kampung Peramas		V160	Kampung Sibuluh
V104	Kampung Sidanu		V161	Kampung Sibuluh
V105	Kampung Bratan		V162	Kampung Apar
V106	Kampung Kuap		V163	Kampung Sudoh
V107	Kampung Punau		V164	Taman Moyan Jaya

Table 4.2 continued

ID	Residential Name		ID	Residential Name
V108	Kampung Bawang		V165	Taman Siniawan
V109	Kampung Mambong		V166	Kampung Melayu Siniawan
V110	Kampung Sikog		V167	Kampung Sungai Pinang Ulu
V111	Kampung Simboh		V168	Kampung Sibulung
V112	Semenggoh		V169	Kampung Pangkalan Baru
V113	Taman Stella		V170	Kampung Batu Kitang Jaya
V114	Kampung Sebetong		V171	Kampung Kandis Baru
V115	Kampung Grait		V172	Kampung Sg. Pinang
V116	Kampung Merimbeh		V173	Kampung Kandis Lama
V117	Kampung Kopit		V174	Kampung Peninjau Baru
V118	Kampung Skio		V175	Kampung Podam
V119	Kampung Sogo		V176	Kampung Siniawan Seberang
V120	Kampung Git		V177	Kampung Keranji
V121	Taman Goldhill		V178	Kampung Bunga Rampai
V122	Taman Mawar		V179	Kampung Bukit Panchor
V123	Taman Mawar		V180	Kampung Sandong
V124	Taman Mawar		V181	Kampung Batu Kitang Lama
V125	Taman Mutiara		V182	Kampung Sega
V126	Kampung Dahan		V183	Kampung Peninjau Lama
V127	Kampung Skiat		V184	Taman Sarmax
V128	Kampung Seromah		V185	Taman Kitang
V129	Kampung Suba Buan		V186	Taman. Penrissen
V130	Kampung Krokong Peros		V187	Taman Kitang, Bumbok
V131	Kampung Bijongon		V188	Taman Muhibbah
V132	Kampung Batu Sepit		V189	Taman Kwang Tiong
V133	Kampung Peros		V190	Taman Kintang
V134	Kampung Pisa		V191	Taman Brilliance
V135	Kampung Bijuray Mongag		V192	Taman Golden View
V136	Kampung Blimbin		V193	Taman Olive
V137	Kampung Kaman		V194	Taman Olive Batu 7
V195	Taman Hilldale		V251	Taman Ling Ling, Matang
V196	Taman Kalian		V252	Taman Matang Baru

Table 4.2 continued

ID	Residential Name		ID	Residential Name
V197	Taman Kalien		V253	Taman Lee Ling
V198	Taman Golden Farm		V254	Taman Balijah
V199	Taman Bengoh		V255	Taman Demak Indah
V200	Taman Batu		V256	Taman Mas Pertama
V201	Taman Kuap		V257	Taman Makmur
V202	Taman Boulder Built		V258	Taman Matang Indah
V203	Taman Kitang		V259	Taman Muhibbah
V204	Taman Cin Muk		V260	Taman Alamanda
V205	Taman Kota Padawan		V261	Taman Duranda
V206	Taman Sri Permai Landeh		V262	Taman Gita Jaya
V207	Taman Quap, Batu 10		V263	Taman Akasia
V208	Taman Paradise		V264	Taman Foong Joon,
V209	Taman Semeba		V265	Taman Kenanga
V210	Taman Victory		V266	Taman Mawar Gita
V211	Taman Sarman		V267	Taman Mawar
V212	Taman Sentosa Phase 1		V268	Taman Bunga Raya
V213	Taman Tematu Hill		V269	Taman Kwong Ming
V214	Taman Stakan Perdana		V270	Taman Intersar
V215	Taman Wei Leong		V271	Taman Evergreen
V216	Taman Sentoria		V272	Taman Hong Nion
V217	Taman Shee		V273	Taman Chong Hin
V218	Kampung Semeba		V274	Taman Gan Swee Cho
V219	Kampung Dangak		V275	Taman Datuk Temenggong
V220	Kampung Semaba		V276	Taman Kapor
V221	Kampung Tematu		V277	Taman Hua
V222	Kampung Bumbok		V278	Taman Kit Fah
V223	Taman Kuching		V279	Taman Ling Hong
V224	Taman Daya		V280	Taman Kenny Hill
V225	Taman Orchid		V281	Taman Kenny Height
V226	Taman Heng Hua		V282	Taman Fortune
V227	Taman Linang		V283	Taman Kangkok
V228	Taman Escovilla Stutong		V284	Taman Major
V229	Taman Centurion		V285	Taman Budi Jasa
V230	Taman Riverview		V286	Taman Everbright

Table 4.2 continued

ID	Residential Name	ID	Residential Name
V231	Taman Park View	V287	Taman Huayau Jalan Arang
V232	Taman Supreme	V288	Taman Hua Yen, Jalan Arang
V233	Taman Stutong Jaya	V289	Taman Mewah ,Jalan Arang
V234	Taman Stutong Indah	V290	Taman Flora Indah Jalan Arang
V235	Taman Stutong Baru	V291	Taman Bdc
V236	Kampung Tabuan Tengah	V292	Taman Mega Juta
V237	Kampung Sungai Nada	V293	Taman Mega Juta
V238	Kampung Sungai Laru	V294	Taman Mega Juta
V239	Tabuan Jaya Tengah	V295	Taman Desa Wira
V240	Kampung Stampin	V296	Taman Casa Wira
V241	Taman Long Seng	V297	Taman Bumiko, Desa Wira
V242	Taman Mabel, Kuching	V298	Taman Hup Kee, Kuching
V243	Taman Pandan Jaya	V299	Taman Fook Ngian
V244	Taman Monah	V300	Taman Khung Phin
V245	Taman Long Seng	V301	Taman How Ching
V246	Taman Long Seng	V302	Taman Borneo
V247	Taman Paradise, Batu 9	V303	Taman Maroon
V248	Taman Mewah	V304	Taman Emas
V249	Taman Feild Force,	V305	Taman Emas
V250	Taman Fitrah Kuching	V306	Taman Sri Matang Kuching
V307	Taman Trinora	V364	Kampung Stapok
V308	Taman Yen Yen	V365	Kampung Kenyalang Park
V309	Taman Sri Permai	V366	Kampung Simpang 3
V310	Taman Sri Perkasa	V367	Kampung Tabuan Lalang
V311	Taman Rahmat	V368	Kampung Cemerlang
V312	Taman Wunmas	V369	Kampung Boyan
V313	Taman Ros,	V370	Taman Pelangi Matang
V314	Taman Sri Matang	V371	Taman Serapi, Kuching
V315	Taman Sri Malaga	V372	Taman Punica
V316	Taman Westwood	V373	Taman Kimpang Garden
V317	Taman Ricketts	V374	Taman Green Acres,Matang
V318	Taman Rafia	V375	Taman Heng Guan Matang
V319	Taman Wee&Wee	V376	Taman Jutaria Matang
V320	Taman Top Green	V377	Taman Desa Matang

Table 4.2 continued

ID	Residential Name		ID	Residential Name
V321	Taman Star		V378	Taman Malihah Jaya
V322	Taman Victoria		V379	Taman Melihah
V323	Taman Stapok		V380	Taman Malihah
V324	Taman Stapok 1		V381	Taman Murni, Kuching
V325	Taman Sunny Hill		V382	Taman Dusun Indah
V326	Taman Union		V383	Taman Dusun Dinda
V327	Taman Sri Segedup		V384	Taman Genesis
V328	Taman Tropimas		V385	Taman Janting Jalan Bt Kawa
V329	Taman Tropimas		V386	Taman Moyan Utama
V330	Taman Seng Goon		V387	Taman Banjaran Serapi
V331	Taman Wawasan		V388	Taman Saujana Indah
V332	Perumahanpersekutuan		V389	Taman Prc
V333	Taman Phonix Garden		V390	Taman Saujana Indah Matang
V307	Taman Trinora		V364	Kampung Stapok
V308	Taman Yen Yen		V365	Kampung Kenyalang Park
V309	Taman Sri Permai		V366	Kampung Simpang 3
V310	Taman Sri Perkasa		V367	Kampung Tabuan Lalang
V311	Taman Rahmat		V368	Kampung Cemerlang
V312	Taman Wunmas		V369	Kampung Boyan
V313	Taman Ros,		V370	Taman Pelangi Matang
V314	Taman Sri Matang		V371	Taman Serapi, Kuching
V315	Taman Sri Malaga		V372	Taman Punica
V316	Taman Westwood		V373	Taman Kimpang Garden
V317	Taman Ricketts		V374	Taman Green Acres,Matang
V318	Taman Rafia		V375	Taman Heng Guan Matang
V319	Taman Wee&Wee		V376	Taman Jutaria Matang
V320	Taman Top Green		V377	Taman Desa Matang
V321	Taman Star		V378	Taman Malihah Jaya
V322	Taman Victoria		V379	Taman Melihah
V323	Taman Stapok		V380	Taman Malihah
V324	Taman Stapok 1		V381	Taman Murni, Kuching
V325	Taman Sunny Hill		V382	Taman Dusun Indah
V326	Taman Union		V383	Taman Dusun Dinda
V327	Taman Sri Segedup		V384	Taman Genesis

Table 4.2 continued

ID	Residential Name	ID	Residential Name
V328	Taman Tropimas	V385	Taman Janting Jalan Bt Kawa
V330	Taman Seng Goon	V387	Taman Banjaran Serapi
V331	Taman Wawasan	V388	Taman Saujana Indah
V332	Perumahan persekutuan	V389	Taman Prc
V333	Taman Phonix Garden	V390	Taman Saujana Indah Matang
V334	Taman Sri Emas	V391	Taman Saujana Indah
V337	Taman Woodland	V394	Taman Sarapi Jaya
V338	Persekutuan, Stampin	V395	Taman Serapi Jaya
V339	Stampin Bdc	V396	Taman Sri Moyan
V340	Taman Sasa	V397	Taman Sejjak Heights
V341	Taman Sejoli	V398	Taman Vision Lane
V342	Kampung Tanjung	V399	RPR Matang Sungai Tengah 2
V343	Kampung Gita Laut	V400	Kampung Sagah
V344	Kampung Gita Lama	V401	Kampung Tanjong Poting
V345	Kampung Tupong Hulu	V402	Kampung Bobak Sejinjang
V346	Kampung Lintang	V403	Kampung Tanjong Bowang
V347	Kampung No 2	V404	Kampung Senibong
V348	Kampung Tupong Batu	V405	Kampung Bobak Sajong
V349	Kampung Sungai Bedil	V406	Kampung Barieng
V350	Kampung Istana	V407	Kampung Daun
V351	Kampung Pinang Jawa	V408	Kampung Atas
V352	Kampung Laruk Skim	V409	Kampung Perian
V353	Kampung Won	V410	Kampung Simpang Bokah
V354	Kampung Masjid	V411	Kampung Baru Jangkar?
V355	Kampung Bandarshah	V412	Kampung Pasir Hulu
V356	Kampung Sungai Lajim	V413	Kampung Opek
V357	Kampung Patingan	V414	Kampung Tanjam
V358	Kampung No. 6	V415	Kampung Sedaing
V359	Kampung No. 5	V416	Kampung Pasir Tengah
V360	Kampung No. 3	V417	Kampung Jangkar
V361	Kampung No. 1	V418	Taman Gading Height
V362	Kampung Sungai Maong	V419	Kampung Sebeban

Table 4.2 continued

ID	Residential Name	ID	Residential Name
V363	Kampung Kudei	V420	Kampung Sebandi Hulu
V421	Kampung Temelan	V478	Taman Sukma Jalan Sultan Tengah
V422	Kampung Pasir Hilir	V479	Taman.Sukma
V423	Kampung Sembawang Besar	V480	Taman Sukma
V424	Kampung Stunggang Dayak	V481	Taman Wawasan Jaya
V425	Kampung Temelan Dayak	V482	Taman Seri Sena,Lorong Samariang
V426	Kampung Stunggang Ulu	V483	Taman Petronesa
V427	Kampung Senibong	V484	Taman Zoriah
V428	Kampung Bengang	V485	Taman Selasih
V429	Kampung Selang	V486	Taman Selasih
V430	Kampung Selang Laut	V487	Taman Sri Depo
V431	Kampung Sri Kandong	V488	Taman Wangsa, Jalan Depo
V432	Taman Jutaria	V489	Taman Pelangi
V433	Taman Grandview	V490	Taman Zokiah
V434	Taman Orkid Wood	V491	Taman Rassnorm
V435	Taman Putra	V492	Taman Sri Matang, Jalan Matang
V436	Taman Roding	V493	Taman Syn Syn
V437	Taman Hillside	V494	Taman Rasa Jaya
V438	Taman Fahtah	V495	Taman Sri Wangi
V439	Taman Matang Ville	V496	Taman Unique
V440	Taman Matang Ria	V497	Taman Peony
V441	Taman Dahlia, Matang	V498	Taman Putri
V442	Taman Hillside	V499	Taman Puteri
V443	Taman Harmoni	V500	Kampung Tupong Tengah
V444	Taman Glory	V501	Kampung Malaysia Jaya
V445	Taman Hillside	V502	Kampung Semerah Padi
V446	Taman Crescent	V503	Kampung Sungai Midin
V447	Taman Palma Indah	V504	Kampung Siol Kandis
V448	Taman Sri Jaya	V505	Kampung Semariang
V449	Taman Suria Jaya	V506	Kampung Semariang Batu
V450	Taman Seri Puteri Kuching	V507	Kampung Rampangi
V451	Taman Suria Indah	V508	Taman Labunda Jalan Bako
V452	Taman Sonia, Batu 9	V509	Taman Dusun Bayu Demak Laut
V453	Kampung Matang	V510	Taman Dusun Baru, Jalan Bako

Table 4.2 continued

ID	Residential Name		ID	Residential Name
V454	Kampung Matang Lot		V511	Taman Dusun Bayu Demak Laut
V455	Kampung Sungai Atas Baru		V512	Taman Dusun Bayu
V456	Kampung Temenggong		V513	Taman Sepakat Jaya
V457	Taman Kasa Jaya		V514	Taman Sepakat Jaya, Jalan Bako
V458	Taman Iwani		V515	Taman Prestema
V459	Taman Mtg Jaya		V516	Taman Sepakat Jaya Demak Laut
V460	Taman Semariang		V517	Taman Sourabaya Indah
V461	Taman Indah		V518	Taman Sourabaya Landeh
V462	Taman Cahaya Indah		V519	Taman Sepakat Demak Jaya
V463	Taman Carisa		V520	Kampung Demak Baru Fasa 1
V464	Taman Gemilang		V521	Kampung Demak Baru Fasa 2
V465	Taman Haji Lemah		V522	Kampung Sejingkat
V466	Taman Mastura		V523	Taman Mesra Bako
V467	Taman Mariyam		V524	Kampung Senari
V468	Taman Midin		V525	Kampung Sungai Bako Jaya
V469	Taman Anib		V526	Kampung Hijrah
V470	Taman Haziq		V527	Kampung Buntal
V471	Taman Asiah		V528	Kampung Sungai Lumut
V472	Taman Daya Riang		V529	Kampung Santubong
V473	Taman Matang Jaya		V530	Kampung Telaga Air
V474	Taman Madehi		V531	Kampung Sg. Batu
V475	Taman Casandra		V532	Kampung Sg. Limo/Kuali, Chupin
V476	Taman Hwa Ling		V533	Kampung Sileng Dayak
V477	Taman Pelita Jaya		V534	Kampung Dagang
V535	Kampung Sg. Lundu		V537	Kampung Tabuan Dayak
V536	Kampung Sekambal		V538	Kampung Sebigo Cina
V456	Kampung Temenggong		V513	Taman Sepakat Jaya
V457	Taman Kasa Jaya		V514	Taman Sepakat Jaya, Jalan Bako
V458	Taman Iwani		V515	Taman Prestema
V459	Taman Mtg Jaya		V516	Taman Sepakat Jaya Demak Laut
V460	Taman Semariang		V517	Taman Sourabaya Indah
V461	Taman Indah		V518	Taman Sourabaya Landeh
V462	Taman Cahaya Indah		V519	Taman Sepakat Demak Jaya
V463	Taman Carisa		V520	Kampung Demak Baru Fasa 1

Table 4.2 continued

ID	Residential Name	ID	Residential Name
V464	Taman Gemilang	V521	Kampung Demak Baru Fasa 2
V465	Taman Haji Lemah	V522	Kampung Sejingkat
V466	Taman Mastura	V523	Taman Mesra Bako
V467	Taman Mariyam	V524	Kampung Senari
V468	Taman Midin	V525	Kampung Sungai Bako Jaya
V469	Taman Anib	V526	Kampung Hijrah
V470	Taman Haziq	V527	Kampung Buntal
V471	Taman Asiah	V528	Kampung Sungai Lumut
V472	Taman Daya Riang	V529	Kampung Santubong
V473	Taman Matang Jaya	V530	Kampung Telaga Air
V474	Taman Madehi	V531	Kampung Sg. Batu
V475	Taman Casandra	V532	Kampung Sg. Limo/Kuali, Chupin
V476	Taman Hwa Ling	V533	Kampung Sileng Dayak
V477	Taman Pelita Jaya	V534	Kampung Dagang
V535	Kampung Sg. Lundu	V537	Kampung Tabuan Dayak
V536	Kampung Sekambal	V538	Kampung Sebigo Cina
V539	Kampung Klaoh	V553	Kampung Perundang
V540	Kampung Sembawang Kecil	V554	Kampung Rukam
V541	Kampung Semunin Cina	V555	Kampung Jantan
V542	Kampung Sebigo Dayak	V556	Kampung Sebat Melayu
V543	Kampung Stunggang Melayu	V557	Kampung Sebako
V544	Kampung Semunin Jaya	V558	Kampung Trusan Jaya
V545	Kampung Sileng Melayu	V559	Kampung Temaga
V546	Kampung Serayan Hulu	V560	Kampung Serayan Besar
V547	Kampung Sebiris	V561	Kampung Judin
V548	Kampung Jampari	V562	Kampung Semapu
V549	Kampung Keranji	V563	Kampung Pugu
V550	Kampung Sedemak	V564	Kampung Perigi
V551	Kampung Titiakar	V565	Kampung Tanah Hitam
V552	Kampung Serayan Hilir	V566	Kampung Selarat
V571	Kampung Siru Dayak	V567	Kampung Sebat Dayak
V572	Kampung Telok Serabang	V568	Kampung Temaga Cina
V570	Kampung Bajo	V569	Kampung Sebuloh

Based on the Index map presented in Table 4.2, the general distribution of HFMD was analyzed and a map was generated from the year 2014 to 2018. Figure 4.12 shows the distribution of HFMD cases in the year 2014.

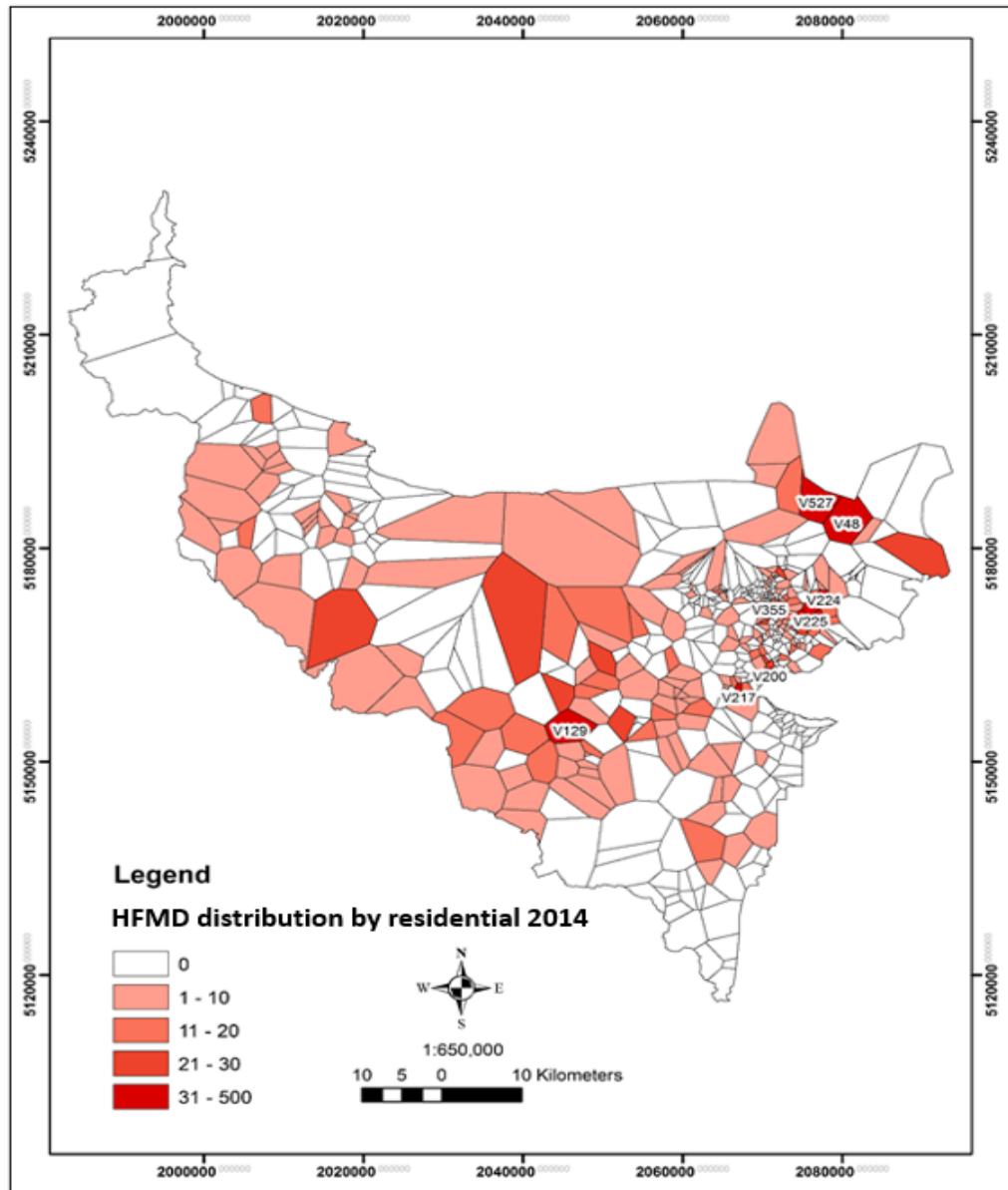


Figure 4.12: HFMD distribution by residential for 2014

The generated map was categorised into five categories namely zero category, 1-10 cases category, 11 to 20 cases category, 21 to 30 cases category, 31 to 50 cases category. For the year 2014, as illustrated in Figure 4.12, it was noticed that several residential areas have

recorded the number of cases of more than 31 cases. Most of the HFMD cases were recorded at the eastern and southern region of Kuching division. This includes Kampung Buntal (V527), Kampung Bako (V48), Kampung Bandarshah (V355), Taman Daya (V224), Taman Orchid (V225) and Kampung Tabuan Tengah (V236). These residential areas were located in Kuching North City Council and Kuching South City Council. Additionally, for Padawan area, there were several residential areas included under this category, which were Taman Batu 9 (V200) and Taman Shee (V217). For Bau area, Kampung Suba Buan (V129) has also recorded the number of HFMD that exceeded 31 cases. On the other hand, 119 residential areas were recorded to have cases of HFMD less than 10 cases. These residential areas such as Taman Lundu Jaya (V5), Kampung Siniawan (V27), Kampung Santubong (V529), Kampung Sri Kandong (V431) and Kampung Sagah (V400) were among the areas that have recorded cases of HFMD less than 10 cases.

