RESEARCH ARTICLE

Spatio-Temporal analysis of Dengue distribution pattern in Kuantan from 2015-2019

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Abstract:

Dengue fever is a health issue that has been a source of concern throughout Malaysia, notably Kuantan, Pahang. Dengue fever cases have been recorded on a regular basis in the local community in recent years. This study aimed to examine the spatio-temporal pattern based on yearly dengue surveillance data for five years from 2015 to 2019. To better understand the pattern of dengue cases, a descriptive analysis that included extensive observation of dengue data as well as the distribution of rainfall in Kuantan was carried out in this study. Data on dengue case distributions over a five-year period were gathered from the Ministry of Health “eDengue” system. A total of 6560 dengue cases in Kuantan was used in this study. Spatio-temporal analysis was performed by plotting the dengue cases distribution using the Geographic Information System (GIS) software and applied with the Kernel Density analysis to trace locality patterns in dengue hotspot. The GIS analysis shows centralized hotspot pattern of dengue cases which mostly focus on the sub-district of Kuala Kuantan. Then, the dengue cases distribution pattern was analysed against the rainfall distribution. The statistical analysis by using the Pearson correlation was used to find the relationship between dengue cases and rainfall. The Pearson correlation brought the value of the R^2 linear ($R^2 = 0.003$) which is far from the accepted value by the research community ($R^2 = 0.19$). The Pearson correlation value ($r = 0.053$) was not close enough to the significance value ($r = 1$). The relationship between dengue and rainfall in Kuantan from 2015 till 2019 was not statistically significant ($p>0.05$). These findings show a clear spatio-temporal trend of dengue cases in Kuantan and no significant correlation between dengue cases and rainfall pattern, thus providing evidence in directing future field works to probe on factors such as vector abundance and dispersion in the area.

Keywords: Dengue cases, Disease surveillance, GIS, Rainfall

1. INTRODUCTION

Dengue fever is a major problem in tropical and sub-tropical countries which is brought by the dengue virus (Arham et al., 2018; Hii et al., 2009; Poovaneswari, 1993; Thi Tuyet-Hanh et al., 2018). The dengue virus causes a vector-borne disease that may affect millions of people worldwide in urban and suburban regions. The symptom of dengue fever is caused by Aedes mosquitoes that could breed rapidly. The World Health Organization (WHO) in 2020 had stated that for the past 50 years ago, there has been a 30-fold rise across the global incidence. Furthermore, there is 50-100 million dengue infections happen each year and are endemic in nearly half of the countries in the world (Chan, 2020).

In general, dengue fever is prevalent in Malaysia, which is mostly found in cities and town areas (Arham et al., 2018; Poovaneswari, 1993). In most city areas, both of mosquito species: *Aedes aegypti* and *Aedes albopictus* have been implicated in the classical dengue fever’s transmission and dengue haemorrhagic fever. However, due to the absence of vaccine, the method of preventing infection transmission is only left with mosquito control. It is important for urban community to keep their surrounding in good sanitation in order to control the emerging of the Aedes mosquitos itself (Shafie et al., 2012).

Besides, there is possibility of dengue being passed directly through transovarial transmission or also known as vertical transmission which is a pathogen spread from parent to offspring. Transovarial transmission is the key factor in dengue spread and has been shown in Aedes albopictus mosquitoes. The rate of such transmission varies by serotype and strain of the virus. Transovarial transmission was observed in *Aedes aegypti* only at relatively low rates. The egg laid by infected mosquitoes are indeed harbouring dengue virus in transovarial transmission (Poovaneswari, 1993; Thi Tuyet-Hanh et al., 2018). There are several types of mosquito species being passed through transovarial transmission including *Ae. albopictus* and *Ae. aegypti*. In addition, the location of the dispersal of dengue cases depends on several factors including the distance of human territory, dengue fever problem, population of dengue species, field measurements, geology, biological solids and control areas (Hamidun et al. 2021; Adnan et al., 2020; Cheah et al., & Lum, 2014; Ling, 2015).

