UNIVERSITI PUTRA MALAYSIA

MAPPING DENGUE RISK HOTSPOTS BASED ON SOCIOLOGICAL, ENVIRONMENTAL AND CLIMATIC FACTORS USING GEOGRAPHICAL INFORMATION SYSTEM

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By

RUHIL AMAL BINTI ADNAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Dengue fever (DF) and dengue haemorrhagic fever (DHF) continue to be major public health problems in Malaysia. These vector-borne diseases are transmitted by *Aedes aegypti* (*Ae.* aegypti) and *Aedes albopictus* (*Ae. albopictus*). Until today, there is no vaccine to control the outbreaks of DF and DHF. The better understanding of relationship between vectors, risk factors and infected human is crucial in devising strategy to control dengue.The main objective of this study is to develop dengue risk map based on sociological, environmental and climatic factors at hotspot areas for dengue transmission by using Geographical Information System (GIS). This research was carried out at three different localities; residential areas, routine areas and intersect areas. The mapping of transmission areas was produced based on interview with three hundred and seventy-nine respondents with dengue history from Parliament Batu and Parliament Wangsa Maju. The ovitrap survey was conducted as indicator for *Aedes* mosquito detection. The impact of sociological and environmental factors contributing to dengue cases were evaluated in this study by chi-square and binary regression. Pearson's Correlation and Mann-Kendall Trend analysis were used for climate evaluation. Inverse Distance Weighting (IDW) was used for produce the map of each factor followed by Weightage analysis for risk maps. Finally, the validation of risk map was carried out by using kernel density estimation in order to identify the contributing factors in hotspot areas. Descriptive data indicated 118 (31%) respondents stayed at home, and 261 (69%) respondents went to work, school and college. The spatial distribution of dengue cases based on the residential areas showed the highest numbers of respondent from Parliament Batu were Kampung Padang Balang, Taman Dato'

Senu and Flat Sri Perak, while in Parliament Wangsa Maju were Kem Wardieburn and Seksyen 2. Light Rail Transit (LRT) Station of Wangsa Maju showed the highest numbers were visited by the respondent, and followed by Tar College. The most frequent intersect point presented at the map were nearby to Flat Sri Perak and Kem Wardieburn. *Ae. albopictus* was found to be most dominant species in study areas with Ovitrap Index values between 65% to 74%. The chi-square results showed there is a significant association between respondents who had one experience with dengue and lived in houses shaded with vegetation (95% CI = 0.263 and 0.836, **p = 0.012**) with playground area near the house (95%CI = 0.304 and 0.859, **p = 0.011**). Furthermore, a significant association with respondent who had once experienced by dengue was not present of playground at routine area (95%CI = 0.186 and 0.99, **p = 0.036**). The analysis from year 2012 to 2016 by using Pearson's Correlation showed that dengue cases in Kuala Lumpur were significantly correlated with temperature, relative humidity and rainfall ($p < 0.05$). Mann-Kendall trend analysis showed in both 2012 and 2014 indicated the rising in dengue cases were affected by the increases in temperature and wind speed, while the relative humidty and rainfall affects the dengue with decreasing pattern. The risk map in residential setting showed high risk areas namely Flat Sri Perak mostly concentrated in Parlimen Batu, and Taman Setapak Indah in Parlimen Wangsa Maju. Routine area's map showed high risk areas namely Sekolah Menengah Setapak Indah, Sekolah Menengah Bandar Baru Sentul and Sekolah Kebangsaan Danau Kota which mostly visited in study areas. The most concentrated intersect areas from risk map were located near to Kem Wardieburn, Sri Pelangi Condominium and Flat Sri Perak.The results indicated most factors in high risk and low risk areas from residential areas showed similarity between risk map and validation map excepting employment status, presence of construction areas, rainfall and wind speed. Routine areas showed four factors presented contradicting between risk map and validation which were presence of construction area, presence of playground area, rainfall and wind speed. Meanwhile, six factors presented contradicting in intersect areas were presence of construction area, presence of playground area, presence of vegetation, relative humidity, rainfall and wind speed. This study revealed that the most common areas for dengue-afflicted patients to be present in included the residential, work, and study areas. Dengue transmission can be influenced by a combination of multi factorial as they may collectively and indirectly contribute to the density of the *Aedes* mosquitoes. Risk map and validation from this study can be used by as a model for vector control program in order to predict the high risk areas and association factors in urban areas.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMETAAN KAWASAN RISIKO TITIK PANAS BERDASARKAN FAKTOR SOSIOLOGI, ALAM SEKITAR DAN CUACA DENGAN MENGGUNAKAN SISTEM INFORMASI GEOGRAFI