For the year 2015, 8 residential areas have been detected to have a case of HFMD more than 31 cases. From 572 residential areas in Kuching division, there were 495 that have not recorded any of HFMD cases. These residential areas were located at Lundu District Council, Bau District Council, and Padawan Municipal Council. Figure 4.13 shows the distribution of HFMD cases in the year 2015. There were 1086 cases of HFMD recorded and the maximum number of cases were recorded at Kampung Pinang Jawa (V268) which was 78 cases. Kampung Pinang Jawa (V268) is located under the administration of Kuching North City Council. During this year, several residential areas have recorded the HFMD case more than one namely Kampung Jambu (V17), Kampung Assum (V65), Kampung Parang (V71), Kampung Pengiran (V100) and Kampung Telaga Air (V530). On the other hand, there were seven residential areas have recorded the number of case of more than 31 cases namely Taman Mawar Gita (V266), Kampung Semariang Pinggir (V38), Kampung Semariang Batu

(V506), Taman Demak Indah (V255), Kampung Semariang (V506), Kampung Rampangi (V507) and Kampung Pinang Jawa (V268).

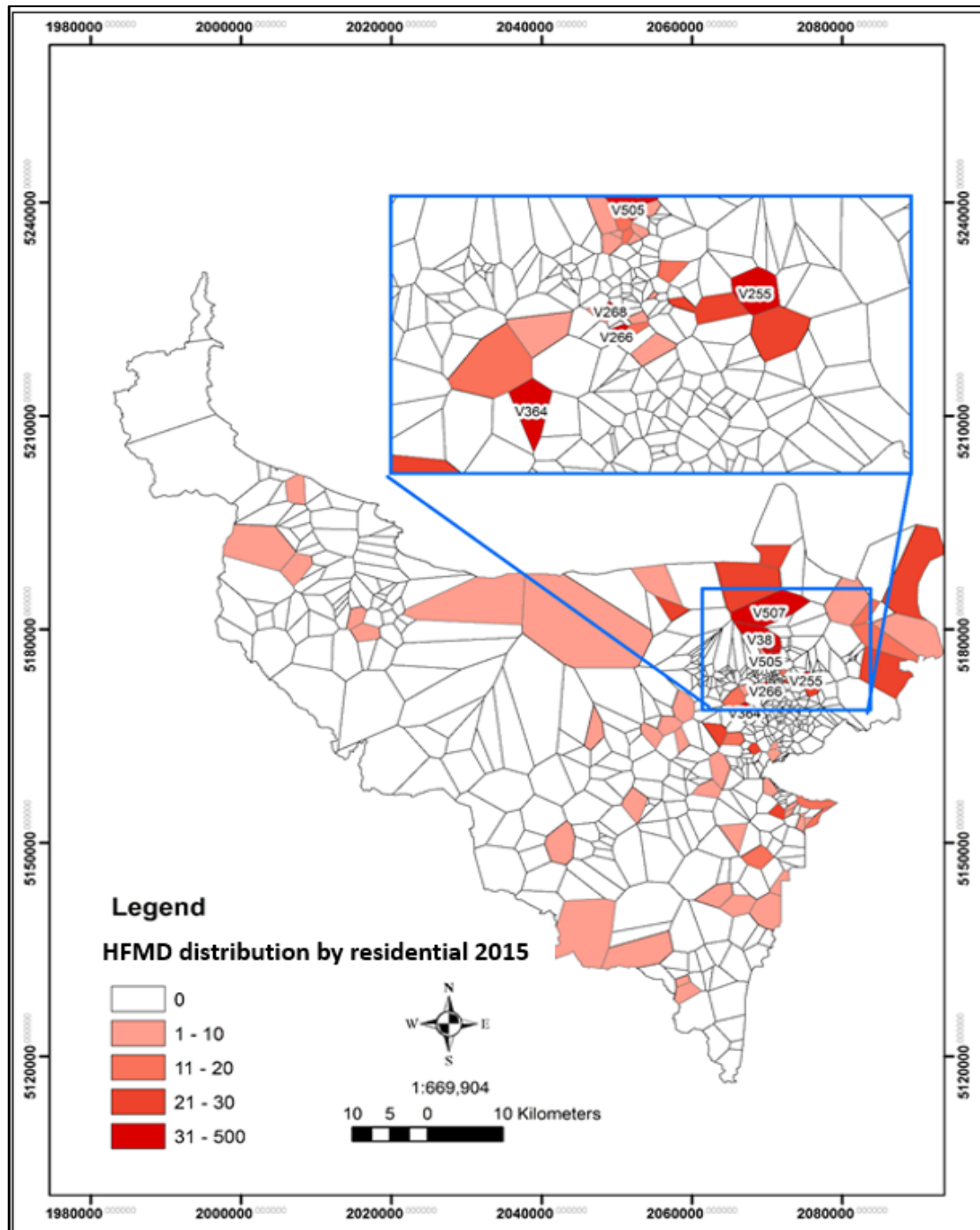


Figure 4.13: HFMD distribution by kampung for 2015

In 2016, there were 149 residentials that recorded more than one case of HFMD.

Figure 4.14 shows the distribution of HFMD cases in Kuching division for the year 2016.

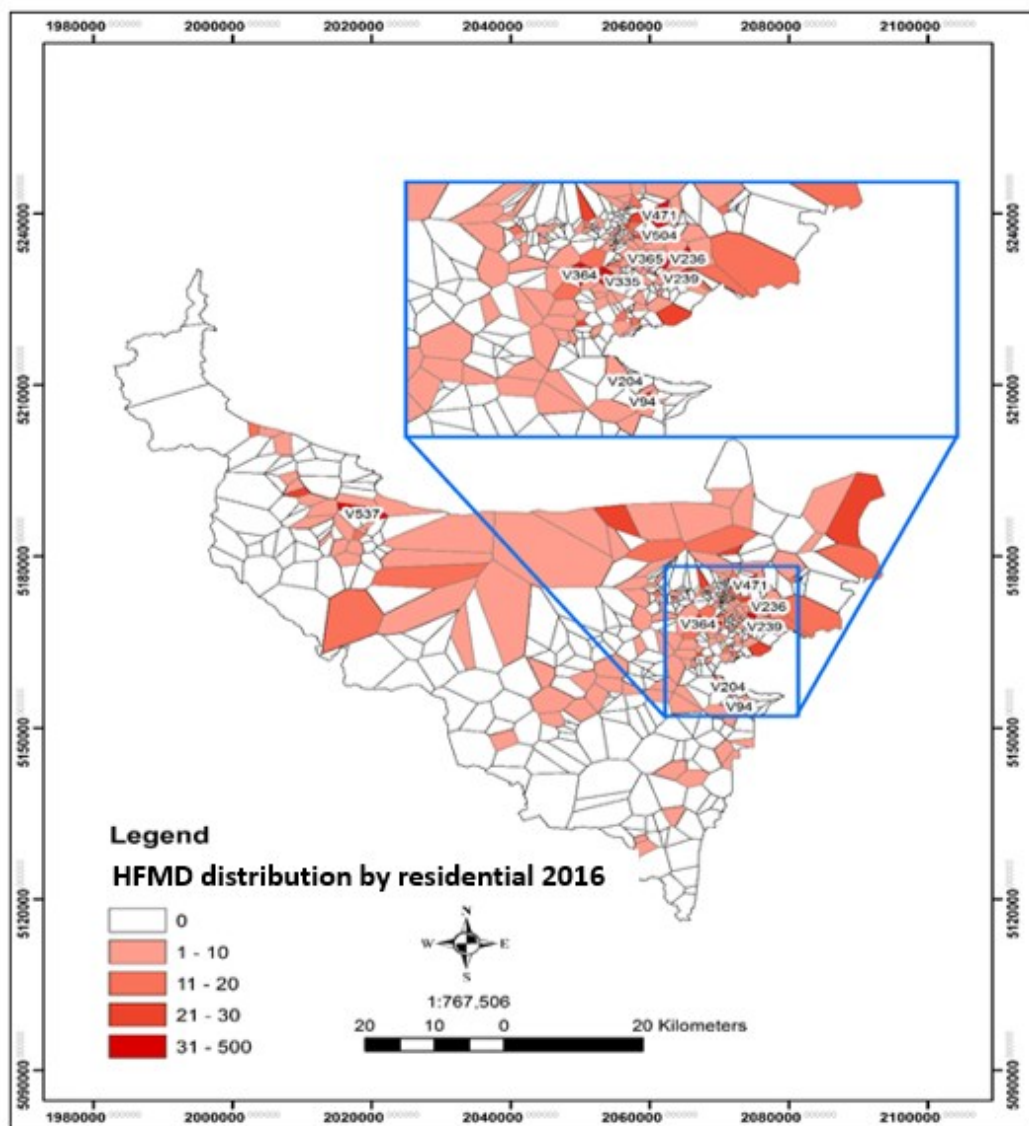


Figure 4.14: HFMD distribution by kampung for 2016

In Lundu area, Kampung Tabuan Dayak (V537) recorded more than 31 cases of HFMD. In northern and eastern part of Kuching division, it was observed that several residential areas fell under the category of more than 31 HFMD cases. These residential areas were Taman Millenium (V94), Taman Cin Muk (V204), Kampung Tabuan Tengah (V236), Kampung Stapok (V364) and Kampung Siol Kandis (V504). The highest number of cases were recorded at Kampung Tabuan Tengah (V236) which was 68 cases. On the other hand, for the year 2017, the total number of HFMD cases were 1861 cases. From 1861 cases, 136

were recorded at Taman Malihah (V380) and 96 cases at Taman Matang Jaya (V473) respectively. The mean of HFMD cases for 572 residentials were 3.1 cases in 2017. Figure 4.15 shows the general distribution of HFMD in Kuching division for 2017. The distribution of HFMD cases were still clustered at northern and southern region of Kuching division.

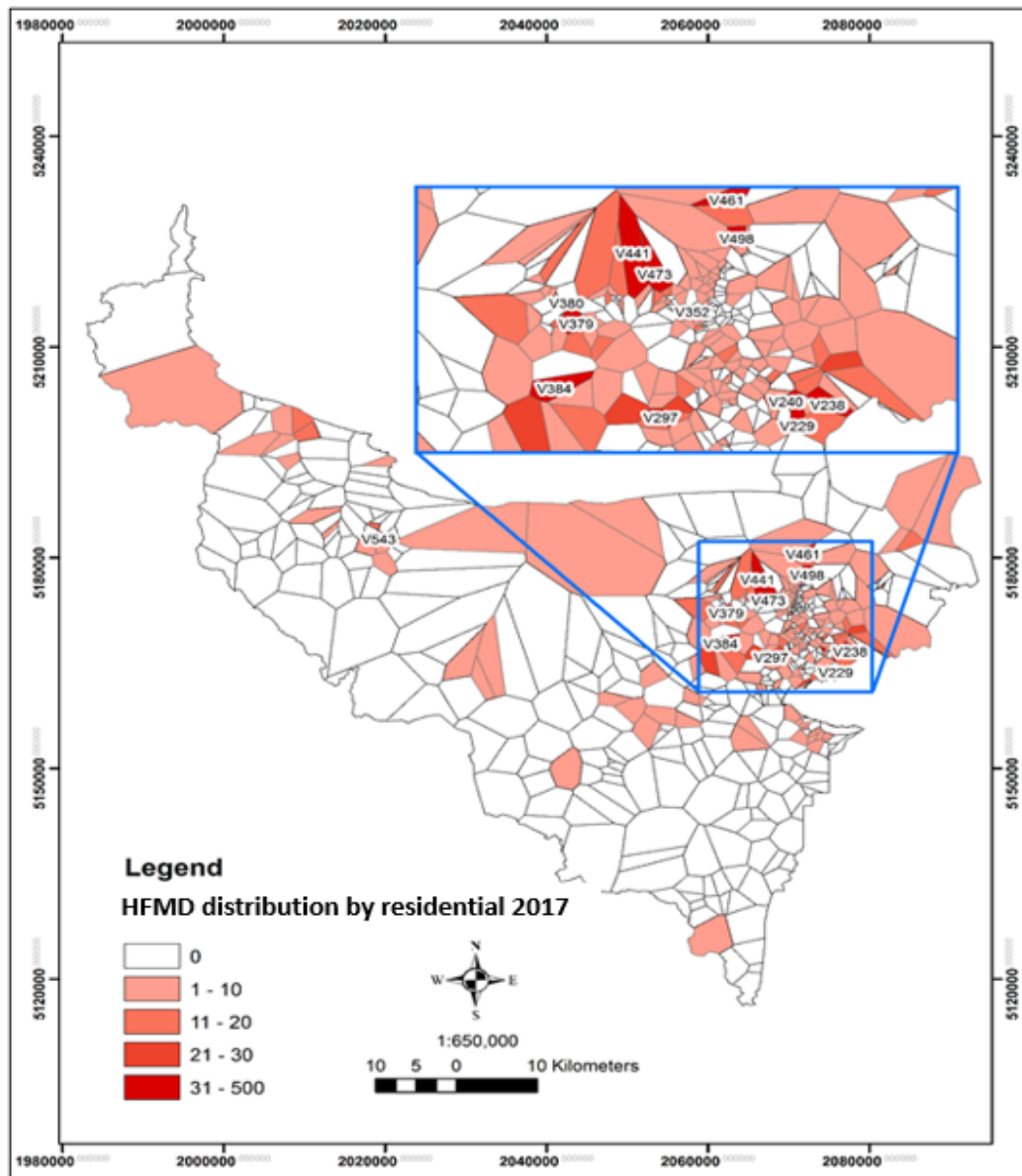


Figure 4.15: HFMD distribution by kampung for 2017

In the year 2018, as shown in Figure 4.16, 862 HFMD cases have been registered with Sarawak State Health Department.

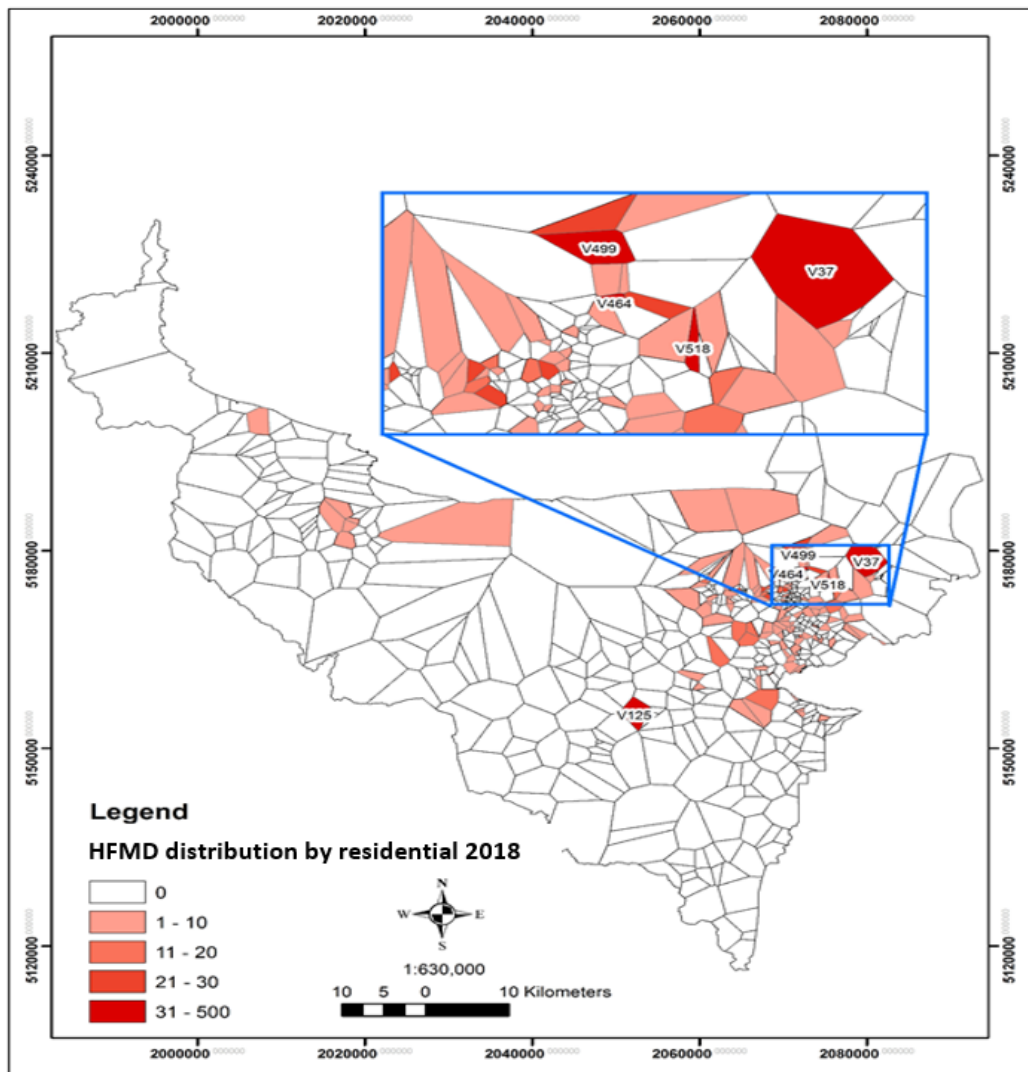


Figure 4.16: HFMD distribution by kampung for 2018

From 862 HFMD cases, 33 cases located at Taman Sourabaya Landeh (V518). The distribution of HFMD cases were concentrated at northern and southern region of Kuching division. Five residential areas recorded cases of HFMD more than 31 cases. It was located at Taman Sepakat Jaya (V37), Taman Mutiara (V125), Taman Gemilang (V464), Taman Puteri (V499) and Taman Sourabaya Landeh (V518). 35 residential were identified to record one case of HFMD such as Taman Mei Lee (V26), Kampung Tabuan Tengah (V236), Taman Supreme (V232), Kampung Simpang 3 (V366), Taman Pandan Jaya (V393), Kampung Lintang (V346), Taman Punca (V372) and Taman Sri Emas (V334).

Figure 4.17 shows the overview of HFMD distributions at the residential areas from the year 2014 until 2018. It appears that the distribution of HFMD cases from the year 2014 to 2015 were clustered at the northern region and southern region of Kuching division. These areas were located under the administration of Kuching North City Council (KNCC), Kuching South City Council (KSCC) and Padawan Municipal Council (PMC). In general, there was a reduce in terms of spatial distribution of HFMD cases from the year 2014 to 2018. In 2014, 58 residential areas have recorded a case of HFMD for more than 58 cases. The location of the affected areas reduced to 23 residential areas in 2018.

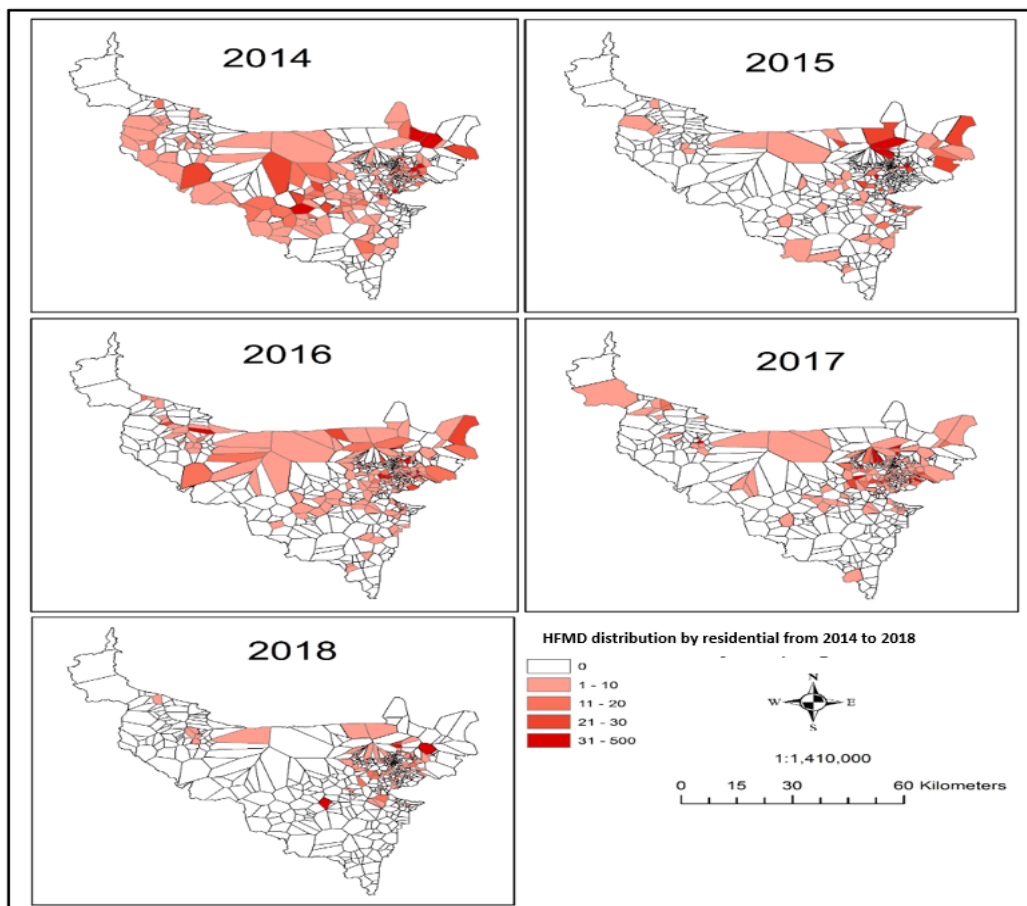


Figure 4.17: General distribution of HFMD from 2014 to 2018

Further analysis was conducted to examine the distribution of HFMD cases in Kuching division based on gender. Figure 4.18 shows the distribution of HFMD by gender.