In general, condition components such as social demographic factor and spatio-temporal analysis influenced the distribution of dengue exposure components in a locality. The relationship between the climate factor and dengue disease was also investigated. Dengue fever has a remarkable relationship with both temporal and geographical design, which is based on mosquito density and duration, which is dependent on natural determinants and environmental factors like precipitation, vector breeding location, rainfall, and temperature (Mustafa et al., 2015).

The district of Kuantan is the state capital of Pahang and has a population of 1.67 million people and covers an area of 35965 km^2 (Department of Statistics Malaysia, 2021). The aim of this study is to explore the distribution of dengue cases in Kuantan district. Kuantan is divided into 7 zones namely Beserah, Kuala Kuantan 1, Kuala Kuantan 2, Sungai Karang, Penor, Hulu Lepar, and Hulu Kuantan. Kuantan exhibits the features of a classic dengue problem, which is an increase in population in an area, resulting in a high overall density.

According to spatio-studies, it can be concluded that certain areas with a high risk of dengue infection may have dengue outbreaks or hotspots (Dom et al., 2012). As a result, this method may provide an inquiry into vector-borne infection, notably in dengue control actions. According to (Mustafa et al., 2015), GIS-based strategies can aid in the detection of dengue cases using spatial and temporal study by superimposing and making an inferential approximately the space and time of environment determinants such as landscape, ecological and weather. Therefore, this study aimed to connect both GIS and spatio-temporal analysis to describe the dengue cases in Kuantan District, Pahang.

Dengue control management in Malaysia is a great challenge which is also the concern in research field (Lee et al., 2015). The study is motivated by the difficulty of exploring the spatiotemporal patterns of dengue distribution in the local environment, as well as determining the relationship between dengue and rainfall distribution amount. It is critical to refer to the propensity of dengue cases in order to make data on the total distribution of dengue cases meaningful. This study is important for developing effective strategies for managing mosquito species and estimating infectious diseases in response to reducing dengue incidence and avoiding outbreaks in Malaysia, particularly in the Kuantan area.

2. MATERIALS AND METHODS

This study was designed to examine the dengue distribution by using space and temporal approaches in Kuantan District in relation to reported cases over a five-years period, from 2015 to 2019. The data presented in Table 1 were used in this study and were collected from several government departments.

Annual population of the Kuantan is extracted from the Information System and Documentation Unit, Pahang Health Department. The rainfall data were analysed using ArcGIS software to plan the location of dengue cases around Kuantan district. Then, descriptive data analysis was performed using Statistical Package for the Social Sciences (SPSS) software by analysing the parameters of rainfall distribution in Kuantan from 2015 to 2019 on the distribution of dengue cases in the same time interval. Besides, the monthly data that consists of maximum, minimum and mean temperature (ºC), rainfall and relative humidity within the five years were collected from Pahang-Malaysia Meteorological Department Kuantan Station. This epidemiological data obtained from this department is to assess the climate status and spread of dengue cases in Kuantan from 2015 to 2019.

Table 1. Dengue Cases, GIS and Environmental Data Matrix of Kuantan

Data	Parameter	Resolution	Time Period	Source
Population	Sex Age groups	Annually	2015 - 2019	Information System and Documentation Unit, Pahang Health Department
Meteorological database	Temperature (Mean, Maximum and Minimum) Rainfall Humidity	Annually	2015 - 2019	Pahang-Malaysia Meteorological Department Kuantan Station
GIS database	Zoning Activity Section	Latitude Longitude	2015 - 2019	Kuantan Divisional Health Office
Disease Notification	Dengue cases	Monthly Annually	2015 - 2019	Vector Control Unit, Pahang Health Department

2.1 Study area

Kuantan is located in the state of Pahang. Pahang is the third largest state in Malaysia with its geographical coordinates span at latitude 3°45’0” North and longitude 102°30’0” East. Kuantan with the 3240 km^2 area is divided to seven subdistricts; Kuala Kuantan 1, Kuala Kuantan 2, Beserah, Penor, Sungai Karang, Hulu Kuantan and Hulu

Lepar. Figure 1 shows a geographical map of Pahang showing the location of Kuantan District.

