# Dengue Haemorrhagic Fever (DHF) in the Central Plain of Thailand. Remote sensing and GIS to identify factors and indicators related to dengue transmission.

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***Abstract*** : *In Thailand, since the first epidemics in 1958, there has been a global upward trend in incidence of Dengue Hemorrhagic Fever (DHF), an acute and severe form of dengue virus infection, which remains a major public health concern. The dengue is due to an arbovirus mainly transmitted by Aedes aegypti, a mosquito living close to human communities. The intensity of the transmission (i.e. number of cases and speed of the spread of the disease) is dependant on the number of vectors, the serotype of the virus, the herd immunity and the environment.*

*In the Central Plain of Thailand despite an apparent very homogenous environment (altitude, climate, type of agriculture) the incidence of DHF exhibits strong variations at the province and sub-province levels. A Geographical Information System using epidemiological data, as well as information about the Land-use, demography, geography, climate has been built to identify indicators likely to help to describe areas and periods at risk for dengue transmission.*

*A particular approach is focusing on the structure of the urban environment, the main field for dengue transmission. Different degrees and types of urbanisation appear to be linked to different intensities of dengue transmission. The main output of this study will be a method to describe areas at risk for high level of transmission and to forecast epidemic periods allowing a quick launch of dengue control activities. This study developed in the Central Plain of Thailand will be extended to other parts of the country and the same methods maybe applied to similar environments in other countries where the dengue is endemic.*

*Key Words: Dengue Hemorrhagic, Risk areas, Remote sensing, GIS, Thailand.*

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# 1 Introduction

Dengue fever is due to an arbovirus mainly transmitted by *Aedes aegypti* and yearly causing in the tropical area tenths of millions of cases. Since its apparition during the 50's the Dengue Haemorrhagic Fever (DHF), a sever form of dengue infection, has followed a global upward trend in incidence and has been a main public health problem in South East Asia (SEA) and countries of the tropical zone. Despite in many countries the DHF case fatality rate has decreased, such as in Thailand, from 6-8% in the 1960s to a mere 0.3% in 1996, epidemics still lead to the first cause of children hospitalization in SEA and associated to the persistent endemicity of the disease, induce a high cost to regional economies (15 to 20 million US$ per year in Thailand) linked to the symptomatic treatment of patients and vector control activities. No specific treatment against the virus neither vaccination is available. Along with the setting up of adulticide spraying campaigns to quickly stop the transmission during epidemics, vector control activities chiefly aim at eliminating breeding sites through community participation. However, the efficiency of prevention and control activities is too slow to reach the level sufficient to interrupt the transmission during epidemic periods, since it takes quite a long time to set up These activities are also difficult to maintain during the non-epidemic periods, due to the defection of the populations towards activities with no perceptible results. In addition, in Thailand and in most of the Southeast Asian countries where the dengue is endemic, the needed infrastructure can be maintained neither permanently nor simultaneously for the whole country.

A quick launch of control activities appears necessary to improve their efficiency but despite the efficient system to survey the DHF (and 60 other diseases) developed by the Thai Ministry of Public Health, the great diversity in the epidemiological pattern of the DHF makes epidemics difficult to predict. The transmission cycle of the disease is the result of a complex system based on several main constituents: the number of vectors, the type of virus, the density of susceptible hosts and the environmental conditions acting on the output of transmission.

Two main patterns may describe the fluctuations of DHF incidence. The cyclic pattern corresponds to the seasonal variations of transmission. The incidence reaches a peak during the hot and rainy season (May-October in the Central Plain). The end of the rainy season leads to a return to a lower level of transmission. This phenomenon is repeated every year and characterizes the endemic mode of transmission. The non-cyclic pattern corresponds to important rises in the incidence of DHF and to the very basis of the epidemics characterization; they are non-seasonal increases of variable duration, separated by periods of lower incidence lasting two to five years.