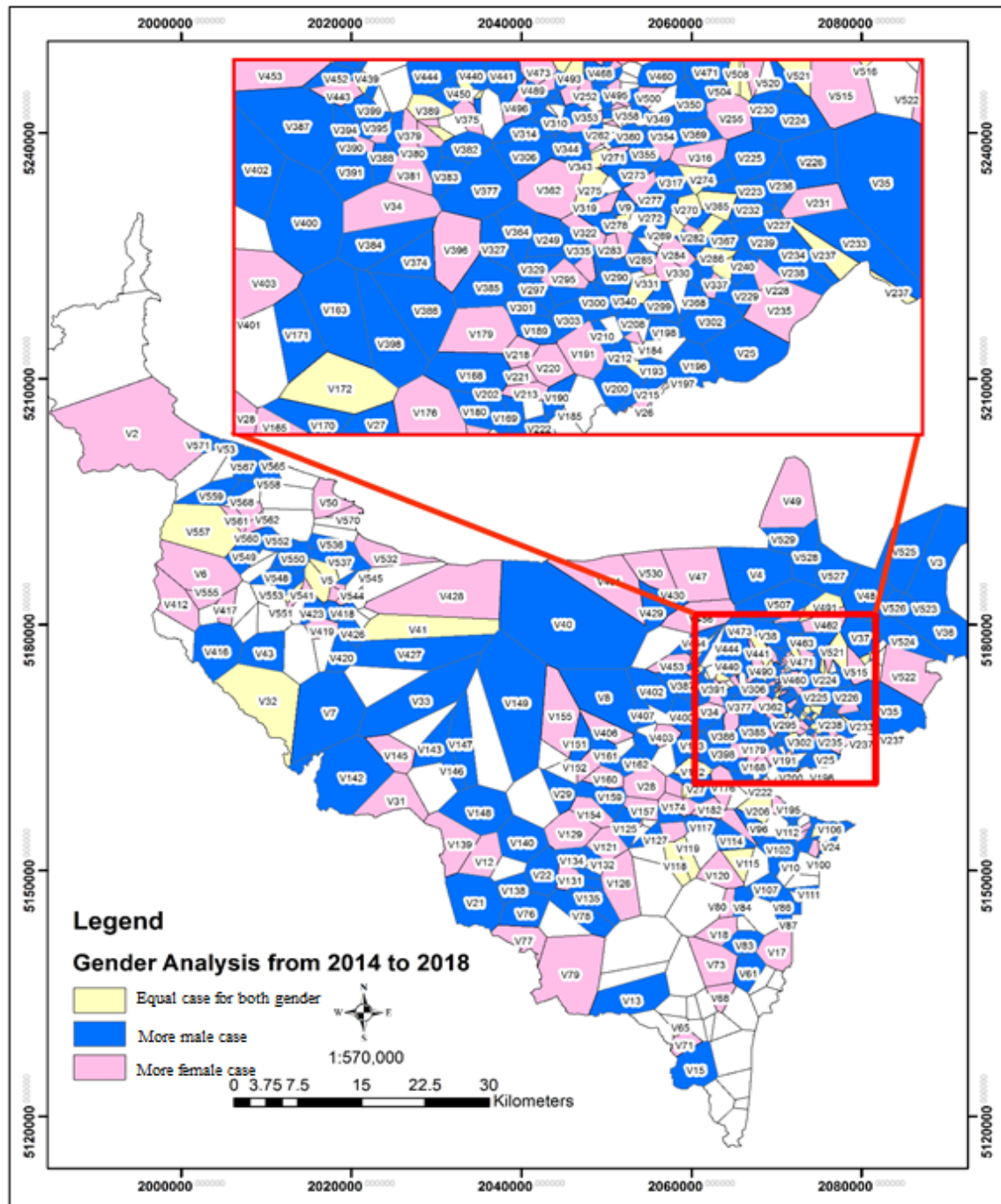


Figure 4.18: Total number of HFMD by gender

The outcome of this analysis provides an understanding of spatial distribution of HFMD by residential areas. Based on Figure 4.18, the residential areas colored in blue represent the residential areas that have recorded the highest number of HFMD cases among male. Meanwhile, the residential areas colored in pink showed the residential areas that have

recorded the highest number of HFMD cases among female and the residential areas that recorded the same number of cases among male and female were colored in light yellow. It was found that 260 residential areas recorded the highest number of HFMD cases among males as compared to 131 residential areas were among females. This can be seen at Kampung Bajo (V570), Kampung Pueh (V2), Kampung Sungai Aur (V47), Kampung Jugan (V178) and Kampung Bukit Panchor (V178), just to name a few where it has recorded the highest number of HFMD among the males. Meanwhile, an example for a residential area that has recorded the highest number of HFMD cases among women was located at Taman Matang Jaya (V473), Taman Synergy (V34) and Taman Brilliant (V191).

Further assessment was made to compare the distribution of HFMD case by gender based on Local council boundaries. Figure 4.19 presents the comparison between male and female of HFMD cases in Kuching division.

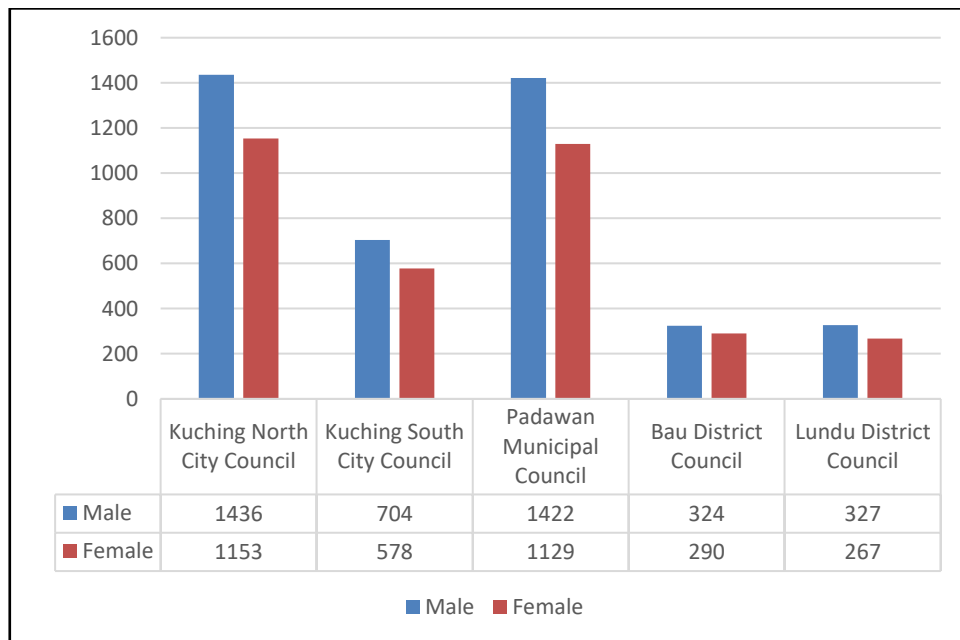


Figure 4.19: HFMD based on gender

Based on Figure 4.19, it appears that male was predominant gender over female for all local councils by looking at the total number of HFMD cases registered by gender. It was

recorded that 56% of the HFMD cases in Kuching division were male. Kuching North City Council, Kuching South City Council and Padawan Municipal Council had the most recorded HFMD cases for male which were 1436, 704, and 1422 respectively.

Similarly, the distribution of HFMD cases by age shows that the occurrences of HFMD in Kuching division for the age range of 1 to 2 years old were very high which were 3758 cases from 2014 to 2018. This was followed by the age range of 3 to 4 years old which were 2066 cases. Figure 4.20 demonstrates the number of HFMD cases by age from 2014 to 2018.

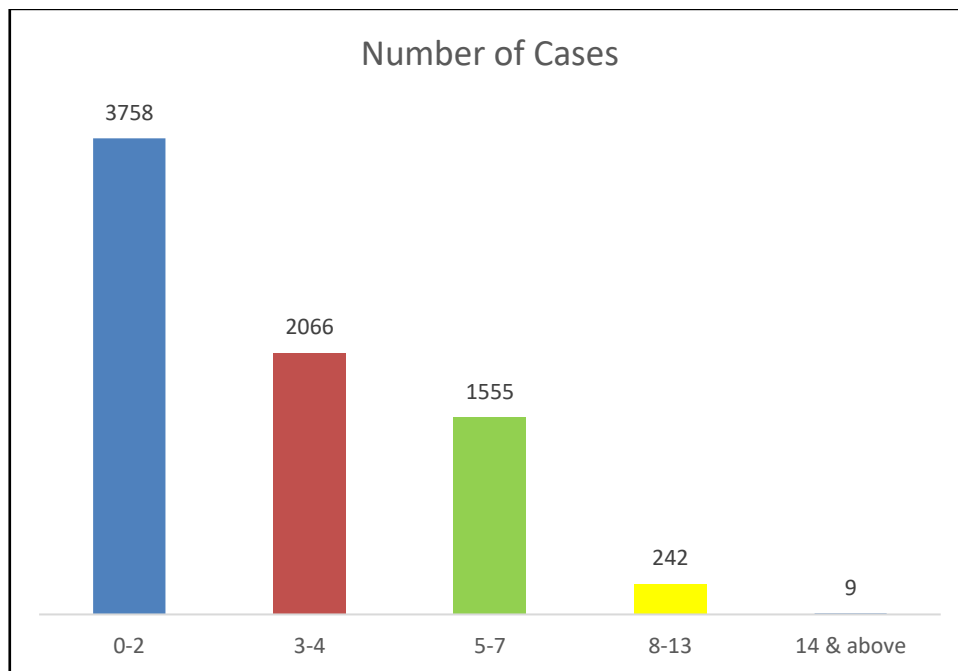


Figure 4.20: HFMD reported cases by age

The decreasing pattern of HFMD reported cases by age can be seen as the number of reported cases reduced from 3558 at the age of 1 and 2 years old to 9 cases at the age of 14 years old and above. This proves that the young children from the age of 1 to 4 years old were vulnerable of getting infected by HFMD. Figure 4.21 shows the distribution of HFMD cases based on age from 2014 until 2018.

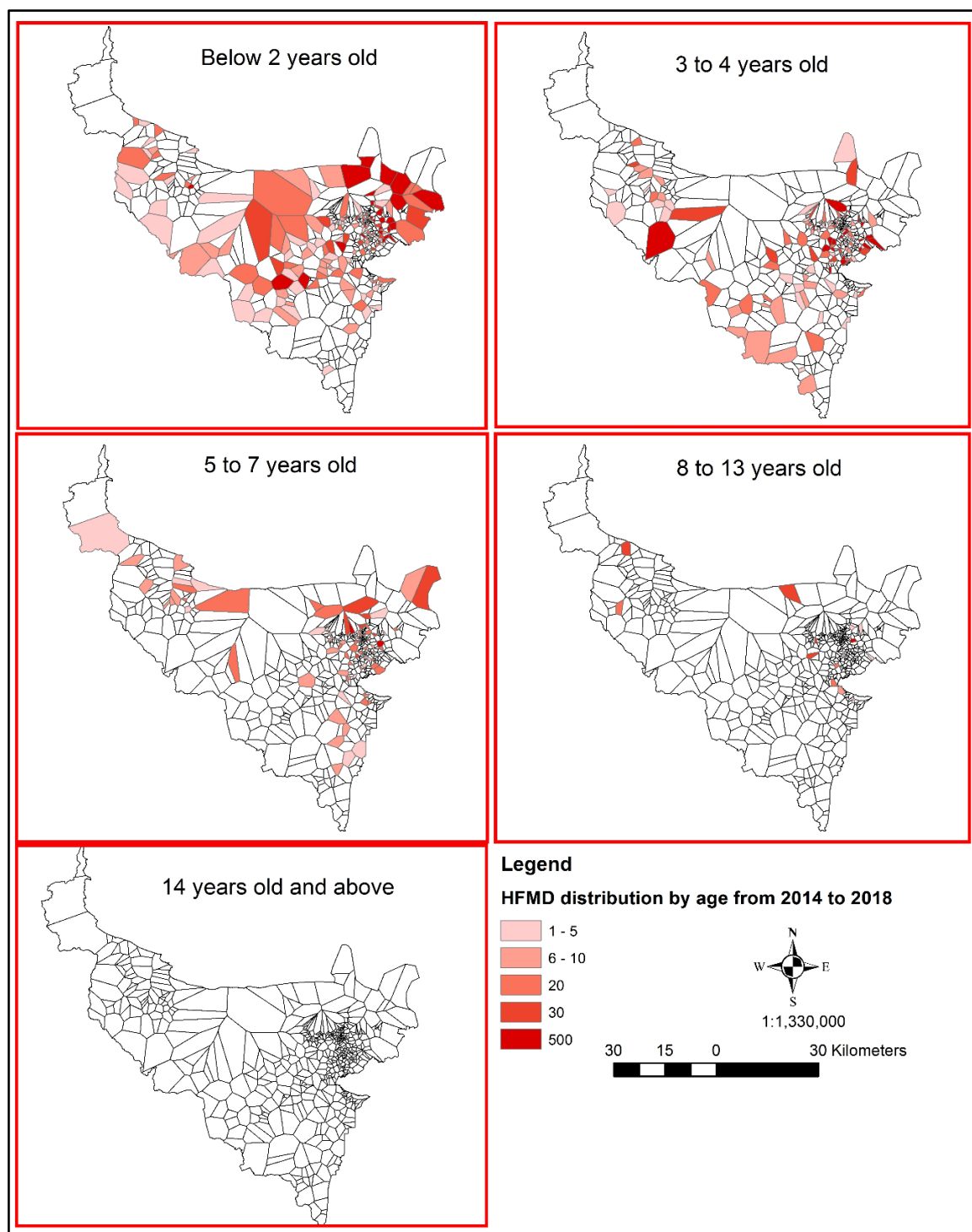


Figure 4.21: HFMD distribution based on age

From 2014 to 2018, it was observed that 11 residential areas have recorded a number of HFMD cases exceeding 51 cases for the age below than 2 years old. These residential areas were mostly distributed at the Southern region of Kuching division. There were several

residential areas that have recorded more than 51 cases of HDMD for above 2 years old such as at Taman Mutiara (V125), Taman Demak (V255), Taman Bunga Raya (V268), Taman Victoria (V322), Taman Indah (V461), Kampung Buntal (V527). Meanwhile, for the age of 8 years old and above, it was found that no residential areas have ever recorded more than 51 cases from 2014 to 2018. The map of HFMD cases for 8 years old and above as shown in Figure 4.21 proved that HFMD threat was more significant for young children below 8 years old. This can be seen from the total number of HFMD cases for 2014 until 2018 where the reported cases of HFMD for the age above 8 years old were 3% from 7630 cases to only 242 cases. Further observation was made on the distribution of HFMD by age according to local council boundary as shown in Figure 4.22.

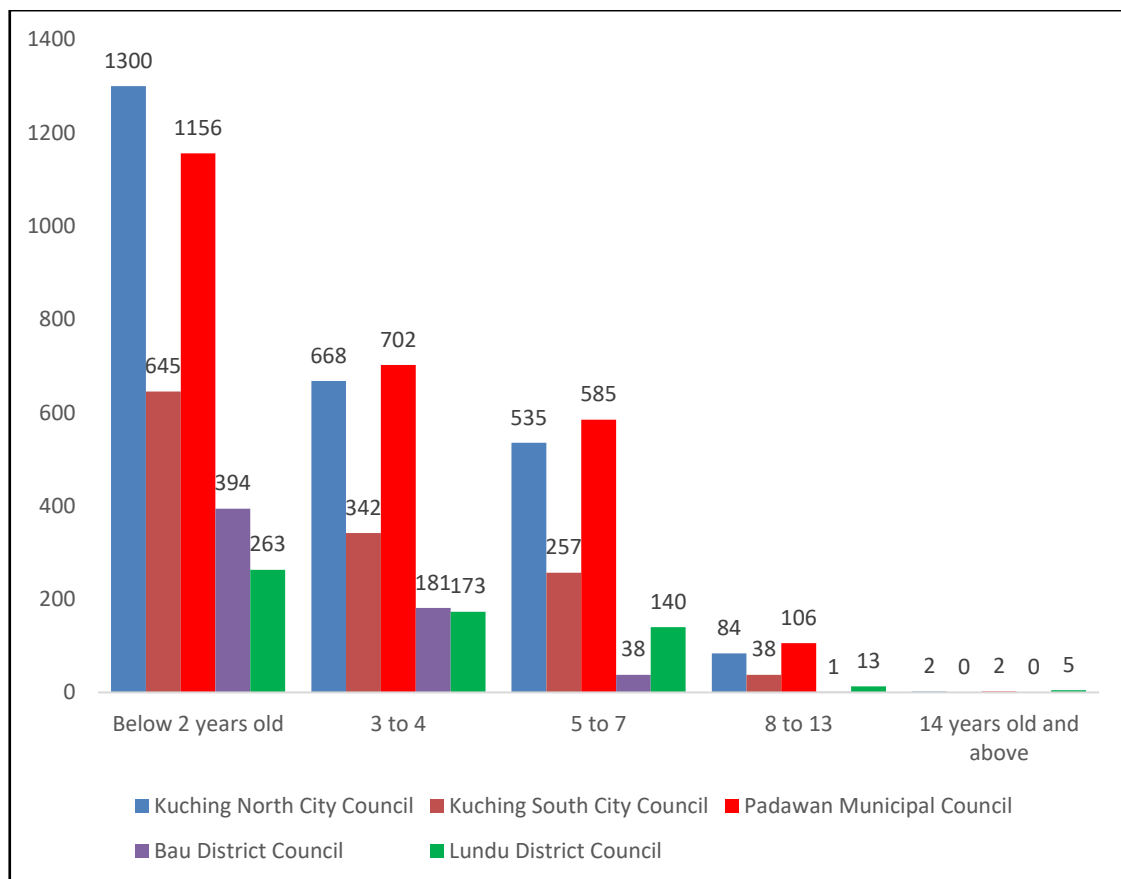


Figure 4.22: HFMD distribution by age based on local councils

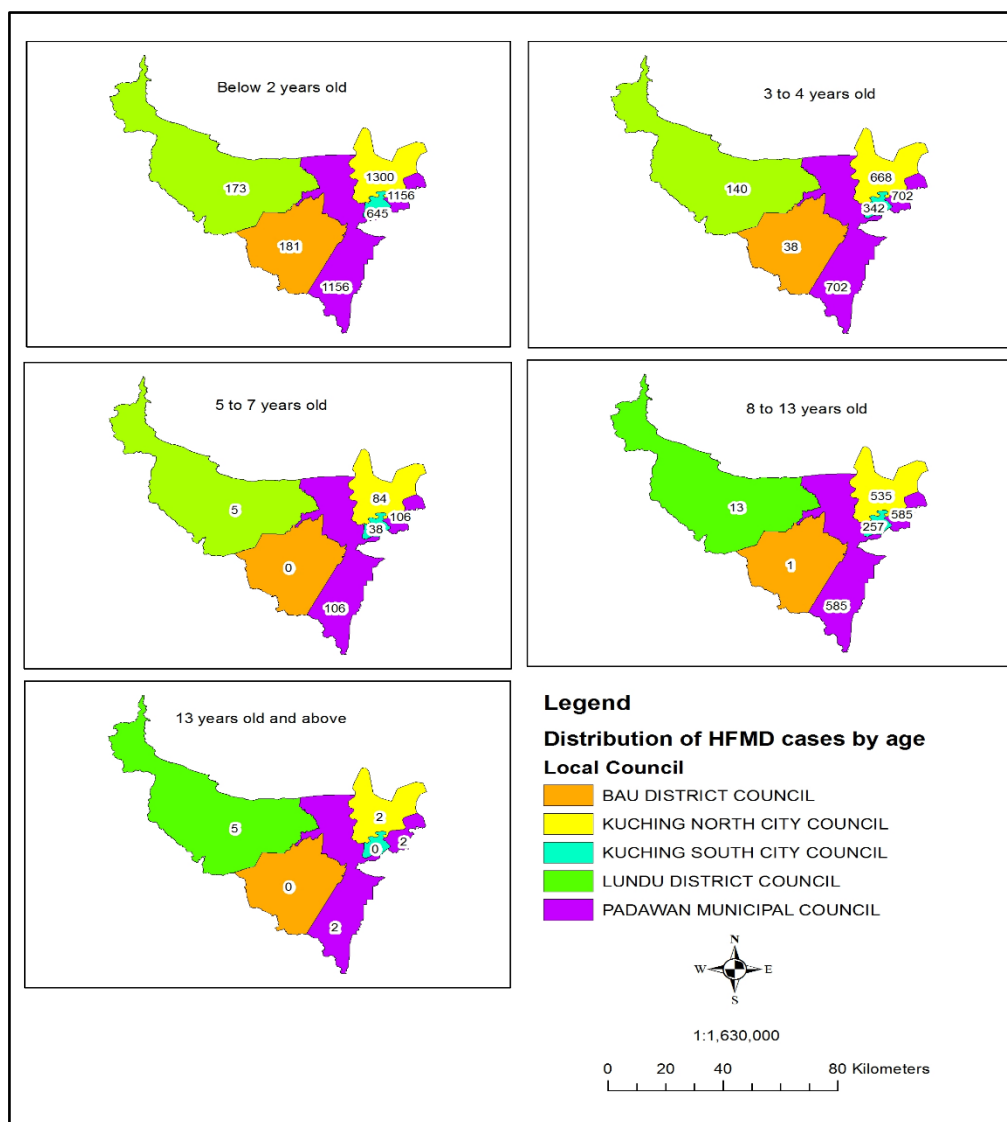


Figure 4.23: HFMD by age according to local council boundaries

As illustrated in Figure 4.23, from 2014 to 2018, it was found that Kuching North City Council and Padawan Municipal Council have recorded the highest number of HFMD cases for children below 2 years old as compared to other councils. Kuching North City Council has registered 1300 HFMD patients under the category of below two years old. It was then followed by Padawan Municipal Council with 1156 cases, 645 cases from Kuching South City Council, 394 cases registered under Bau District Council and lastly 263 cases from Lundu District Council. For the age between 3 to 4 years old, the highest cases

registered was in Padawan Municipal Council with 702 cases, Kuching North City Council with 668 cases, 342 cases in Kuching South City Council, 140 cases in Lundu District Council and lastly one case in Bau District Council. Under the category of 5 to 7 years old, Padawan Municipal Council recorded the highest number of HFMD cases under this category, which was 106 cases. Padawan Municipal Council also led the highest number of cases under the category of 8 to 13 year old, where it has recorded 585 cases.

An analysis of ethnicity was conducted to explore the pattern of HFMD distribution within the study area from 2014 to 2018. Table 4.3 shows the distribution of HFMD cases from 2014 to 2018 within Kuching division (Sarawak State Health Department, 2019).

Table 4.3: Total number of HFMD cases by ethnicity from 2014 to 2018

No	Ethnic	Total of HFMD Cases
1	Malay	3954
2	Bidayuh	1348
3	Chinese	1260
4	Iban	786
5	India	26
6	Others	253

As shown in Table 4.3, Malay has recorded the highest number of HFMD from 2014 until 2018, which were 3954 cases. This was followed by Bidayuh (1348 cases), Chinese (1260 cases), and Iban (789 cases). Further analysis to identify the highest number of HFMD patients based on ethnicity for each residential area from 2014 to 2018 within Kuching division was conducted. As a result of this analysis, a map of spatial distribution of HFMD cases based on ethnicity by residential areas was developed, as illustrated in Figure 4.24.

