Space-Time Analysis Tools of Dengue Epidemics in Chachoengsao Province, Thailand

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Abstract
Dengue has become a major international public health concern over the past decade. The Bureau of Epidemiology, Ministry of Public Health, Thailand has reported several outbreaks in the country. Geographic Information System (GIS) provides quite powerful analysis tools for contemporary spatial epidemiology studies. Epidemiological data can be processed using space-time analysis in GIS environment. This study illustrates space-time analysis procedures of dengue incidences in Chachoengsao province, Thailand. Though the analysis techniques provided by these tools are limited, it is capable to develop epidemiological analysis module based on a general GIS platform. This methodology is general and can be applied in other applications fields such as dengue outbreak or other diseases.

1. Introduction

Dengue is one of the ten major causes of hospitalization and death among children in tropical Asian countries, including Thailand. There are four dengue virus serotypes, called DEN-1, DEN-2, DEN-3, and DEN-4. They belong to the genus *Flavivivus*, family *Flaviviridae* (of which yellow fever virus is the type species), which contain approximately 70 viruses (Gubler, 1998). The clinical spectrum of dengue can vary from asymptomatic disease to more severe infections, characterized by hemorrhagic tendencies (dengue hemorrhagic fever - DHF) and circulatory shock (dengue shock syndrome - DSS). Classical dengue fever in adults is characterized by predominantly clinical symptoms of rashes, joint pain and leucopenia. In children, it can be present with a positive tourniquet test, hepatomegaly and thrombocytopenia (WHO, 1997). The most important transmission cycle from a public health standpoint is the urban endemic/epidemic cycle in large urban centers in tropics. The viruses are maintained in an *A. aegypti*-human-*A. aegypti* cycle with periodic epidemics. Often, multiple virus serotypes co-circulate in the same city (hyperendemicity). The initial temperature may rise to 102 to 105°F and fever may last for 2 to 7 days. The fever may drop after a few days, only to rebound 12 to 24 hour later (saddleback) (WHO, 1999). Spatial epidemiology concerns the study of the occurrence of disease in spatial locations and time points and its explanatory factors (Lawson, 2001). Recent advances in Geographic Information System (GIS) along with Remote Sensing (RS) have added new dimensions to spatial statistics analysis in epidemiological studies (Handique et al., 2011 and Yagoub, 2011). This study introduces several space-time statistical analysis tools in ArcGIS and their applications in spatial epidemiology, and illustrates the space-time analysis procedures of dengue incidence in Chachoengsao province, Thailand. The examples deal with spatial analysis and spatio-temporal analysis of dengue incidence in Chachoengsao province for several years. This paper concludes that these tools are powerful in the study of spatial epidemiology. However, the analysis techniques provided by these tools are still limited. It is difficult to acquire much more complex parameters for the research of spatial epidemiology. So, it is necessary to develop feasible and efficient epidemiological analysis modules based on a common GIS platform.

2. Study Area

Chachoengsao, a province in the central east part of Thailand, was selected as the study area (Figure 1). Chachoengsao province comprises 11 districts, which are Mueang Chachoengsao, Bang Khla, Bang Nam Prieo, Bang Pakong, Ban Pho, Phanom Sarakham, Sanam Chai Khet, Plaeng Yao, Ratchasan, Tha Takiap, and Khlong Khuean.

