Dengue risk map using GIS based on socio-environmental and climatic variables in residential area

Ruhil Amal Adnan (fujima37@gmail.com)
Universiti Putra Malaysia Fakulti Pengajian Alam Sekitar https://orcid.org/0000-0002-7545-7406
Mohammad Firuz Ramli
Universiti Putra Malaysia Fakulti Pengajian Alam Sekitar
Hidayathul Fathi Othman
Universiti Kebangsaan Malaysia
Zulfa Hanan Asha'ri
Universiti Putra Malaysia Fakulti Pengajian Alam Sekitar
Sharifah Norkhadijah Syed Ismail
Universiti Putra Malaysia Fakulti Perubatan dan Sains Kesihatan
Muhammad Amar Zaudi
Universiti Putra Malaysia Fakulti Pengajian Alam Sekitar
Da'u Abba Umar
Universiti Putra Malaysia Fakulti Pengajian Alam Sekitar

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Abstract

Background

Dengue, a major international health problem, is transmitted by aedes mosquitoes. Due to the lack of a vaccine, vector control by tackling the contribution factors may reduce dengue incidence. By understanding the factors contributed to the vector densities such as sociological, environmental and climatic factors, dengue prevention and control will succeed.

Objective

This study is aimed at determining the major sociological, environmental and climatic factors contributing to dengue cases and to produce the risk map based on the contributing factors

Methods

Questionnaire survey of 379 respondent with dengue history were utilized. The climatic data were obtained from Malaysia Meteorological Department. Geographical Information System (GIS) technology has been used to integrate the socio-environmental and climatic factors with dengue cases

Result

The chi-square results revealed that there is a significant association between respondent's dengue history and houses that are shaded with vegetation ($p = 0.012$) and the present of playground areas near the residential ($p = 0.011$) whilst Pearson's Correlation showed that dengue cases in Kuala Lumpur were significantly correlated with temperature, relative humidity and rainfall ($p < 0.05$)

Conclusion

The study identified socio-environmental factors that play an important role to develop the risk maps. The risk map can be useful baseline for decision maker to strategize and create preventive measure for controlling aedes mosquitoes.

Introduction

Dengue infection is a rapidly spreading mosquito-borne virus of global and public health importance, causing high morbidity and economic loss in tropical and subtropical regions. Globally, about 390 million dengue infections were reported annually from more than 125 countries (1). Two species of dengue vectors, *Aedes aegypti* and *Aedes albopictus,* are responsible for dengue transmission (2-3). The dengue virus is vertically transmitted through the bite of an infected mosquito (4).

Malaysia had a pronounced dengue problem since its first epidemic in the 1970s (5). Since then, various outbreaks have been recorded throughout the country. Until October 2019, approximately 107,422 dengue cases, with 153 deaths, were reported in Malaysia (Figure 1) (6). The tropical climate in Asian countries such as Malaysia, Thailand, Indonesia, and Singapore is considered as a suitable condition for the growth of *aedes* mosquitoes. A high density of the vector mosquito may lead to an outbreak of dengue fever (DF) and dengue hemorrhagic fever (DHF) (7).

Aedes albopictus, the Asian Tiger mosquito, is the dominant species in Malaysia compared to *aedes aegypti* (2, 8). However, both species have been found breeding in both indoor and outdoor breeding habitats (9-10). *Aedes albopictus* is common in suburban and rural areas, and it prefers to breed in artificial containers and natural breeding locations such as concrete tanks, drums, flower pots, discarded tires, plant stalks, animal shells, tree holes and bamboo stumps (3, 11-12). These breeding habitats are often close to human areas such as playground areas, cemeteries, and residential areas. *Aedes* also prefers habitat near water bodies including small lakes, swamps, springs and rivers (13). Vegetation is also important for *Aedes* mosquitoes, especially *Aedes albopictus*; thus, landscaping can influence the abundance of mosquitoes. *Aedes* prefers thick and dense vegetation (14). Vegetation also serves as a resting area during the day around residential houses (host availability)(11).

The uncontrolled expansion of urban environments with rapid population growth has accelerated the prevalence of dengue fever (15). Many studies attribute the increasing exposure to the dengue vector to overcrowded households (16, 17). *Aedes* mosquitoes feed on multiple humans per day and crowded conditions make it easy to transmit the virus efficiently (16). Several studies also suggested that dengue is associated with several sociological factors such as poor housing areas, household density, type of housing, multilevel housing, and human activities (13, 18-20).

Daily routines such as working and studying during the peak biting time are contributing factors to the incidence of dengue (21). Daily population movement is an inevitable activity in society. Thus, the risk of human exposure to the disease could vary physically (22). Previous epidemiological studies had incorporated population mobility and the location of daily activities for assessing the exposure and risk of disease transmission (22-24). Several studies assessed the crowd-gathering places (market, school, parks, and bus/train station), and commuting behavior played an important role for dengue transmission (25-26).

Because there is no available vaccine or specific drugs for dengue fever, control measures are based on the biological and chemical control towards *aedes* mosquitoes. In order to improve control, better understanding of factors that lead to the abundance and distribution of *aedes* mosquitoes is crucially needed (13).The aim of this study is to determine the sociological, environmental and climatic factors contributing to dengue cases at high risk areas in Kuala Lumpur, Malaysia and to produce the risk map based on the contributing factors.

Materials And Methods

Description of study sites

Kuala Lumpur is the capital of Malaysia with 243 km2 area and an average elevation of 21.95 m (Figure 2). Kuala Lumpur city has a population of l.8 million as of 2018, which is 5.5% of the total national population. The average annual population growth rate from 2017 to 2018 was 0.1 % (27). The city experiences a hot and humid climate all year round with seasonal variation in temperature and rainfall. The temperature floats between 31 ºC and 33 ºC (average is 32.4 ºC), while minimums hover between 22 and 23 ºC (average is 23.3 ºC). Kuala Lumpur typically receives 2,266 mm of rain annually with June and July being relatively dry (28). The land used lan covered (LULC) distribution of Kuala Lumpur was dominant with built covered almost 90%, followed by vegetation and water bodies (29). 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 to improve the population's quality of health. Kuala Lumpur has the second highest number of dengue cases reported by the Malaysia Ministry of Health in 2019. This study was conducted at the high risk areas of Parliment Batu and Parliment Wangsa Maju. It was recommendation by the Kuala Lumpur City Hall Health Department. The recommendation was based on the hot spot areas of dengue fever in occured Kuala Lumpur.

Study design

The population for this study was respondents who lived in either Parliment Batu or Parliment Wangsa Maju, which had positive dengue between January 2016 and May 2016. The respondents of this study are patients who were clinically diagnosed and serologically confirmed cases following the Clinical Practice Guidelines by Malaysia Ministry of Health (30). All the respondents must have met the inclusive and exclusive criteria. The inclusive criteria are that the respondent had experienced dengue fever and lived in either Parliment Batu or Parliment Wangsa Maju; the exclusion criterion was a patient who lived outside the study area. The list of outbreak areas in Parliment Batu and Parliment Wangsa Maju was obtained from Kuala Lumpur City Health Department.

This study designed and estimated the sample of the respondents from the high risk areas considering the sociological and environmental determinants that contribute to dengue incidence within 5% of true prevalence with 95% confidence (31). The calculation formula of sample size was applied using OpenEpi Software (16) and also by Lemeshow et al., 1990. Based on the calculation, the statistically required sample is 381 respondents derived from dengue case data from January 2016 to May 2016. The respondents for this study were interviewed via phone call to obtain the answers to the questionnaire. The date interval was selected to avoid recall bias if a longer period was chosen (32-33). Of the 730 respondents who were identified as dengue positive by the Kuala Lumpur City Health Department, 379 agreed to participate in this study and gave us full cooperation (Figure 2). All the information gathered through the phone interview and questionnaire was documented The address of 379 respondent then were geocoded in order to produce the spatial point layer by using ArcGIS version 10 (34).

