Impact of climate changes and socioeconomic factors on dengue vulnerability in peninsular Malaysia

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Abstract
Dengue is one of the most vulnerable vector-borne diseases in the tropical and sub-tropical Asia-Pacific region, where significant number of peoples are at-risk. An association between climate or socio-environmental factors and dengue vulnerability was assessed in Selangor and the Federal Territory of Kuala Lumpur where the rate of incidence is high. Climatic factors such as temperature and precipitations change is likely to affect the seasonal and geographical distribution of dengue transmission in the study areas. Last twenty one year precipitation records and dengue incidence rate showed significant correlation. However, empirical evidence linking dengue transmission to temperature change is inconsistent across geographical locations and absent in some areas where dengue is endemic. More detail research is needed across different locations of tropical areas to better understand the relationship between climate change and dengue transmission. Socioeconomic factors such as population density, waste management and water supply of the study areas also affected the dengue incidence rates. Future research should be considered to develop more quantitative index for better understanding the assessment of the climate change-related effects on dengue transmission.

Keyword: Public health, Tropical, Malaysia, Climate changes, Dengue

1. Introduction

Vector-borne diseases such as dengue and malaria have become an important public health concern all over the world from the early 1950s (WHO, 2012; Cheong et al.2013; IPCC report, 2014; Ayala and Estrugo, 2014). Particularly, the dengue disease is growing most quickly in tropical and subtropical Asian countries where significant number of the global population resides. Dengue fever can be demarcated as a mosquito-borne infection caused by virus serotype DEN-1, DEN-

2, DEN-3 and DEN-41. Dengue viruses are transmitted primarily via *Aedes aegypti* and *Aedes Albopictus* mosquitoes as the vectors. From the WHO reports, there were more than 100 countries have experienced the dengue epidemics currently compared to only nine countries before 1970s (WHO, 2012).

The first dengue fever outbreak in Malaysia was recorded in 1902 from Penang with 41 cases and 5 deaths were reported (Skae, 1902). Subsequently, a series of outbreak reported in 1973 with 1,487 cases with 54 deaths, 1974 with 2,200 cases with 104 deaths and 1982 with 3,006 cases reported including 35 deaths (MHM report, 2012; Cheong et al.2014). Malaysia has already been experiencing an extremely high burden of vector-borne diseases, e.g., dengue due to Aedes mosquitoes, which may be increased due to changes in precipitation pattern and temperature of tropical areas (Li et al.1985; Morin et al., 2013). Despite the increasing understanding of health risks associated with climate change, there has been limited systematic study to identify and measure the impact of climate changes on vulnerability of dengue diseases in Malaysia.

The World Health Organization (WHO) considers dengue to be the most important vector-borne viral disease, potentially affecting 2.5 billion people in tropical and subtropical countries throughout the world (Rigau-Pérez et al., 1998; WHO report, 2012). Within Asia, the WHO Western Pacific Region (WPRO) is considered to be the global epicentre of the disease and Malaysia ranked third among countries in the WPRO in terms of the number of reported cases of dengue disease in the period of 1991–2007 (Yusoff 2008; WHO report, 2012). Dengue disease was first reported in Malaysia in the early 1900s (Skae, 1902) and became a public health problem in the 1970s (Wallace et. al., 1980). Significant outbreaks of dengue fever (DF) occurred from 1982, with a gradually increasing pattern of incidence and fatalities.

The impact of climate changes on dengue has recently captured much attention in the scientific community (Thammapalo et al.2005; Cazelles et al.2005; Yang et al.2009; Amin et al., 2011, 2013; Gabriel and Endlicher, 2011; Wardekker et al. 2012; Dickin et al.2013; Fan et al. 2015). Climate change could alter or disrupt natural systems, making it possible for diseases to spread or emerge in areas where they had been limited or had not existed. The most important long-term influences will likely to act through changes in natural ecosystems and their impacts on disease vector-borne and waterborne pathogens. Establishing a consistent causal relationship from these factors to health outcomes requires taking into account that a multiplicity of climatic, economic and socio-demographic elements are combined to create the conditions for the outbreak of diseases, and the subsequent effect on population wellbeing. However, till date less research has been conducted on the effects of climatic and socioeconomic factors on dengue diseases and health vulnerability.

