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SPATIAL PATTERN DISTRIBUTION OF DENGUE FEVER IN SUB-URBAN AREA USING GIS TOOLS

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ABSTRACT

Dengue fever (DF) is one of the major public health problems in Malaysia. The number of cases recorded is always fluctuating. The aim of the study is to identify the high-risk area for the occurrence of dengue disease. Spatial-temporal model was used by measuring three characteristics which are frequency, duration and intensity to define the severity and magnitude of outbreak transmission. This study examined a total of 386 registered dengue fever cases, geo-coded by address in Jempol district between January 2011 and December 2015. Even though case notification figures are subjected to bias, this information is available in the health services. It may lead to crucial conclusion, recommendations, and hypotheses. Public health officials can utilize the temporal risk indices to describe dengue relatively than relying on the traditional case incident figures.

Keywords: spatial pattern distribution, dengue fever, sub-urban, GIS tools, Jempol, Malaysia.

ABSTRAK

Demam denggi (DD) merupakan masalah kesihatan awam yang utama di Malaysia. Kes demam denggi yang dicatatkan sentiasa berubah-ubah. Pada tahun 1901, kes demam denggi pertama kali dilaporkan di Pulau Pinang, dan selepas itu ianya menjadi endemik di kebanyakan kawasan bandar. Fokus kajian ini adalah untuk mengenalpasti kawasan berisiko tinggi bagi kejadian kes-kes demam denggi. Model reruang masa digunakan bagi menentukan tiga pendekatan yang digunakan iaitu frekuensi, tempoh dan intensiti yang bertujuan untuk menentukan tahap jangkitan wabak tersebut. Kajian ini telah melibatkan sebanyak 386 kes demam denggi yang berdaftar berdasarkan alamat di dalam daerah Jempol dari Januari 2011 sehingga Disember 2015. Walaupun terdapat ketidaktepatan jumlah berdasarkan notifikasi kes, maklumat ini adalah data sedia ada di dalam perkhidmatan-perkhidmatan kesihatan. Ianya boleh membantu dalam merangka kesimpulan, cadangan dan hipotesis yang kritikal. Manifestasi risiko masa boleh digunakan oleh pegawai-pegawai kesihatan awam untuk mendefinisikan denggi jika dibandingkan dengan bergantung kepada data-data kes insiden yang lama.

Kata kunci: corak taburan reruang; demam denggi; sub-bandar; perisian GIS; Jempol, Malaysia.

INTRODUCTION

The increasing number of dengue fever cases in Malaysia is distressing the Ministry of Health (MOH). The annual report by Ministry of Health (MOH) of Malaysia reported that over 120,836 positive cases were reported in Malaysia in the year 2015, and 11.2% increases over that reported in the year 2014.

Dengue fever is a tropical mosquito-borne flavivirus with four serotypes (Khan et al., 2007), and the disease is the most crucial arthropod borne viral disease in Malaysia. Many approaches have been taken to handle this problem. There are many researches that have been conducted to identify the risk areas which may cause an occurrence of dengue fever. The breeding has been highly found in high population density area. *Aedes albopictus* which is one of the *Aedes* species, has also been found in natural environment (Gubler 1998: World Health Organization, 2008). A study was conducted by Nazri et al., (2013) which stated that the attracting area of dengue fever is in an urban area, which was also stated by Gubler and Clark as cited in Chen et.al, (2005) and Gubler and Clark, (1995). They also reported that dengue cases shown a fluctuated number every year. Improper sanitation of environment gives bad impact to human life. It may cause the increasing number of dengue fever cases. A study was conducted by Kumarasamy, (2006) who stated that dengue haemorrhagic fever (DHF) was found in 1962. He also mentioned that many factors can contribute to dengue fever growth to produce epidemiological conditions such as population growth, rapid urbanization, rural urban migration inadequacies in urban infrastructure, including solid waste disposal, and rise in household and international travel. Research that has been done by Nazri et al., (2012) stated that dengue fever gives a bad impact to human health. The research is also supported by Ahmad Nizal et al., (2012) in their paper where it said that dengue fever may cause death and hospitalization. This is why the Ministry of Health Malaysia is very committed in monitoring and controlling this disease.

