

Spatial Pattern Analysis on Dengue Cases in Bangi district, Selangor, Malaysia

Nuriah Abd Majid (✉ nuriah@ukm.edu.my)

Universiti Kebangsaan Malaysia

Ruslan Rainis

Universiti Sains Malaysia

Mazrura Sahani

Pusat Perubatan Universiti Kebangsaan Malaysia

Ahmad Fariz Mohamed

Universiti Kebangsaan Malaysia

Sarah Aziz Abdul Ghani Aziz

Universiti Kebangsaan Malaysia

Nurafiqah Muhamad Nazi

Universiti Kebangsaan Malaysia

Research

Keywords: dengue fever, standard distance, mean spatial center, directional distribution, average temperature, rainfall

Posted Date: June 5th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-32929/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at Geospatial Health on March 11th, 2021. See the published version at <https://doi.org/10.4081/gh.2021.915>.

Spatial Pattern Analysis on Dengue Cases in Bangi district, Selangor, Malaysia

Nuriah Abd Majid^{1*}, Ruslan Rainis², Mazrura Sahani³, Ahmad Fariz Mohamed¹, Sarah Aziz Abdul Ghani Aziz¹, and Nurafiqah Muhamad Nazi¹

¹Institute for Environment and Development (LESTARI), University Kebangsaan Malaysia, Bangi 43600, Selangor Darul Ehsan, Malaysia

²School of Humanities, Universiti Sains Malaysia, 11800 Minden, Pulau Pinang.

³ Faculty of Health Sciences, Universiti Kebangsaan Malaysia, 50300 Kuala Lumpur, Malaysia

* Correspondence: nuriah@ukm.edu.my

Abstract

Background: Dengue outbreak has proliferated around the developing countries, including Malaysia, in recent decades. Thus, understanding the distribution pattern is essential for urbanization livelihood.

Method: The objective of this study is to determine the trend of dengue cases reported from year 2014 to 2018 and the spatial pattern for dengue spread with reference to weather elements in Bangi town.

Results: Spatial statistical analyses conducted found that the distribution pattern and spatial mean center for dengue cases was clustered at the east of Bangi region. Directional distribution observed that the elongated polygon of dengue cluster stretched from the northeast to the southwest of Bangi district. Standard distance for dengue cases was the smallest for the year 2014 (0.017 m), and the largest was in the year 2016 (0.019 m), whereas dengue cases in year 2015, 2017, and 2018 were measured at 0.018 m. The average nearest neighbor analysis also observed clustered patterns for dengue cases in Bangi district. Pearson's correlation analysis found that temperature ($r = -0.269$) was negatively correlated with dengue cases for year 2014 and 2018; however, rainfall amount ($r = 0.286$) and rain days ($r = 0.250$) were positively correlated with dengue cases in year 2018.

Conclusions: The three spatial statistical analyses (spatial mean center, standard distance, and directional distribution) findings illustrated that the dengue cases from the year 2014 to 2018 are clustered on the northeast to the southwest of the study region. The rainfall element is found to be a significant positive factor correlated for most study years compared to temperature element.

Keywords: dengue fever; standard distance; mean spatial center; directional distribution; average temperature; rainfall

Background

Dengue fever is one of the world's most deadly mosquito-borne viral diseases caused by closely related dengue viruses as it is spreading promptly. There were about 1.2 million dengue fever cases reported around the world in 2008, which then rose to 3.34 million cases in 2016 [1]. Dengue cases have reported high in tropical areas, include Cambodia, Laos, Malaysia, Singapore, Philippine, China, Vietnam, and Australia, as well as countries in the Pacific Islands [2]. In Malaysia, dengue is predominantly an urban disease, and states of Selangor is the area that has been primarily affected by the disease with high numbers of cases reported [3]. The tropical and subtropical climate enriched with high precipitation, humidity, and temperature lead to vector lifespan and reproduction [4-16].

Aedes aegypti mosquito is the primary vector of dengue. Once the infected female mosquitoes bite humans, this virus transmitted to every individual during its lifespan. Urbanized areas, mostly in human-made containers, are favorite for *Aedes aegypti* to breed and live [1]. Hot and humid climate with an average temperature of 27°C provides suitable conditions for *Aedes* to breed, especially in urban areas. The spread of dengue also linked to the weather and the season. Most studies in Malaysia have identified the association between dengue and rainfall distribution [5, 17-25]. Stagnant rainfall, especially in residential areas, creates more *Aedes* mosquito breeding grounds. However, there is a decline in dengue cases when heavy rains continue in an area as heavy rains destroy *Aedes* mosquito larvae from exposed containers [24]. Surface temperatures and water in agricultural drainage founded to be higher than in forested areas, which can accelerate the growth process of *Aedes* mosquito larvae and reduce the life cycle of adult mosquitoes [26]. However, an increase in temperature above 28°C affects the decline of dengue cases as the water reservoir is dry and impedes the breeding of *Aedes* mosquitoes. Besides, a study was done previously also found that *Aedes* mosquitoes need a neutral pH to reproduce [25]. A recent study conducted shows that the number of *Aedes* mosquitoes also decreases during the haze season and makes it challenging to reproduce *Aedes* [19]. This may be due to smoke and heat carried by haze make it difficult for *Aedes* mosquitoes to detect human body heat to bites. On the other hand, the researcher also argues in their study that the spread of dengue has nothing to do with the haze season [27].

For many years, the government has conducted programs and activities to control and overcome the dengue outbreaks in Malaysia. However, Dengue will be a significant health risk unceasingly with increasing numbers of population density. Therefore, viral disease mapping and monitoring using GIS have finally become significant for epidemic control and further management plan strategies. Spatial analysis help to estimate the risk for dengue fever across affected areas and offer insight into the nature of dengue fever disease clusters [28].

Hence, this study aims to determine and analyze the trend of dengue fever cases and its spatial spread in Bangi, Selangor, as well as the relation with selected weather variables, which are volume of rainfall and temperature according to temporal manner. This study provides valuable information needed for the effective control and decision-making process of the dengue outbreak in a particular area. Geographical Information System (GIS) software ArcGIS10.5 was used to investigate and visualize the distribution pattern in a geographical context [29]. Three spatial statistical methods were used to test the spread trend for dengue

cases and observe the differences between dengue cases reported from the period of the year 2014 to 2018. The methods are directional distribution, spatial mean center, and standard distant analysis. The findings would enhance disease surveillance systems by using the application of GIS in the field of public health and medicine for future management plans.

Methods

Study area

This study area is located in the Bangi town, in Hulu Langat district, Malaysia, with coordinates of $2^{\circ}55'20.6''\text{N}$ and $101^{\circ}46'50.6''\text{E}$ and located 38 km south of Kuala Lumpur (Figure 1). The total area of Bangi is 2243 hectares, with increasing numbers of the population and economic activities. The average temperature in Bangi is 27°C , with an annual average rainfall of 2302 mm. Bangi is a region situated south of Hulu Langat district, the new town and region converted to townships for the last four decades. Bangi is an emerging land developing areas for housing estates, which resulted in the rapid growth of population density. With this characteristic, Bangi is a potential area for high dengue cases. Along with the rise of development growth, dengue epidemiology needs to be controlled to reduce the vulnerability of urban populations towards the outbreaks [30].

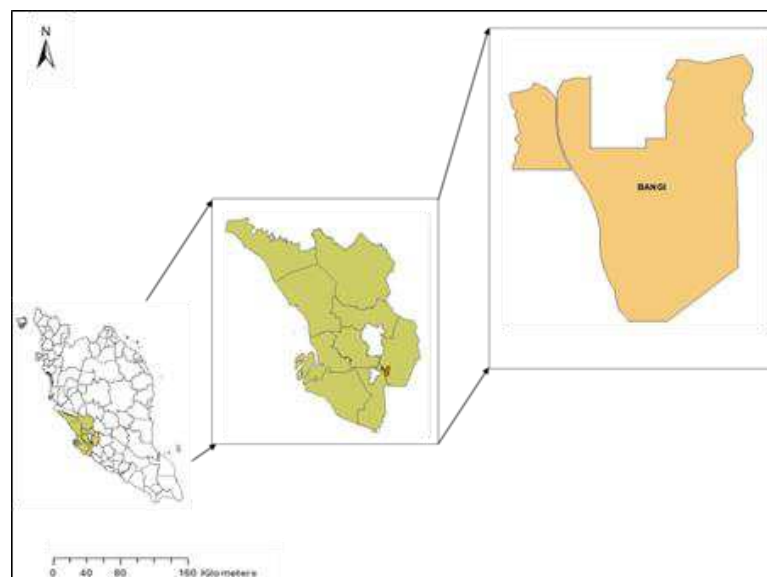


Figure 1: Study Site

Data collection

Dengue Cases Data

A complete dataset of dengue fever cases obtained from the Hulu Langat District Health Office. The dataset based on register records at the government hospital in Bangi from the year 2014 until 2018. There were 7779 positive dengue cases throughout the Bangi town within that period. The location of the patients was extracted from the data to map the distribution in ArcMap10.5.

Meteorological Data

The weather variables in this study included were monthly average temperature and rainfall amount. Meteorological data for the period of 2014 to 2018 obtained from weather monitoring station based in Sepang district (2°45'21.0"N 101°42'25.3"E) by Meteorological Department Malaysia, located in southwest Bangi, which the data generally used to represent the weather conditions for the whole state of Selangor [31].

Statistical Analysis

Spatial Mean Center

A spatial mean center is the average coordinates x and y of all features in the study location. The mean center can detect changes for the distribution based on features, to show the centered phenomena for visualizing based on the dengue cases. The new feature point of the mean center created a new feature point dengue cases for classification where every feature is representing the mean center. The changes in the distribution of the mean center will be detected. The location of the mean center will represent by location x and y value as a feature on the dimensional field. Calculated the mean center as below:

$$\bar{X} = \frac{\sum_{i=1}^n x_i}{n} \quad (1)$$

$$\bar{Y} = \frac{\sum_{i=1}^n y_i}{n} \quad (2)$$

Standard Distance

The standard distance is a single value that measures the compactness of distribution spreading around the center. The standard distance used to create a polygon circle. It is a value that can be mapped by drawing a circle with a radius equal to the standard distance. Distance standards are a new class of property forming a circle polygon centered with the mean center (the center and a circle for each case). Value attributes for each polygon of the circle are the x-coordinate, y-coordinate of the center means, and standard distance (circle radius).

