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REMOTE SENSING IN UNRAVELLING COMPLEX ASSOCIATIONS BETWEEN PHYSICAL ENVIRONMENT AND SPATIAL CLASSES OF EMERGING VIRAL DISEASE

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ABSTRACT: Emerging viral diseases constitute one of the major threats to human being that are arising in the modern world. Besides bio-chemical and medical researches, new orientations are developed to understand the environmental dimensions of such emergence. Questions concerning the inter-plays between the environmental and disease dynamics are building up new investigations, both in remote sensing and GIS, for the elaboration of levels of organization of space and environment in relation to incidences, to gain understandings in these issues.
Environmental attributes attached to land cover types: area, spatial heterogeneity and physical state, are derived from remote sensing and applied to uncover related dimensions of the Dengue disease.

1. INTRODUCTION

Environmental approach of emerging viral diseases is a particularly complex research. Indeed it is generally acknowledged (WHO, 1997) that human exposure is caused by the inter-plays of social, economical, cultural, natural and artificial environments.
This communication explores the potential associations of some dimensions of the physical environment, with different incidence levels of a disease. Space technology, mainly remote sensing, allows the establishment of the necessary environmental knowledge, the land cover and its related attributes: area, location, spatial organization (homogeneity/heterogeneity) and state (physical/biological).
The application is carried out in the province of Nakhon Pathom (Thailand), with the Dengue as disease. Data concerning the incidence of the disease were obtained, courtesy of the Ministry of Public Health of Thailand.

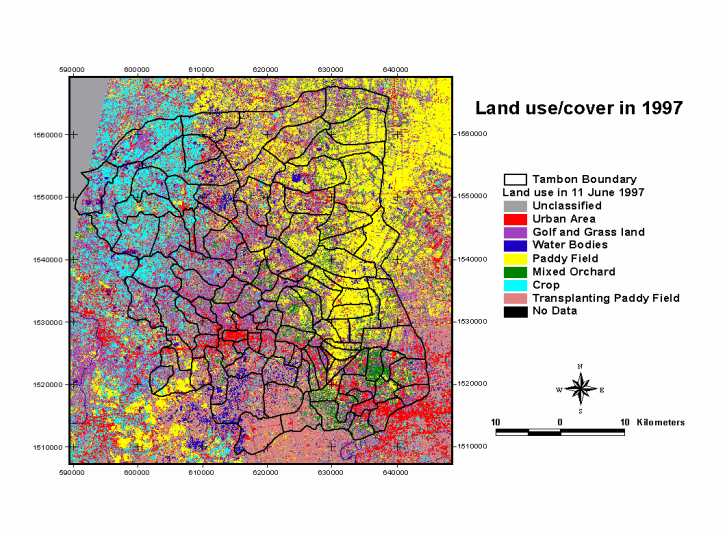
2. APPROACH

Environmental mapping of the province is achieved according to the classification currently used in Thailand by the Ministry of Science and Technology for the Environment (TEI, 1996). Remote sensing supervised process produces a map with a nomenclature of seven items: urban, grass (and golf course), water, paddy fields, mixed orchard, crop, and transplanted paddy fields, plus unclassified. Spatial organization (homogeneity/heterogeneity) of these land cover categories is realized through an unsupervised texture based classification (Andrianasolo & al, 1999), attaching to each land cover type, a level of spatial disorder. Physical/biological state of the land cover is assessed through an application of the vegetation index (Jensen, 1986) derived from the visible and near-infrared wavelengths. Such vegetation index allows qualifying the land cover in terms of more or less water, bare soils and green vegetation. Grouping of administrative entities (sub-districts) in classes are calculated on the basis of each of these three environmental characteristics. Levels of incidence of the disease distinguish also these groupings. The study of these mapped data, relating three different attributes of the physical environment to the disease incidence, permits the analysis of their respective associations. The objective is to find out associations between land cover and classes of diseased sub-districts. The aim is first to gather knowledge and build a database about the environmental conditions of the emerging viral diseases; causal relationships studies would take place only after insights in the complexity of the interplays between environment at large and the emergence are uncovered.

