GeoOneHealth Symposium

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)

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

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)

ANISETTE

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.

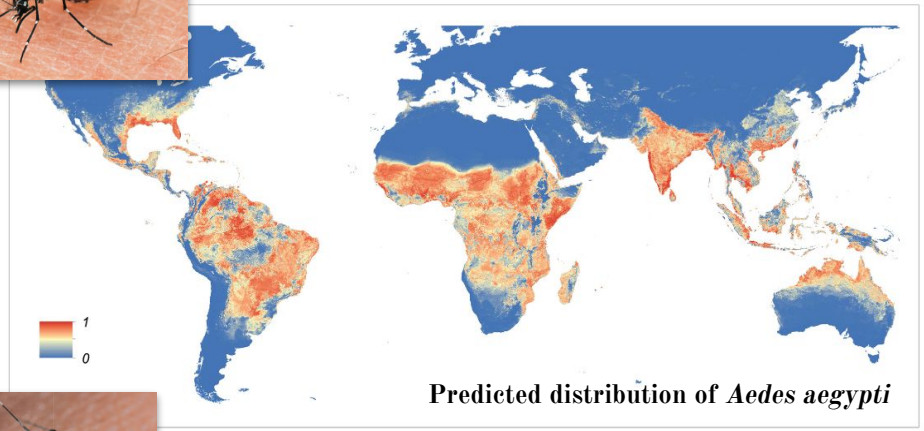
Annelise Tran, CIRAD, UMR Tetis

Context

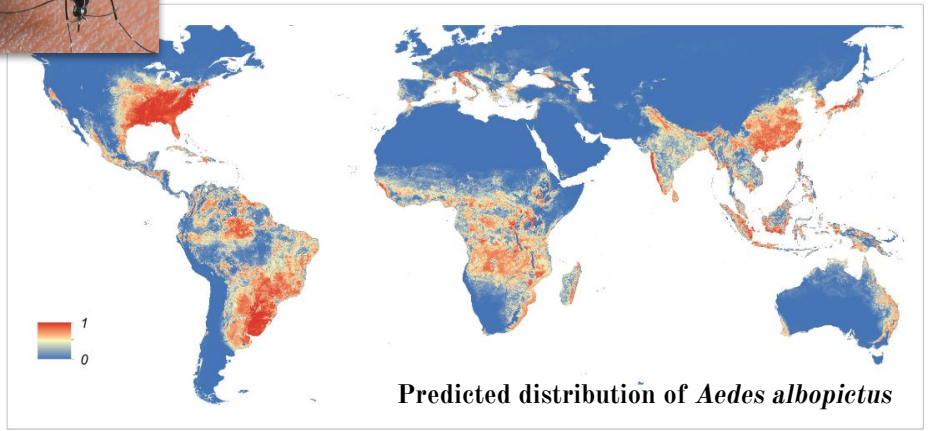
ARBOVIRUSES:

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



Predicted distribution of *Aedes aegypti*

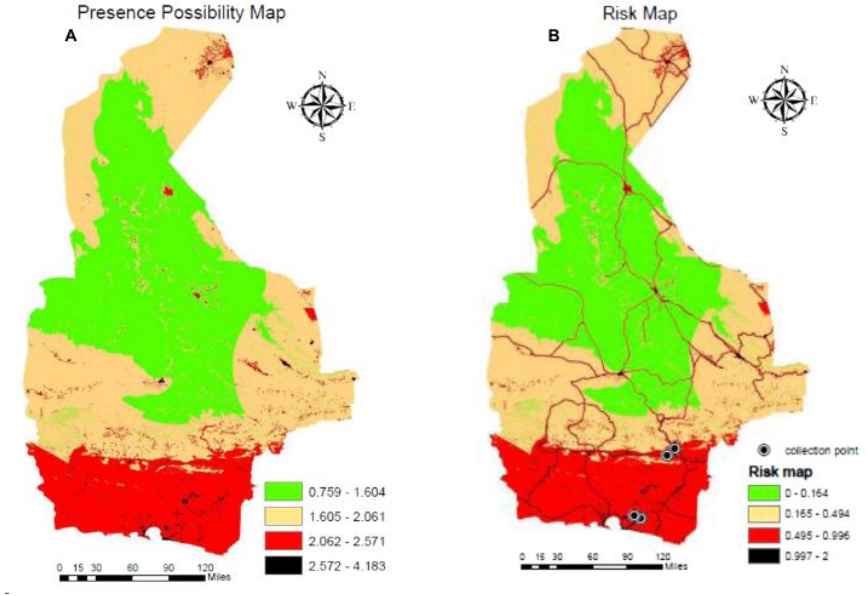


Predicted distribution of *Aedes albopictus*

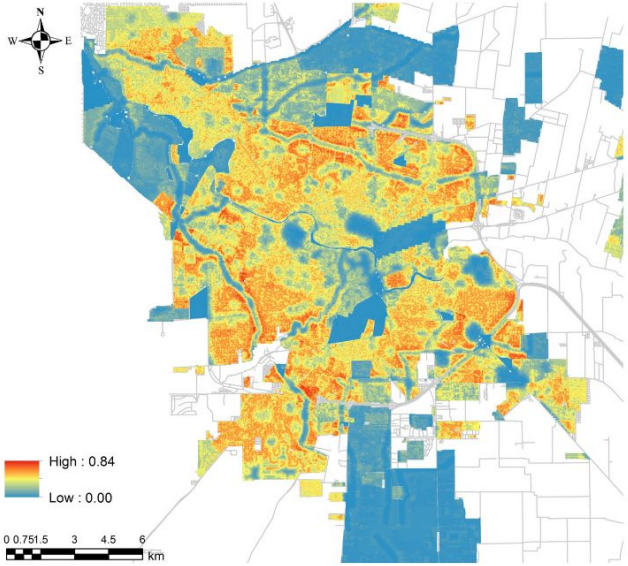
Kraemer et al., 2015, Pictures Duvallet et al., 2017

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)



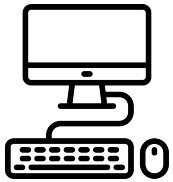
Risk map identifying habitats suitable for *Aedes albopictus* provinces of Iran. Nejati et al., 2017



Risk map identifying habitats suitable for *Aedes aegypti*, in Cordoba City, Agentina. Estallo et al., 2018

