Use of Geographical Information System to Study the Epidemiology of Dengue Haemorrhagic Fever in Thailand

By

Ratana Sithiprasasna, Kenneth J. Linthicum

Department of Entomology, Armed Forces Research Institute of Medical Sciences, Bangkok, Thailand

Kriangkrai Lerdthusnee

National Centre for Genetic Engineering and Biotechnology, Rama VI Road, Bangkok 10400, Thailand

Thomas G. Brewer

Headquarters, Armed Forces Research Institute of Medical Sciences, Bangkok, Thailand

Abstract

A Geographical Information System (GIS) was used to study the spatial distribution of dengue haemorrhagic fever (DHF) in Thailand. The National Oceanic and Atmospheric Administration (NOAA) satellite data, with a spatial resolution of 1 km, were used to produce a land cover map and calculate the percentage of forest cover in each province of Thailand. GIS was used as an analysis tool to map the distribution of DHF by creating overlays of epidemiological and digitized province data on a NOAA normalized difference vegetation index image of Thailand. The countrywide GIS database demonstrated that DHF incidence was not correlated to the area of forest cover in the provinces of Thailand. Global Positioning System (GPS) instruments were used to map villages involved in dengue epidemiological studies in Tak province. Differentially processed GPS data with a spatial resolution of approximately 1 metre were incorporated into a GIS for analysis and mapping. Databases associated with a village GIS included village name, house number, demographic data on house occupants, *Aedes aegypti* populations, *Ae. aegypti* immature breeding sites and seroepidemiology data on house occupants.

Introduction

Dengue virus infection can result in a wide range of clinical symptoms, including asymptomatic infection, undifferentiated febrile illness, classical dengue fever, dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS), which are associated with significant morbidity and mortality. Factors that are involved in the progression of classical dengue fever to DHF and DSS are not well known[1-3]. Dengue infection occurs after the bite of a competent mosquito vector, primarily *Aedes aegypti*, that is infected with one of the four dengue virus serotypes. An analysis of the incidence of DHF cases in Bangkok[4] and experimental studies on the vector efficiency of *Ae. aegypti*[5] suggest that the number of DHF cases is greatly affected by temperature-induced variation in the vectorial capacity of the vector. The spatial distribution of DHF is dependent upon the presence of *Ae. aegypti* or another suitable vector and viremic and susceptible human hosts.

The Geographical Information System (GIS) databases have been recently used to monitor factors affecting disease transmission[6]. Recent studies have demonstrated that satellite imagery, digitized land-use maps and global positioning data are promising for predicting changes in habitats of mosquito vectors as they affect disease transmission[7-10]. In this study epidemiological, digital, satellite and Global Positioning System (GPS) data have been incorporated into GIS databases to better understand the spatial distribution of DHF in Thailand.

Materials and methods

Digital remote sensing data were produced by the advanced very high resolution radiometer (AVHRR) sensor on polar-orbiting satellites operated by the National Oceanic and Atmospheric Administration (NOAA). The AVHRR records visible, near-infrared and thermal channels of the electromagnetic spectrum. The characteristics of the NOAA AVHRR have been described previously by Linthicum et al[8]. The normalized difference vegetation index (NDVI) analysed in this study is a transformation between data from the visible channel and the near-infrared channel. The NDVI data have been shown to be highly correlated with green-leaf biomass and represent the photosynthetic capacity of the area measured. The NDVI data were calculated for NOAA satellite coverages of Thailand for ten dates between December 1992 and April 1993. Data from different dates were then composited by selecting the highest NDVI for each grid cell location. These data have been used as thematic raster base map for displaying DHF incidence by province. The raster map is displayed in a Latitude/Longitude Coordinate system and are georeferenced using the Indian 1975 Datum and Everest 1830 (1975 Definition) Ellipsoid. These data also have been used to calculate forest cover in provinces using unsupervised and supervised classification methods to create vector maps of forest cover [11].