To make the best of these control activities, it is important to have them focused on epidemic periods and to intervene as early as possible. This is made difficult as in Thailand the epidemic outbreaks are apparently uncertain and the range of the "normal" seasonal fluctuations is wide. For instance, the average ratio of the monthly minimum number of cases to the monthly maximum was 1/13 in Nakhon Pathom a province located (50km West of Bangkok) from 1983 to 1998. Therefore "abnormal" fluctuations of the epidemic sort must be defined in relation to this large amplitude of natural fluctuations.

Moreover, spatial variations in incidence add more complexity to the transmission description as the incidence ranged from 0 to 180 cases (per 100 000 inhabitants) in the sub-districts of Nakhon Pathom province during the last ten years.

The goal of this study is to describe the epidemiology of DHF in an area where the environment exhibits relatively homogenous features, the Central Plain of Thailand. This region has been chosen because the homogeneity in climate, altitude and activities of inhabitants allows reducing the amplitude of the factors to be studied to describe the DHF epidemiology. From that description, regional common characteristics of DHF transmission are identified and specific analysis performed. Factors likely to be involved in the spatial and temporal variations of the transmission are described.

# 2 Methods

Satellite images will furnish an up to date and quantitative view of the land cover heterogeneity, mainly of the urban area (from a supervised classification) and its recent extension and modification (comparison of images acquired 10 years apart). Relative localization of urban communities (i.e. polygons from the classification and from field survey by Global Positioning System) will be associated to the Geographical Information System layer on road network and inform on the way dengue serotypes circulate. The comparison between DHF incidence and class distribution (from Remote Sensing) will enlighten those significantly associated to dengue transmission. The national census will furnish layers for demography and health and water networks (water storage).

Storage and processing of data and information. A Geographical Information System (GIS) has been build to store the data related to the study, including their geographical coordinates (latitude, longitude and sub-district code). Statistics and other type of queries including spatial comparison are performed through the GIS. Data refer to different domains: epidemiology, demography, land use, climate, socio-economic information (water network, types of roads).

Definition of epidemic periods. A statistical tools designed to facilitate an early detection of an epidemic emergence versus seasonal variations, has been developed using a statistical departure from the monthly average as a threshold for the risk of emergence of an epidemic phenomena (not described here). From this criterion, an analysis of the distribution and dynamic of DHF epidemics in the districts of the Central Plain of Thailand is done and is related to the type of Land Use prevailing in these areas.

The Land use description. The Land use description is approached from the classification of remote sensing images (SPOT, Landsat). A satellite image is made of pixels (spatial unit, 20m x 20m for SPOT; 30m x 30m for LANDSAT). Each pixel has a specific radiometry in each of the channels or bands of the satellite (3 bands for SPOT; 7 bands for Landsat) depending on the objects on the ground. The radiometry value arbitrary range from 0 to 255. A classification aims at pooling pixels having the same range of values in one or more of the bands. In a supervised classification some objects on the ground which nature is known from field knowledge or maps, such as urban area, crop, river, are used to build a homogenous training areas. In this area the range of the radiometric values of the pixels is measured, in one or more bands (bands 1, 2, 3 for SPOT; 1, 4, 5 for the study of urban areas in Landsat TM). In a second step, a program selects every pixel in the image which radiometry is in the same range than the training area. It is assumed that they constitute a class of objects of the same nature than the training area.

This procedure has been used to classify the Landsat image (and SPOT, not shown here) covering the Nakhon Pathom province for the urban class (and water, vegetation and flooded areas, not shown here).

The size and distribution of polygons corresponding to the urban class in the 106 sub-districts of Nakhon Pathom province is then compared with the incidence of DHF.

# 3 Results

Incidence of DHF in Thailand 1958 - 1998 (figure 1). Since the 50 the DHF incidence exhibits a constant positive trend. The main epidemics (number of cases) occurred in 1987 and 1997-1998.