Standard distance calculation is as follows:

$$SD = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2}{n} + \frac{\sum_{i=1}^n (y_i - \bar{Y})^2}{n}} \quad (3)$$

2.3.3 Standard Deviational Ellipse (SDE)

The standard deviation ellipse is to summarize the geographical space features central tendency, dispersion, and the direction of the trend. The usual way to measure trends in the area is a set of standards to calculate the distance separately on the x and y axes. Both measures include defining the axis of the ellipse distribution characteristics. Ellipse referred to as the standard deviation ellipses, as the method of the standard deviation of the coordinates x and y-coordinates of the center axis of the ellipse min calculated to determine.

The distribution of the ellipse is elongated features and have a particular orientation. Disease surveillance studies used ellipses to model spatial distribution since the central tendency and dispersion are two principal aspects, particularly to epidemiologists [32]. ArcGIS10.5 software used to conduct these spatial statistical analyses.

$$SDE_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2}{n}} \quad (4)$$

$$SDE_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{Y})^2}{n}} \quad (5)$$

Spatial Pattern Analysis

In addition to the spatial distribution analysis, the distance between the location of each incidence point was also analyzed by using the average nearest neighbor (ANN). This analysis calculates the distance between each point centroid with the nearest point centroid, and then averaged all nearest neighbor distances [33]. ANN ratio calculated is considered as the observed average distance divided with expected average distance [34]. This analysis was applied to evaluate whether the dengue incidence in the study area clustered, random, or dispersed [35]. The data shows a clustered pattern when the ratio is less than 1; meanwhile, the ratio is greater than 1 represents a dispersed pattern in the data [28].

Relationship of Dengue Cases with Weather Variable

Since secondary data obtained as quantitative data, the relationship between monthly dengue cases was analyzed with monthly average temperature, rainfall amount, and rain days for the period of 2014 to 2018 consecutively by using the general linear model and Pearson correlation coefficients at $p < 0.05$ [36]. Pearson's correlation is represented as r indicates the magnitude of the association measured between two variants as its range is within -1 to $+1$ [5, 37]. This statistical analysis was carried out using IBM SPSS Statistics 21 software.

Results

This study uses statistical analysis to determine the spatial distribution of dengue fever in Bangi. Besides, it is useful to get a better understanding of the underlying causes that might be associated with the cases. The geographic distribution pattern is used to measure spatial patterns for the dengue outbreak. It is essential to understand how the epidemic spread using the formulation of the spatial mean center, directional distribution, and standard distance. The result shows that the study area had 1240 dengue cases in 2014 and then climb up to 1968 cases reported in 2015 (Figure 2). In 2016, positive dengue cases reduced to 1407 cases compared to the previous year; however, the number rose again to 1687 cases in 2017. There is a downturn of reported dengue cases compared to the previous year, where more than half of positive dengue cases recorded in 2018, with 791 cases reported.

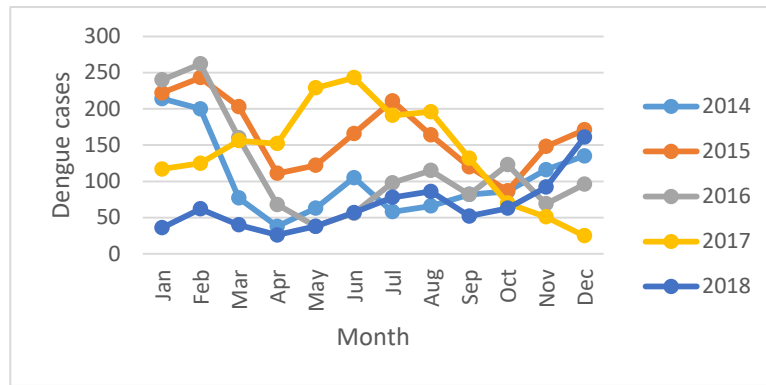


Figure 2: Graph of monthly dengue cases reported in Bangi town from the year 2014 to 2018.

The spatial mean center was used to analyze where phenomena are centralized. Figure 3 shows the location of every dengue fever cases for the period of the year 2014 to 2018, together with their mean centers, respectively. The mean center is calculated based on monthly dengue cases reported for six years independently. The spatial mean center for dengue fever cases for the year 2014 is located at x-coordinate 101.774471 and y-coordinate 2.960287 (Figure 3). The mean center for the year 2015 is located at x-coordinate 101.775198 and y-coordinate 2.955823. For the year 2016, the mean center for dengue cases is located at x-coordinate 101.77213 and y-coordinate 2.955496. Meanwhile, the mean center for the year 2017 is located at x-coordinate 101.774598 and y-coordinate 2.964154, and for the year 2018, it is situated at x-coordinate 101.771081 and y-coordinate 2.956525.

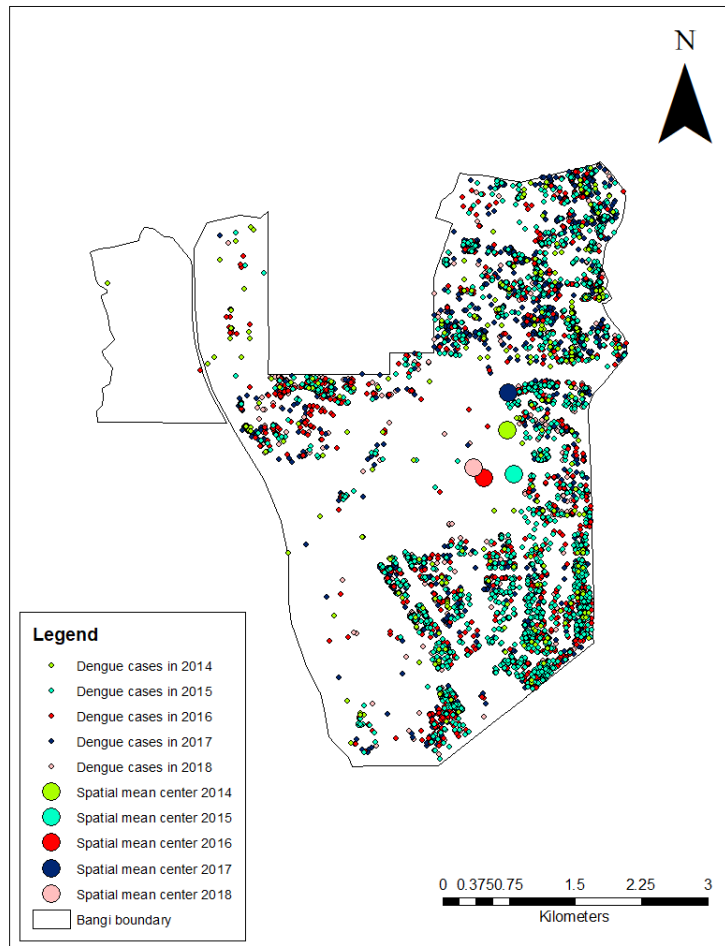


Figure 3: Spatial mean centers of dengue cases in Bangi town from the year 2014 to 2018.

Figure 4 shows the directional distribution of dengue cases for six years, respectively. Generally, the directions for the distribution of dengue cases in all six years are almost similar, stretching from northeast to the southwest of the whole Bangi town (Figure 4). Ellipse polygon of directional distribution for the year 2014 is located at the center from another year with rotation 12.22° on the long axis. For the year 2015, the ellipse polygon was found to be lower and smaller on the upper side of the polygon compared to the year 2014 and extended further towards the south of the study area, with rotation 8.89° on the long axis. Ellipse polygon for the year 2016 was found to spread a larger radius to the west of Bangi town with rotation 1.58° on the long axis. However, ellipse polygon of the year 2017 was observed to be elongated to the outermost among all years' ellipses on the top side of a polygon and narrowed on the long side of its polygon with rotation 15.36° on the long axis. In contrast to the year 2017, ellipse polygon for the year 2018 was elongated to the southwest of the study site with rotation 15.07° on the long axis.

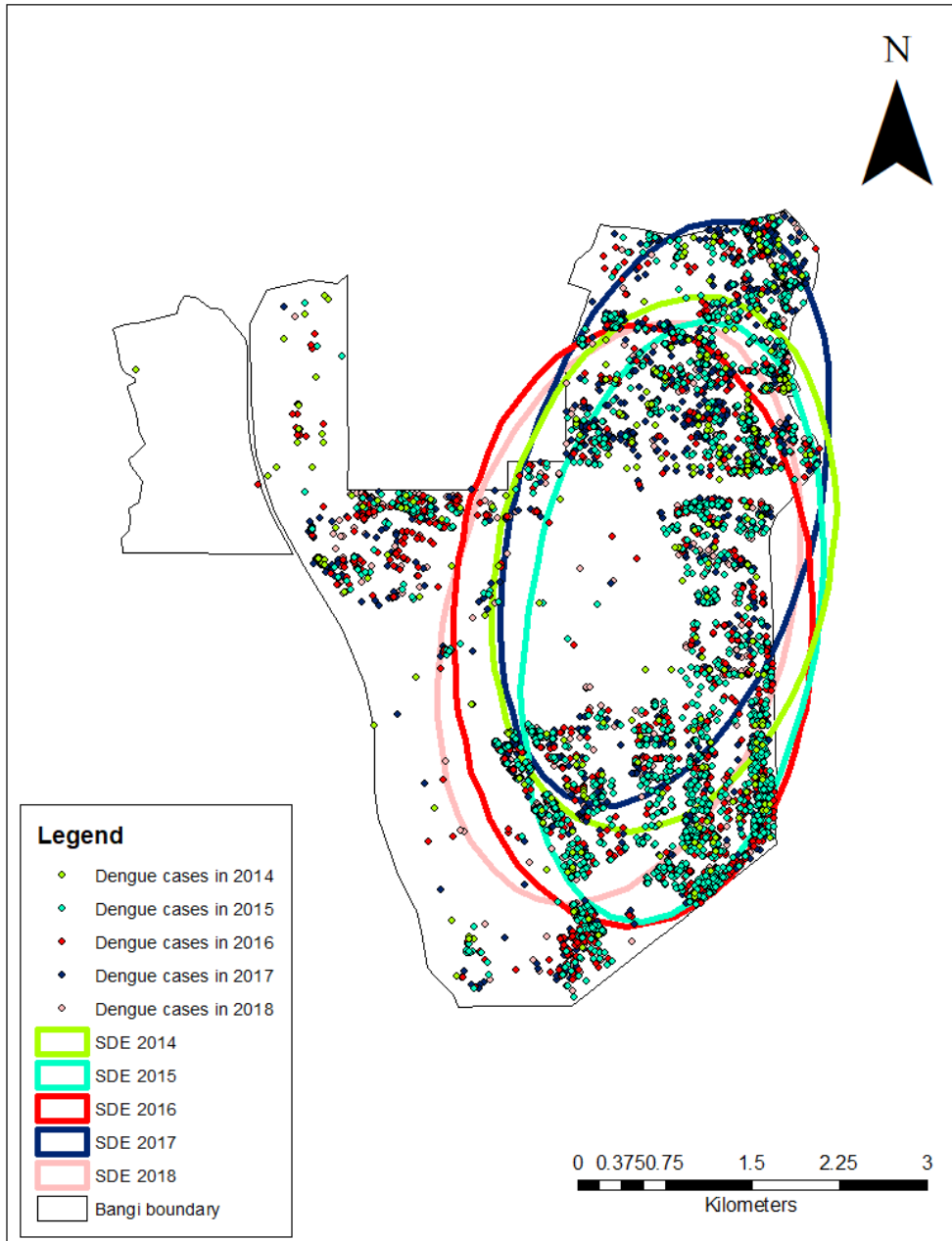


Figure 4: Standard deviational ellipses of dengue cases in Bangi from 2014 to 2018.