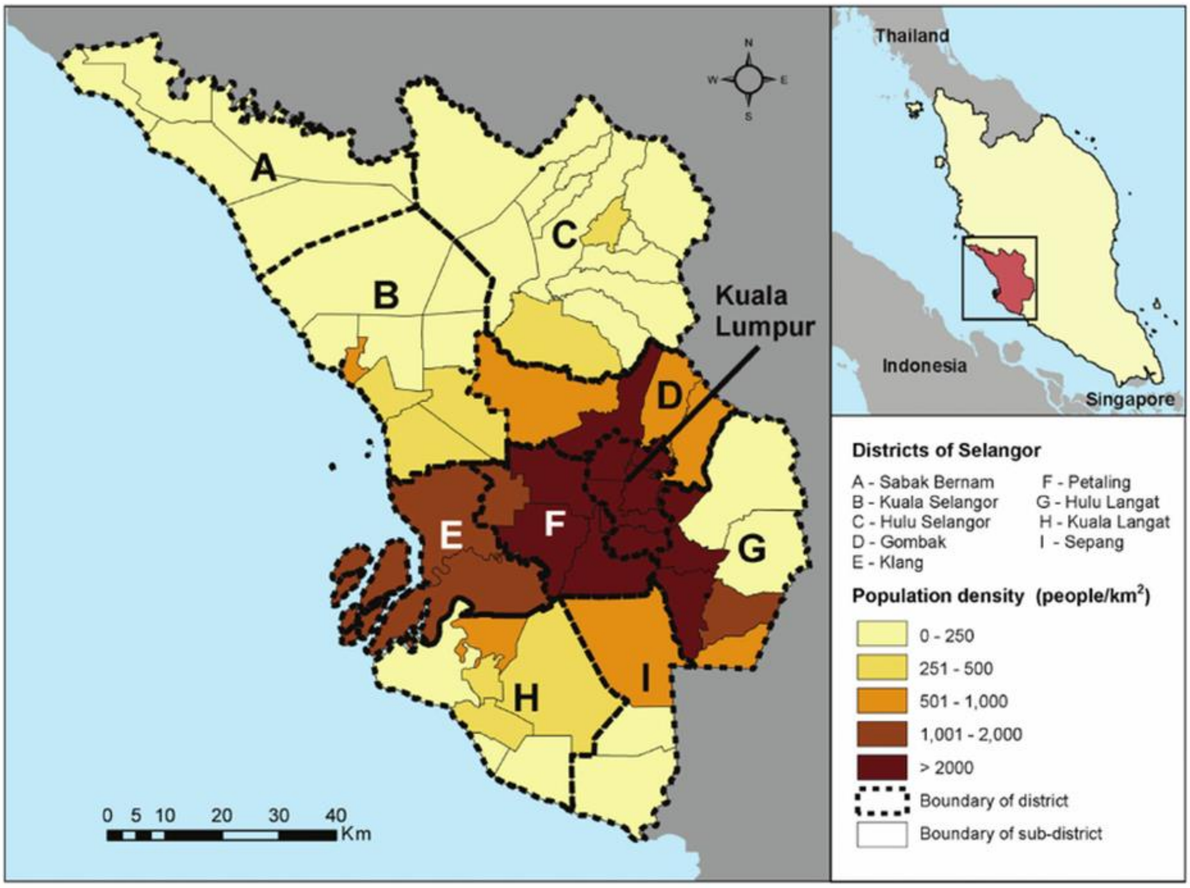

Fig. 1. Geographical distribution and population density (2010) in the 62 sub-districts of Selangor and Kuala Lumpur, Malaysia (Cheong et al., 2014b)

The main objective of this project was to investigate the impact of climate changes and socioeconomic factors on dengue vulnerability in peninsular Malaysia. The specific objectives are: to find out the relationship between climatic factors (e.g., changes of temperature and rainfall) and dengue incidence rate in the study areas; to investigate effects of socioeconomic factors (e.g., livelihood, population density, waste management and water supply) on dengue incidence rate in the Selangor and the Federal Territory of Kuala Lumpur and to develop a climate-induced health vulnerable index based on relationship/association of both climatic and socioeconomic factors to dengue disease incidence rate for risk assessment and public health implications.

