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Spatial density of *Aedes* distribution in urban areas: A case study of breteau index in Kuala Lumpur, Malaysia

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ABSTRACT

Background & objectives: Dengue fever (DF) is a major vector-borne disease in Malaysia. The incidences of DF in Malaysia are caused by viruses transmitted through the bites of infected female *Aedes albopictus* and *Ae. aegypti* mosquitoes. This study aims to establish the spatial density of mosquito population or breteau index (BI) in the areas of Kuala Lumpur using geographic information system (GIS), remote sensing (RS) and spatial statistical tools.

Method: The 2010 weekly report data of BI obtained from the Ministry of Health (MoH) and the 2010 monthly rainfall data obtained from Malaysia Meteorological Services Department were analyzed using RS and spatial statistical tools to show the spatial correlation of dengue in each zone in Kuala Lumpur. The Kernel density was implemented to identify the better dengue hotspot localities.

Results: Results indicated a strong significant positive relationship between the number of localities with high BI and monthly rainfall ($r = 0.64$; $p = 0.024$). In addition, types of landuse did not appear to influence the mosquito's population (Built-up: $r = 0.16$, $p = 0.118$; Cleared area: $r = -0.107$, $p = 0.304$; Vegetation dense: $r = -0.206$, $p = 0.046$; Vegetation sparse: $r = 0.023$, $p = 0.823$; and Water: $r = 0.246$, $p = 0.016$).

Interpretation & conclusion: In the present study, several hotspots identified will be beneficial to assist the local health authorities to reduce and eradicate mosquitoes in these areas. These results will provide valuable information through the application of advanced tools in combating *Aedes* mosquitoes.

Key words *Aedes aegypti*; *Ae. albopictus*; breteau index; Kernel density; Kuala Lumpur

INTRODUCTION

Dengue, a major tropical and subtropical arthropod-borne viral disease still remains as a worldwide public health concern and problem[1–2]. It is an arbovirus infection mainly affecting human populations in endemic areas. Dengue can be caused by any of the dengue virus serotypes, i.e. DENV-1, DENV-2, DENV-3 and DENV-4. These viruses are transmitted to humans by the bites of infected female mosquitoes belonging to the genus *Aedes* (subgenus of *Stegomyia*), namely *Ae. aegypti* (Linnaeus) and *Ae. albopictus* (Skuse)[3–4]. These four distinct viruses can cause dengue fever (DF) and dengue hemorrhagic fever (DHF). Clinically, patients infected with dengue fever can be characterized with severe fever and intense headache, prostration, leucopenia, myalgia, arthralgia and loss of appetite as well as serious pain in various parts of the body[5].

Dengue is widely spread throughout Americas, Eastern Mediterranean and Western Pacific including Southeast Asia countries. The statistical numbers of dengue cases have exceeded 1.2 million cases in 2008 while >2.2 million cases occurred in 2010 with an estimated 500,000 individuals infected with dengue (mainly severe dengue) annually being hospitalized. Of these, almost 2.5% of the affected population succumbed to death[2]. There is currently no effective specific treatment for dengue. However, with appropriate, effective and practical control strategies such as frequent combating mosquito activities, the distribution and transmission of the dengue virus carrier can be prevented and reduced. In addition, the frequent utilization of medical care can also avoid the patient with acute DF from the severe dengue stages including DHF and dengue shock syndrome (DSS)[6].