The predictive variables

The structured questionnaire used in this study consists of questions on sociological and environmental factors. The sociological questions were based on the following rationale: (i) information related to either work or study and the routine of daily activity during peak biting (early morning and late evening) (ii) history of dengue infection in the respondent (32), and in household members (16, 35-37), (iii) and number of people in the household. The environmental section consists of questions about environmental factors surrounding the home, such as (iv) the type of housing (bungalow, terrace, and apartment), (v) nearby water bodies such as lakes and river which could be breeding sites, (vi) nearby playgrounds as potential breeding sites, (vii) nearby cemetery which could provide potential artificial breeding sites; (viii) vegetation such as bushes, house plants, or shrubs near the houses as habitat and resting areas and (ix) construction areas which can serve as transmission areas and also offer breeding sites if there is any standing water, especially during the rainy season (4, 38-39). The climatic data such as mean daily rainfall, temperature, relative humidity were obtained from Malaysia Meteorological Department.

Data Analysis

Data were entered and analyzed using Statistical Packages for Social Sciences (SPSS) version 22.0. The analysis undertaken by using this software at different levels. Chi-square tests followed by binary regression were used for sociological and environmental factors for the association of variables, however Pearson's Correlation test was used and followed by multivariate analysis for investigation of association between climate and dengue cases. The level of significance in this study was set at $P < 0.05$.

Kernel Density Estimation

The Kernel estimation was widely used in several vector borne disease (26, 39). The distribution of dengue cases were transformed into density surface by kernel density estimation and it will be illustrated contiguous pattern instead of point patterns. Through the pattern, the risk concentration in the study area was clearly observed for further analysis and the same time can protect the privacy of dengue cases.

Weighted of socio-environmental and climatic

The risk categories were determined according to the variables in the questionnaires. The spatial resolution of socio-environmental factors was set according to the flight range below 800m (according to the risk level) and also based on the risk impact to the dengue infection by the literature review (34, 40). The climatic factors value were set according to the optimum range that impact to the survival and activities of dengue virus carrying the mosquitoes (41-42). The data of climatic factors were recorded based on the day of respondent start feeling unwell (Table 1).

The "weightage" of the parameters were given based on the literature review (36, 43). The risk levels was given according from high risk to low risk respectively. Each parameter was converted into a raster layer with its weightage by using inverse distance weighing (IDW). IDW interpolation (nearest neighbour technique) was employed to produce the desired results. In the process, a neighbourhood around the interpolated point is identified, the weighted average is taken of the observation values within this neighbourhood (4, 42, 44).The final risk map was produced by using Weighted Overlay. The risk map is the combination of the risk factor layers with presented of low to high risk areas and it visualizes the risks in relation to each other (45).

Table 1: Description of weighted socio-environmental and climatic variable

Category/Variable **Sociological**	Data description	Literature review	Risk indicator	Risk score
People in the house	A crowded houses living in the short mosquitoe's flight range from its breeding sources could be exposed to the transmission. The household members more than 4 were likely to expose greater risk.	(31, 37)	1-4	1
			More than 4	2
Working status	The exposure people who are not working higher compared to the people who are working at the high risk areas of dengue fever during the biting time.	(46)	Working	1
			Not working	2
Routine daily activity during peak biting hours	The transmission of dengue are close related to the houses area. The exposure people who lived at house and surrounding higher compared to the people who are not staying at home during peak biting time (at high risk areas)	(31, 39, 47-48)	Not at houses area	1
			Stay at home	2
Dengue history (house members)	The chances of getting infection at the residential areas was higher if the house members had history of dengue fever	(22, 49)	House members with dengue history	2
			House members without dengue history	1
Environmental				
Types of housing	The higher population density and interconnection houses would lead the transmission of the virus and increased the exposure of infection.	(23, 37)	Attached houses (Terrace and apartment)	2
			Bungalow	1
Present of cemetery areas	The breeding habitat of mosquitoes were found at graveyards/cemeteries area, such as flower pots and vases.	(42)	<200m	4
			200-400m	3
			400-800m	2
			>800m	1
Present of water bodies areas	The water bodies serve as the breeding areas for *aedes*	(49-50)	<200m	4

	mosquitoes.			
			200-400m	3
			400-800m	2
			>800m	1
Present of construction areas	The construction area were close related to the water trap. Improper manage of water trap contributed to the abundance of breeding habitat.	(7, 52)	<200m	4
			200-400m	3
			400-800m	2
			>800m	1
Present of playground/recreational areas	The breeding habitat were found at the recreational/playground areas such as containers, rubbish, discarded tins and bottles.	(4)	<200m	4
			200-400m	3
			400-800m	2
			>800m	1
Present of vegetation areas	The vegetation served as the resting habitat for *aedes* mosquitoes. The vectors were fund in the stagnant water from flower pots of ornamental plants.	(23, 53)	<200m	4
			200-400m	3
			400-800m	2
			>800m	1
Climatic				
Temperature	The temperature significantly associated to dengue transmission. In warmer temperature the female mosquitoes need extra blood in order to lay eggs. The optimum temperature between 25-27oC.	(56)	> 30ºC	1
			25-27 ºC	3
			27-30 ºC	2
Relative humidity	According to the WHO, the activities of *aedes* mosquitoes increased with higher relative humidity. The optimum of relative -humidity ranged from 70-90%.	(43, 55)	< 70%	2
			70-90%	3
			> 90%	1
Rainfall	The rainfall is the important contributor to the abundance of mosquitoes. However, the heavy rainfall will flushed away the vectors habitat. Thus, the optimum rainfall was ranged from 4-8mm.	(41,52)	0 mm	1
			0.1-4 mm	3

			4-8mm	5
			8-20 mm	4
			> 20 mm	2
Wind	The wind was associated with mosquitoes flight activities. The optimum wind speed was ranged from 1-2m/s.	(43, 56)	0.5 -1 m/s	2
			1-2 m/s	3
			2 – 4 m/s	1

Result

Socio-environmental factors for respondent dengue history

A total of 379 respondents with a history of dengue answered the questionnaires provided. The study showed that the majority of the respondents who had only been infected by dengue once were living in a house with more than four people (87.7%), not working (88.8%) and routinely stayed outside during peak biting hours (87.2%) (Table 2). This study found that there was no significant association between a respondent's dengue history and these sociological factors.

A majority of the respondents who had one instance of dengue infection lived in bungalow houses (90.2%). The study also found that majority of the people who had only experienced one dengue infection lived near a cemetery (89.4%) and also near water bodies such as lakes and rivers (88.3%). Houses of respondents who had only one experience of dengue were not near construction areas (88.6%) (Table 3**)**.

This study showed that there is a significant association between respondents who had one experience with dengue and lived in houses shaded with vegetation (95% CI = 0.263 and 0.836, **p = 0.012**) with playground areas near the house (95%CI = 0.304 and 0.859, **p = 0.011**) as shown in Table 2.

Table 2: Association between socio-environmental factors and respondent dengue history.