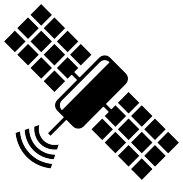
Scientific question and objective

Limited access to epidemiological and entomological data

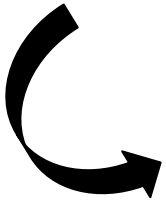


Land cover / spectral indices
vs.
Landscape structure

Need for simple tools for spatialization of risks



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



Objective

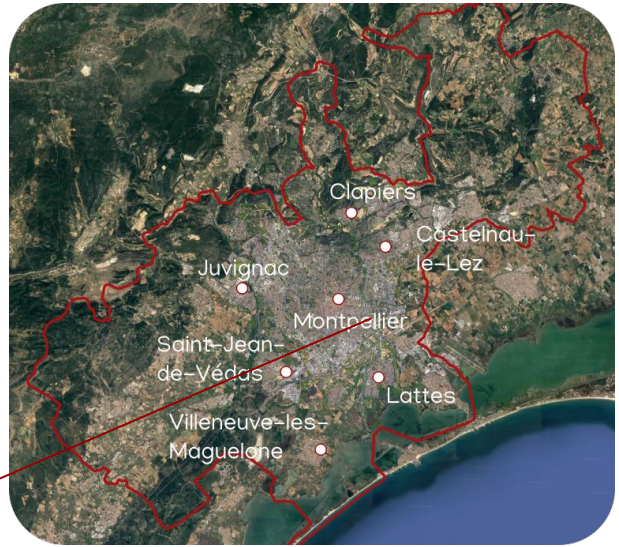
To develop an approach to **spatialize the risk of exposure to Aedes mosquitoes** that makes the **best use of satellite data** and available data (entomological, epidemiological, etc.) in order to make it **reproducible, generic and adapted to the needs of health actors.**

Two contrasting study sites

Cayenne

Equatorial Climate
Regular outbreaks
Aedes aegypti

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

Collectivité Territoriale de Guyane

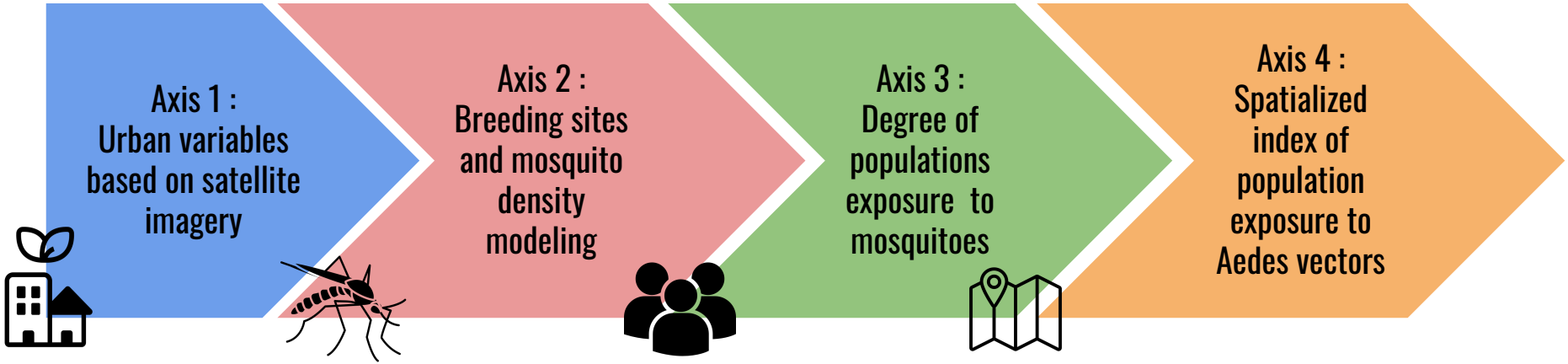
Santé publique France

ars Agence Régionale de Santé

Centre Hospitalier Cayenne Andrée Rosemon

EID MÉDITERRANÉE
OPÉRATEUR PUBLIC EN ZONES HUMIDES

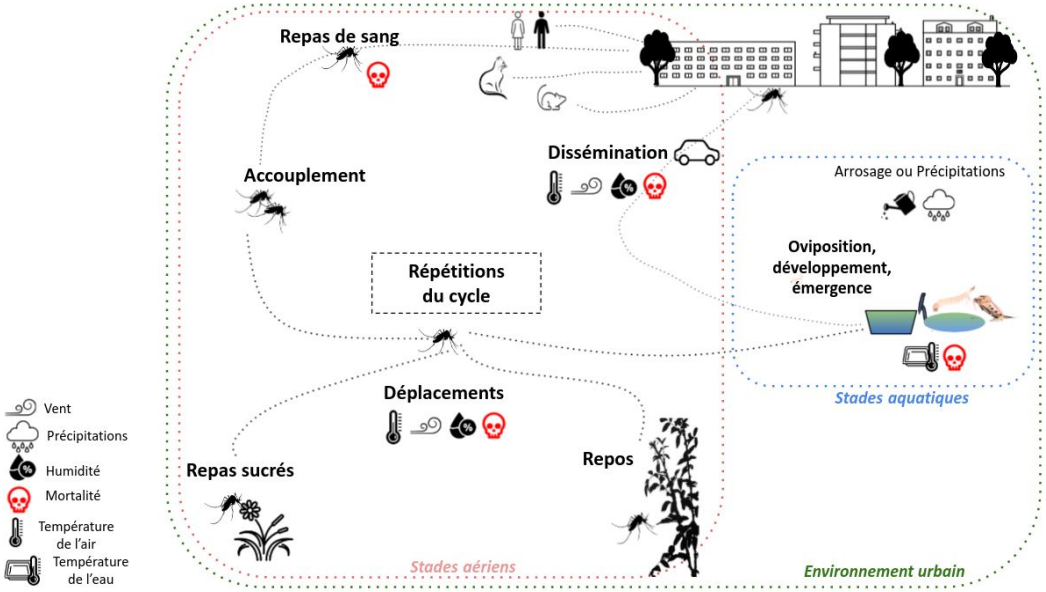
Project axis

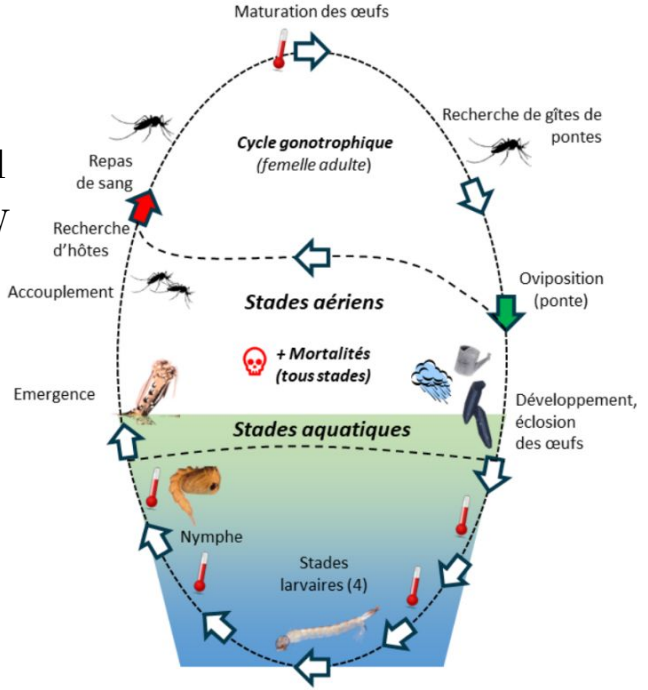


Axis 1: Urban variables from satellite imagery to characterise urban landscapes in relation to *Aedes* mosquitoes