Humans and environment need each other. Humans need a good condition of environment to produce a quality life in terms of health, social and economic. What happen today may be because of the human lifestyle which may affect the cleanliness of the environment to worsen. The condition may cause the environment to suit the habitat of dengue vector. The occurrence of dengue is caused by the transmission of one of four dengue viruses from infected female *Aedes* spp mosquito to human (*Dengue Guidelines for Diagnosis, Treatment, Prevention and Control,* 2009). There are many control methods that are done to destroy the dengue vector from breeding, but the results show an increasing figure, furthermore, there are death cases of dengue fever as stated by Ahmad Nizal et al., (2012).

Based on the model proposed by Wen et al. (2006), the present study described the temporal-spatial model to assess high risk areas for the manifestation of DF outbreak in Jempol district. Based on the result, the distribution and dynamics of outbreaks were analysed and the outcome will be used as indicators of risk in a locality. GIS is a tool that was used in recent years to manage diseases with the advancement of technology (Barbazan, 2001: Cringoli, 2004). Using this tool, the process of disease mapping related to the locality will be improved and it is also a valuable tool to detect and monitor the disease outbreak prior to mapping (Krishna, 2008; Wen et al., 2010). GIS is supposed to analyse the temporal and spatial model, such as frequency, duration and intensity of the dengue cases by locality in each district. Based on the spatial analysis, the high-risk area may be the source of the dengue outbreak. Nazri et al. (2011) who was using this tool in their study stated Subang Jaya, Malaysia as the highest number of reported cases occurred during the dengue outbreak. The scope of study is limited to the study of dengue cases in the whole area of Jempol district. It involves a retrospective study which was recognized as a possible risk area visually for the year 2011 to 2015

The undertaking present study is to determine a dengue outbreak because it is believed to be able to address the spatial pattern distribution in the study location. The definition of outbreak happened when there are no new cases notified after 14 days from the notification of the second case. It describes how spatial pattern distribution is mapped and is particularly useful in understanding the situation. Results from analyses enable lay health officer to understand the outbreak area in Jempol district.

An outbreak is constructed based on three temporal indices which are frequency, duration, and intensity. Understanding the possible risk areas enable us to construct more variations of control methods based on different localities.

The number of dengue fever cases showed a fluctuating trend. E-dengue system illustrated the increased figures from year 2011 to 2014 then the figures decreased in year 2015. Jempol district is classified as a suburban area, consisting of Felda as the major localities. Although Jempol was classified as a suburban area, it recorded the second highest dengue fever cases than Seremban district. There are many researches that are conducted in urban areas. Instead of focusing on urban areas, this paper is concentrating on suburban areas as the study location. The present study focuses on analyzing the possible risk area of dengue cases with GIS tools approach. The tools have been chosen because mapping the possible risk area is a basic information to plan a strategy control. It also plays an important role in how dengue vector interact with environment and to define the surrounding of the spatial. It is felt that by analysing these spatial patterns in writing contribute to an interesting and meaningful interpretation of possible risk area.

MATERIALS AND METHODS

This chapter presents a methodological outline of the research. The data were obtained by E-dengue system and the selected data is based on registered cases only.

Study location

This study is located in Jempol district (lat. 2.8966, long. 102.4055) in Negeri Sembilan in order to evaluate the dengue risk areas based on three temporal indices. Jempol is the largest district in the Malaysia state of Negeri Sembilan. The district is a boundary to another Malaysian state of Pahang to the northeast and Johor to the east. Bandar Seri Jempol and Bahau are the principal of towns of Jempol. It is under the authority of Majlis Daerah Jempol. The area is located 70 kilometers from Seremban. The areas covered by the Felda area have nearly 75% driven factors to the high occurrence of the dengue outbreaks where the number of cases increased yearly. The incremental of cases was due to the improper condition of the surrounding environment. The incremental trend of dengue cases in this area was significantly related to the public health implication in relation to the control and dengue prevention. Therefore, in this study, the observation was focused overall Jempol district.

Data collection

The data source for the research is the corporate annual cumulative incident of DF cases. The registered cases are the primary source at CPBV Unit, Jempol area (From January 2011 to December 2015). All the dengue cases were confirmed by serology tests, virus isolation, dengue ribonucleic acid detection and antibody detection at MOH labs.

