EnvironmentAsia
The international journal by the Thai Society of Higher Education Institutes on Environment

EnvironmentAsia 13(3) 2020 89-102
DOI 10.14456/ea.2020.45
ISSN 1906-1714; ONLINE ISSN: 2586-8861

Implication of Climatic Factors on Dengue Fever in Urban Area: Case Study in 2012-2016

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Received: February 25, 2020; Revised: April 15, 2020; Accepted: May 22, 2020

Abstract

Dengue incidence has grown dramatically around the world in recent years. It is transmitted by *Aedes* mosquitoes. Many climatic factors contributed to the vector densities such as temperature, relative humidity, rainfall and winds. This study is to determine the trend of climatic factor associated with dengue cases. The analysis was performed by using Pearson's Correlation and Mann-Kendall trend analysis from 2012 to 2016. The Pearson's Correlation showed that dengue cases in Kuala Lumpur were significantly correlated with temperature, relative humidity and rainfall ($p < 0.05$). Mann-Kendall trend analysis showed that in both 2012 and 2014, the rise in dengue cases were affected by the increases in temperature and wind speed, while the relative humidity and rainfall affect the dengue with decreasing pattern. As the conclusion, climate factors such as temperature, relative humidity and rainfall contributed to 4.4% of the dengue cases in Kuala Lumpur from year 2012-2016.

Keywords: Dengue; Mann-Kendall; Climatic factor

1. Introduction

Dengue infection is mosquito-borne virus, transmitted by *Aedes aegypti* and *Aedes albopictus*. Globally, dengue caused 390 million infections annually in more than 125 countries (Bhatt *et al.*, 2013). Asian countries such as Thailand, Singapore and Malaysia have suitable tropical climate are always being affected by the outbreak of dengue fever (DF) and dengue haemorrhagic fever (DHF). Although the dengue cases in Malaysia as of September 2018 is 51,450 cases with approximately, 34.6% decreased compare to 2017. However, the current number of cases is still alarming. Public were urged to clean the surrounding of the houses from potential of breeding sites (Malaysia Ministry of Health, 2018).

The dengue transmission is influenced by factors such as environment, climate, human behavior and dengue virus serotype-specific herd immunity in human (Cheong *et al.*, 2013; Halstead, 2008; Hay *et al.*, 2000). The major impact of climate change is the health of human population. The understanding of climate change to specific disease and its relationship is crucial in order to implement the control measures (Díaz-Castro *et al.,* 2017; Epstein, 2005). Several studies indicated the climate is associated to the mosquitoes-borne diseases (Cano *et al.*, 2017; Small *et al.*, 2003; Rogers and Randolph, 2000).

Weather such as rainfall, temperature, relative humidity and wind have direct impact on mosquito populations (Fareed *et al.*, 2016; Halstead, 2008; Gubler, 2001). Temperature found to be influenced in development, behavior and replication rate of dengue virus (Barrera *et al.*, 2011; Rueda *et al.*, 1990; Watts *et al.*, 1987). Rainfall serve as the breeding sites for mosquito larval when the temperature is high (Morin *et al.,* 2013).The rainfall also contributed to the abundance and densities of mosquito due to the increasing of pool and puddles of water for female mosquito to lay eggs (Méndez-Lázaro *et al.*, 2014; Li *et al.*, 1985). The increasing of temperature and rainfall resulting of climate change, together with urbanization may increase dengue incidence and the transmission of dengue (Ebi and Nealon, 2016). The higher temperature and rainfall will increase the evaporation process. As a consequence, the relative humidity increases and causes higher feeding rates, survival and development process of Aedes mosquitoes better (Fareed *et al.*, 2016). The role of wind speed in dengue has been reported for flight influenced to non-endemic areas (Rosa-freitas *et al.*, 2006). Study in Guangzhou indicated that an increasing of minimum temperature and decreasing of wind velocity are correlated with dengue incidence (Lu *et al.*, 2009). The objectives of this study area to determine the climate factors which are correlated to dengue cases and to present the trend of climate factors for dengue incidence in Kuala Lumpur.

