ORIGINAL ARTICLE

Temporal Variation and Spatial Cluster of Dengue in Seremban, Malaysia: A Retrospective Study From 2017 to 2021

Amir Zakuwan Mohammad Foad[1], *Nazri Che Dom[1,2,3], Rahmat Dapari[4]

[1] Centre of Environmental Health & Safety Studies, Faculty of Health Sciences, Universiti Teknologi MARA, UITM Cawangan Selangor, Puncak Alam, Malaysia.
[2] Integrated Mosquito Research Group (I-MeRGe), Universiti Teknologi MARA, UITM Cawangan Selangor, Puncak Alam, Malaysia
[3] Institute for Biodiversity and Sustainable Development (IBSD), Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
[4] Department of Community Health, Universiti Putra Malaysia, Serdang, Malaysia.

ABSTRACT

Introduction: Dengue fever is a vector-borne viral disease in Malaysia, and the increasing incidence of the disease necessitates an investigation of its temporal course to ensure effective detection and containment. The aim of this study is to investigate the spatial and temporal distribution of dengue fever in the region. **Methods:** Daily confirmed dengue fever cases from a five-year epidemic in Seremban were used to generate monthly and annual total case counts for temporal analysis. Then, the Getis-Ord Gi and Global Moran's I were used to plot dengue hotspots and cluster areas. The researchers also calculated and plotted mean and standard deviation ellipses to analyse the direction of dengue case distribution, which runs from southeast to northwest. **Results:** The study found that there was a clustering of dengue cases in Seremban district with a z-score of 36.9 and a p-value of 0.01. The hotspot pattern in Seremban increases over time and expands every year from 2017 to 2021. Finally, the study suggests that the pattern of dengue fever outbreak in the region is likely influenced by environmental conditions related to the ecology of the Aedes mosquito. **Conclusion:** Spatiotemporal dengue studies provide snapshots of the location of future dengue epidemics to ensure effective detection and containment of dengue fever, which is proving difficult due to the complex interactions between relevant epidemiological factors and a range of environmental, climatic, and societal characteristics that require further investigation.

Keywords: Dengue fever; Spatio-temporal pattern; Directional distribution; Malaysia

Corresponding Author:
Nazri Che Dom, PhD
Email: nazricd@uitm.edu.my
Tel: +60332584447

INTRODUCTION

Dengue fever (DF) is a vector-borne disease caused by four types of DF virus (DEN -1, DEN -2, DEN -3, and DEN -4) and spread by two types of Aedes mosquitoes (*Aedes aegypti* and *Aedes albopictus*) (1). The disease is a significant health problem worldwide. In 1902, the first DF epidemic was recorded in Malaysia, and severe outbreaks occurred in Kuala Lumpur in 1973 and Penang in 1962. In 1975, the disease was recognised as contagious, and the Extermination of Carrier Insects Act Disease was enacted to control it (2,3). Dengue surveillance is a method to detect and predict the spread of dengue fever by monitoring disease, vector activity, and environmental and social risk factors (4). In Malaysia, the Ministry of Health has implemented an integrated management strategy for dengue prevention and control that includes interventions from six other ministries. In 2013, a "search and eradication campaign called "Ops Mega" was implemented in four districts of Selangor state, reducing dengue cases by 60% in three months (5). However, maintaining community-level prevention efforts and reducing the number of dengue cases remains a difficult undertaking. The software GIS is used to analyse geographic data and help identify clusters and hotspots of dengue cases, as well as the spatial and temporal distribution of cases and susceptibility transformation (6). For many years, the Malaysian government has implemented programs and measures to control and eradicate dengue outbreaks, but dengue fever will continue to pose a significant health risk as population densities increase. Geographic information systems (GIS) and spatial statistical analysis play a critical role in tracking epidemic transmission and are becoming increasingly important for disease management and control (7).