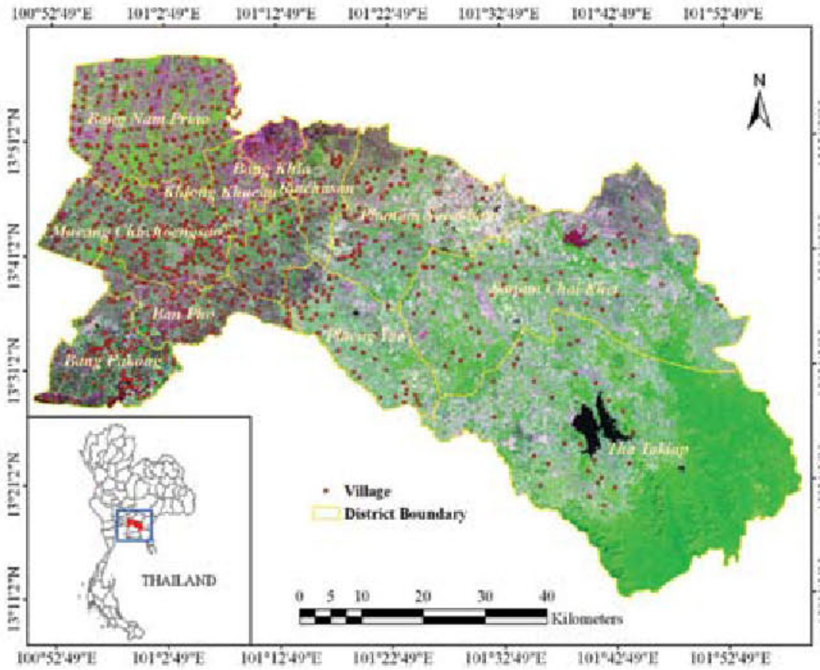

Figure 1: Study area: Chachoengsao province, Thailand

The province is located 80 km away from the eastern part of Bangkok, and covers an area of 5,238 square kilometers. The province has a population of about 645,000 people (Department of Administration, 2007). The western part of the province is the low river plain of the Bang Pa Kong River which is used extensively for farming rice. The eastern part is higher with an average height of more than 100 meters above sea level.

3. Data

Dengue data in the year 2007 was collected from the Chachoengsao Provincial Public Health Office (CPPHO) with regard to the number of reported probable and confirmed dengue cases per district and per month. Data represent only the patients who visited the hospital and filled in the official Form 506 from Ministry of Public Health (MOPH), Thailand. The forms provided data such as the total of dengue cases per month and year, type of disease, gender, and address of each patient. Village data for 820 villages of the province, location data and population data were collected from the Department of Provincial Administration, Thailand. Village point locations were confirmed for accuracy by overlaying on Google Earth Pro.

4. Method

Firstly, standardized mortality ratio (SMR) of dengue incidence was calculated. For each village (i = 1, 2, 3,...,820) the SMR was defined as the ratio of the number of observed dengue cases (ODCi) to the population (Pi):

$$SMR_i = ODC_i / P_i \qquad \text{Equation 1}$$

Calculating the SMR in this way could lead to spurious spatial features. Village with small population could appear highly variable and may contain a disproportionate number of high (or low) parameter estimates. To overcome this problem, an empical Bayes method based on the idea of pooling information across villages has been develop (Chaikaew et al., 2009). Secondly, SMR of dengue in Chachoengsao province using Geostatistical techniques including ESDA, Kriging and Tracking analysis techniques was mapped.

5. Results and Discussions

5.1 Disease Mapping of Dengue in Chachoengsao Province using Geostatistical Analysis

Geostatistical analysis provides ESDA (Exploratory Spatial Data Analysis), deterministic interpolation methods and Kriging interpolation methods (Edward and et al., 1990). Studies have confirmed that Kriging method can work well with some disease data besides natural data. Figure 2 shows villages which were infected with dengue in 2007. The high risk areas (SMR > 0.002760557) mostly occurred in the middle part of Chachoengsao province. These were concentrated in Phanom Sarakham and Plaeng Yao districts. Surface fitting using Geostatistical analysis involves three key steps: i) exploratory spatial data analysis (ESDA), ii) structural analysis (calculation and modeling of the surface properties of nearby locations), iii) surface prediction and assessment of results. Currently, GIS software packages provide many useful tools for many researches of spatial epidemiology. The following figure illustrates the interpolation result of 2007 data of dengue. The Geostatistical disease mapping cleans the noise of the raw disease data and, if possible, recovery the real underlying structure of the disease data (Figure 3).