Figure 1 The location of Kuantan District

Several factors contribute to Kuantan's status as the district with the greatest number of dengue cases in Pahang, including the district's rapid urbanisation and development. This circumstance has resulted in such dramatic rises in dengue cases that it is expected to have an impact on the Kuantan district's dengue cases. Kuantan is made up of urbanised areas, agricultural areas, and forest regions that were converted to housing and business purposes during the study period (Kozaki et al., 2017). Rapid industrialization and urbanisation have fueled economic expansion in Kuantan, resulting in a massive increase in population, with more people becoming vulnerable to dengue transmission (Tay et al., 2014).

2.2 Dengue data

Data from dengue cases in Kuantan District from 2015 to 2019 were used. All of the data contain specific information regarding dengue cases, such as population, weather, GIS, and disease notification. The month of the reported dengue episode was provided as a respond variable, whereas monthly weather variables such as monthly mean, maximum and minimum temperature, total precipitation, and mean relative humidity were computed as temporal variations in the independent variables. The extracted data were imported into Microsoft Excel 2019 and analysed using Statistical Package for the Social Sciences (SPSS). Then, the GIS software was utilized to capture all digital based map data from "eDengue" system and Vector Control Unit, Kuantan District Health Office in order to analyse the geographical data by using ArcGIS version 10.3 following the method by (Chang, 2018). ArcGIS software was used in this study for mapping the spatio location and visualizes the spatio relationship among them.

2.3 Data analysis

GIS software entails the use of a combination of digital maps and geographical data, with all data being analysed based on the spatial placement of real features. As a result, using GIS software, the dengue fever-affected areas were geo-coded to the location's digital base map (Chang, 2018). This study examined current dengue transmission trends as well as the spatio and temporal evolution of dengue cases. Monthly dengue case areas are transformed into coordinates using digital maps made with ArcGIS in order to estimate their geographical change over time and space. The distribution maps generated from annual reports of dengue incidence for five years were assessed in this study.

SPSS was used to analyse the relationship between temperature (mean, maximum and minimum), rainfall and humidity status and the distribution of dengue cases in Kuantan. A descriptive analysis was performed to investigate the prevalence of dengue fever by person, location, and time. To analyse the association between dengue cases and rainfall, Pearson correlation was used to calculate the relationship between dengue incidence components across a five-year study period. The importance of investigating the links between dengue cases and rainfall distribution would contribute to a better understanding of dengue distribution patterns in the Kuantan district.

3. RESULTS AND DISCUSSION

3.1 Spatio-temporal trend of dengue affected areas

This study created a pattern for the distribution of dengue cases in Kuantan during a five-year period, from 2015 to 2019. Based on the analysis of monthly case data, this model visualises the fluctuation in dengue cases over a five-year period to demonstrate the case pattern. Figure 2 presents the monthly incidence of dengue cases in Kuantan from 2015 to 2019.

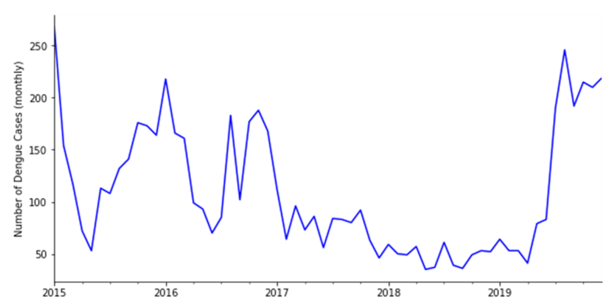

Figure 2. Monthly incidence of dengue cases in Kuantan from 2015 to 2019.

The year 2015 had the highest number of monthly cases, with over 250 cases. In 2016, there was a decrease in the monthly case rate, with dengue cases falling to a level of less than 250 cases. Following a changing trend over a one-year period in 2016, 2017 saw a dramatic decrease in instances, with only 50 cases documented at a one-month rate. In 2018, the number of reported cases fell below 50 for the second year in a row. However, there was a sudden increase in 2019 when cases returned to a high level as in 2015, which was 250 cases each month. The five-year trend analysis showed no significant pattern of the dengue cases in Kuantan.