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Februari 2022

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Demam denggi (DD) dan demam denggi berdarah (DDB) merupakan antara masalah besar dalam kesihatan awam di Malaysia. Penyakit bawaan vektor ini disebabkan oleh dua spesis nyamuk iaitu *Aedes aegypti* (*Ae.* aegypti) and *Aedes albopictus* (*Ae. albopictus*). Sehingga kini, masih tiada vaksin untuk mengawal wabak demam denggi dan demam denggi berdarah. Pemahaman yang mendalam terhadap hubungan di antara vektor (pembawa), faktor-faktor risiko dan orang yang dijangkiti virus adalah penting bagi menyediakan strategi bagi kawalan penyakit denggi. Objektif utama kajian adalah untuk menghasilkan peta risiko penyakit denggi berdasarkan faktor sosiologi, faktor persekitaran dan faktor cuaca pada tempat yang berisiko terhadap jangkitan denggi dengan menggunakan Sistem Informasi Geografi atau GIS. Kajian ini dijalankan di tiga kawasan iaitu kawasan tempat kediaman, kawasan rutin dan kawasan persimpangan (di antara kawasan tempat kediaman dan rutin). Pemetaan tempat jangkitan adalah berdasarkan hasil temubual oleh tiga ratus tujuh puluh sembilan responden yang pernah dijangkiti demam denggi dan tinggal di kawasan Parlimen Batu dan Parlimen Wangsa Maju. Tinjaun Ovitrap dijalankan sebagai penunjuk terdapatnya nyamuk *Aedes* di kawasan kajian. Kesan faktor sosiologi dan persekitaran dinilai dengan analisis chi-square and regresi binari. Korelasi Pearson's dan aliran pergerakan Mann-Kendall digunakan untuk evaluasi faktor cuaca. Pemberat jarak songsang (IDW) digunakan untuk menghasilkan peta bagi setiap faktor untuk kegunaan analisis pemberatan bagi peta risiko. Akhir sekali, validasi peta risiko dijalankan oleh anggran kernel density untuk mengenal pasti faktor-faktor yang menyumbang pada kawasan-kawasan berisiko. Data diskriptif menunjukkan 118 (31%) responden tinggal di rumah, dan 261 (69%) responden keluar bekerja dan juga ke sekolah/ kolej. Peratusan tertinggi taburan ruang kes denggi di kawasan tempat kediaman ialah di Kampung Padang Balang, Taman Dato' Senu dan Flat Sri Perak pada Parlimen Batu, manakala Kem Wardieburn dan Seksyen 2 adalah di Parlimen Wangsa Maju. Stesyen transit aliran ringan (LRT) Wangsa Maju adalah lokasi

