Spatial pattern of 2009 dengue distribution in Kuala Lumpur using GIS application

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Abstract. In the last few years in Malaysia, dengue fever has increased dramatically and has caused huge public health concerns. The present study aimed to establish a spatial distribution of dengue cases in the city of Kuala Lumpur using a combination of Geographic Information System (GIS) and spatial statistical tools. Collation of data from 1,618 dengue cases in 2009 was obtained from Kuala Lumpur City Hall (DBKL). These data were processed and then converted into GIS format. Information on the average monthly rainfall was also used to correlate with the distribution pattern of dengue cases. To asses the spatial distribution of dengue cases, Average Nearest Neighbor (ANN) Analysis was applied together with spatial analysis with the ESRI ArcGIS V9.3 programme. Results indicated that the distribution of dengue cases in Kuala Lumpur for the year 2009 was spatially clustered with R value less than 1 (R = 0.42; z-scores = - 4.47; p < 0.001). Nevertheless, when this pattern was further analyzed according to month by each zone within Kuala Lumpur, two distinct patterns were observed which include a clustered pattern (R value < 1) between April to June and a dispersed pattern (R value > 1) between August and November. In addition, the mean monthly rainfall has not influenced the distribution pattern of the dengue cases. Implementation of control measures is more difficult for dispersed pattern compared to clustered pattern. From this study, it was found that distribution pattern of dengue cases in Kuala Lumpur in 2009 was spatially distributed (dispersed or clustered) rather than cases occurring randomly. It was proven that by using GIS and spatial statistic tools, we can determine the spatial distribution between dengue and population. Utilization of GIS tools is vital in assisting health agencies, epidemiologist, public health officer, town planner and relevant authorities in developing efficient control measures and contingency programmes to effectively combat dengue fever.

INTRODUCTION

Dengue, a mosquito-borne acute febrile viral disease caused by one of the four distinct dengue virus serotypes (DENV 1 - 4) is transmitted to humans through the bite of infected female mosquitoes of the genus *Aedes*, commonly known as *Aedes aegypti* and *Aedes albopictus* (Rudnick *et al.*, 1965; Gubler, 1998). The clinical symptoms of the illness may range from asymptomatic, non-specific acute febrile illness (dengue fever/ DF) to fatal illness with haemorrhagic fever and circulatory shock known as dengue haemorrhagic fever (DHF), which may evolve into dengue shock syndrome (DSS) (Vazquez-Prokopec *et al.*, 2010). Dengue is characterized by sudden onset of fever, intense headache, myalgia, loss of appetite, rash and some non-specific signs and syndromes (Vazquez-Prokopec *et al.*, 2010).

The significance of dengue has been predominantly in the urban and semi-urban areas of tropic and sub-tropic countries. Factors exacerbating the increase in numbers of dengue incidences include rapid urbanization, increased population movement and lifestyle that have contributed to the proliferation of man-made larval habitat of the mosquitoes. Currently, 2.5 billion

people in more than 100 countries throughout the Americas, Southern Europe, North Africa, Mediterranean, Asia and Pacific region are at risk of acquiring dengue. It is causing an estimated 50 to 100 million cases annually, with 500,000 cases of DHF and at least 12,000 deaths (WHO, 2002).

In Malaysia, dengue is a major public health problem due to its tropical climate, which is conducive for vector breeding. The first reported cases of DF and DHF in Malaysia were in 1902 (Skae, 1902) and 1962 (Rudnick et al., 1965) respectively with the first major outbreak occurring in 1970. More recent data from the Ministry of Health Malaysia revealed that the incidence rates of dengue and dengue haemorrhagic fever in Malaysia are 136.89 and 9.67 per 100,000 populations, respectively in 2009. In addition, the death rate or mortality of dengue fever and dengue haemorrhagic fever were 0.02 and 0.29 for every 100,000 population, respectively (Ministry of Health Malaysia, 2010).