2. Materials and Methods

2.1 Study Location

Kuala Lumpur is the capital of Malaysia, making up an area of 243 km^2 with an average elevation of 21.95 m (Figure 1). Kuala Lumpur has a population of 1.8 million as of 2018 which is 5.5% of the total national population. The average annual population growth rate from 2000 - 2010 was 0.1 % (Department of Statistic Malaysia, 2018). The city experiences a hot and humid climate all year-round with seasonal variation in the temperature and rainfall. The maximum temperature floats between 31ºC and 33ºC and have never exceeded 37.2ºC (average is 32.4ºC), while minimums hover between 22 and 23ºC (average is 23.3ºC) and had never fallen below 17ºC. Kuala Lumpur typically receives 2,266 mm of rain annually with June and July being relatively dry (Malaysia Meteorological Department, 2018). Since 1972, Kuala Lumpur has been governed by Kuala Lumpur City Hall (KLCH). The Kuala Lumpur City Hall Health Department was established to monitor the health status of Kuala Lumpur residents as well as improving the population's quality of health.

2.2 Data Collection

The daily dengue cases from 2012 until 2016 were obtained from Vector Unit, Health Department of Kuala Lumpur City Hall. The climatic data obtained from Malaysia Meteorological Department, Petaling Jaya from the local weather station in Petaling Jaya which was the nearest station to the study area. The data consist of daily mean rainfall, temperature, relative humidity and wind speed which were aggregated to monthly data.

2.3 Data Analysis

Pearson's Correlation test was used followed by multivariate analysis for investigation of association between climate and dengue cases. The level of significance in this study was set up at $p < 0.05$ and $p < 0.01$.

2.3.1 Mann-Kendall Trend Test

Mann–Kendall trend test (Mann, 1945; Kendall, 1975) is widely used to detect and assess the significance of a trend (Woon *et al.*, 2018, Samsudin *et al.*, 2017; Mé, 2014). In this study, Mann-Kendall trend test was used to detect the trends of climatic data at Kuala Lumpur from 2012 to 2016. The test is based on the correlation between the observed parameters and their time series. The formula for Mann-Kendall trend test is defined as (equations 1 to 6):

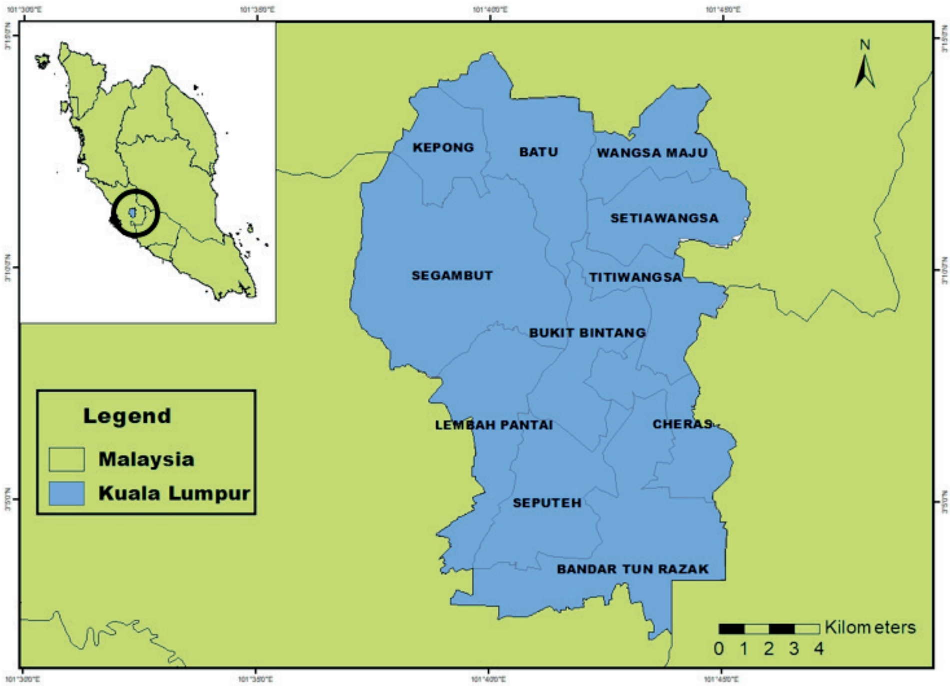


Figure 1. Map of Kuala Lumpur, Malaysia

$$S = \Sigma p < q \; apq \qquad (1)$$

where

apq = sign (xq – xp) = sign (Rq – Rp)

$$\begin{cases} 1 & Xp < Xq \\ 0 & Xp = Xq \\ -1 & Xp > Xq \end{cases} \qquad (2)$$

From the equation (1) and (2), the Rp and Rq are the ranks of observations xp and xq of the time series, respectively. It can be observed that the statistic test relies only on the ranks of the observations, instead of their actual values. This is also known as distribution free test statistic. This test is well-known for its ability in that its power and significance are not influenced by the actual distribution of the data. In contrast, for parametric trend test such as the regression coefficient test, we can assume that the data obey to the normal distribution and its power can be greatly influenced by skewed data (Mann, 1945; Kendall, 1975).