Incidence of DHF in the Central Plain of Thailand 1992 – 1998. Figure 2 Despite a great heterogeneity, for a given year, in the level of incidence in the 19 provinces of the Central Plain, ranging from 1 to more than 20, a strong homogenous pattern of transmission characterizes this area when compared to the other Thai provinces. Referring to seasonal variations, the amplitude of the difference in incidence between the higher and the lower months, is significantly smaller than what is observed in other provinces (3.47 versus 7.03; stdev 5.79 versus 8.59; p=0.1). Moreover, the outbreak occurred simultaneously in the 19 provinces, all of them being involved, when it lasted from the end of 1996 to 1999, or did not occur, in other provinces

Case study in Nakhon Pathom province. Figure 3, Population per sub-district. Figure 4, Incidence of DHF in Nakhon Pathom province 1997-1998; and Figure 5 epidemic months obtained by using a significant (1 stdev) departure from the average as a threshold. The epidemic months occurred from June 1997 to May 1998.

Results of the classification, Figure 5 and Figure 6. The urban class obtained from the Landsat image appears mainly concentrated in the South and South Eastern parts of the province and along a network corresponding to the roads. The correlation between the extend of the area covered by the urban class and the number of inhabitants in the 106 sub-districts is 0,8.

GIS development. Integration of different layers of information, epidemiological, remote sensing and economic, to identify risk areas in Nakhon Pathom province.

The highest incidence and most of the epidemic months were found in sub-districts located in the second range of sub-districts, compared to the main roads and in those with a medium density of urban class.

# 4 Discussion

Surveillance of epidemics. The surveillance of epidemics involves the survey of a host population directly (incidence) or indirectly (e.g. practitioners' activity), of the vector pre-imaginal and adult stages and, of the predominance of serotypes in a specific area. The entomological surveys used for the estimation of the larval, pupal or imaginal populations are not very satisfactory inasmuch as they are difficult to be linked with dengue incidence. Moreover, it has been possible to describe some epidemics in different countries, including in Thailand that can break out or go on during the low vector density season (dry season). The follow-up of the climatic indicators, temperature and rainfall especially, is strongly related to their impact on entomological indicators. Although temperature in particular allows the definition of areas and periods at risk for dengue virus transmission, it does not permit the prediction of an epidemic outbreak.

The emergence of a new serotype, or one that has not been observed for a long period in a given population, can also be considered as a risk indicator. But this method is costly, as it requires systematic blood sampling from suspected cases for identification of the serotype. Similarly, the search for virus from potentially infected vectors even if it is being facilitated by the use of molecular biology cannot be done as a routine activity. Moreover, the study of serotypes prevalence in the Thai population is complex since dengue is endemic, with 4 serotypes described in the past ten years, and where two or more can be found simultaneously in a same area. The rate of immune protection of the population being over 90% (from 3% to 97% among children <1 to 10 years of age in Rayong province prior to the 1980 epidemic; over 95% among 2000 males 20 to 25 years of age coming from all over the country in 1998) limits also the use of seroconversion survey to forecast epidemics.

It then appears that if several tools are available for the surveillance of DHF, in Thailand ands other endemic countries, their permanent use at a countrywide scale is not feasible.

The tools developed in our study aims at identify periods at risk at the province level, from the comparison of monthly incidence with retrospective data. Once the warning has been produced; a more precise study at the district and sub-district scale may help to identify which types of urban structure is the main target for the development of the outbreak, and to focus the control activities on these parts of the. In the Nakhon Pathom province, the sub-districts reached by the epidemic during the first 3 months of the outbreak covered less than 15% of the total province.

A better identification of areas at risk is necessary as DHF is classically described as urban, but this term covers a wide range of social and cultural situations. Moreover an increase of the incidence in rural areas as compared to urban is described since the last ten years enlightening a qualitative change in the epidemiology of DHF in Thailand. Urban should rather only means that virus transmission occurs near houses, prior to the spread of the disease to villages and towns, which is dependent on the structure and organization of the urban communities. Moreover, Southeast Asia presents a challenging emerging economy with a fast growing population and urbanization, both having a determinant impact on Dengue Fever transmission, its mechanisms and also the risks of DHF epidemics. Remote Sensing approaches of transmissible diseases have been recently developed but few studies focus on dengue transmission. The major obstacles refer to the scales at which transmission may be studied and the difficulty to discriminate different types of urbanization. In our study, the remote sensing approach is used to identify the type of urban structure where high level of transmission is mainly recorded.

