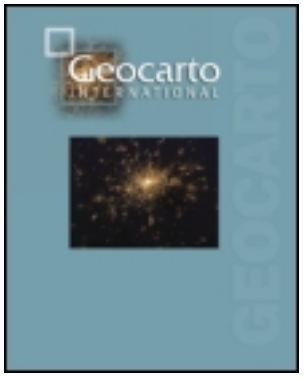
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Coupling of remote sensing data and environmental-related parameters for dengue transmission risk assessment in Subang Jaya, Malaysia

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Coupling of remote sensing data and environmental-related parameters for dengue transmission risk assessment in Subang Jaya, Malaysia

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In Malaysia, the endemic level of dengue fever (DF) has already changed morbidity indicators, and the magnitude of these incidences in the last few years has surpassed the incidences of all other diseases of compulsory notification. The reasons for the dramatic emergence of DF are complex and not well understood. There are many factors that contribute to the epidemiological conditions that favour viral transmission by the main mosquito vector. This study, therefore, is filling this gap by analysing the impact of dengue incidence at a local (Subang Jaya) scale using environmental factors. Meteorological data and land-use pattern were consolidated using geographic information system (GIS) and its components as an analytical tool. We have shown that weather variables (relative humidity, temperature and precipitation) have significant correlation with DF incidence with seasonal variation. Besides land-use pattern, DF incidence shows the higher distribution in the residential area, followed by commercial and industrial area. This is due to the higher population density in residential area as well as favourable places for the breeding of dengue-carrying *Aedes* mosquitos created by humans in the residential area, especially one-storey houses. The analysis on the trends of DF incidence towards various housing types indicate that most of the victims' houses fall into interconnection houses and mixed houses types compared to the independent houses area. The outcome driven from this analysis suggested that each character of the environmental factors has their own risk towards dengue incidence. In line with that, it is possible to develop a dynamic model of DF transmission using the knowledge produced by this comprehensive time series data and the results provided by the different analyses.

Keywords: dengue fever (DF); risk assessment; geographic information system (GIS); remote sensing; Malaysia

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1. Introduction

In general, it has been found that the incidence of dengue fever (DF) has continuously increased in Malaysia (MOH 2005). The pattern of DF incidence is predominant in urban areas where 61.8% of the country's population lives, as compared to only 34% in 1980 (MOH 2005). Rapid industrial and economic development over the last two decades has brought about massive infrastructure

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development and a very active construction sector for housing and commercial development, creating many man-made opportunities for *Aedes* mosquito breeding (Okogun 2003, WHO SEARO 2007). This coupled with rural–urban migration and pockets of illegal settlements, indiscriminate solid-waste disposal and a tropical rainfall provides fertile grounds for *Aedes* breeding and the rise of dengue transmission in the country (Gubler 2002, Dave *et al*. 2007). Areas with a high population density or rapid population growth have a high potential to expose people to the outbreak even though the mosquito's house index is low (WHO 1997). This situation happens due to the ability of human movement from one place to another as well as probability of an increase in the number of human reservoir proportionally to population density.

In the study area, it has been reported that environmental changes have a major contribution to the pattern of dengue incidences distribution (Nazri *et al*. 2009, Siti *et al*. 2009). There are some incidences reported in areas with rapid development as well as high density population (Thammapalo and Chongsuvivatwong 2008). Previous studies showed that there are other environmental factors which also influence dengue outbreak such as inadequacies in urban infrastructure with improper solid waste disposal system (MOH 2005, Sharma *et al*. 2008) coupled with rapid population growth (Kanchana and Tripathi *et al*. 2005) as well as increasing number of domestic and international travel also affecting number of dengue cases occurrence in Malaysia. As stated by Chua *et al*. (2006), *Aedes* mosquitoes breed in non-natural and natural containers in and around houses as well as in construction sites. Massive infrastructure changes and economic developments in recent years had created favourable man-made breeding site (Ghee 1993). The reported case of Dengue fever/Dengue Hemorrhagic Fever is commonly originated from construction sites, factories and school as they are correlated to relatively high *Aedes* index (MOH 2005). Working people as well as school going age groups are among the victims of this disease.

Literature describing changes in climate can affect the distribution and abundance of dengue vectors, and thus population on the ideal environment condition is more likely to be affected by climatic variation than those populations in the core of the species climatic envelope (WHO 1985, Gratz 1991, Narong *et al*. 1998, Sutherst 2001, Hales *et al*. 2002, Kanchana and Tripathi 2005). However, in certain circumstances, the processes that derive vector population dynamics are complex and are not fully understood; therefore, an integrated and holistic approach is required to manage them (Sutherst 2001, Kovats *et al*. 2003, Dave *et al*. 2007, Allen and Shellito 2008, Burattini and Chen 2008, Nath *et al*. 2012).