In order to produce the geographical spatio-temporal pattern, this study used Kernel density estimation in ArcGIS Pro. Figure 3 presents the geographical spatio-temporal pattern for dengue cases in Kuantan from 2015 to 2019 in red dots. The kernel density in the purple square box represents the point characteristics around the Kuantan mapping environment and was used to trace localization patterns in dengue hotspots. The density at each output raster cell was calculated by adding the values of all the kernel surfaces where they overlay the raster cell center.

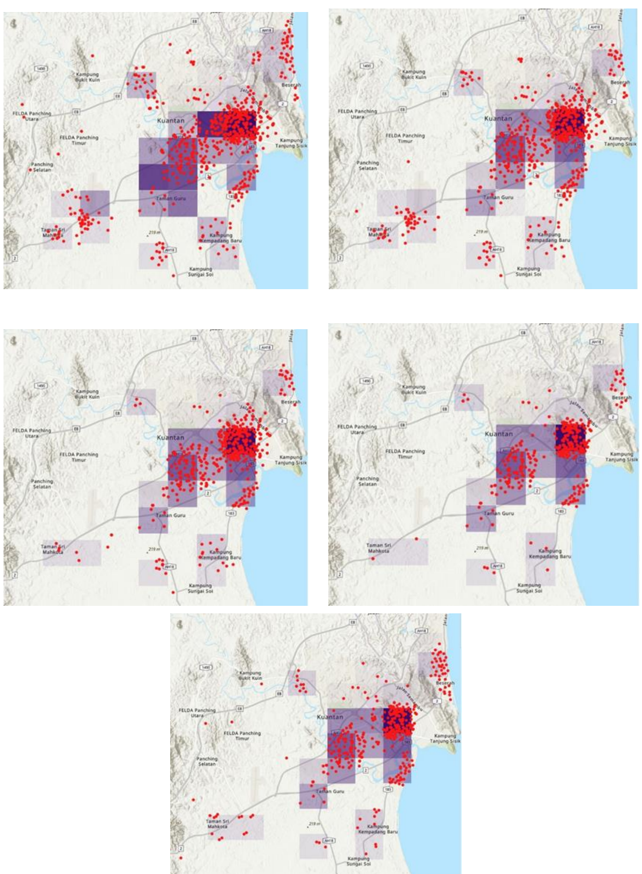

Figure 3. The dengue cases distribution in Kuantan from 2015-2019

3.2 Descriptive analysis

This section refers to the relationship measurement between two groups of datasets which are dengue data group and rainfall data group. The datasets which were selected were the monthly data of dengue cases and monthly data of rainfall amount for five years from 2015 to 2019. Table 2 presents the dengue cases and rainfall amount in Kuantan from 2015 to 2019.

Table 2. Descriptive statistics of dengue cases in Kuantan Malaysia during 2015-2019.

Parameter	2015	2016	2017	2018	2019	Total
Dengue cases	1688	1684	963	575	1650	6560
Yearly Increment of Dengue Cases (%)	* -	-	-	-	187.0	187.0
Yearly Decrement of Dengue Cases (%)	* -	0.2	42.8	40.3	-	83.3
Rainfall Amount (mm)	1947.6	2212.1	2957.8	2744.1	1970.8	11832.4

**As the study period starts from 2015, the dengue cases increment or decrement percentage were not possible to count*

It is clearly presented that the dengue cases were well controlled for two years in a row for 2017 and 2018. Both of the years were having a relatively lower number of dengue cases compared to the other years. In comparison to the other three years, 2017 and 2018 had the largest rainfall quantity distributions despite recording the fewest dengue incidences. As a result, it is safe to conclude that the distribution of dengue cases in Kuantan is unaffected by the amount of rainfall. The Pearson correlation analysis was performed on the dengue and rainfall data to provide statistical support. The Pearson correlation is best suited for measuring two variables and determining the relationships between them. Table 3 presents Pearson correlation analysis of dengue cases per month and rainfall amount per month.

Table 3. Pearson correlation analysis of dengue cases per month and rainfall amount per month.