Dengue was established in Malaysia with its first reported cases of DF and DHF in 1902[7] and 1962[3], respectively. The first major recorded dengue outbreak occurred in 1973 and over the years, the rates of incidence for both DF and DHF in Malaysia showed a remarkable increasing trend from 1999 (44.3 cases/100,000 population) to 2007 (181 cases/100,000 population)[8]. Of these cases, the age group of 15 yr and above was indicated with the highest incidence rates compared to age group of <14 yr. The working and school-going ages remain as the groups that contributed to the highest incidence rates in Malaysia. In addition, the death rates or case fatality rates for both DF and DHF were <0.3% since 2002[8]. In fact, up to 80% of the dengue cases reported in Malaysia occurred in urban areas instead of rural areas where the factors such as high population density, rapid development and increased population movement, and lifestyle might have favoured dengue virus transmission[8]. The condition of Malaysia itself as tropical climate country also provides the conducive breeding site for *Aedes* mosquitoes which facilitate the distribution of dengue viruses into the population[9]. Construction sites, factories and schools in developing areas, as well as industrial and areas of rapid economic development may also contributed to the additional mosquito breeding sites[10–11].

Granted that there is currently no available specific treatment or vaccine for treating DF or DHF, vector control measure remains as the standard tool for effective prevention and control of this disease. Control strategies such as continuous vector surveillance programmes have been implemented in order to monitor the intensity and distribution of adult mosquitoes as well as to reduce the emergence of *Aedes* species. In addition, the utilization of geographical information system (GIS) tools such as spatial density or remote sensing (RS) analysis associated with targeted vector control measures based on vector breeding sites can also be implemented in order to reduce the dengue virus transmission. Conventional indices such as container index (CI), house index (HI) and breteau index (BI) are frequently used as statistical indices for the determination of the transmission of dengue virus for immature stages of mosquito population[12]. Among these indices, BI which is defined as the number of positive containers (i.e. containing *Aedes* mosquito larvae) per 100 houses inspected is widely used since its role in larval surveillance is more accurate in predicting the mosquito intensity in suspected localities even in low infestation areas of *Aedes* mosquitoes[13]. Thus, the present study particularly aims to describe the relationship between the recommended hotspots with environmental factor (rainfall) and to determine the relationship between the utilization of BI and landuse as well as to estimate the spatial density of BI among hotspot areas.

MATERIAL & METHODS

Study area

The study was carried out during January to December 2010 in Kuala Lumpur. Kuala Lumpur (Federal Territory) is the federal capital of the Malaysia, located at 3° 8' 51'' N and 101° 41' 35'' E, the city makes up an area of 243 km^2 with an average of 21.95 m in the middle of Selangor state which is occupied by about 1.6 million people. Statistically, the average maximum temperature of the city is 32.4°C (between 31 and 33°C) but has never exceeded 39.3°C while the average minimum temperature of 23.3°C (between 22 and 23.5°C) and has never fallen below 14.4°C. The city receives almost 2600 mm per year of rain with the months of June and July being relatively dry.

To implement the study objectives, the city has been divided into six zones, i.e. Kepong, Setapak, Damansara, City Centre, Klang Lama and Cheras zones (Fig. 1). High rates of dengue cases in apartments were selected from each zone including Vista Angkasa Apartment [3° 6' 44'' N & 101° 39' 39'' E, Klang Lama (H1) zone]; Seri Selangor Flat [3° 8' 6'' N & 101° 42' 32'' E, City Centre (H2) zone]; Taman Setapak Jaya and Taman Setapak [3° 11' 27'' N & 101° 43' 41'' E and 3° 12' 20'' N & 101° 42' 33'' E, Setapak (H3 & H4) zones]; Desa Tun Razak [3° 4' 43'' N & 101° 42' 57'' E, Cheras (H5) zone]; and Taman Bukit Maluri (3° 11' 9'' N & 101° 38' 21'' E, Kepong (H6) zone]. All the zones were under the jurisdiction of Kuala Lumpur City Hall (KLCH, locally known as DBKL).

Fig. 1: Map showing study areas in Kuala Lumpur city.