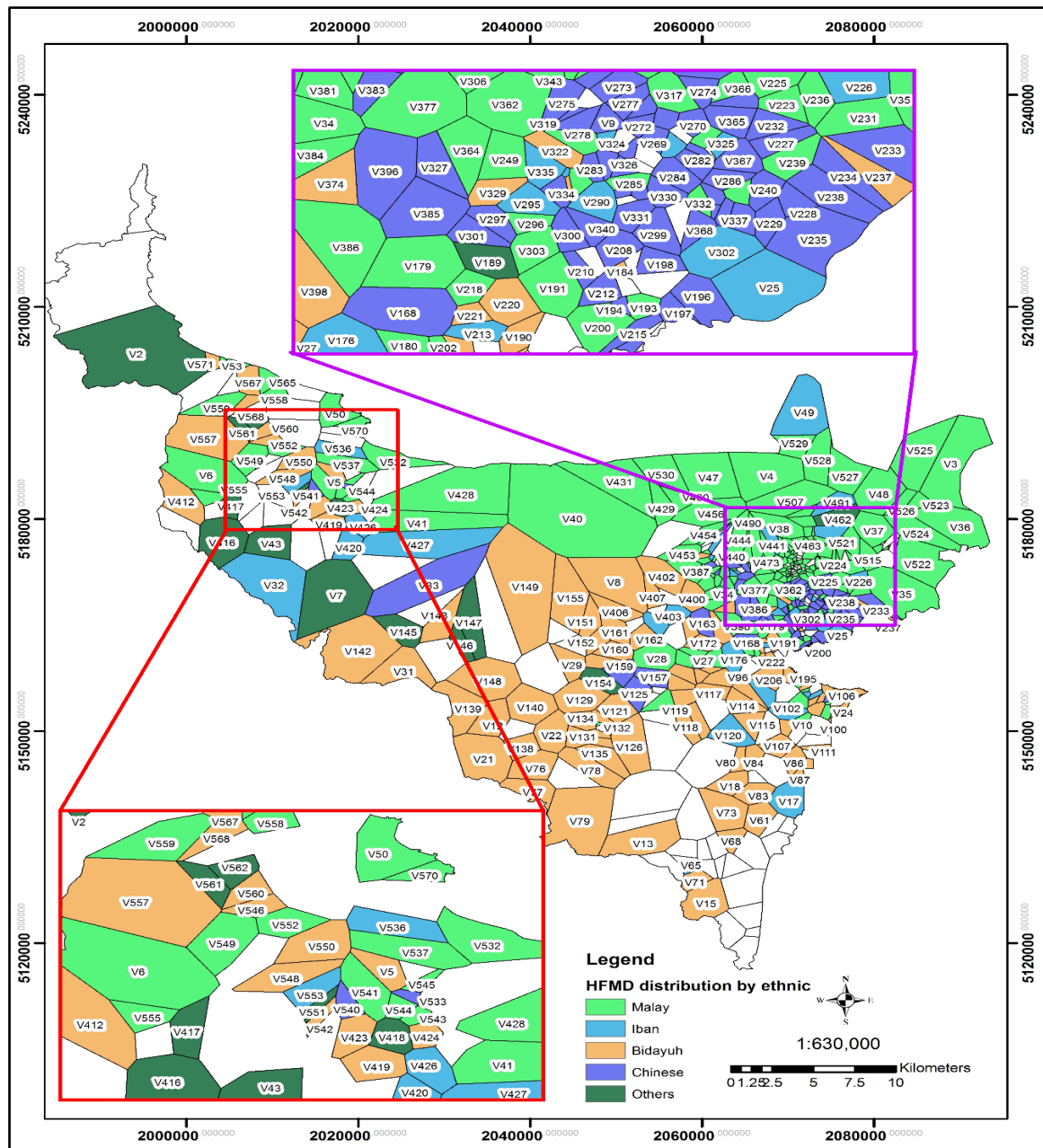


Figure 4.24: HFMD cases based on ethnicity from 2014 to 2018

As shown in Figure 4.24, there were 127 residential areas dominated by the Malay in terms of the highest number of HFMD cases recorded by ethnic. It was then followed by the Bidayuh (108 residential areas), Chinese (80 residential areas) and Iban (36 residential areas). The geovisualisation analysis was based on the majority cases recorded by ethnic in each of the residential areas.

The next assessment was to analyze the spatial spreading pattern of HFMD. It is important to know the spatial spreading pattern of HFMD cases in Kuching division as it provides an information of dependency or independency of HFMD cases between one case to another. At the same time, it can also stipulate some clues on why certain pattern of HFMD distributed at any residential areas in Kuching division occurred. The Average Nearest Neighbour (ANN) analysis was conducted to study the spatial pattern of HFMD. Figure 4.25 shows the result generated from ANN analysis.

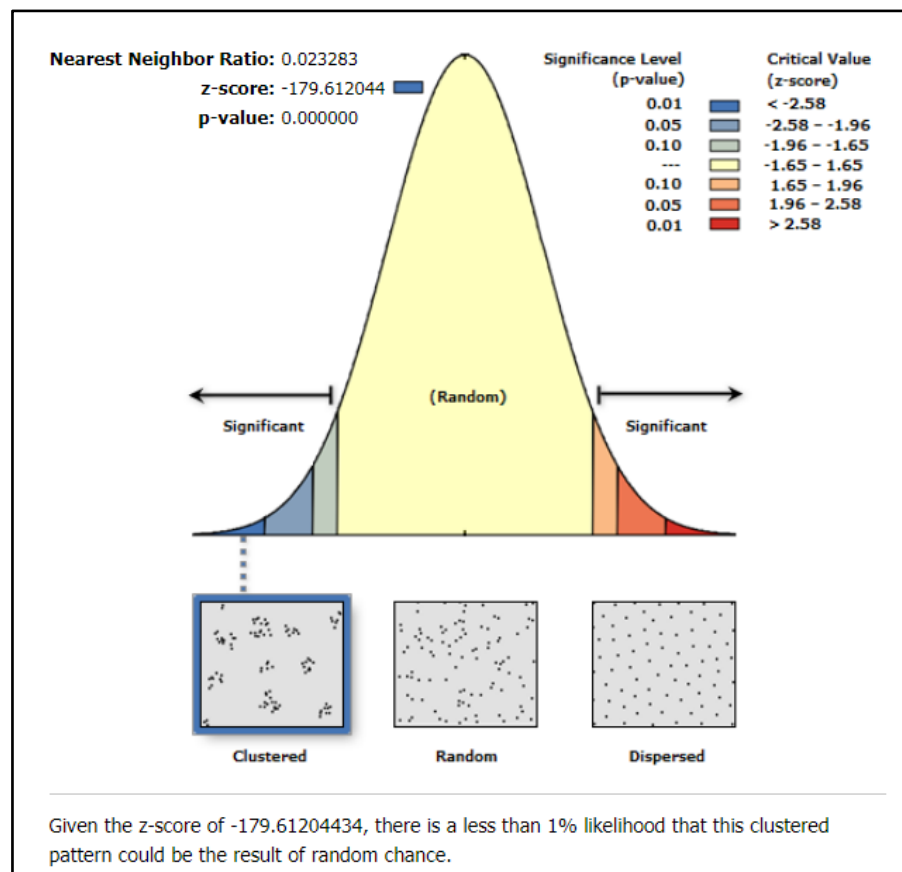


Figure 4.25: Average nearest neighbour result

Based on the result of ANN analysis, it appeared that the pattern of HFMD cases from 2014 to 2018 was clustered. The Nearest Neighbour Ratio was 0.023283 which was less than 1. Any result of ANN that is less than 1 shows that the pattern was clustered and that was the result of ANN for Kuching division. Further analysis was conducted to

understand the pattern of HFMD distribution on a yearly basis from 2014 to 2018. Figure 4.26 shows the outcome of the conducted analysis of ANN within this period.

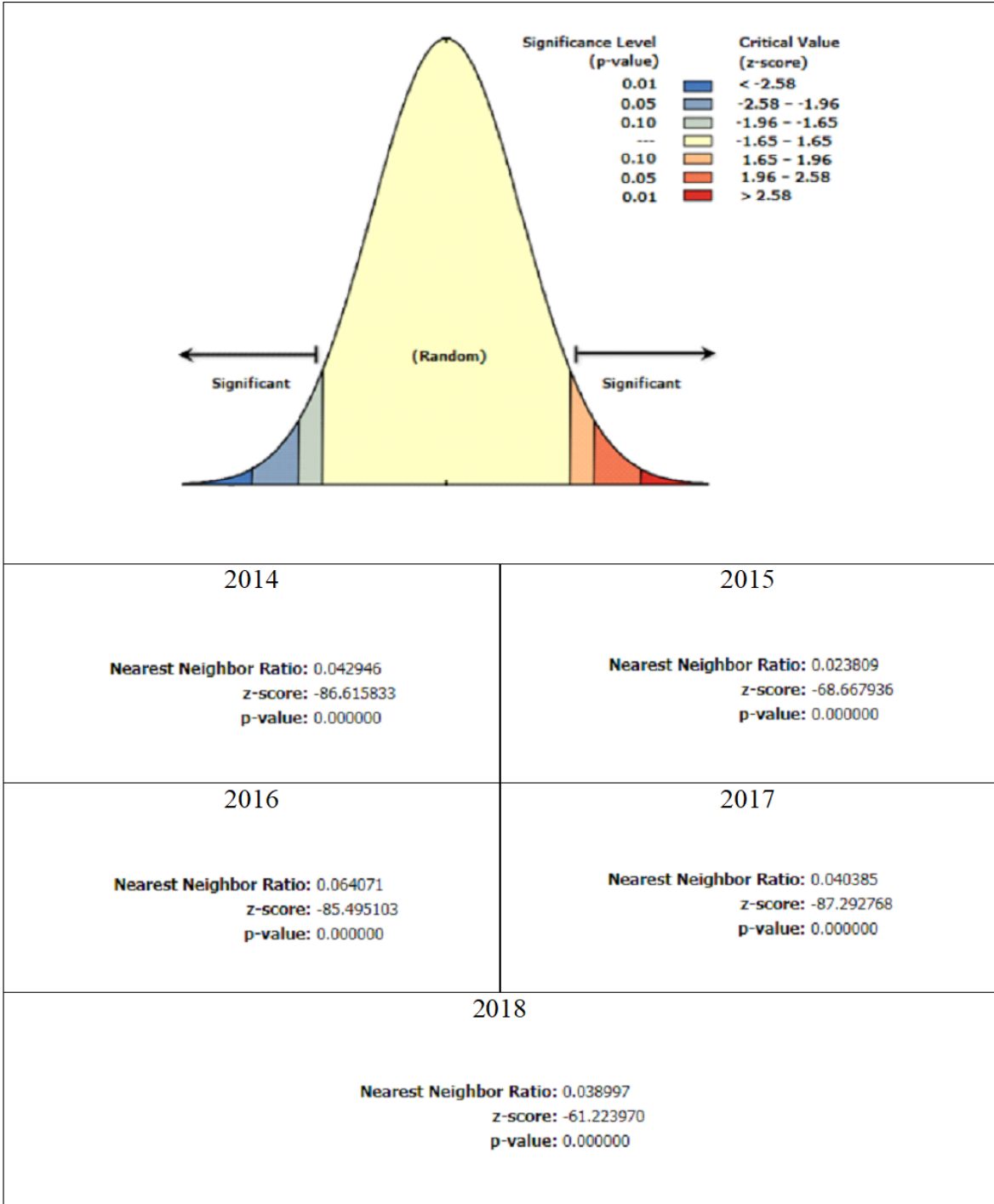


Figure 4.26: ANN results from 2014 to 2018

Based on Figure 4.26, it was observed that within the period of 5 years, the trend and pattern of HFMD registered cases in Kuching division was clustered. This can be proved by looking at the Nearest Neighbour Ratio of ANN analysis which was less than 1. This analysis measured the distance of each cases registered in Kuching division and from there it reveals the spatial spreading pattern of HFMD.

The null hypothesis of this analysis was all points were randomly distributed. The point feature in this context refers to HFMD incident locations. From the conducted ANN analysis, it shows that the spatial spreading pattern of HFMD in Kuching division from the year 2014 to 2018 were clustered and therefore the null hypothesis of complete spatial randomness was rejected.

To strengthen the observation of clustering pattern, the spatial autocorrelation analysis was conducted. The spatial autocorrelation using Moran's Index measured the distance and the number of HFMD incident locations within the study area. While ANN analysis measured the distance of each HFMD incident locations, Moran's Index on the other hand, measures the number of HFMD cases of each residential area in Kuching division as well as the distances between them.

Likewise, ANN, Moran's Index has its own rank based on the calculated feature. If the outcome of calculated feature is positive and close to +1, it indicates the HFMD incident locations are clustered to each other. However, if Moran's Index is negative value, which is close to -1, it means that the case of HFMD within the study area is not clustered but exhibits a dispersed pattern. To confirm this statement, Moran's Index has been calculated and computed. Figure 4.27 shows the outcome of Moran's Index. The calculated Moran's Index for five years from 2014 to 2018 were computed and results of each year were compared.

The Moran's Index ratio from the year 2014 to 2018 indicated that the spatial distribution of HFMD cases in Kuching division was clustered.

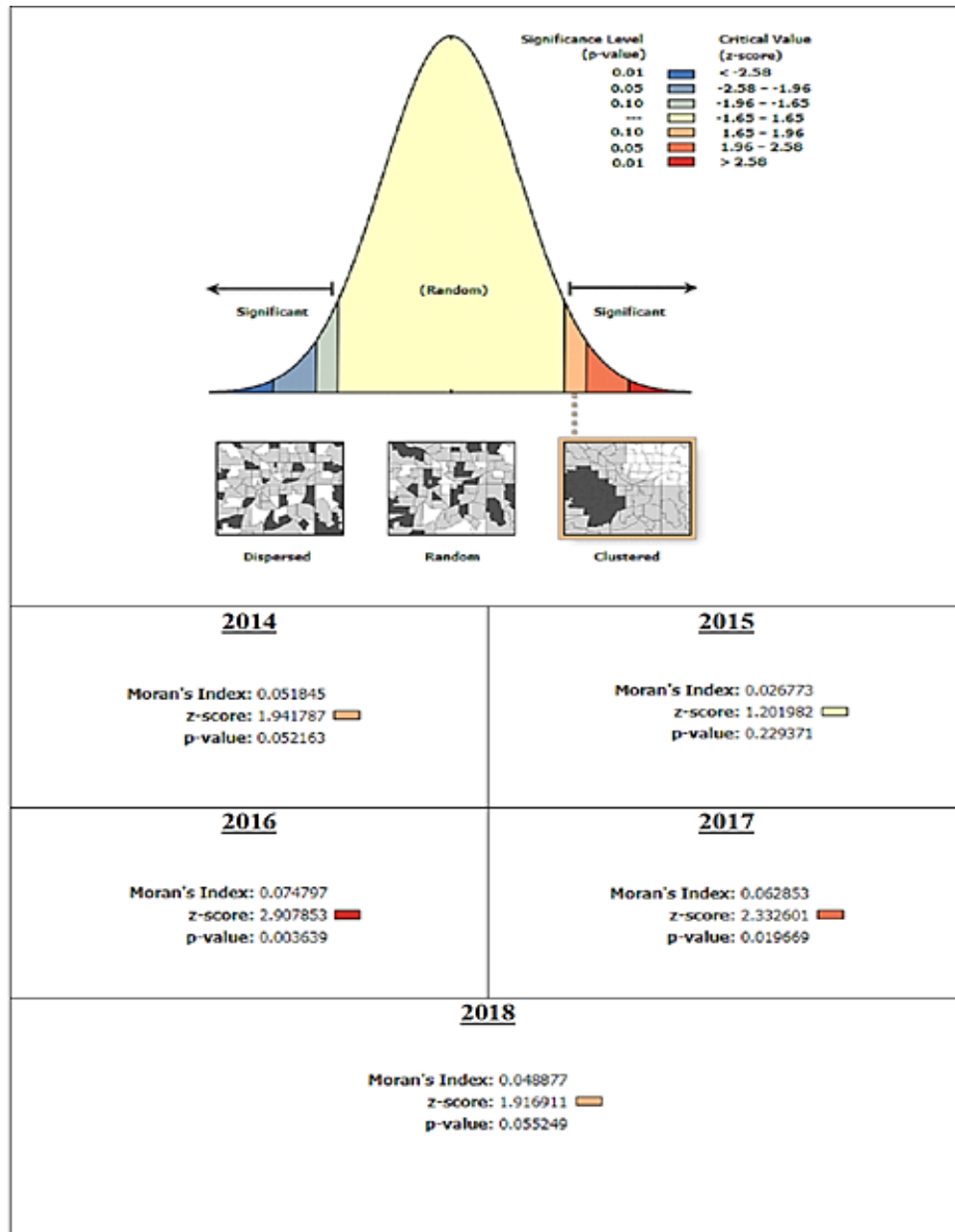


Figure 4.27: Moran's Index from 2014 to 2018

This supports the outcome of the analysis performed using Average Nearest Neighbour that the HFMD reported incidents from the year 2014 to 2018 were clustered. Moran's Index from 2014 to 2018 were all positive values with the range of 0.02 to 0.06

which indicated the clustered index. Based on the calculated Moran's Index for five years of the study period, it shows that the Z-Score values were less than 10%, which mean 90% confident level of clustering detected and therefore the null hypothesis of complete spatial randomness was rejected.

Since ANN and Moran's Index have confirmed the distribution of HFMD reported cases were clustered, this also confirmed the theory of Tobler's first law of geography where "everything is related to everything else, however near things are more related than distant things". The clustered pattern itself proves that the HFMD transmission is expanding to the adjacent areas.

Further exploration on the pattern on HFMD distribution was made by using Inverse Distance Weighted (IDW). This interpolation method creates the assumption that the number of HFMD cases are the same to one another as compared to the number of cases that further apart. The rational of applying this method for this analysis was to observe the spatial spreading pattern of HFMD from the surface perspective. Figure 4.28 shows the outcome of HFMD distribution based on IDW technique.

The outcome of IDW also indicates the trend of having high value of HFMD concentration at the eastern part of Kuching division. This location was administered by three local councils namely Kuching North City Council, Kuching South City Council and Padawan Municipal Council. Several residential areas recorded the number of HFMD cases exceeding 251 cases from 2014 to 2018 at this location namely Kampung Buso (V33), Kampung Semeba (V35), Kampung Stapok (V34), Kampung Matang (V9), Kampung Cemerlang (V40), Kampung Tabuan Lalang (V39) and Kampung Istana (V59). On the other hand, the spatial spreading pattern of HFMD also can be modelled by using surface model (IDW) as shown in Figure 4.28.

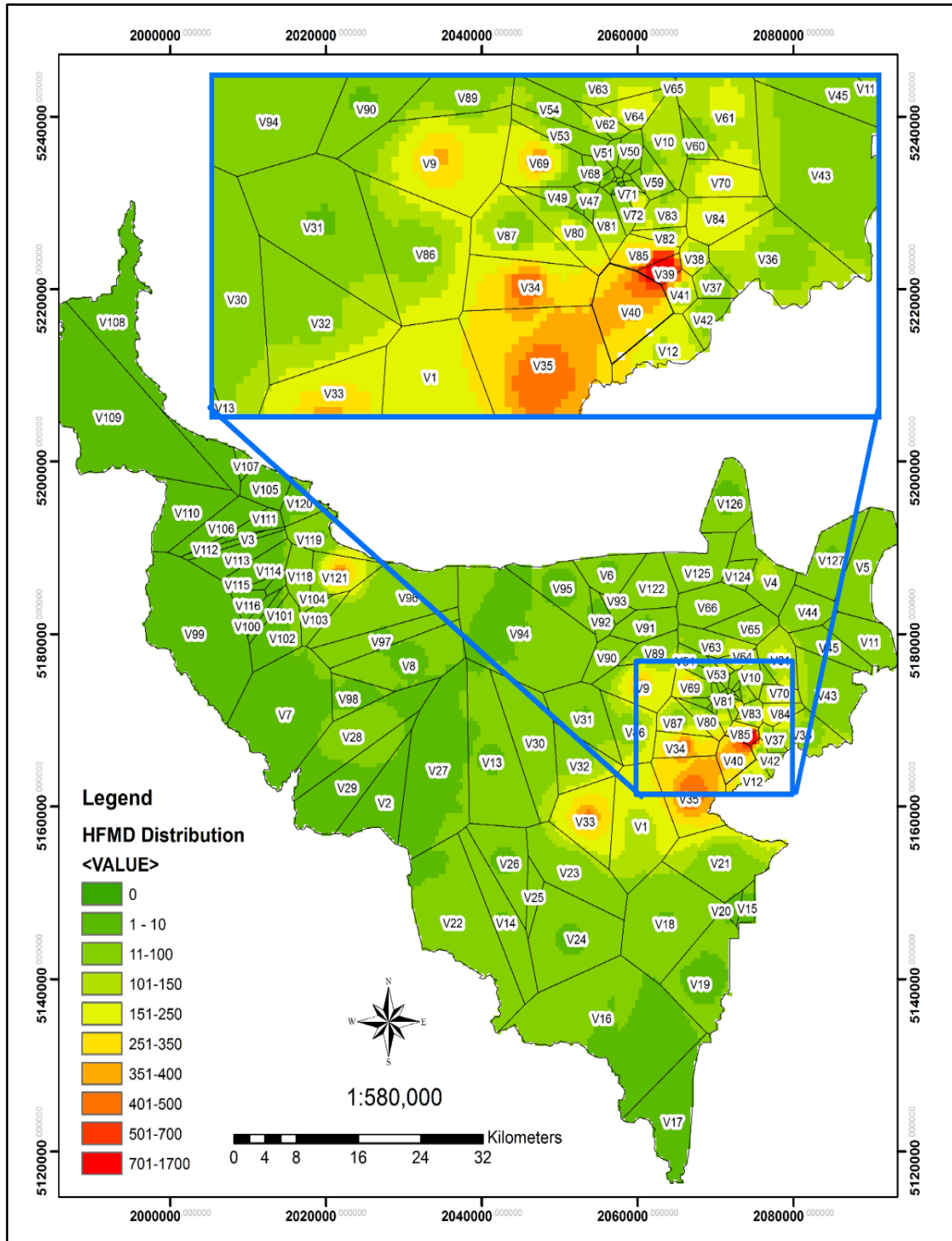


Figure 4.28: HFMD distribution based on IDW

The analysis of spatial mean center was conducted in order to keep track on the changes of HFMD distribution in Kuching division within the study area. This analysis

calculates the average x and y coordinate of HFMD distribution from Kuching district, Bau District and Lundu district. Its provides information on the center of HFMD distribution in Kuching division.