This article attempts to understand the various angles of past and current situations involving weather variables together with urbanization factors being assimilated to better understand their correlation with DF cases occurrence in recent years (Figure 1). This study will hopefully enhance the implementation of geographic information system (GIS) technology in public health application, especially in order to enhance the effectiveness and its efficiency in the dengue surveillance program.

2. Study area

Subang Jaya is a city of metropolitan area of Kuala Lumpur. It has a geographic area of 181 km^2 and situated at latitude 3°05′48.74″ North and longitude 101°33′02.39″ East. Subang Jaya is surrounded by rapid development and has high population density. Subang Jaya was chosen as study area due to the more

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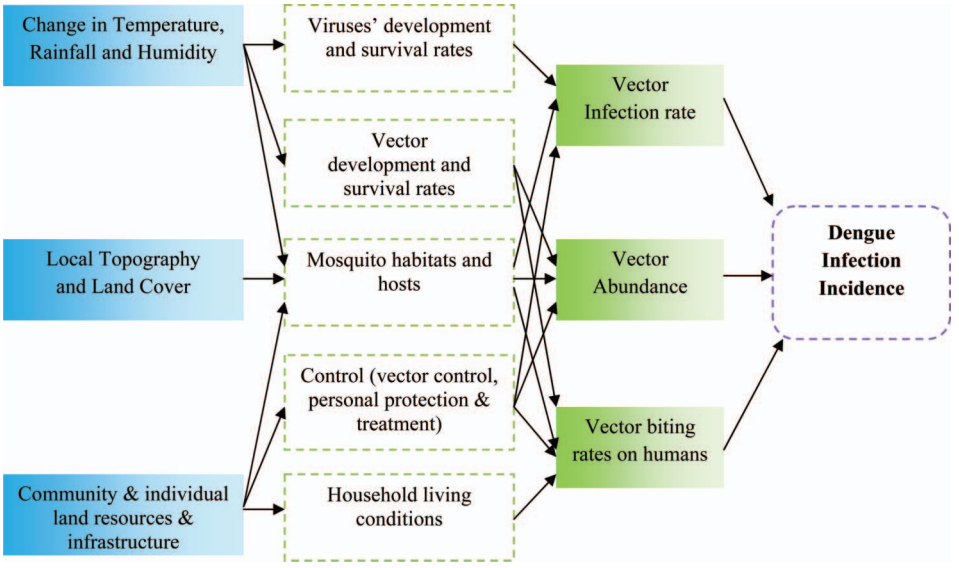


Figure 1. Causal web for the associations between climate and one vector-borne disease (dengue). Modified from Kovats *et al*., 2003.

number of DF cases reported yearly in the Selangor state. It also has been identified as having the highest number of reported DF cases occurred during the outbreak.

Based on the temperature reading acquired by the Malaysia Meteorological Service Department, the overall temperature of the Subang Jaya is typically warm (sometimes hot) with bright sunny days and relatively cool in the evening. Temperature typically ranges from 23°C to 33°C. The humidity level was generally in the range of 80% or higher, and the annual rainfall recorded often exceed 2600 mm. Although some rainfall can be expected throughout the year, the period from December to February is considered as the rainy or wet season. When the rainy seasons ends, day time will be much warmer and hot but not particularly dry as the humidity level remains high. This period will begin from late January and last up to April. From March to October, both rainfall and humidity are at their lowest levels and temperature is pleasantly comfortable.

3. Materials and methods

Secondary data (Table 1) were collected from various government departments such as Malaysia Meteorological Department, Malaysia Remote Sensing Department (MACRESS) and the Department of the statistics. A record of notifiable DF cases was obtained from the Subang Jaya Municipal Council as well as the District Health Office.

The environmental aspects involved in this study were identified and selected from static results analysis on the relationship of factors with the dengue occurrence. Remote sensing imageries have been used to generate the environmental layer. The methods used in this study are applied to spatial and temporal data in order to investigate factors that affect dengue disease risk such as temperature, rainfall, relative humidity, population density, housing type and land-use pattern.

The detailed image processing process for creating the environmental layers used in this project has been identified. The parameters' characteristics chosen from

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Table 1. Disease, GIS and environmental data matrix.