Modelling approach

Conventional disease surveillance comprises of a set of epidemiological procedures that observe the spread of a disease and by finding out how it spreads. The method was reporting the number of cases for each location and time period. The exclusive utilization on incident rates to access the diseases occurrence provides limited results, hence propose a spatial-temporal risk model to map geographic distribution of cases (Wen et al., 2006). All the confirmed dengue cases were mapped using ArcGIS 9.1 (Barbazan, 2001; Cringoli, 2004).

After that, further analyses on the risk patterns of dengue epidemic in epidemic period (2011-2015) were carried out. The three temporal indices were calculated for each spatial unit to identify the potential risk areas. The dengue cases were summarized per the spatial unit, on a weekly basis. The value of the three temporal risk indices was calculated for each locality and its descriptive statistics across the study areas.

A risk model developed by Wen et al., (2006) is to evaluate a dengue epidemic of an outbreak (magnitude and severity) in the study area. Comparison among several categories may pinpoint the differences in this distribution.

Calculation of the three temporal indices as epidemiological measures.

An epidemiological data on daily dengue cases from 2011 to 2015 were analysed to access the risk transmission. From the data, three temporal indices were calculated for each spatial unit and seasonal year as stated by Wen et al., (2006).

Frequency index (α), defined as the mean of probability of the total number of weeks with one or more dengue cases occurred during the entire epidemic period.

$$\alpha = SE/ST \tag{1}$$

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 that occurred in a given week, in the period studied (one year or 52 weeks).

Duration index (β) is defined as the mean number of week per epidemic wave when cases successively occur.

$$\beta = SE/OE \tag{2}$$

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), is described as the mean incident of cumulative dengue cases occurring in consecutive weeks per epidemic wave that persisted for more than two weeks.

$$\gamma = TI/OE \tag{3}$$

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.

Identification of risk profile based on the combination of three temporal indices.

The classification of risk profile was classified into one of the eight categories. It was determined as the risk area. Seven of which (A to G) are considered as high risk, while H is considered as lower risk. The analysis of the mean rank of variables is presented in Table 1

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

Risk categories	Temporal indices			Colour code
	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

Risk characterization areas

Table 2 shows the classification of all eight risk types defined by the three temporal indices. The table can be used to look visually into the risk pattern in spatial unit using mapping technique. Type A has been identified as high frequency-duration-intensity and the spatial has appeared as the red colour. For type B, the spatial is coloured with orange colour which represents a high frequency-duration area. Type C has been described as high frequency area and the spatial is coloured with yellow. Dark green (type D) as a high duration-intensity while light green as type E means high intensity. For type F, means the spatial showed high frequency-intensity and the colour is light blue. Meanwhile, type G spatial means high duration with dark blue colour. Areas with no cases were plotted as type H and appear as green colour in the spatial.

Table 2 Classification of all eight risk types defined by the three temporal indices

Risk categories	Three temporal indices Frequency (α)	Duration (β)	Intensity (γ)	Colour code
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

RESULTS

Epidemiology Profile

From the data, we can have summarized that the highest dengue cases is among 16 to 30 years old (923.10 ± 4.19), while the lowest figure is among people 0 to 15 years old (9.14 ± 4.80). For gender classification, the result describes that women are highly affected with dengue fever compared to men with the figure of 50.5%. Malay states the highest number (66.75%) than Chinese (15.3%) and Indian (11.60%).

Figure 1.1 shows the distribution of dengue cases in Jempol district. The result appears based on the three temporal indices. Frequency index shows highest index in Rompin and Serting Ilir zone with index of 0.019 to 0.7. It can be described that dengue cases occurred about one or more cases in every two or three weeks. Figure 1.2 shows the duration index, which means the duration of outbreak period based on the spatial. Duration index shows a high figure in Rompin and Serting Ilir zone. The data proved that there is no uncontrolled outbreak in Jempol district in the previous five years, while Figure 1.3 illustrates the intensity index showing the people's involvement in one outbreak. The highest intensity index is 0.5 to 1.6.