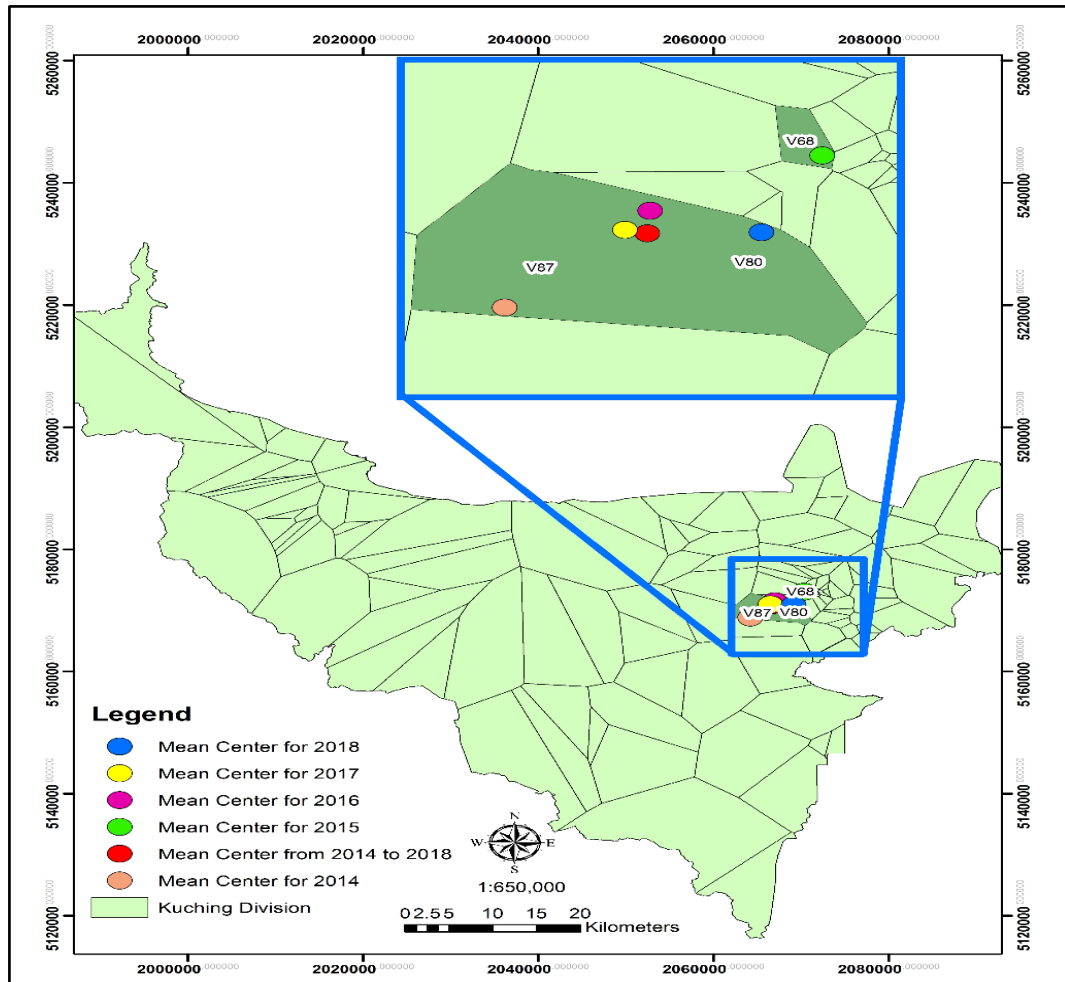


Figure 4.29: Spatial mean center of HFMD distribution

Figure 4.29 shows the spatial mean center of HFMD distribution in Kuching division from 2014 until 2018. This analysis aims to locate the point center of HFMD cases within the study area by calculating all HFMD cases and dividing them by their geographical locations. The outcome of this analysis shows that distribution of HFMD cases from 2014 until 2018 were centered spatially at three residential areas namely Kampung Segedup (V87), Kampung Sungai Maong (V80) and Kampung Laruh Skim (V68).

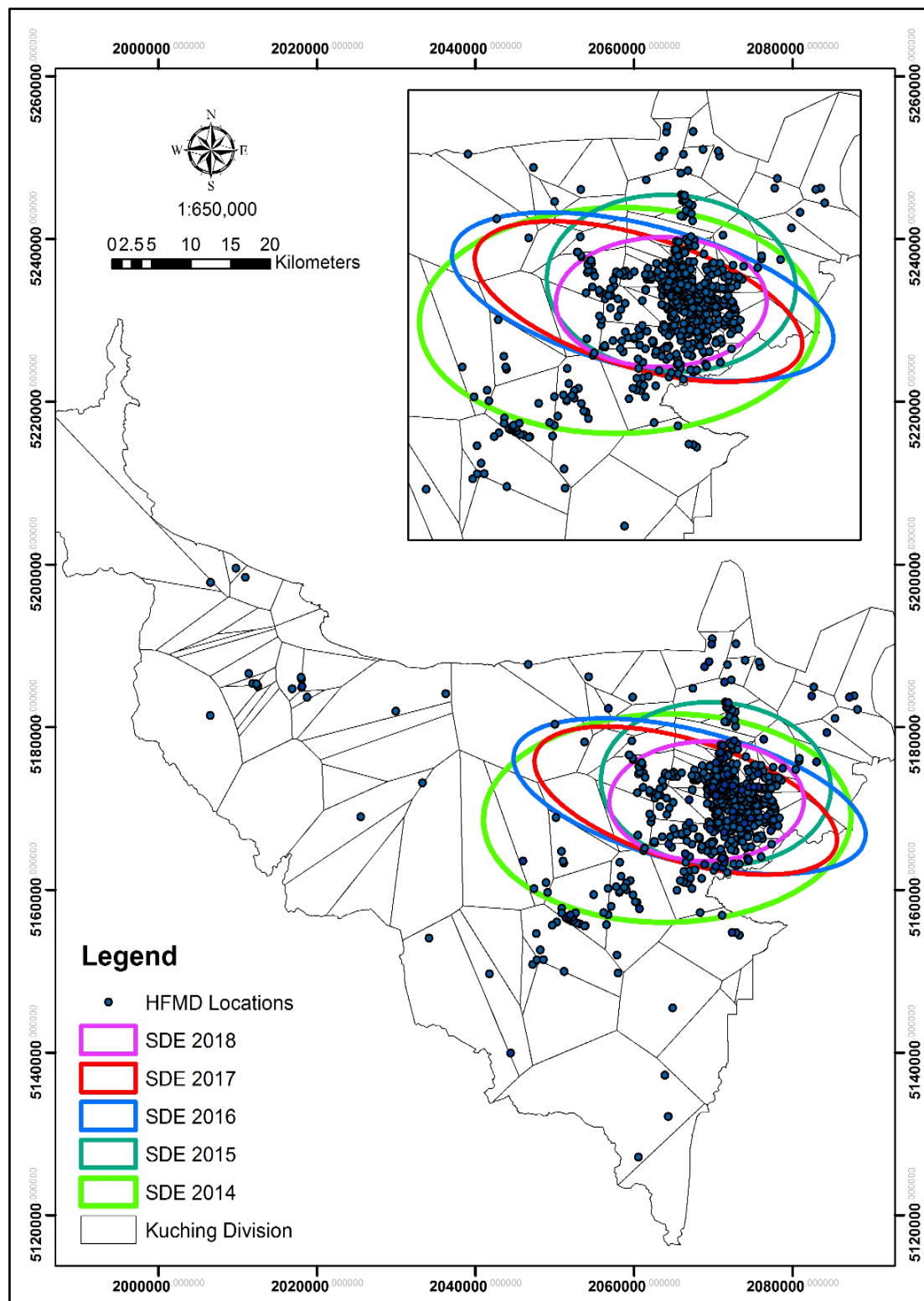


Figure 4.30: HFMD standard deviation ellipse (SDE)

Further analysis using a standard deviation ellipse was conducted to see how far the HFMD spreads from the spatial mean center of HFMD distribution and its direction within

the study area. The HFMD spreading pattern in 2014 was elongated to the west of Kuching division as illustrated in Figure 4.30. The size of the ellipse in 2014 was bigger compared to 2015, which was centered at the eastern part of Kuching division. The revealed pattern describes how far HFMD is transmitted to other areas and which direction it goes. The HFMD occurrences in 2014 was distributed from eastern to west part of Kuching division. Several residential areas were located at this ellipse such as Kampung Matang (V9), Kampung Daun (V31), Kampung Semeba (V35), Kampung Tanjung (V46) and Kampung Tabuan Lalang (V39).

In 2015, the ellipse of HFMD distribution was slightly smaller compared to the ellipse of 2014 and centered at Kuching North City Council and Kuching South City Council. There were 59 residential areas in this ellipse. In 2016, the trend has now changed with the orientation of HFMD distribution which was from northwest to southeast of Kuching division. Similar pattern and trend of HFMD orientation were detected for the year of 2017 and 2018.

Further analysis was conducted to examine the hotspot and coldspot area of HFMD. Hotspot and Coldspot area were grouped as part of spatio-temporal analysis of HFMD. Hotspot area refers to an area that has received a higher number of cases in Kuching division. Hotspot analysis provides the information of the high risk area of HFMD in Kuching division.

Hence, the analysis to identify the high risk area was performed using Getis Ord statistics. The conducted analysis was divided into two categories which was general hotspot from 2014 to 2018 and overall hotspot within the time frame of the study area. Figure 4.32 shows the overall hotspot of HFMD.

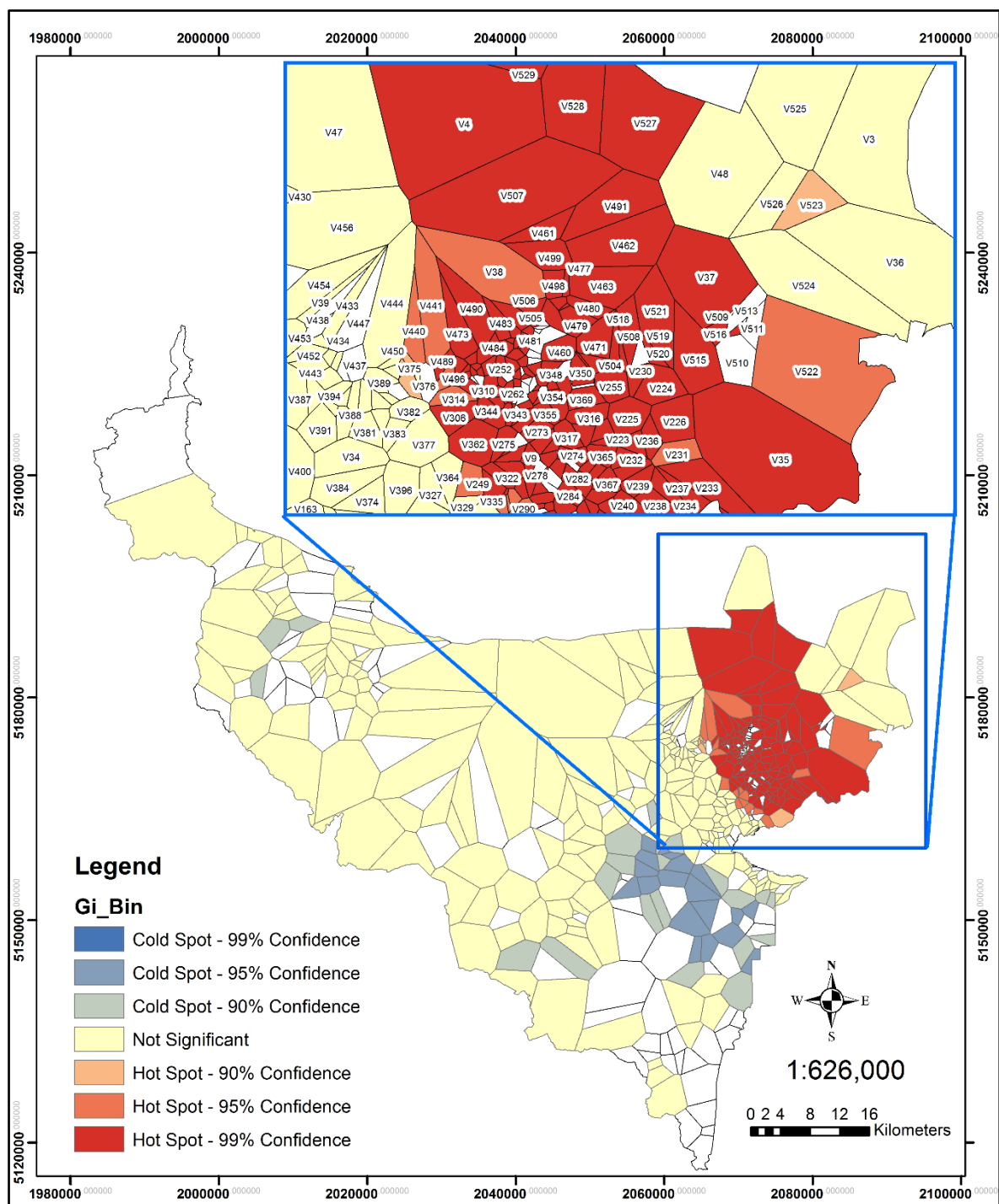


Figure 4.31: Hotspot analysis of all HFMD from 2014 to 2018

As shown in Figure 4.31, the hotspot area was detected at several residential area located at the eastern side of Kuching division. The hotspot area was identified based on the standard deviations (Z Score value) of each HFMD cases recorded by each residential area

compared to the other residential area. The highest number of recorded HFMD cases may not be necessarily be a hotspot area if the neighbouring area records low number of HFMD cases. In this context, the hotspot area was detected happening at 175 residential areas as presented in Table 4.4.

Table 4.4: Hotspot area of HFMD by residential area

ID	Residential Name	ID	Residential Name
V4	Kampung Pasir Pandak	V240	Kampung Stampin
V9	Taman Excella, Jalan Stapok	V241	Taman Long Seng
V25	Kampung Sungai Tapang	V242	Taman Mabel, Kuching
V35	Taman Muara Tabuan	V243	Taman Pandan Jaya
V37	Taman Sepakat Jaya	V244	Taman Monah
V38	Kampung Semariang Pinggir	V245	Taman Long Seng
V47	Kampung Sungai Aur	V246	Taman Long Seng
V48	Bako Bazaar	V247	Taman Paradise, Batu 9
V49	Kampung Budaya Sarawak	V248	Taman Mewah
V192	Taman Golden View	V249	Taman Feild Force
V196	Taman Kalian	V250	Taman Fitrah Kuching
V198	Taman Golden Farm	V251	Taman Ling Ling, Matang
V208	Taman Paradise, 9 1/2 Mile	V252	Taman Matang Baru
V223	Taman Kuching	V253	Taman Lee Ling
V224	Taman Daya	V254	Taman Balijah
V225	Taman Orchid	V255	Taman Demak Indah
V226	Taman Heng Hua	V256	Taman Mas Pertama
V227	Taman Linang	V257	Taman Makmur
V228	Taman Escovilla Stutong	V258	Taman Matang Indah
V229	Taman Centurion	V259	Taman Muhibbah
V230	Taman Riverview	V260	Taman Alamanda
V231	Taman Park View	V261	Taman Duranda
V232	Taman Supreme	V262	Taman Gita Jaya
V233	Taman Stutong Jaya	V263	Taman Akasia
V234	Taman Stutong Indah	V264	Taman Foong Joon,
V235	Taman Stutong Baru	V265	Taman Kenanga
V236	Kampung Tabuan Tengah	V266	Taman Mawar Gita
V237	Kampung Sungai Nada	V267	Taman Mawar
V238	Kampung Sungai Laru	V268	Taman Bunga Raya
V239	Kampung Tabuan Jaya Tengah	V269	Taman Kwong Ming

Table 4.4 continued

ID	Residential Name
V270	Taman Intersar
V271	Taman Evergreen
V272	Taman Hong Nion
V273	Taman Chong Hin
V274	Taman Gan Swee Cho
V275	Taman Datuk
V276	Taman Kapor
V277	Taman Hua
V278	Taman Kit Fah
V279	Taman Ling Hong
V280	Taman Kenny Hill
V281	Taman Kenny Height
V282	Taman Fortune
V283	Taman Kangkok
V284	Taman Major
V285	Taman Budi Jasa
V286	Taman Everbright
V287	Taman Huayau
V288	Taman Hua Yen
V289	Taman Mewah
V290	Taman Flora Indah
V291	Taman Bdc
V292	Taman Mega Juta
V293	Taman Mega Juta
V294	Taman Mega Juta
V295	Taman Desa Wira
V298	Taman Hup Kee
V299	Taman Fook Ngian
V302	Taman Borneo
V304	Taman Emas
V305	Taman Emas
V306	Taman Sri Matang
V307	Taman Trinora
V308	Taman Yen Yen
V309	Taman Sri Permai
V310	Taman Sri Perkasa
V311	Taman Rahmat
V312	Taman Wunmas

ID	Residential Name
V314	Taman Sri Matang
V315	Taman Sri Malaga
V316	Taman Westwood Jalan Tabuan
V317	Taman Ricketts
V318	Taman Rafia 1
V319	Taman Wee&Wee
V320	Taman Top Green
V321	Taman Star
V322	Taman Victoria
V323	Taman Stapok
V324	Taman Stapok
V325	Taman Sunny Hill
V326	Taman Union
V328	Taman Tropimas
V329	Taman Tropimas
V330	Taman Seng Goon
V331	Taman Wawasan
V332	Taman Perumahan Persekutuan
V333	Taman Phonix Garden
V334	Taman Sri Emas
V335	Taman Sri Emas
V336	Taman Satria
V337	Taman Woodland
V338	Taman Perumahan Persekutuan
V339	Taman Perumahan Persekutuan
V340	Taman Sasa
V341	Taman Sejoli
V342	Kampung Tanjung
V343	Kampung Gita Laut
V344	Kampung Gita Lama
V345	Kampung Tupong Hulu
V346	Kampung Lintang
V347	Kampung No 2
V348	Kampung Tupong Batu
V349	Kampung Sungai Bedil
V350	Kampung Istana
V351	Kampung Pinang Jawa
V352	Kampung Laruk Skim

Table 4.4 continued

ID	Residential Name	ID	Residential Name
V314	Taman Sri Matang	V353	Kampung Won
V315	Taman Sri Malaga	V354	Kampung Masjid
V316	Taman Westwood	V355	Kampung Bandarshah
V317	Taman Ricketts	V356	Kampung Sungai Lajim
V318	Taman Rafia 1	V357	Kampung Patingan
V319	Taman Wee & Wee	V358	Kampung No. 6
V320	Taman Top Green	V359	Kampung No. 5
V321	Taman Star,	V360	Kampung No. 3
V322	Taman Victoria	V361	Kampung No. 1
V323	Taman Stapok	V362	Kampung Sungai Maong
V324	Taman Stapok	V363	Kampung Kudei
V325	Taman Sunny Hill	V364	Kampung Stapok
V326	Taman Union	V365	Kampung Kenyalang Park
V328	Taman Tropimas	V366	Kampung Simpang 3
V329	Taman Tropimas	V367	Kampung Tabuan Lalang
V330	Taman Seng Goon	V368	Kampung Cemerlang
V331	Taman Wawasan	V369	Kampung Boyan
V471	Taman Asiah, Jalan Sri Kandis	V376	Taman Jutaria Matang
V333	Taman Phonix Garden	V377	Taman Desa Matang
V334	Taman Sri Emas Batu Kawa	V382	Taman Dusun Indah
V335	Taman Sri Emas	V441	Taman Dahlia, Matang
V336	Taman Satria	V444	Taman Glory
V337	Taman Woodland	V456	Kampung Temenggong
V338	Taman Perumahan Persekutuan	V457	Taman Kasa Jaya
V352	Kampung Laruk Skim	V458	Taman Iwani,
V340	Taman Sasa	V459	Taman Mtg Jaya
V341	Taman Sejoli	V460	Taman Semariang
V342	Kampung Tanjung	V461	Taman Indah
V343	Kampung Gita Laut	V462	Taman Cahaya Indah
V344	Kampung Gita Lama	V463	Taman Carisa
V345	Kampung Tupong Hulu	V464	Taman Gemilang
V346	Kampung Lintang	V465	Taman Haji Lemah
V347	Kampung No 2	V466	Taman Mastura
V348	Kampung Tupong Batu	V467	Taman Mariyam
V349	Kampung Sungai Bedil	V468	Taman Midin
V350	Kampung Istana	V469	Taman Anib
V351	Kampung Pinang Jawa	V470	Taman Haziq

Table 4.4 indicates the statistically significant hotspot with a confident level of 99%. The confident level was based on the Z score value that was greater than +2.58. The cold

spot area was detected at Lundu District Council area. There were several residential areas in this area that were identified with negative Z score value and classified as cold spot area. Table 4.5 shows the residential areas of cold spot area.

Table 4.5: Cold Spot area of HFMD

No	Residential area	ID
1	Kampung Sibatuh	V10
2	Kampung Giam	V80
3	Kampung Siniawan	V175
4	Kampung Peninjau Lama	V183

Further analysis of hotspot area was carried out in order to study the trend of hotspot area over time. The Getis Ord GI* analysis was performed every year starting from 2014 to 2018. Figure 4.32 presents the outcome of hotspot analysis for Kuching division. In 2014, 26 residential areas have been classified as hotspot area. Subsequently in 2015, there were 33 residential areas of hotspot areas identified. Similarly, the trend of hotspot area increases again in the 2016 where 80 residential areas have been classified as hotspot area. On the other hand, year 2017 has seen the improvement of mitigation control in Kuching division. There were only three residential areas that have been classified as hotspot area and two residential areas in 2018.

Based on the output of hotspot analysis from the year 2014 to 2018, it can be concluded that the high concentration of HFMD occurrences were concentrated at the eastern area of Kuching division and these locations were managed by three local councils namely Kuching North City Council, Kuching South City Council and Padawan Municipal Council. All residential areas within Lundu District Council and Bau District Council were the only areas that have not being classified as hotspot area from 2014 to 2018.