Variable	Respondent’s dengue history		p-value	Prevalence Ratio	95% CI	
	More than once n (%)	Once n (%)			Lower	Upper
Number of people in the house						
1-4	15 (14.6)	88 (85.4)	0.562	1.182	0.673	2.077
More than 4	34 (12.3)	242 (87.7)				
Working status						
Working	27 (14.8)	155 (85.2)	0.288	1.328	0.785	2.247
Not working	22 (11.2)	175 (88.8)				
Routine activity during peak biting hours						
Outside home	37 (12.8)	251 (87.2)	0.933	1.026	0.559	1.883
Stay at home	12 (13.2)	79 (86.8)				
Types of housing						
Bungalow	6 (9.8)	55 (90.2)	0.432	0.727	0.324	1.634
Terrace & apartments	43 (13.5)	275 (86.5)				
Presence of cemetery areas						
Yes	10 (10.6)	84 (89.4)	0.445	0.777	0.404	1.496
No	39 (13.7)	246 (86.3)				
Presence of construction areas						
Yes	45 (13.1)	299 (86.9)	0.781	1.145	0.438	2.994
No	4 (11.4)	31 (88.6)				
Presence of water bodies						

Yes	11 (11.7)	83 (88.3)	0.683	0.878	0.468	1.647
No	38 (13.3)	247 (86.7)				
Presence of playground areas						
Yes	28 (10.2)	246 (89.8)	**0.011***	0.511	0.304	0.859
No	21 (20.0)	84 (80.0)				
Presence of vegetation (shaded house)						
Yes	37 (11.2)	292 (88.8)	**0.012***	0.469	0.263	0.836
No	12 (22.0)	38 (76.0)				

*Significant at $p < 0.05$

Influence of climate factors on dengue

For understanding the contribution of climate towards dengue incidence, the continuous data for five years in order to study the trend of climate changes and dengue cases. The cumulative data of dengue in Kuala Lumpur used to tally the data of climate which were obtained from only a station in this area. A total of 27296 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 3**. However, monthly mean of climate variables revealed inconsistent pattern for the five years analysis (Figure 4,5, 6, 7). The highest dengue cases were in January 2014 (953), January (921) and July (861) 2016. While, the lowest dengue cases were in July (79), May (89) and June (91) 2012. Based on the plot, 2016 showed the highest numbers of dengue cases (Figure 4,5,6,7).

The plot also indicates variations in terms of the influence of climatic variables on dengue occurance. Positive and negative relationship existed between dengue cases and the different climatic variables. For instance, there is no positive relationship between relative humidity and dengue cases. The highest relative humidity was in December 2012 (83.7%) which is period of lowest dengue cases. But still, the highest dengue cases occured in January 2014 which is also within conducive range of relative humidity (72%).

Furthermore, the plot in Figure 5, 6 & 7, indicates no relationship between temperature, wind speed and rainfall fluctuation with dengue cases. The highest number of dengue cases occured during period of lowest temperature (27.2 ºC), however during highest temperature , the number of dengue cases remain high as well (710 and 576). The result also indicated similar pattern to the wind speed and rainfall.

The result from 2012-2016 showed that dengue cases in Kuala Lumpur were significantly correlated with temperature, relative humidity and rainfall ($p < 0.05$) (**Table 4)**. However, there is no significant correlation between dengue cases and wind speed. Temperature and rainfall showed positive correlation with dengue cases while relative humidity and wind showed inversely proportional relationship with dengue cases in Kuala Lumpur (**Table 4)**.

Table 3: Mean of climatic factors from 2012-2016

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

Table 4: 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 $p < 0.05$

Assessing the impact of socio-environmental and climatic variable

The study indicated spatial distribution of dengue cases at high risk (red color) localities in Parliament Wangsa Maju and Parliament Batu (Figure 8) by kernel density estimation. The area with blue color classified with low cases localities.

The IDW maps were developed from all the socio-environmental factors to indicate the overall situation (Figure 10**).** All the parameters from IDW were overlaid using weighted overlay analyses demonstrated the final risks map (Figure 9). The outcome of the map has been categorized into low to high risk areas based on the score provided. The high risk area (red) outcome from the risk map was achieved from overlay mapping of highest percentage of socio-environmental and climatic factors contributed in this study. The dengue risk map generated based on the socio-environmental and climatic factors were validated with kernel density estimation.

The risk maps showed several high risk areas were tally with high dengue density cases distribution (Figure 8). The high dengue density distribution map validated dengue risk map with details explanation in table 5. The similar factors for both maps at high risk areas such as number of people in the house (more than four), type of housing (attached house), presence of playground (200-400meter), relative humidity (70-90%), temperature (27-30 ^{o}C) and wind (1 – 2 m/s) (Table 5). Based on the kernel density map, the cemeteries and water bodies mostly not in the high risk and low risk areas. Furthermore, most of them lived in the attached houses with more than four people for both areas.

Table 5: Summarize of socio-environmental and climatic factors at study areas

Factors	**Based on the risk maps**		**Based on validation with kernel density**	
	High risk areas	Low risk areas	High risk areas	Low risk areas
Number of people in the house	More than 4	More than 4	More than 4	More than 4
Working status	Not working	Working	Working	Not working
Routine activity during peak biting hours	Stay at house	Not at houses area	Not at houses area	Not at houses area
Types of housing	Attached house	Attached house	Attached house	Attached house
Presence of cemetery areas	200-400 m	> 800 m	> 800 m	> 800 m
Presence of construction areas	200-400 m	> 800 m	400-800 m	200-400 m
Presence of water bodies	200-400 m	> 800 m	> 800 m	> 800 m
Presence of playground areas	200-400 m	> 800 m	200-400 m	400-800 m
Presence of vegetation (shaded house)	< 200 m	400-800 m	200-400 m	200-400 m
Relative humidity	70-90%	< 70%	70-90%	70-90%
Temperature	27-30 ^{o}C	27-30 ^{o}C	27-30 ^{o}C	27-30 ^{o}C
Rainfall	> 20 mm	> 20 mm	1-4 mm	> 20 mm
Wind speed	1 – 2 m/s	2 – 4 m/s	1 – 2 m/s	0.5-1 m/s

Discussion

An investigation into both sociological and environmental perspectives may provide insight into appropriate and effective vector control responses for combating dengue (49, 57). This study collected the significant variables about sociological data such as number people in the house, routine activity during peak biting time and working status. The chi-square indicated majority of the respondent routinely stayed outside during the peak biting and mostly not working people. Students also among not working category. Although the majority among non-working category, however the percentage of working category also high (85.2%). This result was in line with outcome from kernel density estimation, which was high dengue cases areas showed the majority come from working category. Even though, dengue incidence occurred in all age groups, older people have more behavioural risk factors such as travel, work, study, immigration, and leisure activities (58). Daily population movement is an inevitable activity in society. Successful dengue transmission is dependent upon the time period when these people remain in certain areas, as well as the number of humans that visited the viremic areas (33, 59). This particular study revealed that the most common areas for dengue-afflicted patients to be are residential areas, work areas, and school. Thus, several preventive control measures can be implemented by the public during peak biting hours, such as the application of insecticides, wearing long-sleeved shirts, and using mosquito repellent (59-61).

The finding of this study showed that the households with more than four members were majority among the respondent. In Malaysian, the average of household number was 4.2 and urban areas were smaller compared to rural areas (27). Large household numbers were more at risk compare to small number of households. Due to the exposure of dengue transmission, if one person got infected, mosquitoes who bite that person may transmit the virus to other members as well (31).