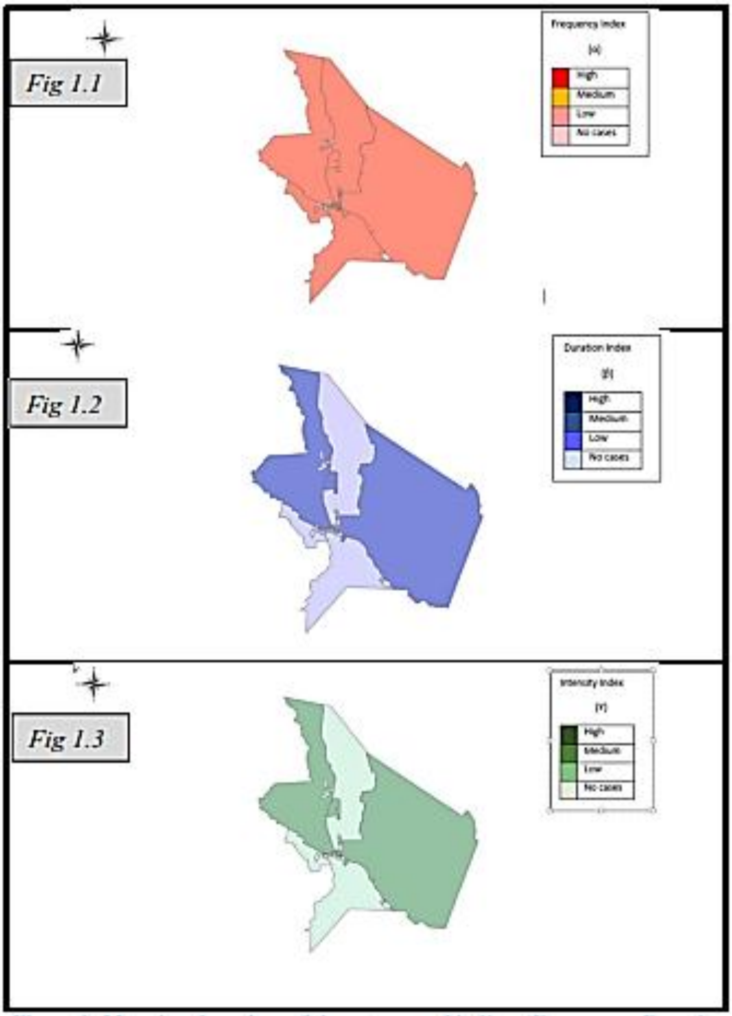

Figure 1 Mapping the values of three temporal indices (Frequency, Duration, and Intensity) with observed unit spatial. The darker areas reflect a higher value of the indicated index. The locations of dengue outbreak are shown as circle areas

In 2014, the result states about 146 dengue cases. In the same year, 26.98% were identified as high frequency-duration-intensity, while 2.33% were identified as high duration and 2.33% high intensity. Besides, 2012 states the lowest number of dengue cases (35). From the figures, 10 spatial were detected as high frequency only.

Year	Zones	Cumulative Incidence		Frequency		Duration		Intensity	
		No of spatial unit	No of cases	No of spatial unit	Index value	No of spatial unit	Index value	No of spatia l unit	Index value
2011	SU	3	4	1	0.01 -0.02	0	-	0	-
	JEL	6	7	2	0.01 -0.02	0	-	0	-
	SI	7	13	4	0.01 -0.02	1	0.1 -3.0	1	0.0 -0.5
	ROM	14	19	5	0.32 -0.45	0	-	0	-
	KJ	2	3	0	0.01 -0.02	0	-	0	-
2012	SU	2	2	0	0 – 0.019	0	-	0	-
	JEL	4	4	1	0.019 -0.02	0	-	0	-
	SI	9	18	5	0.32 -0.45	0	-	0	-
	ROM	6	9	3	0.32 -0.45	0	-	0	-
	KJ	1	1	1	0.019 -0.02	0	-	0	-
2013	SU	5	6	4	0.32 -0.45	0	-	0	-
	JEL	14	21	11	0.57 – 7.0	0	-	0	-
	SI	10	16	7	0.57 – 7.0	1	0.1 -3.0	1	0.0 -0.5
	ROM	6	7	4	0.32 -0.45	0	-	0	-
	KJ	1	2	1	0.32 -0.45	0	-	0	-
2014	SU	5	16	4	0.57 – 7.0	1	0.1 -3.0	1	0.0 -0.5
	JEL	18	27	18	0.32 -0.45	1	0.1 -3.0	1	0.0 -0.5
	SI	17	51	17	0.57 – 7.0	1	3.0 – 6.0	1	00 -0.5
	ROM	13	32	13	0.57 – 7.0	2	3.0 – 6.0	2	00 -0.5
	KJ	6	8	6	0.32 -0.45	0	-	0	-
2015	SU	9	12	9	0.57 – 7.0	0	-	0	-
	JEL	10	18	10	0.32 -0.45	1	3.0 – 6.0	1	0.0 -0.5
	SI	21	51	21	0.57 – 7.0	3	8.5 -11.2	3	0.0 -0.5
	ROM	9	15	9	0.32 -0.45	2	3.0 – 6.0	2	0.0 -0.5
	KJ	6	7	6	0.32 -0.45	0	-	0	-

