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Manifestation of GIS Tools for Spatial Pattern Distribution Analysis of Dengue Fever Epidemic in the City of Subang Jaya, Malaysia

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Abstract

Dengue has now emerged as one of the major public health problems in Malaysia. It was first reported in 1901 in Penang and since then the disease has become endemic concentrating mostly in urban areas. This study used the temporal-spatial model to determine high risk areas for dengue outbreak by measuring three temporal risk characteristics (i.e. frequency, duration and intensity) in order to define the severity and magnitude of outbreak transmission. This study examined a total of 4,651 confirmed dengue fever cases, geo-coded by address in the city of Subang Jaya between January 2006 and December 2009. The values of the three indices were considered high in a spatial unit when their standard values were positive. Measurement of the three temporal risk indices found that there were areas with significant high value for each of the temporal indices. This suggested that areas within Subang Jaya Municipality had different temporal characteristics for dengue occurrence. The utilization of three risk measures enabled to identify higher-risk areas for the occurrence of dengue fever. Even though case notification data are subjected to bias, this information is available in the health services and can lead to important conclusions, recommendations and hypotheses. As a recommendation, the temporal risk indices can be utilized by public health officials to characterize dengue rather than relying on the traditional case incidence data.

Keywords: spatial pattern distribution; dengue fever; Subang Jaya, Malaysia

1. Introduction

Dengue Fever (DF) is a complex health problem to manage due to a combination of factors varying from biophysical to social and economic. No single solution had been identified that could effectively reduce or eliminate the impact of dengue disease (Skae, 1902; Rudnick, 1965; Sharma *et al*., 2008). Hence it is important to identify the factors which really contribute to the transmission of dengue cases in different areas and then correlate these factors to identify high risk areas which could be used to plan cost effective control activities and also to predict future outbreaks (Barbazan, 2001; Kanchana *et al*., 2005; Chiravalloti, 2008). In addition, it is also important to understand the spreading mechanism of DF in the district during the epidemic period as this might be the primary factor that is essential for planning the application of preventive and control measures (Openshaw, 1996; Ratana, 1997).

In Malaysia, the endemic level of 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, but many factors combine to produce epidemiological conditions that favor viral transmission by the main mosquito vector *Ae. aegypti*. Among them are population growth, inadequacies in urban infrastructure, including solid waste disposal, and rise in domestic and international travel.

There is a general agreement that DF can attack anyone in areas which historically have experienced dengue virus outbreak. A high density of the vector or mosquito will increase the possibility of the dengue outbreak. It is well known that there are no vaccines available to protect people living in risk areas of the dengue epidemics and the best alternative is to avoid mosquito bites and to destroy the vector breeding sites. Therefore, it is important to understand the dynamic pattern of DF on a local scale that might influence the outbreak mechanism. According to Wen *et al*. (2006), the clinical manifestation of dengue includes DF, DHF and the most severe and potentially fatal dengue shock syndrome (DSS). They have reported that more DF cases emerged from a dengue epidemic in endemic and hyper-endemic areas, which often correlated with more fatalities, especially with late medical care or when the cases are inappropriately managed (Wen *et al*., 2006; Wen *et al*., 2009).

In recent years, the utilization of Geographic Information System (GIS) as a tool to manage diseases by public health organizations has become a necessity in line with the advancement of technology (Barbazan, 2001; Gong and Liang, 2006; Nitatpattana *et al*., 2007; Cringoli, 2008). With GIS, the precision of disease mapping in relation to the locality will be enhanced and therefore GIS is a valuable tool in the detection and monitoring of the response to disease outbreaks prior to mapping (Andrianasolo, 2001; Jirakajohnkool, 2006; Krishna, 2008; Wen *et al*., 2009). Wen *et al*. (2006) stated that the exclusive utilization of incidence rates to assess the occurrence of diseases provides limited results, and thus he explores the spatial distribution of dengue fever cases in Kaohsiung, a metropolitan in south Taiwan. GIS was employed to analyze the temporal and spatial model, such as frequency, duration and intensity of the dengue fever cases in each district. Based on those spatial analyses, the study concluded the districts with high risk may be the source of DF outbreak. Nazri *et al*. (2011) stated that Subang Jaya, Malaysia has been identified as having the highest number of reported cases occurred during the DF outbreak.

