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Research approaches on dengue surveillance in Malaysia from 2010-2016: A systematic review

Mohd Zulhafiz Mohd Yajid [1,3], Nazri Che Dom[1,2], Siti Nazrina Camalxaman[1]

[1]*Faculty of Health Sciences, Universiti Teknologi MARA, 42300 Puncak Alam Selangor*
[2]*Integrated Mosquito Research Group (I-MeRGe), Faculty of Health Sciences, Universiti Teknologi MARA*
[3]*Pejabat Kesihatan Daerah Tampin, 73009, Tampin, Negeri Sembilan*

Corresponding author: nazricd@salam.uitm.edu.my; nazricd@salam.uitm.edu.my
Faculty of Health Sciences, Universiti Teknologi MARA, 42300 Puncak Alam, Selangor;
Office Telephone Number: 0332584447; Fax Number: 03-32584567

ABSTRACT

Objective: This review provides current information on dengue surveillance approaches in Malaysia from 2010 to 2016 based on analysis of published studies.

Method: A systematic literature search on the topic was conducted using appropriate databases to identify potentially relevant citations. Articles were screened and data from selected studies were extracted based on pre-identified variables.

Result: To date, the majority of dengue studies in Malaysia have utilized quantitative methods. In addition, the advancement and use of GIS-based models have gained popularity to analyze DF risk and to map its distribution. In general, the level of dengue epidemic depends on its antecedents. Nevertheless, limited information is currently available in terms of classification of patterns based on their predictive power.

Conclusion: Although still in infancy, the integration of GIS technology has great potential to strengthen dengue surveillance studies in Malaysia. For this reason, the integration of spatial and temporal data of local DF cases needs to be further developed.

Keywords: *Dengue surveillance, GIS, mapping, Malaysia*

1. Introduction

Dengue fever (DF) is a mosquito-borne viral disease that has become an important public health concern in Malaysia and other tropical countries worldwide (Seng *et al.*, 2005; Barniol *et al.*, 2011). Malaysia has the suitable tropical climate that favours the breeding of *Aedes* mosquitoes (Seng *et al.*, 2005). The first reported DF case in Malaysia was in 1902, and the emergence of dengue haemorrhagic fever (DHF) was documented in 1962. Notifications of DF was instituted which required all medical practitioners to report any case of confirmed or suspected DF or DHF to the nearest health office(Teng & Singh, 2001).

Four closely related but antigenically distinct single-stranded RNA dengue viruses exits, denoted as DEN 1-4, of the genus Flavivirus, belonging to the Flaviviridae family. The viruses are transmitted through its vectors namely *Ae. aegypti* and *Ae. albopictus* (Ferguson *et al.*, 1999; Garba *et al.*, 2008; Morin *et al.*, 2013), predominantly in urbanized communities as well as rural areas in Malaysia. These species are closely related with human habitat and can easily breed, feed, rest in and around houses (Er *et al.*, 2010; Jansen & Beebe, 2010). *Aedes* mosquitoes prefer to feed on human blood to produce eggs and therefore, only female mosquitoes can transmit dengue virus and it frequently boost on multiple hosts during a single gonotrophic cycle.

Methods of dengue prevention and control in Malaysia are based on five elements; i) vector control, based on the principles of integrated vector management; ii) active disease surveillance based on a comprehensive health information system; iii) emergency preparedness; iv) capacity building and training; and v) vector control research (Song, 2016).

Surveillance of *Aedes* potential breeding sites involves house and premise inspection by health authorities. Such efforts are conducted with the intention to educate the public means to prevent *Aedes* breeding sites and the application of Abate larvicide (Foong *et al.*, 2000;Song, 2016). Once the health authorities detect *Aedes* larva within their premises, the Disease-Bearing Insect Act 1975 will be enforced to the owner of the premise (Song, 2016).

Planning, organization, executing and monitoring activities for the modification or manipulation of environmental factors with the purpose to prevent or reduce vector propagation and human, vector and pathogen contact in Environmental Management is the most effective means of vector control (WHO, 1997). This article describes the possible influence of environmental factors on dengue transmission in Malaysia as described in the literature from 2010 to2016. It was conducted to determine gaps in the spatio-temporal features of dengue fever.

