

GeoOneHealth Symposium

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

Claire Teillet

Directors : Rodolphe Devillers and Emmanuel Roux

claire.teillet@ird.fr

Research Institute for development, UMR ESPACE-DEV, Montpellier

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Espace DEV
OBSERVATION SPATIALE, MODÈLES
& SCIENCE IMPLIQUÉE



MUSE
MONTPELLIER UNIVERSITY OF EXCELLENCE

**KEY INITIATIVE
RISKS & VECTORS**

RIV
Risques Infectieux et Vecteurs - 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



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



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



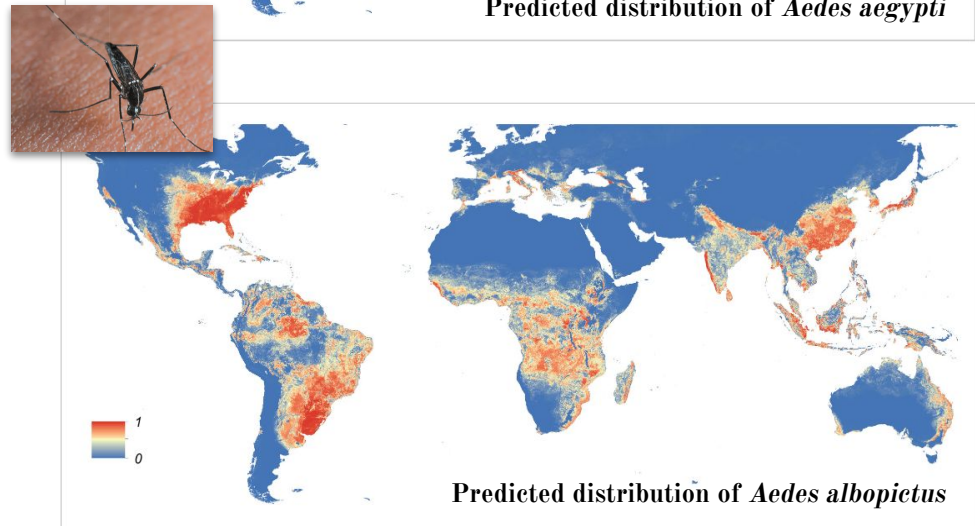
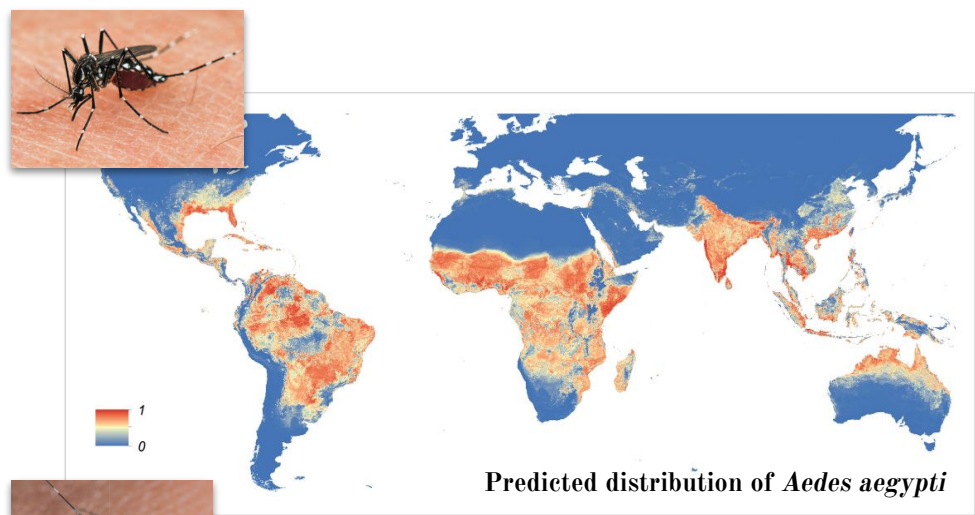
Urban Axis: Analysis of Urban Space Dynamics by Satellite - Nadine Dessay (IRD), Gutemberg Silva (UNIFAP), Paulo Peiter (Fiocruz)