Data sources, integration and management

The 2010 weekly report data of BI were obtained from the Ministry of Health (MoH) which contain list of hotspot localities in six zones of Kuala Lumpur area together with the lowest and highest rates of mosquito breeding from Week 1 to 52 (data not shown). The raw data for monthly rainfall in 2010 were obtained from the Malaysia Meteorological Services Department for further processing. Initially, all the data including rainfall and hotspots localities were extracted into the Microsoft Excel programme in order to document in the vector programme database. Then these data were sorted out according to each zone, cleaned and processed. The addresses of all the suspected hotspot localities were recorded during the data collection by using handheld Garmin GPSMAP 60 CSx which were downloaded from the GPS memory card into a computer by using GPS Panther software. In addition, all the digital data coordinate system was synchronized using World Geodetic System (WGS 1984) which served the x and y as the longitude and latitude, respectively.

Implementation of remote sensing and spatial statistical tools

Remote sensing is referred as the advanced technique of deriving or interpreting the given information mainly about objects on the surface of earth by using specific sensors where physical contact with them is not available[14]. Using the *Systeme Probatoire pour l'Observation de la Terre* (SPOT) five satellite imageries of Kuala Lumpur were acquired in 2010 and the topography map with 1: 50,000 scale and ground truth data were used as a basis for image classification. The digital image processing and classification were performed using the ENVI 4.5 software. A region of interest (ROI), regions of interest (ROIs) or the training area for image classification was selected according to the visual interpretation and the ground truth data. Each ROI classes were calculated using the Jeffries-Matusita and transformed to divergence measures to determine the level of separability exists among each object class. Most of the object classes have values of 2.0, indicating highly separable object class. Five objects were grouped in the ROI-based on the ground truth campaign, i.e. water, built-up area, vegetation sparse, vegetation dense and cleared area. These five groups were used as the basis for landuse classification in the study area. The percentage of each type of landuse around 300 m at each hotspot point was then calculated. Next, the Pearson's correlation coefficient was used to determine the relationship between landuse and BI.

The spatial density of BI within six zones of Kuala Lumpur area was examined using spatial statistical tools. The Kernel density estimation interpolation technique was utilized in order to analyze the hotspot localities. Conceptually, Kernel density estimation is referred as an advanced technique to generalize the incident locations to the whole study area where it is involved in the identification of high risk areas within point patterns of disease incidence by producing a continuous and smooth surface which gives the information about the level of risk for a particular area[15]. Moreover, the Kernel density estimation has been widely used as it can also interpolate the point locations of individual as well as to identify accurately the specific locations, spatial extent and distribution of dengue incidence hotspot. This technique was also observed as a better hotspot identifier compared to cluster analysis as it can also help in calculating density of point features around output raster cell[16].

The Kernel density is formulated as:

$$fK\ (x;\ h) = \frac{1}{W}\sum_{i=1}^{n}\frac{wi}{h}K\left(\frac{x - Xi}{h}\right)$$

Where, $W = \Sigma_{i=1}^{n} wi$; $K(z)$ = Kernel function; H = The smoothing parameter (the Kernel halfwidth or "bandwidth"). Let $X_1, \ldots, X_n$ be a sample from X, where X has the probability density function $f(x)$. Furthermore, let $w_1, \ldots, w_n$ be associated weights (set $w_i = 1$, if there are no weights).

RESULTS

The number of hotspot localities with high BI obtained from the Ministry of Health (MoH) was correlated with the monthly rainfall data obtained from the Department of Meteorological Services, Malaysia by using Pearson's correlation test. In this study, two variables (hotspot and rainfall) were used in order to assess the spatial density of BI within six zones particularly six hotspot localities in Kuala Lumpur area (Fig. 2). The Pearson's correlation coefficient analysis between the number of high BI and rainfall data give the value of Pearson's correlation (r) and p-value as the association between two variables is significantly different if the p-value is below 0.05. Generally, the numbers of hotspot localities with high BI and monthly rainfall data showed significant positive association with $r < 1$ and $p < 0.05$ ($r = 0.64$ and $p = 0.024$) (data not shown). The BI for each of the apartment with high rates of dengue cases was further analyzed based on month. In Vista Angkasa Apartment, the BI was only recorded in January (10%), March (80%) and April (57%). As for Seri Selangor Flat, positive con-