2. Materials and Method

Systematic reviews and meta-analyses are essential tools for summarizing evidence accurately and reliably. The outlines of a systematic review of dengue surveillance in Malaysia is shown in Figure 1 based on preferred reporting items for systematic reviews and meta-analyses (PRISMA) guideline (Moher *et al*., 2009). Searches of published literature for epidemiological studies of dengue disease were conducted between July 2017 and October 2017, by using the following databases: ResearchGate; Springerlink; Science Direct; PLoS; NIH Public Access; and PubMed. Searches were run by using the keyword including "*Dengue Surveillance*", "*Mapping*" and "*Malaysia*" where the original papers published in local and international journals from 2010 to 2016 were selected.

A total of fifty-six articles were retrieved through initial search using databases (*n*=43), and Google Scholar (*n*=13). From this initial search, nine articles were duplicates and hence removed. After removing duplicate citations, the selected full text of published sources was retrieved electronically and final selection of relevant sources to include was performed in a second review which is to ensure that the articles complied with the search inclusion and exclusion criteria. Finally, a total of seventeen articles were included in this meta-analysis and critically reviewed as summarized in Figure 1.

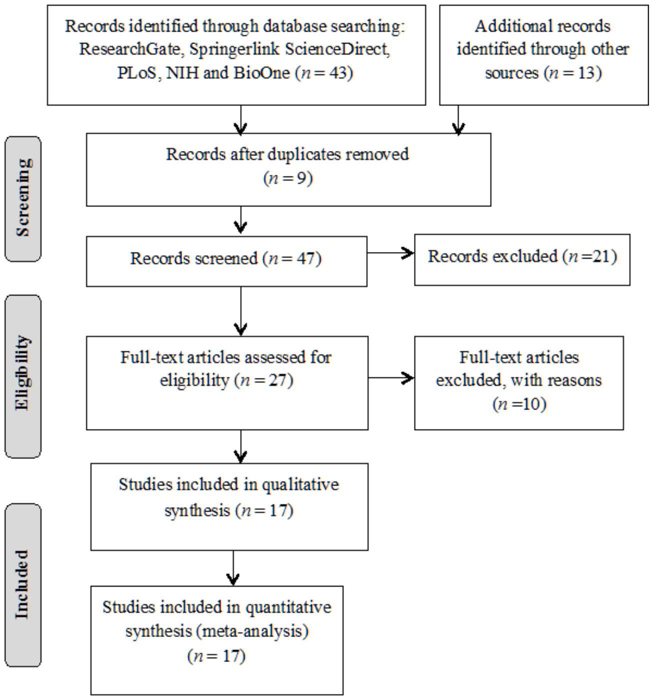

Figure 1.The outlines of a systematic review of dengue surveillance in Malaysia based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Moher *et al*., 2009)

3. Results

3.1. Characteristics of Dengue Surveillance

Table 1 present the characteristics of dengue surveillance in Malaysia according to categorization of study. In terms of study population, most of studies were performed in Klang Valley where Selangor (*n*=11) areas are the targeted area followed by Kuala Lumpur (*n*=4) and Putrajaya (*n*=2). There were two studies conducted outside the Klang Valley which is in Negeri Sembilan and Penang (*n*=1). Most research employed descriptive methodologies.

A key factor that contributed to dengue infection which had an impact on the spread of dengue was identified. The factor was listed in an operating category that consists of environmental characteristics (land use, house types, temperature, rainfall, temporal, climate, and weather) and human population. Most of the studies were based on human population (Er*et al.*, 2010; Hassan *et al.*, 2012; Nazri *et al.*, 2013; Ling *et al.*, 2014; Nazri*et al.*, 2016; and Hazrin*et al.*, 2016), temporal indices (Nazri*et al.*, 2010, Nazri*et al.*, 2012, Nazri *et al.*, 2013, Naim*et al.*, 2014 and Masnita*et al.*, 2016), climate (Nazri *et al.*, 2011; Nazri *et al.*, 2013; Bryan Paul and Tham, 2015), land use (Nazri *et al.* 2011 and Nazri *et al.* 2016) and rainfall(Aziz *et al.*, 2012;Hassan *et al.*, 2012). Three additional factors that have been included in the study were environmental characteristics, weather, and house types which have been explored by Aziz, 2011, Ling *et al.*, 2013and Nazri *et al.*, 2016 respectively.The duration of data collection is listed in the table where most of the studies involved a minimum of one year and maximum seven years duration for data observation. For example, Naim *et al.*, 2014 took seven years data of dengue cases in order to assess society's vulnerability towards dengue.

Table 1. Studies included in the meta-analysis of dengue surveillance in Malaysia from 2010 to 2016.