The univariate analysis indicated bungalow among the majority (90.2%), nevertheless this result in contrast with kernel density estimation where the terrace houses and apartments showed a majority among high dengue cases areas. These types of housing may lead to the rapid transmission of dengue virus in the crowded and urbanized areas (13, 31). The short flight range of the *Aedes* mosquitoes, especially *Aedes albopictus* mosquitoes, will further expose the dangers of dengue and its spread during an outbreak due to the small distance between the source of food and the breeding site, respectively (37, 62). Moreover, the present study also proved that flower vases and the lids of paint buckets commonly seen at apartment houses are a notable breeding site. It may worsen the overall condition should residents fail to manage their planting areas properly (63). Generally, the community that lives in apartments and terrace houses plant their trees and flowers in these vases due to the lack of ground areas, as most of the floors in their houses are covered with cement (64-65). Several studies also revealed that a lesser concentration of vegetation could also serve as suitable resting areas for female mosquitoes, as high rise building apartments revealed high dengue incidences, too (66-67).

Vegetation also serves as the resting areas for *Aedes* mosquitoes. This study indicated the presence of vegetation showed the significant result among the respondent’s dengue history (**p = 0.012**). With regard to this, previous studies had reported that vegetation might remarkably impact dengue infection in combination with a myriad of factors causing dengue cases in study areas (23, 68). Furthermore, plants and vegetation sites serve as a natural habitat and food source for *Aedes* mosquitoes as they feed on the nectar of the plants (69-70). In consideration of their optimum flight range of approximately 200 meters, the growth of *Aedes* mosquito population will be uncontrollable if any breeding site is present near the human community, especially in the urban areas (43). These urban area having a highly dense population will subsequently result in an exploding mosquito population as the food source (human blood) is easily accessible (71). Therefore, a larger mosquito population will lead to an increased incidence of dengue cases attributable to the growing human-mosquito contact (26).

This study indicated a significant result for the presence of playground areas compared to the frequency of dengue history among the respondents (**p=0.011**). The frequency of dengue infection for the respondents is important due to its potential association with the residential areas and their surroundings. The Malaysian Ministry of Health has identified parks (including playground areas), cemeteries, vacant lands, public infrastructure areas and construction sites as the favored breeding sites for these troubling insects (23, 66). These areas are typically linked to overcrowding, whereby artificial containers are easily found (39, 72). This study revealed that about 89.8% patients lived near playgrounds or parks, which were also concomitantly used as the garbage dumps by the public. Water that is trapped after rainfalls is the perfect point for mosquito oviposition areas (73). These playground areas are typically surrounded by trees, ornamental plants, and shrubs. Thus, without the elimination of the rubbish dump, man-made containers, and other breeding sources, the female *Aedes* mosquitoes will oviposit and complete the life cycle. Following this, the number of adult mosquitoes will increase as the areas have already served as a natural habitat for them (3, 74). Similarly, crowd-gathering places like recreation parks, schools, and markets also played an important role in dengue transmission, particularly in case of an abundance of infected *Aedes* mosquitoes in such locations (24, 74).

The study setting was in the crowded and urbanization areas. The ecological setting for both areas is the combination of residential, commercial and densely populated places with development in both infrastructure and residential housing. According to the study areas, most of the respondent in Parliament Batu lived in terrace houses and bungalow, however, those at Parliament Wangsa Maju mostly lived in an apartment. Terrace houses are usually associated with vegetation such as ornamental and house plants (56). Most of the residential areas are nearby to the playground. The socio-environmental and climatic factors considered in this study were likely responsible for creating the suitable condition for the increased breeding and transmission of *aedes* mosquitoes and thus increasing its density and spreads. 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 (56, 74). Furthermore, the finding of this study such as vegetation and playground areas are strongly associated with breeding habitat. The prolonged rainfall will increase dengue transmission. Besides, under shrubbery area and lower temperature, the water may take longer period to dry and it will turn into breeding site (75).

The sociology factors in this study commonly gave general information for the targeted group for the successful disease control program. Meanwhile, the understanding of influential environmental factors is very important for implementing vector control such as chemical and biological control in urban areas, especially during an outbreak. Environmental control can be permanently utilized to control the dengue fever outbreak by improving the overall environmental conditions (72). Elimination of the mosquito's immature stages or disruption of their life cycle is henceforth the principle technique towards decreasing the vector population. Interrupting the larval and pupae stages alike will lead to a decreased number of adult mosquitoes, which would consequently result in a decline in the density of the vector population, and ultimately a reduction of dengue incidence.

The production of risk maps in the study used the spatial distribution of socio-environmental and climatic factors from IDW maps. The distribution of the factors were calculated based on the optimum flight range distance from the residential areas (4,42). However, when the validation has been made using the kernel density of dengue case distribution, it showed that several factors only distributed nearby residential areas in the optimum range (Table 5). Dengue transmission can be influenced by a combination of several factors in different areas. Even though, not all the risk factors presented in particular areas, the density of Aedes mosquitoes can be increased (75-76). The risk map and the validation results from this study can be used as a model to predict the factors contributed during the outbreak in urban areas especially.

Conclusion

The impact of socio-environmental and climatic factors for dengue transmission risk in this study gives meaningful additional information for the improvement of current control measures. This principal finding also will beneficial other researchers in academic institutions. The environmental factors that contributed towards dengue transmission uncovered in this study consisted of the playground areas, and vegetation at shaded houses. The climatic analysis revealed significant determinants such as relative humidity, temperature and rainfall. Although only a few factors were found to be significantly associated with dengue incidence, the combination of multi-factorial circumstances was also crucial as they may collectively and indirectly contribute to the abundance of Aedes mosquitoes. As the factors affecting dengue incidence and transmission are diverse, the implementation of dengue control is challenging. Significant sociological and environmental variables should be taken into consideration to better formulate local dengue control and preventive measures for the community and health authorities.

Declaration

Ethics approval and consent to participate

The ethical approval number for this research:

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Consent for publication

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Availability of data and material

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Competing interests

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

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Author’s contributions

1) Ruhil Amal Adnan carried out the experiment, performed the data analysis, and wrote the manuscript.

2) Mohamad Firuz Ramli and Hidayathulfathi Othman developed the theory and presented the idea of this research.

3) Sharifah Norkhadijah Syed Ismail, Zulfa Hanan Asha’ri, and Muhammad Amar Zaudi contributed the idea of interpretation results. All the authors provided critical feedback and helped the research, analysis and manuscript.

4) Da’u Abba Umar helped for arrangement and English editing for this paper.

