ANALYSIS OF SPATIAL FACTORS AFFECTING DENGUE EPIDEMICS USING GIS IN THAILAND

Kanchana Nakhapakorn*
Nitin Tripathi*, Kaew Nualchawee*, Michiro Kusanagi*, Preeda Pakpien**

* Remote Sensing and GIS FoS, Asian Institute of Technology
**UEEM program, Asian Institute of Technology
P.O.Box 4 Klong Luang, Pathumthani 12120, Thailand
Kanchana.nakhapakorn@ait.ac.th, nakhapakorn@yahoo.com, nitinkt@ait.ac.th

ABSTRACT:

Dengue Fever(DF) and Dengue haemorrhagic fever(DHF) has become a major international public health concern. Dengue Fever(DF) and Dengue haemorrhagic Fever (DHF) is also still the major health problem of Thailand, although many campaigns against it have been conducted throughout the country. GIS and Remotely Sensed data are used to evaluate the relationships between socio-spatial, environmental factors/indicators and the incidences of viral diseases. The aim of the study is to identify the spatial risk factors in Dengue and Dengue Haemorrhagic Fever in Sukhothai province, Thailand using statistical, spatial and GIS Modelling. Preliminary results demonstrated that physical factors derived from remotely sensed data could indicate variation in physical risk factors affecting DF and DHF. The present study emphasizes the potential of remotely sensed data and GIS in spatial factors affecting Dengue Risk Zone analysis. The relationship between land cover and the cases of incidence of DF and DHF by information value method revaluated that highest information value is obtained for Built-up area. A negative relationship was observed for the forest area. The relations between climate data and cases of incidence have shown high correlation with rainfall factors in rainy season but poor correlation with temperature and relative humidity. The present study explores the potential of remotely sensed data and GIS in spatial analysis of factors affecting Dengue epidemic, strong spatial analysis tools of GIS. The capabilities of GIS for analyst spatial factors influencing risk zone has made it possible to apply spatial statistical analysis in Disease risk zone.

KEY WORDS: GIS, Information value approach, dengue epidemics.

1. INTRODUCTION

1.1 General Instructions

Vector-borne diseases have been the most important worldwide health problem for many years and still represent a constant and serious risk to a large part of the world's population. GIS have already been widely used in sector such as the management of natural resources, agriculture, rural and urban planning. Recently, GIS and Remote Sensing (RS) started to be used to evaluate and model the relationships between socio-spatial and environmental factors/indicators and the incidences of viral diseases. Remotely sensed data have been used in many vector disease studies (Beck et al., 1994; Ahearn et al., 1996). The Techniques of Remote Sensing (RS) and geodesy have the potential to revolutionize the discipline of epidemiology and its application in human health.(Hay, 2000) Remote sensing and GIS were used to identify villages at high risk for malaria transmission in the southern area of Chiapas, Mexico (Beck et al., 1994). In Kwara State, Nigeria, a temporal analysis of Landsat Thematic Mapper(TM) Satellite data was used to test the significance of the guinea worm eradication program based on changes in agricultural production (Ahearn et al., 1996) and to predict and map the location of some of the major diseases affecting human health (Bailey and Linthicum, 1989; Hay et al., 1997, 1998). Land cover is a critical variable in epidemiology and can be characterized remotely.(Curran et al., 2000)

Many countries/areas in Asia have been experiencing unusually high levels of dengue/dengue haemorrhagic fever activity in 1998. In Thailand in 1998 reported of incidence/cases for the whole Thailand is 129,954 and Morbidity rate is 211.42 per 100,000 peoples. This is the second epidemic DHF/DSS emerged since 1958 (the first epidemic DHF/DSS emerged in 1987, Morbidity rate per 100,000 population is 366.83), Mortality rate is 0.69 per 100000 populations and percentage of Case Fatality Rate is 0.33. Data on 683 DF/DHF/DSS cases reported in Sukhothai province, Thailand, from January to December 1998 were extracted from Sukhothai Provincial Public Health office. In this paper, we propose a methodology based on exploratory spatio-environmental results obtained from remote sensing in relation to levels of incidence of Dengue to get insights in the relationships between these two elements. GIS modeling is first used to derive spatial categories of levels of incidence of the disease. Then Spatio-environmental indicators/factors are extracted from remote sensing results.

The method is based on the referring of spectral based classification by spatial characteristics to identify the spatial characterized high risk for Dengue fever and to get insights in the relationships between environment and incidences of Dengue Fever and Dengue Haemorrhagic fever.prepared on A4 paper according to these guidelines, and sent to the organisers for scanning.

