Applications of remote sensing and spatial analysis in epidemiology

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Outline

• Context

• Remote sensing
  – Example: Bat-borne diseases (SEAe project)

• Spatial analysis
  – Example: Rodent-borne diseases
    *(Ceropath and BiodivHealthSEA projects)*

• Discussion
Context: an epidemiological system

Ecotope
- Climate
- Landscape

Host

Pathogen

Vector

Reservoirs

Communities

Local practices

Public policies
Remote sensing: definitions

- Broad definition: Acquisition of information of an object or phenomenon, by the use of devices that are not in contact with the object
- In particular:
  - Earth Observation by satellite or aircraft platforms
  - Measure of reflected of emitted electromagnetic radiations
More and more Earth Observation satellites
Remote sensing

- From a measure of electromagnetic radiations …
  … to the detection and characterization of the habitats of vectors or wild reservoirs

![Graph showing spectral signatures of vegetation, soil, and water]

**SPOT image, Loei province, Thailand**
Remote sensing

- Detection and characterization of the habitats of vectors or wild reservoirs: spatial informations
  - Land cover
  - Water bodies
  - Dynamics
Remote sensing

- **Limits**
  - Very specific characteristics (ex. water properties)
    
  
  - Trade-offs between spatial/temporal/spectral resolutions
    
Ex: Spatial resolution / swath width

MODIS ~1100 km / 500 m

LANDSAT ~ 180 km / 30 m

Quickbird ~ 15 km / 2.5 m
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• Discussion
SE Ae project – Nipah virus

• Identifying risk factors for Nipah virus encephalitis

• Reservoir host: bat ‘flying fox’ (genus *Pteropus*)

• Roosts of bats in Cambodia: temples + fruit trees plantations (mango and longane-trees)

*Can we map fruit-trees plantations using satellite imagery?*
SE Ae project – Nipah virus

Gardens with fruit-trees

Longane plantations

Landsat
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• Discussion
Spatial analysis

- Study the correlations between:

<table>
<thead>
<tr>
<th>Variable to explain</th>
<th>Explicative variables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Epidemiological data:</strong></td>
<td><strong>Environmental characteristics:</strong></td>
</tr>
<tr>
<td>cases presence incidence rate</td>
<td>✓ Land cover (vegetation, water bodies,..)</td>
</tr>
<tr>
<td><strong>Entomological data:</strong></td>
<td>✓ Landscape indices</td>
</tr>
<tr>
<td>presence/absence abundance</td>
<td>✓ Climate (temperature, humidity)</td>
</tr>
<tr>
<td>...</td>
<td>✓ Elevation...</td>
</tr>
</tbody>
</table>

- Methodological issues
  - Choice of the spatial unit for analysis and location
  - Choice of the explicative variables
Remote sensing and landscape indices

• Detection and characterization of the habitats of vectors or wild reservoirs: spatial informations
  
  – Surfaces, distances
  
  – Diversity, fragmentation, connectivity indices
  
  – ‘Customized’ indices: defined based on ecological hypotheses
### Example

- **Detection of temporary water bodies, Sénégal**

- **Characterization using landscape indices**

<table>
<thead>
<tr>
<th>Index</th>
<th>Hypothesis</th>
<th>Example – lowest value</th>
<th>Example – highest value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface of water</td>
<td>RVF risk is higher in the vicinity of small ponds (Chevalier, 2005)</td>
<td><img src="image1" alt="Example" /></td>
<td><img src="image2" alt="Example" /></td>
</tr>
<tr>
<td>Vegetation cover in the pond</td>
<td>Ponds rich in vegetation are favourable habitats of mosquitoes (Clements, 1999)</td>
<td><img src="image3" alt="Example" /></td>
<td><img src="image4" alt="Example" /></td>
</tr>
<tr>
<td>Vegetation cover around the pond (100 m buffer)</td>
<td>Vegetation cover favour mosquitoes dispersal (Clements, 1999)</td>
<td><img src="image5" alt="Example" /></td>
<td><img src="image6" alt="Example" /></td>
</tr>
</tbody>
</table>
Patterns analysis

- Example: mapping the landscape ‘at risk’ for Rift Valley fever transmission (Senegal)

**Variable to explain**
RVF sero-prevalence in small ruminants

**Explicative variable**
Landscape indices derived from Quickbird imagery
Pattern analysis

- Importance of landscape indices
  - Landscape ‘at risk’ for Rift Valley fever
  - Vegetation density index

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CERoPath project (ANR 07 BDIV 012):

Community Ecology of Rodents and their Pathogens in South-East Asia

www.ceropath.org

→ aiming at understanding the implication of rodents in the transmission of diseases,
→ in a context of rapid environmental changes.

