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USE OF GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING FOR ASSESSING ENVIRONMENT INFLUENCE ON LEPTOSPIROSIS INCIDENCE, PHRAE PROVINCE, THAILAND

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ABSTRACT:

Severe epidemics of leptospirosis yearly occurred in Thailand since 1997, causing over 1,200 deaths, especially among farmers highly exposed while working in flooded rice fields. Main vectors are wild rodents, spreading the human pathogenic bacteria (spirocheta) in the environment through their urine. Phrae province, which has recorded among the highest incidences, was chosen for a large scale spatial analysis, in collaboration with Phrae provincial Public Health Office. A health geographic database (GIS) was built, using *SavGIS*[®], a Geographic Information System (GIS) and Remote Sensing (RS) freeware developed by the Development Research French Institute (IRD), to understand the disease dynamics and assess the villagers' exposure. GIS and Remote Sensing processing have shown a great potential in analyzing vector-borne diseases but have never been applied to leptospirosis. The land use was extracted and vegetation indices computed from a TERRA ASTER[®] satellite image and described around villages. In a second step, this information was compared with the reported disease incidence. Problems encountered due to the accuracy of biomedical and location-based data are detailed. The results are exposed and discussed in a preventive planning perspective.

KEY WORDS: Leptospirosis, Geographic Information System, Remote sensing, environment, exposure

1. INTRODUCTION

Considered to be the most common zoonosis in the world, leptospirosis has emerged in Thailand since 1997, as a major health concern (Bharti, 2003; Tangkanakul, 2005). Leptospirosis is caused by pathogenic spirochetes (bacteria) of the genus *Leptospira*, directly or indirectly transmitted from animals to humans (Faine, 1999; WHO, 2003). A wide range of animals, small or large mammals, birds, reptiles or even ticks are potential hosts and vectors. In Thailand, main vectors are murine rodents, spreading the bacteria through their urine or feces in the environment (Plank, 2000). High prevalences have been found in *Bandicota indica*, a large rat occurring in rice fields, and in the genus *Rattus*, comprising various species, from domestic to wild habitats (Bunnag, 1983; Imvithaya, 1999; Phulsuksombati, 2001). Leptospirosis is considered as an occupational disease, affecting mostly farmers working in flooded rice fields, where they get infected through skin lesions. Identifications of *Leptospira* spp. have shown a huge number of different serotypes in both rodents and humans (Boonyod, 2001; Kositanont, 2003), and, considering that, after infection, serovar-specific antibodies do not protect against infection with other serovars (WHO, 2003), immunity is a limited factor in the resistance to the disease. *Leptospira*

spp. have proved remarkable survival ability up to several weeks or months in wet environment and alkaline soils (Henry, 1978; Smith, 1955 and 1961; Faine, 1999), making the environmental conditions major factors of the transmission to humans.

Located in northern Thailand, Phrae province has recorded among the highest incidences of leptospirosis with 1,969 cases from 1997 to 2004, i.e. an average incidence of 58 cases per year for 100,000 inhabitants (Ministry of Public Health, MOPH, 2005). 72.9% of patients were farmers when they represent 55.6% of the total population in Phrae province (Census 2000, NSO). Furthermore average age of patients is 39 (34 for the whole population) and 74.6% of them were men. Leptospirosis can be considered as an occupational disease, mostly infecting active male farmers, in their fields. Based on these considerations, this research focuses first on assessing the influence of environmental patterns on the incidence of leptospirosis in rural areas, and second, on estimating whether vulnerability and exposure to a specific environment can predict the scope of the disease without considering other factors complexly interacting in its transmission.

While Geographic Information Systems (GIS) have proved great potentialities in addressing epidemiological problems, the use of High Resolution Remote Sensing

images (HRRS) has shown some fundamental and recurrent limitations, due to the difficult access, high prices and complex technical images processing, resulting in a generalized use of low resolution free images (Herbreteau, 2005a). A few studies have used RS for investigating rodents (Herbreteau, 2005b) or rodent-borne diseases, and especially hantaviruses (Boone, 2000; Glass, 2000) but none have been published combining RS and leptospirosis.

This research aims at searching for any possible relation between environmental patterns nearby villages, identified from satellite images, and leptospirosis incidences in these villages, based on the leptospirosis cases, reported by the MOPH at Phrae. The use of epidemiological records does not necessarily reflect the exact magnitude of an epidemic, regarding the relative recourse and access to health services, or even difficulties to clinically diagnose such fevers. However, by locating patients in their village of residence, records constitute accurate large scale information about the disease.