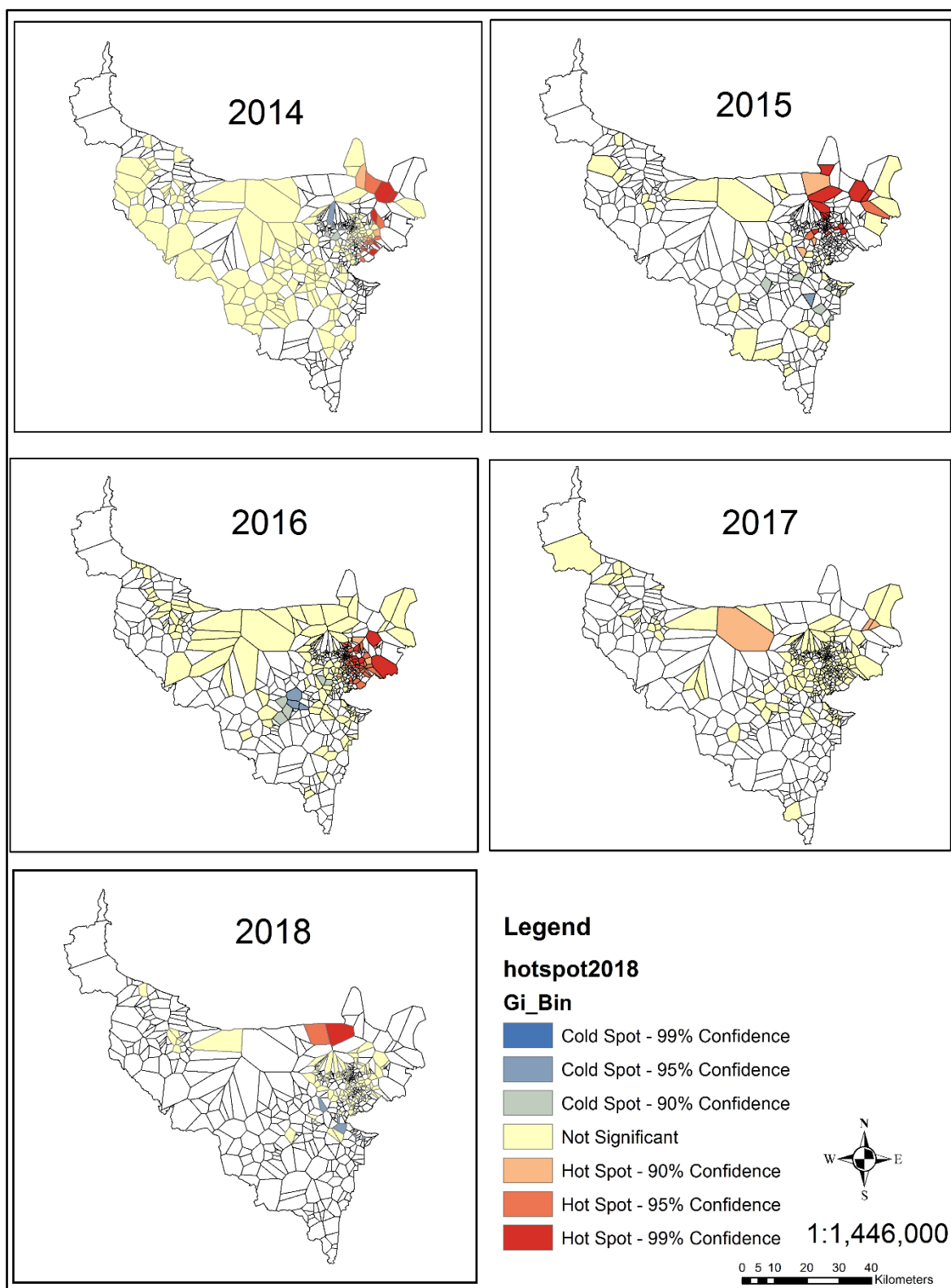


Figure 4.32: Hotspot area by year

The next component of spatio-temporal analysis was the time series analysis of

HFMD occurrences. The temporal patterns or time series analysis of HFMD was conducted based on space time cube model using ArcGIS Pro 2.4. This analysis examined the occurrences of HFMD over time and space from 2014 to 2018. The total number of HFMD cases of each bin (grid) were calculated. Each bin extracted the information of location and time followed by the count of number of cases within each bin. Figure 4.33 shows the concept of space time cube analysis (ESRI, 2019).

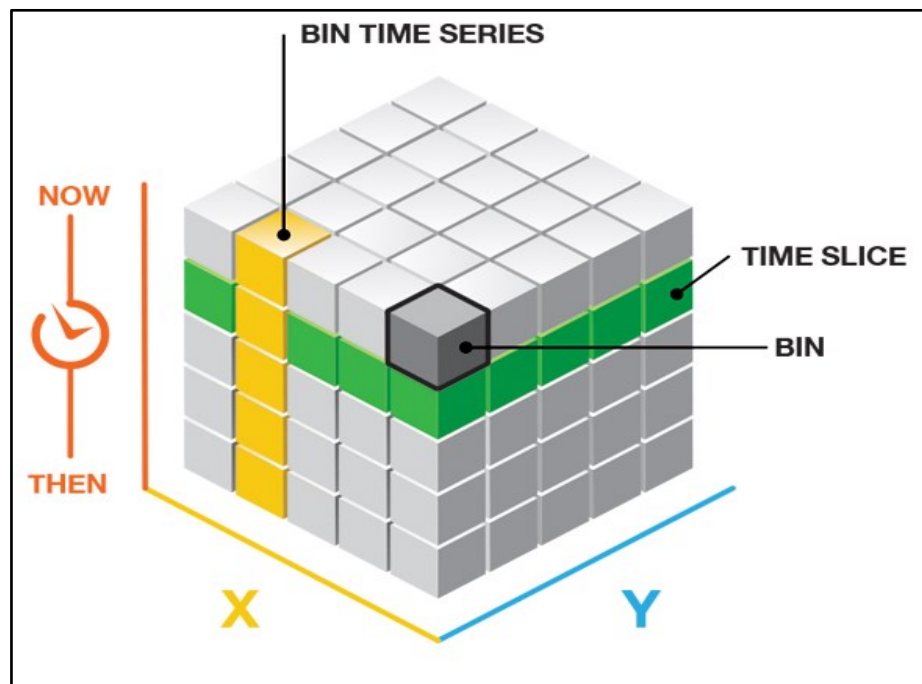


Figure 4.33: Space time cube modeling

Each of HFMD cases were compared to others based on the time series information which was retrieved from the date of HFMD being admitted or registered with Sarawak State Health Department. For every bin or grid, the Mann-Kendall algorithm used in this analysis counts the number of HFMD cases inside the bin and summarises the trend of HFMD cases from there. Figure 4.34 presents the outcome of space time cube analysis for all residential areas within Kuching division.

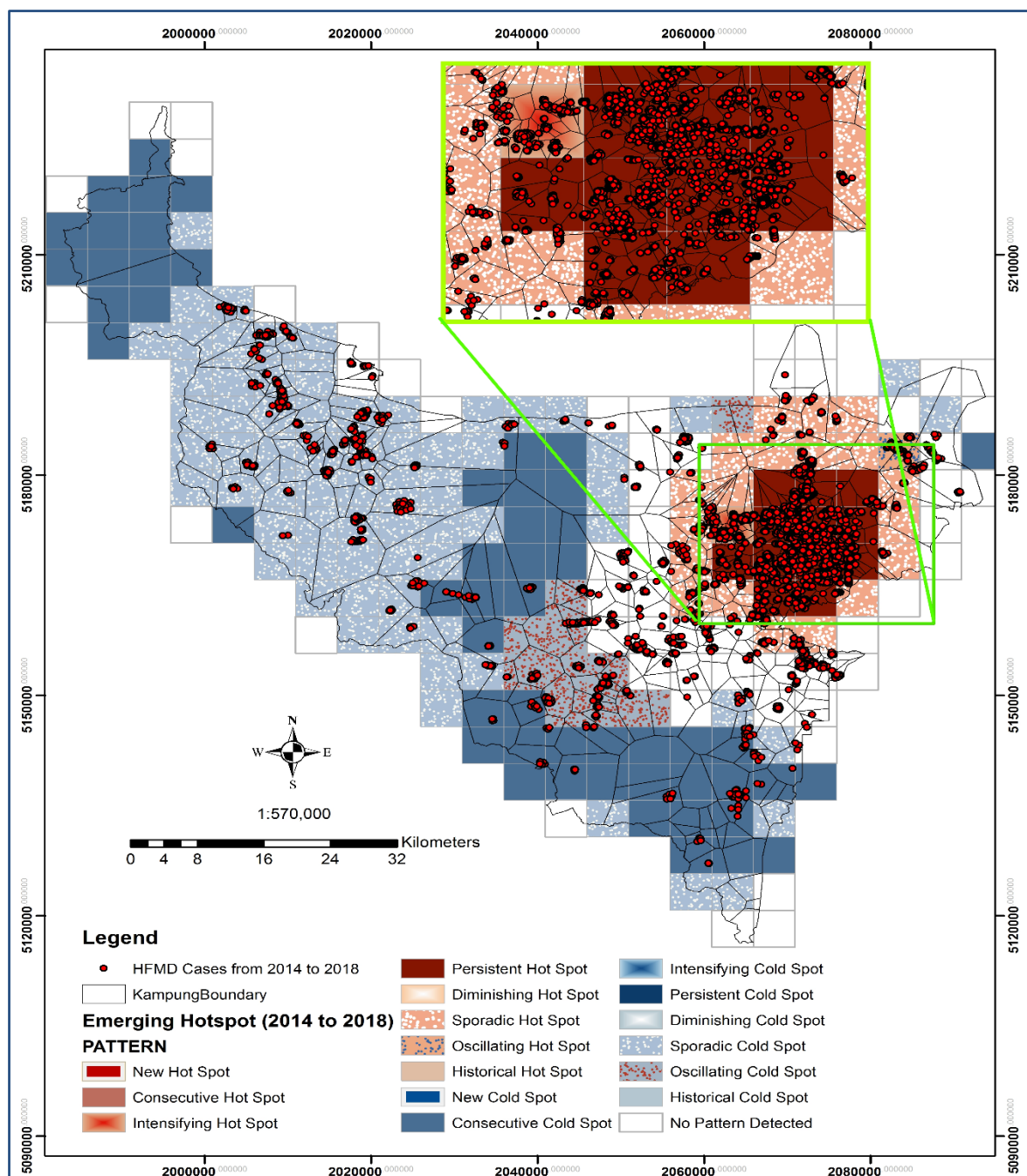


Figure 4.34: Emerging hotspot analysis of HFMD from 2014 to 2018

As shown in Figure 4.34 the pattern of HFMD spreading indicated that most of the cases happened at the eastern part of Kuching division and has been classified as intensifying hotspot, consecutive hotspot, sporadic hotspot and persistent hotspot. Intensifying hotspot is a situation in the area that has been statistically significant hotspot recording high count of

HFMD cases from 2014 to 2018 with 99% of confident level. In other words, these areas have recorded quite a significant amount of HFMD cases every year. Table 4.6 shows the identified intensifying hotspot areas that occurred in eastern part of Kuching division.

Table 4.6: Intensifying hotspot area

No	Residential Name	ID
1	Taman Desa Matang	V377
2	Taman Malihah	V378
3	Taman Murni	V380
4	Taman Dusun Indah	V382
5	Taman Saujana Indah	V388
6	Taman Pandan Jaya	V393
7	Taman Serapi Jaya	V395
8	Taman Putra	V435
9	Taman Matang Ville	V439
10	Taman Matang Ria	V440
11	Taman Dahlia, Matang	V441
12	Taman Harmoni	V446
13	Taman Palma Indah	V447
14	Taman Suria Jaya	V449
15	Taman Sonia	V452
16	Taman Heng Guan Matang	V375
17	Taman Jutaria Matang	V376

On the other hand, from 2014 to 2018, 98 residential areas were observed as having sporadic hotspot based on space time cube model analysis. The sporadic hotspot means between 2014 to 2018, these areas have recorded an intermittent hotspot. These residential areas were Kampung Pasir Pandak (V4), Kampung Sungai Tapang (V25), Kampung Siniawan Lot Melayu (V27), Kampung Buso (V28), Taman Synergy (V34), Taman Muara Tabuan (V35), Kampung Gobielt (V36), Taman Sepakat Jaya (V37), Kampung Semariang Pinggir (V38), Taman Rose (V39), Kampung Sungai Aur (V47), Bako Bazaar (V48), Taman Inling (V89), Taman Eden Feild (V90), Taman Lai Lai (V92), Taman Perwira Landeh (V96), Kampung Sri Arjuna (V101), Kampung Kuap (V106), Taman Stella 2 (V113), Taman

Moyan Jaya (V163), Kampung Melayu Siniawan (V165), Kampung Sungai Pinang Ulu (V166), Kampung Pangkalan Baru (V168), Kampung Batu Kitang Jaya (V169), Kampung Kandis Baru (V170), Kampung Sg. Pinang (V171), Kampung Kandis Lama (V172), Kampung Keranji (V176), Kampung Bunga Rampai (V177), Kampung Bukit Panchor (V178), Kampung Sandong (V179), Kampung Lidah Tanah (V180), Kampung Batu Kitang Lama (V181), Taman Kitang (V187), Taman Muhibbah (V188), Taman Hilldale (V195), Taman Bengoh (V199), Taman Kuap (V201), Taman Kitang (V203), Taman Cin Muk (V204), Taman Kota Padawan (V205), Taman Sri Permai Landeh (V206), Taman Quap (V207), Taman Shee (V217), Kampung Bumbok (V222), Taman Centurion (V229), Taman Stutong Jaya (V233), Taman Stutong Baru (V235), Kampung Sungai Nada (V237), Taman Genesis (V384), Taman Janting Jalan Bt Kawa (V385), Taman Moyan Utama (V386), Taman Banjaran Serapi (V387), Taman Saujana Indah Matang (V390), Taman Saujana Indah (V391), Taman Sarapi Jaya (V394), Taman Serapi Jaya (V395), Taman Vision Lane (V398), Rpr Matang Sungai Tengah 2 (V399), Kampung Sagah (V400), Kampung Tanjong Poting (V401), Kampong Bobak Sejinjang (V402), Kampung Tanjong Bowang (V403), Kampung Senibong (V404), Kampung Bobak Sajong (V405), Kampung Selang (V429), Taman Grandview (V433), Taman Orkid Wood (V434), Taman Fahtah (V438), Taman Matang Ville (V439), Taman Matang Ria (V440), Taman Dahlia (V441), Taman Harmoni (V443), Taman Glory (V444), Taman Palma Indah (V447), Taman Sri Jaya (V448), Taman Sonia (V452), Kampung Matang (V453), Kampung Matang Lot (V454), Kampung Sungai Atas Baru (V455), Kampung Temenggong (V456), Taman Indah (V461), Taman Cahaya Indah (V462), Taman Rassnorm (V491), Kampung Rampangi (V507), Taman Dusun Bayu Demak Laut Jalan Bako Kuching (V509), Taman Dusun Baru (V510), Taman Dusun Bayu Demak Laut (V511), Taman Dusun Bayu (V512), Taman Sepakat Jaya (V513), Taman

Sepakat Jaya (V514), Taman Sepakat Jaya Demak Laut (V516), Kampung Sejingkat (V522), Kampung Senari (V524), Kampung Hijrah (V526), Kampung Buntal (V527), Kampung Sungai Lumut (V528), Kampung Santubong (V529).

Besides sporadic hotspot area, several residential areas were spotted as persistent hotspot. The residential areas were Kampung Sungai Tapang (V25), Taman Synergy (V34), Kampung Semariang Pinggir (V38), Kampung Batu Kitang Jaya (V169), Kampung Lidah Tanah (V180), Taman Semeba (V209) and Kampung Stapok (V364). From 2014 to 2018, these residential areas have been recording HFMD cases consistently.

4.4 Objective Three: Spatial relationship analysis

The Ordinary Least Squares (OLS) linear regression was conducted to model the relationship between HFMD occurrences with water quality index in Kuching division. The water quality index from 2014 to 2018 were obtained from Natural Resource Environmental Board (NREB). Using OLS to model the relationship between water quality index and the HFMD occurrences would reveal the pattern on why HFMD cases occurred at certain area compared to the other areas. Examining this relationship will enable the respective authority concerned to plan their mitigation action more effectively and on alert when certain parameter reaches certain condition.

As elaborated in Chapter 2, microorganism such as Coxsackie and Enteroviruses can live in any condition including contaminated water. Due to the nature of this viruses, it is important to examine if there is any correlation between HFMD cases with the quality of the water that people were consuming from 2014 to 2018. It shall reveal whether it is positive or negative relationship. Water quality in this study focuses on the average water quality that has been recorded by NREB from 2014 to 2018. Water quality index refers to chemical, physical and biological content of river water. It is a tool to quantify the quality of the river

based on certain parameters based on the collected sample from each river station. The collected data from river stations were processed and grouped based on National Water Quality Standards of Malaysia. The interpolation of WQI was performed and Figure 4.36 shows the outcome of the interpolation technique.

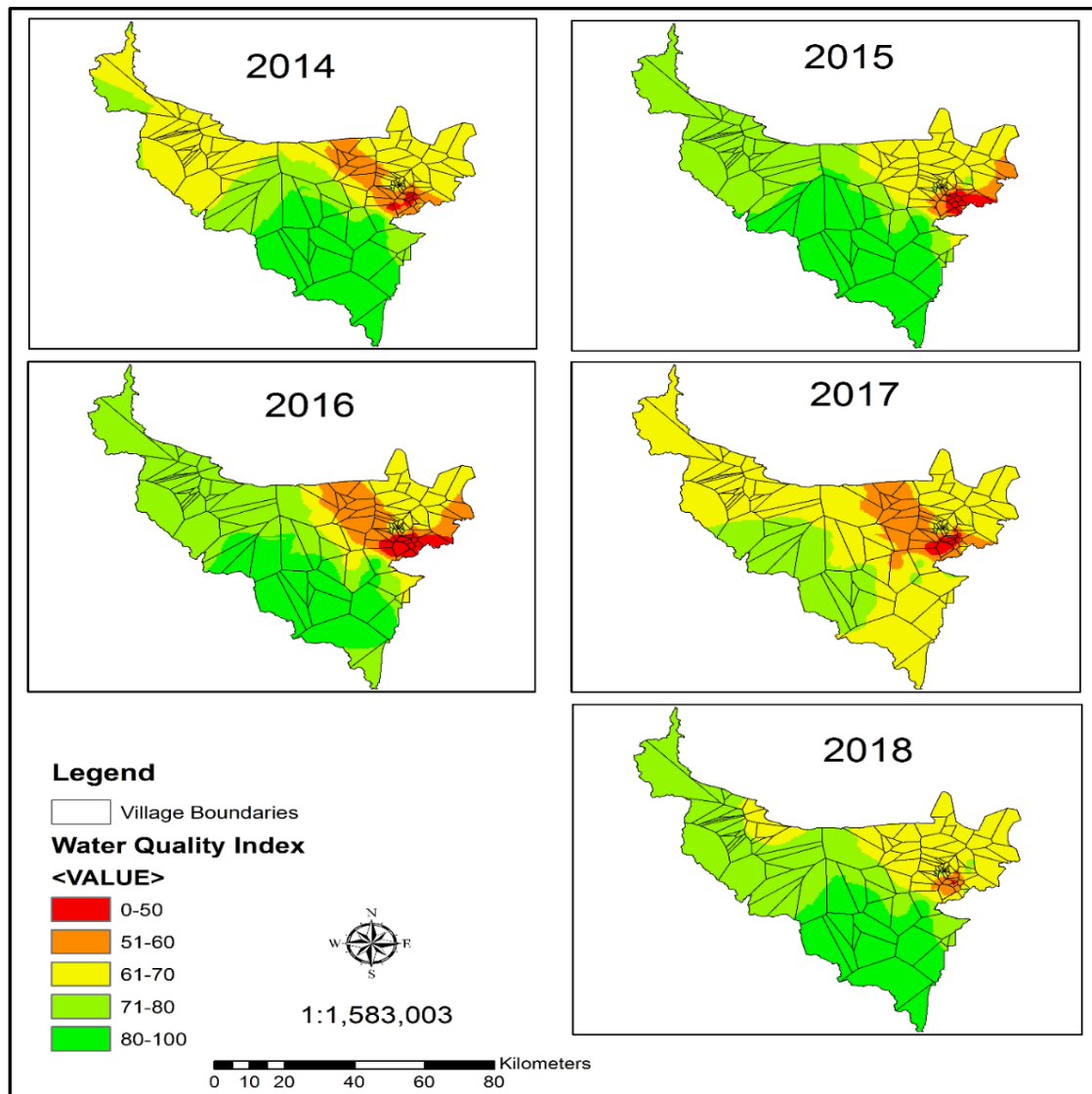


Figure 4.35: IDW of water quality index

Figure 4.35 shows the water quality index in Kuching division from 2014 to 2018. Generally, water quality index for Kuching division falls under the category of Class two, three and Class four. Class two and Class three mean the conventional and extensive

treatment of rivers are required (Department of Environmental Malaysia, 2012). The Ordinary Least Squares (OLS) analysis was performed to examine the spatial relationship of average water quality index (explanatory variable) and HFMD transmission (dependent variable) in Kuching division. Figure 4.36 shows the outcome of OLS analysis.

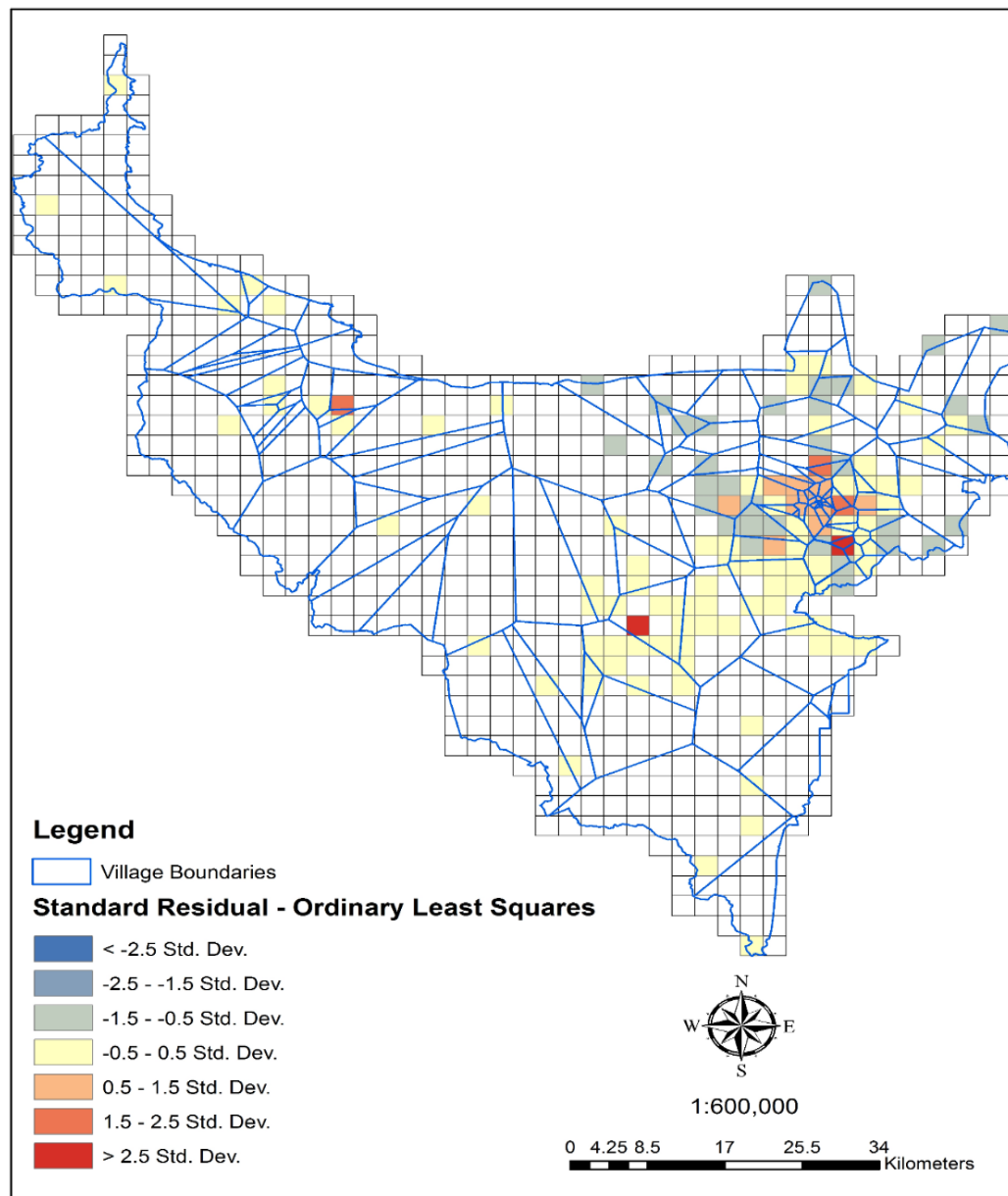


Figure 4.36: OLS standard residual map

Figure 4.36 displays the standard residual map of OLS. The map clearly indicates that the residuals of Over Predictions and Under Predictions were random noise. The red

areas where the observed HFMD value were higher than the predicted model. On the other hand, the blue areas indicate HFMD case were lower than the predicted model. A good model of OLS shall not show the clustering pattern of explanatory variables and a map generated as shown in Figure 4.36 does not show any clustering of standard residual from OLS analysis. It was also proved by the outcome and result from Moran I spatial autocorrelation as shown in Figure 4.37. The Moran's Index indicates that the regression residuals were randomly distributed, and the z-score does not show any statistically significant of clustering and therefore the null hypothesis of regression residuals of complete spatial randomness was accepted.