In recent years, the utilisation of geographical information system (GIS), a computerized system that combines spatial and descriptive data for mapping and analysis is being increasingly used to collate and map available epidemiological information and relate it to factors such as climate and environmental factors known to influence distribution of diseases together with time, people and other dimension of interest (Burrough & McDonnell, 1998). This advanced analytical tool has been widely used in disease surveillance and monitoring, identification of high-risk diseases affected areas, prioritize areas for mitigation and surveillance plan, programming and monitoring the incidence record, providing an effective tool for visualization and spatial analysis of epidemiology data and environmental exposure (Robinson, 1998; Moore & Carpenter, 1999; Cromley & McLafferty, 2002; Lai et al., 2008).

Given that the dengue virus cannot be transmitted directly from human to human as its diffusion depends on the interaction between vector, parasites and human in the natural environment, effective vector control is the only solution for dengue control and prevention in situation where vaccines are unavailable (Er et al., 2010). The spreading of vector and dengue cases are constrained in space and time by population density, human movement, physical and environment factors. As a consequence, the spatial dimension of dengue distribution is important in order to understand the epidemic spreading of this infection. In addition, these spatial distributions or patterns can also help to identify and quantify patterns of features in space so that the underlying cause of the distribution can be determined (Fotheringham et al., 2002).

Epidemiologists normally use the ratio of case numbers at a particular time to past case occurrences using mean or median (Nakhapakorn & Jirakajohnkool, 2006). However, since dengue cases vary from one place to another, the spatial and time component must also be taken into consideration. In public health survey, spatial and temporal pattern is one of the most important components influencing the distribution of diseases (Nakhapakorn & Jirakajohnkool, 2006). Although spatial analytical technique rarely gives reasons for the occurrences of spatial patterns, they do identify where or the locations of the occurrence of spatial pattern. Within this realm, it provides a useful means to hypothesize about the health outcomes or to identify spatial issues that need to be further investigated (Er et al., 2010). Thus, this preliminary study aims to analyze the pattern of spatial distribution of dengue cases by incorporating metrological impact (rainfall) and subsequently identify areas that need high and immediate attention from health agencies in order to plan and implement efficient deterrent programmes for dengue outbreak mitigation effort as well as community participation in prevention and surveillance actions.

MATERIALS & METHODS

Study area
Kuala Lumpur is the capital and the largest city in Malaysia, making up an area of 243 km^2 with an average elevation of 21.95 meter.

Kuala Lumpur has a population of l.4 million as of 2010 which is 5.9% of the total national population. The average annual population growth rate from 2000-2010 was 2.2% (Department of Statistics Malaysia, 2010). It is located at 3º8'51"N and 101º41'35"E. The city experiences a hot and humid climate all year-round with little seasonal variation in the temperature and rainfall. The maximum temperature float between 31ºC and 33ºC and have never exceeded 37.2ºC (average is 32.4ºC), while minimums hover between 22 and 23ºC (average is 23.3ºC) and have never fallen below 17ºC. Kuala Lumpur typically receives 2,266 millimeters of rain annually with June and July being relatively dry. Since 1972, Kuala Lumpur has been governed by Kuala Lumpur City Hall (KLCH). The Kuala Lumpur City Hall Health Department was established to monitor the health status of Kuala Lumpur residents as well as improving the population's quality of health. In order to facilitate this, the city has been divided into 6 zones which include City Centre Zone, Setapak Zone, Damansara Zone, Kepong Zone, Klang Lama Zone and Cheras Zone (Figure 1).

Data sources, integration and management

Symptomatic reported dengue case occurrence data were obtained for 2009 from Kuala Lumpur City Hall Health Department. Firstly, the data were extracted into Microsoft Excel programme in order to be documented in vector programme database. Subsequently, all of the data were sorted according to each zone, cleaned and processed. Socio-demographic attributes include gender, age, race, occupation, address, admitted and discharged dates, dengue serotype, incidence location and number of week. Uncompleted data were excluded during the smoothing process to avoid any biasness. In addition, the spatial location (i.e., in situ data collection) of the dengue incidence was also carried out using handheld Garmin GPSMAP 60CSx and downloaded from the GPS memory card into a computer using GPS Pathfinder software. All the digital data coordinate system were synchronized using World Geodetic System

(WGS 1984) which serve the x (longitude) and y (latitude) of the location. Rainfall data was obtained for Department of Metrological, Malaysia, processed and subsequently utilized in the analysis.