Dengue fever has become a major public health problem in Malaysia, with an increasing trend in dengue outbreaks every year. The district of Seremban is one of the areas most impacted by dengue fever infections. In the months of August 2022 and 2021, a combined total of 1002 persons were hospitalised owing to dengue fever, resulting in two fatalities; this was in comparison to 389 dengue cases, which resulted in one fatality (8). However, the ongoing burden of the disease in the district has not been well studied (9). In Negeri Sembilan, there were 1,263 dengue cases in the Seremban district, 56 in Rembau, 55 in Port Dickson, 43 in Jempol, 43 in Tampin, 19 in Kuala Pilah, and 19 in Jelebu in 2020 indicates that the study location has a climate that is favourable for dengue vector breeding, and Seremban now has the greatest dengue hotspot locations within the district, mostly in residential areas (10,11).The objective of this study is to investigate the distribution pattern of dengue fever cases in the Seremban district of Malaysia, which has experienced an increasing number of dengue fever outbreaks in recent years. The district is particularly impacted by dengue fever, with many locations primarily located in neighbourhoods. The study aims to determine whether dengue cases are clustered or scattered in the area, which can help decision makers develop effective strategies to control the epidemic. This information can be critical for planning interventions such as mosquito control, health education, and community engagement programs. Ultimately, the study should help reduce the burden of disease and minimize the risk of future outbreaks.

MATERIALS AND METHODS

A retrospective study was conducted using data collected at the district level in Seremban, Malaysia. Seremban is located approximately 20 km from the national capital, Putrajaya, and 70 km from the economic centre of Kuala Lumpur. The district is located in the east of Negeri Sembilan and has a lower slope than the middle zone of the state. It is bordered by Jelebu to the north, Kuala Pilah to the east, Rembau to the south, and Port Dickson to the west. The study area consists of eight sub-districts: Ampangan, Labu, Lenggeng, Pantai, Rantau, Rasah, Seremban and Setul. The population of Seremban was 692,000 in 2022, according to the Malaysian Bureau of Statistics. Seremban has the most dengue fever hotspots within the district, especially in residential areas. In 2018, a total of 1800 patients were hospitalised due to DF-associated illnesses, and 6 deaths were reported. Given the increasing development of Seremban district as part of the Kuala Lumpur Extended Mega Urban Region (KLEMUR), which attracts a concentration of population to the developed community, it is important to measure the epidemiology of dengue fever to protect the city's residents from health complications in the district.

Dengue Data: The dataset used for the study included reported dengue cases and population data from the eight subdistricts in Seremban from January 2017 to December 2021, from the official dengue surveillance system produced by the Vector-Borne Diseases Division of the Malaysian Ministry of Health. The data used in the study include only confirmed dengue fever (DF) cases confirmed by serological testing. The variables included in the dataset are: Location, sub-district, and date of case admission for hospitalised and non-hospitalised patients in government and private hospitals in Seremban from 2017 to 2021. The coordinates of the patient's latitude and longitude were also recorded during data collection to perform distribution and geographic analysis.

Temporal Analysis: A time series plot was used to analyse dengue incidence trends. Data were plotted on a graph over different time periods (monthly, yearly, and sub-districts) and analysed using OriginPro v9.9.0.225 software. A waterfall chart and a heat map were also created to illustrate the cyclical and seasonal patterns of dengue cases. The mean of the proportion of cases for each sub-district in each week was standardised with the total number of cases per year to better identify seasonal variations.

Spatial Analysis: Spatial analysis and mapping were performed using the geographic information system (GIS), QGIS v3.24.3, and ArcGIS Desktop v10.8.1. The distribution of DF cases from 2017 to 2021 was presented by region and subcounty over a 5-year period. DF cases were converted to weighted data points on a map. Data points with identical X and Y centroid coordinates were transformed in the GIS format. Consequently, each point on the map represented a unique number of cases to determine the spatial distribution of DF cases. In this study, the DF cases in Seremban are used to illustrate the phenomenon of skewness. The spatial middle centre was used to compare distribution type and feature. The spatial mean centre creates a categorization of feature points, where each feature represents the mean centre. The mean of x and y indicates the middle centre, which indicates that the dimension field was included as a feature product. The mean centres are as follows:

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

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

where x_i and y_i are coordinates for i, and n is the total number of the features.