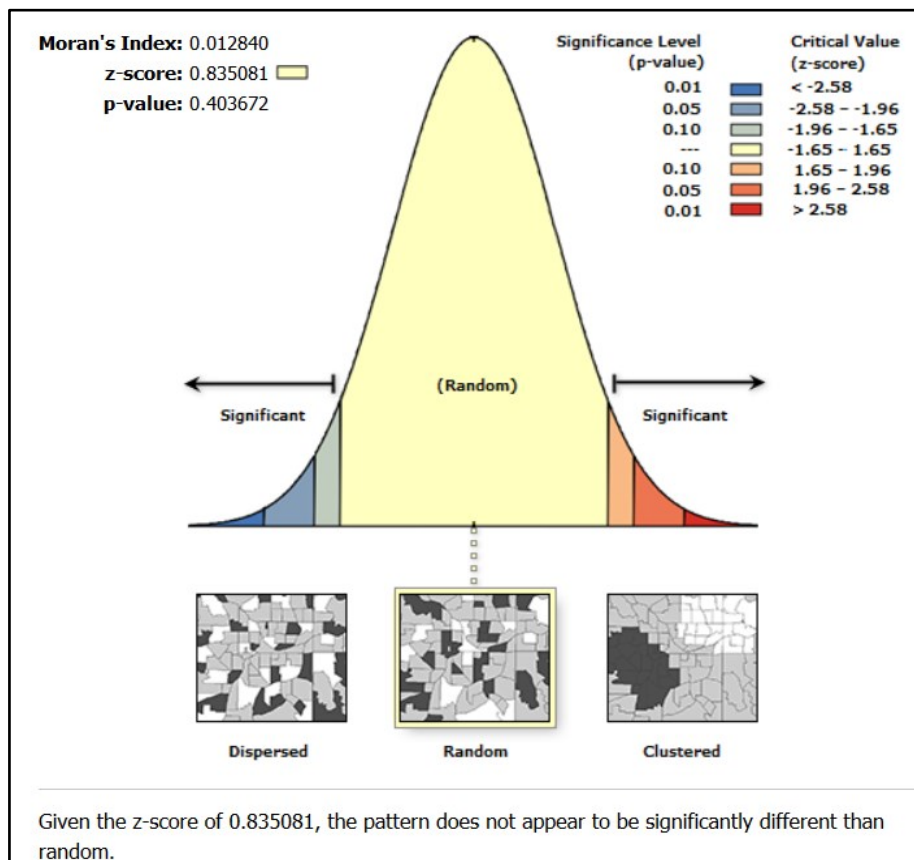


Figure 4.37: Moran's Index of OLS

The outcome of Moran's Index shows that the model of relationship can be trusted. If the regression residual outcome was clustered or dispersed, the model shall be rejected.

Summary of OLS Results - Model Variables								
Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_SE	Robust_t	Robust_Pr [b]	VIF [c]
Intercept	-144.174740	124.716228	-1.156022	0.257442	87.420331	-1.649213	0.110278	-----
WATERQUALITY	46.716847	13.078299	3.572089	0.001306*	13.907149	3.359196	0.002269*	1.147235
OLS Diagnostics								
Input Features:	finalols2019				Dependent Variable:	HFMD		
Number of Observations:	31				Akaike's Information Criterion (AICc) [d]:	322.440954		
Multiple R-Squared [d]:	0.353297				Adjusted R-Squared [d]:	0.307104		
Joint F-Statistic [e]:	7.648266				Prob(>F), (2,28) degrees of freedom:	0.002238*		
Joint Wald Statistic [e]:	13.054743				Prob(>chi-squared), (2) degrees of freedom:	0.001463*		
Koenker (BP) Statistic [f]:	5.039428				Prob(>chi-squared), (2) degrees of freedom:	0.080483		
Jarque-Bera Statistic [g]:	5.876063				Prob(>chi-squared), (2) degrees of freedom:	0.052970		

Figure 4.38: OLS results

Figure 4.38 presents the summary of OLS analysis. Based on the summary result from OLS, it was observed that the coefficient of water quality index shows a positive relationship with HFMD cases. This means that when water quality index changes from class two to class four, the HFMD cases increase too. Based on spatial distribution of HFMD cases, the clustering of HFMD cases was concentrated at the location and area where its water quality index was categorized under class three and four with less HFMD cases reported in the area of class two.

The residential areas located at Bau District Council and Lundu District Council recorded less number of HFMD cases compared to residential areas located in Kuching North City Council and Kuching South City Council. Figure 4.31 and Figure 4.35 illustrate the hotspot areas of HFMD which were located mostly in Kuching North City Council and Kuching South City Council. These were the areas that have their water quality index falls under the category of class three and four. To evaluate the performance of this model based on OLS analysis, the R-squared value was evaluated. The R-Squared valued as stated in

Figure 4.38 was 0.30. The maximum number of adjusted R-Squared value is 1.0. This shows that this model can explain about 30% of the possibility of relation between water quality index and HFMD cases (adjusted R-Squared Value was $0.30 = 30\%$) and the model can be improved if more variables such as information of poverty level or healthcare facilities or any other parameters can be added. The OLS result on the Variance of inflation factor (VIF) for water quality index parameter was 1.14, which was less than 7.5. Any value of VIF that is bigger than 7.5 shall be removed as it does not improve the modelling of correlation between variables and HFMD cases.

4.5 Discussion

As stated in Chapter 2, the epidemiological triangle theory (Stevens, 1960), social determinants of health (World Health Organization, 2005) and Tobler's first law of geography (Tobler, 1970) were used in this study to describe the HFMD cases in Kuching division. The components of these theories namely Agent (Enteroviruses and Coxsackie) and Host (human and animal) are depending very much on the environmental factor that influence them to spread. Enteroviruses 71 and Coxsackie 26 are not able to move to other hosts if there are no conditions that enable them to do so. This is where the environmental factors contribute to the outbreak of HFMD as it provides a platform for the Agent to transmit its diseases. The symbiosis between Agent, Host and Environmental shall determine the rate of HFMD outbreaks.

The conducted analysis revealed that Epidemiological Triangle theory on the environmental component which is also a component under the social determinants of health framework possesses a significant contribution to the rate of HFMD outbreaks. To confirm this assumption, the theory of Tobler's first law of geography, which is "everything is related

to everything else, but near things are more related to distant things” was used. The outcome of Average Nearest Neighbour (ANN) shows that the pattern of HFMD outbreak was clustered. The trend of clustered distribution of HFMD was identified from 2014 to 2018 where it recorded the ANN index Ratio less than 1. The clustered pattern shows that the surrounding environment factor accelerates HFMD outbreaks. This was mentioned by Tobler (1970) where near things are more influential than distant things.

As presented in Figure 4.26, the ANN ratio was from 0.02 until 0.06 from the year 2014 to 2018. Similarly, the Moran’s Index also recorded the same pattern, which was clustered. If ANN studies the distance of geographical location of HFMD cases, the Moran’s Index on the other hand evaluates the number of cases to determine whether the pattern was clustered or randomly distributed. The result from Moran’s Index recorded the index of 0.02 to 0.07, which was less than 1 also confirming the clustered pattern. These two analyses were then supported by Ordinary Least Squares regression and the result of OLS shows that there was a positive relationship between water quality index (Environment) with HFMD cases. Most of the clustered HFMD cases reported at the areas and locations of water quality index were within the category of class four as presented in Figure 4.34 and Figure 4.35.

The interaction of Environment, Agent and Host as stipulated in Epidemiological Triangle theory in this study shows the same results and corresponded with other researches that have been conducted in other places. For instance, a study conducted in Egypt concluded that the waterborne illnesses were due to contaminated water in Middle Delta region (El-Kowranya et al., 2016). Besides a study in Egypt, a recent study in India also reported that there were 9% to 25% of the population was infected by Cholera and 5% to 27% of them were infected by diarrhoea as a result of contaminated water pollution from Tamil Nadu (Gokul et al., 2019).

The outcome of spatial distribution analysis based on age revealed that most of HFMD patients were young infants and young children from the age of below three years old. It was recorded that this group represents 64% (4773 cases) from the total of 7393 HFMD cases in Kuching. This finding was not surprised as similar studies conducted by other researchers revealed the same pattern. According to the study conducted in Hunan province, China from 2013 until 2017 by Qiu et al. (2019), reported that the highest fatality cases of HFMD were from the age group of 3 years old and below. Yang et al. (2017) also reported the similar findings based on South Korean data that the mean age of HFMD patients was 3.5 years old. Another study conducted in China in 2010 by Zhu et al. also showed the same result where the majority of HFMD patients in Central and Southern China were from this group (Zhu et al., 2010).

The HFMD spatial distribution based on local council administration shows that the HFMD cases were highly recorded in central and eastern area of Kuching division, which were located under the jurisdiction of three local councils namely Kuching North City Council, Kuching South City Council and Padawan Municipal Council as illustrated in Figure 4.17.

As presented in Ordinary Least Squares Analysis, the relationship of water quality index and HFMD outbreaks were positive. Based on Figure 4.36, the location of poor water quality index class III was detected at the central and eastern part of Kuching division. According to the Department of Environment Malaysia (2019), Water quality index Class III means the water condition is slightly polluted (WQI between 60 to 80) and polluted (less than 59) requiring an extensive treatment. Contaminated Water is where the Agent (Enteroviruses 71 and Coxsackie A16) can be found easily. Joshi et al. (2018) in their study in Korea has concluded that water quality has a major determinant of HFMD transmission.

A similar pattern and finding was also revealed by Miao et al. (2018) when they conducted a study to associate waterborne diseases with water quality in Tianjin, China. They found out that 79.2% of the water in Tianjin contains enteroviruses.

Additionally, the analysis of spatial distribution of HFMD by ethnic shows that Malay ethnic recorded the highest number of HFMD in Kuching division from 2014 to 2018 and followed by Bidayuh, Chinese and Iban. This analysis was based on how the HFMD cases is being distributed in each residential area spatially. The dominant ethnic that has recorded the highest number of HFMD cases were observed and mapped based on residential areas as illustrated in Figure 4.2.4. A total of 127 residential areas have been identified where the Malays dominate the highest number of cases, 108 residential areas led by the Bidayuh, 80 residential areas by the Chinese, and 36 areas by the Iban. Table 4.7 shows the dominant race reporting HFMD cases by residential areas by ethnic.

Table 4.7: Dominant ethnic of HFMD reported cases by residential areas

Residential Name	Dominant Ethnic of HFMD cases
Kampung Pasir Putih (V3), Kampung Pasir Pandak (V4), Kampung Buang (V6), Kampung Sibatuh (V10), Kampung Siniawan Lot Melayu (V27), Kampung Buso (V28), Taman Synergy (V34), Taman Muara Tabuan (V35), Kampung Gobielt (V36), Taman Sepakat Jaya (V37), Kampung Semariang Pinggir (V38), Taman Rose (V39), Kampung Jaya Bakti (V40), Kampung Gerunggang (V41), Kampung Sungai Aur (V47), Bako Bazaar (V48), Kampung Pandan (V50), Kampung Siru Melayu (V53), Taman Lai Lai (V92), Taman Siburan Baru (V98), Kampung Pengiran (V100), Semenggoh (V112), Kampung Skiat (V127), Kampung Krokong Peros (V130), Kampung Melayu Siniawan (V165), Kampung Batu Kitang Jaya (V169), Kampung Kandis Baru (V170), Kampung Siniawan Seberang (V175), Kampung Bukit Panchor (V178), Kampung Sandong (V179), Kampung Lidah Tanah (V180), Taman Brilliance (V191), Taman Olive (V193), Taman Batu 9 1/2, Jalan Kuching/Serian (V200), Taman Cin Muk (V204), Kampung Semeba (V218), Taman Kuching, Jalan Kuching Bypass (V223), Taman Daya (V224), Taman Orchid, Jalan Foochow No 1 (V225), Taman Park View (V231), Kampung Tabuan Tengah (V236), Kampung Tabuan Jaya Tengah (V239), Taman Long Seng (V241), Taman Pandan Jaya Jalan Matang (V243), Taman Monah, Jalan Serunai (V244), Taman Feild Force, Batu Kawa (V249), Taman Ling Ling, Matang (V251), Taman Matang Baru (V252), Taman Balijah, Off Jalan Mengris (V254), Taman Demak Indah, Jalan Demak (V255), Taman Muhibbah, Jalan Semarak (V259), Taman Petronesa (V483)	Malay

Table 4.7 continued

Residential Name	Dominant Ethnic of HFMD cases
Jalan Semarak (V259), Taman Alamanda (V260), Taman Duranda (V261), Taman Gita Jaya (V262), Taman Akasia, Kampung Pinang Jawa (V263), Taman Foong Joon, (V264), Taman Mawar Gita (V266), Taman Bunga Raya, Kampung Pinang Jawa (V268), Taman Kit Fah (V278), Taman Kenny Hill (V280), Taman Budi Jasa, Jalan Burung Lilin (V285), Taman Bdc (V291), Taman Casa Wira, Jalan Desa Wira, Batu Kawa (V296), Taman Maroon, Jalan Stephen Yong (V303), Taman Emas, Batu 9 1/2, Jalan Penrissen (V304), Taman Sri Matang Kuching (V306), Taman Yen Yen (V308), Taman Sri Perkasa (V310), Taman Ros, Lorong Perupok 2, Jalan Matang 2 1/2 (V313), Taman Sri Matang (V314), Taman Ricketts (V317), Taman Perumahan Persekutuan, Jalan Durian Burung (V332), Kampung Tanjung (V342), Kampung Gita Laut (V343), Kampung Gita Lama (V344), Kampung Tupong Hulu (V345), Kampung Lintang (V346), Kampung No 2 (V347), Kampung Sungai Bedil (V349), Kampung Istana (V350), Kampung Pinang Jawa (V351), Kampung Laruk Skim (V352), Kampung Won (V353), Kampung Masjid (V354), Kampung Bandarshah (V355), Kampung Sungai Lajim (V356), Kampung No. 6 (V358) Kampung No. 3 (V360), Kampung No. 1 (V361), Kampung Sungai Maong (V362), Kampung Kudei (V363), Kampung Stapok (V364), Kampung Simpang 3 (V366), Kampung Boyan (V369), Taman Pelangi Matang (V370), Taman Kimpang Garden, Jalan Matang (V373), Taman Desa Matang (V377), Taman Melisah (V379), Taman Malisah (V380), Taman Murni, Kuching (V381), Taman Genesis (V384), Taman Moyan Utama (V386), Taman Banjaran Serapi (V387), Taman Saujana Indah (V388), Taman Saujana Indah Matang (V390), Taman Saujana Indah, Jalan Matang (V391), Taman Pandan Jaya (V393), Taman Sarapi Jaya (V394), Taman Serapi Jaya (V395), Taman Sejjak Heights (V397), Kampung Bengang (V428), Kampung Selang (V429), Kampung Selang Laut (V430), Kampung Sri Kandong (V431), Taman Jutaria (V432), Taman Putra Jalan Tondong Kuching (V435), Taman Matang Ria (V440), Taman Dahlia, Matang (V441), Taman Hillside Jalan Sungai Tengah (V442), Taman Harmoni (V443), Taman Glory, Jalan Matang, Kuching (V444), Taman Sri Jaya (V448), Taman Suria Jaya (V449), Taman Seri Puteri Kuching Jalan Matang (V450), Taman Suria Indah, Jalan Matang (V451), Kampung Matang (V453), Kampung Matang Lot (V454), Kampung Temenggong (V456), Taman Kasa Jaya Jalan Semariang (V457), Taman Mtg Jaya (V459), Taman Semariang (V460), Taman Indah (V461), Taman Gemilang, Jalan Sungai Tengah (V464), Taman Mastura, Jalan Layang-Layang, Semariang (V466), Taman Mariam, Jalan Tan Sri Abang Ikhwan Zaini (V467), Taman Midin Jalan Camar, Petrajaya (V468), Taman Anib (V469), Taman Haziq (V470), Taman Asiah, Jalan Sri Kandis (V471), Taman Matang Jaya (V473), Taman Madehi (V474), Taman Casandra, Jalan Depo (V475), Taman Hwa Ling, Jalan Matang (V476), Taman Pelita Jaya, Jalan Sultan Tengah (V477), Taman Sukma Jalan Sultan Tengah (V478), Taman. Sukma (V479), Taman Sukma (V480), Taman Wawasan Jaya (V481), Taman Petronesa (V483), Taman Zoriah (V484), Taman Selasih (V485), Taman Pelangi Jalan Matang Kuching (V489), Taman Sri Matang, Jalan Matang (V492), Taman Syn Syn (V493), Taman Sri Wangi (V495), Taman Unique, Jalan Malisah Matang (V496), Taman Peony (V497), Taman Putri (V498), Taman Puteri (V499), Kampung Tupong Tengah (V500), Kampung Malaysia Jaya (V501), Kampung Semerah Padi (V502), Kampung Sungai Midin (V503), Kampung Siol Kandis (V504), Kampung Semariang (V505), Kampung Semariang Batu (V506), Kampung Rampangi (V507), Taman Labunda Jalan Bako (V508), Taman Dusun Bayu Demak Laut Jalan Bako Kuching (V509), Taman Prestema, Jalan Bako, Kuching (V515), Taman Sepakat Jaya Demak Laut (V516), Taman Sourabaya Indah (V517), Taman Sourabaya Landeh (V518)	Malay

Table 4.7 continued

Residential Name	Dominant Ethnic of HFMD cases
Kampung Demak Baru Fasa 1 (V520), Kampung Demak Baru Fasa 2 (V521), Kampung Sejingkat (V522), Taman Mesra Bako (V523), Kampung Senari (V524), Kampung Sungai Bako Jaya (V525), Kampung Hijrah (V526), Kampung Buntal (V527), Kampung Sungai Lumut (V528), Kampung Santubong (V529), Kampung Telaga Air (V530), Kampung Sg. Limo/Kuali, Chupin (V532), Kampung Tabuan Dayak (V537), Kampung Semunin Cina (V541), Kampung Stunggang Melayu (V543), Kampung Semunin Jaya (V544), Kampung Sileng Melayu (V545), Kampung Keranji (V549), Kampung Serayan Hilir (V552), Kampung Jantan (V555), Kampung Trusan Jaya (V558), Kampung Temaga Cina/Dayak (V559), Kampung Tanah Hitam (V565), Kampung Bajo (V570), Taman Lundu Jaya (V5), Kampung Segong (V8), Kampung Sibobog (V12), Kampung Semban (V13), Taman Borneo Heights (V15), Kampung Semadang (V18), Kampung Jagoi Serikin (V21), Kampung Bogag (V22), Kampung Seratau (V24), Kampung Rumih (V29), Kampung Raso Ii (V31), Kampung Bayur (V61), Kampung Jabir (V68), Kampung Parang (V71), Kampung Bengoh (V73), Kampung Padang Pan (V76), Kampung Gumbang (V77), Plaman Monggok (V78), Kampung Tringgus Tabak Rotan (V79), Kampung Giam (V80), Kampung Karu (V83), Kampung Giam Baru (V84), Kampung Sitaang (V86), Kampung Bangau (V87), Taman Millenium (V94), Taman Cavery (V95),	Malay
Kampung Peramas (V103), Kampung Sidanu (V104), Kampung Bratan (V105), Kampung Kuap (V106), Kampung Punau (V107), Kampung Simboh (V111), Taman Stella 2 Jalan Poh Kwong Batu 12 Kuching (V113), Kampung Sebetong (V114), Kampung Grait (V115), Kampung Merimbah (V116), Kampung Kopit (V117), Kampung Skio (V118), Kampung Sogo (V119), Taman Goldhill (V121), Taman Mawar Jalan Jambusan (V124), Kampung Dahan (V126), Kampung Suba Buan (V129), Kampung Bijongon (V131), Kampung Batu Sepit (V132), Kampung Pisa (V134), Kampung Bijuray Mongag (V135), Kampung Blimbun (V136), Kampung Kaman (V137), Kampung Duyoh (V138), Kampung Stass (V139), Kampung Serasot (V140), Kampung Raso I (V142), Kampung Stungkor Baru (V143), Kampung Skibang (V148), Kampung Stenggang (V149), Kampung Tembawang Baru (V151), Kampung Nowang (V152), Kampung Jugan (V155), Kampung Grogo (V158), Kampung Sibuluh (V160), Kampung Apar (V161), Kampung Sudoh (V162), Kampung Sibulung (V167), Kampung Sg. Pinang (V171), Kampung Kandis Lama (V172), Kampung Peninjau Baru (V173), Kampung Podam (V174), Kampung Sega (V182), Kampung Peninjau Lama (V183), Taman Sarmax, Batu 6, 93000 Kuching (V184), Taman Kitang (V185), Taman Kintang, Jalan. Batu Kawah Matang, Kuching. (V190), Taman Hilldale Bt 10 Jalan Penrissen (V195), Taman Kuap, Km 10, Jalan Kuching-Serian (V201), Taman Boulder Built (V202), Taman Kota Padawan (V205), Taman Sri Permai Landeh (V206), Taman Shee, Jalan Batu Kitang (V217), Kampung Semaba (V220), Kampung Tematu (V221), Kampung Bumbok (V222), Kampung Sungai Nada (V237), Taman Emas (V305), Taman Victoria, Jalan Stapok Utama (V322), Taman Tropimas, Jalan Field Force (V329), Taman Green Acres, Matang (V374), Taman Vision Lane (V398), Kampung Sagah (V400), Kampung Bobak Sejinjang (V402), Kampung Barieng (V406), Kampung Daun (V407), Kampung Pasir Hulu (V412), Kampung Sebeban (V419), Kampung Sembawang Besar (V423), Kampung Stunggang Dayak (V424), Taman Sonia, Batu 9, Jalan Matang (V452), Kampung Sebiga Dayak (V542), Kampung Serayan Hulu (V546), Kampung Jampari (V548), Kampung Sedemak (V550), Kampung Sebako (V557), Kampung Serayan Besar (V560), Kampung Sebat Dayak (V567), Kampung Temaga Cina (V568), Kampung Siru Dayak (V571).	Bidayuh