Context

ARBOVIRUSES:

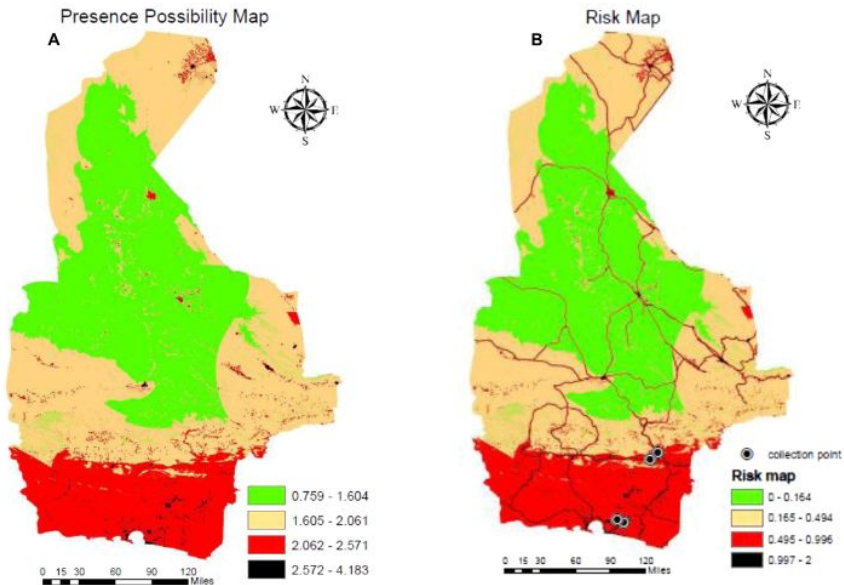
viral diseases caused by a virus transmitted by an arthropod vector
(focus on *Aedes* mosquitoes)

- 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

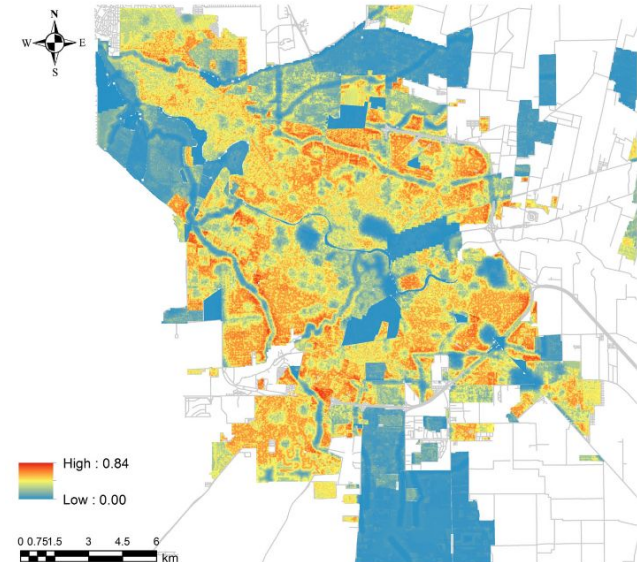


Context

- 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. Nejadi 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



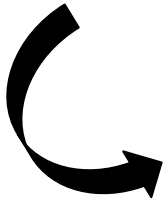
Land cover / spectral indices
vs.
Landscape structure



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.