Note : SU: S.Ulu; JEL: Jelai; SI": S.Ilir; ROM: Rompin; KJ: Jempol

Figure 2 shows the spatial distribution of dengue cases from year 2011 to 2015. The results show the risk category in Jempol district. The spatial category for 2012 showed 91.6% of the units were classified as type H (no cases). High values of the frequency index were identified in 10 units (4.65%), and none (0%) for duration and intensity index. The year of 2014 was the one highest dengue fever incidence. In addition, it was the year when all the risk profile showed maximum number of cases. Of all tracks, 73.36% were classified as type H. A total of 59 units were identified as high values which is 27.6% for the frequency index and five units (2.33%) for the duration and intensity index. It also shows the distribution of spatial unit according to risk categories, where a pattern with concentration of spatial unit into difference temporal risk characteristics over the district is verified (2011 to 2015). By comparing the mean ranks of the incidence rates for each risk category in each wave (Figure 12), a significance difference was observed among the three categories (Hi-FDI, Hi-F) with an ascending gradient for all the wave.

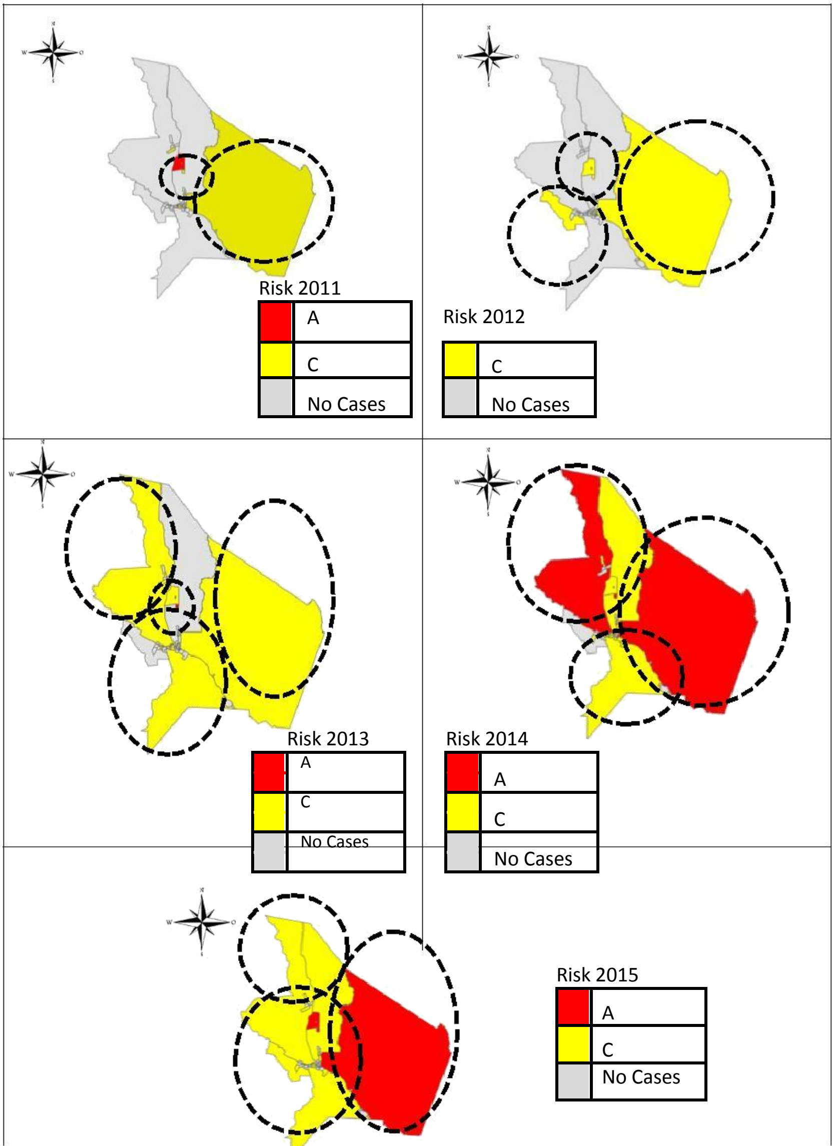

Figure 2 Distribution pattern of spatial units according to risk classifications for the occurrence of dengue cases. Jempol district, Negeri Sembilan. (January 2011-December 2015)

Assessment of the magnitude and severity of the dengue (2011 to 2015) epidemic in Jempol district.

The analysis of the epidemics, according to risk category is presented in Figure 3. From 2011 to 2015, the trend of the average annual dengue incidence in the whole Jempol district has significantly increased. Dengue temporal distribution in the entire locality indicates Hi-FDI and Hi-F risk types with the highest DF density. From the waves, it was presented in comparable trend every year.

The result shows that 2014 has reported the worst incident. Dengue cases epidemics can be defined based on their own characteristics from the spatial and temporal distribution epidemic. Retrospectively map from three temporal indices presented spatial patterns of dengue cases and the vulnerability areas visually for the year 2011 to 2015 were identified.

The study area classified retrospectively adequate based on the temporal risk indicator classification in the study period (five years). It may also facilitate the transmission or maintenance of the disease. Public health organization can apply this method to focus more on the high risk areas. Focus of effective control measures can be implemented at the high risk areas. Locality with high duration index value could be controlled by focusing more on the neighboring area that contribute to the extended occurrence of dengue cases, while for those area with intensity values, but low frequency and duration of the dengue cases, an adequate control measures may break the transmission and prevent further spread of dengue virus (Nazri et.al, 2012).

This study focuses to survey data to enhance basic spatial modeling, which uses the incident data. However, there is a limitation to this study. The data cannot access the neighboring areas which are important to effective control. From the basic data, the high-risk area can be determined without using expensive technology. It also may help to allocate the resources to the mostly risked area in prevention action.