Table 4.7 continued

Residential Name	Dominant Ethnic of HFMD cases
Taman Excella, Jalan Stapok (V9), Taman Mei Lee, Jalan Stakan (V26), Kampung Siluk (V33), Taman Beverly Hills Batu 13, Kuching Serian (V91), Taman Mutiara (V125), Kampung Skiat Lama (V157), Kampung Suba Bandar (V159), Taman Moyan Jaya (V163), Taman Siniawan (V164), Kampung Pangkalan Baru (V168), Taman Olive Batu 7, Jalan Penrissen (V194), Taman Kalian, Jalan Sungai Tapang Bt.7 (V196), Taman Kalien, Jalan Sungai Tapang (V197), Taman Golden Farm, Batu 11 1/2, Jalan Kuching-Serian (V198), Taman Paradise, 9 1/2 Mile (V208), Taman Victory, Jalan Semeba, Kuching (V210), Taman Sentosa Phase 1, Batu 8 1/2, Jalan Penrissen (V212), Taman Wei Leong Jalan Stakan Batu 7 (V215), Taman Linang, Jalan Wan Alwi (V227), Taman Escovilla Stutong (V228), Taman Centurion, Jalan Stutong (V229), Taman Riverview (V230), Taman Supreme (V232), Taman Stutong Jaya (V233), Taman Stutong Indah (V234), Taman Stutong Baru (V235), Kampung Sungai Laru (V238), Kampung Stampin (V240), Taman Mabel, Kuching (V242), Taman Paradise, Batu 9 (V247), Taman Lee Ling (V253), Taman Kwong Ming Jalan Pending (V269), Taman Intersar (V270), Taman Evergreen Jalan Nanas Barat (V271), Taman Hong Nion (V272), Taman Chong Hin, Jalan Pisang Barat (V273), Taman Gan Swee Cho (V274), Taman Datuk Temenggong Tan Meng Chong (V275), Taman Hua, Lorong Poh Kwong Bt 12 (V277), Taman Fortune, Jalan Laksamana Cheng Ho (V282), Taman Kangkok (V283), Taman Major, Jalan Sharif Masahor (V284), Taman Everbright (V286), Taman Huayau Jalan Arang (V287), Taman Mewah, Jalan Arang (V289), Taman Mega Juta, Lorong 1, Jalan Batu Kawa (V292), Taman Bumiko, Desa Wira (V297), Taman Fook Ngian Jalan Benggang Kuching (V299), Taman Khung Phin (V300), Taman How Ching, Jalan Stephen Yong (V301), Taman Westwood Jalan Tabuan (V316), Taman Rafia 1, Jalan Manggeris, Petra Jaya (V318), Taman Wee&Wee, Jalan Kapor (V319), Taman Top Green, Jalan Kapor (V320), Taman Star, Jalan Sky Garden (V321), Taman Union, Jalan Stapok Selatan (V326), Taman Sri Segedup (V327), Taman Seng Goon (V330), Taman Wawasan, Jalan Arang (V331), Taman Phonix Garden, Jalan Batu Kawa (V333), Taman Sri Emas Batu Kawa (V334), Taman Satria (V336), Taman Woodland, Jalan Stutong (V337), Taman Perumahan Persekutuan, Stampin (V338), Taman Sasa (V340), Kampung Kenyalang Park (V365), Kampung Tabuan Lalang (V367), Kampung Cemerlang (V368), Taman Serapi, Kuching (V371), Taman Heng Guan Matang (V375), Taman Dusun Indah (V382), Taman Dusun Dinda (V383), Taman Janting Jalan Bt Kawa (V385), Taman Prc, Jalan Matang Batu Kawa (V389), Taman Sri Moyan (V396), Rpr Matang Sungai Tengah 2 (V399), Taman Crescent, Jalan Matang (V446), Kampung Sileng Dayak (V533), Kampung Sembawang Kecil (V540)	Chinese
Kampung Jambu (V17), Kampung Sungai Tapang (V25), Kampung Kendaie (V32), Kampung Budaya Sarawak (V49), Kampung Assum (V65), Taman Inling, Lorong 1, Batu 12 (V89), Taman Perwira Landeh (V96), Taman Penrissen (V97), Kampung Sinar Baru (V102), Kampung Git (V120), Kampung Keranji (V176), Taman Tematu Hill Jalan Datuk Stephen Yong (V213), Taman Heng Hua, Jalan Sungai Apong (V226), Taman Long Seng (V245), Taman Fitrah Kuching (V250), Taman Flora Indah Jalan Arang (V290), Taman Desa Wira (V295), Taman Borneo, Lorong Lapangan Terbang (V302), Taman Stapok (V324), Taman Sunny Hill (V325), Taman Tropimas (V328), Taman Sri Emas Jalan Batu Kawa (V335), Taman Punica, Jalan Batu Kawa Matang (V372), Taman Pandan Jaya, Malihah (V392), Kampung Tanjong Poting (V401), Kampung Tanjong Bowang (V403), Kampung Sebandi Hulu (V420), Kampung Stunggang Ulu (V426), Kampung Senibong (V427), Taman Grandview.	Iban

Table 4.7 continued

Residential Name	Dominant Ethnic of HFMD cases
Jalan Matang (V433), Taman Matang Ville (V439), Taman Carisa (V463), Taman Zokiah (V490), Taman Rassnorm (V491), Kampung Sekambal (V536), Kampung Perundang (V553).	Iban

In terms of gender assessment on HFMD cases, it was found that male dominated the HFMD cases as compared to female. Figure 4.18 clearly indicated that male has dominating close to 56% of the total case of HFMD in Kuching division. The outcome of gender analysis appears to be the same with the existing studies conducted in other countries. For example, a study conducted in Taiwan from 1998 to 2005 found out that the ratio of male to female was 2.5:1 (Chen et al., 2007). The same results happened in the study conducted in Mainland China from 2008 to 2009. It was recorded that male dominated the HFMD cases by 65% as compared to female (Zhu, 2011). The interesting question to ask would be why male has always recorded the highest number of HFMD cases as compared to female? A study conducted by a scientist in Standford University School of Medicine may have the answer to this problem. According to this study, female has stronger antibody response when it comes to vaccine compared to male (Goldman, 2013). This statement was then supported by the recent study conducted in Bloomberg School of Public Health where it concluded that male has lower antibody response to the vaccine as compared to female (Johns Hopkins University Bloomberg School of Public Health, 2019). This revealed as to why the HFMD cases are more dominant to male as opposed to female

In terms of spatiotemporal HFMD distributions, it appears that the emerging hotspot from 2014 to 2018 were concentrated at the central and eastern part of Kuching division. The emerging hotspot analysis which was based on Mann-Kendall statistic creates space

time cube model by calculating the incident of HFMD from January 2014 to December 2018. 41 Residential areas have been identified as hotspot areas in Kuching division as presented in Table 4.6 and Figure 4.34 for the map of emerging hotspot analysis output. The intensifying hotspot was located at the central and eastern part of Kuching division, an area of where Kuching City is administrated. As the capital city of Sarawak, it was not a surprise that 325,132 people representing 13% of the Sarawak total population has recorded the highest number of HFMD as compared to other divisions (Sarawak State Health Department, 2019). With the rapid development of infrastructures in Kuching division, the mobilization of infected young children and infant has become so easy and that makes it hard to control. The infected HFMD carries the Enteroviruses 71 and Coxsackie 16 as they mobilize from one place to another and may transmit HFMD to those who interact physically with them.

4.6 Chapter Summary

Epidemiological Triangle framework (Stevens, 1960) and Social determinants of health (World Health Organization, 2005) were evaluated and used in this study. The three main components of these frameworks namely Host, Agent and Environment were tested based on HFMD reported cases in Kuching division. The host component was represented by human and animal whereby Agent was represented by Enteroviruses 71 and Coxsackie 16. On the other hand, Environment was represented by water quality index. Several analyses have been conducted to evaluate the effectiveness of epidemiological triangle framework to reveal the issue related to HFMD. The data driven analysis powered by GIS such as Nearest Neighbour Analysis and Moran's Index concluded the clustering pattern of HFMD and that explains the strength of environmental component of epidemiological triangle and social determinants of health where the in-situ condition has more influence and prominence to the rate HFMD outbreaks. The relationship of each variable which was water

quality index was evaluated to examine the strength of epidemical triangle model and social determinants of health and the result has confirmed the positive relationship between these variables. This means that the increase of HFMD cases in Kuching division is a proportionated to the increase of water quality index. This statement was supported with the outcome of Mann-Kendall analysis in Space Time Cube analysis on emerging hotspot from January 2014 to December 2018. In a nutshell, GIS is a powerful tool that can be used to address public health issue particularly in the areas of HFMD. Its beyond mapping as the capability of GIS to perform advanced analysis and modelling have made this technology a hot demand.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary and conclusion of the conducted research on HFMD in Kuching division. It also discusses limitations, findings and recommendation for future research. The findings from this study may improve and enhance decision making process especially when it comes to mitigation planning. The identified hotspot area in Kuching division indirectly revealed the high risk area of HFMD. This information can be used as reference for the authorized parties concerned to prepare details planning to control HFMD.

5.2 Research summary

HFMD is a dangerous disease if it is not treated properly as it can lead to serious complications and can cause death too (Zheng et al., 2017). It is not only happening in developing countries like Malaysia and Indonesia but also in developed countries such as Singapore, China and Japan (World Health Organization, 2019). Despite the cruciality of this disease that can cause death, the understanding on how it was spatially distributed in Kuching division is very limited. Unavailability of this information may contribute to the lack of decision-making process when it comes to mitigation planning.

As a result of this current situation, this study was conducted to evaluate and assess the spatial pattern of HFMD in Kuching division and at the same time to model the correlation of HFMD with water quality index in order to identity the high risk area of HFMD. Several research questions have been set and used as a guideline to meet the research

objectives. The first question was about the availability of GIS data Model that can be used for the purpose of analyzing HFMD outbreaks. Bad data model will always produce bad result too (Shelley, 2018). Therefore, it is essential that a proper GIS data model that can be identified and used for HFMD study not only to cater the current requirements but also for future study when it is available. Subsequently, the second question was set to address the spatiotemporal spreading patterns of HFMD in Kuching division from 2014 to 2018.

This is an important question as it provides vital information for precautionary measures to be taken to combat HFMD. By understanding the pattern of HFMD, it will improve the mitigation planning (Yazici, 2017). The next question asked was the relationship between environmental conditions with HFMD incidents. This question tries to link the “why” scenario of HFMD outbreaks. By using Epidemiological triangle (Stevens, 1960) as a framework, the water quality index was reviewed and grouped as environmental factor, besides Agent and Host.

GIS technology has been selected and used in this study particularly to answer the questions addressed in this study. There is no doubt that GIS is one of the best technology that can be used to process, model, analyze and visualize any geographical elements including HFMD distribution. Several GIS techniques were used in this study namely Nearest Neighbour Analysis, GIS interpolation, Spatial Autocorrelation, Space time cube analysis, Hotspot analysis using Getis Ord GI* and Ordinary Least Squares analysis. Nearest Neighbour Analysis was used to calculate the positional location of each HFMD cases to determine the patterns of HFMD distribution whether it exhibit the clustering, randomly distributed or dispersed distribution pattern. GIS interpolation on the other hand was used to interpolate the point location of water quality index to become a raster surface data. By using Water quality sampling station data, surface data for Kuching division was generated.

In the process of confirming the pattern of HFMD distributions, Moran's Index was used in spatial autocorrelation analysis. Moran's Index studies the strength of the HFMD cases based on the number of registered cases per residential area. If Moran's index is more than 0 it will be considered as clustered and if the index value is less than 0, it exhibits a dispersed HFMD pattern.

The other GIS technique used in this study was Getis Ord G_i^* analysis. This analysis focuses on identifying the hotspot area of HFMD. The hotspot area is classified based on the value of each feature and will be categorized as hotspot if the feature value is high and at the same time surrounded by other feature with high value too. After Getis Ord G_i^* was performed, Mann-Kendall statistic was performed for emerging hotspot analysis. This model also known as space time cube analysis was executed to analyze the trend and pattern from the year 2014 to 2018. The hotspot area from 2014 to 2018 was compared and the outcome of this analysis revealed the trend and pattern of the hotspot whether it consistently happened at the same areas and locations.

The last technique of GIS employed in this study was Ordinary Least Squares Analysis. The linear regression analysis was used to evaluate the relationship between HFMD occurrences with water quality index. The outcome of this analysis revealed and confirmed whether HFMD cases have significant relationship statistically with water quality index.

5.3 Findings and Contributions

5.3.1 GIS Data Model

The development of GIS data model is crucial as it determines the level of accuracy of the analysis. The accuracy of the Data does not rely solely on positional accuracy of

HFMD reported cases on the ground, but also the attribute information that has been collected. For the purpose of supporting the objective of this study, several themes of layers have been identified and proposed. Among others were facilities, environment, school and child care centres, transportation, demographic and HFMD themes. Each of these themes came together with entity-relationship structure.

From the contribution of body of knowledge, especially in the area of spatial epidemiology, the proposed GIS Data model provides framework for researchers to use as a guide for them to jump start in designing their analysis from spatial perspective. The proposed Data model was designed to be flexible so that it can be incorporated with future data model requirements. The technical specification of spatial data requirements that zoom to feature types, scale, and coordinate systems to be used will definitely help researchers with basic requirements to develop GIS Datasets in the area of GIS in public health applications.

5.3.2 Spatio-Temporal pattern of HFMD

Several GIS techniques have been used in this study in order to identify the high risk area of HFMD in Kuching division. The Average Nearest Neighbour Index and Moran's Index analysis have been used because of the ability to measure and detect the patterns based on the distribution of HFMD cases on the ground. The results shows that the pattern of HFMD distribution was clustered. This has been confirmed from the index calculated from Average Nearest Neighbour analysis which was within 0.02 to 0.06 from 2014 to 2018. Any value of Average Nearest Neighbour index that is less than 1 was classified as clustered. This pattern supported by Moran's Index where the value calculated is less than 1 which was from 0.02 to 0.02. The positive value of Moran's index indicated clustering pattern. The

result of clustering pattern has answered the second objective of this study which is to examine the spatial pattern of HFMD cases in Kuching division.

From the contribution of knowledge, the detected pattern of HFMD may help the respective authorities concern to prepare their mitigation plan effectively. The information given will enable them to focus more on the area that has recorded the highest number of HFMD cases. For example, from 2014 to 2018, Kuching North City Council administrative boundary has recorded the highest number of cases which were 633 cases in 2014 and 831 cases in 2015. In 2016, an area administered by Kuching South City has recorded the highest number of cases which were 802 cases.

On the other hand, Padawan Municipal Council has taken the lead from Kuching South City Council in 2017 and 2018 where it recorded the highest number of cases in 2017 which is 918 cases and 398 cases in 2018. Further analysis was conducted to identify the HFMD cases by gender. It was recorded that Male has dominated the case of HFMD in Kuching division.

From 2014 to 2018, Lundu has recorded 579 cases of HFMD of which 320 were male. The same case happened in Kuching North City Council and Kuching South City Council administrative areas where it has recorded 5571 cases on which 3107 cases were male. Besides Gender, the analysis on age distributions recorded that there were 50% of the cases which were 4527 cases were at the age below 2 years old.

This was then followed by the group of 3 to 4 years old who contributed to 27% of the total case of 9232 HFMD cases in Kuching division. In the case of ethnic distribution, the Malays recorded the highest number of HFMD from 2014 to 2018 in Kuching division, which has recorded 4529 equivalents with 48% of total 9297 cases. It was then followed by the Bidayuh (20%) and the Chinese (18%).

Additionally, the detected spatio-temporal pattern also revealed that certain areas in Kuching division had recorded the case of HFMD every year from 2014 to 2018. Based on Spatial Mean Center analysis from 2014 to 2018, it was detected that the case of HFMD located at the three residential areas namely Kampung Segedup, Kampung Sungai Maong and Kampung Laruh Skim.

The Standard Deviation Ellipse was also conducted to see the trend of HFMD occurrences within the study area. In 2014 for example, the case of HFMD was elongated to the west, in 2015 the ellipse was centered in Kuching North City Council and Kuching South City Council areas. From 2016 and 2018 the orientation of HFMD was more towards the northwest to southwest of Kuching division. The hotspot area of HFMD from 2014 to 2018 were concentrated at the 42 residential areas which were located at the central and eastern part of Kuching division, primarily under the jurisdiction of Kuching North City Council and Kuching South City Council.

Apart from the contribution of body of knowledge in the area of epidemiology in HFMD occurrences in Kuching division, this study also introduced a technique to generate an artificial boundary of residential area in the study area. The artificial boundary of each residential area was generated as a result of non-availability of residential area boundary. The boundary of the residential area in Kuching division was never being gazetted at the time this study was conducted.

By using Thiessen Polygon method as an alternative, the issue of not being able to identify the boundary of any area of interest can be resolved. For example, Sarawak State Health Department may use Thiessen polygon method to draw the boundary of service for each clinic and that will help them to plan their resources effectively.

5.3.3 Spatial relationship Analysis

The modelling of Spatial relationship between HFMD and water quality index may provide an insight on how HFMD is distributed. The conducted analysis was based on epidemiological triangle framework popular by Stevens (1960). According to this theory, environmental factor has significant influence on disease outbreaks. From the OLS analysis, it was observed that the coefficient of water quality index was positive value, which was 4.3. This indicates that when water quality increase, HFMD will increase too. This is then supported by Variance of Inflation factor (VIF) for water quality index that is less than 7.5. Any variables that is more than 7.5 shall be removed as it is not significant to the predicted model.

5.4 Recommendation

While this study has successfully answer several research questions and met the objective of the research, there were several areas that can be improved for better result. One of the limitations that has been identified was the availability of residential area boundary. Due to unavailability of this boundary, the precise location of HFMD outbreak based on residential area became very difficult to identity. Thank to GIS as it functions to create an artificial boundary of each residential area based on Thiessen polygon Method. Although this method may not represent the actual boundary of each residential area, it was sufficient to be used as a guide and reference. Therefore, for future study, it is hoped that the actual and gazetted boundary of each residential areas can be used to analyze the HFMD outbreak at the micro level.

Other than that, it is also hoped that the Sarawak State Health Department could enforce and amend the policy to capture the coordinate system of each HFMD cases. During

the interview with the officer in charge in Sarawak State Health Department, the coordinate system of HFMD cases will be captured if it is a clustered case. In other words, if there is no cluster case of HFMD reported, there will be no coordinate system of location of HFMD cases captured. By having this policy, it will limit the capability of future analysis. The coordinate of HFMD cases should be captured regardless if there is clustered or randomly distributed as it might be useful for future analysis. With GPS coordinate available for HFMD cases, the distribution of HFMD cases on the ground can be visualized geographically. Some case may not be necessarily clustered but was happening exactly at the same spot and therefore it is important to capture each case.

It was observed that almost 40% of the data obtained from Sarawak State Health Department does not contain any coordinate system. As a result of this, address geocoding based on the availability of patient's address was used. Using address as a reference for georeferencing of HFMD cases on the ground introduced some level of accuracy compromisation. To maintain the positional accuracy of HFMD cases, it is hoped that in the future Sarawak State Health Department shall capture the coordinates of every cases by using standard GPS device with horizontal accuracy of ± 5 meters.

Besides coordinate system, the availability of population data in GIS format can be made available for future study. As for today, the census block of population has not been made available for the public or academic study to use. Therefore, it limits the capability to analyze the population data by residential areas. If the data of census block is available from Department of Statistics Malaysia, local assessment based on census block can be performed.

For the purpose of evaluating the performance of epidemiological triangle theory of HFMD, it is suggested that future research should also include other variables. In this study

there was only one variable to be used which was water quality index. To get better result, there are other parameters that can be considered such as poverty level, health accessibility, school and childcare centres condition, transportation network, rainfall and humidity level.

In terms of research implication, the identified clustered pattern of HFMD in Kuching division from 2014 to 2018 will certainly help the responsible authorities concern to prepare a better plan to mitigate and focus more on the sensitive area or hotspot area of HFMD. The intensified hotspot revealed the sensitive area of HFMD. As mentioned in Chapter 4, intensified hotspot area was the area that received a high number of HFMD every year thus provide a good information for respective authorities concern to focus more on this particular area.

Public awareness campaign can be conducted in this particular area as this is the targeted area of HFMD. With the constant public awareness campaign conducted at the hotspot area, it can reduce a number of HFMD case. This strategy is based on what has been conducted in other countries. For instance, the continuous campaign in New York City about the danger of tobacco in 2002 has seen the Tobacco business reduced significantly in 2003 (Stopka et al., 2014). A study conducted in Azerbaijan also reported the success rate of constant public awareness in preventing Rabies outbreaks was higher as a result of effective public campaign. It has recorded that 80% of the people in Gakh and Sheki, Azerbaijan has their dog vaccinated as compared to 52% of dogs in Ogus and Gabala where public awareness was very low (Hasanov et al., 2017).

Besides public awareness campaign at the targeted areas, this study also proved that HFMD occurrences have significant relationship with water quality index. This can be an early warning system to the respective authorities concern to be on alert with the condition of water quality especially at the water treatment plan and also well prepared when the water

quality reached certain index. A study conducted in Pakistan has proved that consuming contaminated drinking water had contribute 33% of deaths (Daud et al., 2017).

The revealed pattern from this study also helps the respective authorities concern to change the approach of collecting data for future analysis. The collected data with coordinates only represents 40% of the total cases. The remaining 60% were geocoded based on the addresses given. This shows that the clustered case is not only the 40% cases recorded by Sarawak State Health Department as the 60% cases might have the same trend and pattern too.

5.5 Chapter Summary

To conclude, GIS plays a major role when it comes to spatial data analytics. At present, there are no other tools that offer these capabilities in the market. Certainly, this unique feature of GIS makes it different from the rest. Thus, this undeniably proves that GIS is worthwhile for public health agencies and organizations to use this technology in supporting their current business operations including to prepare a mitigation plan to prevent the outbreak of HFMD in future. The epidemiological triangle framework on the other hand provide a very good foundation of how HFMD study can be conducted. The outcome of conducted analysis confirms that HFMD outbreaks does relate to environmental situation, apart from Host and Agent factors.

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