2. MATERIALS AND METHODS

2.1 Study area and population

Located in northern Thailand, the study area covers around 27,000 hectares, in the central part of Phrae province where land use and elevation are heterogeneous (Figure 1 and 2). The study site is made of a central flat basin (150-200 meters high) surrounded on each side by hills (900-1,400 meters high).

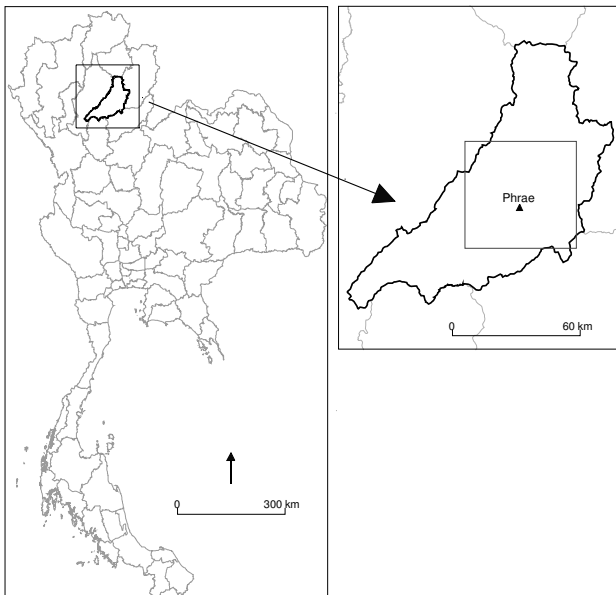


Figure 1. Map of Phrae province in Thailand and delineation of the study area

This site was chosen regarding the high incidences of leptospirosis in rural areas, among the highest in Thailand, suitable to investigate the potential influence of environment on Leptospirosis incidence per village.



Figure 2. Harvest scene in Phrae, a place for leptospirosis infection

In the study area, 267,500 people are listed in 411 villages (gathering each between 99 and 2350 inhabitants), not including agglomerated population (5 municipalities). Both demographic data and villages' location were provided by the National Statistic Office (NSO) of Thailand.

2.2 Satellite image data

In order to estimate the environmental conditions around the villages, we assessed the land use and the levels of vegetation activity. Indeed paddy fields have to be extracted from active vegetation. We acquired from Internet a free TERRA EOS AM-1 (Earth Observing System) ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) image from the 7th of March 2003 (15 meters spatial resolution). It was not possible to get an image during the rainy season because of a permanent cloud cover. The image was arranged in a false color composition merging bands 4, 2, and 1, which contain wavelengths in the near infrared, red and green visible light spectral regions. These wavelengths are useful for discriminating different land covers and vegetation types. The satellite image was geo-referenced based on seven rectified topographical maps (1:50,000) from the Royal Thai Survey Department (RTSD), and later integrated into the location-based dataset.

The Digital Elevation Model (DEM) was generated from the Shuttle Radar Topography Mission (SRTM) available at the United States Geological Survey (USGS) website (<http://srtm.usgs.gov/>).

2.3 Epidemiological data

Seven hospitals and 75 local health care centers were inventoried in the study area, and plotted by GPS during field surveys. Each center diagnosing leptospirosis case, records information about the patients and details about the consultation, later reported to the MOPH, via its provincial representation at Phrae. Exhaustive records of leptospirosis cases notified between January 1997 and December 2004 were integrated into the GIS database in a collaborative effort with the MOPH to conduct a spatio-temporal epidemiological mapping out of leptospirosis. 1,969 cases were reported in Phrae province during this period, corresponding to the emergence and decline of the

disease. No cases were reported in 1997, whereas epidemics were already notified in northeastern provinces. Patients were located at their village of residence.

2.4 Methodology

To assess the influence of environment on leptospirosis incidence, we classified first the satellite image. Then we analyzed the remotely sensed land cover around villages with and without leptospirosis cases, within a three-kilometer buffer (a plausible average maximum distance for farmers from their house to their fields). At last, we statistically tested for any relation between environment and leptospirosis incidence.

The health GIS database implementation and also the following geomatics queries and remote sensing processing were carried out using *SavGIS*[®], a GIS and RS freeware developed by the IRD (Development Research French Institute), downloadable from Internet (<http://www.savgis.org>).