Figure 5 shows the standard distance of dengue fever cases in the Bangi district. The standard distance for dengue cases reported in the year 2014 is 0.017 m, which is the smallest range among all years of dengue cases in Bangi. Meanwhile, dengue cases reported in the year 2015 has the standard distance measured 0.018 m, the same as the year 2017 and 2018. The standard distance for dengue cases recorded in the year 2016 observed to be the largest compared to other years' cases, measured with 0.019 m.

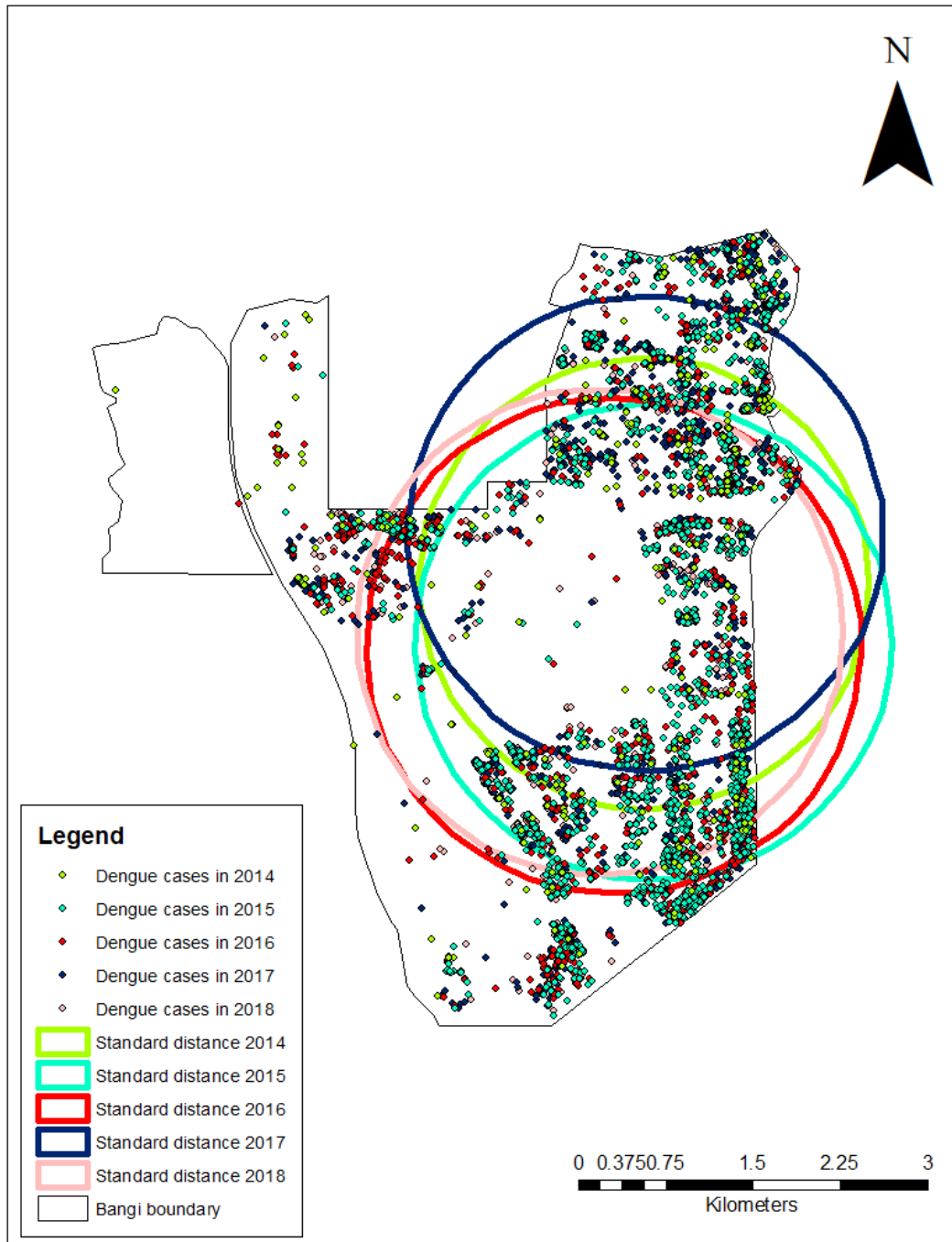


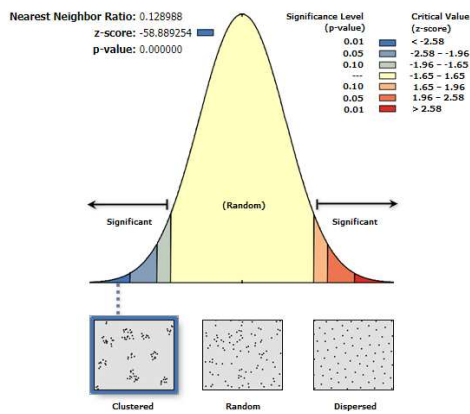
Figure 5: Standard distance for dengue cases in Bangi district from the year 2014 to 2018.

The table shows the average nearest neighbor analysis performed found that the p-value was 0, and the ratio was less than 1 for each year of the study period, which suggested a less than 1% likelihood that this clustered pattern could be the result of random chance. This shows that the spatial pattern of dengue fever cases was aggregated (Figure 6).

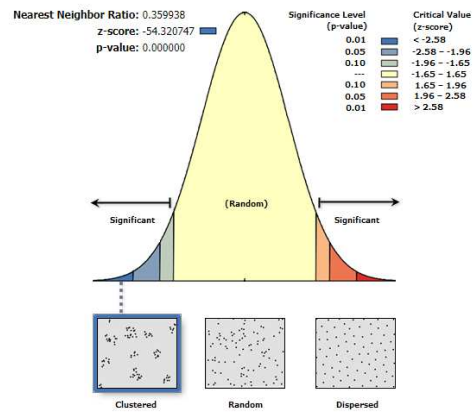
Table 1: ANN statistical analysis for dengue cases reported in the year 2014 to 2018.

Year	Ratio	z-score	p-value
2014	0.128988	-58.889254	0.000000
2015	0.359938	-54.320747	0.000000
2016	0.375227	-44.833228	0.000000
2017	0.399819	-47.159633	0.000000
2018	0.396804	-32.454686	0.000000

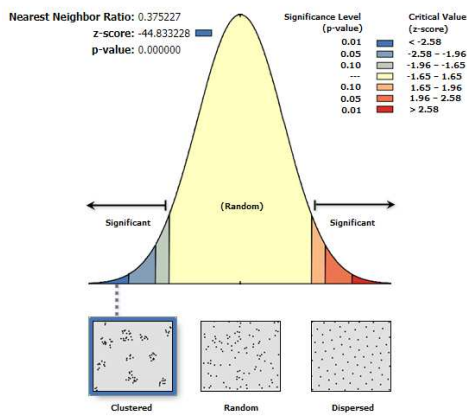
(a)



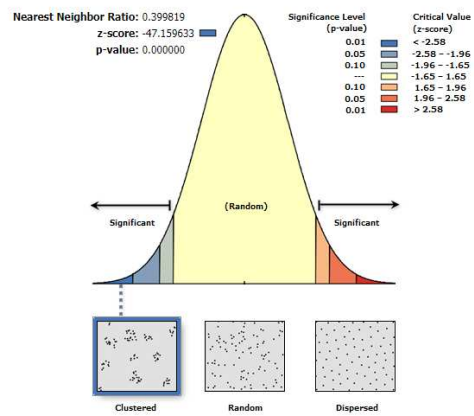
(b)



(c)



(d)



(e)

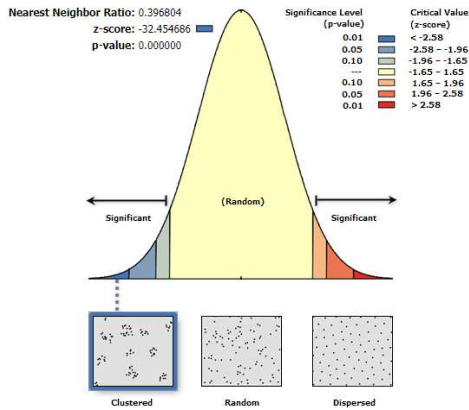
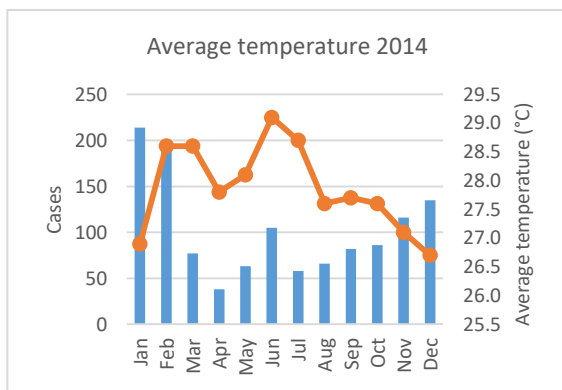


Figure 6: Average nearest neighbor (ANN) analysis for dengue cases reported on year (a) 2014, (b) 2015, (c) 2016, (d) 2017, and (e) 2018.