The heterogeneity observed and in our study and the highest incidence recorded in sub-district with medium density of urban class and relatively distant from the main roads, are apparently in contradiction with the main description of DHF risk areas. They are described as the densest urban areas where the virus can spread easily and located near high traffic roads allowing the importation of virus by infected travelers. But the results have to be considered in a temporal perspective developed from 2 main observations. If at least 2 or 3 serotypes circulate simultaneously in most of the provinces of Thailand, they did not necessarily arrived at the same time and the immunity induced by each serotype may greatly vary. The spread of each serotypes in different parts of the provinces is linked to the displacements of infected people carrying the virus and to the season, allowing or not the dispersal of the virus over a large part of the province.

Two hypothesis based on the different level of herd immunity can contribute to explain the observed heterogeneity. A first model assumes that the serotype responsible of the 1997-1998 epidemic was endemic since several years, circulating at a low level of incidence in the most urbanized part of the province, inducing an increasing immunity in that population but never able to reach the neighboring districts distant from several kilometers. In a second model, the 1990 epidemic (supposed to be due to the same serotype than the 199è-1998 epidemic) reached the most dense urban areas, but stopped, for example because of the dry season, before to reach the other sub-districts. In the 2 situations the arrival of the serotype involved in the former transmission process, in 1997 in the sub-districts with a lower immune protection could lead to a localized epidemic, spreading to densely urbanized areas of the province only at the onset of the rainy season, because of the increasing vector population. Serological and virological studies, allowing to identify the virus responsible of different epidemics will help to test the validity of these hypothesis.

This study aims to a better use of known strategies to prevent and control DHF by an innovative use of new spatial technologies in DHF study. A geo-referenced database (GIS) will be built, computing epidemiological data on DHF and associated features from endemic areas of Thailand: demography, climate, environment, remote sensing, urbanization, socio-economic development. The GIS will be kept up to date by constant actualization of the data. Main outputs will be the production of durable indicators of risk, validated by prospective studies and constantly enriched by the comparison with observed information. These indicators will allow to continuously identify areas and periods at risk of increasing incidence and help to design and focus adapted strategies for prevention and control.

## Acknowledgements

We thank the CDC Thailand department of the MOPH, who furnishes regularly the data on DHF incidence. We acknowledge the Mahidol University, the Institute for Science and Technology for Development, the Center for Vaccine Development Team, and the Department for Technical and Economic Cooperation (Thailand) for providing exceptional facilities for our research activities. We thank Professor Natth Bramapavarati for his constant support.

Financial support. This study was supported by the Department for Technical and Economic Cooperation, Thailand, the Center for Vaccine Development, Mahidol University, Thailand and the Department of Societies and Health, IRD, France.

## References

DENGUE AND DHF

Gubler DJ, Kuno G, eds. *Dengue and dengue Hemorrhagic fever.*. Wallingford, UK: CAB International, 425-462.

DENGUE TRANSMISSION.

Kuno G, 1995. Review of the factors modulating dengue transmission. *Epidemiol Rev 17:* 321-335.

Focks DA, Daniels E, Haille DG, Keesling JE, 1995. A simulation model of the epidemiology of urban dengue fever: literature analysis, model development, preliminary validation, and samples of simulation results. *Am J Trop Med Hyg 53*: 489-506.

Jetten TH, Focks DA, 1997. Potential changes in the distribution of dengue transmission under climate warming. *Am J Trop Med Hyg 57:* 285-297.

DENGUE IN THAILAND.

Nimmannitya S, 1978. Dengue haemorrhagic fever in Thailand. *Asian J Infectious Diseases 2:*19-21.

Nimmannitya S, 1987. Dengue haemorrhagic fever in Thailand. *Southeast Asian J Trop Med Pub Hlth* 18: 291-294.