The standard deviation ellipse (SDE) is a method used in GIS to measure the trend of a group of points or regions by calculating the standard distance on the x, y, and z axes independently. The method uses an ellipse (or ellipsoid) to capture the distribution of the feature. The central tendency, dispersion, and trend direction of geographic regions can all be described by SDEs. These measurements are used to determine the axis of the ellipse. The location of the ellipse is determined by first calculating the standard deviation of the x and y coordinates of the centre axis of the ellipse. The shape of the ellipse can also be expanded or oriented in a particular way. In disease surveillance studies, ellipses are often used to simulate regional distribution because they are important for epidemiologists to understand central tendency and dispersion. The mean midpoint is an important metric for understanding the ellipse distribution:

$$\mathrm{SDE}_x = \sqrt{\frac{\sum_i^n (x_i - \bar{X})^2}{n}} \qquad (3)$$

$$\mathrm{SDE}_y = \sqrt{\frac{\sum_i^n (y_i - \bar{Y})^2}{n}} \qquad (4)$$

where x_i and y_i are the coordinates for feature i, $\{\bar{X},\bar{Y}\}$ shows mean center, and n is the total number of features. When applied to data, the standard deviation ellipse creates a new feature class consisting of polygons centred around the mean of each attribute (or for cases where values have been defined). The ellipse polygon has the characteristics of a standard distance (long and short axis) and an elliptical orientation. The orientation means that the long axis rotates clockwise from noon. In this study, the SDE was used to quantitatively investigate the spread of DF fever by looking at the direction of reported cases. In addition, the number of standard deviations was reported. It was found that one standard deviation can explain up to 68% of all centroid input data when features have a normal spatial distribution (highest density in the centre and decreasing toward the edges), while two standard deviations can explain up to 95% of all features and three standard deviations can explain up to 99% of all centroid features.

Dengue Hotspot Analysis: ArcGIS was used to analyse geographic autocorrelation and spatial clustering of DF cases using global Moran's I and hotspot analysis. The spatial autocorrelation of DF patients' addresses showed the trend of the disease. The result was plotted on a Getis-Ord Gi hotspot map, which colour-codes subdistricts based on group characteristics when high (hot) or low (cold) values are found in a cluster. A hotspot has a high z-score and a low p-value, indicating grouping. A cold spot has a low negative z-score and a modest p-value, indicating that there is no DF grouping (12). To understand how the disease spreads, a geographic centre and directional distribution were needed. To further validate and identify the causes of hotspot occurrence, we contacted the heads of vector control units and asked them to answer three questions: (i) whether hotspots coincide with areas where they have dengue control problems; (ii) what factors might facilitate the occurrence of hotspots; and (iii) what surveillance and control measures can be implemented in hotspot areas.

RESULTS

Temporal distribution of DF cases in Seremban from 2017-2021

Figure 1A describes the results of a study of dengue cases in Seremban from January 2017 to December 2021. The total number of reported cases is 8,710. The sub-districts with the highest number of cases are Labu with 2,949 cases, Ampangan with 1,712 cases, and Rasah with 1,542 cases. In Setul, Lenggeng and Pantai sub-districts, the number of cases is low compared to the other sub-districts. The distribution of dengue cases varies greatly among sub-districts for each year in the study period. Figure 1B shows that the highest number of cases was recorded in week 21 in 2017, week 49 in 2018, week 1 in 2019, week 33 in 2020, and week 3 in 2022. In addition, the highest number of cases in Labu sub-district was recorded in week 20 (82 cases). Compared to previous years, it was found that the number of dengue cases in all sub-districts in 2017 was higher than the number of cases in the previous epidemic cycle (2018-2021, above week 52).

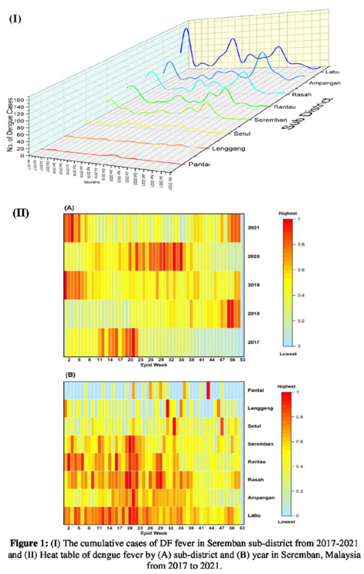

Figure 1 : (A) The cumulative cases of DF fever in Seremban sub-district from 2017-2021 and (B) Heat table of dengue fever by (A) sub-district and (B) year in Seremban, Malaysia from 2017 to 2021.

