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CLIMATE RISK MAPPING OF DENGUE AND MALARIA CASES IN KUALA LUMPUR AND SELANGOR, MALAYSIA

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CLIMATE RISK MAPPING OF DENGUE AND MALARIA CASES IN KUALA LUMPUR AND SELANGOR, MALAYSIA

By

HAFIZ BIN HASSAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement of the degree of Masters of Science

CLIMATE RISK MAPPING OF DENGUE AND MALARIA CASES IN KUALA LUMPUR AND SELANGOR, MALAYSIA

By

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June 2013

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Local health enforcement activities regarding mosquito-borne disease control and eradication seldom takes climate factors into consideration. The objectives of this study are to find out the historical trend of dengue fever (DF) and malaria fever (MF) in Peninsular Malaysia, to find out the spatial relationship between the climate factors and cases of DF and MF in Selangor and Kuala Lumpur and to prove the feasibility of climate factors to be used in predictive risk mapping for dengue and malaria in Selangor and Kuala Lumpur. For objective one, simple choropleth maps are used with secondary data to visualize the trend and change of DF and MF cases from 1980 to 2010 among states in Peninsular Malaysia supplemented with simple correlation analysis with land uses of forest and urban area percentage. The next objective is carried out by using the geospatial analysis of Standard Deviation Ellipse (SDE) and cluster analysis based on the Getis-Ord General G (Gi*) Hotspot Analysis spatial statistics. Lastly, the risk map based on climate

factors is formulated through Co-Kriging method which will then be validated against real data. In the initial mapping of Peninsular Malaysia's DF and MF cases of 1980 to 2010, dengue has a rising trend while malaria decreases with Malaysia's population and urbanization growth. Statistical analysis has shown positive correlations for urban areas and dengue (r = 0.49), population density and dengue (r = 0.48); and forested areas and malaria (r = 0.74). Next, SDEs visualized the distribution of climate factors against dengue and malaria cases in Selangor and Kuala Lumpur and through overlay, showed that the mean distributions of dengue and malaria cases were situated within the same focal hotspot as the climate factors. The DF, MF, and rainfall values are found to be clustered with z-values of 2.72, 3.64 and 2.77. A risk map was produced using multiple co-kriging method to predict the cases of DF and MF in Selangor and Kuala Lumpur. Validation using scaled choropleth comparisons showed that the risk map's predicted cases have a difference of 0.2 levels against dengue cases and malaria cases. In conclusion, Peninsular Malaysia's DF trend is rising while MF is decreasing between 1990 and 2010. The climate factors, which are spatially correlated with the distribution of DF and MF cases, can be used to predict of the distribution of future DF and MF cases in Selangor and Kuala Lumpur.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah sarjana.

PEMETAAN RISIKO IKLIM KES DEMAM DENGGI DAN MALARIA KUALA LUMPUR DAN SELANGOR, MALAYSIA

Oleh

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Aktiviti penguatkuasaan kesihatan tempatan berkenaan kawalan dan pembasmian penyakit bawaan nyamuk jarang mengambil kira faktor-faktor iklim. Objektif kajian ini adalah untuk mengetahui tren sejarah demam denggi (DF) dan demam malaria (MF) di Semenanjung Malaysia, untuk mengetahui hubungan reruang antara faktor-faktor iklim dan kes-kes DF dan MF di Selangor dan Kuala Lumpur dan untuk membuktikan kebolehgunaan faktor-faktor iklim untuk digunakan dalam pemetaan risiko ramalan untuk DF dan MF di Selangor dan Kuala Lumpur. Untuk objektif pertama, peta 'choropleth' yang ringkas dibina menggunakan data sekunder untuk menggambarkan trend dan perubahan kes DF dan MF antara tahun 1980-2010 di antara negeri-negeri di Semenanjung Malaysia. Ia disokong dengan analisis korelasi DF dan MF dengan guna tanah hutan dan peratusan kawasan bandar. Objektif seterusnya dijalankan dengan menggunakan analisis reruang daripada Elips Sisihan piawai (SDE) dan analisis kluster berdasarkan statistik reruang Getis-Ord Am G (Gi *) Hotspot Analisis . Akhir sekali, peta risiko berdasarkan faktor-faktor iklim dirumuskan melalui kaedah 'Co-kriging' yang