The mean and variance of the S statistic in equation (1) above are given by the equations as shown below based on the assumption that the data set are independent and distributed;

$$E(S) = 0 \qquad (3)$$

$$V_o(S) = n\,(n-1)\,(2n+5)\,/18 \qquad (4)$$

where n is the number of observations. A reduction of the variance of S will be computed when the tied ranks exist in the data. The equation of σs is given below;

$$\sigma s = \sqrt{n\,(n-1)\,(2n+5)\,/18 - \Sigma b \; td\,(td-1)\,(2td+5)\,/18} \qquad (5)$$

where b is the number of groups of tied ranks and td is the tied observations. When the number of observations becomes large, the statistic S will be normally distributed as implied in the equation below.

$$Z = \begin{cases} (S-1) & S > 0 \\ & S = 0 \\ (S+1) & S < 0 \end{cases} \qquad (6)$$

The results obtained from the Mann-Kendall trends test are then interpreted. Parameters processing which have the p-values smaller than 0.1, indicate that there is an existence of significant difference for that particular parameter. If the statistic S shows a positive value, it is an indication there is an upward trend and if it shows a negative value, it indicates a downward trend. Instead, for the parameter which showed the p-value that greater than 0.1, it indicates that there is no significant difference occurred for the parameter. The accepted of null hyphothesis (H0) meant that there was no trend in the series data (Mann, 1945; Kendall, 1975).

3. Results

3.1 Daily mean variation rainfall, temperature, relative humidity, wind speed and dengue cases from year 2012 until 2016

A total of 27,296 confirmed dengue cases had been recorded by Kuala Lumpur City Health Department from 2012 to 2016. The five years cummulative averages of climatic factors in Malaysia is shown in Table 1. However, monthly mean of climate variables were ploted in figure 2 and it revealed inconsistent pattern for the five years analysis. The highest dengue cases was in January 2014 (953 cases), followed by January and July 2016 (921 and 861 cases, respectively). While, the lowest dengue cases was in July 2012 with 79 cases, followed with May (89 cases) and June 2012 (91 cases).

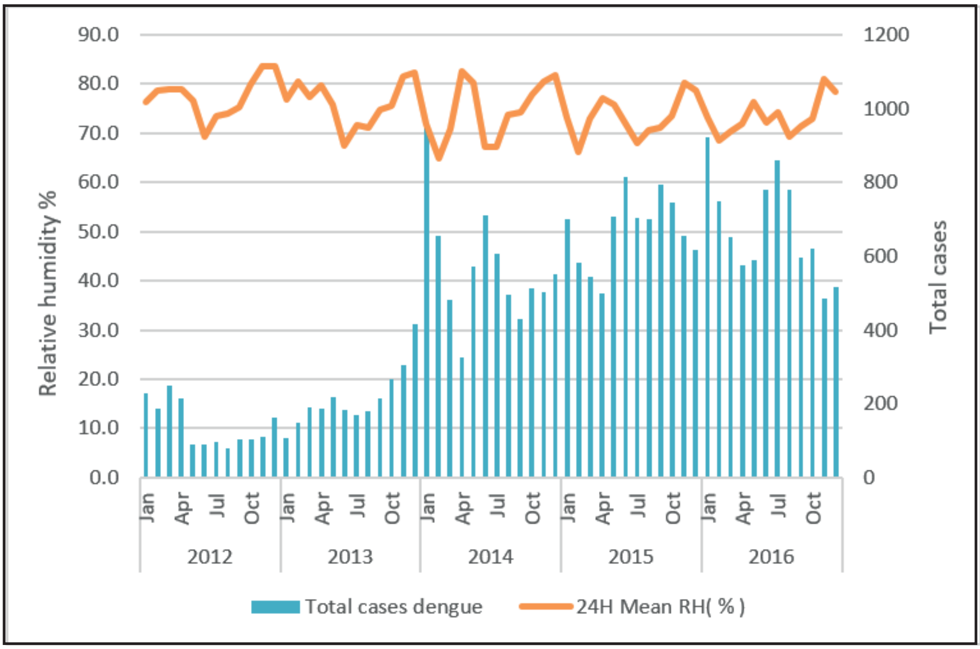
The plot also indicates variations in terms of the influence of climatic variables on dengue occurance. Climatic variable influenced the increase and decrease of dengue cases in area. For instance, during the highest period of dengue cases (953 cases), the presence of relative humidity was 72% , meanwhile at the lowest dengue cases, the reading of relative still in conducive range which was 73.5%. The highest relative humidity was in December 2012 (83.7%) which is period of lowest dengue cases (Figure 2a).