Provincial border boundary data for Thailand were digitized using MapInfo software[12]. DHF case data were reported by provincial health offices and published by the Ministry of Health, Thailand[13,14]. The province population data were provided by the Ministry of Interior, Thailand. The DHF incidence was calculated as the number of cases of reported DHF/100 000 population of the province.

The position of houses in three villages in Tak province, Thailand, were mapped using a Trimble Geoexplorer GPS instrument as the rover unit. A Trimble Pathfinder Pro XL GPS instrument was run as a base station at our laboratory in Bangkok (13^0 45’ 58.878” N Latitude, 100^0 32’ 08.504” E Longitude). Both rover and base station units were run simultaneously to allow differential correction of rover data using Trimble software[15]. The regression between DHF incidence and per cent forest area were calculated with SPSS software[16].

Results and discussion

The distribution of the DHF incidence in 1996 in the provinces of Thailand is shown in Insert A. The relative size of the yellow circle represents the incidence of DHF as indicated in the legend. The darkest green colors on the NOAA/NDVI satellite data-generated base map represent forested areas of Thailand. Approximately 70 000 cases of DHF were reported in 1996. This suggests that there were at least 7 000 000 dengue infections in Thailand during 1996 based upon a conservative ratio of 1 DHF case/100 dengue infections [17]. The DHF incidence ranged from 0 to 220/100 000 population. The highest incidence occurred in Tak province in the central-western part of the country bordering Myanmar. High incidence was also observed in several provinces bordering Laos and Cambodia in eastern Thailand. Lowest incidence of transmission was observed in the northern-most and southern-most provinces. It appeared to the authors that most of the DHF occurs in provinces of the central plains and Korat plateau in the east, with the exception of Tak province. Most of these provinces have little forest cover.

The relationship between the DHF incidence and forest cover is shown in Figure 1. There is no correlation between disease incidence and forest cover ($R^2 = 0.001$, $F = 0.05$, $P = 0.83$). The primary mosquito vector of DHF in Thailand, *Ae. aegypti*, is a species that is closely associated with humans and breeds in artificial containers associated with human habitation, and it is not ecologically linked to forests. Furthermore, most human habitations in Thailand are not associated with forest. For these reasons and from the distribution of DHF illustrated in Insert A, the authors suspected that there might be a negative correlation between forest cover and DHF incidence. Malaria incidence in Thailand, where the mosquito vector is closely linked to forests (*Anopheles virus*), has been strongly correlated with forest cover[6]. The relation-ship between DHF transmission and ecolo-gical variables might be better evaluated by analysing temporal data with GIS.

Figure 2 shows a small portion of the GIS map and database created for one of the three villages that was mapped with a GPS instrument. The GPS data were subjected to differential processing to create a map with a spatial resolution of one metre. These data were then imported into a GIS and a new database created that included village name and house number (portion of data shown), and demographic data on house occupants, adult and immature *Aedes aegypti* populations, *Ae. aegypti* immature breeding sites and seroepidemiology data on house occupants (data not shown). These GIS relational databases are being used as a powerful tool to monitor the status of efforts to control *Ae. aegypti* breeding sites and to evaluate the impact of this control effort on dengue and DHF transmission.

Figure 1. Relationship between per cent forest cover and dengue haemorrhagic fever incidence/100 000 population for the year 1993 for all provinces of Thailand.

Figure 2. Portion of GIS map and database for a village in Tak Province, Thailand.

House locations shown by circle with a spatial resolution of 1 metre.

Historically, maps describing the spatial distribution of DHF and other diseases have been limited to hand-drawn representations on pre-existing maps. GIS, with new advances in image processing and GPS to georeference databases, provides a new and powerful tool to efficiently store, retrieve and interpret DHF databases for epidemiology, ecology and control studies.

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Insert A

Distribution of dengue haemorrhagic fever incidence/100 000 population for the year 1996 in different provinces of Thailand plotted on provincial boundary layer in a GIS. NOAA/NDVI satellite image showing forest cover in dark green colour used for base map. Water shown in dark black colour.