HOSTED BY
ELSEVIER
Contents lists available at ScienceDirect
Asian Pacific Journal of Tropical Disease
journal homepage: www.elsevier.com/locate/apjtd

Dengue research doi: 10.1016/S2222-1808(16)61158-1

Application of geographical information system-based analytical hierarchy process as a tool for dengue risk assessment

Nazri Che Dom[1*], Abu Hassan Ahmad[2], Zulkiflee Abd Latif[3], Rodziah Ismail[1]

[1]*Faculty of Health Sciences, Universiti Teknologi MARA, Selangor, Malaysia*

[2]*School of Biological Sciences, Universiti Sains Malaysia, Pulau Pinang, Malaysia*

[3]*Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Selangor, Malaysia*

ARTICLE INFO

Article history:
Received 18 Sep 2016
Received in revised form 9 Oct 2016
Accepted 16 Oct 2016
Available online 25 Oct 2016

Keywords:
Dengue
Analytical hierarchy process
Geographical information system
Malaysia

ABSTRACT

Objective: To highlight the use of analytical hierarchy process (AHP) in geographical information system that incorporates environmental indices to generate dengue risk zonation area.

Methods: The medical database considered for the study was referenced to the environmental data layers. Factors related to the risk of dengue fever (DF) were selected throughout previous research and were arranged in a hierarchical structure. The relative weights of factors were calculated, which were within acceptable range with the consistency ratio being less than 0.1. The outcomes from AHP based DF risk zonation area produced useful information on different levels of risks.

Results: As a result, factor weights used in AHP were evaluated and found to be acceptable as the consistency ratio of 0.05, which was < 0.1. The most influential factors were found to be housing types, population density, land-use and elevation. Findings from this study provided valuable insights that could potentially enhance public health initiatives. The geographical information system and spatial analytical method could be applied to augment surveillance strategies of DF and other communicable diseases in an effort to promote actions of prevention and control. The disease surveillance data obtained could be integrated with environmental database in a synergistic way, which will in turn provide additional input towards the development of epidemic forecasting models.

Conclusions: This attempt, if successful, will have significant implications that could strengthen public health interventions and offers priorities in designing the most optimum and sustainable control program to combat dengue in Malaysia.

1. Introduction

Dengue fever (DF) is a vector borne disease which generally emerges in certain season of the year. The major option in preventing the spread of DF is to control and monitor its vector by focusing on specific localization areas and via the destruction of suitable breeding environment. Spatial analysis is capable to identify localized cluster of the disease that is in excess of what would normally have been expected given the underlying population and demographic structure[1]. An analysis of the spatial distribution or dependencies of disease remains to be one of the most important public health interest[2-4]. Therefore, to better understand the distribution of DF in term of time and space, it is essential to develop spatial database, apply spatial statistics and link this information with environmental factors in an area.

The use of spatial analysis in geographical information system (GIS) for health purposes is becoming one of the major techniques to identify spatial association and has thus been adopted by several researchers worldwide[5-7]. The integration of an analytical hierarchy process (AHP) method in GIS for solving spatial planning problems has received considerable attention among multidisciplinary planners. The ability of GIS to integrate with AHP has been demonstrated in several studies related to natural and environmental management[8,9]. Multi-criteria decision making techniques can be used to make the process more explicit, rational and efficient. For such evaluation, AHP is used to determine the weights of each individual characteristic. Determination of weights in AHP depends on the pair-wise rank matrix which was developed based on expert opinion[10]. Systematic decision making process

*Corresponding author: Nazri Che Dom, Ph.D, Faculty of Health Sciences, Universiti Teknologi MARA, Selangor, Malaysia.
Tel: +6019-6143465
E-mail: nazricd@salam.uitm.edu.my
Foundation Project: Supported by the Ministry of Higher Education (600-RMI/FRGS 5/3 (77/2015)).

helps the decision maker to summarize and evaluate information effectively, define the right questions and determine the optimum and most appropriate solutions. The AHP method was applied to derive the weights of parameters because of its simple hierarchical structure, sound mathematical basis, widespread usage and its ability to measure inconsistencies in judgments[3,4,11].

