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A SPATIAL CLUSTERING APPROACH TO IDENTIFY RISK AREAS OF DENGUE INFECTION AFTER INSECTICIDE SPRAYING

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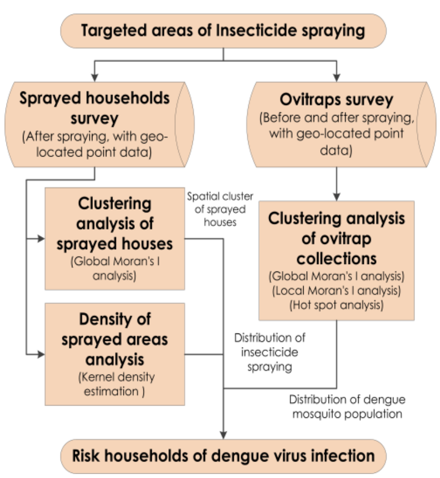
Graphical abstract



Abstract

This study aims to demonstrate a spatial clustering approach for identifying risk households of dengue virus infection during the period of insecticide spraying-ultra low volume (ULV). All households located within 100 m radius of spraying area were recorded with geographic coordinates and divide into three groups of spraying (unsprayed, only outdoor and indoor plus outdoor sprayed house). A total of 45 households with geographic coordinates, were randomly selected to monitor ovitrap index, the percentage of positive ovitraps and the number of eggs per trap, in pre- and post-ULV spraying. Application of spatial analyst tools and spatial statistics tools in ArcGIS 10.1 were used to determine mosquito density and identify risk households using ovitrap index. The prediction maps of *Aedes aegypti* vector abundance were illustrated by kriging technique. Base on the results, the cluster of *Ae. aegypti* populations were detected on four day after the spraying. This finding shows the significant spatial pattern of dengue vector populations which may cause high risk areas of dengue virus infection after insecticide treatment. This methodological framework could be used for improving the strategy of dengue vector and outbreak control. The spatial association between dengue vector and the coverage of space spraying requires further study.

Keywords: Spatial clustering, *Aedes aegypti*, Dengue, Ultra low volume, Ovitrap

1.0 INTRODUCTION

At dengue outbreak areas, space spraying, thermal fogs and ultra low volume (ULV), is the major method to reduce dengue virus transmitted mosquito, adult female *Aedes aegypti*, populations using insecticide control [1]. However, there were insufficient evidences that the insecticide spraying is the effective way to prevent dengue virus infection [2]. In addition, human health and environmental impact of chemical spray to control dengue vector has become the public concerns [3].

Behavioral avoidance to insecticides of mosquitoes may reduce the effectiveness of chemical vector control measures [4]. In laboratory, a small number of ULV droplets with sub-lethal of synthetic pyrethroids on mosquito bodies cause immediate excitation movements of flying mosquito, increasing duration of fight and speed [5]. After insecticide treatment, the immigration pattern from untreated to treated areas of *Ae. aegypti* populations were detected [6]. Similarly on previous study, it has been presented that the recovery of adult female *Ae. aegypti* population density after the spraying in the endemic urban area is rapid within a week [7]. Thus, it is possible that the actions of ULV spraying on mosquitoes not only the direct toxicity (knockdown/death) but also the excitation or repellency, which may play a critical role to improve chemical control intervention of transmitted dengue mosquitoes [4, 8]. The escape effect of external ULV spray which may cause high risk of dengue virus infection in the group of households without spraying with rapid immigration of transmitted mosquitoes from treated houses is still lacking.

During dengue outbreaks, the prioritized areas of proactive vector control with high or low risk of dengue transmission were determined using the Priority Area Classification (PAC), the mapping approaches of entomological indices [9]. Ovitrap Index, the percentage of positive ovitraps and the number of eggs per trap, is the entomological parameter of *Ae. aegypti* to assess the impact of insecticide spray treatment [10]. The predict map of Potential Breeding and Resting (PBR) sites of *Ae. aegypti* was generated by total egg numbers of ovitrap using spatial autocorrelation, Moran's Index and hot spot identity [11]. The ovitrap survey was used to estimate the spatial risk of urban dengue infection using a geographic information system (GIS) [12]. Moreover, the study of a space-time clusters analysis shows that vector monitored by ovitrap and mosquito trap can use to predict the risk of dengue transmission [13].

The objective of this study is to develop a spatial clustering method to identify households within dengue transmission risk areas after insecticide spraying, by using households and ovitraps survey data (Figure 1).