The present study described the temporal-spatial model to assess high-risk areas for the occurrence of DF outbreak at Subang Jaya based on the model proposed by Wen *et al* (2006). From this criteria, the distribution and dynamics of dengue outbreak were analysed and the outcome from the result used as indicators of risk in a locality.

2. Materials and Methods

2.1. Study area

Subang Jaya is a suburban city in the Klang Valley, Selangor, Malaysia. It has a geographic area of 181 km2 and situated at latitude 3°05'48.74"North and longitude 101°33'02.39"East. Subang Jaya comprises the southern third of the district of Petaling, and a home to a third of the district population of 1.78 million.

2.2. Data collection

In this study, data on the annual cumulative incidence of DF cases registered at the vector control Unit, Subang Jaya area (January 2004 to December 2008) were used as source of data. In Malaysia, the epidemiological surveillance system which includes data collected of DF was set up in 1971. Its cover every level of health administrative and service which provides monthly notification. The homogeneity of its protocol and clinical criteria (World Health Organisation) for DF among district and over decades allows a good level of data reliability and validity. The Subang Jaya area was selected as point of data collection because the data was summarized before it being sent to the Ministry of Health Malaysia (MOH) and the control strategies are defined and launched at this level. All the DF cases were confirmed by serological tests, virus isolation and detection of dengue ribonucleic acid at MOH labs.

2.3. Modeling approach

Traditional disease surveillance comprises a set of epidemiological procedures that monitor the spread of a disease and determine how it is spreading. These approach reports the number of cases for each location and time period. Wen *et al*. (2006) mentioned that the exclusive utilization of incidence rates to assess the occurrence of diseases provide limited results, and thus propose a spatio-temporal risk model to map geographic distribution of cases. In this study, all the confirmed DF cases with complete residential addresses were mapped using ArcGIS 9.1 (Barbazan, 2001; Cringoli, 2004) and further analyses on the risk patterns of the dengue epidemic in the epidemic period (2004-2008) were carried out. To identify potential risk areas and analyze different spatial patterns using appropriate temporal risk indices, the three above defined temporal indices were calculated for each spatial unit. The DF cases were summarized according to the spatial unit, on a weekly basis. Therefore, to identify potential risk areas and analyze different spatial patterns using temporal risk indices, the values of the three temporal risk indices were calculated for each locality and its descriptive statistics across the study areas. A risk model developed by Wen *et al*. (2006) was used to evaluate a dengue epidemic in both magnitude and severity of an outbreak in the study area. To pinpoint the difference in this distribution, the comparison among several categories was performed.

2.4. Calculation of the three temporal indices (Frequency, Duration and Intensity Index) as epidemiological measures.

To identify potential risk areas and analyze different spatial patterns using temporal risk indices, the values of the three temporal risk indices were calculated for each locality and its descriptive statistics across the study areas. Each temporal index covered different size and numbers of spatial unit. From the temporal distribution of epidemics, several characteristic of DF epidemic may be described. Data from monthly reports on DF incidence during the 5 years of the study period (2004-2008), were calculated to three temporal risk indices for each spatial unit and seasonal year which was adopted from Wen *et al*. (2006) in order to assess the risk transmission severity and magnitude of the outbreak.

Frequency index (α), defined as the probability that the total number of weeks with one or more dengue cases occurred during the entire epidemic period. It can be expressed as:

$$\alpha = SE / ST \quad (1)$$

where ST is the total number of weeks during the period in question, and SE is the total number of weeks with one or more cases occurring during the period in question. It represents the proportion of weeks with one or more cases or the probability that one or more cases occur in a given week, in the period studied (one year or 52 weeks).

Duration index (β), define as the mean number of week per epidemic wave when cases successively occur. It can be expressed as:

$$\beta = SE / OE \quad (2)$$

where SE is described above and OE is the total number of epidemic waves during the period in question. One epidemic wave, according to Wen *et al*. (2006), is defined as a sequence of weeks with the occurrence of uninterrupted cases. This index gives an idea of the persistence of transmission and represents the average duration, in weeks, of epidemic waves that occurred in the given period.

Intensity index (γ), characterized as the mean incidence of cumulative dengue cases occurring in consecutive weeks per epidemic wave that had persisted for more than two week. It can be expressed as:

$$\gamma = TI / OE \quad (3)$$

where TI is the incidence rate during the given period and OE is described above. It assesses the severity of transmission, and is based on sequences of weeks with the occurrence of uninterrupted cases. High values mean time-concentrated transmission.