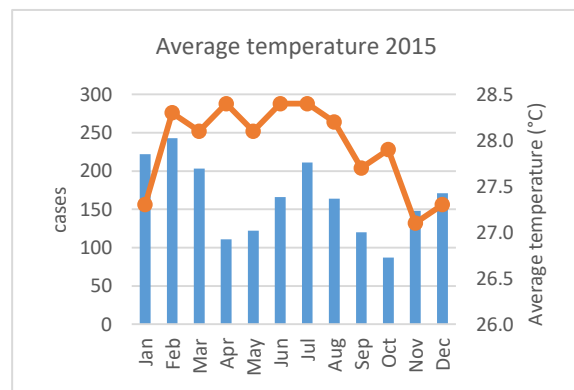
The association of weather pattern data with the dengue case frequency is shown in Figure 7. Generally, the number of monthly dengue cases reported for six years increases as the monthly average temperature increases as well. However, the graph of dengue cases in the year 2018 shows a different situation compared to other years as the number of monthly dengue cases reported a decrease as the monthly average temperature increases.

(a)

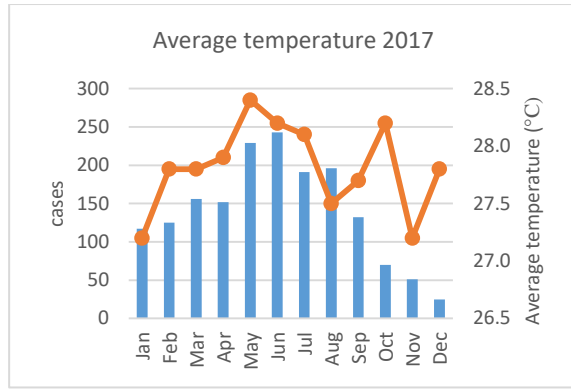
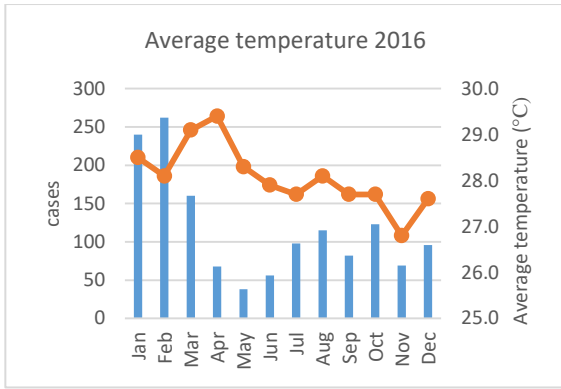


(c)

(b)



(d)



(e)

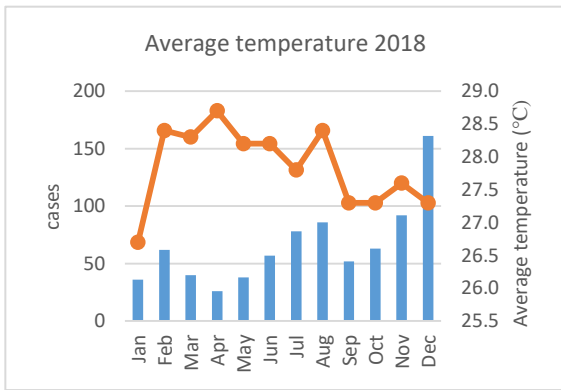
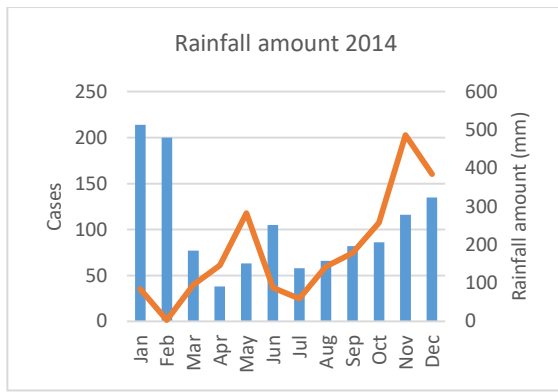


Figure 7: Monthly dengue cases against average temperature from year (a) 2014, (b) 2015, (c) 2016, (d) 2017, and (e) 2018.

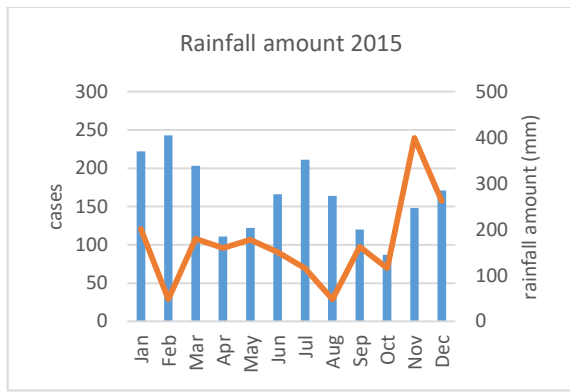
Another weather attribute observed in this study is the relationship of rainfall amount with dengue cases reported annually. Overall, it is found that annual dengue cases in the study site increases as the annual rainfall amount decreases for the year 2014 and 2015 (Figure 8). Later on, when the annual rainfall amount decrease in the year 2016, the dengue cases reported in the same year also decrease. Eventually, the year 2017 shows an increase in dengue cases where the annual rainfall amount also increases. A significant drop in dengue cases in the year 2018 from the previous year, where the annual rainfall amount increases slightly.

(a)

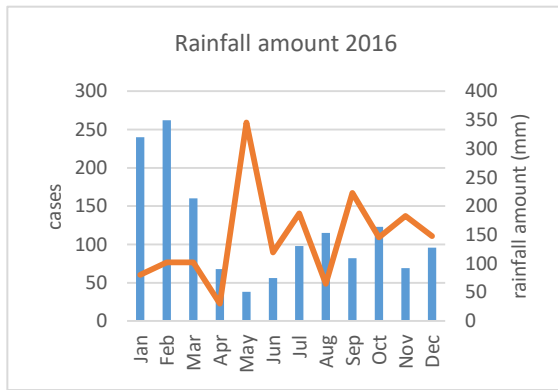
(b)



(c)



(d)



(e)

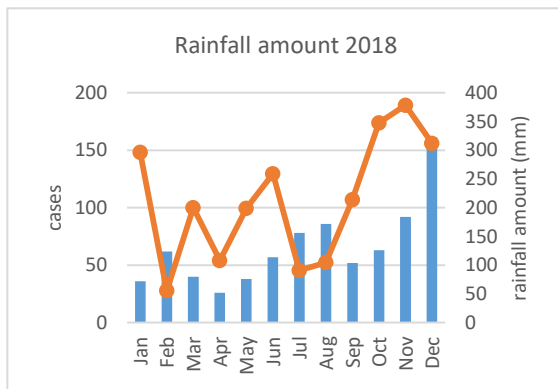
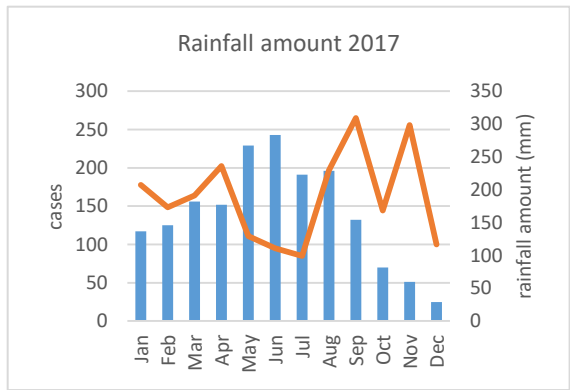
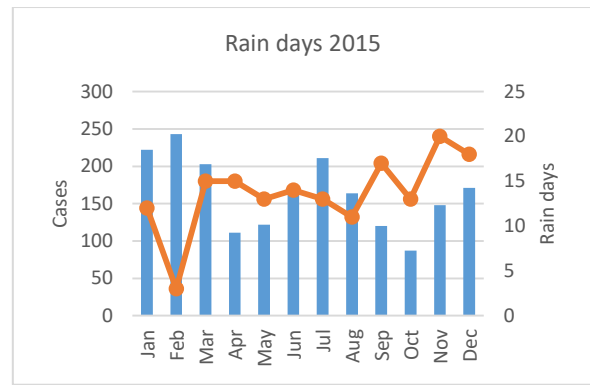
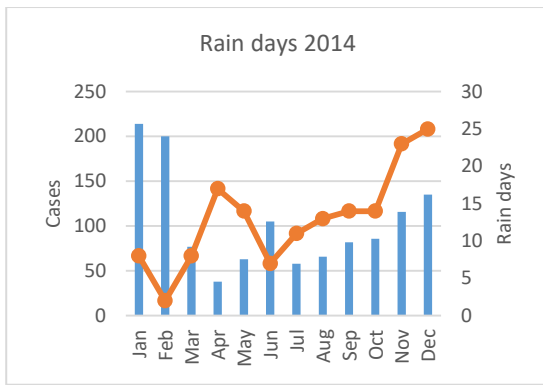


Figure 8: Monthly dengue cases against rainfall amount from year (a) 2014, (b) 2015, (c) 2016, (d) 2017, and (e) 2018.

The relationship of rain days with dengue cases reported is also observed in this study. It is found that annual dengue cases in the study site decrease as the annual rainfall amount increases for every year observed (Figure 8).