Chareonsook O, Foy HM, Teeraratkul A, Silarug N, 1999. Changing epidemiology of dengue hemorrhagic fever in Thailand. *Epidemiol Infect 122:*161-166.

Sommani S, Okanurak K, Indaratna K, 1995. Social and economic impact of dengue haemorrhagic fever in Thailand. Social and Economic Research Unit, Faculty of Tropical Medicine Mahidol University, Bangkok.

Ungchusak K, Kunasol P, 1988. Dengue hemorrhagic fever, 1987. *Southeast Asian J Trop Med Pub Hlth, 19:* 487-490.

DENGUE SURVEILLANCE

WHO, 1986. Dengue Haemorrhagic Fever : Diagnosis, Treatment and Control. World Health Organization, Geneva

Stroup DF, 1994. Special analytic issues. Teutsch SM and. Churchill RE, eds. *Principles and practices of Public Health Surveillance*, New York: Oxford University Press, Inc, 136-149.

Chan KL, 1985. Methods and indices used in the surveillance of dengue vectors. *Mosquito Borne Dis Bull, 1:* 79-88.

Deparis X, Chungue E, Pauck S, Roche C, Murgue B, Gleize L, 1998. Surveillance épidémiologique de la dengue: Méthode et intérêt lors de l'épidémie de dengue 2 en Polynésie française en 1996. *Trop Med and International Health 3:* 566-570.

Sangkawibha N, Rojanasuphot S, Ahandrik S, Viriyapongse S, Jatanasen S, Salitul V, Phanthumachinda B, Halstead SB, 1984. Risk factors in dengue shock syndrome: a prospective epidemiologic study in Rayong, Thailand.I. The 1980 outbreak. *Am J Epidemiol 120:* 653-669.

Chungue E, Boutin JP, Roux J, 1991. Dengue surveillance in French Polynesia: an attempt to use the excess number of laboratory requests for confirmation of dengue diagnosis as an indicator of dengue activity, *Europ J Epidemiol 7*: 616-620.

Rigau-Pérez JG, Millard PS, Walker DR, Deseda CC, Casta-Vélez A, 1999. A deviation bar chart for detecting dengue outbreaks in Puerto Rico. *AM J Pub Hlth*, 89, 374-378.

## Figures

Figure 1. Incidence of DHF in Thailand, 1958 – 1998.