Furthermore, the plot in Figure 2b, 2c and 2d, indicates fluctuation trend between temperature, wind speed and rainfall with dengue cases. The highest number of dengue cases (953 cases) occured during period of lowest temperature (27.2 ^{o}C), however during highest temperature (30.1 ^{o}C), the number of dengue cases remain high as well which was 710 cases.

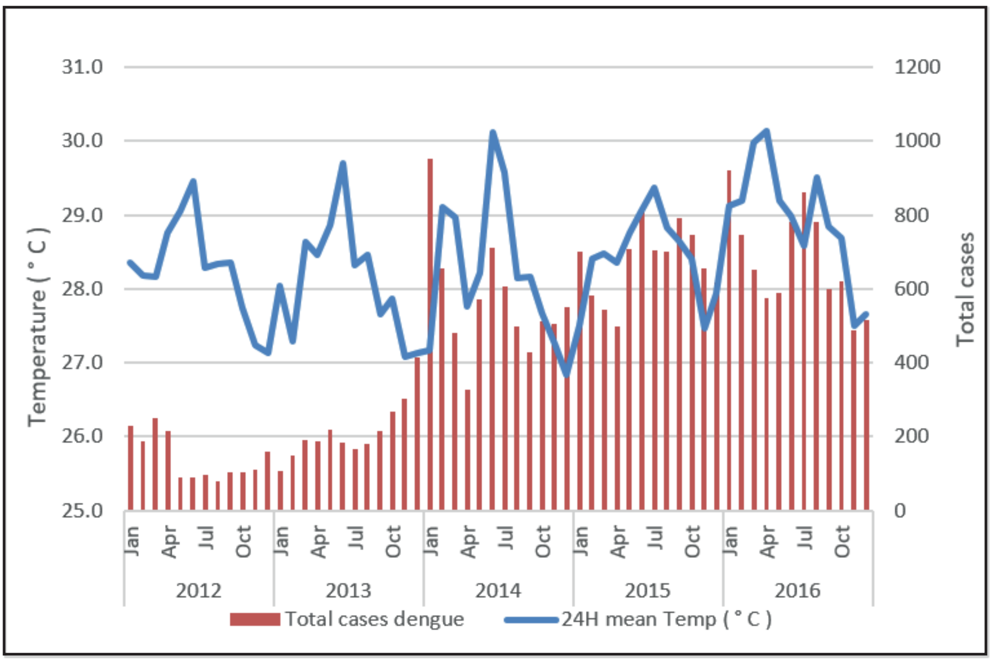
The result also indicated similar pattern to the wind speed and rainfall. During the highest dengue cases, the monthly rainfall showed was 8.2 mm. Meanwhile, in November 2012 during the highest mean rainfall, dengue incidence indicated among the lowest range in the five years (111 cases). The highest peak of wind speed in February 2014 which was 1.5 m/s with dengue incidence was 657cases. However, at the lowest wind speed (0.8 m/s), dengue cases remain high in December 2014 (550 cases).

Table 1. Mean of climatic factors from 2012-2016

Climatic factors	Mean
Temperature (^{o}C)	28.1 - 29.0
Relative Humidity (%)	73.4 - 77.4
Rainfall (mm)	9.3 - 11
Wind (m/s)	1.1 - 1.2