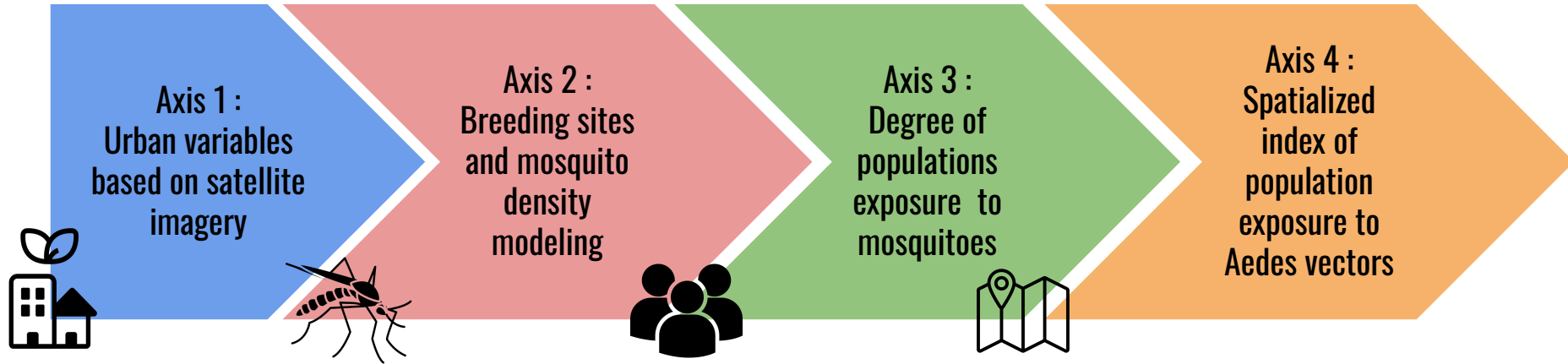


Different scales of analysis (Global, Regional, City, Neighborhoods...)

→ Focus on the city and neighborhoods scales



Project axis

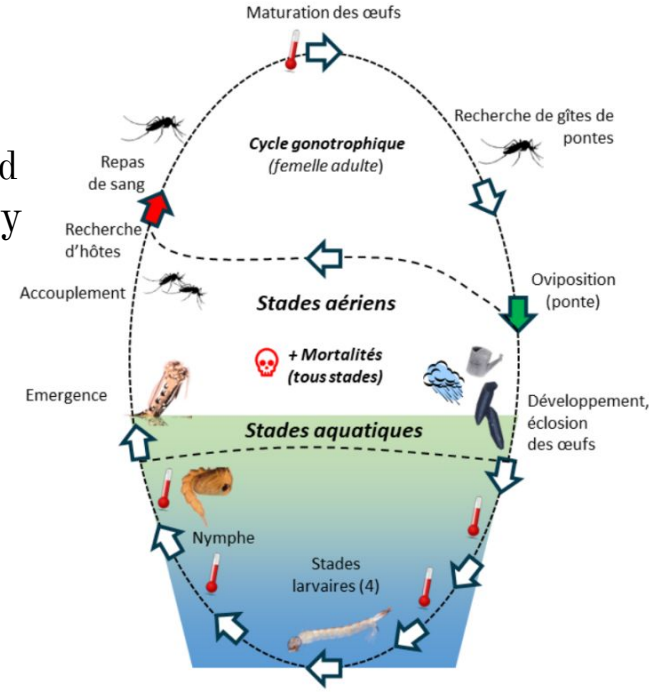
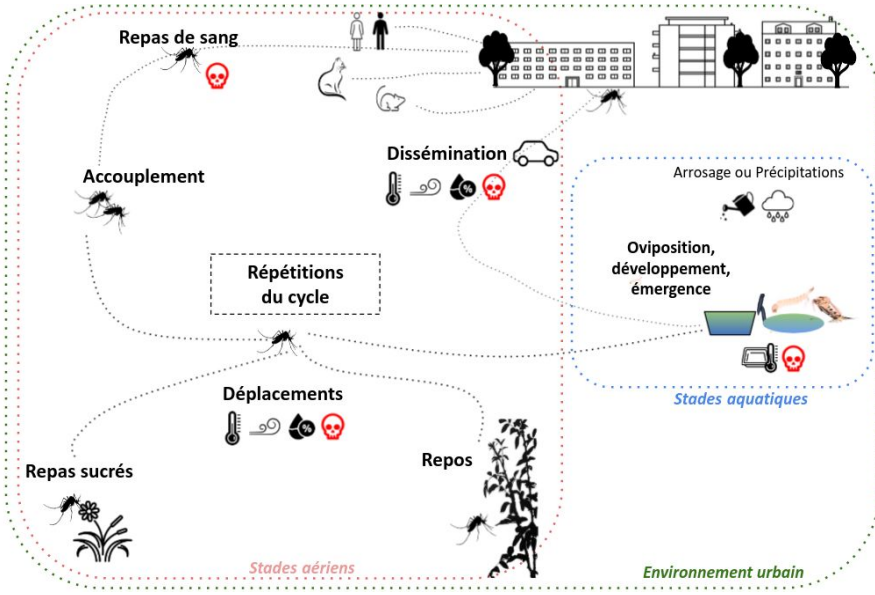