The potential of GIS for disease mapping and risk zonation studies has been proven by several authors when it is integrated with AHP[12,13]. Nakhapakorn and Tripathi performed a study to explore the influence of physical environment factors on dengue incidence in Sukhotai Province, Thailand using the information value method which shows that a built up area has the maximum influence on the incidence of dengue compared to other land-cover of land-uses classes[5]. Rakotomanana *et al*. carried out a study using the multi-criteria evaluation method of weighted linear combination technique with GIS to determine risk zones from the malaria epidemic in the central highlands of Madagascar[14]. Kumar *et al*. used the pair-wise comparison method developed by integrating AHP and GIS based methods to develop the first volume of the Atlas which looks at the spatial distribution of 5 natural hazards (flood, landslide, wind speed, heat and seismic hazards)[15]. Faisal *et al*. used AHP methods to establish and optimize health case waste management systems[16]. Demesouka *et al*. adopted a map-based, interactive AHP implementation, which provided support in terms of methodology with exploratory geographic visualization[17].

Previously, most studies employed GIS and high resolution satellite images to model DF risk by predicting the risk based on a limited number of variables such as mosquito counts. Alternatively, environmental variables would be integrated with DF incidence or with mosquito counts. Such technique has it's limitation and for this reason, we propose the use of multiple variables (*i.e.* confirmed DF cases, population densities, micro-land-use and elevation) to formulate DF risk zones. This study assesses the correlation of DF risk with environmental factors and analyzes the dynamic of DF cases. With those references, this study aims to use environmental variables to develop a DF risk zonation in Subang Jaya using AHP in GIS.

2. Materials and methods

2.1. Study design

Criteria and indicators were evaluated by applying GIS techniques coupled with physical-environment and demographic factors in association with DF incidence locations.

2.2. Determination of preliminary list of criteria

Previous researchers used several factors to analyze the influence of DF incidence such as physical environment, land cover types, location of DF affected, climate factors and population data[5,18-22]. Satellite images and environmental and epidemiological data were also frequently used[23,24]. In tandem, the following physical environment factors were considered in this study (Figure 1).

Data for DF cases were obtained from 2006 to 2010 in order to formulate buffers of specific sizes, affected by DF cases. This buffer was used to identify the geographic environmental conditions such as land-use, water bodies and surrounding conditions of the areas. The buffer distance was considered due to the flight distance factors covered during the lifespan of *Aedes mosquitoes*[25]. The average lifespan of the female mosquitoes is about 8–15 days and it can fly at an average speed of 30–50 m per day. This indicated in general that the female mosquitoes are capable to move about a range of 240–600 m in their life time[26,27].

The land-use map had been used in this study to determine area activities and socio-economic status (residential/housing types). There were various types of land-use classes in the Subang Jaya Municipality including residential, industrial, commercial area, cleared land, dumping site, forest and others. A housing type of classification was used whereby; the house class was been given an attribute based on the possibility and potential of the dengue disease transmission and distribution with the types of houses. Classes of houses were based on the estimation of the level potential of the dengue transmission and the distribution for each houses class. It was important to consider commercial areas as an attribute due to the real situation in the ground where it was found that for some areas, residential houses were located in the same building as the commercial shop. Then, the housing types were classified as interconnection houses, mix houses, independent houses, commercial area and none residential area.

Subang Jaya area had variable topography. Elevation was considered to reflect its influence in risk zonation. Elevation data were created using the Shuttle Radar Topography Mission data collected from the Malaysian Remote Sensing Agency. Annual population data in each locality in Subang Jaya for the period of 2006–2010 were obtained from the Department of Statistics. The data included a variety of population characteristics including educational level.

2.3. The AHP

AHP is a multiple decision making tool which was used in this study to evaluate the environmental assessment towards developing dengue susceptibility risk map based on environmental characteristics. The first step in the AHP methodology was to break down the decision problem into a hierarchy of interrelated decision elements (*i.e.*, to define a goal and identify criteria and sub criteria relevant to identify DF risk zone areas). A hierarchical structure was established to interrelate and chain all decision elements of the hierarchy from the top level down[8,28]. The main objective (DF risk zones) was placed at the top of the hierarchical structure. The lower level of the hierarchical structure consisted of more detailed elements, which interrelated to the criteria in the next higher level. The hierarchical structure of the decision tree was presented in Figure 2.

After the hierarchical structure was established, the relative importance of all decision elements was captured and revealed through pair wise-comparison by creating a ratio matrix. Pair-wise comparisons of the main and the sub-criteria within the same hierarchical level were established. The numerical scales as proposed by Saaty and Vargas ranging from 1 to 9 were used in the pair-wise comparison matrices (Table 1)[29]. AHP was introduced as the most appropriate method because it allowed partitioning the problem and focusing on smaller decision sets one at the time.

Following this, a weighted linear combination (WLC) method, which was one of the most often used techniques for tracking spatial multi-attribute decision making was applied to identify specific DF risk zonation[30]. The method of WLC was used to assess the