Table I : Confirmed dengue fever cases georeferenced by address in Seremban, Malaysia during 2017-2021

Year	Total no confirmed DF cases	Georeferenced confirmed dengue cases	
		No of cases	%
2017	2614	2541	97
2018	1461	1419	97
2019	1849	1798	97
2020	2471	2434	99
2021	524	513	98
Total	**8919**	**8705**	**97.6%**

Spatial distribution of DF cases in Seremban from 2017-2021

Table I provides an overview of the number of DF cases that were successfully georeferenced. On average, 97.6% of the cases were georeferenced, while the remaining cases were not georeferenced due to insufficient information such as missing address or unspecified location. The actual distribution of DF cases is thus clearly evident, as the database coverage was more than 90%. Figure 2A shows the point density of the 8,919 confirmed DF cases by sub-district differences in DF cases between 2017 and 2021. The analysis was able to group all DF cases by year. The analysis showed that the number of cases in 2017 was distributed in Labu and Ampangan sub-districts. However, the frequency of DF cases decreased in 2018. In the following two years, from 2019 to 2020, the frequency of DF cases increased and the density started to spread to neighbouring sub-districts such as Rantau, Rasah, and Seremban Town. Then, in 2021, the density of DF cases decreased.

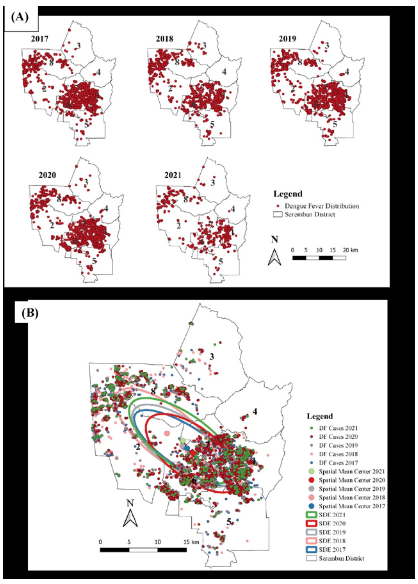

Figure 2 : (A) Spatial mapping of DF cases density in Seremban, Malaysia (2017-2021) and (B) Standard deviational ellipses of DF cases in Seremban from 2017 to 2021. Representing; (1) Ampangan, (2) Labu, (3) Lenggeng, (4) Pantai, (5) Rantau, (6) Rasah, (7) Seremban and (8) Setul.

Next, the spatial centre was used to determine where the phenomena were centred. Figure 2B shows the locations of all DF cases from 2017 to 2021 along with their mean centres and standard deviation ellipses. Calculated using monthly DF cases reported independently over a five-year period. The geographic mean centre of DF cases for 2017 is 101.90510, 2.735295. The mean centre of DF cases in 2018 is at x coordinate 101.873524 and y coordinate 2.759412. The mean centre for 2019 is at coordinates 101.897506 and 2.7395187 on the x and y axes, respectively. For 2020, the mean midpoint is at x coordinate 101.914441 and y coordinate 2.727431, and for 2021, the mean midpoint is at x coordinate 101.8986431 and y coordinate 2.747748.

In the five years, DF cases were mainly distributed in one direction, from the northeast to the southeast of the whole Seremban sub-county. For the 2017 record, an ellipse polygon with a directional degree of 124.3° on the long axis was used. In 2018, the elliptical polygon with a directional degree of 130.3° on the long axis moved farther east of the study area and was largest and longest at the top of the polygon. In 2019, the elliptical polygon moved 128 degrees to the east. In 2020, the elliptical polygon moved 128 degrees further east while maintaining a relatively constant direction. The elliptical polygon in 2021 was much smaller with a directional degree of 126.7°. The direction of the distribution of DF

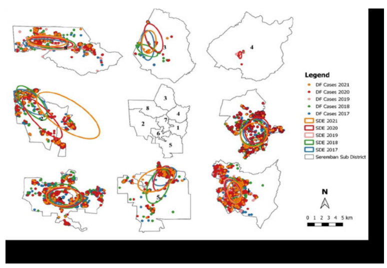

Figure 3 : SDE Summary of dengue cases in Seremban from 2017 to 2021 by sub-district.