Data	Parameter	Geographic	Resolution	Time Period	Sources
Population	Sex and age groups	Township	Annually	2006–2010	Town Planning Department, MPSJ
Demographic and Housing Census	Sex, age distribution, elders, land use	Township	Annually	2006–2010	MPSJ, Town Planning Department
GIS Database	Zoning, Hectare, Activity, Section		1:89741 Decimal Degree Latitude Longitude	2010	MPSJ, Town Planning Department
Meteorological Database	T_{mean}, T_{max}, Mean RH, Precipitation	5 Meteorological Station	Daily, Weekly, Monthly	2006–2010	Malaysia Meteorological Department
Disease Notification	Dengue	Township	Daily, Weekly	2006–2010	MPSJ, Vector Control Unit
Hospital Admission	Dengue	Township	Daily	2006–2010	MPSJ, Vector Control Unit
Death Registration	Dengue	Township	Daily	2006–2010	MPSJ, Vector Control Unit

remote sensed data are based on the high potential contribution from each parameter to an impending dengue outbreak. The most important factor that must be taken into account in order to identify the relevant environmental parameter generated from satellite imagery is the potential of each parameter in influencing the dengue distribution pattern.

In this study, we used the screen digitizing process using the ERDAS imagine 8.5 version (remote sensing application) imaging software to create the land-use map due to the urban classification needs (Biro *et al.* 2011). The land-use map had been used in this study to determine area activities and socio-economic status (residential/housing types). There are various types of land-use classes in the Subang Jaya municipality including residential, industrial, commercial area, cleared land, dumping site, forest and others. All the land-use classes were extracted using on-screen digitizing method due to the limitation of using the supervise classification method for urban area (Figure 2(a)).

On-screen digitizing captures data from digital images or scanned maps by using the mouse instead of the cursor. This allows for creating map layers by adding labels during tracing. While the features are still manually traced and provided images have been taken at high resolution, on-screen digitizing grants a higher level of accuracy because the operator can use the zoom facility. In addition, on-screen digitizing allows for editing features when enough information is available from the image. In this study area, we had classified the land-use map into residential, commercial, industrial, construction and recreational, classification extracted from the IKONOS satellite imagery.

All the identified layers will be tested with the dengue case distribution to measure their significant relationship between the trends of case distribution with the environmental condition. This test is significant as it can be used to measure the contribution of the environmental parameters to the dengue transmission and distribution pattern. It is important to check the significant correlation for each parameters; therefore, the inputs parameters that been selected are more valuable.

In addition, a housing type of classification was used, where the house class has been given an attribute based on the possibility and potential of the dengue disease transmission and distribution with the types of houses. Classes of houses are based on the estimation of the level potential of the dengue transmission and the distribution for each houses class. It is important to consider commercial areas as one attribute due to the real situation in the ground where it is found that for some areas, residential houses are located in the same building as the commercial shop. These have been classified as interconnection houses, mixed houses, independent houses, commercial area and non-residential area (Figure 2(b)).

Interconnection houses have been defined as housing areas which are linked to each other like terrace houses, apartments and condominia. The mixed houses have been defined as a housing area which has mixed types of houses. For example, terrace houses, flat, commercial, small industry and a squatter area were found to be located in the same area. The independent house category refers to single houses such as bungalows and houses found in the villages. The Commercial area is defined as an area meant purely for commercial purposes or areas where shop and houses are located in the same building. The housing types map or layers will be used as inputs in the dengue risk map model development.

The distribution of the dengue incidence has been counted via administrative area (locality) in order to study the trend of the dengue distribution and to identify the status level of the dengue outbreak. The cumulative cases in each locality will be

