Remote sensing analysis of the links between urban landscapes and the risk of exposure to *Aedes* mosquitoes, vectors of arboviruses.

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Funded by CNES & Région Occitanie
PhD Context

Regional Cooperation Project for the Observation of the Guyana Shield by SATellite (PROGYSAT)

**Health:** Malaria and mosquito-borne arboviruses
- Emmanuel Roux (IRD), Margarete Gomes (SVS-AP)

**Urban Axis:** Analysis of Urban Space Dynamics by Satellite
- Nadine Dessay (IRD), Gutemberg Silva (UNIFAP), Paulo Peiter (Fiocruz)

PhD labelled by RIVOC in MUSE program which deals with the sustainable management of vectors risk as an issue for global health in France

Project financed by the French Spatial Agency to work on several methods combining remote sensing and spatial modelling to predict the dynamics of mosquito vectors and associated diseases.

Annelise Tran, CIRAD, UMR Tetis
**Context**

**ARBOVIRUSES:**

viral diseases caused by a virus transmitted by an arthropod vector (focus on *Aedes* mosquitoes)

- Increasing risk to global health
- Distribution of vectors - spatial boundaries of transmission of this diseases
- Great diversity of factors affecting the distribution of *Aedes* vectors at different scales

Kraemer et al., 2015, Pictures Duvallet et al., 2017

Predicted distribution of *Aedes aegypti*

Predicted distribution of *Aedes albopictus*
**Context**

- Spatial modelling of vector-borne diseases
  - based on a number of heterogeneous data (entomological, epidemiological, environmental, socio-economic) and at different scales
- Potential of remote sensing (proxy extraction, diversity of data, genericity of methods)

Risk map identifying habitats suitable for *Aedes albopictus* provinces of Iran. Nejati et al., 2017

Risk map identifying habitats suitable for *Aedes aegypti*, in Cordoba City, Argentina. Estallo et al., 2018
Scientific question and objective

Limited access to epidemiological and entomological data

Need for simple tools for spatialization of risks

Land cover / spectral indices vs. Landscape structure

Unsuitable global products for city scale applications, especially for health issues

Objective

To develop an approach to spatialize the risk of exposure to Aedes mosquitoes that makes the best use of satellite data and available data (entomological, epidemiological, etc.) in order to make it reproducible, generic and adapted to the needs of health actors.
Two contrasting study sites

Equatorial Climate
Regular outbreaks
*Aedes aegypti*

Cayenne

Montpellier
No outbreak, imported and autochthonous cases detected and controlled
Crisis risk area
*Aedes albopictus*
Public health partners

Collaboration with public health partners to identify needs in terms of cartography and tools

- Better identify risks between outbreaks and at a finer scale
- Target priority areas so that their efforts and resources can be directed according to the need.

Differents scale of analysis (Global, Regional, City, Neighborhoods...)

→ Focus on the city and neighborhoods scales
Project axis

Axis 1: Urban variables based on satellite imagery

Axis 2: Breeding sites and mosquito density modeling

Axis 3: Degree of populations exposure to mosquitoes

Axis 4: Spatialized index of population exposure to Aedes vectors
Objectives:

- Identify factors that influence the presence of breeding sites and *Aedes* mosquitoes
- Identify which urban variables are related to this factors and how to extract them from thanks to several satellite imagery
Review focus on articles that use remote sensing and geomatics, which variables are used for modeling *Aedes* distribution?

**Axis 1: Urban variables from satellite imagery to characterise urban landscapes in relation to Aedes mosquitoes**

- Number of occurrence of articles
- Types of variables
- Most often used:
  - vegetation index,
  - humidity index,
  - brightness index,
  - land cover map,
  - temperature
Analysis of sensors and remote sensing variables used in modelling

- Imagery allows to study urban landscapes at different scale
- Majority of sensors allows to work at the city scale but much less at neighborhoods scale which can be interesting for health studies
- Climatic variables is at low spatial resolution no matter the scale of analysis, other variables depends on the scale and resolution

![Diagram showing the analysis of sensors and remote sensing variables used in modelling](image)
Different types of spatial modelling of mosquito densities:

- "Mechanistic" differential equation model based on the bio-ecology of the *Aedes* vector (Tran et al., 2013) ARBOCARTO - tool CIRAD & French Health Ministry

Input of this model:

https://www.arbocarto.fr/

Tran et al., 2013

→ Objective: To refine and improve the estimation of the number of potential breeding sites based on remote sensing information
Focus on characterization on urban landscape:

- Texture analysis with **FOTOTEX** algorithm ([Teillet et al., 2021](#))
- Allows to improve knowledge of landscape by analysing the texture of different images at different scales

Open source python code available:

- [https://framagit.org/espace-dev/fototex](https://framagit.org/espace-dev/fototex)
- [https://pypi.org/project/fototex](https://pypi.org/project/fototex)
Texture can be defined as a function of spatial variation of the brightness intensity of the pixels.

In other terms: arrangement, disposition of elements in relation to each other create a pattern that you can see with your eyes!
Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of *Aedes* mosquitoes

- **Principle of the FOTOTEX method**

  **A- Partitioning the image into analysis windows**
  block or sliding window

  **B- Fourier transform analysis**
  Decomposition of the signal linked to the repeating patterns as a sum of sinusoidal functions (texture-to-frequency conversion)

  **C- PCA on the spatial frequency matrix**
  each window is characterised by a large number of frequency variables (repetition of patterns) which are reduced

  **D- RGB colour composition**
  Spatial representation of the distribution of the frequencies that make up the initial image
  \( R = \text{PC1}, \ G = \text{PC2}, \ B = \text{PC3} \)
Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of Aedes mosquitoes

- Modelling breeding sites with the help of remote sensing
  - Statistical model developed in Reunion (*Aedes albopictus*, specific spatial delimitation)

Internship of Ophélie Hoarau

**Explicative variables**

<table>
<thead>
<tr>
<th>Environmental variables</th>
<th>Topo-climatic variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrals indices (vegetation, brightness, humidity)</td>
<td>Altitude</td>
</tr>
<tr>
<td></td>
<td>Annual average temperature</td>
</tr>
<tr>
<td>Textural indices from FOTOTEX</td>
<td>Rainfall cumul</td>
</tr>
</tbody>
</table>

**Dependant variable**

Entomologic data

- Number and types of gites from field

**Generalized linear model**

Spatialized prediction of the number and type of potential breeding sites
Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of Aedes mosquitoes

- Modelling breeding sites with the help of remote sensing
  - Statistical model developed in Reunion (Aedes albopictus, specific spatial delimitation)

Correlation between predicted values and observed values
Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of *Aedes* mosquitoes

- **Application of the statistical model in Cayenne:**
  - value of breeding sites very high
  - heterogeneous areas especially close to dense urban areas
Application of the statistical model in Montpellier

○ values between 20 to 150
○ high values concentrated in the city center and some neighborhoods in particular
Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of *Aedes* mosquitoes

- Exploratory approach to estimate the number of potential breeding sites over study sites

1. Improve the existing method implemented in ARBOCARTO
2. Improve statistical model
3. Validation
4. Acquisition of validation data (request still pending)
5. Adding other training dataset or other urban variables (axis 1)
6. Ameliorate experts estimation by adding more information of urban landscapes knowledge
Socio-economic factors in relationship to population exposure have been found in literature.

**Objective:** Integrate more information on population exposure into modelling risk.
Internship of Nicholas de Kock (3 months)

- Creating socio-economic classes from remote sensing information combined with OSM data and global data (GHSL)

Axis 3: Spatialize the areas where the population is most exposed to mosquitoes using urban variables from remote sensing and spatialized information
Axe 4 : Production of a indicator of risk of exposure to Aedes mosquitoes

- Spatialized risk indicator
  - Combine predictions on mosquitoes and the degree of exposure of populations
  - Apply all the approach and validate on Cayenne and Montpellier
  - Apply to other study sites to test the reproducibility, automatic and generality of the entire approach
Thank you
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thank you

https://www.quae.com/produit/1784/9782759236299/teledetection-et-modelisation-spatiale