2.5. Identification of risk profile based on the combination of three temporal Indices

To determine the risk profile of an area, each spatial unit was subsequently classified into one of the eight categories created for all possible combination of the temporal indices, seven of which (A to G) were considered high risk whereas, H categories was considered lower risk. The analysis of the mean rank of variables, according to risk category is presented in Table 1.

3. Results

3.1. Distribution of epidemic using three temporal indices as epidemiological measures

From the temporal distribution of epidemics, several characteristic of DF epidemic may be described. By comparing the areas for the three temporal indices versus incidence rates (Table 2), all zones had a

Table 1. Classification of all eight risk types defined by the three temporal indices

Risk Categories	Three temporal indices		
	Frequency (α)	*Duration (β)*	*Intensity (γ)*
A	High	High	High
B	High	High	-
C	High	-	-
D	-	High	High
E	-	-	High
F	High	-	High
G	-	High	-
H	-	-	-

Risk classification: Type A: High Frequency-Duration-Intensity; Type B: High Frequency-Duration; Type C: High Frequency; Type D : High Duration-Intensity; Type E : High Intensity, Type F: High Frequency-Intensity; Type G: High Duration, Type H: No cases

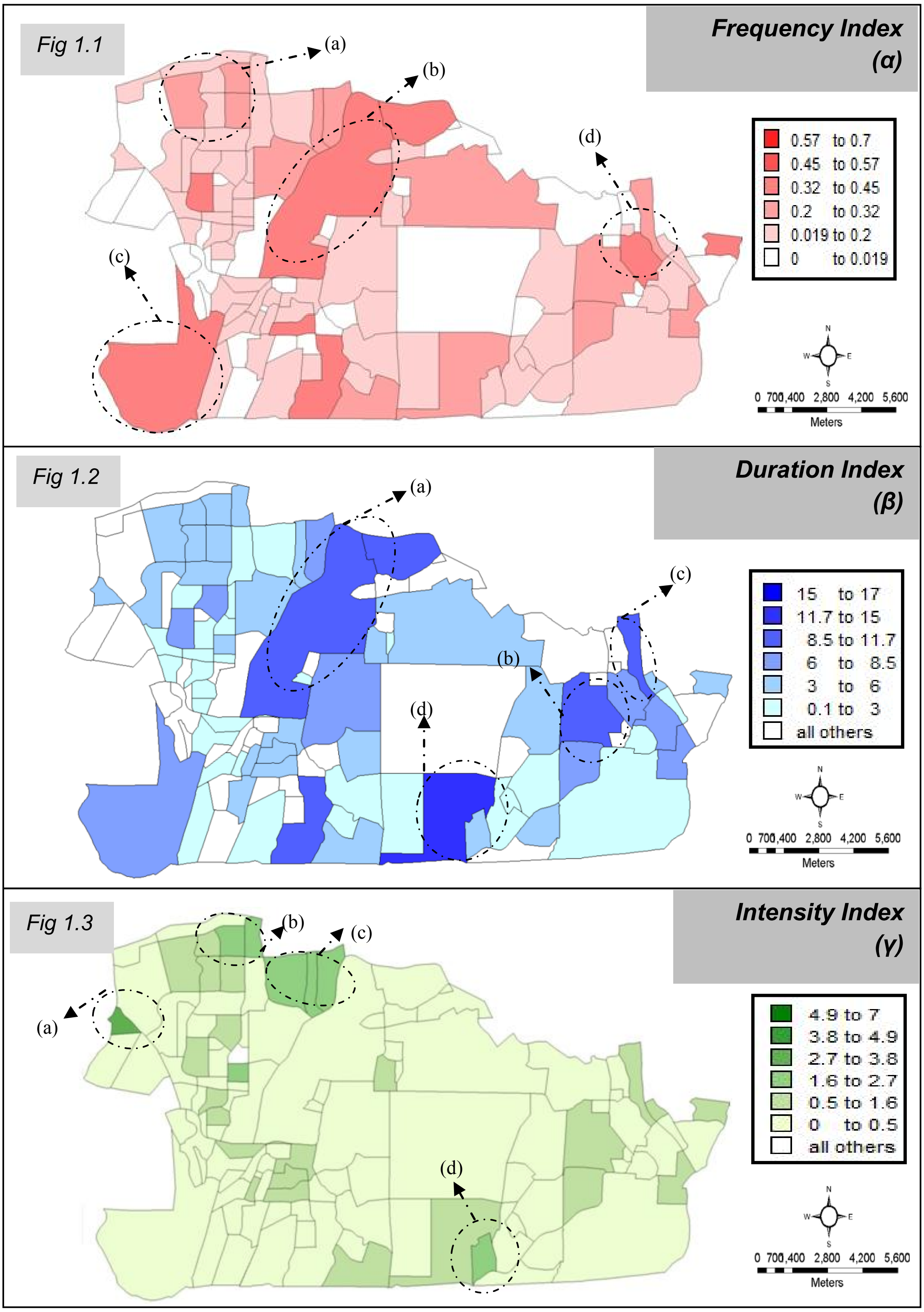

Figure 1. Mapping the values of three temporal indices (Frequency, Duration and Intensity) with observed spatial unit. The darker areas reflect a higher value of that indicated index. The locations of dengue hotspot are shown as circle areas.

similar high cumulative incidence, but they had different temporal risk pattern shown by these three temporal indices. Each year has shown a dramatic increase of these temporal risk indicators. Fig. 1 display the spatial pattern of dengue cases using three temporal indices in terms of Frequency (Fig. 1.1), Duration (Fig. 1.2) and Intensity indices (Fig. 1.3).

3.2. Risk classification using the combined three temporal indices

Table 3 presented the distribution of DF stratifying spatial unit classification according to risk and value for the three temporal risk measures for a study period. A clear difference and a gradient among the averages were observed. The results for the year 2004 showed the highest number of units without DF cases (62%). A total of 13 (13%) were identified with high value of the frequency and 4 (4%) for the duration index. no spatial unit was reported as high intensity index for the year 2004.

