International Journal of Mosquito Research

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Spatial density of dengue incidence: A case study of a dengue outbreak in Seksyen 7, Shah Alam

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Abstract
Dengue is a major vector-borne disease caused by any one of four closely related dengue viruses. The viruses are transmitted to humans by the bite of an infected mosquito (*Aedes aegypti* or *Aedes albopictus*). The study was conducted in the Seksyen 7, Shah Alam where there is a marked increase of dengue cases evidenced during the last few years. This study aimed to establish spatial density of dengue incidence in Seksyen 7, Shah Alam using Geographical Information System (GIS) and spatial statistical tools. Methodology: We analysed 23 ovitrap index and 2389 dengue cases from 2013 to 2014. Data were collected from Petaling District Health Office and Shah Alam City Council. Spatial statistical tools were used to show spatial correlation of dengue cases and kernel density was implemented to identify dengue hotspot localities. Results: The result showed that dengue cases were spatially random ($p<0.001$) by using spatial autocorrelation analysis. Average Nearest Neighbour analysis showed that dengue cases were highly clustered and occurred at an average distance of 219.2 meters. Location especially residential areas had been identified as hotspot by using kernel density estimation analysis. Discussion and Conclusion: Our results showed that GIS and spatial statistical tools could be an effective mean to establish spatial density of dengue. Mapping of dengue cases would serve as guidance for stakeholders to identify source of outbreaks. It will generate more hypotheses and further investigations. Understanding the spatial of Aedes index and its impact on human health, particularly outbreaks of dengue is important in controlling the transmissions of the disease.

Keywords: Dengue, outbreak, GIS

1. Introduction
Dengue flourishes in urban poor areas, suburbs and the countryside, but additionally affects more affluent neigh bour hoods in tropical and subtropical countries. Dengue is a mosquito-borne viral infection causing a rigorous flu-like illness and, sometimes causing a potentially lethal complication called rigorous dengue. The incidence of dengue has increased 30-fold over the last 50 years. Up to 50-100 million infections are now estimated to occur annually in over 100 endemic countries, putting almost half of the world's population at risk [1].
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) [2]
The World Health Organization (WHO) estimates that there are 50-100 million recorded cases of dengue fever annually. In the Malaysia, there were 120,836 recorded cases of infection from January to December in the year 2015. This is an 11.2% increase in cases in 2015 compared with the same period in 2014 (Fig. 1)
The rates of incidence for both dengue fever and dengue hemorrhagic fever in Malaysia showed a remarkable increasing trend from 2000 (31.6 cases/100,000 population) to 2015 (396.4 cases/100,000 population). (Fig. 2) This exceeds the national target for the incidence rate of DF and DHF which is less than 50 cases/100,000 population. Dengue fever accounted for almost 95% of all reported cases. The serologically confirmed cases were approximately 40%-50% of these cases at the time of notification.
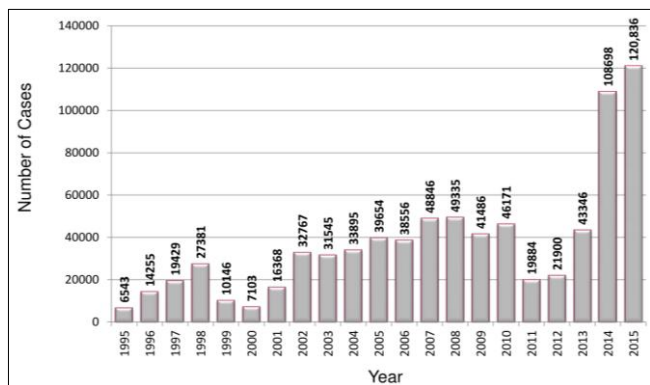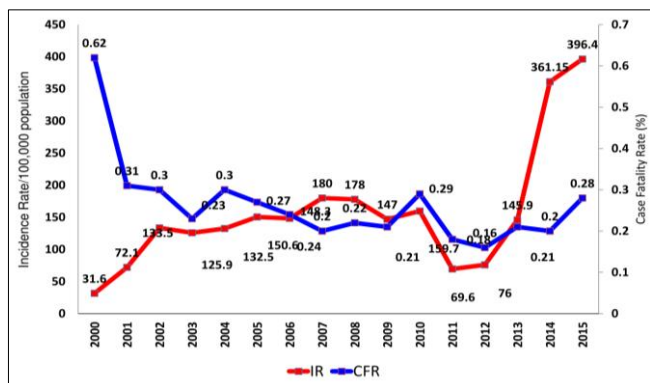
Fig 1: Malaysia dengue cases 1995-2015