2. EMERGING VIRAL DISEASES

Each year, tens of millions of cases of dengue fever (DF) occur worldwide as well as several hundred thousand cases of the more deadly dengue hemorrhagic fever (DHF). The emergence of viral diseases did not stop developing themselves. Of the five percent of cases that end in death, most are children and young adults. At present, GIS are seeing primarily as research tools in the field of vector-borne disease; they will become an increasingly important research tool as geographic database, data analysis, modeling, and decision support systems. Our approach is to find the models in conjunction with Remote Sensing and incidences of viral diseases and to demonstrate that the Spatial characterized combined to GIS modeling is the right way to approach this kind of problem (Andrianasolo, 2000). In Asia, in most countries of the tropics such as southern China and Hainan, Vietnam, Cambodia, Laos, Thailand, Myanmar, India, Sri-Lanka, Indonesia, Philippines and Malaysia, dengue viruses are highly endemic but are low endemic in Bangladesh, Papua New Guinea, Nepal and Taiwan. In Vietnam, 370,000 DHF cases were reported in 1987. It is the biggest outbreak ever reported(WHO, 1994).

3. MATERIALS AND METHODS

3.1 Geographical Distribution

Study area is Sukhothai province that located at the lower edge of the northern region of Thailand. The province covers some 6,596 sq. km. and is divided into 9 Amphoes (Districts): Muang Sukhothai, Ban Dan Lan Hoi, Khiri Mat, Kong Krailat, Sawankhalok, Si Nakhon, Si Samrong, Si Satchanalai and Thung Saliam. The most occupations are agricultural products; sugarcane, cassava, corn. The climate is subtropical. The seasonal fluctuation of temperature is 22.9? C – 27.0? C. The average rainfall during 1969 to 2000 is 917.7 mm. The geographic distribution of population density by district presented a geographic pattern similar to the one described for case of DF/DHF incidence.

3.2 Secondary data

Secondary data included demographic information, climate, DF/DHF case of incidence, physical environment (land use/cover), and administrative map. The information contained in the spatial database is held in the form of digital coordinates, which describe the spatial features. These can be points (hospitals location), lines (roads), or polygons (administrative boundary). Normally, the different sets of data will be held as separate layers, which can be combined in a number of different ways for analysis or map production. The attribute database is of a more conventional type. It contains data describing characteristics or qualities of the spatial features: land use, type of soil, type of road, population. We could have health districts (polygon) and health care centers(points) in the spatial database, and characteristics of these features in the attribute database, for instance persons having access to clean water, number of births, number of 1 year old children fully immunized, etc.

3.3 Factors influencing on Dengue Haemorrhagic Fever in the study area

Various factors are examined which influence the number of DHF cases in Sukhothai Province. Major factors to influence the occurrence of DF/DHF cases are rainfall, temperature, humidity, and land use/cover area. Average Monthly temperatures and monthly rainfall was obtained from the meteorological station provided by the Department of Meteorology, Ministry of Communication. The area of Sukhothai province is 6,596.02 sq.km. In 1998, the reporting area for the land utilization purpose for agricultural is 50.10%, forest area is 41.99% and unidentified area is 7.91%. Remotely sensed data can be used to provide information on land cover and can be used to provide information on the spatial distribution of the vector-borne disease.

3.4 Information Value Methods for Risk Zone Mapping Disease

Understanding of spatial relationship of Dengue epidemic with each of affecting parameter is essential before applying any statistical based on models for influence of factor in dengue epidemic The simple technique to understand the statistical relationship is conditional analysis, which attempts to assess the probabilistic relationship between relevant factors affecting dengue epidemic and environmental factors The technique is based on Baye's theorem Bayesian classifier according to which frequency data can be used to calculate the probabilities that depends upon the knowledge of previous events or dengue epidemic outbreak (Yin, 1988; Suresh, 1999)

Map crossing results in a cross table showing the number of pixels per class occupied by dengue epidemic and total number of pixels in each class. The remaining values, necessary to calculate information value, area obtained from these values, actually can represent in term of information value process, therefore

$$\text{i-value} = \log(\text{classden}/\text{mapden})$$
$$\text{classden} = \text{ndclass}/\text{nclass}$$
$$\text{mapden} = \text{ndmap}/\text{nmap}$$

i-value = information value
ndclass = area with dengue epidemic in a class(i.e. land use/cover types)
nclass = area in the class(i.e. land use/cover types by district)
ndmap = total of dengue epidemic area in the map(thematic layer)
nmap = total area in the map

4. RESULTS

The spatial distribution of the districts corresponding to the highest levels of incidence of DHF is calculated. As shown in the following figure, analysis is demonstrating that the most prominent districts are in the southern part of the province. It appears that 23.6% of the area of the province is having the highest case. Information value of various parameters can be utilized to interpret the relationship of the parameters and dengue epidemics (Figure 1).