Photos: Herbreteau V.
Material and Methods: 
Rodent sampling

7 study sites in 3 South-East Asian countries (Cambodia, Lao PDR, Thailand):

**Trapping in lines:**
30 lines of 10 traps, left 4 nights:
- 10 in forested areas
- 10 in dry fields
- 10 in wet ricefields.
→ total of 1,200 night-traps

Trapping during 2 season (wet / dry):
→ 2,400 night-traps per site
→ Total of 16,800 night-traps.

**Complementary trappings:**
in villages
in places with signs of rodent presence from hunters.

Total of 2,136 murine rodents
27 different species
(incl. 10 species with less than 10 individuals)
Material and Methods: Satellite imagery

High spatial resolution multispectral images

- SPOT scenes (PAN: 2.5 m, MS: 10 m)
- Three dates from 1987 to 2008
- As possible, cloud-free scenes

Digital Elevation Models

- SPOT-DEM (20m)
- Shuttle Radar Topography Mission (SRTM) (90m)
Results:
Land-cover maps

Various landscapes

- 2 sites largely covered by wooded areas (Luang Prabang, Lao PDR, and Mondolkiri, Cambodia)
- 1 site with limited forested areas (Buriram, Thailand)
- Differences in size of forested patches

Photos: Morand S.
Results:
Land use / cover changes

Land use / land cover classification in Loei province, in 1987
Results:
Land use / cover changes

Land use / land cover classification in Loei province, in 1996
Results:
Land use / cover changes

Land use / land cover classification in Loei province, in 2007
Results:
Land use / cover changes

Land use / land cover classification in Mondolkiri province, in 1988

- Agricultural areas
- Clouds and shadows
- Forested areas
- Built-up
- Water

[Map showing land use/cover changes in Mondolkiri province, 1988]
Results:
Land use / cover changes

Land use / land cover classification in Mondolkiri province, in 1998

- Agricultural areas
- Clouds and shadows
- Forested areas
- Built-up
- Water
Results:
Land use / cover changes

Land use / land cover classification in Mondolkiri province, in 2008
Results:
Landscape and rodents

Rats inhabit different biotopes

- **Houses, village, cities**
  - *Rattus losea, R. exulans, R. norvegicus*

- **Low land - irrigated**
  - *Bandicota indica, R. argentiventer, Mus caroli, B. savilei, M. cervicolor*

- **Midland – degraded / cultivated**
  - *Rattus tanezumi, Mus cookii, Berylmys spp., Niviventer fulvescens*

- **Forests – preserved / degraded**
  - *Leopoldamys spp, Maxomys spp.*

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• Microparasite richness: number of pathogen species (viruses, bacteria, protozoans) for which each rodent species was found positive

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Discussion (1)

- Remote sensing and spatial analysis: tools for epidemiologists
  - Environmental-related diseases
  - Inter-disciplinarity

Predicted probability of HPAI H5N1 virus presence

(Gilbert et al. 2008)
• Challenges
  – Characterizing different urbanization types
  – Dynamics processes
    • Short-term (flooding, satellite tracking data…)
    • Long-term (landscape changes and communities)
  – Use of very high spatial resolution imagery / scale issues
• Integration of social sciences in the understanding of sanitary and environmental risks

PhD J-F Cornu “Infectious diseases, ecological, epidemiological and cultural landscapes" (project BiodivHealthSEA)

• Modelling landscape dynamics: drivers and impacts on health (Ocelet)
Acknowledgments

CERoPath and BiodivHealthSEA projects
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SEAe project
(Funded by AVIESAN, Total foundation, European Commission)

CNES - ISIS program

Thanks for your attention!
Development of operational tools

• Surveillance of *Aedes albopictus* in Southern France
  - High spatial resolution imagery - > mosquito habitats
  - Mosquito dynamics population model
  - Population statistics

• Development of an extension for Quantum GIS (freeware)
Development of operational tools

- Surveillance of *Aedes albopictus* in Southern France
Patterns analysis

- Example: mapping the distribution of different mosquito species (Southern France)
  - Which are the main breeding sites of each species?
  - Impact on the spatial distribution of adult populations?

**Variable to explain**
Presence / absence of larvae

**Explanatory variable**
Land cover (Landsat imagery)

Mosquitoes larvae collections April - October 2006
*Anopheles hyrcanus:*

- Present
- Absent
Pattern analysis

- **Results**
  - *An. hyrcanus*: rice fields and marshes with *Scirpus*
  - Map of the breeding sites
  - Validation using trapping data of adult mosquitoes