In the year 2005, 51.4% of the unit were classified as type H. High values of the frequency index were identified in 22 units (20.1%), one (1.0%) for the duration index and same value (1.0%) for the intensity index. The year 2006 was the one that showed highest dengue fever incidence. It was the year when all the risk profile showed maximum number of cases. Of all tracts, 51% were classified as type H. A total of 15 unit were identified with high values (8.3%) for the frequency index and four (3.7%) for the duration and intensity index.

Table 2. Comparison of the clustering area respectively was using the three temporal indices.

Year	Zones	Cumulative Incidence		Frequency		Duration		Intensity	
		No of Spatial unit	*Index value*	*No of Spatial unit*	*Index value*	*No of Spatial unit*	*Index value*	*No of Spatial unit*	*Index value*
2004	Subang Jaya	8	8-41	26	0.02-0.44	18	1.00-10.00	15	0.24-2.19
	Kinrara	4	6-42	15	0.02-0.50	3	4.00-6.50	3	0.10-2.83
	Seri Serdang	15	6-57	31	0.02-0.50	16	1.00-13.00	12	0.10-2.41
	Seri Kembangan	5	5-25	28	0.02-0.35	9	1.00-6.00	6	0.06-3.08
2005	Subang Jaya	17	6-26	28	0.02-0.40	20	2.50-10.00	17	0.10-2.78
	Kinrara	6	5-27	22	0.02-0.33	4	1.50-1.70	4	0.16-2.29
	Seri Serdang	11	9-40	39	0.02-0.42	18	1.00-14.00	16	0.09-3.22
	Seri Kembangan	18	4-40	43	0.02-0.52	18	1.00-14.00	11	0.10-6.35
2006	Subang Jaya	15	6-94	30	0.02-0.54	18	1.00-14.00	15	0.19-3.32
	Kinrara	7	3-18	23	0.02-0.33	8	1.00-17.00	7	0.10-0.74
	Seri Serdang	22	4-41	39	0.02-0.42	22	1.80-14.00	21	0.04-3.75
	Seri Kembangan	20	3-37	37	0.02-0.44	20	0.09-6.00	13	0.04-2.63
2007	Subang Jaya	15	5-45	26	0.02-0.42	14	2.00-6.00	14	0.14-7.74
	Kinrara	17	3-40	24	0.02-0.44	11	2.50-13.00	11	0.15-2.22
	Seri Serdang	29	3-39	42	0.02-0.33	20	1.00-7.00	19	0.12-3.43
	Seri Kembangan	17	3-40	39	0.02-0.31	12	1.00-16.00	11	0.04-4.99
2008	Subang Jaya	23	5-89	33	0.04-0.50	19	2.00-15.00	16	0.21-5.17
	Kinrara	15	5-49	26	0.02-0.69	10	1.00-18.00	11	0.13-1.89
	Seri Serdang	23	8-54	42	0.02-0.54	24	1.00-13.00	23	0.10-3.81
	Seri Kembangan	17	4-45	35	0.02-0.46	16	1.00-16.00	11	0.35-4.14

Table 3. Spatial unit according to risk classification for the occurrence of dengue fever, frequency, duration and intensity indices. Subang Jaya, Selangor from 2004-2008.