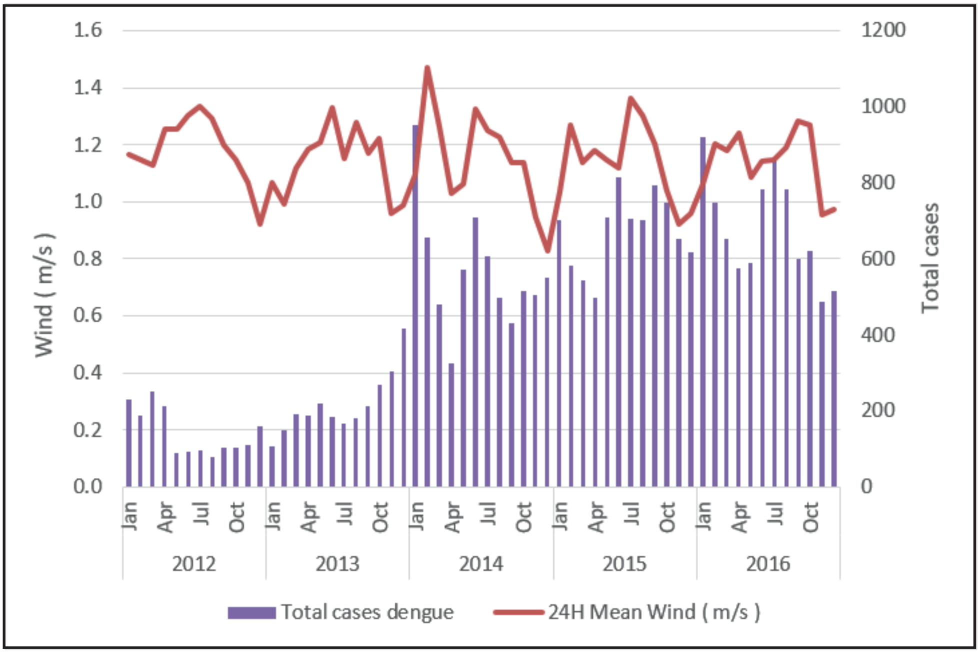


(a)

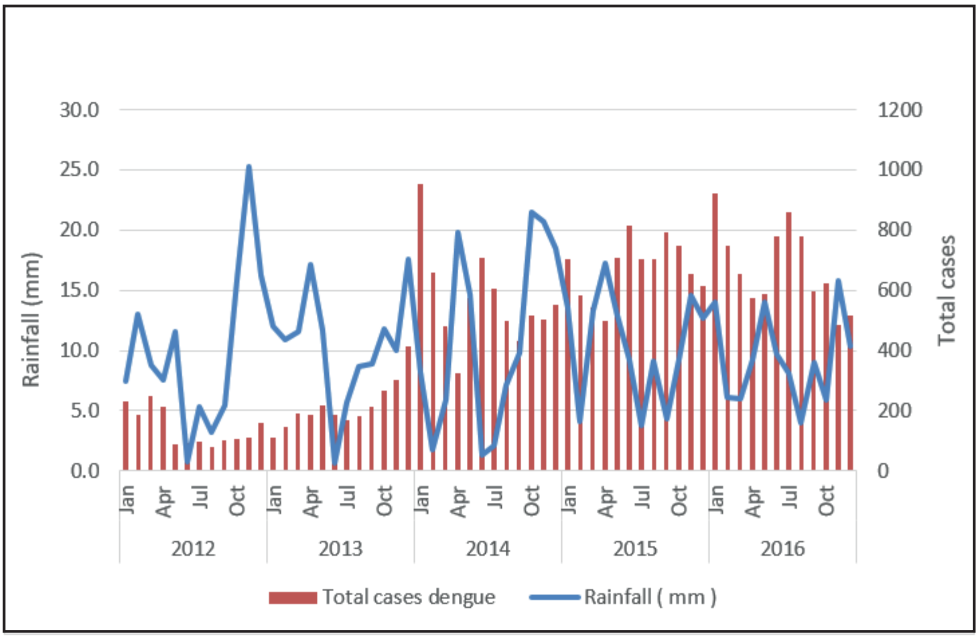


(b)

Figure 2. A-relative humidity and total dengue cases, B- temperature and total dengue cases, C- wind and total dengue cases, D- rainfall and total dengue cases from 2012 to 2016.



(c)



(d)

Figure 2 (Cont.) A-relative humidity and total dengue cases, B- temperature and total dengue cases, C- wind and total dengue cases, D- rainfall and total dengue cases from 2012 to 2016.

3.2 The Pearson's Correlation between dengue cases and environmental factors

The result from 2012 until 2016 showed that dengue cases in Kuala Lumpur were significantly correlated with temperature, relative humidity and rainfall ($p < 0.05$) (Table 2). However, there is no significant correlation between dengue cases and wind speed. Temperature, rainfall and wind showed positive correlation with dengue cases while relative humidity showed inversely proportional relationship with dengue cases in Kuala Lumpur. Based on table 2, the result demonstrated that wind showed no significant correlation ($p = 0.149$).