Spatial analysis

The spatial distribution of dengue incidence within Kuala Lumpur city was managed and examined using spatial statistic method with ESRI ArcGIS V9.3 program. The point pattern analysis was used to determine whether there is significant clustering of points in the particular area. Average Nearest Neighbor (ANN) Analysis is commonly used to study the point pattern analysis in epidemiology (Moore & Carpenter, 1999). The purpose of the analysis is to calculate ANN Index (R) that relates how clustered or dispersed locations of dengue cases are within the particular area. The ANN tool measures the distance between each feature centroid and its neighbour centriod location. It then averages these entire nearest neighbor distances. If the average distance is less than

Figure 1. Map of Kuala Lumpur by health zone areas

the average for a hypothetical random distribution, the distribution of the analyzed features are considered clustered. If the average distance is greater than a hypothetical random distribution, the features are considered dispersed. R calculates the distance between one case to its nearest case and was calculated using the equation below (Moore & Carpenter, 1999):

$$R = \frac{r_{obs}}{r_{exp}} \qquad (1)$$

where r_{obs} is the observed average distance between nearest neighbours and r_{exp} is the expected average distance between nearest neighbours as determine by theoretical pattern being tested.

$$r_{obs} = \sum_{i=1}^{N} \left\{ \frac{Min\ (d_{ij})}{N} \right\} \qquad (2)$$

$$r_{exp} = \sqrt{\frac{A}{N}} \qquad (3)$$

where $Min\ (dij)$ is the distance between each point and its nearest neighbour, A is the area of the space of concern and N is the number of points in the distribution. The R value that is less than 1 indicates that the distribution is clustered and value more than 1 indicates that distribution is dispersed or uniform. If the value is totally equal as 1, it indicates random distribution pattern.

RESULT

A total of 1,618 dengue cases were reported during 2009 in Kuala Lumpur city with Setapak zone (380 cases) recording the highest cases followed by Klang Lama (321 cases), Cheras zone (320 cases), Kepong zone (276 cases) and City Centre zone (205 cases), while Damansara zone (116) recorded the lowest cases. The result of ANN analysis gives three values which are Nearest Neighbour Ratio (R), z-scores and p-value. In general, it

was found that the distribution of dengue cases in the Kuala Lumpur city for 2009 was spatially clustered with R value less than 1 ($R = 0.42$; z-scores = - 4.47; $p < 0.001$) (data not shown). The z-scores are a test of statistical significance whether or not to reject the null hypothesis. In this study, the null hypothesis is that there is no spatial pattern among dengue cases within Kuala Lumpur city. With small z-scores, there is a small probability which is less than 1% likelihood that this clustered pattern could be a result of random chance, so, the null hypothesis is rejected. The distribution of dengue cases is further analyzed according to the health zones within Kuala Lumpur city which is Kepong, Damansara, Setapak, City Centre, Klang Lama and Cheras. Similarly, the overall distribution of dengue cases in each zone within Kuala Lumpur city such as Kepong zone ($R = 0.55$; z-scores = - 11.83; $p < 0.001$), Damansara ($R = 0.58$; z-scores = - 10.36; $p < 0.001$), Setapak ($R = 0.36$; z-scores = - 22.94; $p < 0.001$), City Centre ($R = 0.47$; z-scores = - 16.12; $p < 0.001$), Klang Lama ($R = 0.42$; z-scores = - 20.44; $p < 0.001$) and Cheras ($R = 0.41$; z-scores = - 20.20; $p < 0.001$) were highly clustered (data not shown).