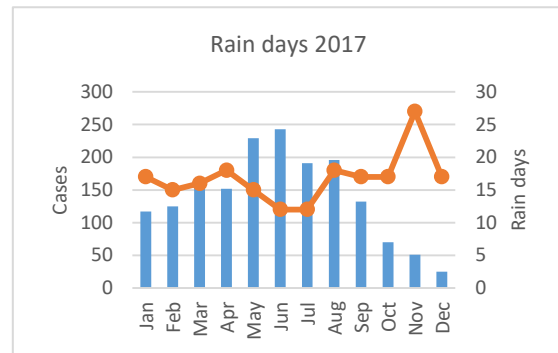
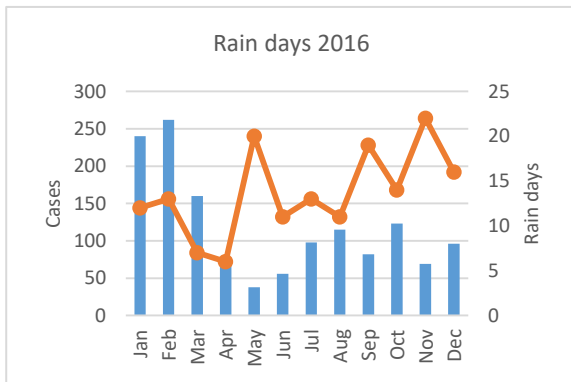
(a)

(b)



(c)

(d)



(e)

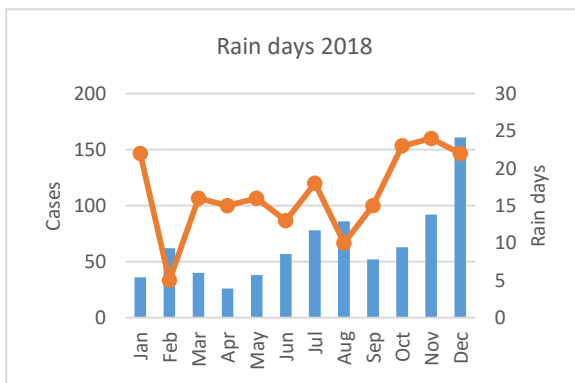


Figure 9: Monthly dengue cases against rain days from year (a) 2014, (b) 2015, (c) 2016, (d) 2017, and (e) 2018.

Pearson’s correlation coefficient was adopted to find the relation of meteorological elements with the frequency of dengue cases reported and summarized in Table 2. All significance level was set at $p\text{-value} < 0.05$ (2-tailed). It is found that all three weather variables show a significant negative correlation with annual dengue cases in the year 2014. Moreover, there is a significant positive correlation for dengue cases reported from the year 2015 to 2017 with average temperature attribute where rainfall amount shows a significant negative correlation during that period. However, it is observed that the average temperature in the year 2018 shows a significant negative correlation ($r = -0.269$), meanwhile, a significant positive

correlation showed by rainfall amount ($r = 0.286$) and rain days ($r = 0.250$) towards dengue cases reported that year.

Table 2: Pearson’s correlation analysis result between monthly dengue cases with monthly average temperature and rainfall amount from the year 2014 to 2018.

Year	Average temperature	Rainfall amount	Rain days
2014	-0.269	-0.134	-0.310
2015	0.046	-0.164	-0.495
2016	0.216	-0.458	-0.306
2017	0.468	-0.305	-0.610
2018	-0.269	0.286	0.250

Correlation is significant at level 0.05 (2-tailed). Significant at p-value < 0.05

The general linear model analysis was used to define the relationship of weather factors with dengue cases. From Table 3, it can be concluded that there were significant associations between average temperature, rainfall amount, and rain days with dengue fever cases.

Table 3: General linear model output between the relation of average temperature, rainfall amount, and rain days with dengue fever cases.

Model	Sum Squares	ofdf	Mean Square	F	p-value
Regression	28671.364	3	9557.121	2.451	.073 ^b
Residual	218380.819	56	3899.657		
Total	247052.183	59			

Significant at p-value < 0.05

Thus, an equation can be derived from Table 4 based on the intercept and Beta value as follows:

$$\text{Dengue case} = 1013.905 - 29.086 (\text{Average temperature}) + 0.002 (\text{Rainfall amount}) - 5.721 (\text{Rain days}).$$

According to the equation generated, it shows that dengue cases decrease by 29.086 for every unit decrease in average temperature, given that rainfall amount and rain days remain unchanged. For every unit increase in rainfall amount, dengue cases increase by 0.002, given that the average temperature and rain days remain unchanged. Dengue cases decrease by 5.721 for every unit decrease in rain days, given that the average temperature and rainfall

amount remain unchanged. Thus, the rainfall amount was the most significant variable for dengue cases in the Bangi district.

Table 4: General linear model values of intercept, Beta, standard error, t value, p-value, and 95% confidence interval.

Variable	Unstandardized Coefficients		t	P-value	95.0% Confidence Interval for B	
	B	Std. Error			Lower Bound	Upper Bound
Intercept	1013.905	554.720	1.828	0.073	-97.332	2125.142
Average temperature	-29.086	19.133	-1.520	0.134	-67.413	9.242
Rainfall amount	0.002	0.137	0.016	0.988	-0.273	0.278
Rain days	-5.721	2.844	-2.012	0.049	-11.418	-0.024

Significant at p-value < 0.05

Discussion

From the spatial statistical analysis performed in this study, it is found that dengue cases reported throughout the study period were clustered at about around the same range, which is from the northeast to the southwest of Bangi town, covering almost half of the study site. This situation could propose that these ranges are the hotspots for dengue cases to occur and perhaps the preferred breeding sites of the dengue vector. This situation has seen a rapid increase in population in the area. This increase is due to the growth of urban areas in the Klang Valley region that has reached saturation levels for any area expansion. Growth of new urban areas such as Bandar Baru Bangi, and the new industrial areas such as Sg. Chua, Kajang, Cheras Batu 9, Cheras Batu 11, and Balakong around Bangi town has contributed to the increase in population in the area. Besides, its proximity that is close to the capital city of Kuala Lumpur and administrative city Putrajaya has also made the Bangi town a prime destination and home for its ease of commuting using good public transport and existing road systems [38].

From this study, it is observed that most of the years of dengue cases reported have a positive correlation with rainfall amount and rain days variable compared to the average temperature factor (Table 1). It is well-known that the abundance of dengue vector has always been correlated with rainfall in Malaysia [5, 6, 12]. Rainfall is one of the most critical factors contributing to the abundance of Aedes mosquito populations and dengue spreading [7-10, 13]. However, in the year 2018, the number of dengue cases reported dropped dramatically compared to the previous year. From Table 1, it is suggested that the positive correlation of rainfall amount contributes to the decline of dengue cases frequency as the average temperature for that year was found to be quite high along the year compared to another study

period. This phenomenon might occur due to the temperature for the hatching rate of *Aedes* mosquitoes affected with the higher temperature as their egg hatching percentages are always associated with a lower temperature of the breeding site [36, 37]. Thus, the dependency for the *Aedes* breeding to the rainfall amount is low compared to the temperature element. Studies done by researchers proposed that heavy rainfall caused water spilled inside containers, which gave a negative effect on the number of eggs produced and mosquitoes larvae hatchment at the breeding sites [18, 38-41].

Meteorological data such as daily temperature and rainfall precipitation are unable to be associated directly with the frequency of dengue cases. As there was no weather station inside the study site, and we had to rely on the closest weather station, which is about 30 km from Bangi town. Thus, the meteorological data were temporally but not spatially variable. GIS application in this study has shown that this tool could be used for the foundation of multiple disease surveillance to create a linkage between disease occurrence, identification of their causes, and the area affected. These linkages and the information help regulatory action decision making and could be applied to the targeted area. Research also can be broadened to cover other aspects such as land use, social action, and even for the effectiveness of preventive action such as fogging by the government agencies.

Conclusions

Spatial statistical distribution plays a significant role in understanding the epidemiology of dengue cases in the study region. Therefore distribution and spatial patterns are derived from specific processes [9]. The three spatial statistical analyses (spatial mean center, standard distance, and directional distribution) findings illustrated that the dengue cases from the year 2014 to 2018 are clustered on the northeast to the southwest of the study region. The average nearest neighbor analysis also shows the clustered pattern for every dengue case during the study period. Hence, clustered patterns formed would assist responsible organizations to focus on the area with frequent dengue cases on the identification of hotspots. Together with the community living in the hotspot areas, authorities may stimulate mitigation actions to eliminate *Aedes* breeding sites and eventually improves community resilience. Therefore this could decrease the magnitude of hotspot on targeted areas.

Adequate rainfall is essential for *Aedes* breeding as the rainfall element is found to be a significant positive factor correlated for most study years compared to temperature element. Therefore continuous monitoring strategy with GIS applications and on the ground surveillance help to manage and control dengue cases, mainly in Bangi town. This study contributes to framing better intervention measures to reduce the outbreak and spread of dengue. This would help to enhance the quality of public health in the growing urbanization in Bangi town and state of Selangor in its challenge to become a state free from dengue risks.

Ethics approval and consent to participate

The study was approved by the Medical Research & Ethics Committee, Ministry Of Health Malaysia (NMRR No.: NMRR-18-3498-44411).

Consent for publication

Not applicable.

Availability of data and materials

Data supporting the conclusions of this article are included within the article. The datasets used and/or analyzed during the present study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

University Kebangsaan Malaysia funded this research and the APC under the project "Application of GIS in the Spread Trend of Dengue in the Liveability City, Bangi Selangor," grant number GGPM-2018-030.

Authors' contributions

NAM designed and supervised the study, acquired the funding, provided project administration, carried out data acquisition with MS. RR and SAAGZ conceptualized and propose methodology for this study. AFM review and validated the manuscript. NMN analyzed the data, performed statistical analysis, and wrote the manuscript drafted by NAM. All authors read and approved on the final manuscript.

Acknowledgements

Courtesy to the Ministry of Health Malaysia and Meteorological Department Malaysia for the data provided.

References

1. World Health Organization. Dengue and Severe Dengue. Retrieved from World Health Organization. Available online: <https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue> (accessed on 17 November 2019).
2. Malaysia Ministry of Health. History and Epidemiology of Dengue. Retrieved from Ministry of Health Malaysia. Available online: <http://denggi.myhealth.gov.my/history-and-epidemiology-of-dengue/?lang=en> (accessed on 17 November 2019).
3. Khormi, H.M.; Kumar, L.; Elzahrany, R.A. Modeling Spatio-temporal risk changes in the incidence of dengue fever in Saudi Arabia: A geographical information system case study. *Geospatial Health*, 2011, 6, 77–84.
4. Nik Syaza Lina, N. R.; Haliza, A. R. The Association between Climatic Factors and Dengue Fever: A Study in Subang Jaya And Sepang, Selangor. *Malaysian Journal of Public Health Medicine*, 2017, *Special Volume (1)*: 140-150.