The multivariate analysis was proceeded (Table 3) and equation model were tested. It was found that the regression models for total dengue cases fit at $\alpha = 0.05$ (Table 3) with insignificant value, F = 20.953 ($p = 0.001$). Slope test showed that all variables contribute significantly for total dengue cases temperature with t value 5.448 ($p = 0.001$), relative humidity with t value -8.479 ($p = 0.001$), rainfall with t value 2.541 ($p = 0.011$) and wind with t-value -2.613 ($p = 0.09$) (Table 4). The equation model was generated as followed:

y = 0.135 (temperature) – 0.212 (relative) (humidity) + 0.059 (rainfall) – 0.061 (wind)

$\hat{y} = b_o + b1x1$;
$\hat{y}$ = Predicted value of dengue cases
bo = Y intercept
x_1 = temperature, relative humidity, rainfall, wind

Table 2. Pearson's Correlation Value between Environmental Factors with Dengue Cases at Kuala Lumpur

Variable	**Temperature**		**Relative humidity**		**Rainfall**		**Wind**	
	r value	p value	r value	p value	r value	p value	r value	p value
Total Cases	0.054	**0.022**	-0.151	**< 0.001**	0.049	**0.038**	0.034	0.149

*Significant at p < 0.05
**Significant at p < 0.01

Table 3. The ANOVA values for the environmental factors and variables

Model		**Sum of squares**	**Df**	**Mean square**	**F**	**p**
Total Dengue Cases	Regression	7686.750	4	1921.688	20.953	**0.001****

*Significant at p < 0.05
**Significant at p < 0.01

Table 4. The equation values for total dengue cases in Kuala Lumpur

Model		**Unstandardized Coefficients**		**Standardized coefficients**		
		B	**Std. Error**	**Beta**	**t**	**p**
	(Constant)	19.362	2.649		7.841	**0.001**
Total Dengue Cases	Temperature	0.438	0.080	**0.135**	5.448	**0.001**
	Relative humidity	- 0.196	0.023	**-0.212**	-8.479	**0.001**
	Rainfall	0.029	0.011	**0.059**	2.541	**0.011**
	Wind	-2.090	0.800	**-0.061**	-2.613	**0.009**

*Significant at p < 0.05
**Significant at p < 0.01

Table 5. The model summary for total dengue cases

Model	R	R square	Adjusted R square	Std. Error of the estimate
Total Dengue Cases	0.210	0.044	0.042	9.577

The analysis was proceeded to identify the R square value (Table 5). The R square value for total dengue cases was 0.044. Therefore, based on the summary of the model, (Table 5) the temperature, relative humidity, rainfall and wind contributed 4.4% of the total dengue cases in study area.

3.3 Mann-Kendall Trend Analysis

The Mann-Kendall (MK) result revealed the trend variation for all the parameters. Generally, the temperature indicated negative trend from 2012 to 2016, however in year 2015 the data of temperature showed no trend. On the other hand, the trend results of relative humidity showed positive trend all through except in 2013 that showed no trend (Table 6). For the rainfall analysis, a positive trend for 2012 and 2014 was revealed. Meanwhile, a negative trend was shown for the wind speed for 2012, 2014 and 2015.

For the dengue cases; however, the variation for the 5 years indicates negative and positive trends. Dengue showed downward trend in year 2012, 2014 and 2016 meanwhile in year 2013 and 2015 the cases showed upward trend. The analysis showed similar trend pattern (increasing and decreasing) between all climatic variables and dengue cases for 2012 and 2014 (Table 7). Based on climate variables, temperature and wind demostrated similar trend pattern (downward trend) meanwhile relative humidity and rainfall showed opposite trend pattern. Based on year 2012 and 2014, the Mann-Kendall trend analysis showed that the rise in dengue cases were affected by the increases in temperature and wind speed, while the relative humidty and rainfall affects the dengue with decreasing pattern.

4. Discussion

The transformation of the climate condition for the long period of time including temperature, precipitation, relative humidity, winds, and rainfall may lead to the changes in survival, replication, development and distribution of dengue virus and mosquitoes (Li *et al.,* 2018; Wu *et al.,* 2016). The occurrence of infectious disease determined by multiple factors including environmental factors such climate, vegetation, and water bodies (Palaniyandi, 2014).

The changing of average monthly temperature found to be associated with dengue transmission. The Pearson's correlation from this study showed temperature significantly associated with dengue incidence (WHO, 2011). Trend analysis from this study also indicated that the rising temperature trend was parallel with the increasing pattern of dengue cases. The similar study in Malaysia showed that high temperature (29.5 °C) with presence of rainfall increased the number of dengue incidence (Nazri *et al.,* 2011). The warmer temperature had been shown to increase the rate of dengue transmission (Vazquez-prokopec et.al., 2010; Wongkoon *et al.,* 2007; Kuno, 1997). The warmer temperature allows the mosquito to survive and matured faster. Thus, the female vectors need extra blood in order to lay eggs. A study in China found that the biting temperature ranged between 15 °C to 35 °C. However, the optimal range is 25 °C to 30 °C which is also the average temperature in Malaysia (Díaz-Castro *et al.,* 2017; Jemal and Al-thukair, 2016; Chen and Hsieh, 2012; Zhang and Zhang, 1994).