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

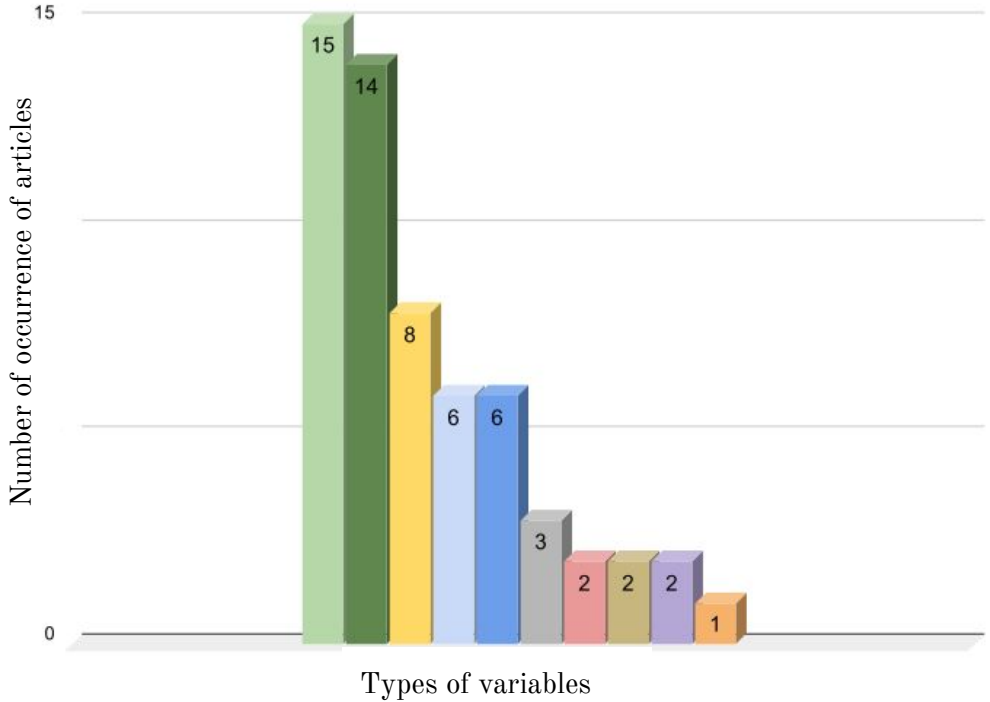




Life cycle of mosquitoes (illustration for *Aedes albopictus*) Marti, Teillet et al., 2022

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

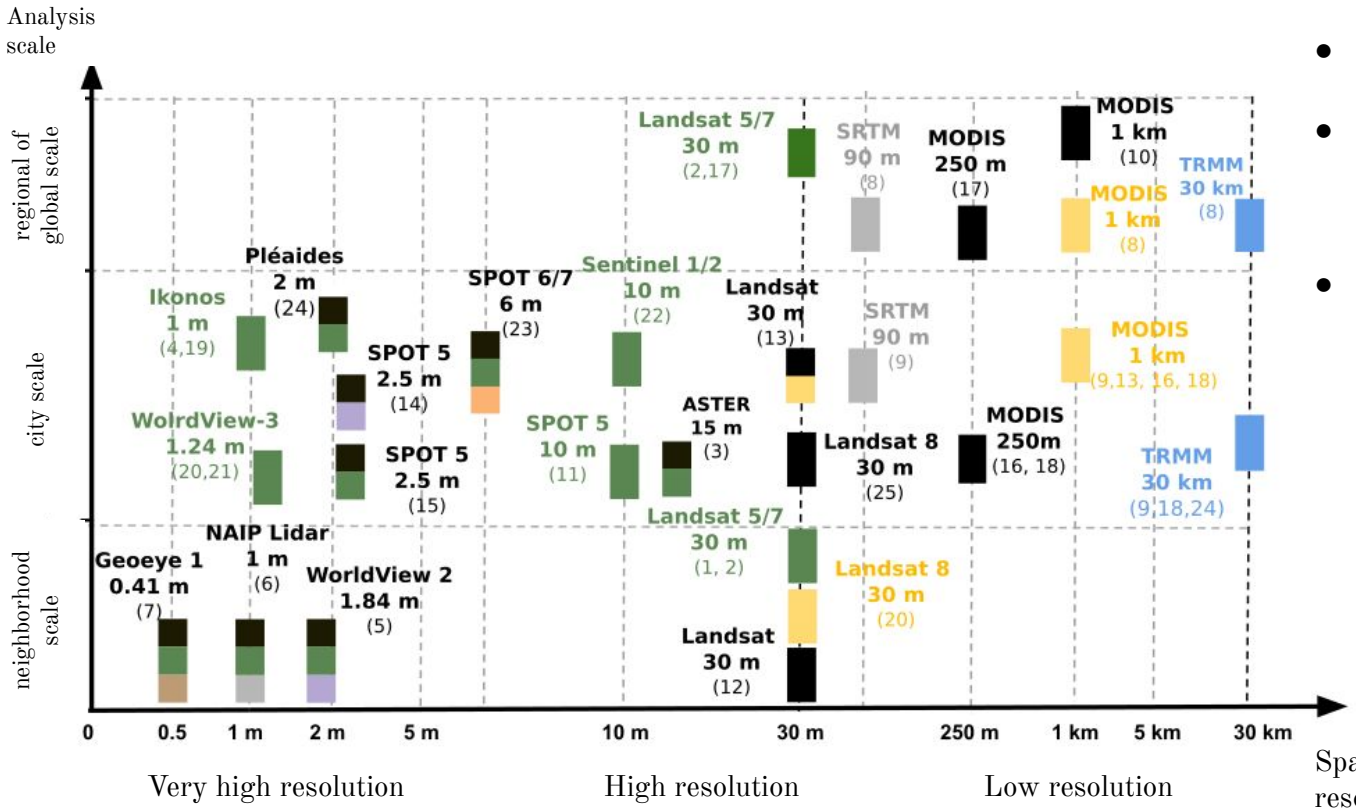
- Review focus on articles that use remote sensing and geomatics, which variables are used for modeling *Aedes* distribution ?