kemudiannya akan disahkan dengan data sebenar. Dalam pemetaan awal kes DF dan MF dari 1980 hingga 2010 bagi Semenanjung Malaysia, denggi mempunyai tren yang semakin meningkat sementara malaria berkurangan seiring dengan pertumbuhan populasi dan perbandaran Malaysia. Analisis statistik telah menunjukkan korelasi positif bagi kawasan bandar dan denggi (r = 0.49), kepadatan penduduk dan denggi (r = 0.48), dan kawasan hutan dan malaria (r = 0.74). Seterusnya, SDE membayangkan taburan faktor-faktor iklim dan kes-kes DF dan MF di Selangor dan Kuala Lumpur dan melalui tindihan. Dari tindihan ini, ia menunjukkan bahawa taburan min kes DF dan MF yang terletak di dalam fokus hotspot yang sama dengan faktor-faktor iklim. DF, MF, dan taburan hujan purata didapati berkelompok dengan nilai-Z sebanyak 2.72, 3.64 dan 2.77. Sebuah peta risiko telah dihasilkan menggunakan kaedah 'Multiple co-kriging' untuk meramalkan kes DF dan MF di Selangor dan Kuala Lumpur. Pengesahan menggunakan perbandingan choropleth berskala menunjukkan bahawa kes yang diramalkan peta risiko mempunyai perbezaan tahap 0.2 berbanding kes denggi dan malaria sebenar. Kesimpulannya, trend DF Semenanjung Malaysia semakin meningkat manakala MF semakin berkurangan dari tahun 1990-2010. Faktor-faktor iklim, yang berkait rapat dengan taburan reruang kes DF dan MF, boleh digunakan untuk meramal taburan kes-kes DF dan MF di Selangor dan Kuala Lumpur.

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I certify that a Thesis Examination Committee has met on 18 June 2013 to conduct the final examination of Hafiz Bin Hassan on his thesis entitled "Climate Risk Mapping Of Dengue And Malaria Cases" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Masters of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

DF Dengue Fever

GIS Geographical Information Systems

KL Kuala Lumpur

JUPEM Jabatan Ukur dan Pemetaan Malaysia

MET Meteorological Department

ASMA Alam Sekitar Malaysia

JAS Jabatan Alam Sekitar

JPS Jabatan Pengairan dan Saliran

MOH Ministry of Health, Malaysia

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Dengue and malaria are the most persistent insect-borne diseases in the Third world. Both of these diseases thrive in poor and developing countries alike, within their endemic zone near the equator with favorable environmental conditions. The diseases claim millions of lives living in such endemic areas, including children. The problem regarding dengue and malaria also concerns the socio-economic conditions of the endemic countries, which hamper the eradication and control efforts. Malaysia is fortunate to have adequate health service funding, but it is still insufficient to eradicate the diseases although the overall number of deaths and cases has decreased (Statistics Department of Malaysia, 2011).

Malaysia has been dealing with dengue fever since its first epidemic in the 1970s. Between the years 1962-1972, an average of 19.4 dengue cases were reported per year in Peninsular Malaysia with majority of the cases in Johor, Melaka and Selangor (Ministry of Health Malaysia, 1986). In the 1980s, a biannual pattern is seen, where case numbers and death tolls peak every two years before going irregular at the end of the decade. Besides the humid and rainy climate being suitable for the vector (*Aedes sp.*) to thrive, the unsanitary conditions of citizens' homes provide plenty of breeding sites, which account for 70% of mosquito larvae found during inspections (Merican,M.I., 2010).