Table 6. Hypotheses of Mann-Kendall trend analysis for Climatic factors from 2012-2016

Climatic factors/Year	S	p-value (Two-Tailed)	Test Interpretation
Temperature (Daily mean, ° C)			
2012	-13810.0000	< **0.0001**	Reject H_0
2013	-9675.0000	< **0.0001**	Reject H_0
2014	-11670.0000	< **0.0001**	Reject H_0
2015	-412.0000	0.8599	Accept H_0
2016	-19516.0000	< **0.0001**	Reject H_0
Relative humidity (Daily mean, %)			
2012	8444.0000	**0.0003**	Reject H_0
2013	1397.0000	0.5489	Accept H_0
2014	13728.0000	< **0.0001**	Reject H_0
2015	9077.0000	< **0.0001**	Reject H_0
2016	11264.0000	< **0.0001**	Reject H_0
Rainfall (Daily mean, mm)			
2012	7501.0000	**0.0009**	Reject H_0
2013	2643.0000	0.2445	Accept H_0
2014	11134.0000	< **0.0001**	Reject H_0
2015	2294.0000	0.3091	Accept H_0
2016	-137.0000	0.9508	Accept H_0
Wind (Daily mean, m/s)			
2012	-7923.0000	**0.0006**	Reject H_0
2013	-1528.0000	0.5086	Accept H_0
2014	-14977.0000	< **0.0001**	Reject H_0
2015	-7352.0000	**0.0015**	Reject H_0
2016	-2309.0000	0.3199	Accept H_0
Dengue cases			
2012	-16561.0000	< **0.0001**	Reject H_0
2013	23242.0000	< **0.0001**	Reject H_0
2014	-11605.0000	< **0.0001**	Reject H_0
2015	5036.0000	**0.0304**	Reject H_0
2016	-15741.0000	< **0.0001**	Reject H_0

Positive —"S" indicates a positive trend. Negative —"S" values indicate negative trends. If $p < 0.05$, the slope is significantly different from zero.

Table 7. Mann-Kendall trend analysis for Climatic factors from 2012-2016

Climatic factors/Year	2012	2013	2014	2015	2016
Temperature (Daily mean, ° C)	↓	↓	↓	No Trend	↓
Relative humidity (Daily mean, %)	↑	No Trend	↑	↑	↑
Rainfall (Daily mean, mm)	↑	No Trend	↑	No Trend	No Trend
Wind (Daily mean, m/s)	↓	No Trend	↓	↓	No Trend
Dengue Cases	↓	↑	↓	↑	↓

Higher temperature may increase the length and efficiency of Extrinsic Incubation Periods (EIPs) of arboviruses in the vectors (Lindsay and Mackenzie, 1997). Therefore, the infected mosquitoes may survive for a longer period in higher temperature. However, this only occurs when the temperature range between 32 °C to 35 °C. The duration of dengue EIPs only 7 days compared to temperature at 30oC with 12 days dengue virus EIPs (Christiansen-Jucht *et al.,* 2014; Westbrook *et al.,* 2010; Focks, 2003).

This study also proved the rainfall has low positive correlation with dengue cases ($r = 0.049$, $p = 0.038$). The rainfall data were prearranged before analysis for optimum result. The data were selected 7 days before the date of dengue incidence. Seven days are the time needed for successful completion of mosquito life cycles, from eggs to adult in stagnated water (Wardekker *et al.,* 2012). The studies related the rainfall as the main contributor to the abundance of *Aedes* mosquitoes (Sharmin *et al.,* 2015; Barrera *et al.,* 2011; Promprou *et al.,* 2005). The increasing rainfall may increase the suitable breeding sites such as aim proper disposed of man-made container, roof gutter, water trap, and discarded rubbish (Cheong *et al.,*2013 ; Wan-Norafikah, 2012). Furthermore, the prolonged rainfall will increase dengue transmission risk (Hashizume *et al.,* 2012; Bich *et al.,* 2011). *Aedes* mosquitoes preferred rain water compared to the tap water because of the chlorine (Ho *et al.,* 2014), thus it is strongly associated with presence of shrub/ vegetation above the container (Arunachalam *et al.,* 2010). Under shrubbery area, the water may take longer period to dry, and it will turn as breeding areas. This situation is one of major problem in order to eliminate the breeding resources to this country since Malaysia is the tropical country surround by vegetation area (Cheong *et al.,* 2013).