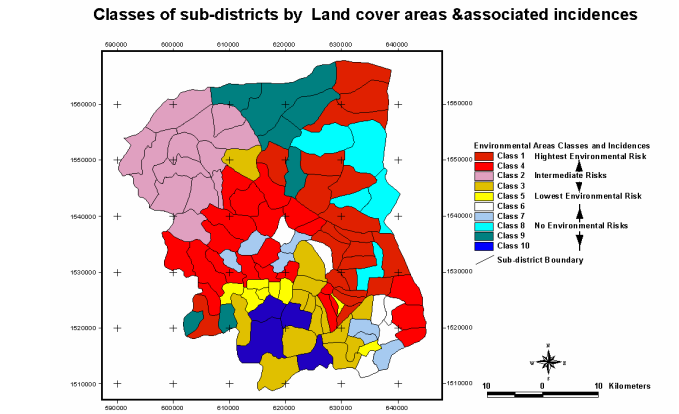
3. ENVIRONMENTAL CLASSIFICATIONS OF SUB-DISTRICTS

3.1 Parameters: Land use/cover areas

The sub-districts are organized in classes according to the distribution of the land cover (Map1) areas. Ten classes (Map2) are obtained, depicting 10 different environmental behaviors of the administrative entities, characterized by distributions and densities of the disease cases (Figure1).



Map 1: Land use/cover



Map 2: Classes of sub-districts by land cover areas & associated incidences

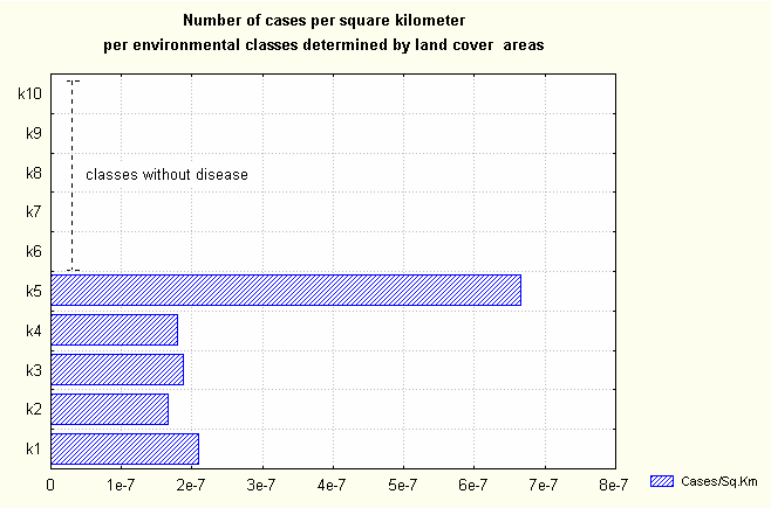
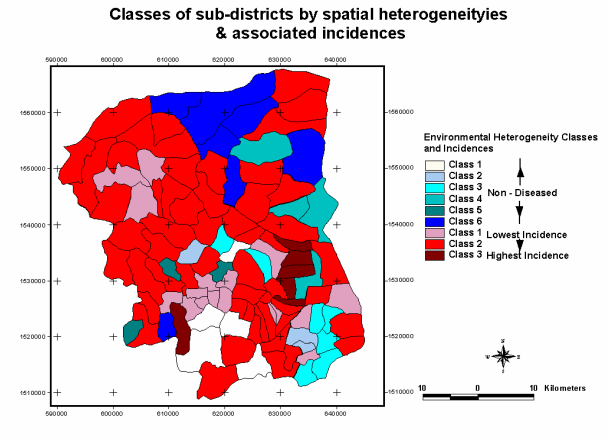


Figure 1: Disease incidence per square kilometer per class

3.2 Parameters: Land use/cover spatial heterogeneities

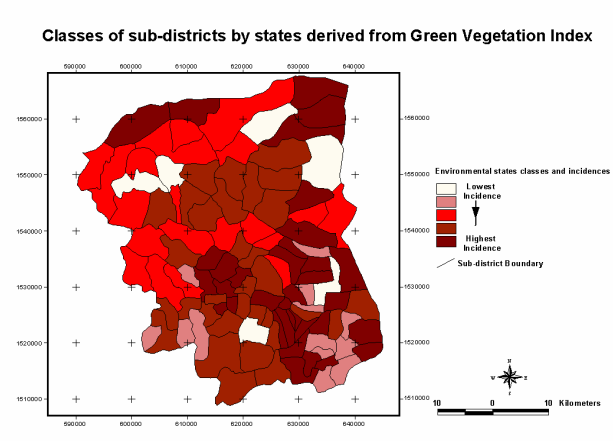
The sub-districts are organized in classes according to the distribution of the land cover types heterogeneity. Nine classes (Map3) are obtained, depicting 9 different land cover spatial organization behaviors of the administrative entities.