→ **most often used :** vegetation index, humidity index, brightness index land cover map, temperature

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

- Analysis of sensors and remote sensing variables used in modelling



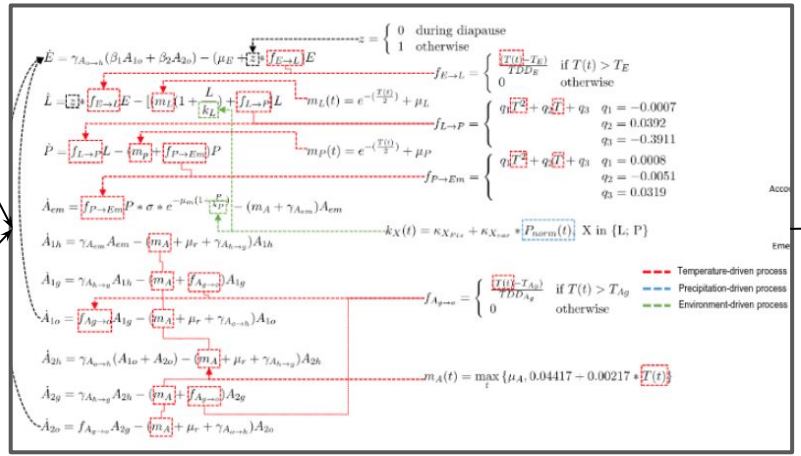
- Imagery allows to study urban landscapes at different scale
- Majority of sensors allows to work at the city scale but much less at neighborhoods scale which can be interesting for health studies
- Climatic variables is at low spatial resolution no matter the scale of analysis, other variables depends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

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

- 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 :

Daily weather data

Number of potential breeding sites per hectare



ARBOCARTO

Mosquito density

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

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

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 differents images at differents scales

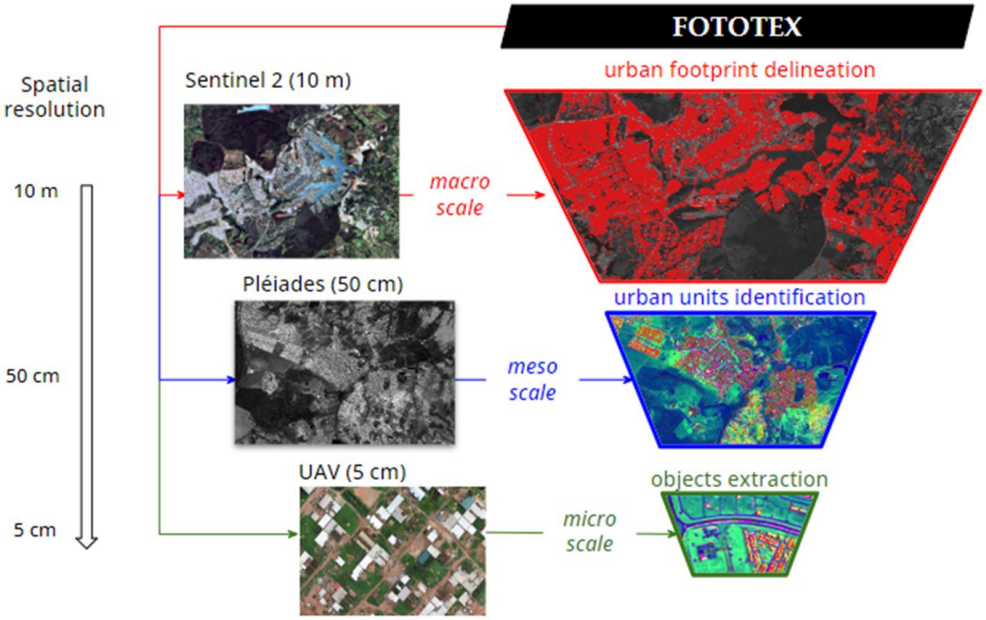
remote sensing MDPI

Article

Fast Unsupervised Multi-Scale Characterization of Urban Landscapes Based on Earth Observation Data

Claire Teillet [1,*], Benjamin Pillot [1], Thibault Catry [1], Laurent Demagistri [1], Dominique Lyszczarz [2], Marc Lang [3], Pierre Couteron [4], Nicolas Barbier [4], Arsène Adou Kouassi [5,6], Quentin Gunther [7] and Nadine Dessay [1]

Open source python code available :
https://framagit.org/espace-dev/fototex
https://pypi.org/project/fototex