Relative humidity found has been found to impart negative effect on dengue fever (Chen *et al.,* 2016; Cheong *et al.,* 2013; Maimusa *et al.,* 2012). However, the relative humidity in this study showed negative correlation, however it was the highest r value compared to other climatic factors ($r = -0.151$, $p < 0.005$). A study in China proved that minimum relative humidity (68%) affect dengue transmission, however it showed negative associated when it exceed 78.9% which was in line with the finding of this study (Xiang *et al.,* 2017). The study in India showed, the enormous quantity of Aedes albpictus were found at plant area with suitable value of relative humidity (70%-90%) (Palaniyandi, 2014). Another study in Dhaka City indicated that relative humidity at 72.8% associated with dengue transmission and affected time of replication and development of mosquitoes (Banu *et al.,* 2014). It maybe differs to each country since the association between climate and dengue fever depend principally on the local climate condition to specific study area and study periods (Li *et al.,* 2018).

Pearson's analysis revealed that wind speed showed a poor association with dengue incidence which was statistically insignificant. Several studies have shown that the wind can increase the frequency of mosquito flights, so it can also affect feeding and oviposition activities (Lu *et al.,* 2009, Wang and Chen, 2014; Chadee, 2004; Clements, 1999). Nevertheless, the strong wind > 10.7 m / s in China suggested that it could suppress mosquito flight activity and reduce the risk of dengue transmission (Xiang *et al.,* 2017). Air movement (wind) plays an important role in transporting the infected mosquito but, due to strong wind, it may also limit flying activity and human contact (Rosa-freitas *et al.,* 2006).

The climate and dengue cases showed the same trend pattern for both 2012 and 2014, based on Mann-Kendall's analysis. Cases of dengue showed decreasing trends as rainfall and relative humidity increased, while it decreases with the decrease in wind speed and temperature (Table 7). This study suggested that the flood-related rainfall can flush away the breeding areas, and decrease the mosquito population (Chien and Yu, 2014). In addition, the increasing trend in relative humidity has affected adult mosquito mortality and its survival (Tuladhar *et al.,* 2019; Sahay, 2018). The decreasing temperature trend leads to decrease of vector mosquito feeding activity. The female mosquito requires more blood and nutrient to produce more offspring (Yang *et al.,* 2009). In this analysis, the range of wind speeds for 2012 and 2014 (0.8 m/s to 1.5 m/s) had no effect on the dengue mosquito flight activity. The previous study showed that mosquito flight speed was roughly ~ 1 m/s (Enrih *et al.,* 2011). And the mosquito is still free to fly. The decreasing trend of wind speed in the study region can also affect the sheltering effect of the local topography (Enrih *et al.,* 2011). Throughout this study, climatic conditions showed that only 4.4 per cent lead to the incidence of dengue. The rising or declining pattern of dengue incidence cannot be determined by the individual climatic factor but from combination of several climatic factors. In addition, the incidence of dengue was not based solely on climatic factors, but other factors such as sociological factors may also contribute to the dengue problem (Cheong *et al.,* 2013).

5. Conclusion

This study indicated that 4.4% contribution of climatic factors to dengue cases. Temperature, rainfall, relative humidity and wind speed showed a significant correlation to the dengue cases with low r value. Even though the contribution of climate is small to dengue cases, but the climate is the major factor for vector abundance. Besides the climatic factors, there were other factors influenced the distribution of dengue fever such as sociological, environmental and ecological factors. The current study suffered limitations mainly regarding weather data due to the spatial distribution (not closely located) of weather stations in the study area. Though preliminary, the study will serve as the bases upon which future studies will be rooted, and will help the health authorities with important information regarding the factors and distribution of epidemic in the study area. The study recommends an integrated approach to dengue disease involving other factors such as sociology, ecology and human behaviour for better understanding, and action to deadly disease.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgement

The authors would like to express their deepest gratitude and thanks to Universiti Putra Malaysia for Putra Grants Sponsorship (GP-IPS/2015/9453500) and Vector Control Unit Staff in Dewan Bandaraya Kuala Lumpur (DBKL) for their cooperation.

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