Map 3: Classes of sub-districts by spatial heterogeneities & associated incidences

3.3 Parameters: Land use/cover states according to green vegetation index

The sub-districts are organized in classes according to the distribution of the land cover types states. Five classes (Map4) are obtained; depicting 5 different land cover states behaviors of the administrative entities.



Map 4: Classes of sub-districts by Green Vegetation Index & associated incidences

4. ASSOCIATIONS: CLASSES OF SUB -DISTRICTS and DISEASE and LAND COVER

4.1 Land cover areas based associations

Data analysis (Figure2) of the classes of sub-districts as organized by the areas of land cover shows variations in the types of associations. Remarkable groupings are noticed, which produce precise classes of the administrative entities joined to land use/cover categories characterize.

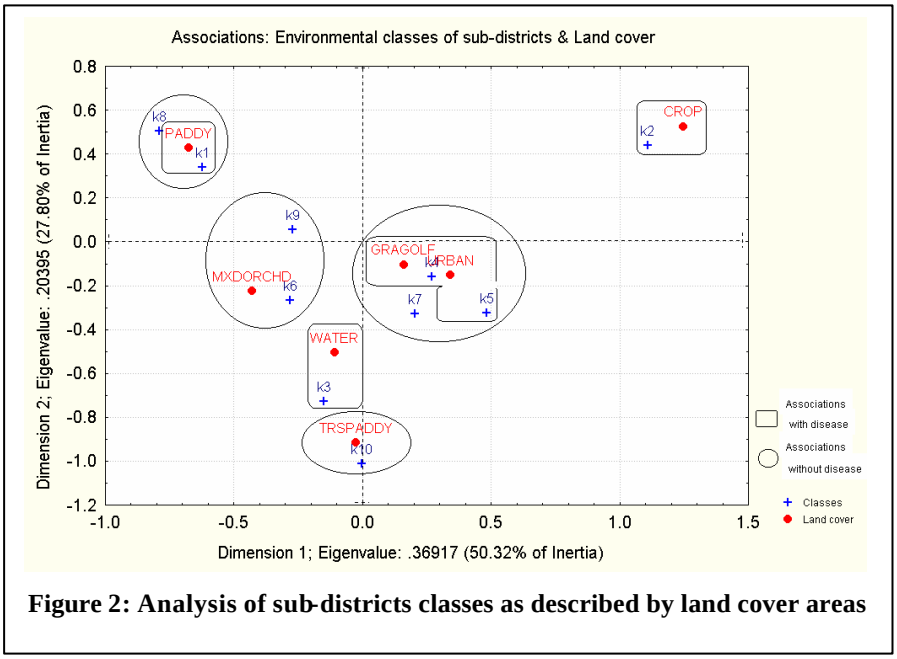


Figure 2: Analysis of sub-districts classes as described by land cover areas

- Diseased classes with types of land cover have variability:
  - Class “k1” is associated to “paddy fields”
  - Class “k2” is associated to “crop”
  - Class “k3” is associated to “water”
  - Classes “k4” and “k5” are associated to “grass & golf course” and “urban”
- Non-diseased classes with types of land cover have variability:
  - Class “k8” is associated to “paddy fields”
  - Classes “k6” and “k9” are associated to “mixed orchard”
  - Class “k10” is associated to “transplanted paddy fields”
  - Class “k7” is associated to “grass & golf course” and “urban”
- Some diseased and non-diseased classes are associated to the same types of land cover:
  - Diseased class “k1” and non-diseased class “k8” are associated to “paddy fields”
  - Diseased classes “k4” and “k5” and non-diseased class “k7” are associated to “grass & golf course” and “urban”

In the case of the diseased classes “k2” and “k3”, the associated land covers “crop” and “water” can be mapped, to display the areas characterizing these classes.
In the cases of the land covers “paddy fields”, “grass & golf course” and “urban” it would be difficult to decide whether they are associated to the diseased classes “k1”, “k4” or “k5”, or non-diseased “k7” and “k8”.