Pearson Correlation Results	**Dengue case per month**	**Rainfall amount per month**
R^2 linear	0.003	
Pearson Correlation, r	0.053	
Significance 2-Tailed	0.686	

R-squared is an appropriate measure for a linear regression model as this study wants to prove the linear relationship between the high number of dengue cases to the high amount of rainfall and vice versa. These statistics show the percentage of variance in the dependent variable i.e., dengue cases, which is explained by the collectively independent variable i.e., rainfall distribution. In research community, the R^2 linear finding suggests that this value must be equal to or greater than 0.19 to be acceptable as having a significance correlation. As for this study, the R^2 linear value in this study is 0.003 which is far from the acceptable value.

Furthermore, the Pearson correlation (r) value in this study is not even close to 1. The Pearson correlation coefficient, r, can take a range of values from +1 to -1. A value of 0 indicates that there is no relationship between the two variables. Values greater than 0 indicate a positive relationship; that is, as the value of one variable increases, so does the value of the other variable. These analyses prove that the amount of rainfall does not affect the increase in the number of dengue cases in Kuantan for 2015 to 2019.

The significance 2-tailed value is more than 0.5 which means that the relationship between dengue and rainfall distribution in Kuantan from 2015 till 2019 is not statistically significant. The Pearson correlation analysis already determined the relationship between the dengue cases and the weather variable (rain) at Kuantan based on the five years of study (2015-2019). From 2015 to 2019, the connection between dengue and rainfall in Kuantan was not statistically significant. These findings suggest that, in addition to severe rainfall, other factors may be to blame for the rise in dengue cases in Kuantan.

To provide a more graphical representation of the relationship between dengue cases and rainfall amount, a heat map of rainfall and dengue cases data in Kuantan from 2015 to 2019 was created. Each darker graphic colour in the heatmap exhibits a greater value than the lighter colour. Different colours show different values. Similarly, the same colour stands for the same value. A heat map is another data visualisation tool that depicts the magnitude of a phenomenon in two dimensions as colour. Colour variations can be created by hue or intensity, providing visual cues as to how the events are grouped or altered. Heatmaps are employed in a variety of analyses, but in this study, they are utilised to highlight the relationship between the number of dengue cases and the amount of rainfall. The heatmap for this study is shown in Figure 4.

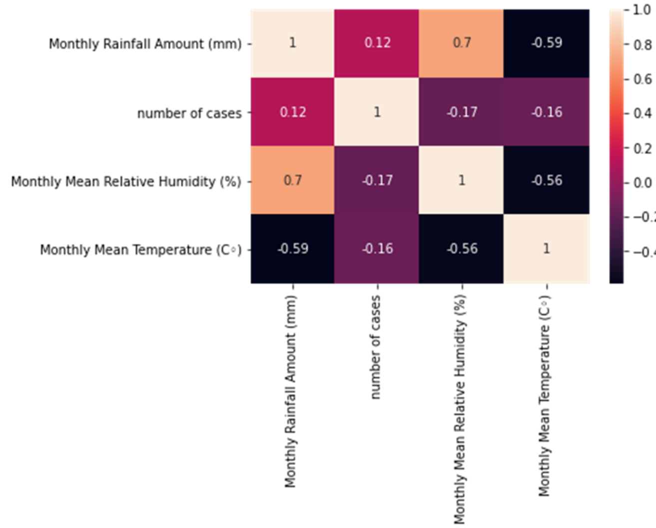

Figure 4. Heatmap between factors for rain and dengue cases data in Kuantan for 2015 to 2019

Each plot shows the correlation between the variables on each axis. The correlation ranges from -1 to +1. A value close to 0 indicates that there is no relationship between the two variables. Closer to 1 correlation values have a more positive correlation, and increasing and becoming closer to 1 will lead this association to get stronger. Correlations closer to -1 are similar, except instead of both increasing, one variable will drop while the other grows. Diagonals all focus on a single colour because each collared box connects each variable to itself to indicate a perfect correlation. The rest, the larger the number and the deeper the colour (dark purple/black), the stronger the association between the factors examined. The plot is also symmetric about the diagonal since two identical variables are paired together in the plot. The major point here is that the association between the number of dengue cases and rainfall distribution is 0.12, which suggests that the value is far from significant in terms of the relationship between these two variables. This is due to the fact that the value of 0.12 is distant from the correlation value of 1.