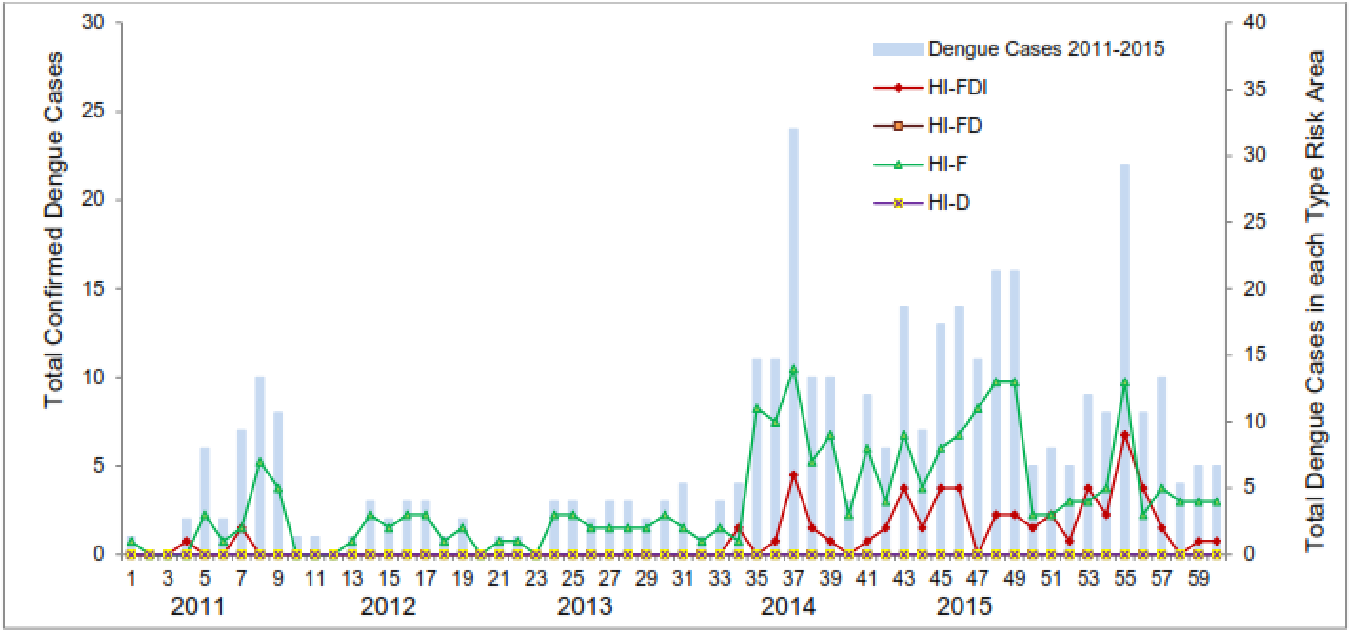

Figure 3 Epidemic curve of a weekly total confirmed dengue cases in areas with each risk types

DISCUSSION

Field of epidemiology and computational management combination is a crucial effort for surveillance and effective control of health problem (Valerie, 2000). This study classifies area of Jempol district based on three temporal indices. From the data, the high-risk areas was identified, and provides a helpful picture of the epidemic and present the risk. Dengue epidemics can be described using the spatial and temporal distribution of epidemic. Retrospectively map was used to identify possible risk area visually in Jempol district for the year 2011 to 2015. The darkest area represented the high value for each index.

This study categorizes Jempol district based on the vulnerability of the transmission of dengue and characterizes them based on the three temporal risk measures. GIS is one of the tool to classify the area. It has 8 types of risk area. From A to H. Type A for High Frequency-Duration-Intensity. Spatial which classified as type A is the highest risk area. The area must be focused more to make sure the control method can be effective. Followed by type B, High Frequency-Duration, type C mean as High Frequency. Majority of the spatial area consist of type C. For type C, it also has a risk to spread more without effective control. Type D means High Duration-Intensity, Type D and E identified as High Intensity. For type F means High Frequency-Intensity and type G classified as High Duration while spatial which classified as type H means there are no cases in the areas.