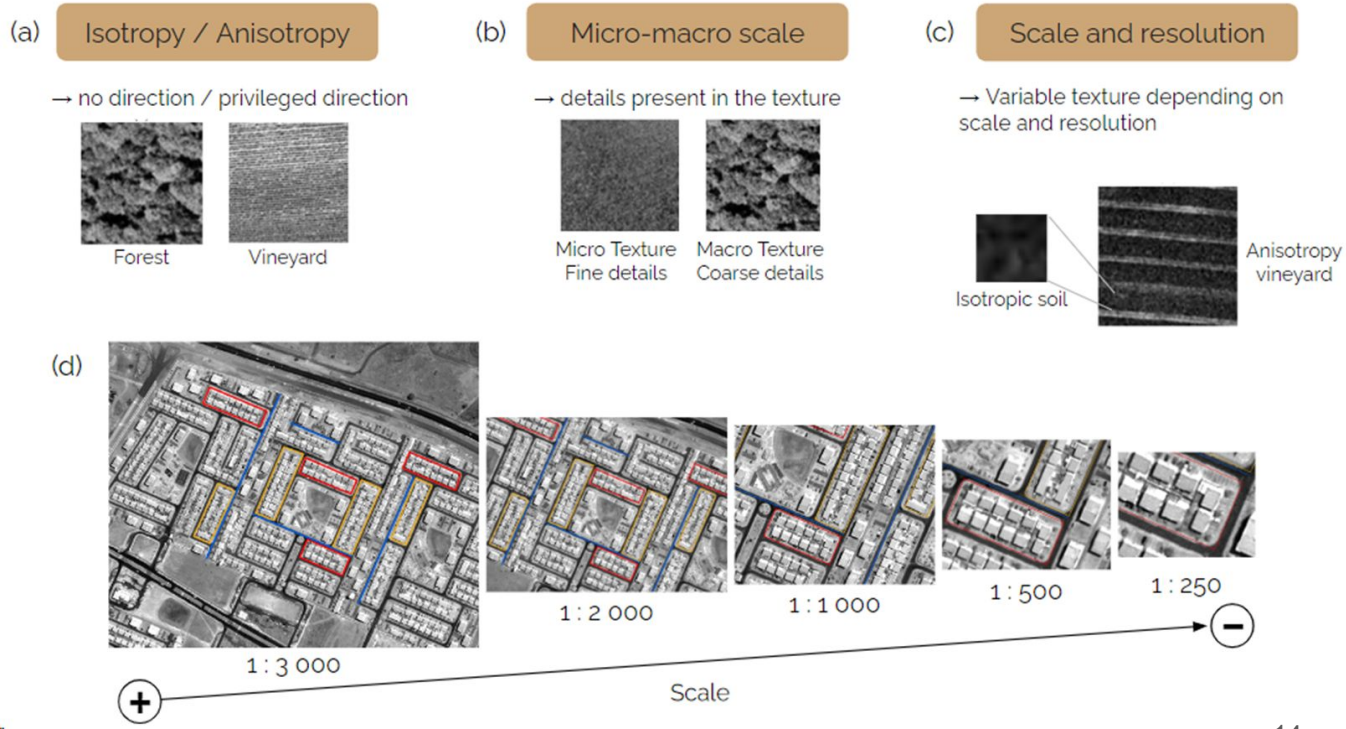


Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of *Aedes* mosquitoes

- **What is a texture in image processing ?**

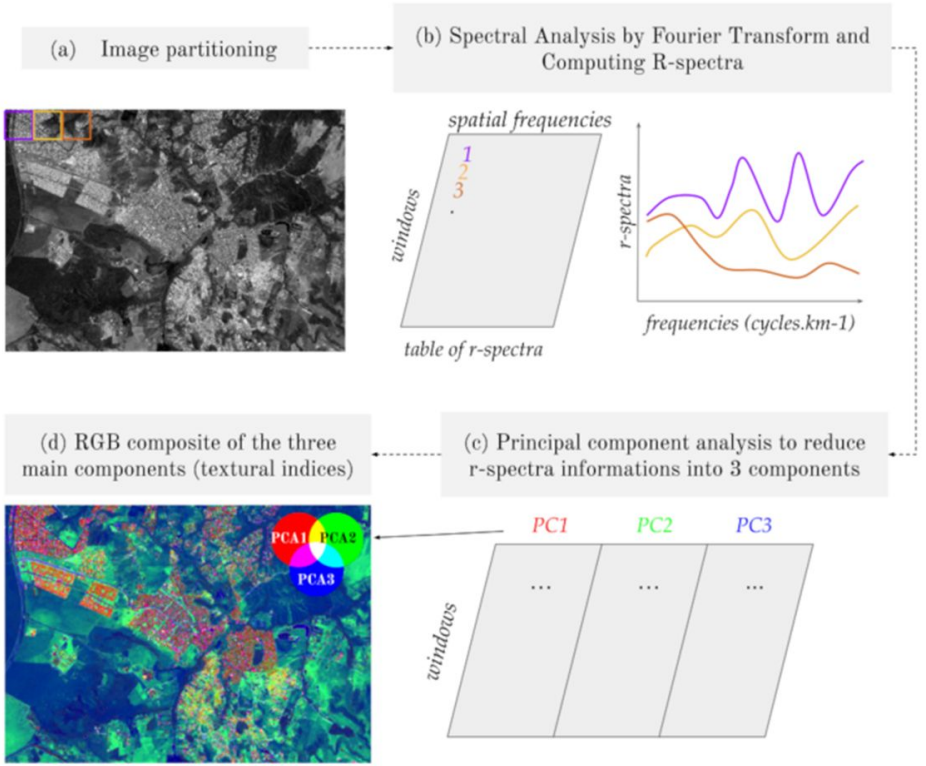
Texture can be defined as a function of spatial variation of the brightness intensity of the pixels.

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)

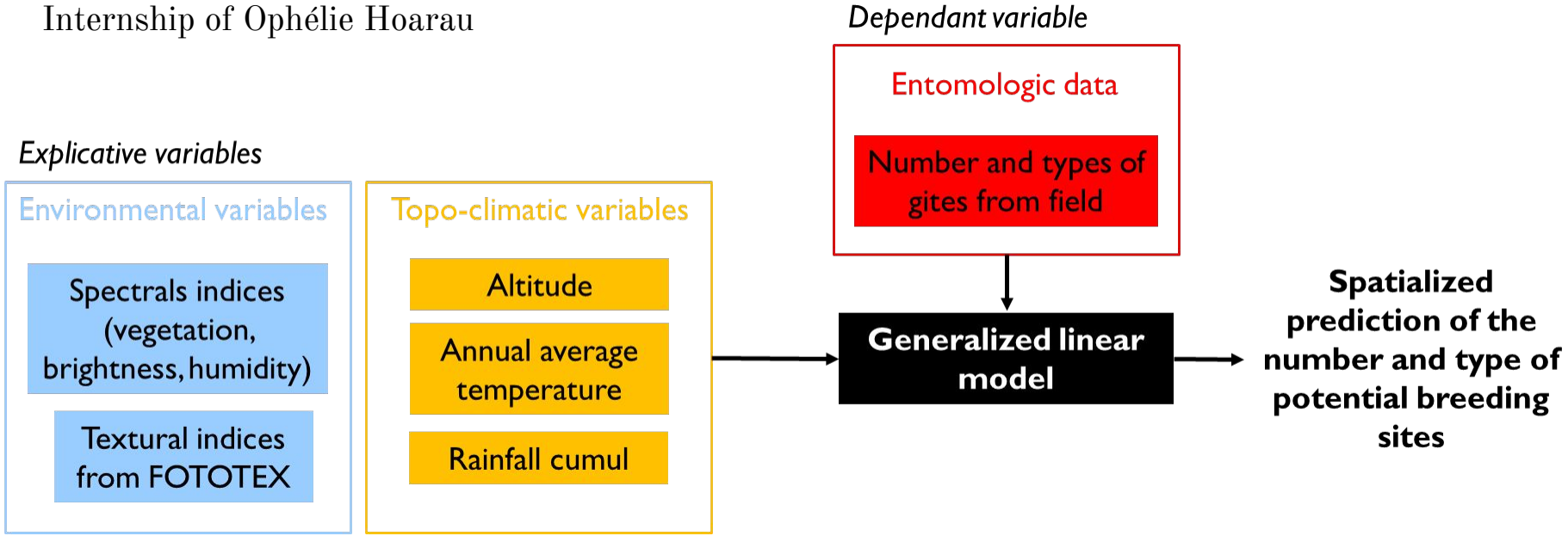
C- PCA on the spatial frequency matrix
each window is characterised by a large number of frequency variables (repetition of patterns) which are reduced