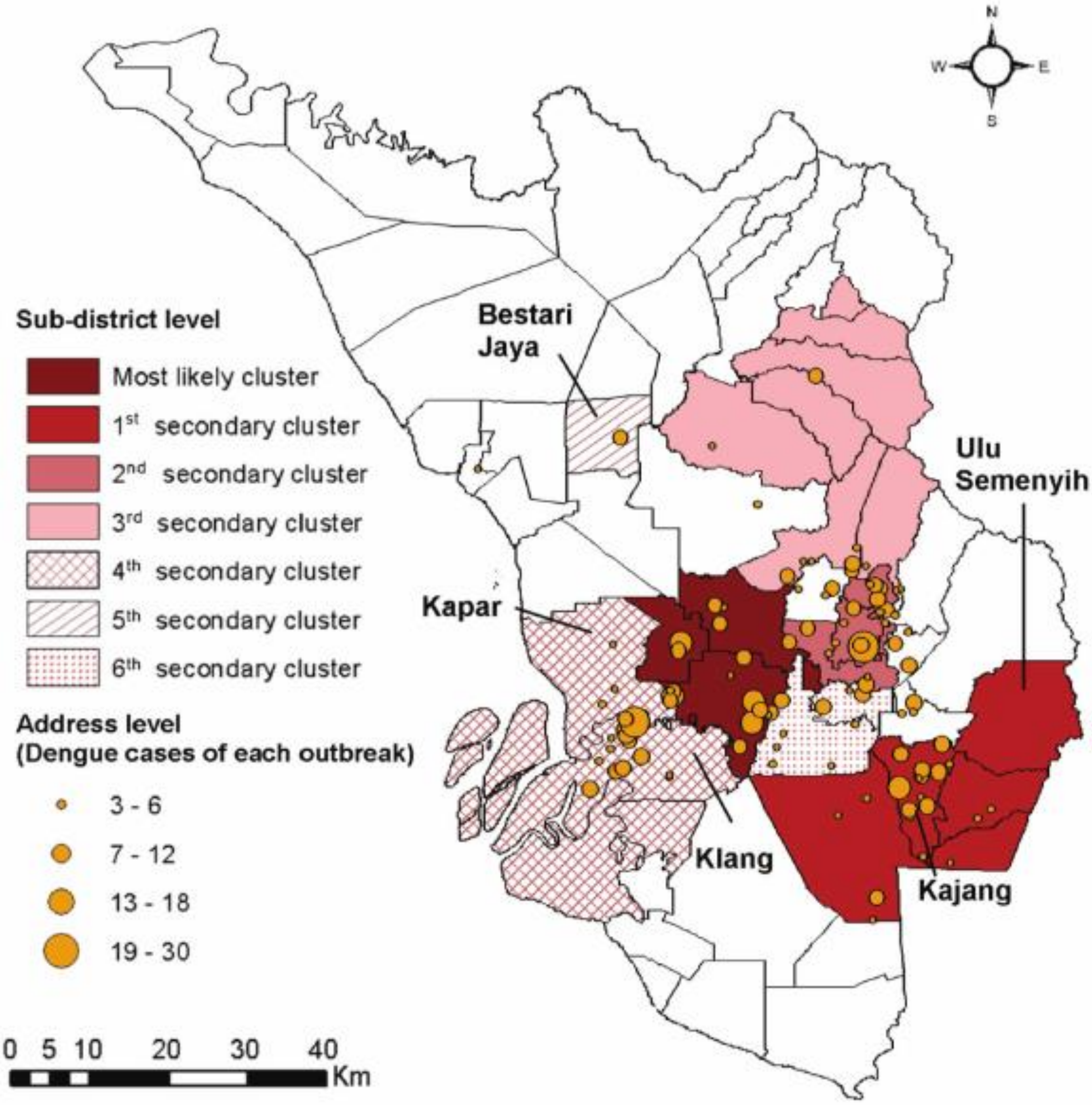

Fig. 2. Spatio-temporal clusters of dengue cases at the address level (circular shape) and sub-district level (shaded area) 2008-2010 in the 62 sub-districts of Selangor and Kuala Lumpur, Malaysia (Cheong et al., 2014b).