Nazri et al. (2012) has proven that this information affords a helpful picture of the epidemic and thus a more comprehensive representation of the risk. In 2011, spatial in type A has been identified at zone Serting Ilir. The locality is Bandar Baru Serting with 12.50 dengue density. From 215 spatial, 11 spatial detected as type C which is a high frequency area. 2012 stated no spatial area for type A, but it recorded about 10 spatial in type C. There are about 1 spatial in type A which is Felda Raja Alias 3 from zone Serting Ilir, while 28 from type C. 2014 stated the highest number of dengue fever compared to other years. It has recorded about 5 spatial in type A which is Felda Pasoh 3, Pekan Bahau, Raja Alias 4, Felda Palong 7 and Felda Palong 8. For type C, about 59 unit spatial were identified. For the previous year for this study, year 2015 stated the highest spatial unit in type A. The localities are Taman Satelite, Felda Raja Alias 4, Felda Raja Alias 3, Felda Palong 7 and Felda Palong 8, while about 49 spatial units in type C.

The area classification may help the public health official to focus more on the risk area as an effective control strategy. This study uses basic surveillance and from that the risk areas can be identified without using expensive technology. It will help to allocate the resources to prevent further cases occurring and spreading to mostly risked areas.

CONCLUSION

Epidemics dynamics and risk distribution can be characterized based on epidemic spatial and temporal aspects. Even though it has many methods to tackle this situation, but it is not a simple task. It involves the complicated statistical analysis or sophisticated surveillance system, and they are difficult to be implemented in developing countries. This study has differentiated risk patterns of a dengue epidemic using the three temporal indices.

Based on the result, 13 spatial identified as type A in the study period. The incidence rate or numbers of cases were mapped to characterize the dengue cases. Public health authorities should focus on the high-risk areas to make sure the dengue outbreak will be effectively controlled and managed.