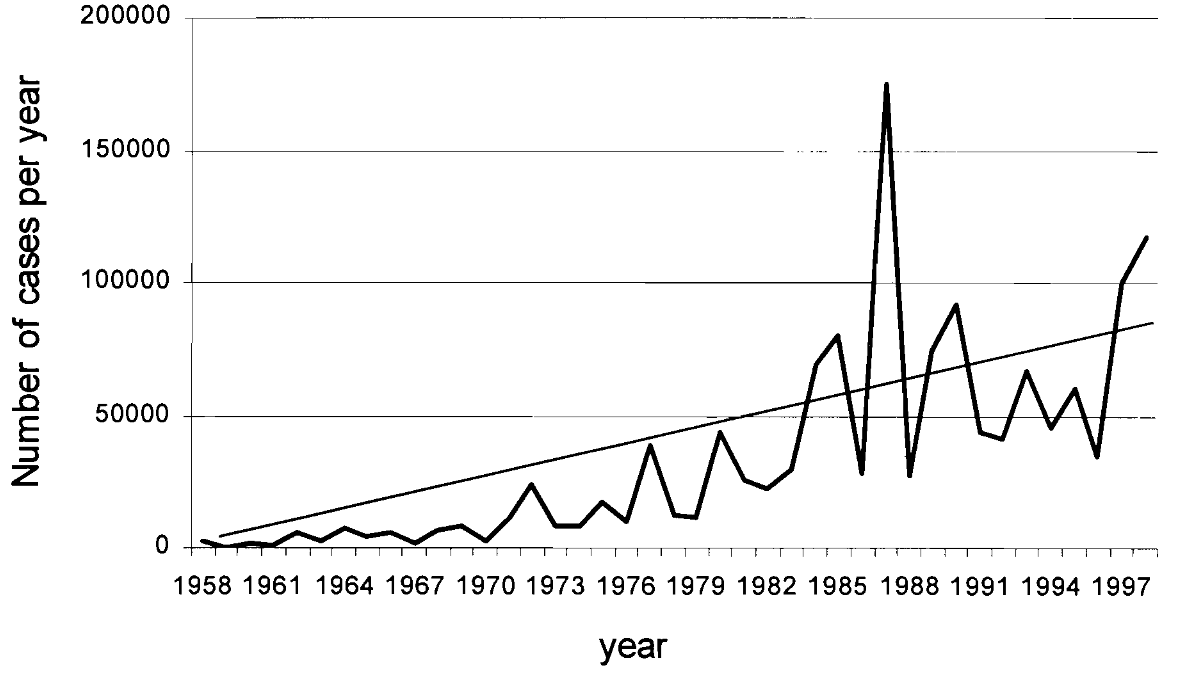


Figure 4. Spatial Heterogeneity in DHF Incidence at the Sub-district scale. DHF Cases / 100,000 Inhabitants, 1997 – 1998 in the 106 sub-districts of Nakhon Pathom Province, Thailand.

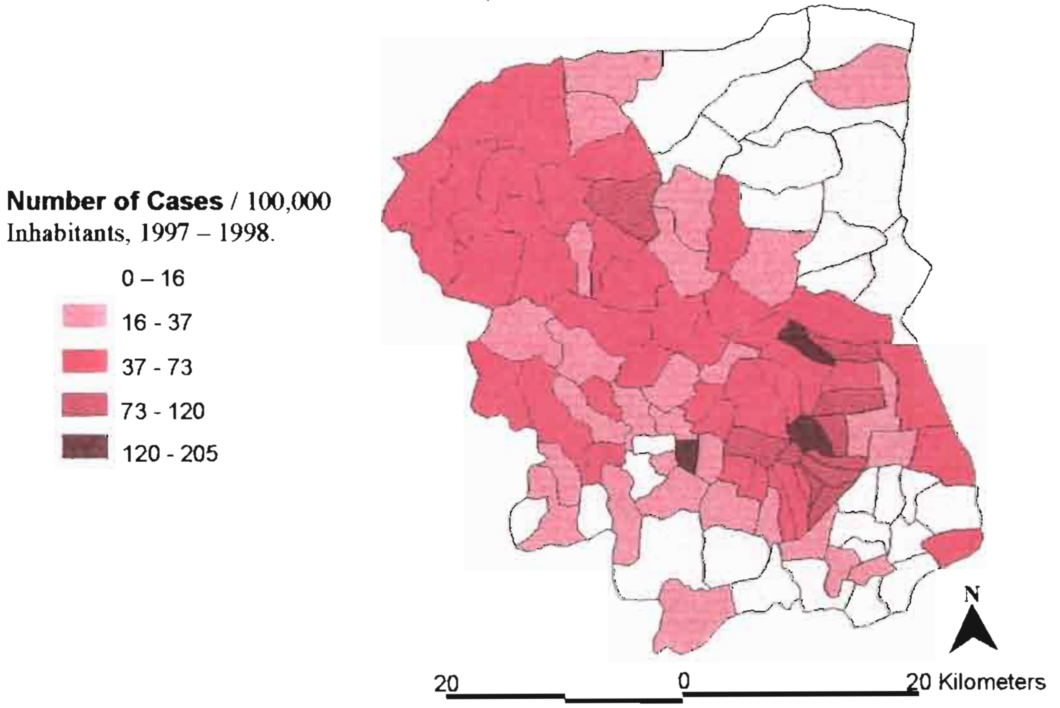



Figure 5. Population in Nakhon Pathom, 1997 (from National Census).