5. Aziz, S.; Aidil, R. M.; Nisfariza, M. N.; Ngui, R.; Lim, Y. A. L.; Wan Yusoff, W. S.; Ruslan, R. Spatial density of *Aedes* distribution in urban areas: A case study of breteau index in Kuala Lumpur, Malaysia. *J Vector Borne Dis* 51 2014, pp. 91–96.
6. Mohd Salleh, N. H.; Ali, Z.; Noor, N. M.; Baharum, A.; Saad, A. R.; Sulaiman, H. M.; Wan Ahmad, W. M. A. Modelling the breeding of *Aedes albopictus* species in an urban area in Pulau Pinang using polynomial regression. *AIP Conference Proceedings* 1605, 844, 2014, DOI: 10.1063/1.4887700.
7. Das, M.; Gopalakrishnan, R.; Kumar, D.; Gayan, J.; Baruah, I.; Veer, V.; Dutta, P. Spatiotemporal distribution of dengue vectors & identification of high risk zones in district Sonitpur, Assam, India. *Indian J Med Res.* 2014, 140(2): 278–284.
8. Moreno-Madriñán, M. J.; Crosson, W. L.; Eisen, L.; Estes, S. M.; Estes Jr., M. G.; Hayden, M.; Sarah N. Hemmings, S. N.; Irwin, D. E.; Lozano-Fuentes, S.; Monaghan, A. J.; Quattrochi, D.; Welsh-Rodriguez, C. M.; Zielinski-Gutierrez, E. Correlating Remote Sensing Data with the Abundance of Pupae of the Dengue Virus Mosquito Vector, *Aedes aegypti*, in Central Mexico. *ISPRS Int. J. Geo-Inf.* 2014, 3, 732-749; DOI:10.3390/ijgi3020732.
9. Bowman, L. R.; Runge-Ranzinger, S.; McCall, P. J. Assessing the relationship between vector indices and dengue transmission: a systematic review of the evidence. *PLoS Negl Trop Dis* 2014, 8(5): e2848.
10. Sang, S.; Yin, W.; Bi, P.; Zhang, H.; Wang, C.; Liu, X., Chen, B.; Yang, W.; Liu, Q. Predicting Local Dengue Transmission in Guangzhou, China, through the Influence of Imported Cases, Mosquito Density and Climate Variability. *PLoS ONE* 2014, 9(7): e102755.
11. Morin, C. W.; Comrie, A. C.; Ernst, K. Climate and dengue transmission: evidence and implications. *Environ Health Perspect* 2013, 121(11-12): 1264-72.
12. Cheong, Y. L.; Burkart, K.; Leitão, P. J.; Lakes, T. Assessing weather effects on dengue disease in Malaysia. *Int J Environ Res Public Health* 2013, 10:6319-34.
13. Aigbodion, F. I.; Uyi, O. O. Temporal distribution of and habitat diversification by some mosquitoes (Diptera: Culicidae) species in Benin City, Nigeria. *J Entomol* 2013, 10(1): 13-23.
14. Wardekker, J.; de Jong, A.; van Bree, L.; Turkenburg, W.; van der Sluijs, J. (). Health risks of climate change: An assessment of uncertainties and its implications for adaptation policies. *Environmental Health* 2012, 11, 67:61-67:16.
15. Wongkoon, S.; Jaroensutasinee, M.; Jaroensutasinee, K. Distribution, seasonal variation & dengue transmission prediction in Sisaket, Thailand. *Indian J Med Res* 2013, 138: 347-53.
16. Rohani, A.; Suzilah, I.; Malinda, M.; Anuar, I.; Topek, O.; Tanrang, Y.; Ooi, S.C.; Rozilawati, H.; Lee, H.L. *Aedes* larval population dynamics and risk for dengue epidemics in Malaysia. *Trop Biomed.* 2011, 28(2): 237–248.
17. Zaki, R.; Roffeei, S. N.; Hii, Y. L.; Yahya, A.; Appannan, M.; Said, M. A.; Wan, N. C.; Aghamohammadi, N.; Hairi, N. N.; Bulgiba, A.; Quam, M.; Rocklov, J. Public perception and attitude towards dengue prevention activity and response to dengue early warning in Malaysia. *PLoS ONE* 2019,14(2): e0212497.

18. Masnita, M. Y.; Nazri, C. D.; Rodziah, I.; Ariza, Z. Assessing The Temporal Distribution Of Dengue Vectors Mosquitoes And Its Relationship With Weather Variables. *Serangga* 2017, 23(1):112-125.
19. Ahmad, R.; Suzilah, I.; Wan Najdah, W. M. A.; Topek, O.; Mustafakamal, I.; Lee, H. L. Factors determining dengue outbreak in Malaysia. *PLoS ONE* 2018, 13(2): e0193326.
20. Noor Nashuha, A.; Samsul Ariffin, A. K. Assessing Climate Factors on Dengue Spreading in State of Perak. *J. Phys.: Conf. Ser.* 2018, 1123 012026.
21. Hii, Y. L.; Zaki, R. A.; Aghamohammadi, N.; Rocklöv, J. Research on Climate and Dengue in Malaysia: A Systematic Review. *Current environmental health reports.* 2016, 3(1), 81-90.
22. Williams, C. R.; Gill, B. S.; Mincham, G.; Mohd Zaki, A. H.; Abdullah, N.; Mahiyuddin, W.R.W.; Ahmad, R.; Shahr, M. K.; Harley, D.; Viennet, E.; Azil, A.; Kamaluddin, A. Testing the impact of virus importation rates and future climate change on dengue activity in Malaysia using a mechanistic entomology and disease model. *Epidemiol. Infect.* 2015, 143, 2856–2864.
23. Safian, N. Transmission Dynamics of Dengue in Malaysia. Doctor of Philosophy, Imperial College London, United Kingdom, 17 September 2015.
24. Mohiddin, A.; Jaal, Z.; Md-Lasim, A.; Dieng, H.; Zuharah, W.F. Assessing dengue outbreak areas using vector surveillance in north east district, Penang Island, Malaysia. *Asian Pac. J. Trop. Dis.* 2015, 5, 869–876.
25. Rohani, A.; Aidil Azahary, A. R.; Malinda, M.; Zurainee, M. N.; Rozilawati, H.; Wan Najdah, W. M. A.; Lee, H. L. Eco-virological survey of Aedes mosquito larvae in selected dengue outbreak areas in Malaysia. *J Vector Borne Dis* 51 2014, pp. 327–332.
26. Kweka, E. J.; Kimaro, E. E.; Munga, S. Effect of deforestation and land use changes on mosquito productivity and development in Western Kenya Highlands: implication for malaria risk. *Front Public Health*, 2016, 4:1–9.
27. Thiruchelvam, L.; Dass, S. C.; Zaki, R.; Yahya, A.; Asirvadam, V. S. Correlation analysis of air pollutant index levels and dengue cases across five different zones in Selangor, Malaysia. *Geospatial Health*, 2018, 13:613.
28. ESRI. 2018. Available online: <https://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/an-overview-of-the-spatial-statistics-toolbox.htm> (accessed on 16 November 2019).
29. Abdul Samad, H.; Shaharudin, I. The Emerging Kuala Lumpur Extended Mega Urban Region (KLEMUR): Implications on Urban Prosperity in Malaysia. *Int. J. Malay World Civilis.* 2017, 5, 67–74.
30. Mutheneni, S.R.; Mopuri, R.; Naish, S.; Gunti, D.; Upadhyayula, S.M. Spatial distribution and cluster analysis of dengue using self-organizing maps in Andhra Pradesh, India, 2011–2013. *Parasite Epidemiol. Control* 2018, 3, 52–61.
31. Malaysian Meteorological Department. Available online: <http://www.met.gov.my/?lang=en> (accessed on 3 April 2020).
32. Abd Majid, N.; Nazi, N.; Mohemed, A. F. Distribution and spatial pattern analysis on dengue cases in Seremban District, Negeri Sembilan, Malaysia. *Sustainability*, 2019, 11(13). <https://doi.org/10.3390/su11133572>

33. Hazrin, M.; Hiong, H. G.; Jai, N.; Yeop, N.; Hatta, M.; Paiwai, F.; Joanita, S.; Othman, W. Spatial Distribution of Dengue Incidence: A Case Study in Putrajaya. *Journal of Geographic Information System* 2016, 8, 89-97.
34. Yajid, M. Z. M.; Che Dom, N.; Camalxaman, S. N.; Nasir, R. A. Spatial-temporal analysis for identification of dengue risk area in Melaka Tengah district. *Geocarto International*, 2019, DOI: 10.1080/10106049.2019.1581265.
35. Abd Majid, N.; Rainis, R.; Muhiyuddin, W. M. ANALISIS TABURAN DAN CORAK RUANGAN PELBAGAI JENIS KEGAGALAN CERUN DI PULAU PINANG, MALAYSIA. *International Journal of Environment, Society and Space* 2016, 4(2), 1-15.
36. Choy, E.A.; Mohd-Khair, E.; Atan, A.; Sahani, M.; Mohd-Ali, Z. Perubahan Cuaca Dan Penyakit Denggi: Kajian Kes Di Daerah Seremban, Negeri Sembilan, Malaysia. *J. E-Bangi*, 2011, 8, 38–48.
37. Kannan, M.; Prabhakaran, S.; Ramachandran, P. Rainfall forecasting using data mining technique. *Int J Eng Tech* 2010, 2(6): 397– 401.
38. Shahrudin, I.; Shamsul, A. S.; Tahir, A.; Mariam, M.; Azah, D.; Nik Shamsidah, N. I. Sistem Maklumat Geografi (GIS) dan sektor kesihatan awam: Kajian demam denggi di Bandar Baru Bangi dan Kajang. *Jurnal Kesihatan Masyarakat* 2002, 8(S):34-42.
39. Crepeau, T. N.; Healy, S. P.; Bartlett-Healy, K.; Unlu, I.; Farajollahi, A.; Fonseca, D. M. Effects of bioagents sentinel trap field placement on capture rates of adult Asian tiger mosquitoes, *Aedes albopictus*. *PLoS One* 2013, 8(3):e60524.
40. Dickerson, C. Z. The effects of temperature and humidity on the eggs of *Aedes aegypti* (L.) and *Aedes albopictus* (Skuse) in Texas [dissertation]. Texas A&M University, Texas, 2007.
41. Naish, S.; Dale, P.; Mackenzie, J. S.; McBride, J.; Mengersen, K.; Tong, S. Climate change and dengue: a critical and systematic review of quantitative modelling approaches. *BMC Infect Dis* 2014, 14:167.
42. Saifur, R. G.; Hassan, A. A.; Dieng, H.; Salmah, M. R.; Saad, A. R.; Satho, T. Temporal and spatial distribution of dengue vector mosquitoes and their habitat patterns in Penang Island, Malaysia. *J Am Mosq Control Assoc* 2013, 29(1): 33-43.
43. Mazrura, S.; Hidayatulfathi, O.; Nadia Atiqah, M. N.; Rozita, H.; Zainudin, M. A.; Mohamad Naim, M. R.; Choy, E. A. Kajian Ekologi Nyamuk *Aedes* di Senawang Negeri Sembilan, Malaysia. *Sains Malaysiana* 2012, 41(2): 261–269.
44. Chen, S. C.; Liao, C. M.; Chio, C. P.; Chou, H. H.; You, S. H.; Cheng, Y. H. (). Lagged temperature effect with mosquito transmission potential explains dengue variability in southern Taiwan: Insights from a statistical analysis. *Science of the Total Environment* 2010, 408, 4069-4075.