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REFERENCES

Ahamd Nizal, M. G., Roziah, H., Mazrura, S., Zainudin, M. A., Hidayatulfathi, O., Faridah, M. A., Noor Atika, I., E, A. C. 2012. Dengue Infections and Circulating Serotypes in Negeri Sembilan, Malaysia. *Malaysian Journal of Public Health Medicine* Vol. 12(1): 21–30.

Barbazan P. 2001. DHF in the Central Plain of Thailand Remote Sensing and GIS to identify factors and indicators related to dengue transmission. *The Chao Phraya Delta: Historical Development, Dynamics, and Challenges of Thailand* 1-12.

C.D. Chen, S. Benjamin, M. M. Saranum, Y. F. Chiang, H. L. Lee, W.A. Nazni, M. Sofian- Azirun. 2005. Dengue vector surveillance in urban residential and settlement areas in Selangor, Malaysia. *Trop Biomed*, 22 (1): 39–43

Cringoli RT. 2004. Use of remote sensing geographical information systems to identify environmental features that influence the distribution of paramphistomosis in sheep from the Southern Italian Appennines. *Veterinary Parasitology* 2004: 122(1): 15-26

Dengue Guidelines for Diagnosis, Treatment, Prevention, and Control. 2009. New Edition. World Health Organization.

Gubler D. J, Clark G. G. 1995. Dengue/dengue haemorrhagic fever: the emergence of a global health problem. *Emerg Infect Dis* 1(2):55–7.

Gubler D. J. 1998. Dengue and dengue hemorrhagic fever. *Clin Microbiol Rev* 11(3): 480–96.

Khan, E et al. 2007. Dengue Outbreak in Karachi, Pakistan, 2006: Experience at a Tertiary Care Center." *Transactions of the Royal Society of Tropical Medicine and Hygiene* 101(11): 1114–19. http://www.ncbi.nlm.nih.gov/pubmed/17706259 (December 22, 2014).

Krishna Prasad Bandari PR. 2008. Application of GIS Modelling for Dengue Fever Prone Area Based on Socio-cultural and Enviromental Factor- A study case of Dehli City Zone. *The International Archieve of The Photogrammetry, Remote Sensing, and Spatial Information Sciences* 36: 165-70.

Kumarasamy, V. 2006. Dengue Fever in Malaysia: Time for Review*? Med J. Malaysia* Vol. 61(1): 1–3.

Nazri, C. D., Abu Hassan, A., Zulkiflee, A. B., Rodziah, I. 2011. Impact of climate and landuse variability based on dengue epidemic outbreak in Subang Jaya. *IEEE Colloquium on Humanities, Science and Engineering Research (CHUSER)* 907-12

Nazri, C. D., Zulkiflee, A. B., Abu Hassan, A., Rodziah, I., P. Biswajeed. 2012. Manifestation of GIS Tools for Spatial Pattern Distribution Analysis of Dengue Fever Epidemic in the City of Subang Jaya, Malaysia. (Dengue Fever): *Thai Society of Higher Education Institutes on Environment*: 11

Nazri, C. D., Abu Hassan, A., Zulkiflee, A. L., Rodziah, I. 2013. Measurement of Dengue Epidemic Spreading Pattern Using Density Analysis Method: Retrospective Spatial Statistical Study of Dengue in Subang Jaya, Malaysia, 2006-2010. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 107(11): 715–22. http://www.ncbi.nlm.nih.gov/pubmed/24062522 (December 22, 2014).

Valerie Crossa A. F. 2000. Fuzzy objects for geographical information systems. *Fuzzy Sets and Systems.* 13: 19-36.

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

Wen T. H, Lin N. H, Chao D. Y, Hwang K. P, Kan C. C, Lin K. C, Wu J. T, Huang S. Y, Fan I. C, King C. C. 2010. Spatial-temporal patterns of dengue in areas at risk of dengue hemorrhagic fever in Kaohsiung, Taiwan, 2002. *International Journal of Infectious Diseases* 14: 334-43

World Health Organization. 2008. Dengue and Dengue Haemorrhagic Fever. *Health in Asia and the Pacific*. 244–255.