2.0 EXPERIMENTAL

2.1 Ethics Statement

The study received approval from the ethics committee of Prince of Songkla University, Thailand. The Ethical Protocol number is 57-068-19-9. All respondents signed an informed consent form.

2.2 Study Site

The study site (7°12′ N, 100°36′ E) with tropical monsoon climate, is located in Songkhla province, lower southern Thailand. Songkhla City municipality was divided into 32 communities, 26,000 households with population of 71,000 people and density of population of 7,400 persons per sq. km. in 2013. Thasaan community of Songkhla City was randomly selected as study site with population of 4,074 people and 1,513 households.

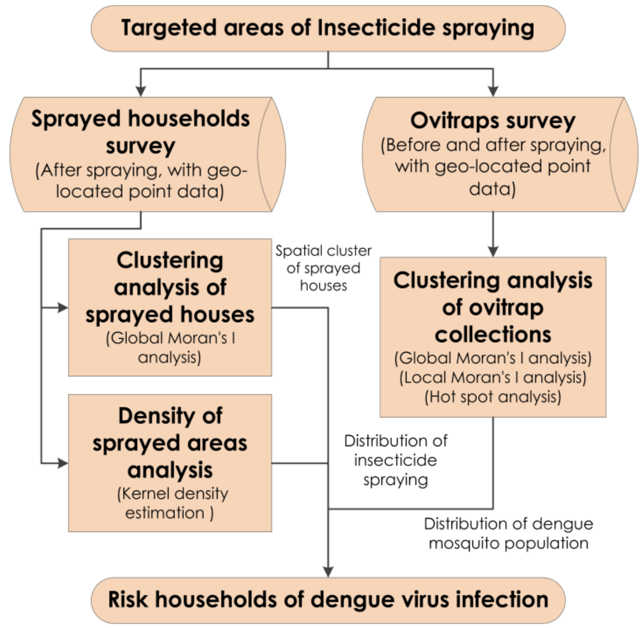


Figure 1 The methodological framework of spatial clustering approach to identify the risk households of dengue virus infection

2.3 Spraying Operation

Base on guideline of WHO [14], the hand-portable ULV generators (Fontan Portastar S, Germany) and chemical (Deltamethrin 2% w/v) were calibrated at the Office of Disease Prevention and Control 12 (DPC-12) before the space spraying of insecticide for prevention and control of mosquito vectors were carried out by DPC-12 staff. The spraying area cover all households located in a circle of 100 m radius.

2.4 Ovitrap Collection

Base on guideline of WHO [10], the oviposition activity of adult female *Ae. aegypti* populations in treated area were monitored at pre- and post-space spraying by using infusion-baited ovitraps. A total of 45 households were randomly collected ovitraps in March 2014. Ovitraps were placed indoors (living room, bath room or kitchen) and outdoors (sheltered areas) of houses. Ovitrap collections were performed and replaced at the same time every two day on day of spraying (D0), and after 2 (D2), 4 (D4) and 6 (D6) days of spraying in the same house. The percentage of positive ovitraps and the number of eggs per trap were counted in the laboratory with the aid of a magnifying glass at Faculty of Medical Technology, Prince of Songkla University.

2.5 Spatial Clustering Analysis

To display and analyze spatial data of households and ovitrap survey we used Spatial Analyst Tools and Spatial Statistics Tools [15] in ArcGIS 10.1 (ESRI ArcGISTM, Redlands, CA, United States) with high-resolution satellite images from Southern Regional Geo-Informatics and Space Technology Center, Faculty of Environmental Management, Prince of Songkla University.

2.5.1 Spatial Clustering Of Sprayed Houses and Area

The spatial analyses were carried out on dataset of geo-located houses in spraying areas. To determined the distribution of sprayed houses, we used Average Nearest Neighbor Analysis to calculate mean distance of houses, and to identify the location of cluster or hotspots of significant sprayed houses (unsprayed, outdoor sprayed and indoor plus outdoor sprayed houses) by using Cluster and Outlier Analysis (Anselin Local Moran's I) [15]. We used Kernel Density to calculate and display the density of sprayed area.

2.5.2 Spatial Clustering of Ovitrap Collections

To determine the distribution of ovitraps, we used Average Nearest Neighbor Analysis to calculate mean distance of ovitrap collected houses. We used Hot Spot Analysis (Getis-Ord Gi*) to identify statistically significant hot spots and cold spots of number of *Ae. aegypti* eggs, and to identify the location of hotspots by using Cluster and Outlier Analysis (Anselin Local Moran's I). To illustrated the spatial pattern of *Ae. aegypti* eggs, we used Kriging Interpolation to create prediction maps [15].