3. RESULTS

3.1 Classification of land cover

Land cover was interpreted from the TERRA ASTER scene using a supervised classification. Lakes, villages and bare lands were easily identified by their specific reflectance. Different vegetation indices were calculated to separate agricultural lands, rice or other cultivations and forests. Vegetation indices measure chlorophyll abundance, and are consequently correlated with vegetation biomass, coverage and productivity. The normalized difference vegetation index (NDVI) could discriminate different levels of dense vegetation coverage, in the forested mountains or in the agricultural plains for rice fields with high vegetation (Rouse et al., 1973). NDVI is a ratio-based index, ranging between -1.0 and $+1.0$, with vegetation having positive values:

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \quad (1)$$

where NIR = value of pixel in Near-Infrared band
 R = value of pixel in Red band

NDVI could hardly distinguish between rice fields with low vegetation and other agricultural lands, such as corn. The soil adjusted vegetation index (SAVI) has proved to be an alternative to NDVI in case of a low vegetation cover, by integrating an adjustment factor “L” (Huete, 1988).

$$SAVI = (1 + L) \frac{(NIR - R)}{(NIR + R + L)} \quad (2)$$

This correction factor is determined by the relative coverage of vegetation and color of soil. For this study, L was given a value of 1 for bare soils and emergent crops, 0.5 for an intermediate stage, and 0 for dense vegetation cover (equivalent to NDVI). Then SAVI could

discriminate rice fields from corn fields. NDVI and SAVI were combined to obtain a classification of the whole image.

Vegetation indices only describe the chlorophyll activity and place in the same class rice fields and forests. Considering that the presence of rodents and exposure to leptospirosis are high in the first one and low in the second, we split them into two categories. To do so, we used the slopes to differentiate rice fields and forests, taking into account that no forest remains on flat lands. Slopes, derived from the DEM, allowed to delineate flat areas (slopes less than three degrees) and especially the large flat plain. Then different land uses could be extracted from the classified image (Figure 3), both in highlands and lowlands.

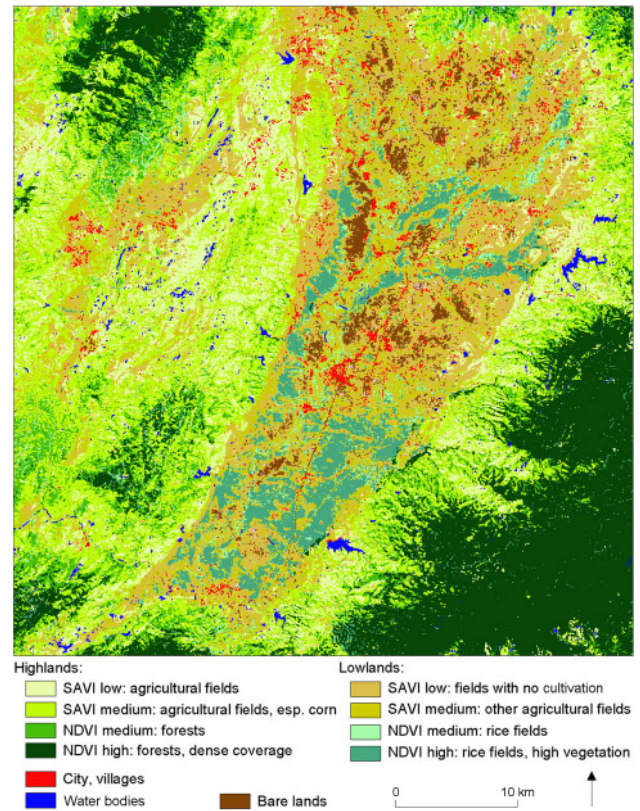


Figure 3. Supervised classification of a TERRA ASTER image from March 2003 in Phrae province, Thailand

3.2 Spatial distribution of leptospirosis cases

The sum of incidences reported from 1998 to 2004 was calculated for 10,000 inhabitants (Figure 4). Some villages registered a total incidence up to 490 cases for 10,000 inhabitants during this period. The highest incidences are concentrated in lowlands, mostly covered by rice fields, and where most of the villages are located (Figure 4).

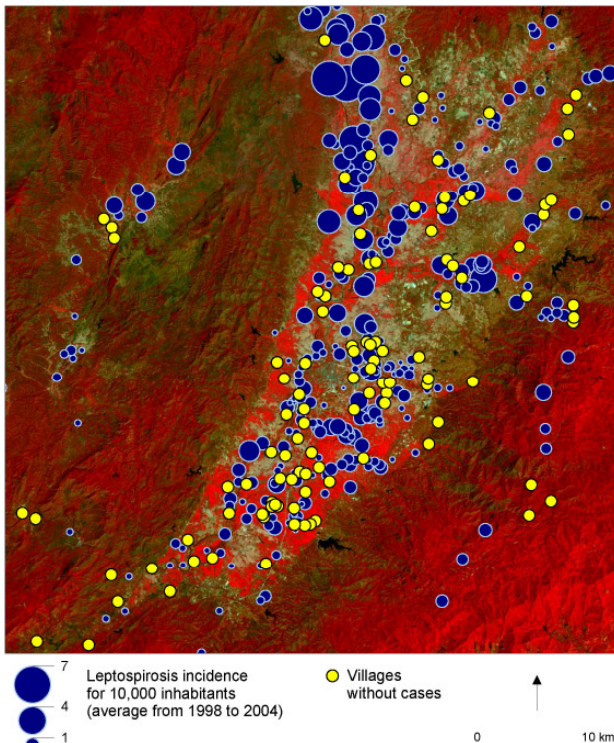


Figure 4. Average annual leptospirosis incidence (for 10,000 inhabitants) from 1998 to 2004 and villages without cases, in Phrae province, Thailand (mapped on a false-color composite image derived from ASTER scene)