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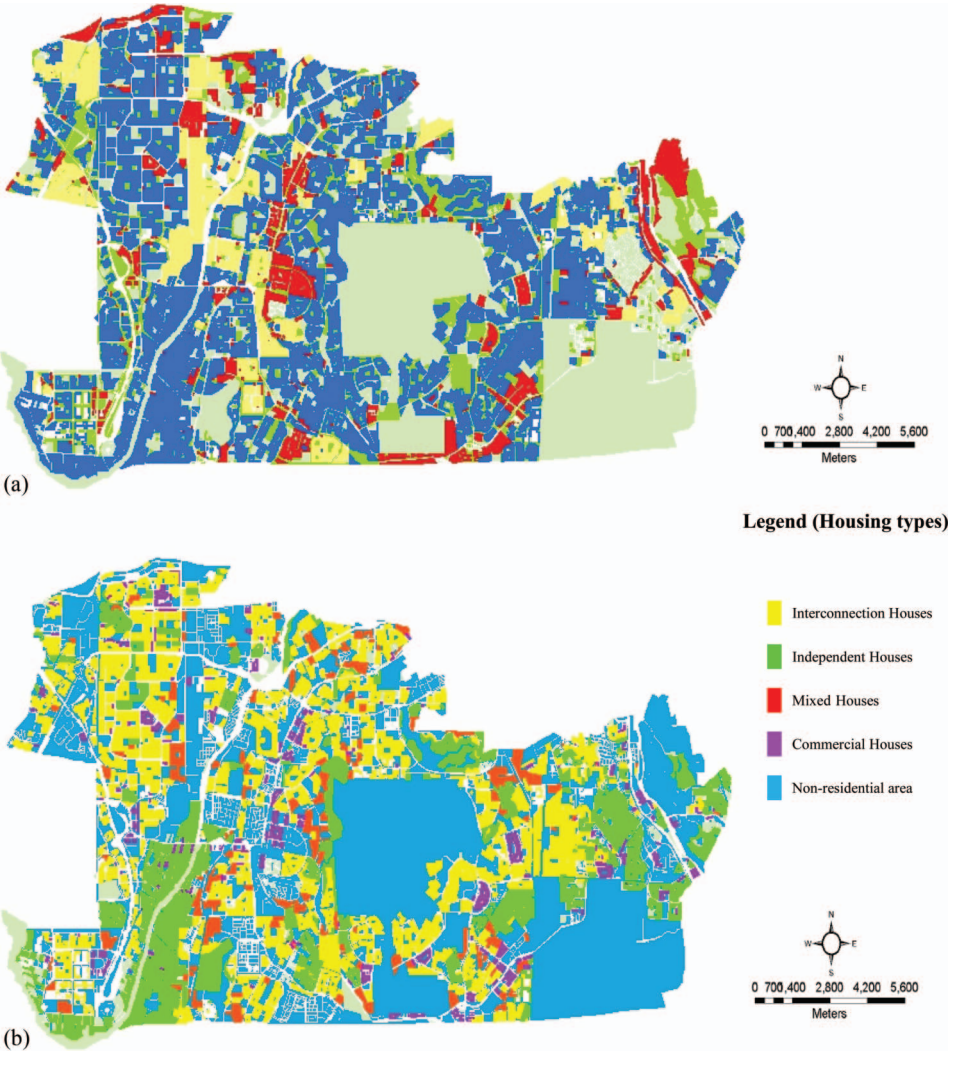


Figure 2. Mapping of land cover variation in Subang Jaya. (a) Distribution pattern of land-use pattern varies in Subang Jaya. (b) Distribution pattern of housing types in Subang Jaya.

represented as a sample to study the trend of the dengue incidence distribution in the housing type's area. The dengue cases were overlaid with the housing types map for the year 2010.

4. Results

4.1 *Correlation between rainfall and dengue incidence*

In an effort to understand about the contribution of rainfall and temperature towards case incidence, we have come out with a graph for a continuous five years in order to study the trend of climate changes and the trend of dengue distribution. Figure 3 shows the graph of incidence case distribution vs. rainfall (Figure 3(a)), temperature (Figure 3(b)) and relative humidity (Figure (3c)) for a continuous period

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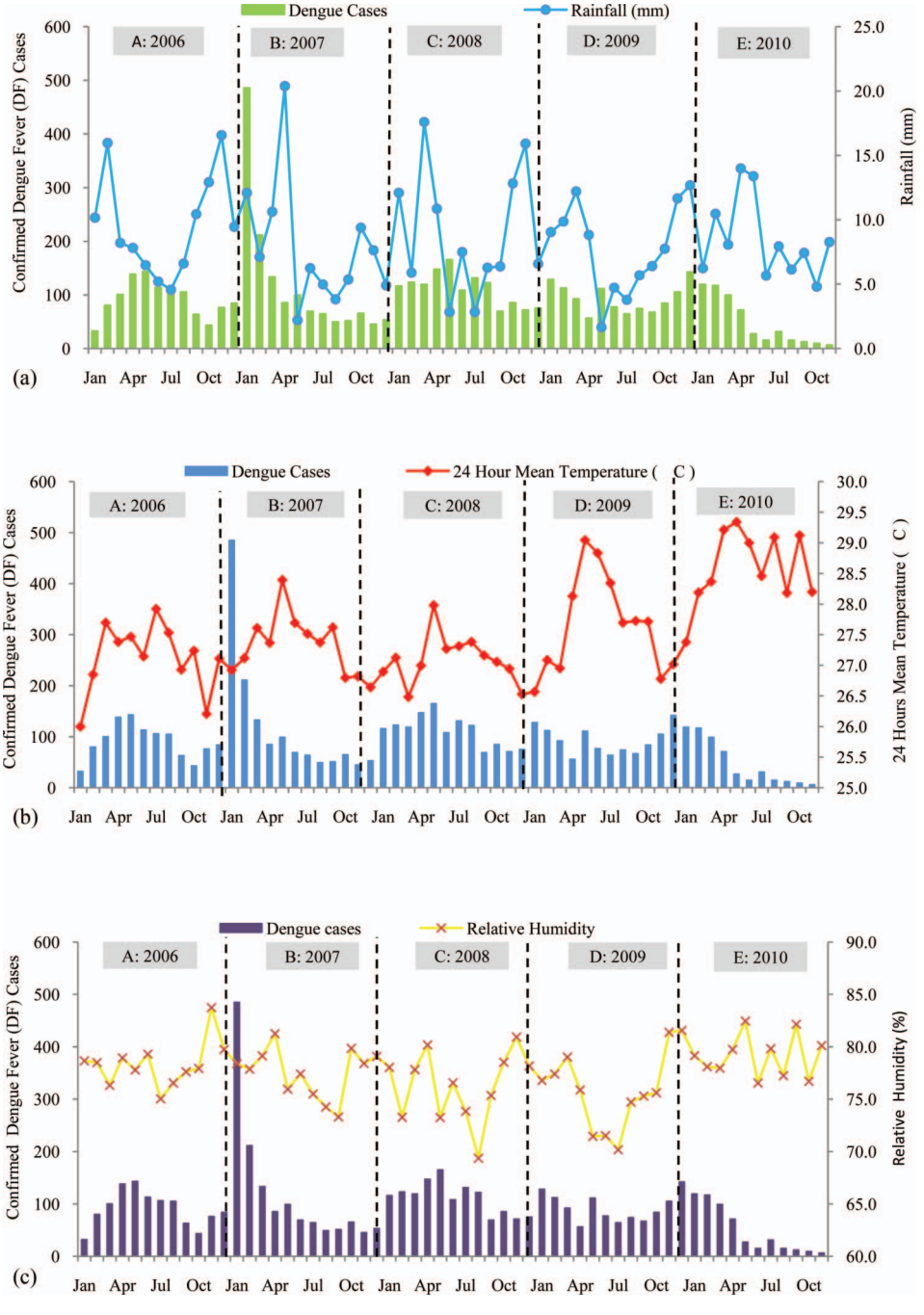