Ref. ID	Author	Study Population	Operating Category	Year of Observations						
				1st	2nd	3rd	4th	5th	6th	7th
A1	Hazrin *et al.* 2016	Putrajaya	• Human Population	■	■	■				
A2	Nazri *et al.* 2016	Subang Jaya, Selangor	• Human Population • Land use • House Types	■	■	■	■	■		
A3	Masnita *et al.* 2016	Jempol, Negeri Sembilan	• Temporal	■	■	■	■	■		
A4	Bryan Paul & Tham, 2015	Malaysia	• Climate	■						
A5	Naim *et al.* 2014	Seremban, Negeri Sembilan	• Temporal	■	■	■	■	■	■	■
A6	Ling *et al.* 2014	Selangor and Kuala Lumpur	• Human Population	■	■	■				
A7	Nazri *et al.* 2013a	Subang Jaya, Selangor	• Climate	■	■	■	■	■		
A8	Nazri *et al.* 2013b	Subang Jaya, Selangor	• Human Population	■	■	■	■	■		
A9	Ling *et al.* 2013	Selangor, Kuala Lumpur and Putrajaya	• Weather	■	■	■				
A10	Nazri *et al.* 2013c	Subang Jaya, Selangor	• Temporal	■	■	■	■	■		
A11	Hassan *et al.* 2012	Selangor and Kuala Lumpur	• Rainfall • Human Population	■						
A12	Nazri *et al.* 2012	Subang Jaya, Selangor	• Temporal	■	■	■	■	■		
A13	Aziz *et al.* 2012	Kuala Lumpur	• Rainfall	■						
A14	Nazri *et al.* 2011	Subang Jaya, Selangor	• Climate • Land use	■	■	■	■	■	■	
A15	Aziz, 2011	Georgetown, Pulau Pinang	• Environmental Characteristics	■	■	■	■			
A16	Er *et al.* 2010	Hulu Langat, Selangor	• Human Population	■						
A17	Nazri *et al.* 2010	Subang Jaya, Selangor	• Temporal	■	■	■	■			

Note :Symbol (■) indicated the study period

Table 2.Study and potential factors in dengue epidemic in Malaysia, 2010-2016.

Ref ID	Research Focus	Model used	Findings
A1	Spatial distributions of dengue cases	GIS, Moran's I, Average Nearest Neighbour (ANN) and Kernel density	• *Moran's I* test showed that spatial autocorrelation among dengue incidence was positive • ANN analysis stated that the dengue cases were highly clustered and the significant spatial autocorrelation of dengue incidences was found occurred at an average distance of 264.91 meters. • Kernel density estimation was a practical tool to locate the "hot spot" with maximum dengue incidence density. • GIS and spatial statistic tools used can determine the spatial autocorrelation between dengue cases and population.
A2	Factor associated with dengue risk	Analytical Hierarchy process (AHP)	• Housing types, population density, land-use and elevation are the most influential factors for DF incidence. • The GIS and spatial analytical method can be used for surveillance strategies of DF.
A3	Factor associated with dengue risk	Temporal analysis	• Epidemics dynamics and risk distribution can be characterized based on epidemic spatial and temporal aspects.
A4	Factor associated with dengue fever occurrence	Pearson correlation and ANOVA	• There is no positive correlation in increasing dengue transmission between temperature and precipitation . • The author considers that the reported number of dengue cases will continue to vary depending on how global warming affects the regional and local climate.
A5	Relationship between temporal pattern and dengue outbreak	GIS, Temporal analysis, LISA, Moran's I, Average Nearest Neighbour (ANN) and Kernel density	• A significant clustering pattern of dengue cases in the study area with Moran's Index of 0.16. • Average distance of dengue cases by ANN was within 55m ($p<0.001$). • The specific area that are vulnerable to dengue outbreaks is enables to identify by using Spatial- temporal analysis.
A6	Interpretation of dengue fever occurrence	Kulldorff's spatial scan statistic	• Combination of the outbreak information from address and sub-district level facilitates the planning of effective health interventions.
A7	Prediction model for dengue fever infection	Autoregressive Integrated Moving Average (ARIMA)	• Arima closely described the trends of dengue incidence and confirm the existence of DF cases. • ARIMA was found to be best fit and consistent to predict the dengue incidence.
A8	Spatial distributions of dengue cases	GIS, Average Nearest Neighbour (ANN) and Kernel Density	• Based on the monthly frequency data during the 5-year period, the spatial patterns of dengue fever cases were spatially clustered.. • KD techniques showed a spatially diffused pattern on the hotspot map.
A9	Factor associated with dengue risk	Poisson GAM model	• Dengue cases are positively associated with increased minimum temperature. • Rainfall had a positively strong effect on dengue cases. • The wind speed is negatively associated with dengue cases.
A10	Factor associated with dengue risk	GIS and Temporal analysis	• There was no significant difference except for the existence of abandoned houses across the study area for the environmental attributes. • Temporal indices were found high in the locality for breeding index.
A11	Spatial distributions of dengue cases	GIS and Co-kriging	• There are positive correlation between population density and risk for outbreaks. • High volume of rainfall provide more breeding sites and hence increases *Aedes* survival. • Risk map capable to show general predictions of high-risk areas based on population density and rainfall variables.
A12	Factor associated with dengue risk	GIS and Temporal analysis	• There were areas with significant high value for each of the temporal indices.
A13	Factor associated with dengue risk	GIS and Average Nearest Neighbor (ANN) analysis	• The distribution of dengue cases was spatially clustered. • The spatial autocorrelation between dengue cases and population can determine by using GIS and spatial statistical tools
A14	Factor associated with dengue risk	GIS and ERDAS imaging	• Weather variables including relative humidity, temperature and precipitation have significant correlation with confirmed dengue cases distribution.
A15	Factor associated with dengue risk	GIS and logistic regression analysis	• Population density influences the probability of the incidence of DF and DHF. • The occurrence and spread of disease was influence by Environmental characteristics. • The risk areas is possible to predict without relying on the information about the density of mosquitoes or the occurrence of cases.
A16	Spatial distributions of dengue cases	GIS, Moran's I, average nearest neighborhood (ANN) and kernel density	• ANN analysis indicacated that the ratio is less than 1 which is 0.518755 ($p < 0.0001$). • Dengue cases pattern in Hulu Langat district is exhibiting a cluster pattern. • The significant spatial autocorrelation of dengue incidences occurs at an average distance of 380.81 meters ($p < 0.0001$).
A17	Factor associated with dengue risk	GIS and Temporal analysis	• There is no significant distribution pattern for intensity index as the high value tended to stay at the same locality throughout the years. • There was a strong correlation between frequency-duration relation, frequency-intensity relation and duration-intensity relation.