D- RGB colour composition
Spatial representation of the distribution of the frequencies that make up the initial image
R=PC1, G=PC2, B=PC3

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

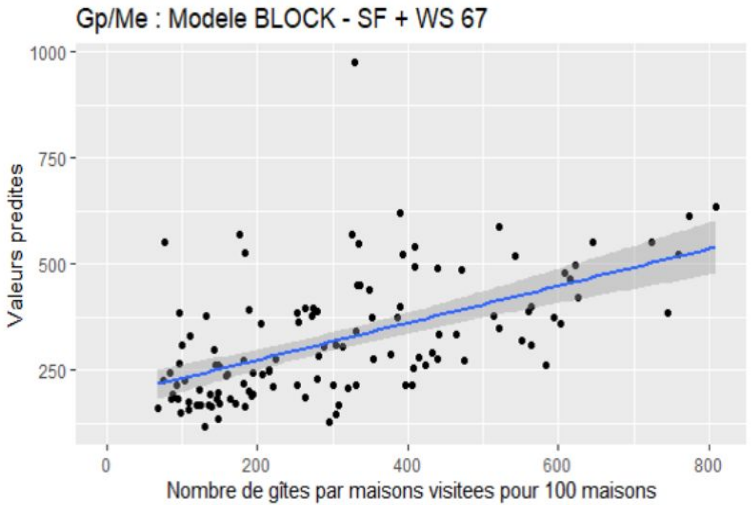
- **Modelling breeding sites with the help of remote sensing**
  - Statistical model developed in Reunion (*Aedes albopictus*, specific spatial delimitation)

Internship of Ophélie Hoarau

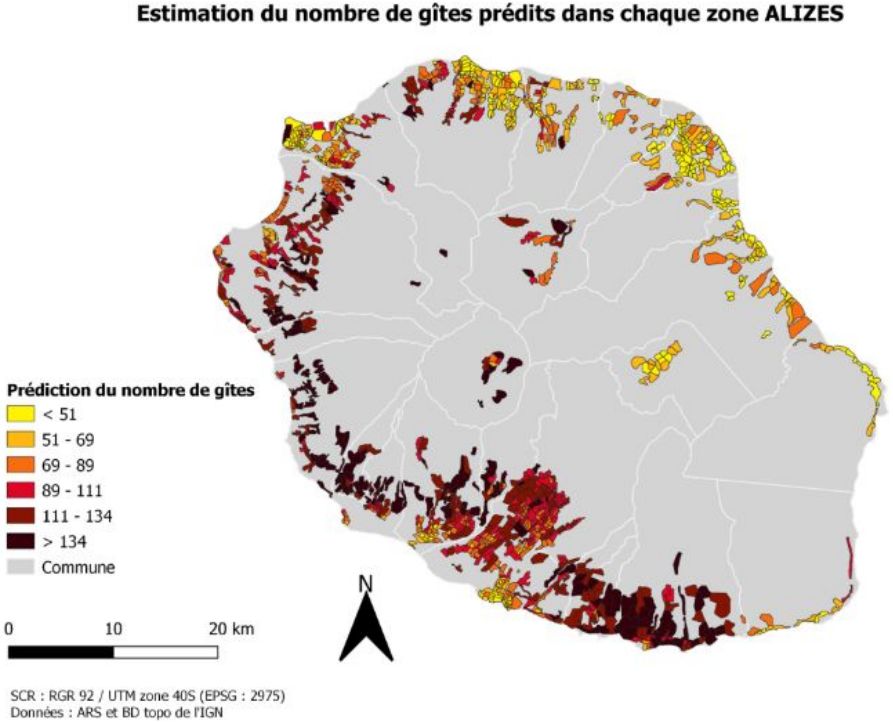


Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of *Aedes* mosquitoes

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

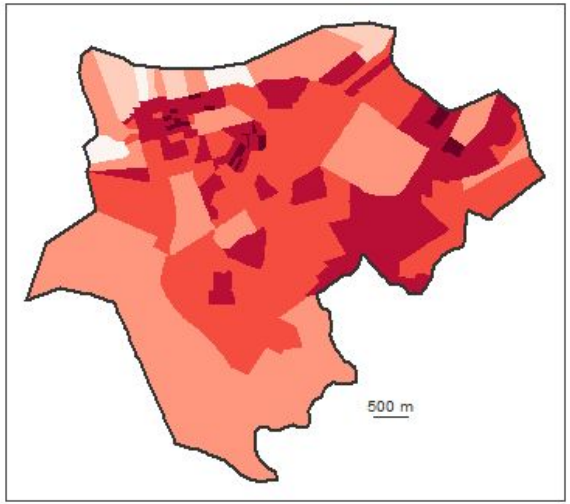


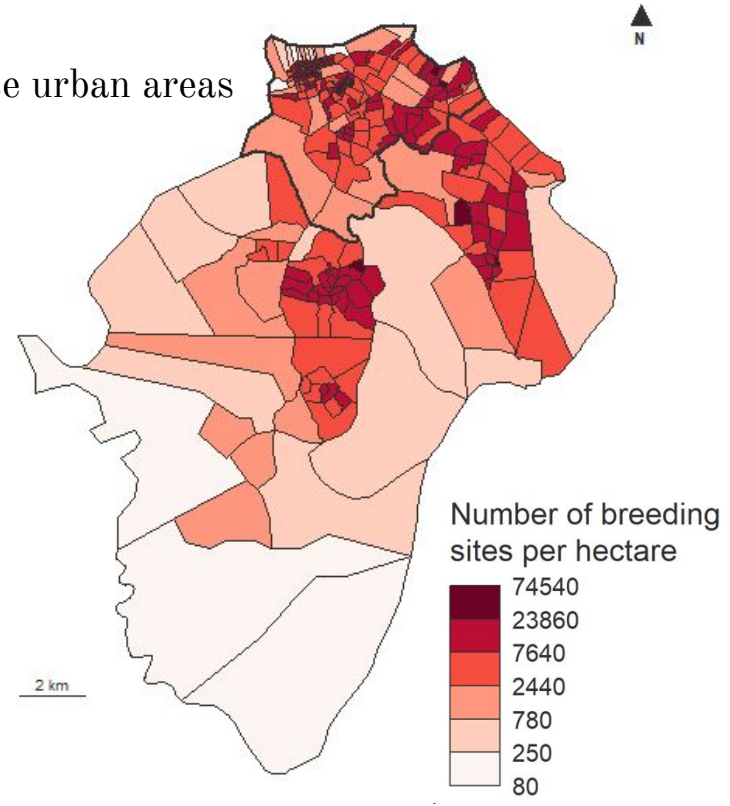
Correlation between predicted values and observed values