The requirement to visualise distribution patterns to improve dengue case management in Malaysia necessitates the generation of models for spatio-temporal patterns using graphs and geographical diagrams based on GIS software (Majid et al., 2019). Dengue case distribution pattern analysis was successfully demonstrated in this study. According to the case distribution depicted in Figure 3, dengue cases in Kuantan are more centralised and grouped.

The majority of the instances are centred in the vicinity of Jalan Semambu in Kuala Kuantan. The examination of this study's geographical spatiotemporal pattern clearly demonstrates that Kuala Kuantan has a significant concentration of case distribution each year from 2015 to 2019. Previous research have shown that a centralised spatial pattern for the distribution of dengue cases occurs in the Seremban district (Majid et al., 2019).

As the rainfall is a variable that has been highlighted in influencing dengue cases, it is related to the location of Kuantan on Malaysia's east coast, which has a high quantity of rainfall virtually every year (Cheong et al. 2013; Hii et al. 2009). The situation led to the idea that dengue cases worsen when the amount of rainfall is large. According to the analysis, the high distribution of dengue in Kuantan district from 2015 to 2019 is unaffected by the high distribution of rainfall. This is clear when, in 2017 and 2018, Kuantan experienced a lot of rain, but the number of dengue cases recorded was lower compared to the previous three years. This shows that other reasons are driving the increase in dengue cases. According to earlier study, the increase in dengue infections is also related to human everyday activities requiring water in order to manage daily necessities, which has allowed Aedes mosquitoes to spawn in any reservoir of water produced by such activities (Arham et al., 2018). This fact emphasizes the significance of hygiene control in all daily activities, particularly those involving the usage and presence of water.

The pattern of dengue case spread in Kuantan from 2015 to 2019 has been properly analysed using acceptable scientific methods. According to a monthly data analysis, dengue is a non-seasonal disease in the Kuantan area, with its peak occurring outside of the rainy season. When observed in 2015, the total rainfall distribution was the lowest compared to the other four years with a rate of 1947.6 mm per year. However, when compared to the previous four years, 2015 had the greatest number of dengue cases. Despite the fact that all five years of data revealed a centralised pattern of data that clearly showed the hotspots area of dengue cases that occurred from 2015 to 2019. Hotspot locations are community groups that are at a high risk of developing dengue virus (Dom et al., 2012). All of this information is extremely valuable for managing Dengue control in Malaysia, and it also contributes to the field of study dengue management (Lee et al., 2015).

4. CONCLUSION

Pattern analysis and spatio-geographical diagrams are helpful in understanding the distribution of dengue cases in the Kuantan district. In order to improve the list of references for information on findings of distribution of dengue cases in the country, the analysis and the pattern of spatial distribution distribution was also undertaken. In addition, it reveals that Dengue cases of the coastal regions in Kuala Kuantan were most concentrated between 2015 and 2019. Over the five years analysed, there was a definite case centralization tendency. The spread of this centralization tendency demonstrates that there are variables influencing the centralization of dengue cases in Kuala Kuantan. Most importantly, this implies that using spatio-modeling causes the majority of reported dengue case studies to be clustered in specific places. In terms of the relationship between the distribution of dengue cases and the amount of rainfall in Kuantan, it is improbable that there are other explanations for the growth and decrease in the number of dengue cases in Kuantan from 2015 to 2019 other than the amount of rainfall. This is because the rainfall distribution elements investigated were shown to be unrelated to dengue cases in Kuantan from 2015 to 2019. The findings of this study indicate the probability of other undiscovered factors impacting the pattern of dengue cases which is centralised and influences the fluctuation of dengue occurrences in Kuantan. One of the required efforts made for the time being is a collaborative effort of the local community in cleaning the surrounding area, which is one of the finest activities in preventing breeding and managing Aedes mosquitoes.

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