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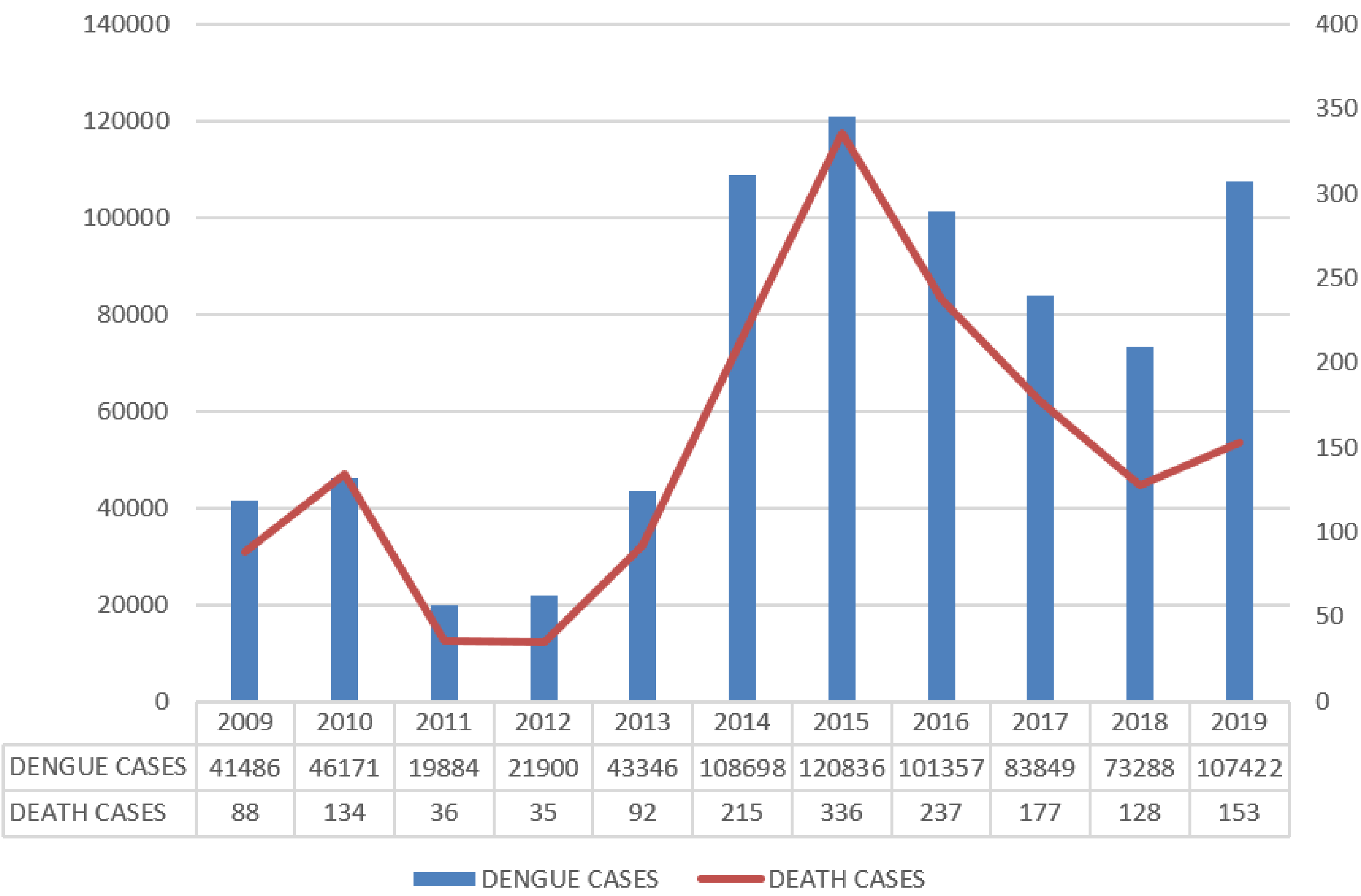
Figures



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
DENGUE CASES	41486	46171	19884	21900	43346	108698	120836	101357	83849	73288	107422
DEATH CASES	88	134	36	35	92	215	336	237	177	128	153

Figure 2

Dengue incidence in Malaysia from 2009-2019 (Source: Malaysia Ministry of Health)

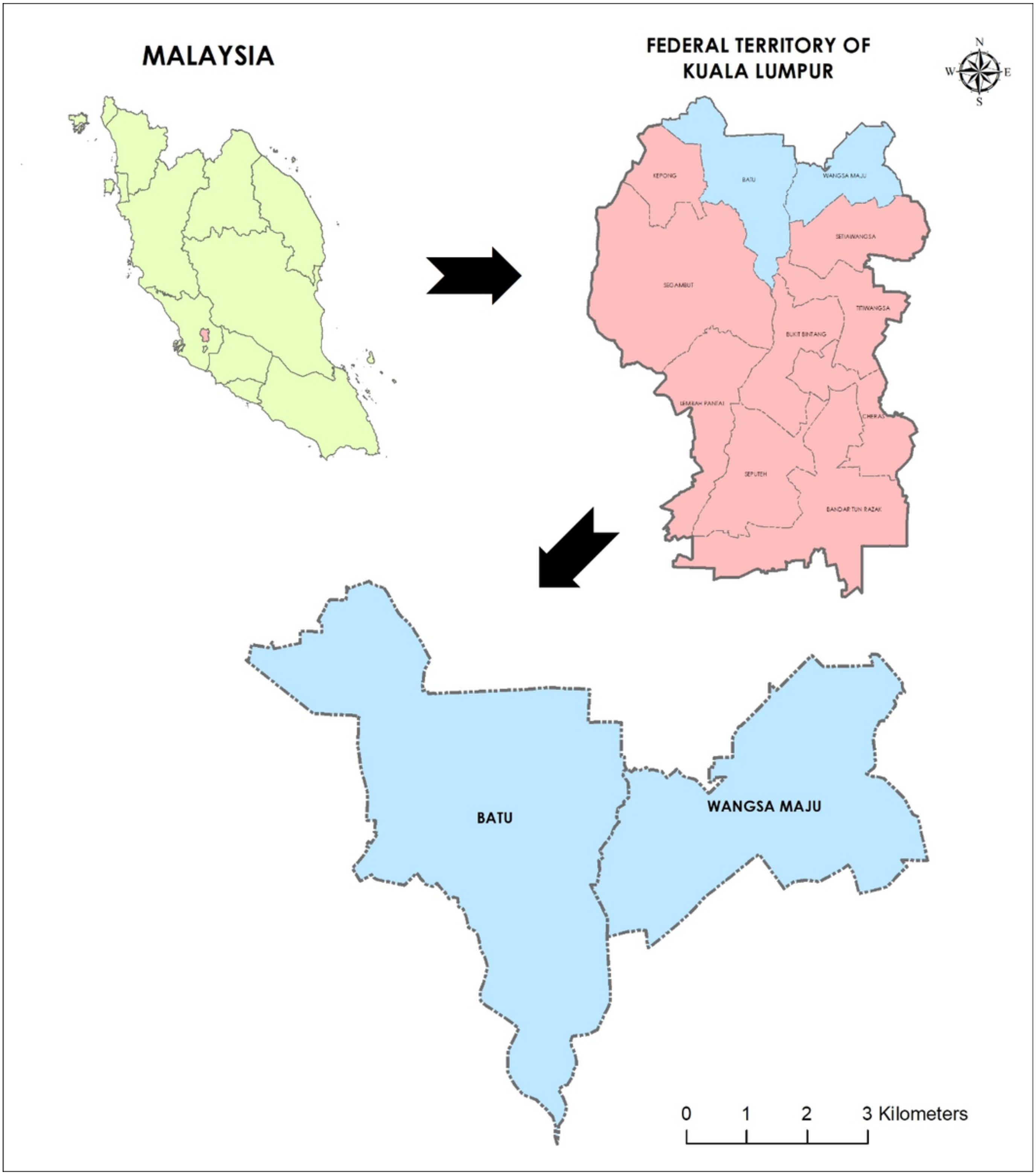


Figure 4

Map of study areas in Kuala Lumpur, Malaysia.