Figure 3. Monthly temperature (°C) (shown in red symbol line), rainfall (mm) (shown in blue symbol line) and relative humidity (%) (shown in yellow symbol line) with the total dengue cases (histogram) in year 2006–2010.

from 2006 to 2010. The graph analysis has been divided into five fractions namely A, B, C, D and E in which representing 2006, 2007, 2008, 2009 and 2010, respectively, for a better view of the results.

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The analysis of the results from Figure 3(a) showed clearly that the incidence cases is high (more than 100 cases) when there is the presence of rainfall and temperature in the relative range above 28.5°C, and this fact refers to the graph results in fraction A, B, C and D. The number of incidence cases is steadily medium in fraction A, C and D when compared to the trend of case distribution in fraction B and D. The graph shows that (Figure 3(b)) even though high amounts of rainfall (peak) were detected in fraction B, C and E, the temperature distribution in the range of 28.5–29°C contributed to a drop in the number of incidence cases compared to its distribution pattern throughout the year (2006–2010). As a conclusion, the number of incidences is much influenced by the trend of temperature level.

The presence of rainfall with very high temperature is a very good time period for the vector to breed which would very well see an increase in the number of incidence cases. Referring (Figures 3(a) and 3(b)) to the fraction distribution trend for fractions A and D, the distribution trend for rainfall is quite similar in both fractions, but each has a different incidence cases distribution trend. We can see that the number of incidence cases in fraction A is lower than what is shown in fraction D, which resulted from a different distribution trend of temperature level. The temperature distribution trend shows that, in fraction A, the temperature level was most likely in a range of less than the 28.5°C in a relative distribution, while for fraction D, the relative distribution trend of the temperature peak was more than 29.5°C. Therefore, as a result, the number of incidence cases in fraction D is much higher than the case distribution in fraction A.

This analysis has uncovered that rainfall is a very important factor that contributes to the trend changes of a dengue outbreak. It has also found that temperature plays a major role during the presence of rainfall that influences the case of distribution changes. Temperature is also another factor that might influence the number of incidences as found in results shown by fractions A and D when compared analytically. The relative humidity distribution has also been compared with the trend of dengue distribution to study the correlation of relative humidity with the incidence case (Figure 3(c)).

The graph in Figure 3 shows variations in the trend of rainfall, temperature and relative humidity with dengue incidence distribution. This information is important in order to study the correlation between the climate changes with the dengue incidence analysis. This analysis result was carried out by using SPSS 17.0, correlation test (Table 2). Table 2 shows the distribution trend of incidence cases vs. the trend of climate variability.

The analysis of the results show that relative humidity is not a contributing factor in influencing the dengue outbreak. There were no significant results which showed a correlation between the trend of relative humidity and case distribution unless as shown in year of 2009 with fair correlation score 0.407, significance level at $p < 0.01$ (two-tailed). Therefore, we can conclude that the relative humidity has no average effect to the incidence cases throughout the year of 2006–2010.