Table II : Summary of hotspot cluster of DF cases in Seremban, 2017-2021

Types of clusters	Confidence levels	2017	2018	2019	2020	2021
Hot spot	99% Confidence	Tmn Desa Melati	Tmn Desa Anggerik	Manipal Hostel	Tmn Desa Ria	Mesahill Apt
		Kasturi Heights	Laman Jasmin	Mesahill Apt	Laman Delfina	Laman Delfina
		Tmn Desa Casuarina	Putra Point Nilai	Tmn Desa Kasia	Nilai 3 Industrial	Putra Point Nilai
	95% Confidence	Tmn Semarak 1	Tmn Melor	Tmn Semarak Apt	Cempaka Court	Tmn Desa Ria
		Tmn Semarak Apt	Kg Ulu Lalang	Garden Homes E	Hijayu 1B	Tmn Teratai
		Tmn Desa Jasmin	Kg Jerangkang	Tmn Arowana Indah	Tmn Sri Mawar 2	Tmn Desa Seringin
	90% Confidence	Tmn Tuanku Jaafar	Laman Bakawali	Melody S2 Heights	Tmn Desa Ixora	Tmn Desa Jasmin
		Tmn Semarak 2	Tmn Nada Alam	Tmn Mambau Baru	Tmn Marida 2	Tmn Desa Anggerik
		Recron Hostel	Tmn Dahlia	Nilai 3 Industrial	Tmn Semarak 2	Puncak Jati Apt
Cold spot	99% Confidence	Tmn Bukit Galena	Tmn Tasik Jaya	Tmn Choong Loong	Tmn Dato Syahbandar	Tmn Bukit Mutiara
		Tmn Pulai Impian	Seroja Apt	Rimbun Vista Heights	Tmn Rasah Jaya 1	Casa Prima Apt
		Tmn Bukit Mutiara	PPR Paroi	Tmn Berlian Tropika	Tmn Mok Som	Tmn Bukit Delima
	95% Confidence	Apt Seremban Putra	Tmn Pinggiran Senawang	Tmn Jasper Jaya	Kg Jiboi Baru	Tmn Bukit Galena 7
		Kg Baru Rasah	Tmn Desa Temiang	Tmn Bukit Mutiara	Tmn Punca Emas	Tmn Temiang
		Tmn Permai 2	Tmn Bukit Margosa	Tmn Permai	Tmn Pinggiran Golf	Tmn Bukit Galena 5
	90% Confidence	Tmn Tuan Sheikh	Nusari Aman 1A	Tmn Permai 3	Tmn Jujur (Kanan)	Tmn Labu Utama
		Kg LB Johnson	Tmn Semarak Apt	Tmn Harmonium Indah	Tmn Bukit Emas	Tmn Rasah
		Garden City Homes (Acacia)	Tmn Gadong Jaya	Tmn Mantin	Tmn Bukit Kepayang 6	Tmn Desa Temiang

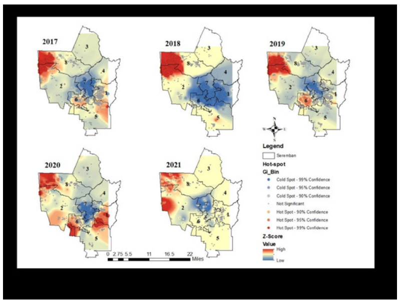

Figure 4 : Map of Seremban district showing spatial clustering of dengue cases from 2017 to 2021 by sub-district. Hotspot and coldspot analyses based on Getis-Ord-Gi* statistics.

cases in each subcounty on an annual basis was then examined using the data shown in Figure 3, which were subsequently obtained. The DF cases tend to be distributed in the southeast direction in Ampangan, Labu, and Lenggeng, in the northeast direction in Pantai and Rantau, in the north direction in Seremban, and finally in the east direction in Setul.

Hotspots analysis of dengue in Seremban

The analysis identified statistically significant clusters of high and low levels of dengue cases, shown on a map as hotspots (indicated by red coloured dots) and coldspots (indicated by blue coloured dots). The map shows that the highest density of hotspots is found in Setul sub-district, followed by Labu, Ampangan and Rantau sub-districts. The hotspot pattern in Seremban increases over time and expands each year from 2017 to 2021 (Figure 4). From the hotspot analysis, 10 locations were identified based on the highest GiZscore values for a more thorough examination of the hotspot zone. Locations that frequently become hotspots include Taman Semarak Apartment, Taman Semarak 2, Taman Desa Jasmin, Taman Desa Anggerik, Mesahill Apartment, Laman Delfina, and Taman Desa Ria. Regions with the most cold locations include Taman Bukit Mutiara and Taman Desa Temiang (Table II).