4.2 Diseased “k4 & k5” / Non-diseased “k7” in relation to environmental heterogeneity

GIS model, involving the conjunction of the layers “sub-districts classes by environment areas” and “sub-districts classes by environment heterogeneity”, results in a new layer where classes “k4”, “k5” and “k7” are broken up in 7 classes:

Envtal. Areas	K4	K4	K5	K7	K7	K7	K7
Heterogeneity	K11	K12	K11	K1	K2	K3	K5
Conjunction	K114	K124	K115	K17	K27	K37	K57

Spatial heterogeneity
Study of spatial heterogeneity associated to these new categories (Figure3) demonstrates that for:

- The diseased “k115” and “k114” there is an association with the heterogeneity of the land cover “transplanted paddy fields” (TXTC7)
- The non-diseased “k37” there is an association with the heterogeneity of the land cover “urban” (TXTC1)

On the contrary, simultaneously associated to the heterogeneity of “grass & golf course” (TXTC2) are the diseased “k124” and non-diseased “k17”, k”27” and “k57” types, requiring deeper investigations.

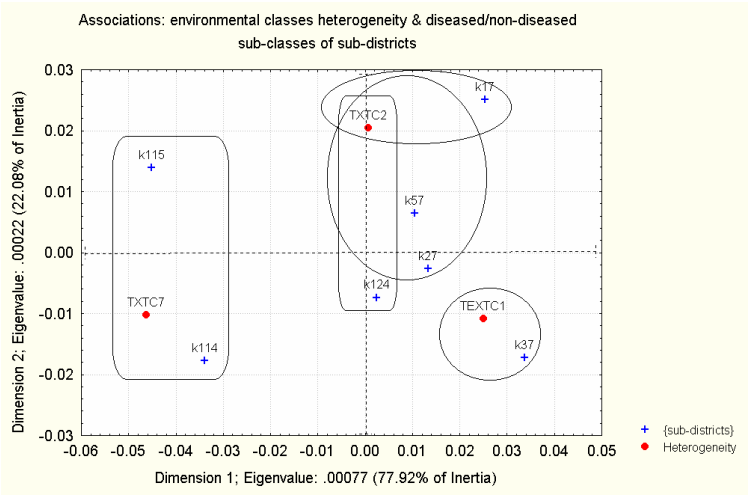


Figure 3: Analysis of the associations between diseased/non-diseased sub-classes & spatial heterogeneity

Analysis of these 4 mixed classes (Figure 4) demonstrates that the diseased category is associated to the highest levels of "urban", and to the lowest – up to the average levels of "grass and golf course" heterogeneity.

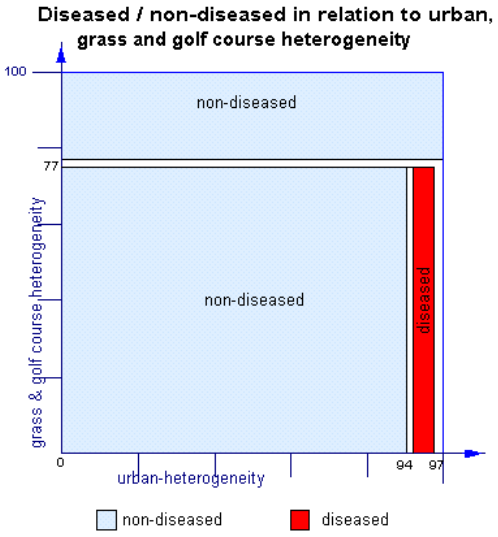


Figure 4: Urban and Grass & Golf Course heterogeneities splitting diseased/non-diseased classes

4.3 Diseased "k8" / Non-diseased "k1" in relation to Paddy fields' attributes

Previous analysis (cf. Figure 2) shows that the classes "k1" and "k8", respectively diseased and non-diseased, are both associated to the land use/cover "Paddy fields". This step is aiming at identifying complementary associations able to distinguish between these classes, using the attributes state derived from the "Green Vegetation Index" and "spatial heterogeneity" of "Paddy fields".