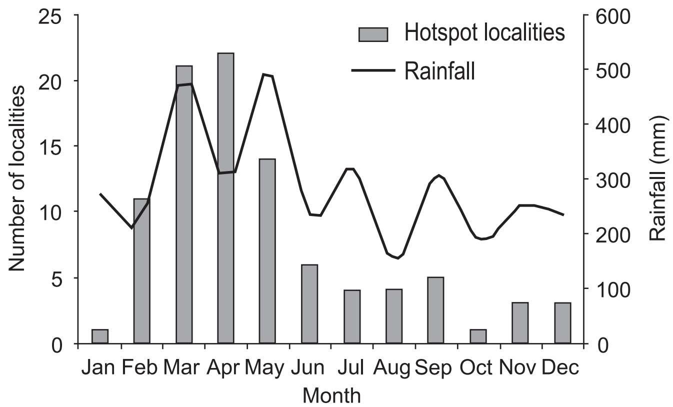

Fig. 2: Number of hotspot localities and rainfall.

tainers were observed in February (4%), March (21%), April (21%) and November (1.1%) while Taman Setapak Jaya was only positive in February (7%) and March (14.7%). In Taman Setapak, positive containers were reported in May (10%) and June (29%), while in Desa Tun Razak, the BI was recorded in February (21%), March (10.8%) and April (3.3%). In Taman Bukit Maluri, the BI was recorded only in November (40%).

The spatial density of BI was further analyzed by using RS analysis. The results of RS analysis showed that the types of landuse did not appear to influence the population of mosquito within six zones in Kuala Lumpur area (Built-up area: $r = 0.16$, $p = 0.118$; Cleared area: $r = -0.107$, $p = 0.304$; Vegetation dense: $r = -0.206$, $p = 0.046$; Vegetation sparse: $r = 0.023$, $p = 0.823$; and Water: $r = 0.246$, $p = 0.016$). All the given r and p-values were significantly two-tailed (data not shown).

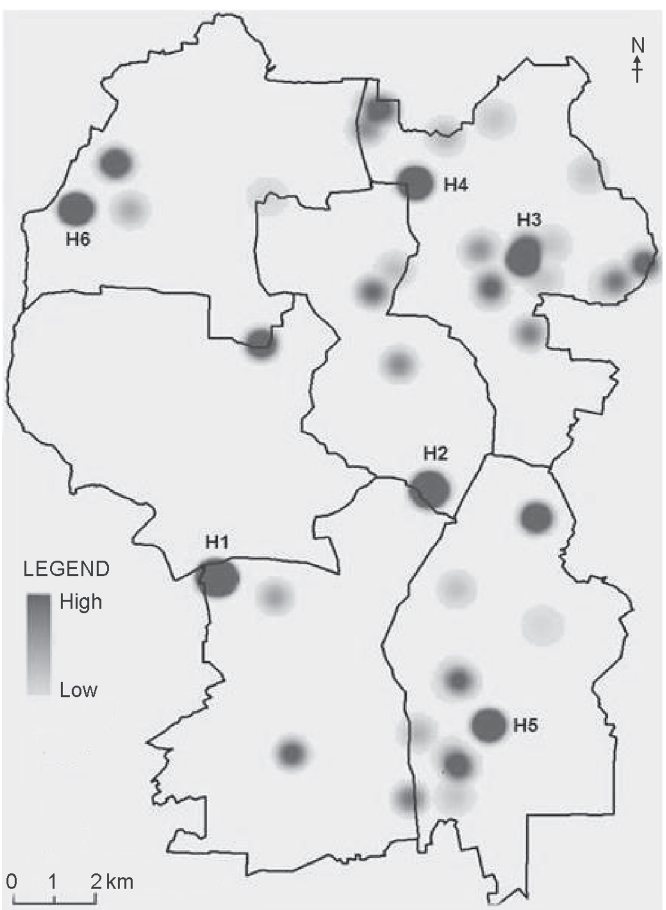

Fig. 3: Hotspots analysis of BI using Kernel density.