The director of vector control reported that there was a high degree of consistency between the hotspots identified in the study and the areas where most dengue cases have occurred in the past. The study suggested that the pattern of dengue fever outbreaks in the region is likely influenced by environmental conditions related to the ecology of the Aedes mosquito. Factors such as poor drainage facilities and waste disposal, poorly constructed and improperly managed sanitation systems, and other social factors have been identified by vector control officials as underlying problems in

Table III : Hotspot analysis agreement with locations indicated as vulnerable for dengue fever transmission (Dzul-manzanilla et al., 2020)

Sub-district (Locality)	Does the hotspot area match with areas you identify as problematic (yes, partially, no)?	What local conditions determine the occurrence of hotspots (ecological, environmental, infrastructure, social, or other determinants)?	What surveillance or control activities could you implement in your city considering the presence of hotspots?	Surrounding Images
Labu (Taman Semarak)	**Yes:** The most problematic region corresponds to a hotspot	**Sociodemographic:** regions with a high population density by 680 housing units and 2790 residents. **Ecological:** high risk on infested dwellings with a variety or breeding grounds especially at the illegal dumping site.	**Surveillance:** Collecting and analyzing population related data in detail to target control, prevention and health education **Control:** Preventive vector control before transmission season and ultra-low volume and indoor space spraying.	
Setul (Taman Desaria)	**Yes:** Cases have typically accumulated in the hotspot region	**Environmental:** Inadequate planning and continuous population increase have produced informal settlements and many larval habitats, and land ownership is unstable. **Social:** This is a border city to Selangor which movement and mobility may bring diseases.	**Surveillance:** Enhance primary health care to increase active case detection (ACD) searches in hotspot locations. **Control:** integrated vector control actions sequentially by source reduction, larval control, residual spraying, and spatial spraying in coordination with epidemiological surveillance	
Rantau (Taman Tuanku Jaafar)	**Yes:** The hotspots correspond to problematic regions.	**Sociodemographic:** Densely populated regions with varying levels of education **Social:** Limited access of vector control personnel into the areas; low socioeconomic status prevails, and houses are often crowded with large numbers of families	**Surveillance:** Throughout the year, entomo-virological monitoring in hotspot locations would identify early transmission. **Control:** Increase monitoring using ovitraps in hotspot regions; further measures include thermal fogging of alleyways and difficult-to-access locations, and administration of larvicide using portable sprayers to minimise home entry.	

hotspot areas. Mosquito infestations can be exacerbated when residents illegally dump their trash or garbage in the residential area. The condition of buildings was also observed to determine if they were structurally well maintained or poorly maintained, which could contribute to mosquito infestations. This information is presented in Table III.

DISCUSSION

The prevalence of dengue fever in Seremban district in Malaysia peaked in different weeks in different years, with the highest number of cases recorded in week 21 in 2017, week 49 in 2018, week 1 in 2019, week 33 in 2020, and week 3 in 2022. This was likely due to a combination of factors such as temperature, precipitation, and the presence of artificial water bodies that can serve as breeding sites for mosquitoes. The study by Lypez-Montenegro et al. (13) in Colombia also found that the peak of dengue fever cases occurs in different weeks in different years and that the peak is influenced by environmental factors such as temperature and precipitation. Similarly, Abdulsalam et al. (14) found that Nakhon Si Thammarat province in the Gulf region of Thailand had the longest dengue transmission period from week 22 to week 39 in 2021.

It was also noted that the number of dengue fever cases in Seremban district has fluctuated over the years, with 2,614 cases reported in 2017, 1,460 in 2018, 1,849 in 2019, and a sharp decline in 2020 due to the pandemic COVID -19. The study by Haider et al. (15) in Bangladesh also found that June is the first official monsoon month and one of the warmest months of the year, which creates favourable breeding sites for Aedes mosquitoes and shortens the extrinsic incubation period and biting interval. It is also noted that the temporal patterns of dengue fever cases in different locations are not always consistent, making it difficult to identify a common pattern (16). This highlights the importance of conducting further research and deepening cluster analysis to better understand the factors that influence the spread of dengue fever and to develop more effective strategies to control the disease.