2. Material and method

2.1. Study area

Since a significant number of dengue cases occurred in the Selangor and the Federal Territory of Kuala Lumpur between 2008 and 2010; indeed accounting for

50.9% of all reported cases in Malaysia according to the Department of Statistics in Malaysia (Department of Statistics Malaysia 2011), we have selected these areas to study the impact of climate changes and socioeconomic factors on dengue vulnerability. In addition, Selangor and the Federal Territory of Kuala Lumpur are the most urbanized areas in the country, where great variations in population density, topography and land use changes are found (Fig.1). We have also selected some areas for household survey considering previous dengue incidence rate or hotspots (Fig.2).

The population of Malaysia in 2012 was estimated to be 28,855,000 (MHM reports, 2012). The main races are Malay (50.4%), Chinese (23.7%), and Indian (7.1%) (WHO reports, 2013). Malaysia consists of two geographical regions (Peninsular and Eastern Malaysia, separated by the South China Sea) and is divided into 13 states and three federal territories. Most people (81%) live in coastal areas and on peninsular Malaysia. Since the mid-1970s, urbanization has increased markedly (Kwa, 2008). The climate is characterized by high average temperatures and rainfall, with only small differences in temperature reported throughout the year (Fig.3). High rainfall patterns follow the monsoon winds, which occur between November and March and from June to September.

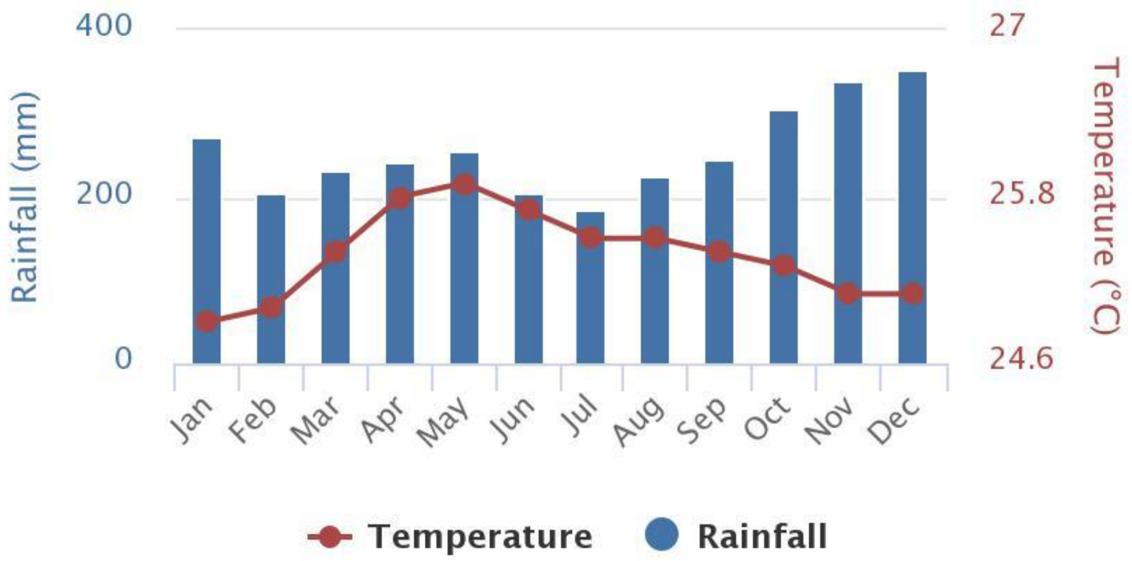

Fig.3 Average monthly precipitation and temperature variations over last one hundred years.

2.2. Data collection

Available data on the monthly/yearly number of notified dengue cases in Selangor and the Federal Territory of Kuala Lumpur were obtained from the Directorate General of Health Services (DGHS), Malaysia. As dengue is a notifiable disease in Malaysia, any case detected based on the World Health Organization (WHO) clinical criteria must report to the DGHS by the Hospital. According to the WHO clinical criteria, a dengue case was defined by the presence of acute fever accompanied by any two of the following clinical symptoms such as headache, myalgia, arthralgia, rash, positive tourniquet test and leucopenia. The following climate variables were considered in the studies: maximum, minimum and mean temperature, rainfall and relative humidity. These data were collected from the Malaysian Meteorological Department (MMD; www.met.gov.my). Population and land use data were obtained from the Department of Statistics in Malaysia. Socioeconomic factors including demography, education, profession, income level, housing conditions, access to public services such as waste management and water supply etc were collected through household survey using semi-structured questionnaire and focus group discussion (FGD) during our study time. Total 50 randomly selected households were interviewed from each selected area. A questionnaire was designed on the basis of previous research related to both climate change science and dengue vulnerability in tropical and subtropical areas.