Fig 2: Dengue Incidence rate and case fatality rate for year 2000-2015

A Geographic Information System (GIS) is a computer aided database management and mapping technology that acquires, organises stores and integrates large amounts of multi-purpose information from different sources, programmes and sectors. GIS adds the dimension of geographic analysis to information technology by providing an interface between the data and a map. Tasks such as temporal modelling of climate changes, environmental degradation, disease transmission and other factors relevant to an outbreak can then be easily analysed. This rapidly provides information to key decision makers, efficiently and effectively. GIS are currently recognized as a set of strategic and analytic tools for public health, so the design and implementation of an information system for dengue control with GIS capacity should be considered. A GIS based approach is proposed in this paper to determine the relationship between dengue cases and their spatial pattern [3]. Space-time interaction among health events or between health events and environmental variables is an important component for epidemiological studies and public health surveillance. Statistical analysis of geographical data has been greatly enhanced in recent years with the advent of GIS [4]. Thus, in this study spatial analysis was applied in order to map the spatial distribution of dengue cases in Seksyen 7, Shah Alam through a spatial statistics method. Section 7, Shah Alam was selected for the highest number of dengue cases recorded in Malaysia representing 21% of the total 120,836 in 2015.

2. Methodology
2.1 Study Area
Seksyen 7 in Shah Alam is an area located at 3° 03' to 3° 05'

North latitude to 101° 28' to 101° 30' East longitude. It is near the Sekolah Menengah Kebangsaan Seksyen 7 within close neighbour with the I-City MSC One Stop Centre, and also the Universiti Institut Teknologi Mara (UiTM) and Universiti Industry Selangor (UNISEL). (Fig. 1)
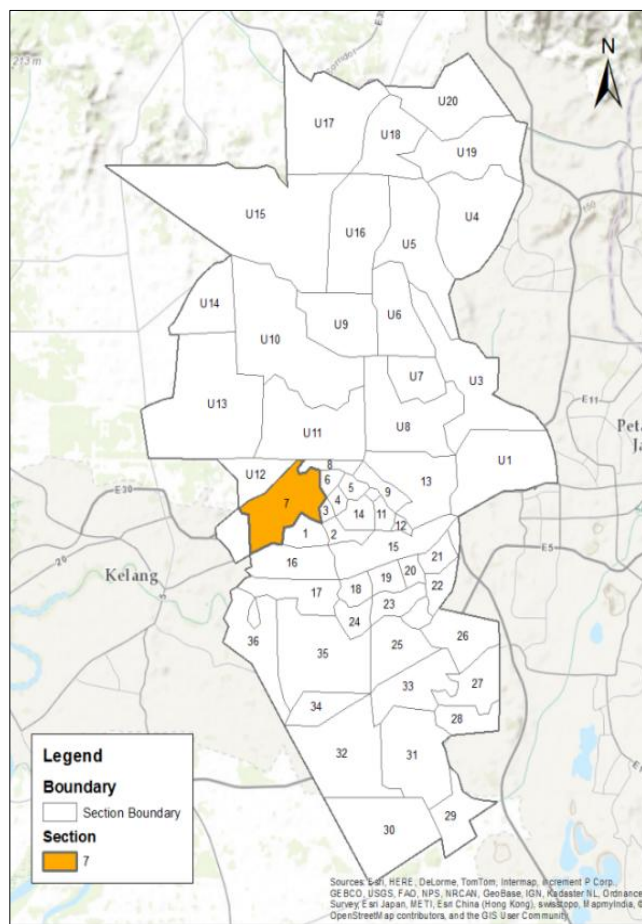

Fig 3: Map of Seksyen 7, Shah Alam

Seksyen 7 is strategically located and easily accessible from the Klang Valley via excellent highways through the New Klang Valley Expressway (NKVE), NSE (North South Expressway) exit via Toll Sungai Rasau, Federal Highway, Lebuhraya Damansara-Puchong Highway (LDP), New Guthrie Corridor Expressway and Sprint Expressway.