4.2 *Relationship between land-use and dengue incidence*

Population distribution in Subang Jaya was clearly concentrated to urban area due to the higher population density. The land-use map (Figure 2) is a subset image of the Subang Jaya municipality. The land-use types show spatial distribution of residential, commercial, industrial and open areas (Figure 4). It was found that a

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Table 2. Climatic variables correlation test.

	Climate variables								
	Rainfall (mm)			Temperature (°C)			Relative humidity (%)		
Year	*t*	*t*(1)	*t*(2)	*t*	*t*(1)	*t*(2)	*t*	*t*(1)	*t*(2)
2006	0.750**	0.649**	0.310	0.099	0.003	0.002	0.056	0.662**	0.208
2007	0.298*	0.369**	0.430**	−0.231	−0.261	−0.330*	0.140	0.257	0.343*
2008	−0.061	−0.168	−0.185	0.203	0.246	0.205	−0.181	−0.304*	−0.284*
2009	0.269	0.073	−0.032	−0.405**	−0.378**	−0.234	0.407**	0.384**	0.202
2010	0.168	0.004	0.191	−0.361*	−0.414**	−0.485**	−0.125	−0.145	0.007

Note: *Significant level $p < 0.05$ (two-tailed). **Significant level $p < 0.01$ (two-tailed).

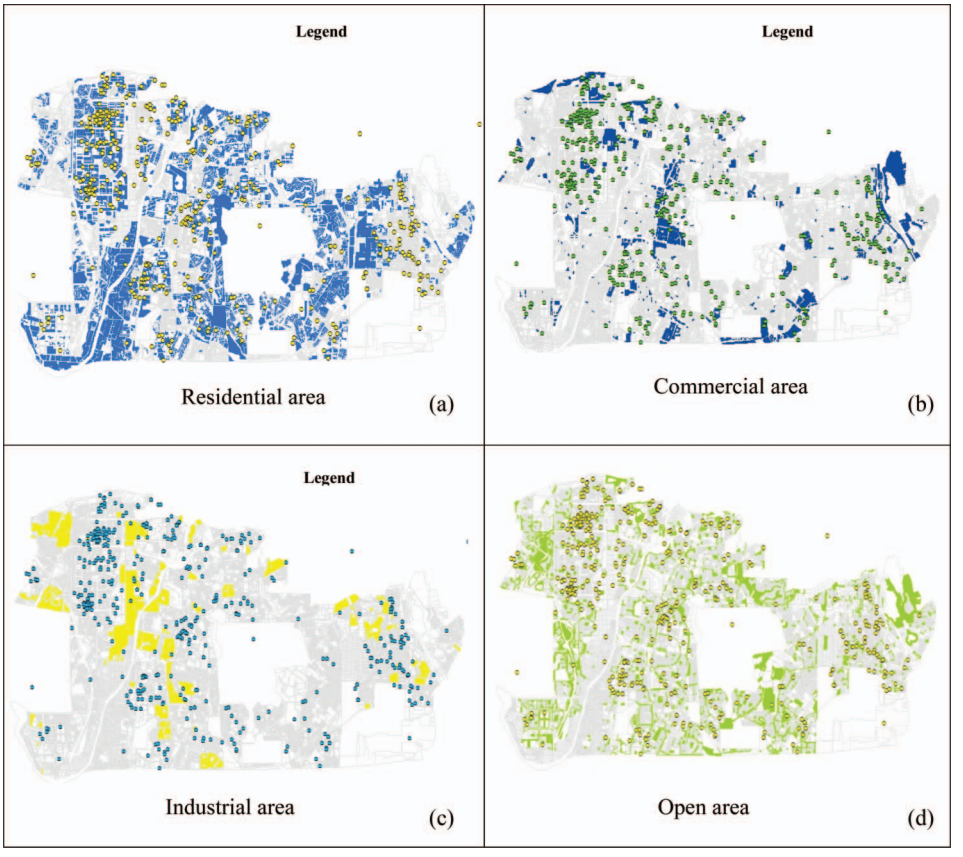


Figure 4. Mapping of distribution pattern of dengue incidence according to land-use pattern. (a) Residential area, (b) commercial area, (c) industrial area and (d) open area. Note: 1 dot represents 1 DF case.

residential area (Figure 4(a)) acts as the main exposure area for distributing the dengue virus, followed by open area (Figure 4(d)), industrial (Figure 4(c)) and commercial areas (Figure 4(b)). With abundant rainfall and uniform temperature, residential area provide favourable places for the breeding created by human in residential area especially one-storey house (Mondini and Chiaravalloti-Neto 2008).