2.3. Data Analysis

Both qualitative and quantitative comparisons were made between dengue incidence rate and climatic as well as socioeconomic factors. Linear regression models were used for determining potential associations between the climatic and epidemiological variables. Statistical significance defined as $p < 0.05$. Based on the association of dengue incidence rate and climatic and socioeconomic factors, a new Climate-induced Health Vulnerability model was proposed. This pragmatic model can be rapidly applied to assess the vulnerability to a climate-induced vector borne disease by employing known factors and thresholds and by using existing datasets. To apply the model approach, a conceptual framework was developed to guide the construction of composite index that can describe dengue vulnerability of peninsular Malaysia (Fig.4).

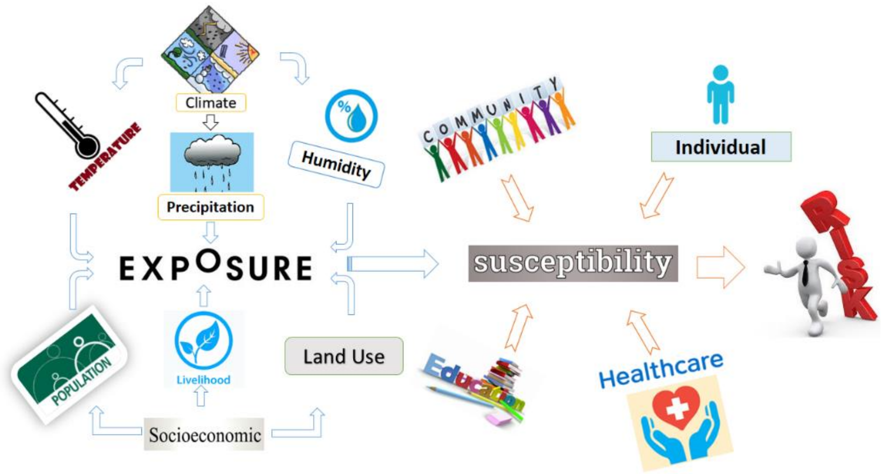

Fig.4 Climate-induced health vulnerability model frameworks

3. Result and discussion

3.1. Dengue incidence rate and seasonal variations

The annual number of reported dengue death cases and the trend of dengue incidences in Selangor and Federal Territory of Kuala Lumpur areas during last twenty one years, i.e. 1995 to 2016 shown in figure 5. It can be seen that the incidence of the disease has increased several-fold over the period 1995-2016. In the year 2000, the number of reported dengue cases was 7103. However, more than 30000 cases have been reported every year from 2002 to 2006. The country experienced the greatest burden of the disease (on average 48,500 cases) in 2007 and 2008 culminating with the highest number of 49,335 cases in the year 2008. The annual number of reported dengue cases dropped to 41486 in the year 2009. But, in 2010, an increase in the number of reported dengue cases has been notified, making 2010 another worse year on record. The findings reveal that there is an overall escalating trend in annual incidences of dengue in Malaysia in recent years though there are ups and downs in the trend. The exponential curve fitted to these data shows an average increase in dengue incidence of 12% per year.

Since year 2000, the number of dengue cases and incidence rate continue to increase with the highest ever reported in 2015. A total of 120,836 cases were reported which is equivalent to incidence rate of 361.1 cases in 100,000 populations in that year (Fig5). Fifty six percent (56%) of the cases contributed by Klang Valley in which 49% were from Selangor and 7% from Federal Territory of Kuala Lumpur. In the period of 1995 to 2016, the number of reported dengue cases was between 7,103 and 120,836 cases per year and the annual incidence rate range from 31.6 to 361.1 cases per 100,000 populations.