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

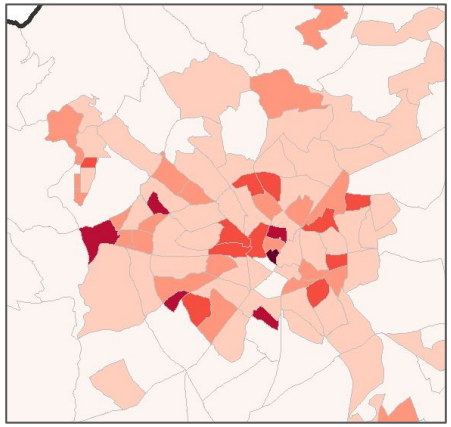


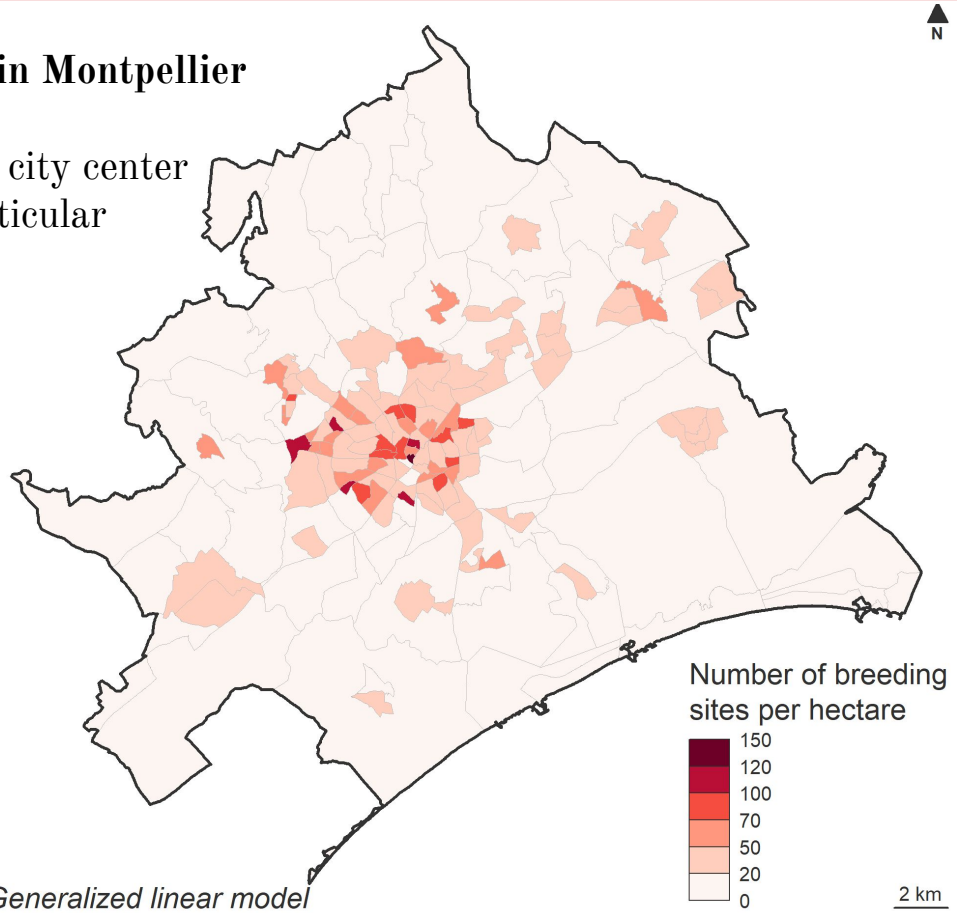


Generalized linear model

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 Montpellier**
  - values between 20 to 150
  - high values concentrated in the city center and some neighborhoods in particular





Generalized linear model

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

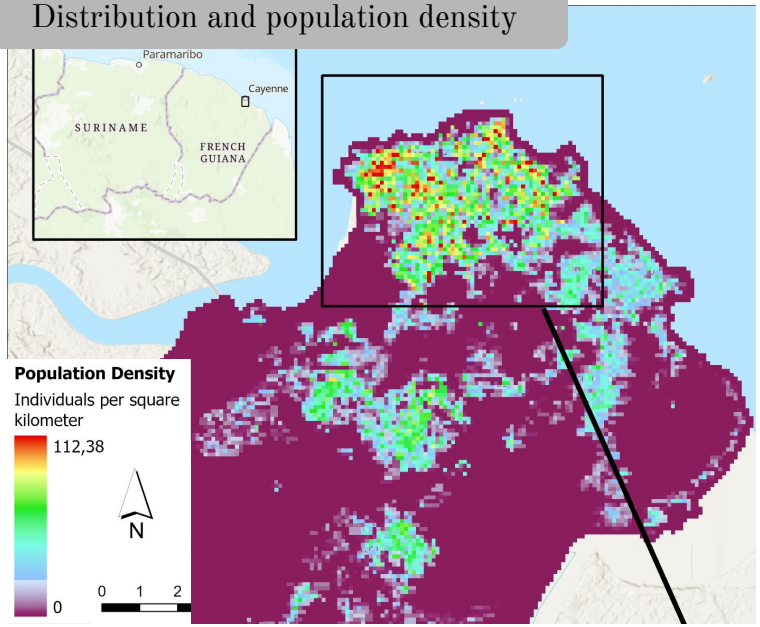
- Exploratory approach to estimate the number of potential breeding sites over study sites

Improve statistical model	→	Adding other training dataset or other urban variables (axis 1)
Validation	→	Acquisition of validation data (request still pending)
Improve the existing method implemented in ARBOCARTO	→	Ameliorate experts estimation by adding more information of urban landscapes knowledge

Axis 3: Spatialize the areas where the population is most exposed to mosquitoes using urban variables from remote sensing and spatialized information

- Socio-economic factors in relationship to population exposure have been found in literature