Malaria fever has been endemic in Malaya since before independence with the local name 'Demam Kura'. Compared to dengue's painful symptoms, the common symptoms of malaria is a period of chills and cold sensations phase alternating with a hot, feverish phase. The disease is related to the conditions of colonial Malaya, with lush vegetation and orchards in place before rapid urbanization (Mohamed Hassan, 2008). The clearing of jungles for economic agricultural activities in support of British's Industrial Revolution coupled with migrant labor saw the dawn of an emerging threat of malaria. In the 1960s, the Malayan government started its Malaria Eradication Program in which free Quinine tablets were given to alleviate the sickness (WHO, 2001). The national situation improved, with lesser infections and deaths. Three decades later, malaria saw a resurge in disease rates, with a possibility of imported cases caused by migrant workers (Dewi, 2009).

The highly urbanized areas in Selangor and Kuala Lumpur have high population density, and are the most populated states in the whole Peninsula. This is due to the various developments and economic opportunities in the region, which attracts many people to work and live in the area, dubbed the Klang Valley. Dengue fever, which vector is the anthropophilic the *Aedes sp.*, is closely monitored as they present immediate risk to the human populations (Ahmad Zahawir, 2009; Shaharuddin et al. 2001). Related to places with high human population in urban areas is the factor of rapid and far-reaching transportation networks such as roads, trains, airplanes and ships which can bridge the gap between places easily in a short time. Such conveniences are built for commerce and travel alike, but it also helps facilitate the spread of infectious diseases (Ferreira, 2005).

Control of dengue and malaria fever has been carried since the first instance of its emergence by the Ministry of Health, Malaysia. For a common locality in Malaysia, the pre-emptive

activity done by the local health office includes breeding source reduction (sanitation), usage of larvicidal powder ABATE, distribution of treated mosquito nets, preventive fogging and mass blood screening (Ministry of Health Malaysia, 1986). If a case does occur and was confirmed, vector control activities were carried out to eliminate mosquitoes and prevent further spread of the disease by fogging and mass sanitation programs (Ministry of Health Malaysia, 1986).

Despite the efforts of controlling, prevention and education by the Ministry of Health, the number of cases still continues to rise after instances of heavy rain and dry spells (Muhammad Harawi, Deputy Environmental Health Officer, Vector Department, Hulu Langat Health Office, pers comm. August 2008). Although the population has done everything it could to control their surroundings, but nature prevailed at last and favored the rapid breeding and growth of the vectors.

1.2 Problem Statement

The extent of mosquito control activities in Malaysian local health authorities' heavily depends on the occurrence of cases (incidences) and the density of mosquito adult and larvae population (Aziz, 2011) in terms of Aedes Index and Breteau Index (Ministry of Health Malaysia, 1986). However, in literature by Kolivras (2006), Richards et al. (2010), and Troyo et al. (2009) environmental and demographic factors rank high in influencing the breeding of mosquitoes and subsequently the incidence and spread of dengue cases in tropical countries. This study aims to utilize the available climatic data for determining the susceptibility of

dengue and malaria in Selangor and Kuala Lumpur without relying on reactive input such as incidences or mosquito population density.

Mapping has been used by the local health authorities, but only retroactively. The extent of the usage of mapping only involves plotting the point coordinate of an event of interest. While useful in determining locations of cases or causal factors, the mapping method employed only records events which have already happened. Such is the case with the dengue enforcement units, which cases pop up rapidly. The modus operandi for the dengue eradication programme's call for action also depends on received case reports reactively (Aziz, 2011).

Modeling serves to fill in the gap of knowledge encountered by decision-makers when complete data is unavailable (Lloyd and Yu, 1994). Due to breakdowns in communication or inefficiency in relaying information, empirical data could be unavailable for use. As an example, some districts may have an abundance of case data while others do not. At times, the case data collected by field staff are incomplete and compromised, leaving it unusable to be recorded and used. Rather than being discarded, the data can be compared with the modeled ones to gain approximation to the real values.