4.3 *Housing types and case distribution*

Table 3 presents distribution of housing type from 2006 till 2010 in Subang Jaya infected with dengue diseases. As the percentage data are much more presentable for recent situation of housing distribution, Table 3 allocates the percentage of type of housing in Subang Jaya administrative area from 2006 to 2010. Figure 2 displays the distribution of spatial data according to type of housing in its classification (Figures 2(a) and (b)). It was clearly found that interconnection houses (Figure 5(A)) act as the main exposure area for distributing the dengue virus, followed by independent houses (Figure 5(B)), mixed houses (Figure 5(C)) and commercial houses (Figure 5(D)). As discovered by Achu (2008), interconnection houses provide artificial breeding places mainly caused by its design that capable to store water.

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Table 3. Type of housing distribution infected with dengue from 2006 till 2010 in Subang Jaya.

	Category of housing infected with dengue							
	Interconnection houses		Independent houses		Mixed houses		Commercial houses	
Year	*n*	(%)	*n*	(%)	*n*	(%)	*N*	(%)
2006	224	86.82	25	9.69	4	1.55	9	3.49
2007	1312	94.19	65	4.67	23	1.65	16	1.15
2008	1268	92.89	58	4.25	19	1.39	39	2.86
2009	1044	94.05	42	3.78	34	3.06	24	2.16
2010	738	96.72	22	2.88	10	1.31	3	0.39

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5. Discussion

Climate change is one of the environmental factors that might influence the trend of the dengue outbreak distribution and transmission. From the result of the present study, it is evident that climate factors such as temperature and rainfall will not give a direct impact to the trend of incidence cases, but will indirectly influence the number of incidence and the trend of transmission. The predominant vector transmitting DF in Subang Jaya was *Aedes aegypti*, which hatched from eggs and went through several stages in their life cycle between 7.2 and 39.7 days in a range of temperature between 25°C and 35°C before becoming adults, and higher temperature would reduce the time needed for development (Macdonald 1956, Chan 1977, McDonald 1977). When temperature gets relatively high, it will effectively evaporate the water from these man-made, stagnant water sites and thus might in turn affect the vector population density through decreasing the survival of immature vector by drying the breeding site, as we have observed in Subang Jaya. On the other hand, high temperature also associates with maturity period of the larvae according to the Rueda *et al.* (1990). Relative humidity is another crucial factor affecting the life pattern of mosquitoes, such as mating, oviposition and seeking host pattern (Wu *et al.* 2010, Supawan *et al.* 2005).

All the above facts have proven that climate changes have played a role in influencing the trend of dengue distribution and transmission (Wiwanitkit 2006, Rozilawati *et al.* 2007). It is very important to understand the presence of water that will provide breeding sites for the mosquito and which will then increase the vector population density as well as the possibility of transmitting the dengue virus to human beings. Therefore, the public should be more alert during the raining season due to the fact that rainfall is one of the important factors which influence the number of dengue incidence cases besides temperature.

The trend of the dengue case distribution is mainly influenced by land-use changes. It is found that a residential area acts as the main exposure area for distributing the dengue virus, followed by open area, industrial and commercial areas. Land-use pattern and dengue cases distribution show the higher distribution on the residential area due to the higher population density in residential area as well as favourable places for the breeding created by human in residential area especially one-storey house (Mondini and Chiaravalloti-Neto 2008). As reported by Achu (2008), interconnection houses provide artificial breeding places mainly caused by its