Distribution and population density



Types d'habitats

Shops | Intermediate housing | Collectif housing

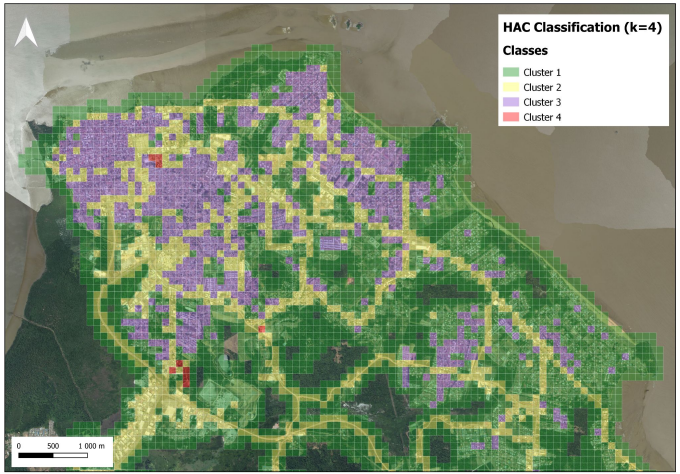
Atlas des tissus urbains, AUDEG, 2019

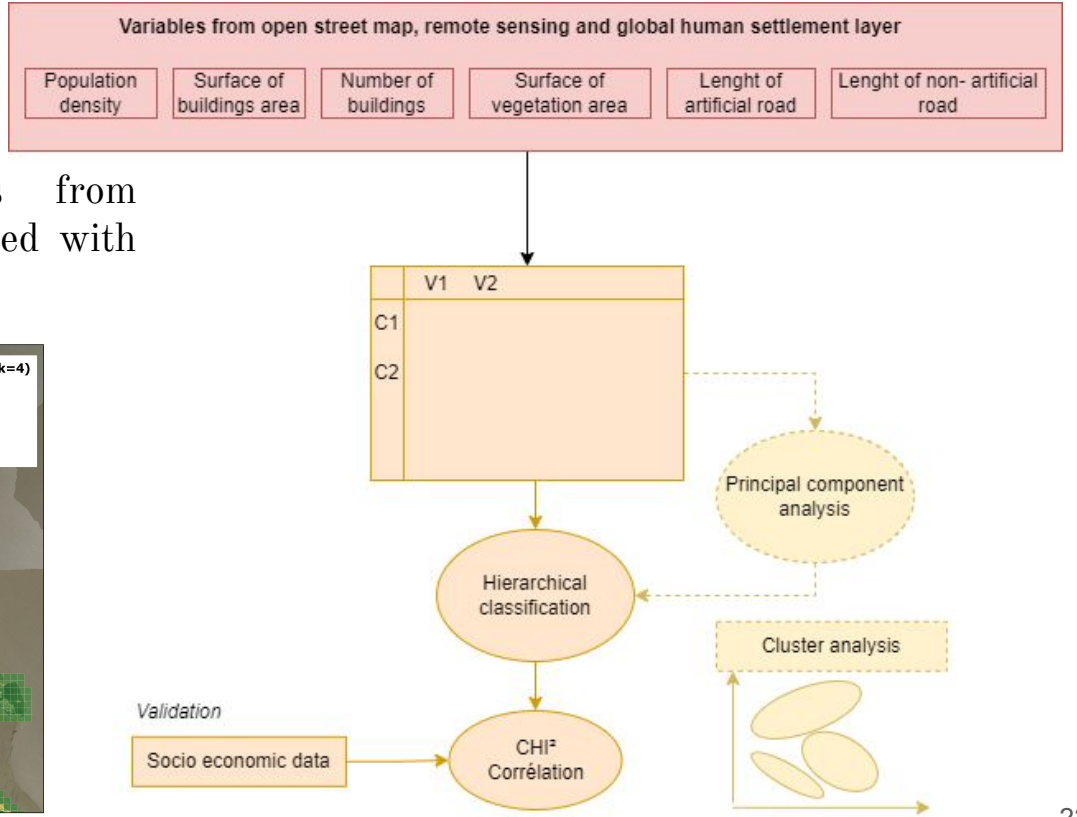
→ Objective : Integrate more information on population exposure into modelling risk

Axis 3: Spatialize the areas where the population is most exposed to mosquitoes using urban variables from remote sensing and spatialized information

Internship of Nicholas de Kock (3 months)

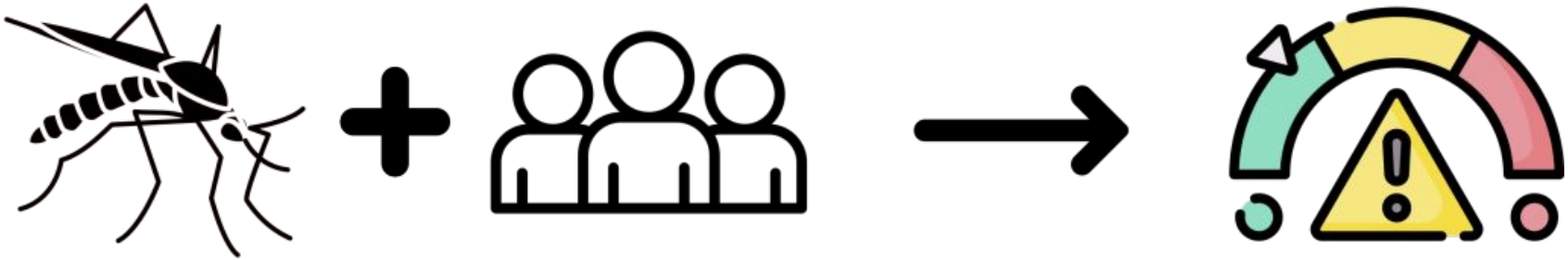
- Creating socio-economic classes from remote sensing information combined with OSM data and global data (GHSL)





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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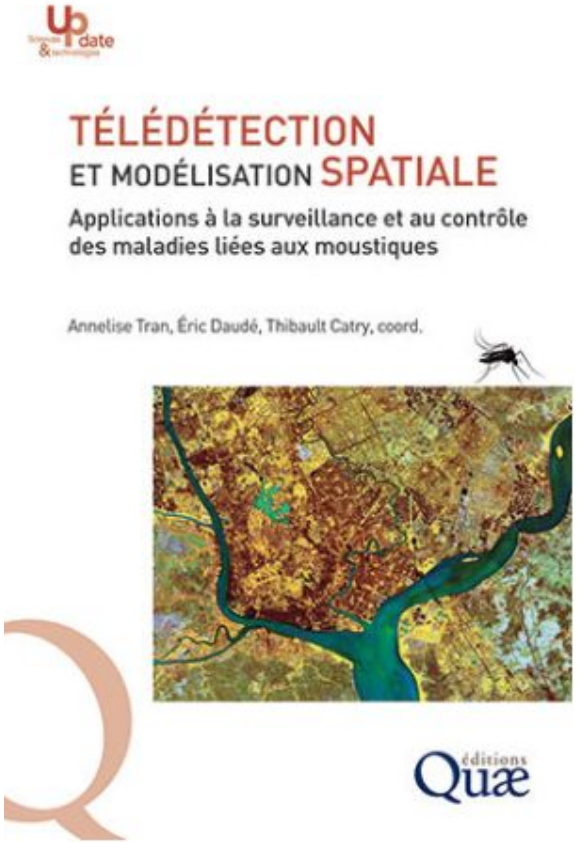
Merci



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