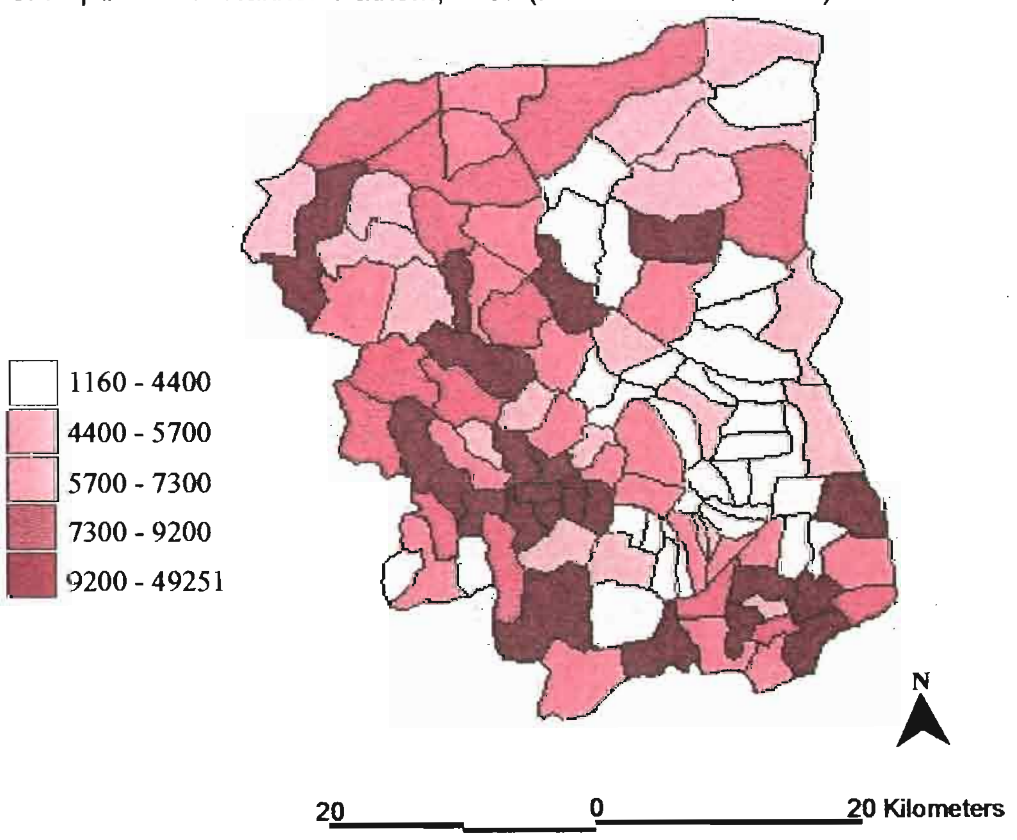
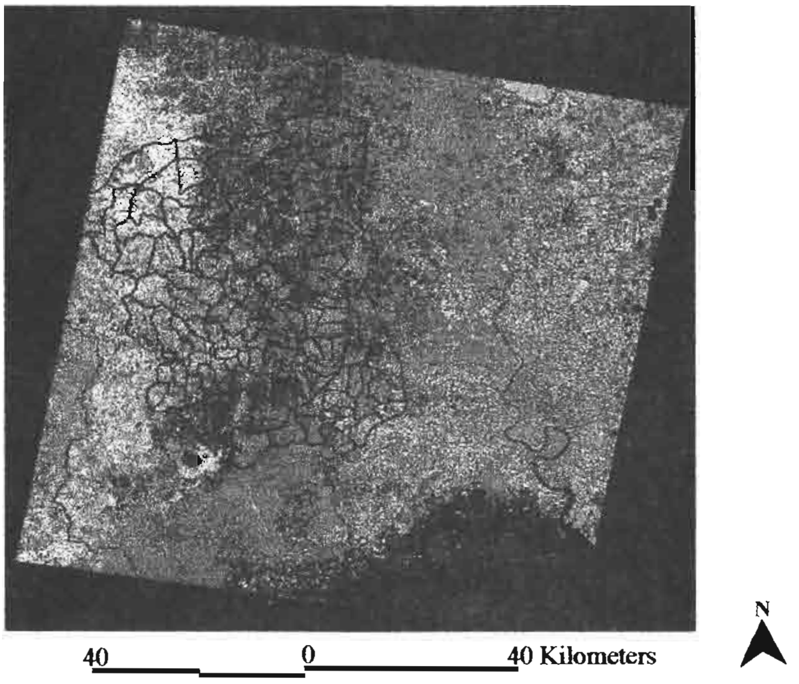