3.0 RESULTS AND DISCUSSION

3.1 The Mosquito Oviposition Survey Data

A total of 253 ovitraps, comprising 124 (49%) indoor ovitraps and 129 (51%) outdoor ovitraps, were collected with the percentage of positive ovitraps of 53 (indoor traps) and 47 (outdoor traps), and the mean numbers of *Ae. aegypti* eggs per trap (SD) of 14(24) indoor traps and 14(37) outdoor traps. In a comparison between the two places (indoor and outdoor) of ovitrap, there were not significantly different.

3.2 Spatial Cluster of Sprayed Houses

A total of 444 houses, comprising 208 (46.8%) unsprayed houses, 70 (15.8%) only outdoor sprayed houses and 166 (37.4%) indoor plus outdoor sprayed houses, located in Thasaan treatment area. Global Moran's I analysis of study sites revealed that types of sprayed houses was significantly clustered (Table 1). The result revealed that high coverage of indoor insecticide spraying as vector control intervention need more community involvement with awareness of household owner to allow inside house spraying. Because indoor sprayed was more effective to suppress the transmitted mosquito [16], two clusters of households (unsprayed and only outdoor sprayed) likely be still habitats of *Ae. aegypti* mosquito which is risk areas of dengue infection after conducted space spraying.

Table 1 Spatial characteristics of houses and ovitraps survey data in Thasaan community

Spatial characteristics of survey data	Thasaan
Data of collected ovitrap houses	
Number of collected ovitrap houses	45
Mean distance to the nearest neighbor (m)	18.1
Data of sprayed houses	
Number of sprayed houses (100 m radius)	444
Number of unsprayed houses (%)	208 (46.8)
Number of outdoor sprayed houses (%)	70 (15.8)
Number of indoor plus outdoor sprayed houses (%)	166 (37.4)
Mean distance to the nearest neighbor (m)	5.6
Global Moran's I analysis of sprayed houses	
Moran's Index	0.04
Z-score	2.07
P-value	0.04
Spatial pattern of type of sprayed houses	Cluster

3.3 Distribution of Insecticide Spraying

As Figure 2 (A) shows, the maps of high and low value of indoor sprayed houses was determined by using Anselin Local Moran's I, and displayed spatial pattern by using Kernel density analysis. The method can be help to visualize the spatial distribution of insecticide sprayed. In the next study, to improve the method meteorological factors such as win speed and direction should be use to determined the density of insecticide sprayed [17].

3.4 Distribution of Dengue Mosquito Population

Result of Global Moran's I analysis, there were only significantly clustered of *Ae. aegypti* eggs after space spraying on D4 (Table 2). In addition, the number of hotspots was detected throughout the follow up period, but little locations of hotspots were identified.

As Figure 2 (B) shows, the distribution of *Ae. aegypti* mosquito populations were estimated by using Kriging Interpolation of the number of *Ae. aegypti* eggs per trap by days.

Ovitrap has the potential for predicting adult mosquito abundance [18]. As Table 2 shows, adult female *Ae. aegypti* mosquito activity were cluster detected within four days after ULV spraying. The spatial cluster of adult mosquito abundance was presented by the prediction map (Figure 2 (B)). Base on result, the escape effect of external ULV spray likely play a role in the spread of transmitted mosquito and required further investigation.

Table 2 Spatial distribution of *Ae. eagypti* mosquito after spraying by day of collections of ovitraps in Thasaan study site

Day of collection	Spatial analysis of number of *Aedes aegypti* mosquito eegs per traps	Thasaan	
		Indoor	Outdoor
D_0	Global Moran's I analysis (Cluster detected?)	No	No
	Local Moran's I analysis (Number of clusters)	-	1
	Hot spot analysis (Number of hot spots)	4	1
D_2	Global Moran's I analysis (Cluster detected?)	No	No
	Local Moran's I analysis (Number of clusters)	-	2
	Hot spot analysis (Number of hot spots)	1	3
D_4	Global Moran's I analysis (Cluster detected?)	Yes	No
	Local Moran's I analysis (Number of clusters)	2	1
	Hot spot analysis (Number of hot spots)	3	3
D_6	Global Moran's I analysis (Cluster detected?)	No	No
	Local Moran's I analysis (Number of clusters)	1	2
	Hot spot analysis (Number of hot spots)	3	1

3.5 Risk Households of Dengue Infection

Mapping of risk households of dengue infection were demonstrated in Figure 2 (C) by using overlay analysis of the spatial clustering maps (insecticide spray density map, sprayed houses map and distribution map of *Ae. aegypti* after spraying). To identify high risk households of dengue virus infection, house constructed with corrugated iron sheet and full windows screened [19], and house without being insecticide sprayed were key factors of dengue risk identification.