4. Discussion

Majority of the previous studies on dengue surveillance focussed on several operating categories that can be classified into climatic and non-climatic factors that have impacts on the spread of dengue. The study of climatic factors included rainfall (Hassan *et al*., 2012 and Aziz *et al*., 2012), temperature (Bryan Paul &Tham, 2015 and Nazri *et al.*, 2013a), and humidity (Nazri*et al.*, 2013b). The study of non-climatic factors included human population (Hazrin *et al.* 2016;Nazri*et al.,* 2016; Ling *et al.,* 2014; Nazri*et al.,* 2013,Hassan *et al.,* 2012, and Er*et al.,* 2010), land use activity (Nazri*et al.*, 2011 and Nazri *et al*., 2016), house type (Nazri*et al.*, 2016) and temporal indices (Masnita *et al*., 2016; Naim*et al*., 2014; Nazri*et al*., 2013c; Nazri*et al*., 2012 and Nazri*et al*., 2010). Between this ranges of study, most of them chose non-climatic factors in their operating category rather than climatic factors.

Most studies of dengue epidemic in Malaysia have been based on quantitative approaches (Table 2). For example, Nazri *et al*., (2016) proposed an Analytical Hierarchy Process (AHP) with housing types, population density, land-use and elevation as the predictor and confirmed that most factor have influential factors for the occurrence of DF incidence. Hazrin*et al*., (2016) focused on spatial distribution of dengue cases in Putrajaya, by investigating area with high dengue incidence but have not included any climate factors in their analysis. Bryan Paul &Tham (2015) proposed a nonlinear model based on climatic factors concluded that correlation between temperature and precipitation in increasing dengue transmission were negative. Depending on how global warming affects regional and local climate, the authors assume that the number of reported dengue cases would continue to fluctuate. The retrospective analysis also showed that temporal pattern is not a probable predictor of dengue outbreak. This implies that dengue outbreaks are becoming increasingly unpredictable due to the rapid climate change (Nazri*et al*., 2013a;Nazri*et al*., 2013b).