The study found that the spatial distribution of dengue fever (DF) incidence varied considerably in Seremban district, with cases clustering in the northwestern to southwestern areas, consistent with the findings of a previous study (7). This suggests that these areas are hotspots for DF cases and potential breeding sites for the vector. The increase in population in these areas is likely due to urban expansion and growth of new areas such as industrial parks. The study suggests that a model of smallpox hotspots based on previous data and a colour-coded representation of risk could be used to rapidly detect and respond to potential epidemics in the area (17).

The study also found that the most populous districts have been identified as dengue hotspots over the years, which is also confirmed by other studies (7). However, the capital city (Seremban), which has experienced rapid economic development, was surprisingly found to be a cold spot for dengue incidence. The study found that most of the clustered cases were detected in the industrial, residential, and construction areas of the main urban subdistricts of Labu with a population of 101 202. Spatial analysis is critical for effective management of dengue fever cases. In Malaysia, for example, the identification of dengue hotspots would trigger a response that includes the search and destruction of mosquito breeding sites within a 200-metre radius of the index case, taking into account the maximum flight range of the *Aedes aegypti* mosquito and its tendency to be active within a 100-metre radius of its breeding site (12). Other studies have also found that spatial analysis with hotspots is cost-effective for focusing health control measures and epidemiological surveillance in resource-poor countries (18). Spatiotemporal cluster analysis is essential for the prevention and control of dengue fever and other vector-borne diseases.

Spatial analysis revealed that most dengue fever cases were located in the upper left and lower right quadrants of the Seremban city map, and that cases were concentrated in the same region in the centre of the Seremban district map, extending from southeast to northwest. A comparative study in Johor Bahru found that the epicentre of dengue fever was in the centre of the study area and that human activities were the primary contributors to the spread of the disease in the community (19). The Vector Control Department acknowledged that problem areas can be found in any area and that factors such as unreliable water supply, high crime area, lack of trust between communities, and the presence of informal settlements and mobile residents can contribute to transmission dynamics in hotspots (20). The study supports the World Health Organization's view that identifying high-risk transmission sites or "hotspots" is critical for effective control of the Aedes mosquito and the diseases it spreads.

CONCLUSION

The study found that using the recommended methods and tools can help public health professionals visualize and understand disease distribution patterns, create alerts, and conduct public awareness campaigns. The study suggests that public health education efforts are needed to reduce mosquito breeding sites and improve waste management. Importantly, households need to maintain these measures to prevent the reintroduction of vectors even after the mosquito species of concern have been eradicated. Further spatiotemporal studies are needed to uncover other factors that may cause dengue fever outbreaks and to assist public health professionals in protecting citizens in areas where dengue fever is present or may spread. Identifying the spatiotemporal spread patterns and hotspots of dengue fever can help limit and predict spread, saving time and money and improving public health programs. Future research should examine the time-dependent effects of climate to gain a deeper understanding of the distribution of dengue fever cases.

ACKNOWLEDGMENT

This study has received funding from the UiTM Cawangan Selangor, Universiti Teknologi MARA (600-UITMSEL (PI. 5/4) (014/2022).

REFERENCES

1. Abhishek KS. Circulating dengue serotypes in central Delhi during 2015 outbreak. J. adv. med. med. res. 2020;07(01):1–4.
2. Murphy A, Rajahram GS, Jilip J, Maluda M, William T, Hu W, et al. Incidence and epidemiological features of dengue in Sabah, Malaysia. PLoS Negl Trop Dis. 2020;14(5):1–19.
3. Gwee SXW, St John AL, Gray GC, Pang J. Animals as potential reservoirs for dengue transmission: A systematic review. One Health [Internet]. 2021; 12:100216. Available from: https://doi.org/10.1016/j.onehlt.2021.100216
4. Chin J. Surveillance, emergency preparedness and response. 2009 [cited 2022 Sep 3];624. Available from: https://www.ncbi.nlm.nih.gov/books/NBK143158/
5. Nani Mudin R. Dengue incidence and the prevention and control program in Malaysia. Int. Med. J. Malays. 2015;14(1):5–9.
6. Rizwan M, Dass SC, Asirvadam VS, Gill BS, Sulaiman LH. DenMap: A dengue surveillance system for Malaysia. J Phys Conf Ser. 2018;1123(1).