Kernel density estimation was used to map the density of mosquitoes throughout the study area and hotspots identification in order to provide beneficial information as well as to assist the local health authorities to reduce and eradicate the mosquito distribution and transmission in these areas (Fig. 3). As a result, the dark colour area shows the hotspot localities that identified the highest number of BI which is represented as H1 (Vista Angkasa Apartment, Klang Lama zone), H2 (Seri Selangor Flat, City Centre zone), H3 and H4 (Taman Setapak Jaya and Taman Setapak, Setapak zones), H5 (Desa Tun Razak, Cheras zone) and H6 (Taman Bukit Maluri, Kepong zone).

DISCUSSION

The mosquito control measure remains the ideal strategy to control transmission of dengue virus by the infected female *Aedes* as well as to reduce the number of dengue cases significantly within hotspot areas. It is still considered as the priority measure and there are continuous efforts from health authorities (i.e. public health sectors) to define and search new entomological control strategies to monitor the proliferation of *Aedes* mosquitoes throughout the urban areas[17]. Given that there is no vaccine to treat both DF and DHF infections, routine surveillance such as conventional indices method used in this study incorporated with GIS advanced technique and spatial statistical tools analysis in order to analyze the spatial density of mosquito population during the year 2010 in several hotspot localities within Kuala Lumpur areas is crucial.

The BI was used in this study as it is purposely based on larval indices by the combination of mean monthly rainfall. The effectiveness of BI method was proven in the previous study which indicated the capability of BI to predict the transmission of dengue based on larval indices[18]. Pearson's correlation, as denoted as r, is a measurement of the strength of the association between two variables as its range located within -1 to $+1$[19]. By the implementation of this analysis in the study, it was found that there was a strong correlation between number of hotspot localities with high BI and monthly rainfall data.

The relationship between rainfall and BI was able to provide a useful guide for the planning and implementation of *Aedes* prevention activities in the studied areas.

Overall, the total monthly rainfall from January 2007–December 2010 is shown in Fig. 4. However, monthly rainfall varied each month and did not show a regular pattern (Fig. 2) in which March to April and November to December recorded a high amount of rainfall. Elimination of mosquitoes, particularly through the fogging activity should be further enhanced in these months. When Aziz *et al*[9] analyzed the spatial distribution of dengue cases in Kuala Lumpur, it was found that the dispersed patterns in the coming months were correlated with high rainfall. This showed that rainfall was not only strongly associated with BI, but also influenced the occurrence and spatial pattern of dengue cases. Based on these evidences, rainfall should be one of the factors to be considered in the planning and implementation process of mosquito control and prevention of dengue fever.

Furthermore, the findings also discovered the influences of types of vegetation and ground cover by using remote sensing analysis but the results showed none of the criteria analyzed such as cleared area, built-up, vegetation dense, vegetation sparse and water correlated with the association of hotspot localities to mosquito population within six zones of Kuala Lumpur. This may be due to the study areas as these are located in urban areas that have a pattern of landuse which is almost uniform with minimized vegetation variation and ground cover to be associated with BI[13].

Moreover, the use of Kernel density estimation could contribute to the study as it can be used to design and map high risk areas of dengue incidence. The spatial mapping of dengue incidence in Hulu Langat also conducted with Kernel density produced a designed dengue density map which was able to target specific area within points of highest dengue cases prevalence[20]. Incorporation of more details of meteorological information such as humidity or temperature must be considered in future studies as these may also contribute to the assessment of spatial distribution of dengue incidence or other vector-borne diseases[9]. However, a previous study has suggested that it is important not to simultaneously oversimplifying the relationships among meteorological information, distribution of mosquito population and dengue cases in the targeted areas[21].