paling tinggi yang dilawat oleh responden dan kemudian diikuti oleh Kolej Tuanku Abdul Rahman (TAR). Titik persimpangan yang paling tinggi dilawati ialah berdekatan dengan Flat Sri Perak dan Kem Wardieburn. *Aedes albopictus* merupakan spesis nyamuk *Aedes* yang paling dominan di kawasan kajian dengan nilai Indeks Ovitrap adalah 65% ke 74%. Hasil Chi-square menunjukkan perkaitan signifikan di antara responden yang pernah dijangkiti demam denggi sekali dengan rumah yang mempunyai tumbuh-tumbuhan (95% CI = 0.263 dan 0.836, **p = 0.012**) serta juga berdekatan dengan tempat permainan (95%CI = 0.304 dan 0.859, **p = 0.011**). Tambahan lagi, perkaitan signifikan di antara responden yang pernah dijangkiti demam denggi sekali dengan kawasan rutin yang tiada taman permainan (95%CI = 0.186 dan 0.99, **p = 0.036**). Analisis dari tahun 2012 ke 2016 menggunakan korelasi Pearson's menunjukkan korelasi signifikan di antara kes denggi di Kuala Lumpur dengan suhu, kelembapan relatif dan hujan ($p < 0.05$). Analisis arah aliran Mann-kendall menunjukkan peningkatan kes denggi pada tahun 2012 dan 2014 dipengaruhi oleh peningkatan suhu dan kelajuan angin, manakala kelembapan relatif dan hujan pula menunjukkan corak penurunan. Peta risiko menunjukkan Flat Sri Perak adalah kawasan tempat tinggal yang paling berisiko di Parlimen Batu, manakala Taman Setapak Indah adalah kawasan kediaman berisiko tinggi di Parlimen Wangsa Maju. Tempat paling berisiko yang kerap dilawati berdasarkan peta rutin ialah Sekolah Menengah Setapak Indah, Sekolah Menengah Bandar Baru Sentul dan Sekolah Kebangsaan Danau Kota. Kawasan persimpangan yang paling padat adalah berdekatan dengan Kem Wardieburn, Sri Pelangi Condominium dan Flat Sri Perak. Hasil kajian menunjukkan persamaan untuk kebanyakan faktor di antara peta risiko dan peta validasi di kawasan tinggi dan rendah risiko pada tempat kediaman kecuali status pekerjaan, kewujudan tapak pembinaan, hujan dan kelajuan angin. Terdapat empat faktor yang menunjukan perbezaan di antara peta risiko dan validasi di kawasan rutin iaitu kewujudan tapak pembinaan, taman permainan, hujan dan kelajuan angin. Manakala pada kawasan pertembungan pula, terdapat enam perbezaan iaitu kewujudan tapak pembinaan, taman permainanan, tumbuh-tumbuhan, kelembapan relatif, hujan dan kelajuan angin. Kajian ini mendedahkan bahawa tempat-tempat umum yang mempunyai kaitan dengan denggi ialah tempat kediaman, tempat kerja dan kawasan menuntut ilmu. Jangkitan denggi boleh dipengaruhi oleh kombinasi pelbagai factor secara keseluruhan dan tidak langsung kepada ketumpatan nyamuk *Aedes.* Peta risiko dan validasi dari kajian ini boleh dijadikan model untuk program kawalan vektor bagi membuat jangkaan tempat berisiko tinggi dan faktor-faktor yang berkaitan terutamanya di kawasan bandar.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

UPM	Universiti Putra Malaysia
AE	Aedes
ANN	Average Nearest Neighbour
IDW	Inverse Distance Weightage
EIPs	Extrinsic Incubation Periods
KDE	Kernel density estimation
MK	Mann-Kendall
LRT	Light rail transit
MRT	Mass Rapid Transit
KTM	Keretapi Tanah Melayu

CHAPTER 1

INTRODUCTION

1.1 General introduction

Dengue is the most important communicable disease transmitted by *Aedes* mosquitoes. The first documented epidemics of dengue hemorrhagic fever (DHF) occurred in Philippines (1953–1954) followed by Thailand (1958), in the 1960s by Singapore, Malaysia, India and Vietnam, and Indonesia and Myanmar in the 1970s (WHO, 2022, Vikram et al., 2016 & Bhatt, 2013). Annually there are an estimated 50-100 million cases of dengue fever (DF), and 250 000 to 500 000 cases of dengue haemorrhagic fever (DHF) in the world (WHO, 2011a). Dengue viruses are maintained in an urban transmission cycle in tropical and subtropical areas by mosquitoes; *Aedes aegypti* and *Aedes albopictus* (Giatropoulos et al., 2022 & Suaya et.al., 2009). There are four strains of dengue virus transmitted by the *Aedes* mosquitoes are four serotypes of dengue virus, which are designated as DEN-1, DEN-2, DEN-3, and DEN-4 (WHO, 2022).