2.2 Data Collection
GIS environment was used to integrated dengue cases and administrative data. These data were gathered from Petaling District Health Office and Shah Alam City Council. This is a secondary data review of all dengue cases notified to Petaling District Health Office, Selangor for year 2015. All the cases were documented in the e-dengue database. From that, it was extracted to Microsoft Excel. Fig. 2 shows the number of dengue cases for each sub-district in Seksyen 7, Shah Alam.

The World Geodetic System (WGS84) is a standard for use in cartography, geodesy, and navigation including GPS. It comprises a standard coordinate system for the Earth, a standard spheroidal reference surface (the datum or reference ellipsoid) for raw altitude data, and a gravitational equipotential surface (the geoid) that defines the nominal sea level.

2.3 Implementation of Spatial Analysis

Three spatial statistical analysis (Moran's I, Average Nearest Neighborhood (ANN) and Kernel Density estimation) were used to access spatial distribution cases. Firstly, The Spatial Autocorrelation (Global Moran's I) tool measures spatial autocorrelation based on both feature locations and feature values simultaneously. Given a set of features and an associated attribute, it evaluates whether the pattern expressed is clustered, dispersed, or random. The tool calculates the Moran's I Index value and both a z-score and p-value to evaluate the significance of that Index. P-values are numerical approximations of the area under the curve for a known distribution, limited by the test statistic.

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

Where x is the number of cases, x is the mean of the variable, x_i is the variable value at a particular location i, x_j is the variable value at another location j, and W_{ij} is a weight indexing location of i relative to j. The value of Moran's I range from-1 for strong negative spatial autocorrelation to +1 for strong positive spatial autocorrelation. A value near 0 would indicate a spatially random pattern. The Average Nearest Neighbor (ANN) tool measures the distance.

The ANN tool measures the distance between each feature centroid and its nearest neigh bour's centroid location and averages all these nearest neigh bour distances. If the average distance is less than the average for a hypothetical random distribution, the distribution of the features being analyzed is considered clustered. If the average distance is greater than a hypothetical random distribution, the features are considered dispersed. The average nearest neigh bour ratio is calculated as the observed average distance divided by the expected average distance (with expected average distance being based on a hypothetical random distribution with the same number of features covering the same total area).

The average Nearest Neigh bour is given as:

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

Where D_O is the observed mean distance between each feature and their nearest neighbour:

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

And D_E is the expected mean distance for the features given a random pattern:

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

In the above equations, d_i equals the distance between feature i and its nearest feature, n corresponds to the total number of features and A is the total study area. The Z_{ANN} score for the statistic is calculated as:

$$Z_{ANN} = \frac{\overline{D}_O - \overline{D}_E}{SE}$$

Where:

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

Hot spot analysis using kernel density estimation interpolation technique was used to calculate the density of point features around each output raster cell. 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 [5].

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 the density of point features around output raster cells [6].
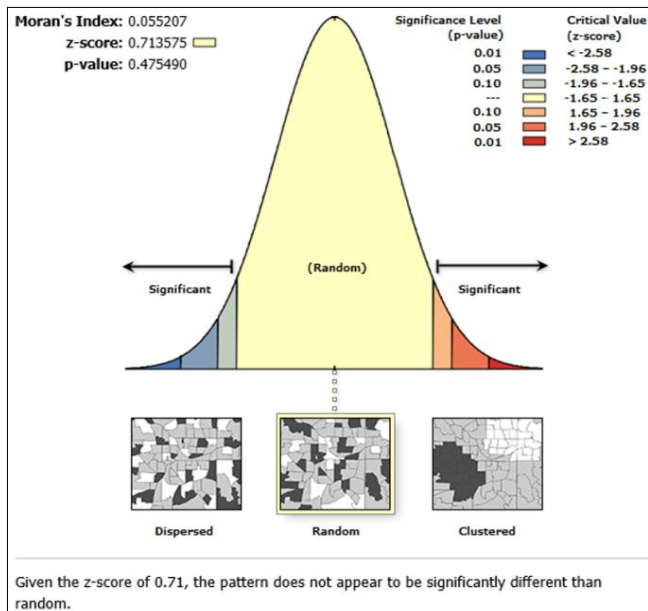
3. Results