However when the occurrences of dengue cases in each zone within Kuala Lumpur were further analyzed by month (Figure 1), two distinct patterns were observed. Between April to June, a clustered pattern (R value < 1) was seen whereas a dispersed pattern (R value > 1) was more prominent between August and November. Given that it is more difficult to implement control measure in dispersed pattern, zones with this pattern was analyzed in greater detail. Based on statistical significant of the distribution pattern ($P < 0.001$), dengue cases were highly dispersed (R value > 1) in Kepong (September to November), Damansara (August to November), City Centre and Klang Lama (September). It was also observed that most of the dispersed cases in Kepong ($R = 1.87$; z-scores = 4.39; $p < 0.001$), Damansara ($R = 2.02$; z-scores = 4.37; $p < 0.001$), City Centre ($R = 2.21$; z-scores = 5.66; $p < 0.001$) and Klang Lama ($R = 1.52$; z-scores = 4.10; $p < 0.001$) happened in the month of September.

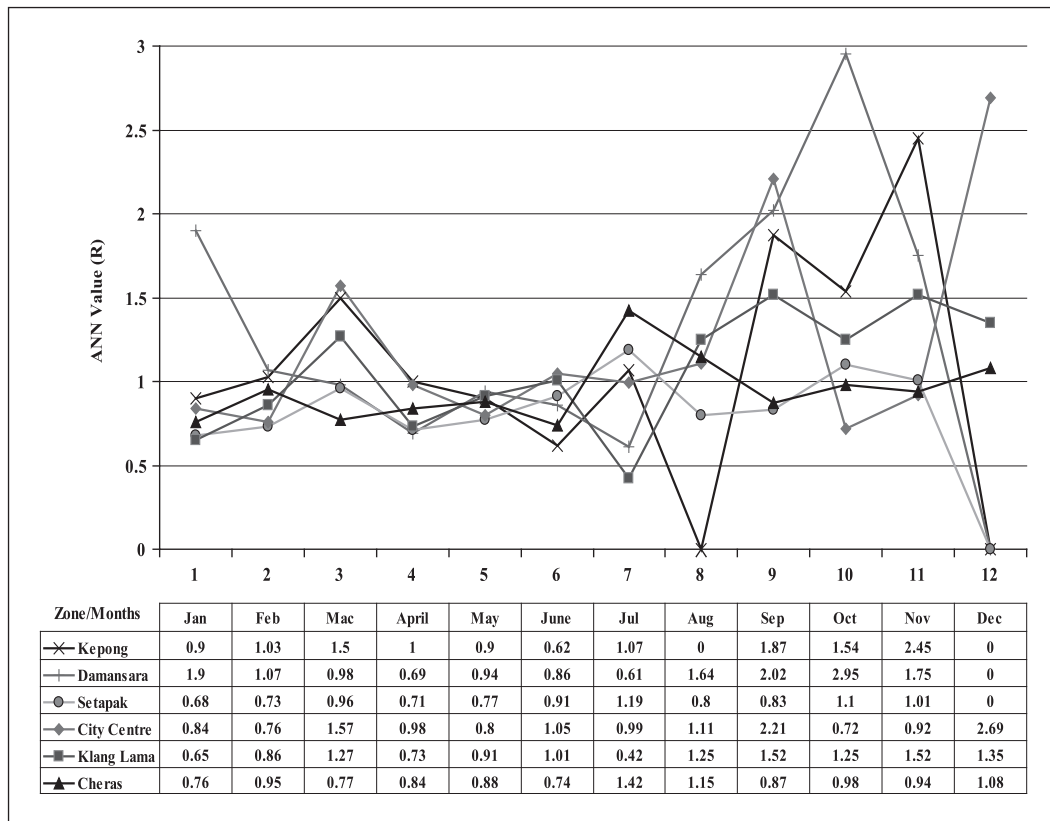| Zone/Months	Jan	Feb	Mac	April	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Kepong	0.9	1.03	1.5	1	0.9	0.62	1.07	0	1.87	1.54	2.45	0
Damansara	1.9	1.07	0.98	0.69	0.94	0.86	0.61	1.64	2.02	2.95	1.75	0
Setapak	0.68	0.73	0.96	0.71	0.77	0.91	1.19	0.8	0.83	1.1	1.01	0
City Centre	0.84	0.76	1.57	0.98	0.8	1.05	0.99	1.11	2.21	0.72	0.92	2.69
Klang Lama	0.65	0.86	1.27	0.73	0.91	1.01	0.42	1.25	1.52	1.25	1.52	1.35
Cheras	0.76	0.95	0.77	0.84	0.88	0.74	1.42	1.15	0.87	0.98	0.94	1.08