From the past local studies (Che Dom et al. 2010, Aziz et al. 2012), there are some applications of GIS in the sector of health, especially dengue monitoring. However, none of them involved a state-wide scale with multiple environmental factors including population density using the method of co-kriging. There is no malaria risk mapping in Selangor and Kuala Lumpur as of yet. Being a factor that influences the cases of dengue (and probably malaria too), this study has found that climate factors can be mapped as a risk factor for dengue and malaria can be done to characterize the susceptibility for the area of Selangor and Kuala Lumpur. Thus, the

mapping and modeling in this study can prove useful not only in demonstrating climate factors' influence on the cases, but also predict the areas which will have the risk of having high or low potential for outbreaks.

1.3 Objectives

The main objective is to create a climate-based risk map of dengue and malaria fever-susceptible areas in Kuala Lumpur and Selangor. The high, medium and low risk areas are identified and displayed in a map, and compared to the actual data. The map also needs to be verified to be as close as it can be to the real data, to become a predictive tool. The resulting risk map will function as a map of the susceptibility of areas in Selangor and Kuala Lumpur to dengue, and the probability map for any location in the area to have the highest future incidence. The secondary objectives for this study are to provide a historical overview of the dengue and malaria situation in Peninsular Malaysia and to determine the spatial correlation between climate factors and dengue and malaria cases in Selangor and Kuala Lumpur.

1.4 Limitations of Study

This study has delimitations and limitations in terms of factors, scope and breadth given its time and resources. The limitations of this study are time, cost and manpower. A lot of time was taken for gathering, organizing and processing the data from its raw form for it to be ready for spatial analysis. Budget constraints have limited the amount of data bought from the Meteorological Department to only two selected parameters (rainfall and rain days) for limited number of years and stations.

This study's delimitations are related to its scale and extent of study. The factors used in this risk mapping only involve environmental factors i.e. climatic and population but does not include the factors of vector population. Vector populations (in this case, mosquitoes) consist of emerging populations (larval and egg survey) and infective populations (adult survey). In field surveys, field staff is instructed to eradicate the discovered larvae on sight to prevent future infections. Thus, the emerging population of mosquito larvae is removed from becoming a future risk factor. The presumptive larval surveys are not done continually to all districts under the jurisdiction of the local health office, so the records from larval surveys are not comprehensive. It is impossible to cover all districts all the time with limited resources and time. As for adult populations, the surveys are done after control measures have been taken. This time consuming process of bare leg catching is done in confirmed high risk areas or focal points to evaluate the effectiveness of control measures. The records collected do not represent the true mosquito population, and its timing is too late to be considered into a risk map as the events (dengue and malaria cases) have already taken place.

In terms of scope, the risk map focuses on the states of Selangor and Kuala Lumpur only, and the district-level data used for comparison consist of data from years 2009 and 2010 only as per its availability. The model which uses a smaller spatial scale will ensure a more accurate rendering of risk compared to a nationwide modeling with the same amount of input. In terms of population data, it does not take into account unregistered immigrants, who were also included in the incidence of malaria cases. The census done by the Statistics Department of Malaysia collected their census data in residential areas but often could not overlook shanties and slum areas resided by immigrants who are often inaccessible and hidden. As a result, the population count is not 100% representative of Malaysia's real population.

1.5 Thesis Outline

This thesis contains seven chapters including the current chapter, Introduction, which contains the problem statement and objectives of the study. Chapter 2 is the review of literature related to the problem of mosquito-borne diseases in Malaysia, the influence of weather and climate to the distribution, and application of risk mapping in mosquito-borne diseases. The following chapter, Chapter 3, contains information about the study area including the weather stations from which climatic data was extracted in this study. Chapter 4 presents the historical overview of Peninsular Malaysia's dengue and malaria pre-2010, while Chapter 5 visualizes the spatial distribution of various climatic factors with dengue and malaria cases as Standard Deviation Ellipses (SDE) and cluster analysis in the conurbation of Selangor and KL (Kuala Lumpur). Next, Chapter 6 applies the climate factors to create a model a climate-based of

dengue and malaria risk in for Selangor and KL which is verified against real data. Lastly, the conclusions of the study are presented in the final chapter with suggestions for future research.

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