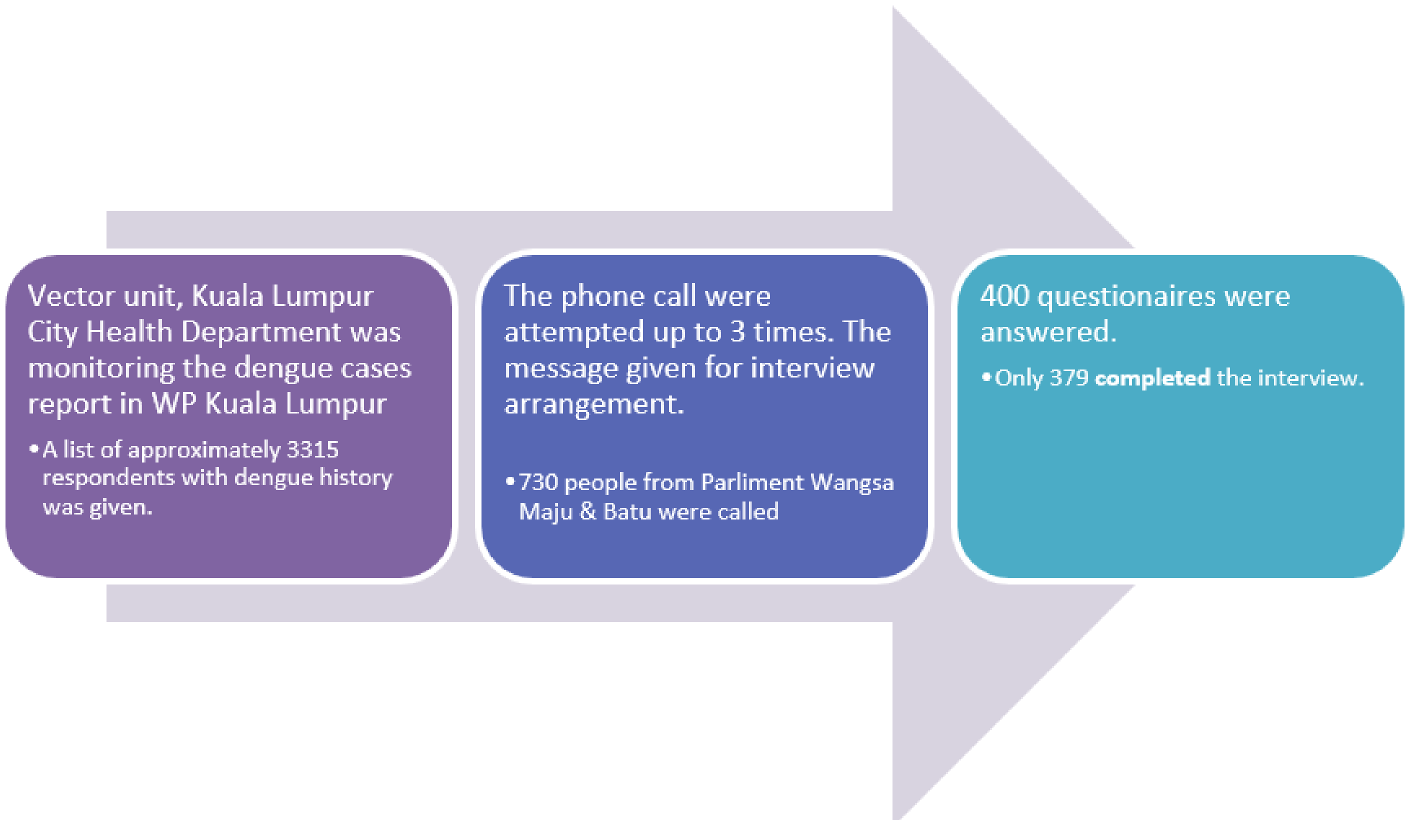


Figure 5

Flow diagram of respondent selection

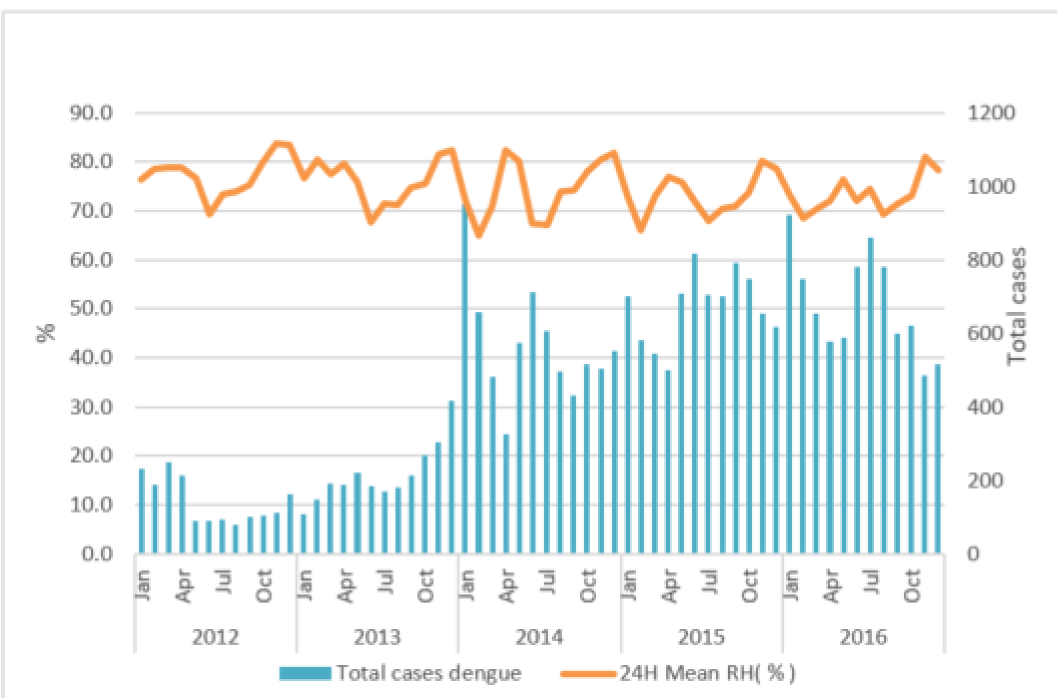


Figure 7

Relative humidity and total dengue cases from 2012 to 2016

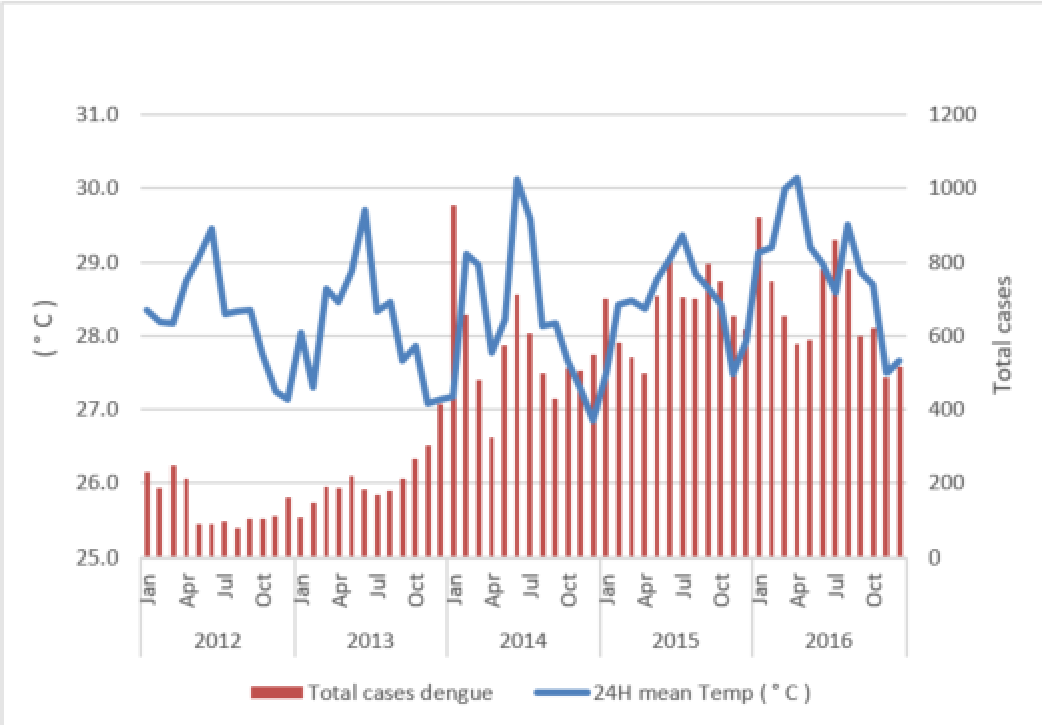


Figure 9

Temperature and total dengue cases from 2012 to 2016

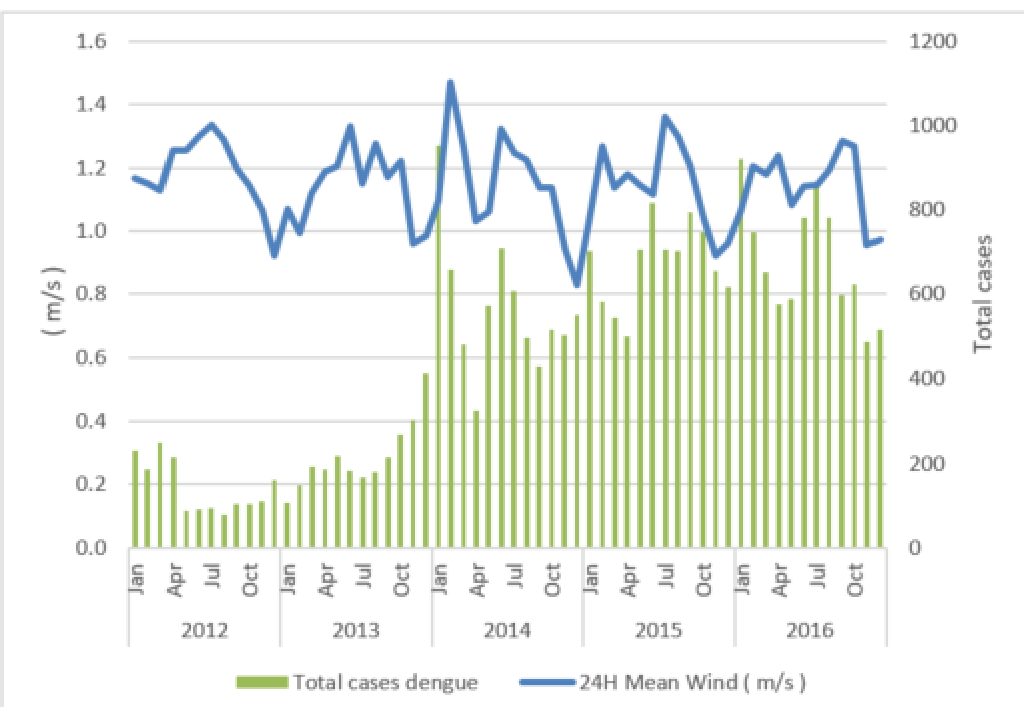