Figure 1. Average Nearest Neighbour (ANN) statistic results according to the zones by months

In addition, there was no dengue cases recorded in Kepong, Damansara and Setapak during the month of December.

The occurrences of dengue cases were further analyzed according to mean rainfall for each month with the R value (Figure 2). In general, there was no significant association between mean of rainfall for the year 2009 with the total dengue cases (p=0.471). Additionally, further analysis also demonstrated there was no significant correlation between the distribution of dengue cases with on mean of monthly rainfall by each zones [Kepong (p=0.044); Damansara (p=0.571); Setapak (p=0.949); City Centre (p=0.907); Klang Lama (p=0.202); Cheras (p=0.273)]. The highest mean rainfall was recorded in March while the lowest was in June. It was demonstrated that the pattern of dengue cases in June was clustered (R value <1) or nearly random pattern (R=1) for each zones within the Kuala Lumpur city. Analysis also showed that during middle of 2009 when the mean rainfall were less than 200 mm, the distribution pattern was cluster especially during June when R value for each zones were less than 1, which indicated clustered pattern. When the average rainfall is high such as in March, the distribution pattern tend to be dispersed rather than clustered. There were 3 zones showing statistically significant dispersed pattern in March which were Kepong (R = 1.50; z-scores = 3.60; p < 0.001), City Centre (R = 1.57; z-scores = 3.07; p < 0.001) and Klang Lama (R = 1.27; z-scores = 2.53; p < 0.001) (data not shown).

DISCUSSION

As activities for the prevention and control of dengue carried out in Malaysia do not give special attention to environmental factors, thus this study analyzed the spatial distribution of dengue in Kuala Lumpur city
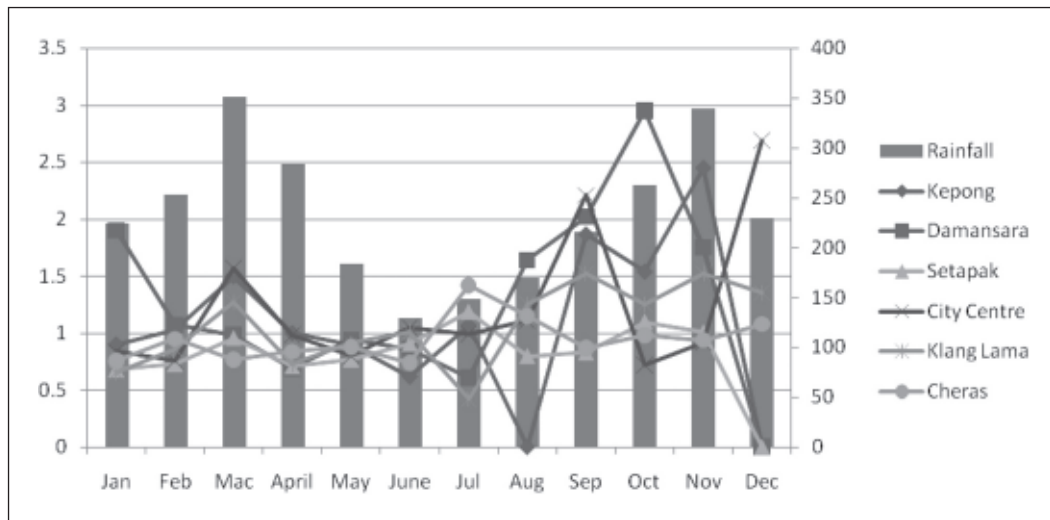
Figure 2. Average Nearest Neighbour (ANN) statistic results and mean of monthly rainfall by zones