Malaysia had pronounced dengue problem since its first epidemic in the 1970s (Malaysia Ministry of Health, 1986). Since then, various outbreaks had been recorded throughout the country. Major dengue outbreaks have been recorded since 2009 with 41 486 cases and it decreased to 19 884 cases in 2011. However, starting from 2012 the dengue cases had increased to 21 900 and overwhelmingly increased to 120 836 cases in 2015. The cases starting to decrease until 2018. Unfortunately, as of December 2019, the cases spiked to 127407 which is the highest number of dengue cases in 10 years.

Dengue control and surveillance in urban and pre-urban areas with high levels of dengue transmission need great enforcement from health authorities. The better understanding of relationship between vectors and infected human is crucial in devising strategy to control dengue (Reinhold et al., 2018). Transmission areas are various, not only at the residential areas, but also the virus may be transferred at non- residential areas such as routine place in daily activities (Wen et al., 2012) . Common exposure site such as school, working areas or market had been shown to have higher risk than residential area (Ratanawong et al., 2016 & Stoddard et.al., 2009). Therefore, the understanding on the human movement on dengue perspective can be useful in order to identify the possibility transmission area and demographic characteristic. Targeting the dengue risk areas is of a high priority by implementing control measures in areas with high population (Wen et al., 2015).

The occurrence of dengue fever and dengue haemorrhagic fevers are determined by multiple risk factors including sociological, environmental and climate (Egid et al., 2022 & Suárez et al., 2009). Sociological factors prior to dengue infection such as human movement, working status, type of housing and household characteristic had been identified by many researchers (Ryan et al., 2019 & Matysiak & Roess, 2017). Daily routine activities such as working and studying during the peak biting time are contributing factors to the incidence of dengue (Chandra et al., 2015). Previous epidemiological studies had incorporated population mobility and the location of daily activities for assessing the exposure and risk of disease transmission (Wong et al., 2014, Hagenlocher et al., 2013 & Axinia, 2012). Crowd-gathering places such as market, school, parks, and bus/train station, and commuting behavior played an important role for dengue transmission (Wen et.al., 2015). Besides, dengue also has been associated with sociological factors such as poor housing areas, household density, type of housing, multilevel housing, and human activities (Cano et al., 2017 & Wan-Norafikah et al, 2012).

The environmental factors generally related to the breeding habitat of vector mosquitoes. The habitats are often close to human areas such as playground areas, cemeteries, and residential areas. *Aedes* also prefers habitat near water bodies including small lakes, swamps, springs and rivers (Zellweger et al., 2017). Vegetation is also important since it serves as a resting area during the day around residential houses when the human resources available (Muhammad et al., 2020). The uncontrolled expansion of urban environments with rapid population growth has accelerated the prevalence of dengue fever (Delmelle et al., 2016). Many studies attribute the increasing exposure to the dengue vector to overcrowded households. *Aedes* mosquitoes feed on multiple humans per day and crowded conditions make it easy to transmit the virus efficiently (Soghaier et al., 2015 & Honório et al., 2003).

Climate impacts dengue fever through three aspects which are dengue virus, vector (*Aedes* mosquito) and transmission condition (Li et al., 2018 & Cano et al., 2017). Rainfall, temperature, relative humidity, and wind have direct impact on mosquito populations (Nguyen et al., 2020 & Fareed et al., 2016). Temperature found to be influenced in the development, behavior and replication rate of dengue virus (Alkhaldy, 2017 & Barrera et al., 2011). Rainfall serves as suitable breeding environment for mosquito larval when temperature is high (Gananalatha, 2017 & Morin et al, 2013). Rain water also contributed to the abundance and densities of mosquito, forming pool and puddles, where female mosquito lay eggs (Pablo et al., 2014). Increase in temperature and rainfall due to climate change, together with urbanization may increase dengue incidence and the transmission of dengue (Ebi & Nealon, 2016). Higher temperature and rainfall increases evaporation, resulting in higher relative humidity an optimum condition for higher feeding rates, survival, and development process of *Aedes* mosquitoes (Fareed et al., 2016). Wind speed in dengue had been shown to influence mosquitoes flight in non-endemic areas (Ehelepola et al., 2015). A study in Guangzhou indicated that an increase of minimum temperature and decreasing of wind velocity are correlated with dengue incidence (Lu et al., 2009).