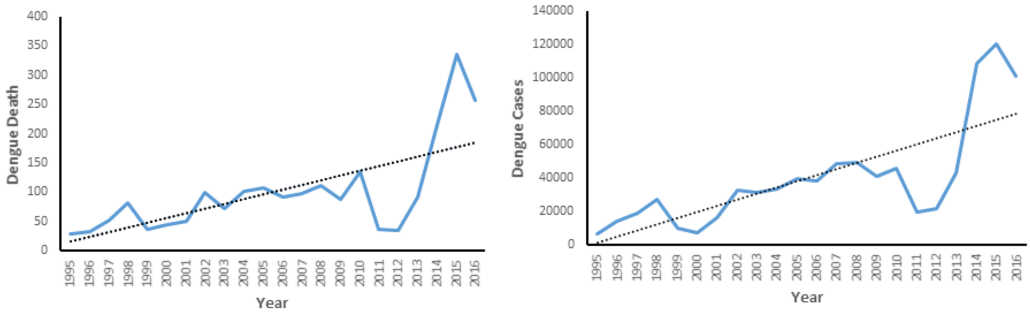

Fig.5 Variations of dengue cases and deaths for Malaysia, 1995-2016.

Bi-seasonal peak of the dengue epidemic was observed in different years (Fig 6). It is also observed that the seasonal peak of the epidemic occurred at different month. In 2015, the bi seasonal epidemic peak happened in the month of March to May and October to December. However in 2016, the epidemic peak occurred mostly from March to May and showed small variations in October to December. The seasonal trend of dengue in Malaysia is complex and changes in the pattern of epidemic peak could be the influence of regional climate change especially precipitation and temperature changes in this region as well as the socioeconomic and other factors.

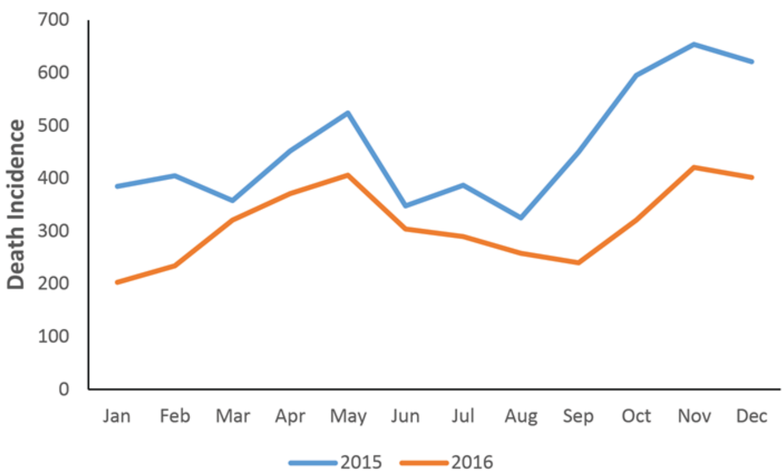

Fig.6 Monthly variations of dengue incidence rate for year 2015 and 2016.

3.2. Association dengue with climatic factors

The climatic parameters involved in this study were yearly average temperature, average rainfall and average relative humidity. Figures 3 shows the monthly readings of the average climatic parameters of last one hundred years (both Temperature and precipitation) that were received from Malaysian Meteorological Department. Data on climatic variables specially the average temperature and rainfall, as well as dengue cases for 1995 and 2016 in Selangor and Kl were associated. Using general linear regression model, the association between the climatic variables and dengue cases were studied (Fig.7). The findings showed that rainfall and humidity were significant contributors to dengue cases with p-value of <0.001 and p-value of 0.002 respectively. However, there was no significant relationship between monthly average temperature and monthly dengue cases (p= 0.561).