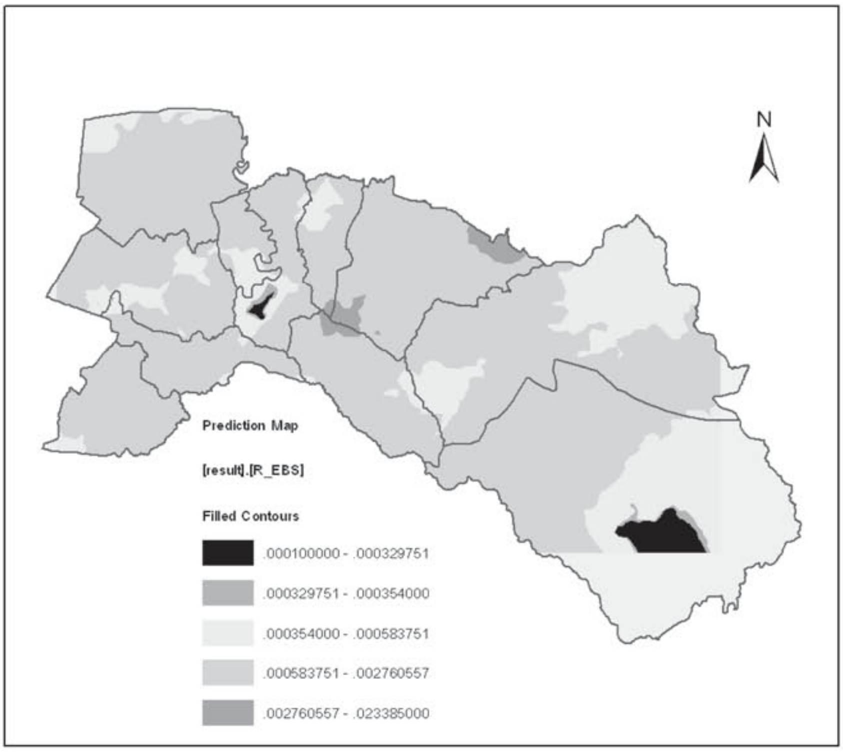

Figure 2: SMR mapping of dengue using Universal Kriging, in the year 2007

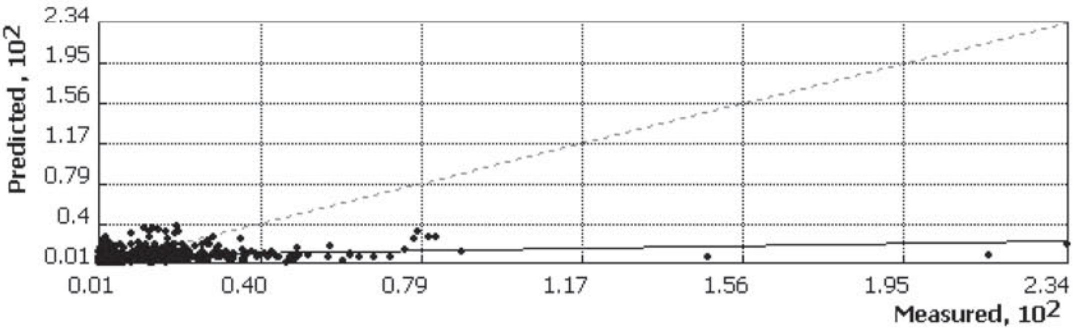

Figure 3: The standardized error, which is the square root of what is called Kriging variance and is a statistical measure of uncertainly for the prediction