The three main elements (i.e. breteau index, remote sensing and Kernel density estimation) were implemented in this study and it was found that this analysis can assist the public health management in providing beneficial information as well as to reduce and overcome the risk of dengue infections throughout the suspected dengue cases reported areas. Coupled with computerized GIS tools, technologies and meteorological data such as rainfall, this study showed that there is an existence of strong correlation among these elements and this knowledge can improve the understanding level of spatial density of dengue cases distribution together with the utilization of mosquito surveillance (i.e. breteau index)[18]. Using larval indices of BI, prediction of dengue transmission throughout any hotspot

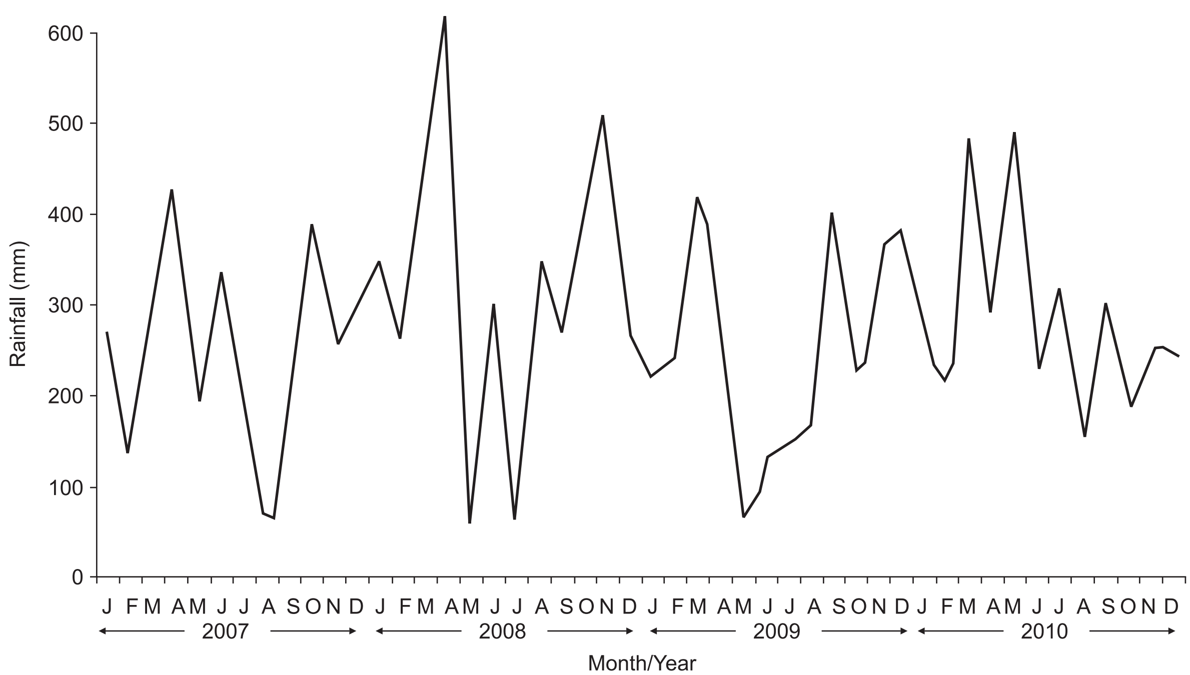

Fig. 4: Total monthly rainfall from 2007 to 2010.

area was determined. This information was further strengthened with Kernel density which acts as a tool to identify the location of hotspot area based on dengue cases incidence. Besides that the use of RS also provided another advantage in the investigation of the influences of environmental factors (i.e. built-up, vegetation dense, cleared area, vegetation sparse or water) as these factors could be major contributors to the dengue incidence pattern within identified hotspot areas. All these advanced tools have significant potential in assisting public health sectors such as city hall, health department or Ministry of Health to plan a more effective and practical dengue control strategies in order to combat this infection and subsequently reducing the number of dengue cases.

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