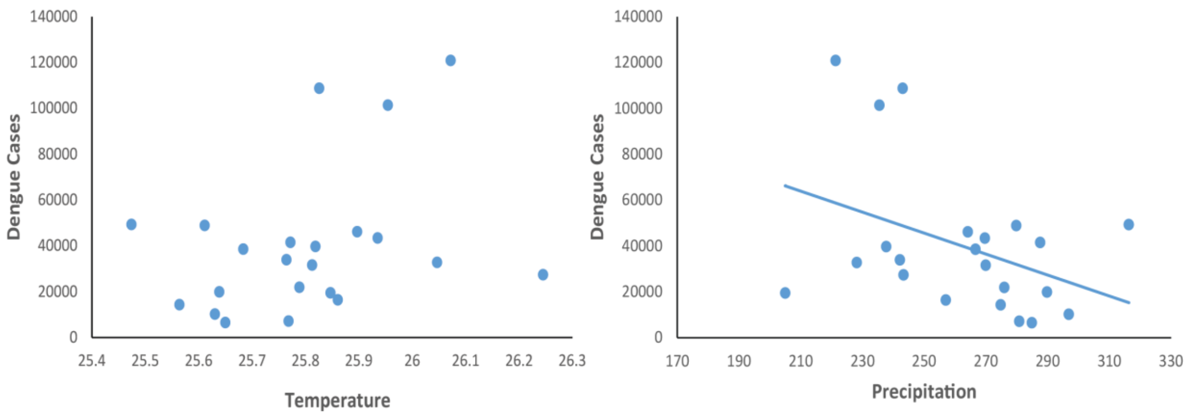

Fig.7 Association between dengue cases and climatic parameters (Temperature and precipitation)

Rainfall was identified as the most significant factor. Rainfall had been identified as a significant contributor to dengue fever in many studies (Li et al.1985; Siasu, 2008; Tosepu et al.2018). Generally, rain provides more breeding places for the vectors of dengue fever, *Aedes* Mosquitoes (Fig.8 Photo). All mosquitoes have aquatic larval and pupil stages. Therefore, water is needed for breeding. Abandoned water containers can be easily filled up with rain. Some of the common breeding places for *Aedes* mosquitoes include drinking water containers, discarded car tyres, flower vases and ant traps (Fig.8 Photo).

Regardless of the fact that rainfall can be significantly related to dengue fever, the amount of rainfall is an important factor to be considered. Extremely heavy rainfall may wash out breeding sites and thus have a negative effect on vector populations (Bhatt et al.2013; Butterworth et al.2017). Besides that, the timing of rainfall may also affect vector life cycle. If the number of rainy days were too low, there would not be enough water for mosquito larvae to complete their development (McMichael et al.2006; Butterworth et al.2017).

Fig.8 Field photos of dengue breeding places for the vectors, *Aedes Mosquitoes*

Rain is actually inter-related to humidity and temperature. Higher rainfall causes humidity to be high, whereas higher temperature causes humidity to be low. The relative humidity in Malaysia is high, ranging from 70 to 90% (Malaysian Meteorological Department: www.met.gov.my). Higher humidity had been associated with increased Aedes aegypti feeding activity, survival and egg development. At high humidity, mosquitoes generally live longer and disperse further.Therefore, the feeding activity would increase as they would have a greater chance to feed on human blood and therefore transmit dengue virus. Relative humidity also directly affects the evaporation rate of vector breeding site (Méndez-Lázaro et al., 2014).

Temperature do not showed any significant relationship to dengue incidence (Fig.7). In most areas of Malaysia, the average maximum and minimum temperature per month vary less than 2°C annually (Malaysian Meteorological Department: www.met.gov.my). This small fluctuation of temperature and yet large differences in dengue fever cases by month may have caused the insignificance in association. In case of temperature, the data may be needed in longer duration. Positive association between temperature and dengue fever had been found in many studies (Promprou et a.2005; reference therein). According to Morin et al., 2013 temperature is a key component in the ecology of dengue virus. Higher temperature was related to faster viral replication within the vector. Temperature can even affect the *Aedes* mosquito ecology, primarily *A. aegypti*. This was proven by a laboratory procedure by Rueda et al. 1990. In the laboratory setting, Rueda et al. 1990 found that immature *Ae. Aegypti* development rates generally increased with incubation temperatures to 34ºC and then slowed.

In Selangor, a study was conducted by (Sani, 2009) to investigate the relationship between temperature and the prevalence of dengue fever. Based on the findings of that study, the climatic variables were significant, but not for all of the areas in Selangor. The relationship between dengue fever and local temperature, for instance, were only found significant in Kuala Selangor and Shah Alam. As for rainfall, significant association were found in Sepang and Kuala Selangor. This indicated that the occurrence of dengue fever do not only dependent on climatic factors. There were many other factors that can contribute to the prevalence of dengue fever. As for this study, the possible confounders were urbanization and knowledge, attitude and practice of the community, i.e. socioeconomic factors as discussed in the next section.