3.3 Environmental study around positive villages

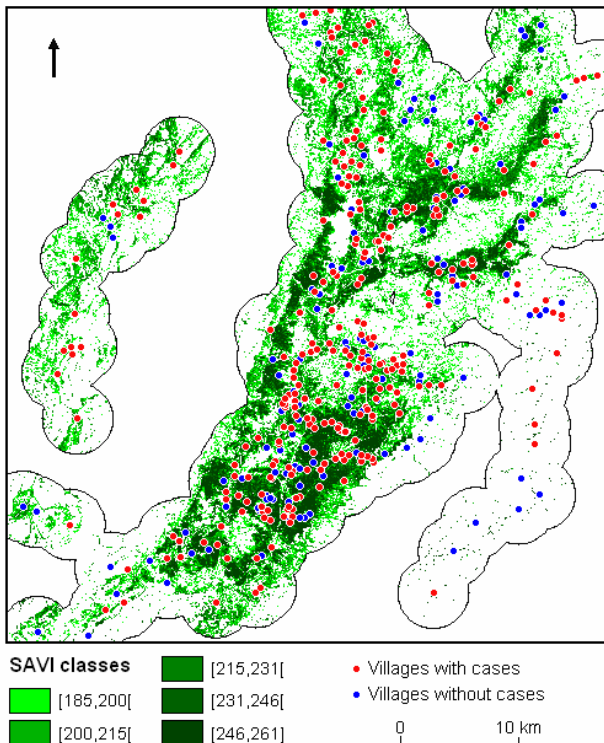


Figure 5. Three-kilometer buffers around positive villages to study their close environment, in Phrae province, Thailand

Assuming that most of the farmers are working within a three-kilometer radius from their village, we computed for each village the percentage of cover with high chlorophyll activity within buffers (highest SAVI values, mostly rice fields). This coverage with high chlorophyll activity represents 41.3% of buffers around villages where leptospirosis cases were notified and 36.9% around villages without any leptospirosis cases (Figure 5). It seems that the presence of rice fields is slightly higher around villages with reported cases. However, no significant correlation was found between leptospirosis incidence and the percentage of rice field extent.

4. DISCUSSION

The use of satellite images allows the description of the land cover and places where infections occur. Working on the assumption that the villagers get infected in the fields nearby their villages does not afford to establish a correlation between the environment and leptospirosis notified cases. First of all, the hypothesis proposed for the distance from fields to villages (defining the buffer zone) may not be sufficient to set the limits of the elusive places where villagers get infected. A thorough analysis on farmers' labour practices should be conducted in addition.

Furthermore, even if epidemiological records have shown that 72.9% of cases in Phrae province are farmers, a more precise environmental analysis is required to improve the delineation of agricultural fields and especially rice fields where the transmission is helped by the presence of water. Beyond exposure to a contaminated environment, other factors strongly intervene in the transmission or not of *Leptospira* spp., contributing to the absence of correlation: i.e. protective gear (boots or gloves), presence of injuries or wounds, presence of infected rodents or free *Leptospira* spp., close contact with rodents (behavioural vulnerabilities associated with hunting, cooking) and eventually immunity with a small implication regarding the numerous different *Leptospira* spp. serovar found in the environment.

Secondly, this study is based on epidemiological data which report what has been diagnosed and not the reality of an infection. To be notified, cases require the recourse to health services by villagers and a correct clinical diagnosis. The similarities of leptospirosis symptoms with those of other fevers may regularly result in misdiagnosis. Lower incidences may also be the consequence of a lower recourse to health care or a difficult access to health facilities.

5. CONCLUSION

Studying vector-borne diseases implies understanding complex interactions between the numerous factors at the origin of the risk of transmission. This present work was carried out at the largest possible scale in Thailand, i.e. the village scale with an unprecedented example in epidemiology. Usually researches linking environment to

diseases incidence deal with small scales databases (large areas, low resolution). Despite limited results, we do believe that the village scale is the only one which will reveal the complexity of leptospirosis infections, this work contributing as a first step in this exploration.

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