during the year 2009 by combination of data exploitation and geographic presentation capability of GIS and spatial statistical analysis. Hence, this study provided a new dimension to the health authorities in Malaysia, specifically in the potential of using GIS application, GPS and other applications to develop strategies for the implementation of preventive and control activities for DF and DHF. In particular, it was demonstrated that the distribution of dengue cases were either clustered or dispersed rather than in random chances. This was supported by the ANN analysis which showed that the pattern of dengue cases in the Kuala Lumpur city was statistically clustered. This could be due to the fact that spatial clustering of disease is almost inevitable since human population generally live in spatial clusters rather than random distribution in space (Lawson & Williams, 2001).

In addition, when the data was further analyzed according to the health zones within Kuala Lumpur city, it was found that the overall distribution of dengue cases in each zones within Kuala Lumpur city such as Kepong zone, Damansara, Setapak, City Centre, Klang Lama and Cheras were also highly clustered. A recent study in Hulu Langat district, Malaysia also indicated that dengue cases pattern in that area was

exhibiting a cluster rather than random pattern (Er *et al.*, 2010). However further ANN analysis demonstrated that in some months, the distribution of dengue cases occurred dispersedly within some zones, hence contributing to the complexity of implementing effective control, prevention and surveillance programme (Morrison *et al.*, 1998; Wen *et al.*, 2006). Currently, control measures are undertaken without clear understanding of the distribution pattern, therefore findings from this study will be crucial in filling this gap of knowledge.

We also discovered that there was weak correlation between distribution patterns of dengue cases with the mean monthly rainfall. It was found that the distribution patterns tend to be more clustered when the mean rainfall was low, while cases became more dispersed during rainy season (or when mean monthly rainfall was high). Despite numerous studies on the effect of rainfall on the distribution pattern dengue cases, convincing information supporting the association of dengue prevalence with rainfall is scarce especially in Malaysia. Modeling of dengue fever transmission and seasonal temperatures from 1988 to 1992 in East Africa exposed a weak relationship between mean temperature, rainfall and dengue incidence (Hay *et al.*, 2002). Guha-Sapir & Schimmer (2005) highlighted the danger of over-

simplifying the relationship between meteorological data and vector-borne disease. More detailed meteorological data (i.e. temperature, humidity) and vector surveillance (i.e. *Aedes* or container index) must be obtained in order to assess the forecasting ability of the spatial distribution of dengue cases with the meteorological variables. Moreover, as in the study of arboviruses, data on disease vectors is important because human-mosquito contact is the main risk factor of dengue fever, thus additional data on the principal mosquito vector, such as number of containers or control measures of breeding sites would give an estimate of vector presence (Wen *et al.*, 2006; Mondinia & Chiaravalloti-Neto, 2008). Future research should extend from current study to a national scale analyzing with more rigorous geostatistical analysis tools to avoid oversimplification of climatological impact on dengue transmission. Better understanding of the mosquito's gonotrophic cycle and virus latency period may also be crucial in the planning of an efficient dengue control programme (Tran *et al.*, 2004). Furthermore, it would also be useful to take into account the human density, movement pattern and time which give additional information in the analysis of dengue transmission and distribution patterns.

It was shown that by integrating spatial analysis using GIS, this study proved that it is possible to improve understanding of dengue cases distribution within areas without relying on information about the density of mosquitoes. This study has shown that implementation of spatial analysis with metrological factor (i.e. rainfall) has enhanced the understanding of dengue distribution and assist in identifying areas that are in need of immediate attention from health agencies in order to plan and implement efficient deterrent programmes for future dengue outbreak. This data will benefit both local and health authorities such as Ministry of Health, Malaysia (MOH) and Kuala Lumpur City Hall (DBKL) in identifying and prioritizing their efforts in effective dengue control activities.

REFERENCES

Burrough, P.A. & McDonnell, R.A. (1998). *Principals of Geographical Information Systems*. Oxford University Press.

Cromley, E. & McLafferty, S. (2002). *GIS and Public Health*. New York: The Guilford.