Figures

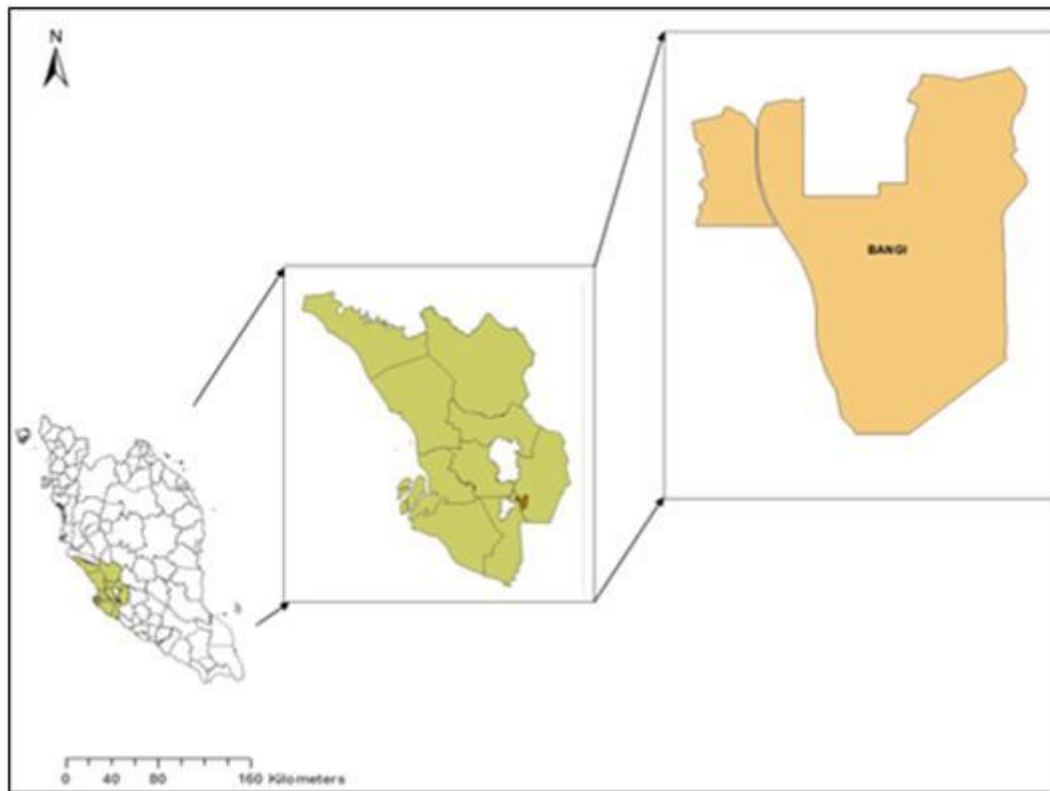


Figure 1

Study Site

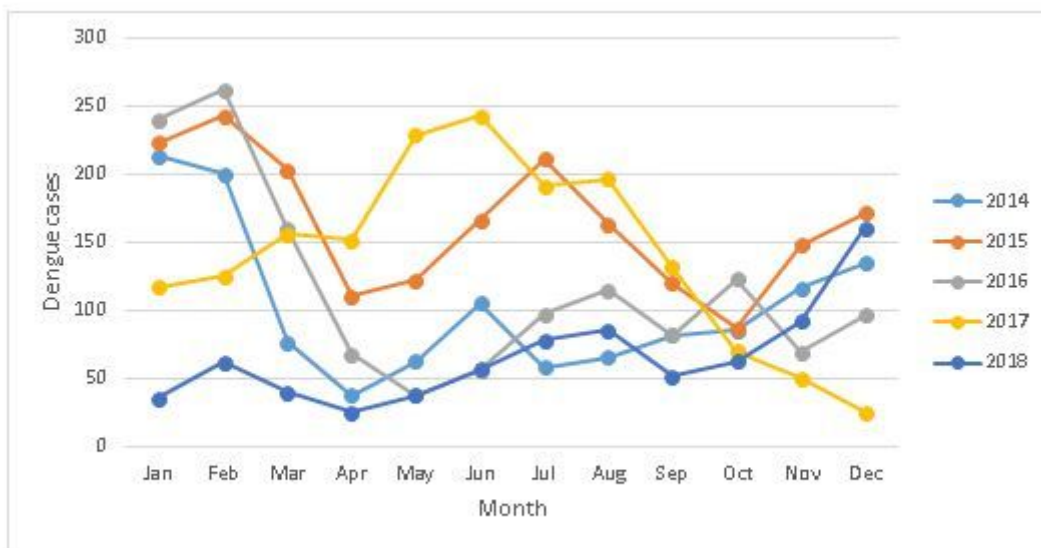


Figure 2

Graph of monthly dengue cases reported in Bangi town from the year 2014 to 2018.

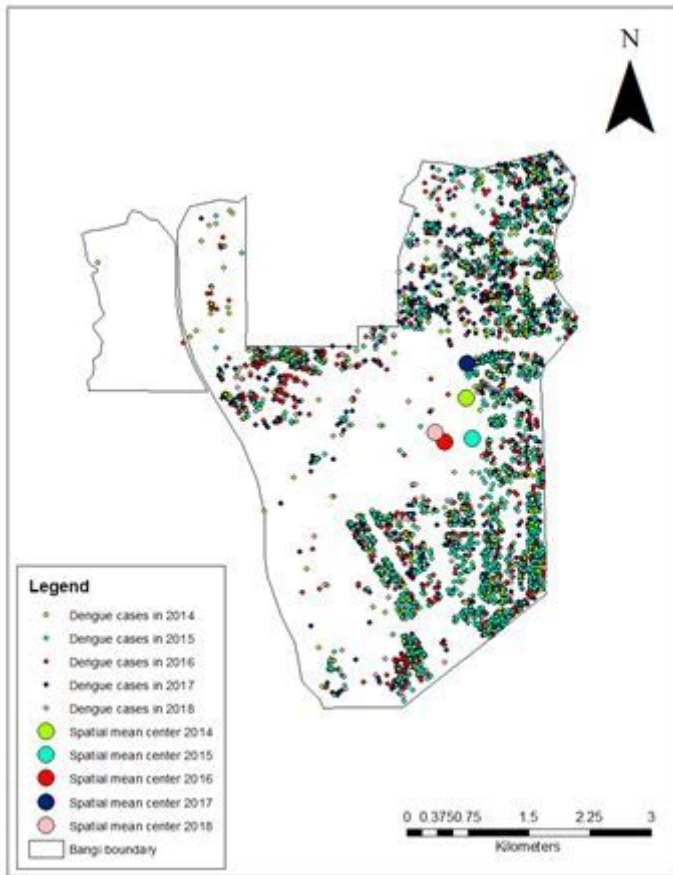


Figure 3

Spatial mean centers of dengue cases in Bangi town from the year 2014 to 2018.

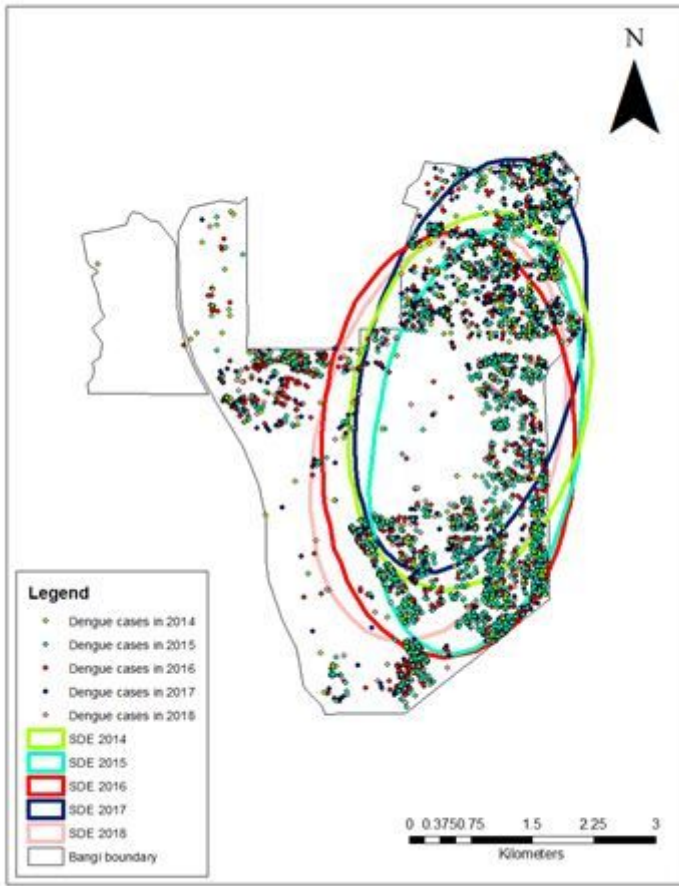


Figure 4

Standard deviational ellipses of dengue cases in Bangi from 2014 to 2018.