Year	Risk Classification	Mean of the three Temporal Risk Indices			Regional Characteristics		Evaluation indices	
		Frequency (α)	*Duration (β)*	*Intensity (γ)*	*Number of spatial units*	*Population Density*	*Dengue Fever Cases*	*DF Density*
2004	A	0.23	6.93	1.73	9	6980	163	3.02
	B	0.25	6.64	0.63	12	17944	250	1.59
	C	0.13	3.69	0.46	13	18665	107	2.31
	G	0.04	2.25	1.80	4	2132	12	1.80
2005	No cases (H)	0.00	0.00	0.00	72	7981	0	0.00
	A	0.15	7.88	1.74	8	6345	65	1.60
	B	0.31	8.53	0.49	12	37155	279	1.09
	C	0.13	3.53	0.38	22	16216	167	0.79
	E	0.12	6.00	0.49	1	18190	9	0.49
	F	0.13	4.86	2.94	7	2975	78	3.90
	G	0.08	4.00	2.14	1	1865	4	2.14
2006	No cases (H)	0.00	0.00	0.00	54	2435	0	0.00
	A	0.24	8.17	1.85	13	9783	300	2.71
	B	0.27	7.52	0.40	11	32083	217	0.80
	C	0.21	3.64	0.30	15	27155	221	1.07
	D	0.09	5.00	1.23	1	4865	8	1.64
	E	0.09	5.00	0.53	4	16357	22	1.00
	F	0.15	3.06	1.24	5	3052	50	3.71
	G	0.05	2.50	1.93	4	1807	13	1.90
2007	No cases (H)	0.00	0.00	0.00	56	2595	0	0.00
	A	0.21	8.02	2.77	10	7643	203	3.92
	B	0.22	6.29	0.50	14	25135	221	0.80
	C	0.16	3.61	0.52	24	19676	267	1.30
	F	0.20	2.85	1.82	2	2739	35	6.00
	G	0.06	3.33	2.15	8	2806	59	2.45
2008	No cases (H)	0.00	0.00	0.00	54	3809	0	0.00
	A	0.29	11.33	3.69	9	5333	246	5.62
	B	0.34	9.93	0.61	11	33457	274	1.21
	C	0.27	4.77	0.72	23	20998	517	1.71
	D	0.13	7.00	3.74	1	2140	8	3.73
	E	0.21	8.63	1.00	4	16162	52	3.91
	F	0.20	5.30	2.19	5	3336	68	4.38
	G	0.08	3.17	2.06	8	2272	47	0.77
	No cases (H)	0.00	0.00	0.00	53	2320	0	0.00

Risk classification: Type A: High Frequency-Duration-Intensity; Type B: High Frequency-Duration; Type C: High Frequency; Type D : High Duration-Intensity; Type E : High Intensity, Type F: High Frequency-Intensity; Type G: High Duration.Type H: No cases