Figure 6: A search for risk areas for DHF. Use of Remote Sensing. Approach in the study of DHF spatial variations. Landsat TM cover of Nakhon Pathom Province, Thailand




**Landsat –TM5, 06/1997. Path/Row : 129/51. Colour Composite : R : 1 - G : 4 - B : 5**

**—— Sub-districts boundaries in Nakhon Pathom Province**

**Figure 7: Remote Sensing. Approach in the study of DHF spatial variations. Result of the supervized classification Urban class obtained from training areas in a Landsat TM cover of Nakhon Pathom Province, Thailand**

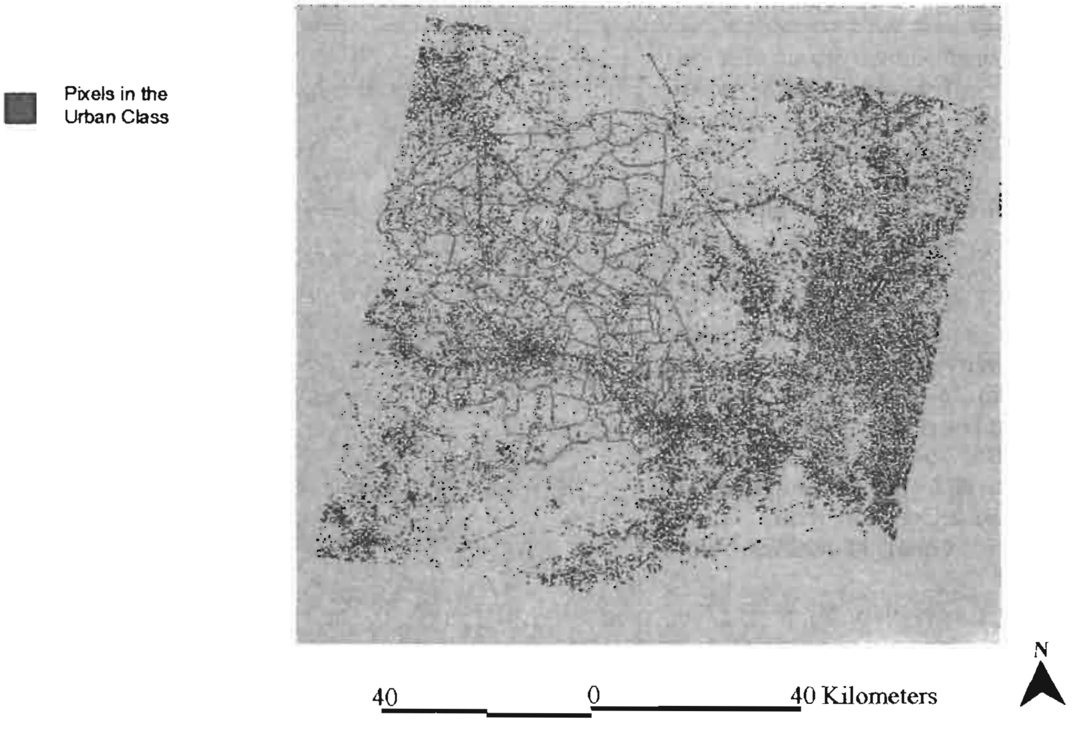


**Figure 8. GIS application. Epidemic sub-districts in Nakhon Pathom Province, 1997 - 1998, urban class and road network.**

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**Volume 1**

12-13-14-15 December 2000, Kasetsart University, Bangkok

Kasetsart University
IRD (Institut de Recherche pour le Développement)
Chulalongkorn University, CUSRI
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