A total of 2389 dengue cases were reported from 2013 to 2014 in Seksyen 7, Shah Alam with PKNS Apartment (285 cases) notified the highest number of cases followed by commercial area (207 cases).

3.1 Spatial Distribution

The global spatial autocorrelation analysis with Moran index showed that the spatial distribution of

Dengue cases was randomed (Fig. 4). This information is a major finding to suggest public health departments that dengue is occurring in cluster and not spread uniformly or randomly throughout the province. These locations may be considered as hotspots for future strategy to control. The highest of Moran's I and G-statistic (Z-score) values were confirmed 0.05 and 0.71 respectively in the year (Fig. 2).
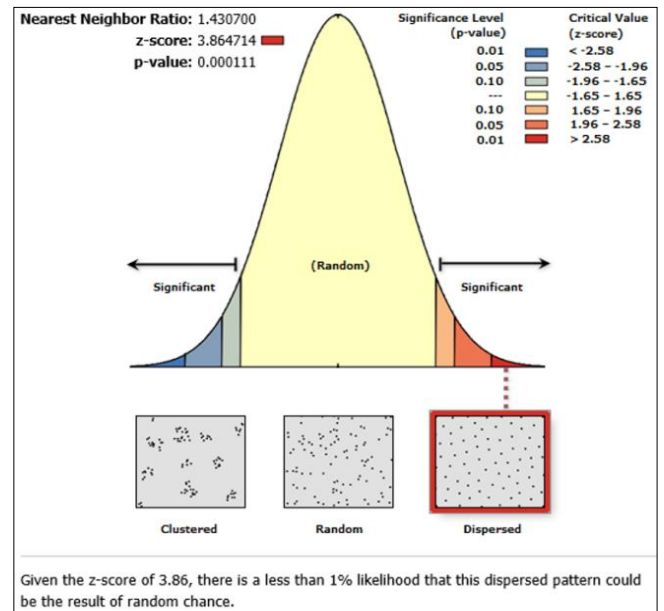
Fig 4: Result of Global Moran's I for dengue cases within Seksyen 7, Shah Alam

Fig 5: Average nearest Neighbour statistic result

3.2 Distance Analysis

Results from ANN analysis showed the dengue cases pattern is exhibiting a dispersed pattern which is 1.43 ($p<0.01$). The z-score for dengue incidence within the district is 3.86 ($p<0.0001$). (Fig. 5) By using ANN also, we can determine that the significant spatial autocorrelation of dengue incidences occurs at an average distance of 329.6 metres.