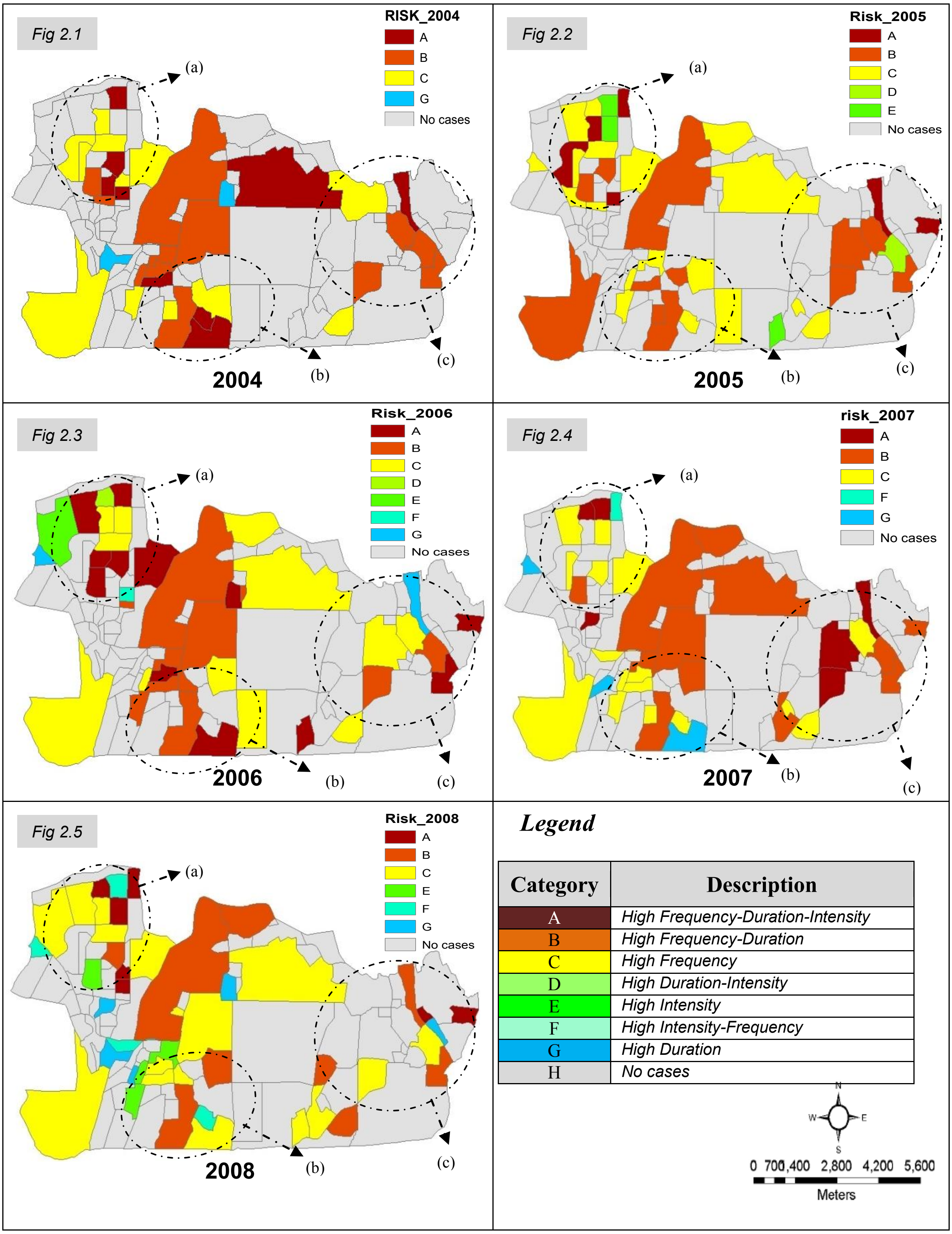

Figure 2. Distribution pattern of spatial units according to risk classifications for the occurrence of dengue cases. Subang Jaya, Selangor, (January 2004 – December 2008).

The analysis of the mean according to risk category for 2007 showed 48% of the unit were classified as type H. High values of the frequency index were identified in 10 units (8.9%), eight (7.1%) for the duration index and none (0.0%) for the intensity index. The year of 2008 was the one that showed highest dengue fever incidence. In addition, it was the year when all the risk profile showed maximum number of cases. Of all tracts, 46% were classified as type H. A total of 9 unit were identified with high values (7.9%) for the frequency index and eight (3.5%) for the duration and four (3.5%) for the intensity index.

Fig. 2 displays the distribution of spatial unit according to risk categories, where a pattern with concentration of spatial unit into different temporal risk characteristics over the district is verified (2004-2008). By comparing the mean ranks of the incidence rates for each risk category in each wave (Fig. 3), a significance difference was observed among the three categories (Hi- FDI, Hi-FD, Hi-F) with an ascending gradient for all the wave.

3.3. Assessment of the magnitude and severity of the dengue (2004-2008) epidemic in Subang Jaya

The analysis of the epidemics, according to risk category is presented in Fig. 3. From 2004 to 2008, the trend of the average annual DF incidence in the whole Subang Jaya district was significantly increased. Two different patterns in the outbreak of epidemic period can be seen in Fig. 4. The dengue temporal distribution in the entire locality indicate Hi-FDI, Hi-FD and Hi-F risk types had the highest DF density, presented in similar trend every year. The worst incidence was reported in Jan 2007 with more than 250 cases.