Figure 12

Wind and total dengue cases from 2012 to 2016

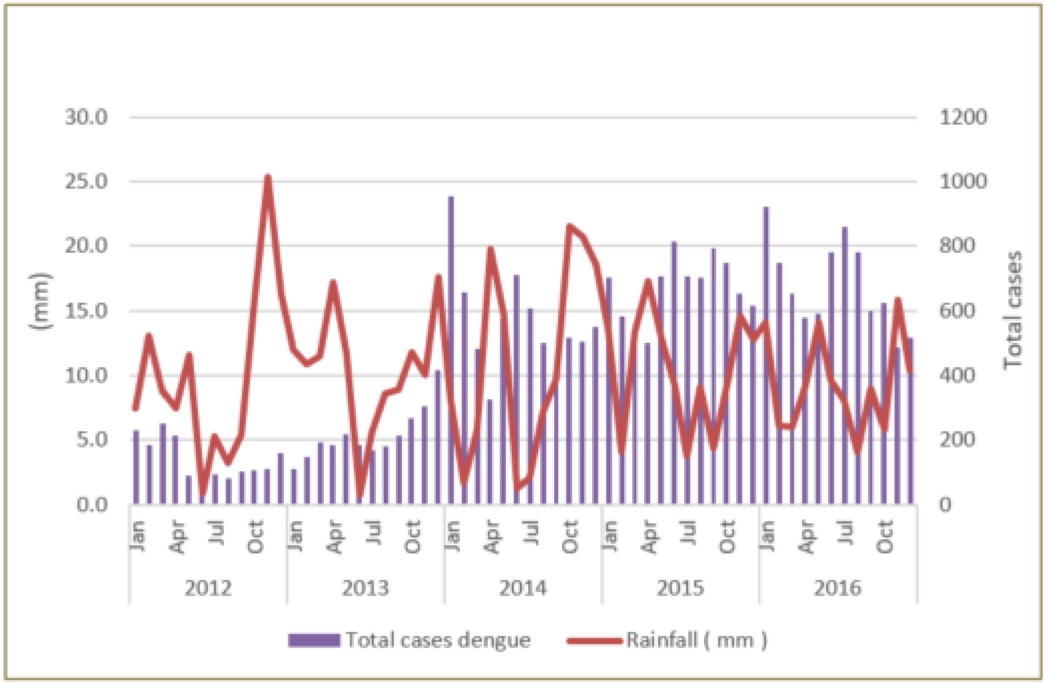


Figure 14

Rainfall and total dengue cases from 2012 to 2016

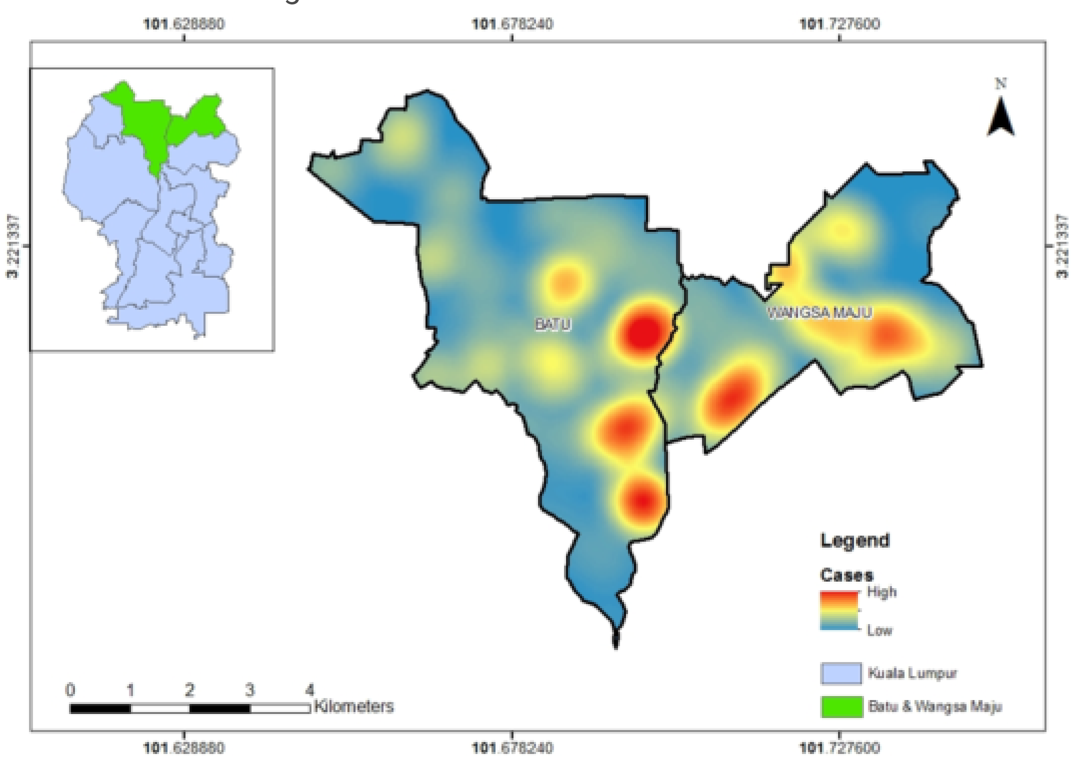


Figure 16

Spatial distribution of dengue cases in Parliament Batu and Parliament Wangsa Maju with kernel density estimation