3. 3 Hotspot analysis

Three locations with most hotspot were at Flat A (Block 1-12, 38-43), Flat B (Block 13-37) and Commercial Center. Hotspot locations also show at Teres E Jalan 7/29-7/35, Teres D, Jalan 7/23-7/27, Teres B, Jalan 7/29-7/30, Kristal Condominium, Unisel, Teres K, Jalan 7/70-7/89, Teres J, Jalan 62-69A, Teres L, Jalan 7/101-7/103 and Flat C (Block 44-51). All of the detected hotspot were situated at residential area, business center and educational area.
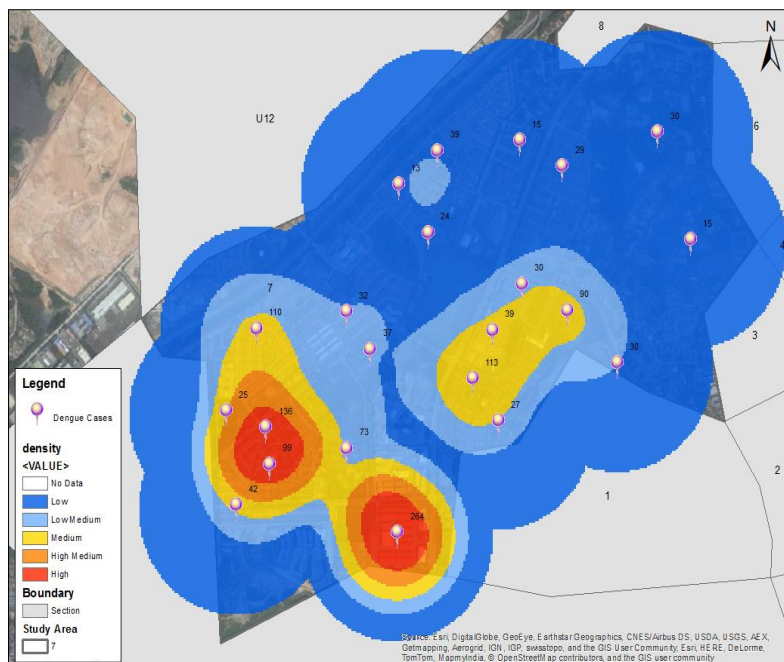
Fig 6: Hotspot locations of dengue cases in Seksyen 7, Shah Alam

4. Discussion

Our study found out that the dengue cases in the precincts were spatially auto correlated through Moran's I indices. The dengue cases were distributed at random chances. These findings were the same with the Kaohsiung study in Taiwan where spatial distributions were spatially clustered [7].

However, ANN analysis stated that the dengue cases were highly clustered and it was found that the significant spatial autocorrelation of dengue incidences occurred at an average distance of 329.6 metres. This could be due to the fact that spatial clustering of disease is almost inevitable since human populations generally live in spatial clusters rather than

random distribution in space [8]. Previous studies in Putra jaya [9] and Hulu Langat district [10] also indicated spatial clustered patterns of dengue cases.

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. [11]

Kernel density estimation was used to map the density of mosquitoes throughout the study area and for hotspot 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. 6). As a result, the dark colour area shows the hotspot localities that were identified which are represented as commercial area and PKNS apartment.

Mapping of dengue cases would serve as guidance for stakeholders to identify sources of outbreaks. Understanding the spatial of Aedes index and its impact on human health, particularly outbreaks of dengue is important in controlling the transmissions of the disease. GIS and spatial statistic tools can determine the spatial autocorrelation between dengue cases and the population. [12] Spatial mapping of dengue cases distribution also may assist health agencies, epidemiologists, public health officers, town planners and responsible authorities to combat dengue fever. GIS, with new advances in image processing and GPS to geo reference databases, provides a new and powerful tool to efficiently store, retrieve and interpret DHF databases for epidemiology, ecology and control studies.

Cumulative incidence of dengue fever from the findings reported that was similar with the geographical distribution of *A. aegypti*. The relation between of urban isation to dengue fever are found by study was conducted in Taiwan [13]. *A. aegypti* emerged to breathing in areas adjacent to dense human residence [14]. Urban developments has led to increasing sources of resources of artificial water, such as water storage spots, tires or old containers in garbage for vectors to breed [15], [16]. The most obviously potential breeding sites in Shah Alam are the flat area and construction sites.

Another independent factor for this study is the knowledge, attitude and practice of local residents on dengue fever. Community members could prevent dengue fever and incidence can be reduced if knowledgeable as well as possess a positive attitude and practice towards [17]. Both of these factors were not studied in this research, however, they may impose some effects.

5. Conclusion
Our results showed that GIS and spatial statistical tools could be an effective means to establish the spatial density of dengue. GIS technologies were found to be an important tool for the effective surveillance and prediction of the dengue outbreak in order to reduce the number of dengue cases. GIS analysis has the ability to model a risk map of dengue distribution through the use of the weighted overlay function,

which enabled the users to easily identify high risk areas in a short time period. This initial finding points the way to the wider application of this technology by the relevant authorities to improve monitoring of potential future dengue outbreaks.

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