4. Discussions

Combining the field of epidemiology and computational management of information is an important endeavour for surveillance and effective control of health problem (Valerie, 2000; Tripathi, 2009). This study classifies area of Subang Jaya according to the susceptibility to the transmission of dengue and characterizes them based on the three temporal risk measures. The utilization of the three temporal risk measures proposed by Wen *et al*. (2006) enable the identification of high risk area of DF occurence This information provides a helpful picture of the epidemic and thus a more detailed representation of the risk.

From the spatial and temporal distribution of epidemic, several characteristics of DHF epidemics may be described. This study used the three temporal indices to retrospectively map the spatial patterns of dengue cases and to identify possible risk areas visually for the 2004 to 2008 year. Due to the nature of epidemic which is a dynamic process, it is important to identify spatial risk areas through the use of different temporal risk characteristics. For example, some area might have longer epidemic duration while others might have stronger intensity even though the duration is short. The high value for each index was represented by the darkest area.

Mapping of the three temporal risk indices produced spatial risk areas for each index. When visual analysis was done, 2008 proved to be the year with the most number of areas with high values of frequency indices. This pattern showed that, if not effectively controlled plus poor attitude of the people in seeking and destroying *Aedes* breeding habitats, there will be more areas with high frequency indices in the future. Distribution pattern of duration index showed that the high values are found at the same locality but their occurrance are erratic, appearing in one year, dis-appearing the next and reappearing again in the following year. This could be traced back to the environmental conditions of these areas; Taman Kinrara and Taman Serdang Raya. The two areas were undergoing construction interspersed with abandoned areas which could have contributed to the prolonged dengue outbreak (Triphati, 2005). The situation was made worse with the lack of public participation in seeking and destroying potential *Aedes* mosquitoes breeding areas. The distribution pattern for intensity index showed a consistent pattern. It tended to remain stable at the same localities. This could be due to the public health officials' reliance on the traditional total number of dengue cases. Thus, they could not detect the temporal difference of each area and continuously apply methods that were not suitable to the temporal characteristics of dengue in those areas. Therefore, when dengue outbreak started occurring in those areas, it would suddenly rise to unexpected levels.

The classification of the spatial unit according to the temporal risk indicator, establish after 5 years of epidemics, was enough to retrospectively discriminate these areas. This corroborates the hypothesis that factors inherent to these sites may facilitate or restrict the transmission and/or maintenance of the disease.

Public health officials may apply the methods developed from this study to focus more on risk areas that have high duration index value and high intensity index value. Using the spatial patterns from the three temporal indices, more effective control measures can be implemented at the risk areas. For example, areas with longer duration of epidemic wave could be applied with control strategies that would minimize