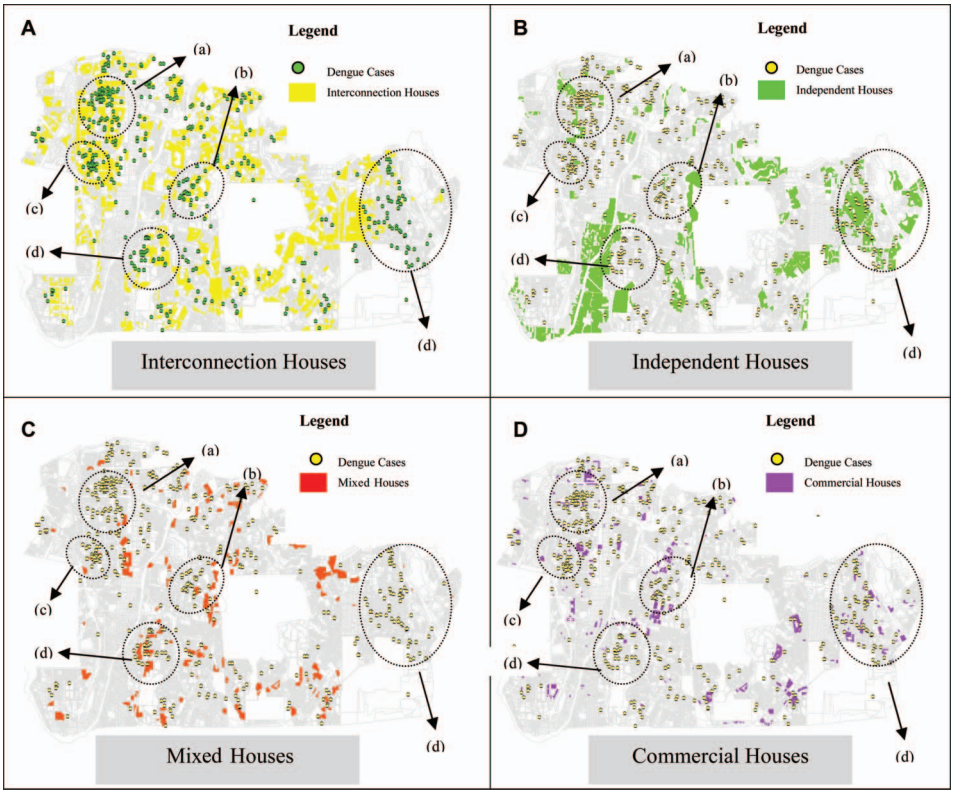


Figure 5. Mapping of distribution pattern of dengue incidence according to housing types. (A) Interconnection house, (B) independent houses, (C) mixed houses and (D) commercial houses. The location of dengue hotspot is shown as a circle area as denoted by (a), (b), (c), (d) and (e). Note: 1 dot represents 1 DF case.

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design that capable to store water. A separate study by Sophie *et al*. (2006) indicated that land cover and spatial organization of villages and the surrounding landscape play a role in the dengue infection. They had also mentioned the role of land cover as a source of breeding habitat.

The results from the land-use analysis revealed that the open area and industrial areas play a main role in influencing the trend of number of the dengue incidences as well as the pattern of the dengue distribution. The zoning analysis of the exposure parameter [Industrial (Figure 4(c)) and open area (Figure 4(d))] influencing the number of dengue incidence as recorded for year 2010. The figure shows the positive correlation contribution of open area and industrial areas to the dengue outbreak distribution pattern. Most of the reported cases had occurred near such areas. This is supported by the findings of the study conducted by MOH (2005) in identifying areas with a high percentage of *Aedes* breeding sites.

The distribution pattern is not however solely dependent on open area or industrial areas as breeding sites for the vector, as it differs over time and space due to the contribution of other environmental factors. Due to this fact, besides the land-use factor contribution, other environmental factors that might have a high possibility of influencing the trend of the dengue transmission and distribution will also be taken

into account. As a comparison analysis, it is evident that commercial sites might contribute or influence the number of cases over time and space (Figure 4(b)).

Interconnection houses are predominantly related to dengue cases throughout the 2006–2010 year, followed by the independent houses, mixed houses and commercial houses, respectively. The interconnection houses are significantly affected by the dengue cases because of the larger population density. Types of housing as well as their design such as guttering or window curbs create possible artificial breeding places for *Aedes* mosquitoes. Overall, the findings of the present study are consistent with those reported by Mondini and Chiaravallotti-Neto (2008). This study discerned that identification of one-storey homes and other interconnected houses is an important risk factor in DF occurrence. These findings are also in line with Guha-Sapir and Schimmer (2005), indicating that neighbouring individuals have effects on each other and on the area they live which in turn affect the breeding sites for mosquitoes.

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6. Conclusion

The findings in the present study have shown the significant correlation of contributing factors from various environmental parameters in the dengue transmission and distribution pattern. Moreover, hotspot identification maps can be used as a part of an early warning system for dengue management in Subang Jaya municipality area. This integrated data from multi-sectorial agencies are beneficial to supplement current practices of dengue management by providing other contributing environmental factors that have been statistical, significantly proved at particular characteristic of the surrounding area. Distribution pattern of dengue cases and its interaction with climatic and spatial factors can be used for modelling of interactive dengue surveillance and effective management system not merely in Subang Jaya municipality area but also in the other highly reported dengue cases area in Malaysia or elsewhere.

The present study will stimulate further discussion on how to strengthen current existing dengue prevention and control actions which should be implemented regularly rather than an emergency basis. Furthermore, this research will lead to further discussion on how to come out with ways of sustaining resources over a period of several years for effective control strategies for testing and implementation which is vital. In addition, routine monitoring and field evaluation of all activities is needed so that program personnel as well as receptor community have the same goal towards minimizing effective management of this disease.

As all the data from multi-sectorial agencies were obtained and integrated into fundamental analysing tools, the results of this study need to be validated so as to be applicable at similar characteristic as Subang Jaya Municipal area. Towards developing a model for prediction dengue cases occurrences, all the data must be accurately recorded and updated from time to time to come out with real-time situational analysis. Preventive actions taken by the management team also need to be considered as a main factor of dengue cases distribution pattern in those particular zones.

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