Geographical information systems (GIS), a computer-based systems are widely used in modelling and mapping of public health problem such as controlling vector mosquitoes (Jemal & Al-thukair, 2016). GIS is commonly used for data visualization in dengue surveillance particularly for public health professional since maps is more practical compared the raw numbers or graph (Duncombe et al., 2012). It is powerful tool and widely used in numerous dengue studies (Tami et al., 2016 & Kikuti et al., 2015). Inverse Distance Weightage (IDW), Weighted Overlay and Kernel Density are geostatistical methods used for analyzing spatial pattern of dengue in many studies (Prasetiyowati & Sibaroni, 2018, Fareed et al., 2016 & Naish & Tong, 2014). By mapping dengue cases for just certain areas (residential areas only) without considering the contributed factors that lead to the of increasing vector population, it will become harder to suggest the control strategies for different localities.

1.2 Problem statement

Increasing dengue cases is not contributed by sole determinant, but associated with several factors such as sociology, environmental and climate (Díaz-Castro et al., 2017, Quintero *et.al.,* 2014 & Wong & AbuBakar, 2013). Most of previous studies only concentrate on individual factor towards dengue, however there is no study been undertaken on sociological, environmental and climate factors concurrently. Thus, the problems remain unsolved. Effective vector control is the only solution for dengue control and prevention in situations where vaccines are unavailable (Withanage et al., 2021 & Halton et al., 2013).

Furthermore, in the urban areas with high human population contributed to densities of *Aedes* mosquitoes are difficult to control. Thus, a better understanding of the factors leading to their abundance and distribution is crucially necessary (Cano et.al., 2017).

The target of control measure in Malaysia only focus in residential areas based on the confirmed dengue patient address. The distribution of dengue cases based on patient address could not reflect comprehensively the dengue transmission areas. The transmission areas are numerous since the same individual could be at different place in daily activities. Furthermore, the dengue transmission may occur in crowded-areas where there were human-vector contact such as school, working place and also public transport stations (Wen et al., 2015).

1.3 Research questions

a. Where are the dengue patients probably infected and how its entomological condition?
b. What is the relationship of sociological and environmental factors with dengue cases?
c. How about the impact of climate factors with dengue cases and also its trend analysis?
d. How about spatial risk map of all the factors for the hotspot areas?

1.4 General Objectives

The general objective for this study is to develop dengue risk map based on sociological, environmental and climatic factors at hotspot areas for dengue transmission in Kuala Lumpur.

1.5 Specific Objectives

The specific objectives for this study are:

1) To develop spatial map of hotspot areas for dengue transmission areas and entomological surveillance areas
2) To determine sociological and environmental factors association with dengue cases
3) To correlate climatic factors and trend analysis with dengue cases in study areas
4) To generate dengue spatial risk maps of sociological, environmental and climatic factors for hotspot areas

1.6 Significance of studies

Mapping dengue risk supports a resilience environment to control, monitor, and manage future disasters. This resilience environment for Malaysia can be achieved by assimilating and synthesizing sociological, environmental and climate. Therefore, GIS is a powerful tool used in this study to combine and analyze the updated sociological, environmental and climate data and determine the correlations among them to generate a risk map for the first time in Malaysia. The correlation among the elements in GIS was modelled to make the resilience environment efficient for a better decision-making performance.

Control and prevention programs are the main methods of reducing the incidence of the dengue cases in Malaysia. In order to implement the control measure, the identification of transmission areas are crucial especially in the urban areas where the human movement influence routine activities and lead to disease transmission. The utilization of geographical information system (GIS) is important to integrate the information on various aspects such situation and current information of the disease in order for immediate action in controlling dengue outbreak. With the availability of up-to-date maps in dengue or vector mosquito study play the important role for mosquito control program.

1.7 Definition of variables

The conceptual definition of variables is in **Appendix A**.

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