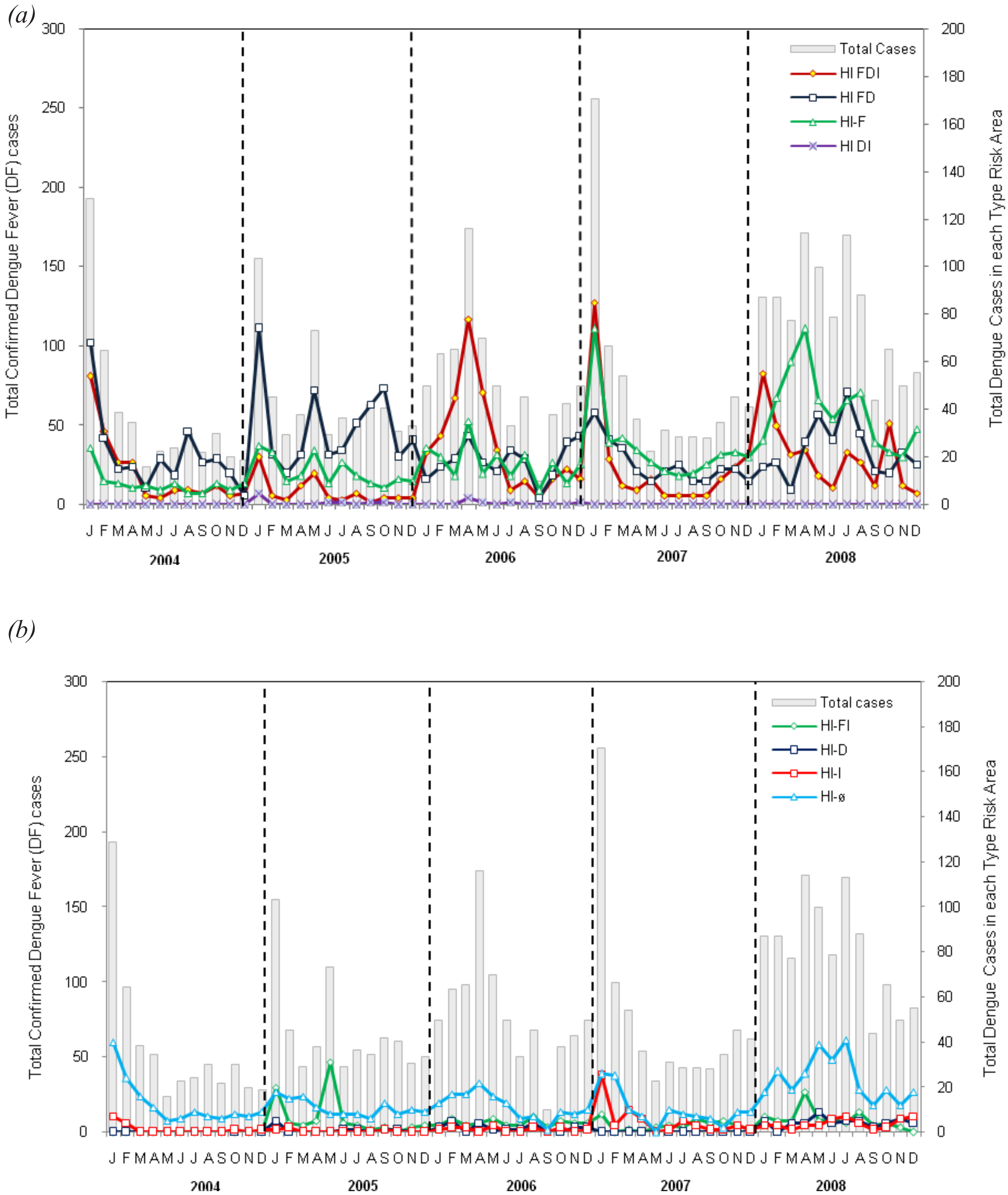

Figure 3. Epidemic curve of a weekly total confirmed dengue cases in areas with each risk types

the transmission intensity. Meanwhile, areas with high duration index value could be controlled using measures that focus more on the surrounding area that contribute to the prolonged occurrence of dengue cases. Areas with high duration value might have been overlooked if surveillance was based on incidence data alone. As a result, the continuous presence of *Aedes* mosquitoes might explain the prolonged duration in these areas. For those areas with high intensity values, but with low frequency and low duration of the dengue cases, the data sample could be due to adequate control measures in those areas resulting in the break of transmission and the prevention of further spread of dengue virus.

Currently, vector control is the only way to break the chain of dengue transmission as long as a vaccine is still not available. However, vector control is not a simple task due to the complexities of urban setting. Failure in control programs was pointed by several authors. These findings may provide one way to overlap the limitation of the traditional indicator by introducing other variables to establish priorities area not only for vector control but also for surveillance purposes to optimize resources which are generally reduced in periods of lower incidence.

This study relies on surveillance data to enhance basic spatial modelling using temporally defined indices, rather than traditional approach which uses dengue incidence data. The use of incidence data cannot distinguish the spatial differences in risk areas from those of the neighbouring areas which are crucial to the effective control of vector-borne infectious diseases. This study uses basic surveillance data that is routinely collected in most countries, but with the addition of the three temporal risk indices, risk areas can be identified without using expensive technology. This will help in the allocation of resources to the most at-risk areas to prevent further cases occurring and spreading.

5. Conclusions

Spatial and temporal aspects are vital variables that can be used to characterize epidemics dynamics and risk distribution. Even though there are other methods available which apply either complicated statistical analysis or sophisticated surveillance systems, they are difficult to perform in developing countries. This study provides public health authorities with a tool to differentiate risk patterns of a dengue epidemic using three temporally-defined indices to comprehensively identify high risk areas early in the epidemic episode based on their integrated spatial-temporal profiles. Apart from relying on mapping of incidence rate or number of cases, this study proposed a new set of parameters which can characterize the dengue cases in a more comprehensive manner thus providing the public health authorities with an alternative option to predict and effectively manage dengue outbreak.

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