The results and maps (Figure 2) showed that the spatial distribution patterns of dengue vector after insecticide spraying were significant difference from the baseline. The recovery patterns of *Ae. aegypti* populations were found to be significantly clustered in households located near the border of spraying area within four days after space spraying. In addition, the map revealed that all unsprayed houses located within detected cluster of *Ae. aegypti* populations could be high risk of dengue virus infection after conducted space spraying. The finding of clustering pattern of dengue vector may be related to the behavioral responses of mosquitos to chemical control [4] and environmental factors, housing and man-made breeding sites [1, 16]. However, the limitation of the study was the number of study site. This suggests that the spatial correlation between dengue vector density within insecticide treated areas and environmental factors need further study.

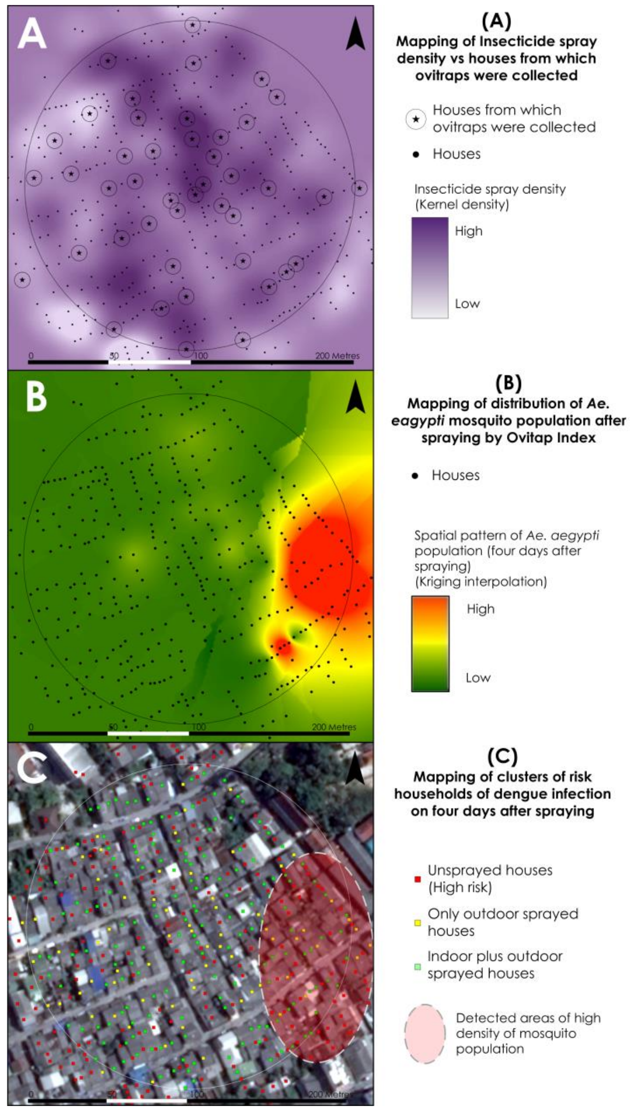


Figure 2 Set of maps showing the results of spatial clustering analysis of the study, A: Mapping insecticide spray density vs houses from which ovitraps were collected, B: Mapping of distribution of *Ae. aegypti* population after spraying by ovitap index, C: Mapping of clusters of risk households of dengue infection on four days after spraying

4.0 CONCLUSION

This study demonstrated the use of spatial clustering analysis to predict risk households of dengue virus infection in endemic urban area after insecticide spraying measure using ovitrap index. The spatial approach can be applied to identify the high risk area of dengue virus infection in household scale which is informative data to reduce and control dengue outbreak in community level. In addition, this method could be use for improving the coverage of space spraying application. The spatial and temporal risk factor analysis can be potential tools for developing the local strategies of dengue prevention and control [20]. However, the spatial association of dengue vector populations, environmental factors and the coverage of insecticide spraying require future study.

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