3.3. Association of Dengue with socioeconomic factors

A total of 150 samples from field /household survey were included in this study to investigate the association between dengue incidence and major socioeconomic factors. The majority were Malaya's (62%) and female (76%). They were married (92.8%), had lived there for more than 5 years, had a low level of education

(81%), were not working (45%) and came from households with a monthly income of minimum wages or less (78%). Most of the household had at least four or more family members, with four or fewer children under 15 years. Among them, 42% had experienced dengue fever in family (Table 1). Although travel history contributed to dengue incidence, only 12% of reported family members traveling to other endemic areas. Habits that promote *Aedes aegypti* breeding, such as hang-drying clothes, cleaning waste containers, garbage disposal within week were found to be 55, 23 and 12 %, respectively. Most of the households had no proper waste disposal system (73%); however, some of the household owners cleaned their household waste/garbage less than once every two weeks (27%). Even though most of the respondent having good knowledge and attitudes regarding dengue fever, a majority of them did not achieve optimal dengue prevention (Table 1). Concrete houses with an interconnecting construction style were most common. There were garbage dumps and no animal shelters in most cases. More than half of the households used piped bottled water supply (63%) as their source of drinking water and 37% obtained drinking water from bottled water.

The results of linear regression model revealed that waste management and sources of drinking water are two important variables associated with dengue incidence rates of field survey areas. Household waste, such as plastic bottles and discarded plastic, provides habitats for dengue vector. Poor waste management makes a breeding ground for *Aedes* mosquitoes. Thus, waste management has an impact on the presence of *Aedes* mosquitoes and dengue incidence rates. In this study, a frequency of disposal of wastes of more than once per week was higher in dengue incidence rate compared with that of less than once per week. Similar findings were reported by Cordeiro et al. (2011) and Suwannapong et al. (2014) in Thailand.

There was an association between piped water as the source of drinking water and dengue incidence rates. In reality, even though the respondents were using piped water, the water supply was not regular. Thus, these residents often stored water in water containers, providing breeding places for Aedes mosquitoes. Inadequate water supply was associated with the presence of breeding habitats for Aedes aegypti (Khan and Hasan, 2011). Spiegel et al. (2007) performed a study to determine the association of social and environmental factors with the presence of Aedes aegypti and found that leaky water pipes were associated with an increased risk of infestation. Likewise, Schmidt et al. (2011) found that the risk of dengue was higher in rural than in urban areas due to a lack of piped water supply.

Table 1- Summary of socioeconomic and household survey (n=150)

Variables		Cases		Remarks
		No.	%	
Gender/Family				
	Male	36	24	
	Female	114	76	
Income				
	>Minimum wages	33	22	
	<Minimum wages	117	78	
Education				
	High	28	19	
	Low	122	81	
Dengue incidence				
	Yes	54	36	
	No	96	64	
Travel				
	Yes	18	12	
	No	132	88	
Waste management				High
	>Week	132	88	
	<Week	18	12	
Drinking water				High
	Piped water	94	63	
	Bottled water	56	37	
Knowledge's about Dengue				
	Yes	99	66	
	No	51	44	

In general, the level of education is related to knowledge. Therefore, it was supposed that a higher level of education would lead to a greater knowledge of dengue prevention. In this study, there was significant association between education level and dengue incidence rates. Low education was significantly associated with dengue incidence rates. Siqueira et al. (2004), found similar results in in central Brazil. Furthermore, preventive measures are related to knowledge and education level. Lack of knowledge will have an impact on the practice of dengue prevention. Generally, increasing knowledge will improves practices for reducing the number of unprotected containers, thus reducing potential vector breeding grounds. Overall it can be concluded social and environmental factors play a role in the dengue incidence. This findings could be used as a recommendation for health organization enhance their public intervention for reducing the dengue incidence of the study areas, especially Selangor and the Federal Territory of Kuala Lumpur, Malaysia.

Conclusion

In conclusion, recent climate changes play a significant role on the dengue incidence rate in peninsular Malaysia. Precipitation changes of the study areas significantly related to the dengue incidence rates. Temperature was not a significant predictor according to this study. However, climate changes is just one of the associated factors of dengue incidence rates. There are other factors that must be considered such as the population and the socioeconomic factors such as education, income, household waste management and domestic water uses. For active control measures to reduce the dengue incidence rates, it is important to increase the knowledge of the community regarding dengue prevention.

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