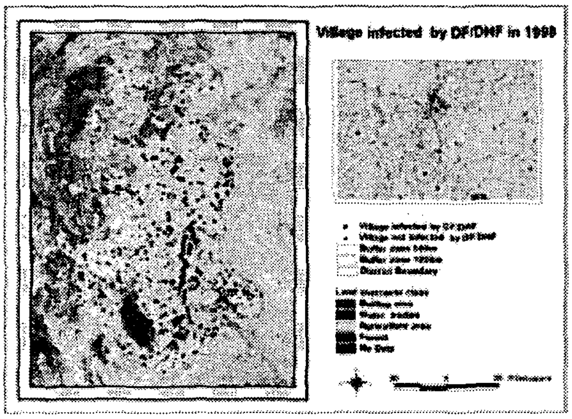

Figure 1 Village infected DF/DHF in 1998 with Land use/cover class

Interpretation of Information value of Land cover classes

Information value is calculated for each land cover types. Negative values indicate low risk level and positive values indicate high risk level of Dengue. Six possible risk classes were identified; Information-value scores at each range of 0.5 could be used as the cut-off level that calculated from quartile of a data set. Risk classes were designed as follows:

Information value range	Risk Class
< -1.0	Very Low
-0.5 to -1.0	Low
-0.5 to 0.0	Moderately Low
0.0 to 0.5	Moderately High
0.0 - 1.0	High
> 1.0	Very High

In a whole study area, information value is calculated of each risk class to find the potential risk zone due to all spatial affecting factors. As clear from the chart, the affecting area by DF and DHF having information value less than 0 are negligible. The highest information value was obtained for the Built-up area. This indicated that Built-up area has the maximum influence on the incidence of dengue. The other classes showing negative values indicate lesser influence on dengue epidemics. Two buffer regions of 500 m and 1000 m in the land use/ land cover maps were analysed for the information value(Figure 2). It was done to investigate if the changes of neighbourhood sizes have any effect on the information value or not. Information values were clustered in 4 groups: first group represented the high positive values i.e. Built-up (BU) area. Information value in this group represented the highest value that meant built-up category is the highest spatial risk factor in all the districts both for 500 and 1000 m buffer zones. Second group represented the positive relationship with Water Bodies (WB). Information value in this group represented the high values for both buffer regions of 500 meter in D1, D6 and D7 districts. Third group represented the positive values for the Agriculture areas. Information value in this group represented positive values for 500 meter buffer zones that mean the Agriculture category has shown positive influence as a risk factors in D2, D3, D4, D5, D6 and D7 district. Fourth group represented that for all the districts forest (FR) area indicated no risk for dengue, as information values were negative for 500 meter buffer zones. The information value obtained using Land use/Land cover risk zone is shown in Figure 2.

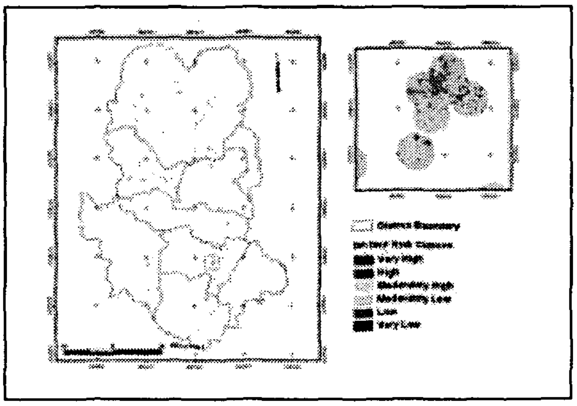

Figure 2 Dengue Risk Zones receive from Physical Environment Analysis by Information Value

Most of the risk zones areas are located in the moderately risk class both for 500 meter buffer zones.