7. Majid NA, Nazi NM, Mohamed AF. Distribution and spatial pattern analysis on dengue cases in Seremban District, Negeri Sembilan, Malaysia. Sustainability (Switzerland). 2019;11(13).
8. Official Portal of Ministry of Health Malaysia [Internet]. Kenyataan Media Ketua Pengarah Kesihatan: Situasi Semasa Demam Denggi Di Malaysia Minggu Epidemiologi 32/2022; c2022 [cited 2022 Sep 3]. Available from: https://www.moh.gov.my/index.php/database_stores/store_view_page/17/2178
9. Mia S, Er AC, Begum RA, Pereira JJ, Ahmed F. Assessing Demographic Distribution of Dengue Infections in Seremban District, Malaysia. Indian J Public Health Res Dev. 2020;(October).
10. Bernama. Dengue cases on the rise in Negri Sembilan. New Straits Times 2020 Jul 1. [Internet]. [cited 2023 Jul 4]. Available from: https://www.nst.com.my/news/nation/2020/07/604979/dengue-cases-rise-negri-sembilan
11. Ah Choy E, Bte Mohd Khair E, Atan A, Sahani M, Mohd Ali Z. Climate change and dengue: Case study in Seremban District, Negeri Sembilan, Malaysia. e-bangi. 2011; Available from: https://www.researchgate.net/publication/245586264_Perubahan_Cuaca_Dan_Penyakit_Denggi_Kajian_Kes_Di_Daerah_Seremban_Negeri_Sembilan_Malaysia
12. Masrani AS, Nik Husain NR, Musa KI, Yasin AS. Trends and Spatial Pattern Analysis of Dengue Cases in Northeast Malaysia. Journal of Preventive Medicine and Public Health. 2022;55(1):80–7.
13. Lypez-Montenegro LE, Pulecio-Montoya AM, Marcillo-Hern6ndez GA. Dengue cases in Colombia: Mathematical forecasts for 2018–2022. MEDICC Rev. 2019;21(2–3):38–45.
14. Abdulsalam FI, Yimthiang S, La-Up A, Ditthakit P, Cheewinsiriwat P, Jawjit W. Association between climate variables and dengue incidence in Nakhon Si Thammarat Province, Thailand. Geospat Health. 2021;16(2).
15. Haider N, Chang YM, Rahman M, Zumla A, Kock RA. Dengue outbreaks in Bangladesh: Historic epidemic patterns suggest earlier mosquito control intervention in the transmission season could reduce the monthly growth factor and extent of epidemics. CRPVB [Internet]. 2021;1(November):100063. Available from: https://doi.org/10.1016/j.crpvbd.2021.100063
16. Sanna M, Hsieh YH. Temporal patterns of dengue epidemics: The case of recent outbreaks in Kaohsiung. Asian Pac J Trop Med [Internet]. 2017;10(3):292–8. Available from: http://dx.doi.org/10.1016/j.apjtm.2017.03.009
17. Dom NC, Ahmad AH, Latif ZA, Ismail R. Integration of GIS-based model with epidemiological data as a tool for dengue surveillance. EnvironmentAsia. 2017;10(2):135–46.
18. Sun W, Xue L, Xie X. Spatial-temporal distribution of dengue and climate characteristics for two clusters in Sri Lanka from 2012 to 2016. Sci Rep [Internet]. 2017;7(1):1–12. Available from: http://dx.doi.org/10.1038/s41598-017-13163-z
19. Hamidun S, Che Dom N, Salleh SA, Abdullah S, Precha N, Dapari R. An investigation of the spatial distribution of dengue cases in Johor Bahru, Johor, Malaysia. Geocarto Int [Internet]. 2022;0(0):1–13. Available from: https://doi.org/10.1080/10106049.2022.2032400
20. Sekti A, Irina SZ, Noordini CM, Al-Ashwal RH, Syafie S. Dengue risk prediction in illegal dumpsite of housing area by using geospatial analysis. Journal of Architecture, Planning and Construction Management (JAPCM). 2019;9(1):75–6.
21. Dzul-manzanilla F, Correa-morales F, Che-mendoza A, Palacio-vargas J, S6nchez-tejeda G, Gonz6lez-roldan JF, et al. Articles Identifying urban hotspots of dengue , chikungunya , and Zika transmission in Mexico to support risk stratification efforts : a spatial analysis. Lancet Planet. Health. [Internet]. 2020;5(5):e277–85. Available from: http://dx.doi.org/10.1016/S2542-5196(21)00030-9