There have been a growing number of studies utilizing Geographical information system (GIS) to analyze dengue fever risk. Majority of the studies use GIS as a tool in developing the map for distribution of dengue cases. Naimet al., (2014) used GIS to examine the spatial and temporal distribution of dengue outbreak in Seremban, Negeri Sembilan. The spatial clustering pattern for all reported cases was characterized by spatio-temporal analysis. The control measures within the areas surrounding houses of reported cases have to be changed where the control measures should be applied to an entire municipality due to the rapid temporal and spatial spread of the disease within the community. Most of the statistical analysis using spatial data can now be performed in a GIS environment. Spatial analysis that commonly used in the study are *Moran's I*, Average Nearest Neighbour (ANN) and kernel density (Hazrin*et al.,* 2016, Nazri *et al.,* 2013a, Naim *et al.,* 2014, Aziz *et al.,* 2012 and Er *et al.,* 2010). *Moran's I* was used within the study area to analyse whether all the reported cases are spatially correlated or not and ANN used to evaluate the pattern of clustering of the dengue cases while kernel density (KD) was used to analyse dengue hot spots area. All the aforementioned studies documented that the use of GIS technology and spatial analysis can provide precious information to forecast future outbreaks of DF cases.

A time series model showed that a dengue epidemic in Malaysia was associated with time periods as well as environment and climate (Nazri*et al*., 2010; Aziz, 2011; Naim*et al*., 2014), while temperature was identified as a relevant factor for dengue fever epidemic in Kuala Lumpur and Putrajaya (Ling *et al*., 2014). A Poison GAM model was used to determine the association of weather variable (temperature, rainfall and wind speed) on the occurrence of DF cases. The review as tabulated in Table 2 shows that most studies in Malaysia focus on climate factors (temperature, humidity and rainfall) without an integrated environment, human population and temporal factors. In general, the level of dengue epidemic depends on its predecessor, but previous studies provide limited information with regards to classifying factors according to their predictive power. For example, it is unknown whether temperature is a stronger predictor than humidity or vice-versa.

Environmental factors contribute and interact in determining the transmission of dengue (Aziz, 2011; Nazri*et al*., 2011; Nazri*et al*., 2016). Unplanned and uncontrolled urbanization was due to the population growth. This resulted in the deterioration of water and waste management in urban centers. The ideal condition for increased of DF cases was created by the growth of human populations living in intimate contact with increasingly high densities of mosquito populations (Er*et al*., 2010; Hassan *et al*., 2012). Immune status, mosquito breeding and other factors pertaining to the host was also affected by environment factors. In addition, these factors may also have an impact on human behaviour, demographics and the likelihood of human exposure to dengue (Ling *et al*., 2014; Hazrin*et al*., 2016). Relative humidity, temperature and precipitation have significant correlation with confirmed distribution as documented by Nazri *et al.* 2011. This finding is similar to Ling *et al.* 2013 where dengue cases are positively associated with an increase in the minimum temperature. But one article stated that there is no correlation between temperature and precipitation in increasing dengue transmission (Bryan Paul &Tham, 2015).

The relationships between climate variation and dengue disease have been examined by some studies (Nazri*et al*., 2011; Aziz *et al*., 2012; Hassan *et al*., 2012). Several approaches have been used to assess the distribution of DF cases in a locality. However, in previous study, some important methodological issues have not been formally addressed such as stationary and auto-correlation of spatial-temporal data. Fully integrated spatial-temporal data need to be further developed for local DF cases in Malaysia.

According to the literature, the current knowledge gap of the previous study only deals with the factors causing the spread of dengue without considering the spatio-temporal features of this disease. Fully integrated spatio-temporal datahave not been formally attempted. From the methodological point of view, the mapping of dengue cases found in the literature can be summarized by the following phases: (i) Multiple factors including environmental characteristics was used to determination of DF cases; (ii) Identification to vector development can limit DF cases and (iii) Introduction of DF cases data for evaluating the pattern and behaviour of the cases. In many studies, all phases have been used in different ways, with a variety of alternatives for subjective assessment, the literature or expert consultation dedicated to the use of statistical techniques and simulation models. In epidemiology, maps have been used for two diverse purposes. The first involved retrospective analysis of spatio-temporal dynamic of disease transmission and also used to describe the characteristics of "*travelling waves*" in epidemics.

5. Conclusion

In summary, most of the research conducted highlighted the value of open data mining in the context of public health care by using GIS. This application has great potential for dengue surveillance in Malaysia based on the following notions (i) the utilization of data mining to predict dengue epidemic, (ii) the integration of multiple open data sources and (iii) the derivation of practical insights from empirical qualitative surveys of specialist and experts. Results show that classification-oriented data mining technique can be successfully applied to Malaysia dengue open data. From the health care management perspectives, variables used to describe Malaysia dengue epidemic are mainly congenital (location, season, climate and individual) and hence mostly are uncontrollable or acquired and derived from existing relationships. Therefore, future studies should emphasize the possible impacts of such factors on DF.

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