Information values representing the very high and high-risk classes were in built-up area and water body categories as shown in the Figure 2. Risk zones showing the negative or low risk classes are mostly in the forest area. Sithiprasasna and Linthicum have also shown that DHF incidence was poorly correlated with the forest cover in Tak province of Thailand (Sithiprasasna, 1997). It confirms that the DF/DHF cases mostly occur in urban and suburban areas. The reporting area affecting DF/DHF of the land use/land cover for agricultural is 85%, forest area is 5%, water bodies is 1% and Built-up area is 9%. Result of DF/DHF risk zone was represented 28% of the total affecting DF/DHF was high risk at Built-up area. 15% of the total affecting DF/DHF was moderately high risk at Water bodies. 5% of the total affecting DF/DHF was moderately high risk area at Agriculture category. Almost 52% of the total affecting DF/DHF was very low risk zone in Forest area. Information value shows the physical categories and their Information Values for each of the districts. Very High Risk zone (information value > 1.0) was in D4, D5, and D6 districts. High Risk zone (information values between 1.0 and 0.5) were observed in D7 and D1 districts. The spatial statistical relationship of various land use/land cover classes with dengue-affected areas was quantified in the form of information value and a dengue risk map was generated as shown in the Figure 2. Very High Risk or highest zone (information value > 1.0) was in D4, and D5 district in both for buffering 500 meter affected by Dengue fever.

5. CONCLUSION

The present study emphasizes the potential of remotely sensed data and GIS in spatial factors affecting Dengue Risk Zone analysis. The capabilities of GIS for analyst spatial factors influencing risk zone has made it possible to apply spatial statistical analysis in Disease risk zone. Spatial factor affecting Disease is attempted using information value method. The link between land use/cover and case of incidence by information value can be understood that highest information value is obtained for Built-up area almost a whole province and the forest area which the relationship showing negative value. This spatial factor of land use/cover is based on explicit physical processes and link between other environmental variables that have been working in the remote sensing of disease risk zone. The affecting area by DF and DHF are having information values in moderately risk zone and high risk zone.

REFERENCES

Ahearn, S.C., De Rooy, C. (1996). Monitoring the effect of dracunculiasis remediation of agricultural productivity using satellite data. International Journal of Remote Sensing. Vol. 17. No. 5, 917-929.

Andrianasolo H., Nakhapakorn K., Gonzalez J. P., 2000. *"Remote Sensing and GIS Modelling applied to Viral Disease in Nakhon Pathom Province, Thailand"*, IGARSS 2000, Taking the Pulse of the Planet, by IEEE Geoscience and Remote Sensing Society, Hawaii, USA, July 24 - 28, 2000.

Bailey, C.L. and Linthicum, K.J., 1989. Satellite remote sensing: the newest technology for monitoring vector populations and predicting arbovirus outbreaks.

Beck LR, Rodrigues MH, Dister SW, Rodrigues AD, Rejmankova E, Ulloa A, et al. (1994). Remote sensing as a landscape epidemiologic tool to identify villages at high risk for malaria transmission. Am J Trop Med Hyg. 51: 271-80.

Curran, P.J., Atkinson, P.M., Foody, G.M., Milton, E.J., 2000. *Linking Remote Sensing, Land Cover and Disease.* Advances in Parasitology: Remote Sensing and Geographical Information Systems in Epidemiology. Vol. 47., 37-80.

Hay, S.I., 2000. *An Overview of Remote Sensing and Geodesy for Epidemiology and Public health Application.* Advances in Parasitology: Remote Sensing and Geographical Information Systems in Epidemiology. Vol. 47., 1-35.

Hay, S.I., Packer, M.J. and Rogers, D.J., 1997. *The impact of remote sensing on the study and control of invertebrate intermediate hosts and vectors for the disease.* International Journal of Remote Sensing. 18, 2899-2930.

Hay, S.I., Snow, R.W., and Rogers, D.J., 1998. *From predicting mosquito habitat to malaria seasons using remotely sensed data: practices, problems and perspectives.* Parasitology today 14, 306-313.

Suresh K. G., 1999. Rainfall Effect in Landslide hazard Zonation using Remote Sensing and GIS. Master Thesis. Indian Institute of Technology, Kanpur, India, 87 pp.

World Health Organization, Regional Office for South-East Asia. Control of Preventable Diseases. (Report on Progress made by Member Countries in their Elimination, Reduction and Control) In: Regional Committee Document. Forty-seventh session, Provisional agenda item 15, SEA/RC47/14. 11 May 1994.

Yin, K.L., and Yan, T.Z., 1988. Statistical Prediction models for slope instability of metamorphosed rocks, Proceedings of the 5th International Symposium on Landslides, Lausanne, Vol. 2, pp. 1269-1272.

Sithiprasasna R. and Linthieum K. J.: Use of Geographical Information System to study the Epidemiology of Dengue Haemorrhagic Fever in Thailand. Dengue Bulletin. Volume 21, December 1997.