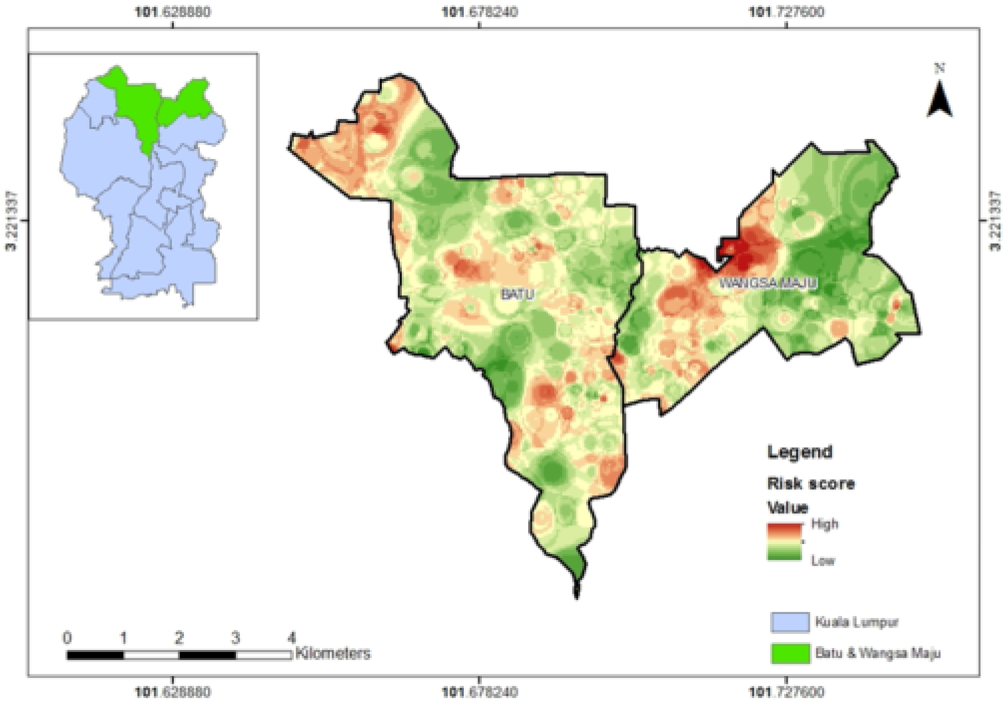


Figure 18

The risk map produced showed localities with high risk areas and low risk areas.

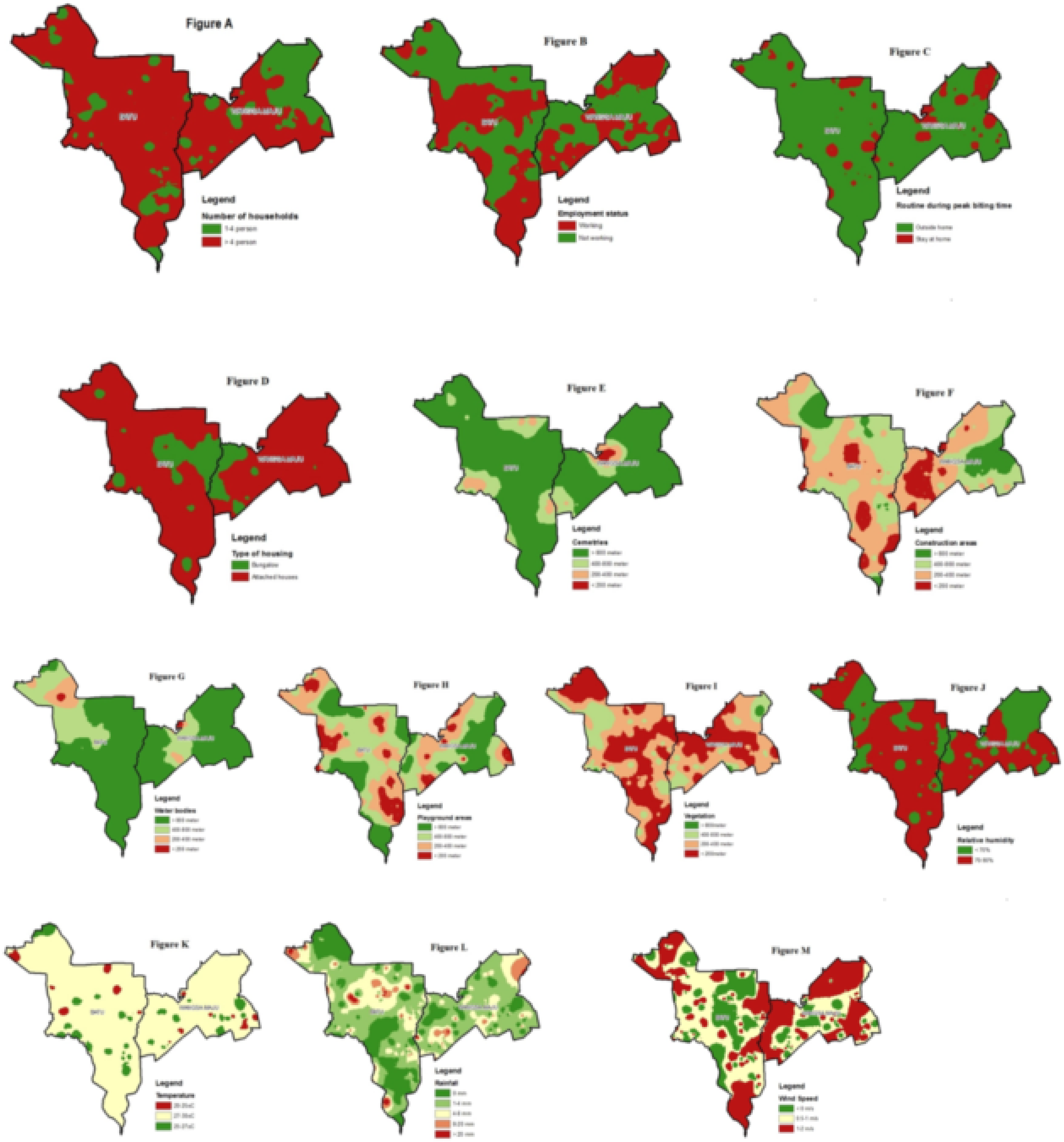


Figure 20

Inverse Distance Weighted interpolated map. Each map has been assigned weight value. (A) Number people in the house, (B) Working status, (c) Routine daily activity during peak biting time, (D) Type of housing, (E) Cemeteries, (F) Construction areas, (G) Water bodies, (H) Playground areas, (I) Vegetation, (J) Relative humidity , (K) Temperature, (L) Rainfall, and (M) Wind Speed.