Er, A.C., Rosli, M.H., Asmahani, A., Mohamad Naim, M.R. & Harsuzilawati, M. (2010). Spatial mapping of dengue incidence: A case study in Hulu Langat District, Selangor, Malaysia. *International Journal of Human and Social Sciences* **5**: 410-414.

Department of Statistics Malaysia. (2010). http://www.statistics.gov.my. (accessed on 20 April 2010).

Fotheringham, A.S., Brunsdon & Charlton, M. (2002). *Geographically Weighted Regression: the Analysis of Spatially Varying Relationships*. England: John Wiley and Son, Ltd.

Gubler, D.J. (1998). Dengue and dengue hemorrhagic fever. *Clinical Microbiology Reviews* **11**: 480-489.

Guha-Sapir, D. & Schimmer, B. (2005). Dengue fever: new paradigms for a changing epidemiology. *Emerging Themes in Epidemiology* **2**: 1.

Hay, S.I., Cox, J., Rogers, D.J., Randolph, S.E., Stern, D.I., Shanks, G.D., Myers, M.F. & Snow, R.W. (2002). Climate change and the resurgence of malaria in the East African highlands. *Nature* **415**: 905-909.

Lai, P.C., So, F.M. & Wing, C.K. (2008). *Spatial epidemiology approaches in disease mapping and analysis*. Baco Raton: CRC Press.

Lawson, A.B. & Williams, F.L.R. (2001). *An Introductory Guide to Disease Mapping*. England: John Wiley & Son, Ltd.

Ministry of Health Malaysia (MOH). (2010). Weekly dengue situation update. http://www.moh.gov.my (accessed on 20 April 2010).

Mondinia, A. & Chiaravalloti-Neto, F. (2008). Spatial correlation of incidence of dengue with socioeconomic, demographic and environmental variables in a Brazilian city. *Science of the Total Environment* **393**: 241-248.

Moore, D.A. & Carpenter, T.E. (1999). Spatial analytical methods and Geographic Information System: Use in health research and epidemiology. *Epidemiology Reviews* **21**: 143-161.

Morrison, A.C., Getis, A., Santiago, M., Rigau-Perez, J.G. & Reiter, P. (1998). Exploratory space-time analysis of reported dengue cases during an outbreak in Florida, Puerto Rioco, 1991-1992. *American Journal of Tropical Medicine and Hygiene* **58**: 287-98.

Nakhapakorn, K. & Jirakajohnkool, S. (2006). Temporal and spatial autocorrelation statistics of dengue fever. *Dengue Bulletin* **30**: 177-183.

Robinson, G.M. (1999). *Methods and Technique in Human Geography.* Chichester: John Wiley & Sons.

Rudnick, A., Tan, E.E., Lucas, J.K. & Omar, M.B. (1965). Mosquito-borne haemorrhagic fever in Malaya. *British Medical Journal* **5445**: 1269-1272.

Tran, A., Deparis, X., Dussart, P., Morvan, J., Rabarinson, P., Remy, F., Polidori, L. & Gardon, J. (2004). Dengue spatial and temporal patterns, French Guiana, 2001. *Emerging of Infectious Disease* **10**: 615-621.

Skae, F.M. (1902). Dengue fever in Penang. *British Medical Journal* **2**: 1581-1582.

Vazquez-Prokopec, G.M., Kitron, U., Montgomery, B., Horne, P. & Ritchie, S.A. (2010). Quantifying the spatial dimension of dengue virus epidemic spread within a tropical urban environment. *PLoS Neglected Tropical Diseases* **4**(12): e920.

Wen, T.H., Lin, N.H., Lin, C.H., King, C.C. & Su, M.D. (2006). Spatial mapping of temporal risk characteristics to improve environmental health risk identification: a case study of a dengue epidemic in Taiwan. *Science of the Total Environment* **367**: 631-40.

World Health Organization (WHO). 2002. Dengue Prevention and Control. Fifty-fifth World Health Assembly, Provisional agenda item 13.14. A55/19.