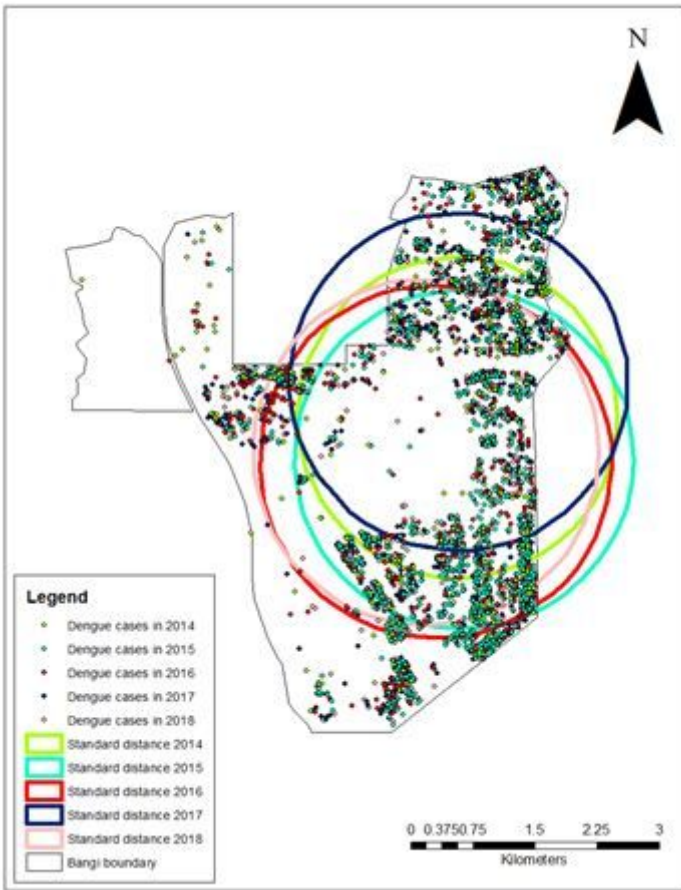


Figure 5

Standard distance for dengue cases in Bangi district from the year 2014 to 2018.

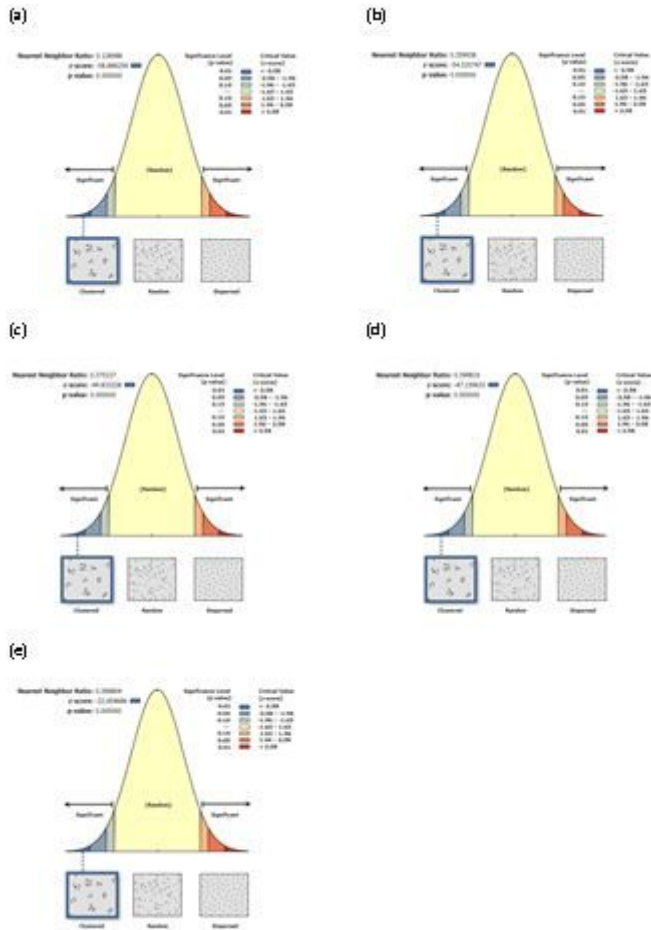


Figure 6

Average nearest neighbor (ANN) analysis for dengue cases reported on year (a) 2014, (b) 2015, (c) 2016, (d) 2017, and (e) 2018.

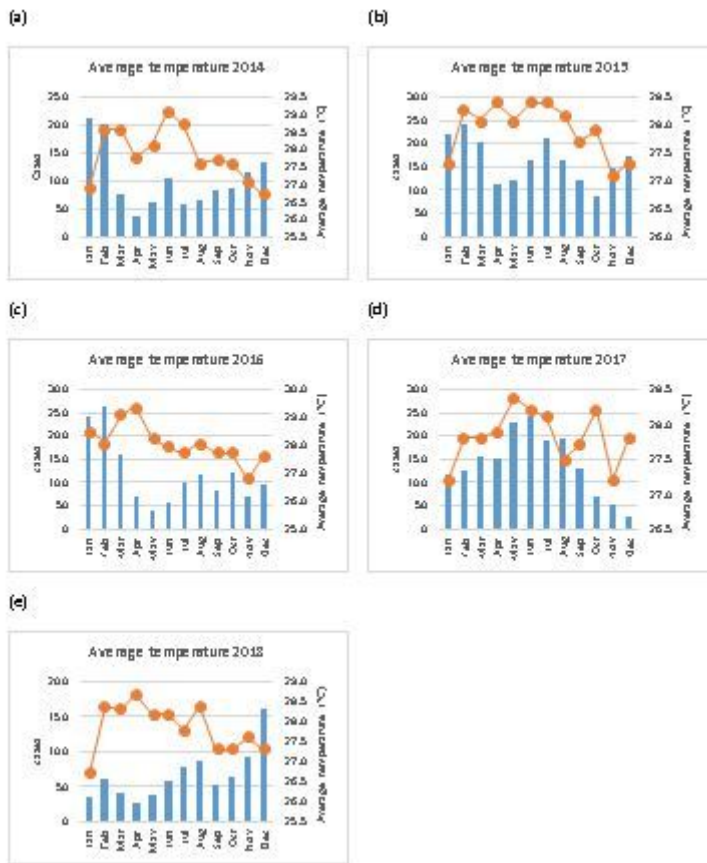


Figure 7

Monthly dengue cases against average temperature from year (a) 2014, (b) 2015, (c) 2016, (d) 2017, and (e) 2018.

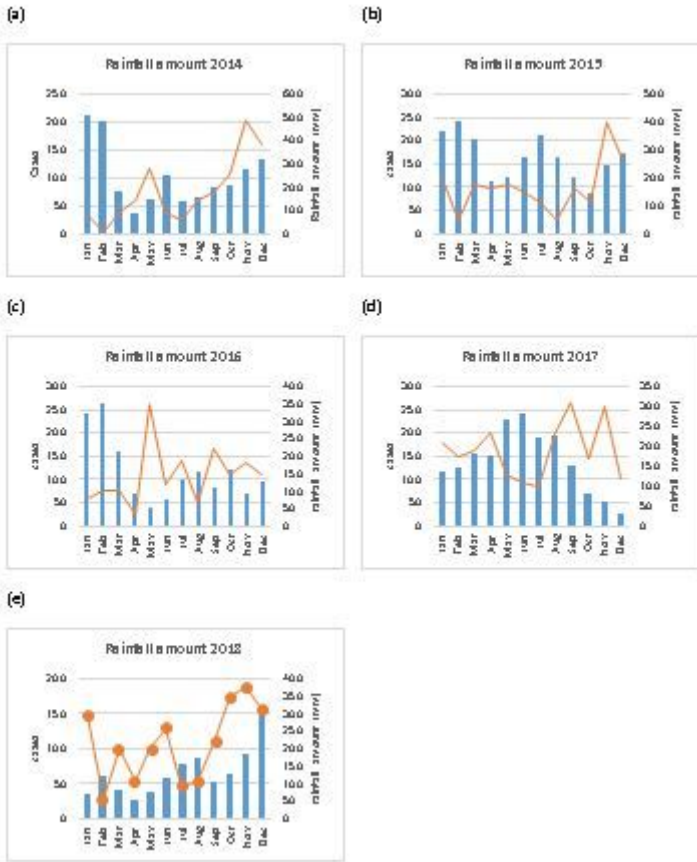


Figure 8

Monthly dengue cases against rainfall amount from year (a) 2014, (b) 2015, (c) 2016, (d) 2017, and (e) 2018.

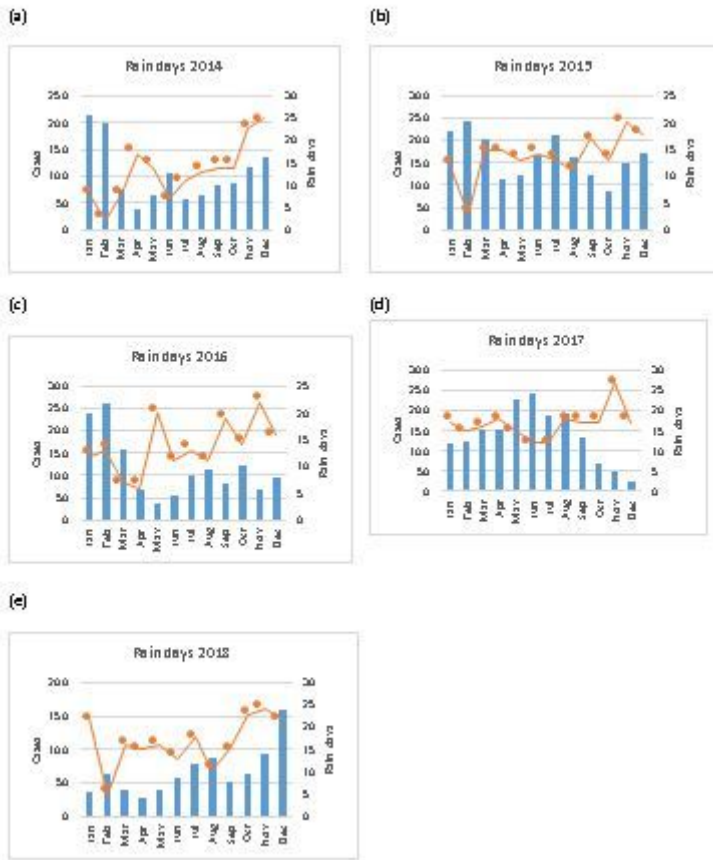


Figure 9

Monthly dengue cases against rain days from year (a) 2014, (b) 2015, (c) 2016, (d) 2017, and (e) 2018.