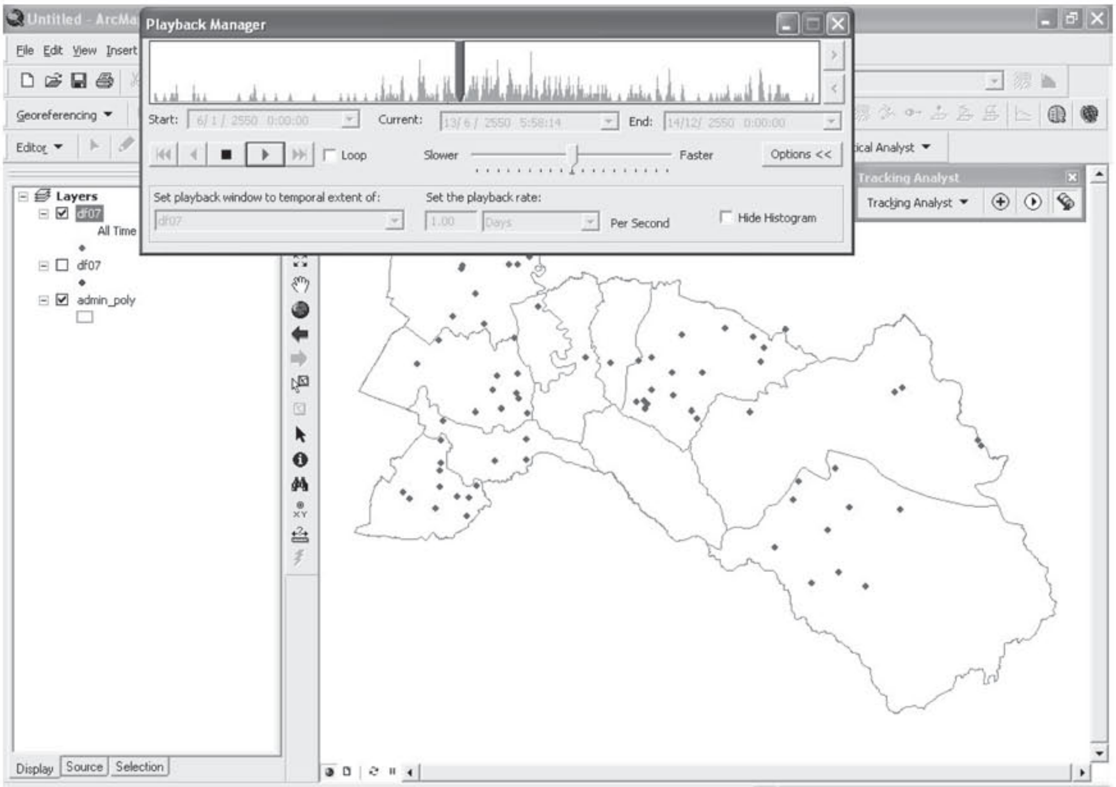

Figure 4: The tracking analysis of dengue in the year 2007, Chachoengsao province

5.2 Spatio-Temporal Analysis of Disease Data using Tracking Analyst

Tracking analyst can map objects that move or change status through time. In ArcGIS, tracking analyst can tracking temporal data, displaying data, charting temporal data and so on, and the Figure 4 is the screenshot when executing spatio-temporal analysis. Through this tool, we can easily see the evolvement of dengue incidence through time further the analysis. Tracking analysis of daily cases were presented, which indicated the dynamics of dengue diffusion through time (start date: 06/01/07 and end date: 14/12/07). A total of 792 suspected dengue cases were recorded. Approximately 53.7% of the cases occurred in June to July.

6. Conclusions

Dengue disease is a very serious illness in Thailand. There is no specific treatment and no vaccine against dengue. Previous research revealed that the *Aedes Aegypti* mosquito that carries dengue does not travel far from its breeding place. Recent monitoring and planning of control measures for dengue epidemics have become a critical issue.

This study offered useful information relating to the dengue incidences. To analyze the dynamic pattern of the 2007 dengue outbreaks in Chachoengsao province, Thailand, all dengue cases were positioned in space and time by addressing the respective villages. In 2007, the Chachoengsao Provincial Public Health Office reported 792 suspected dengue cases and a total of 171 dengue cases. During the 152 days of epidemic, there were as many as 521 suspected dengue cases spread throughout the region and affected 0.08% of the total population. Spatial epidemiological research has a long history but study on epidemiology using GIS technique appears for the first time. With the developing computer technologies and spatial analysis methods, using GIS becomes more resourceful (Zhong et al, 2005). Spatial statistical capability, advanced 3D visualization capability, spatio-temporal analysis capability, and more complex spatial analysis functions etc. have been added to mainstream GIS software packages, which provide comprehensive approaches for spatial epidemiology, and traditional research approaches will enhance thoroughly.

Not only it is applicable in epidemics, but this technique is general and can also be applied in other application fields such as outbreak of other diseases during natural disasters.

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