Paddy fields' state

Green vegetation index is able to order the states of land cover globally from water to green vegetation, through bare soils. The values of the paddy fields (Figure 5) are ranging from bared soils to highly green vegetation. Interpretation highlights that associations to the disease take place first with bared, and then with green highly vegetative paddy fields. On the other hand, non-diseased classes are associated to vegetative and very highly green vegetative paddy fields.

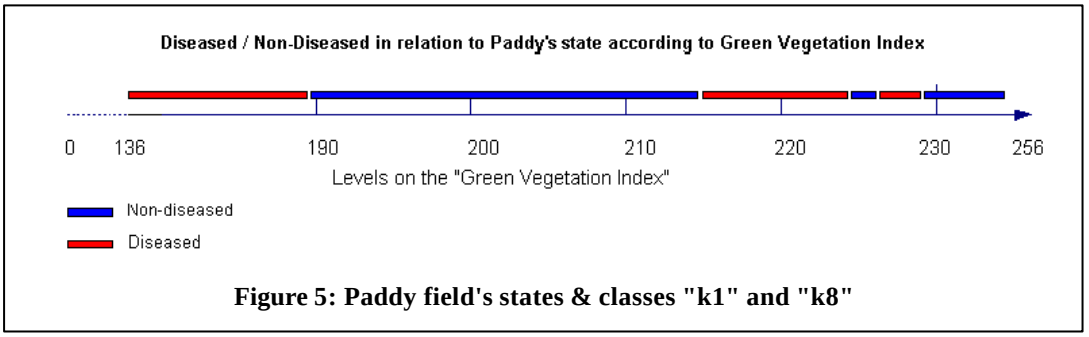


Figure 5: Paddy field's states & classes "k1" and "k8"

Paddy fields' spatial heterogeneity

On a heterogeneity scale (Figure 6) of [0,100], the levels associated to paddy fields are globally under the average, belonging to the interval [23,65]. Out of it, relatively homogeneous spatial organization [23,40], and from average to just above average [43,65] are associated to the disease. Levels just under the average [40,43] are associated to no-disease.

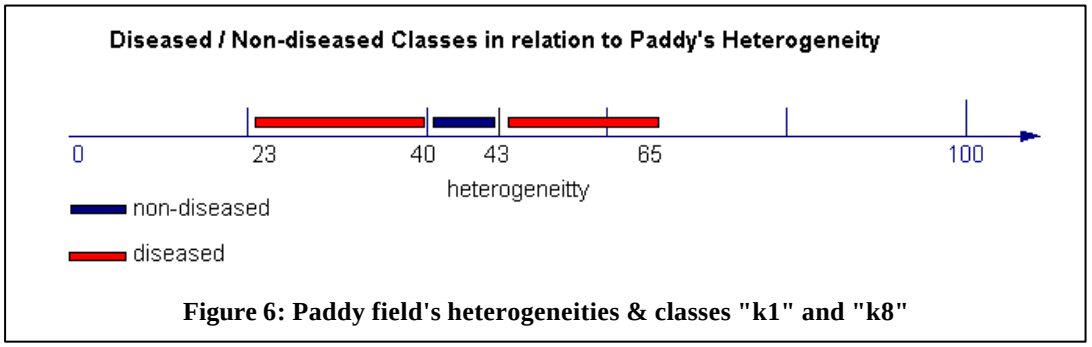


Figure 6: Paddy field's heterogeneities & classes "k1" and "k8"

CONCLUSION

These results highlight the great complexity of the environmental health issues. They demonstrate that to advance forward, and before discussing causal relationships and/or risk zones establishment, a complete system approach has to be built up to explore, break down the complexity and gather out coming factual and punctual results. This would allow seeking for regularities and actual knowledge.

Our approach here is involving databases, GIS, remote sensing, data analysis and mining. Remote sensing is playing a central and fundamental role in that without it, knowledge on the physical environment: location, area, heterogeneity, physical and biological state, would be actually difficult to acquire in the same synoptic and exhaustive way.

The approach developed here is potentially usable even with the inclusion of the socio-economic environment. Which constitutes our next steps, to really tackle this problematic at all the necessary dimensions, and to demonstrate that information, space and science technologies are an inherent part of this sustainable development essential issue.

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