Axis 1: Urban variables from satellite imagery to characterise urban landscapes in relation to *Aedes* mosquitoes

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

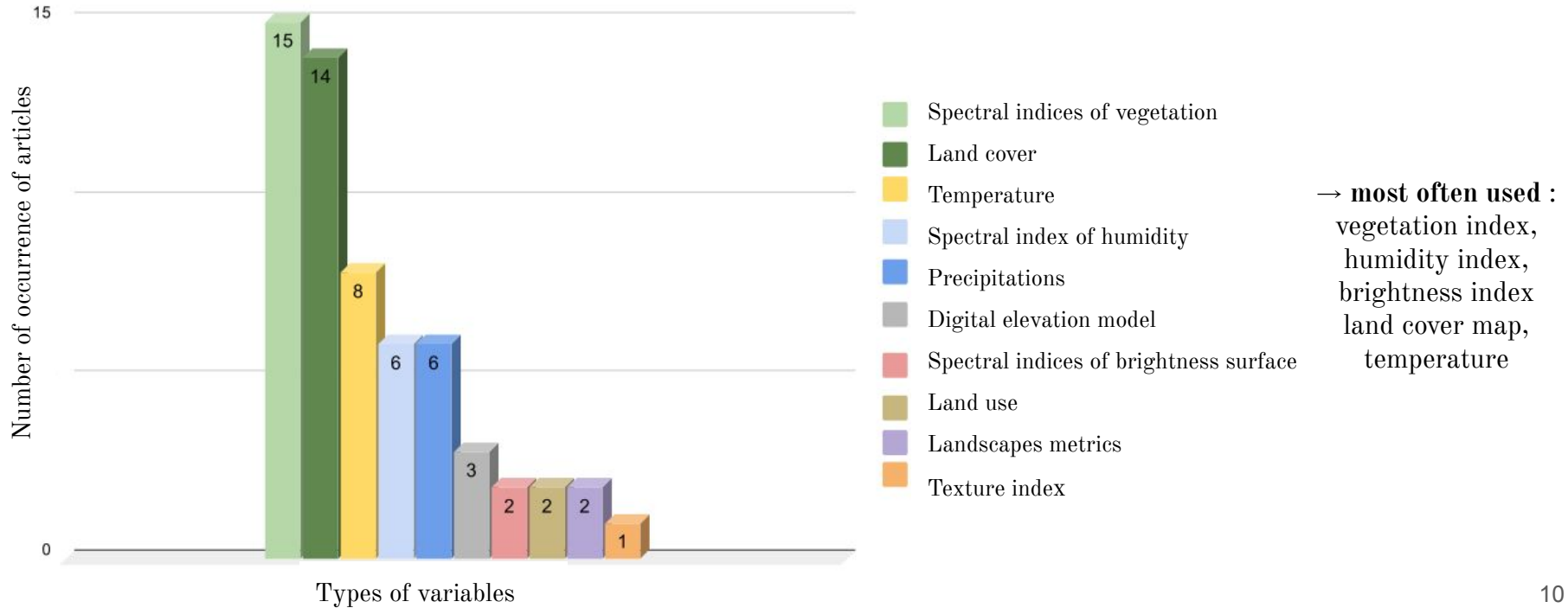


Life cycle of mosquitoes (illustration for *Aedes albopictus*) Marti, Teillet et al., 2022



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 ?

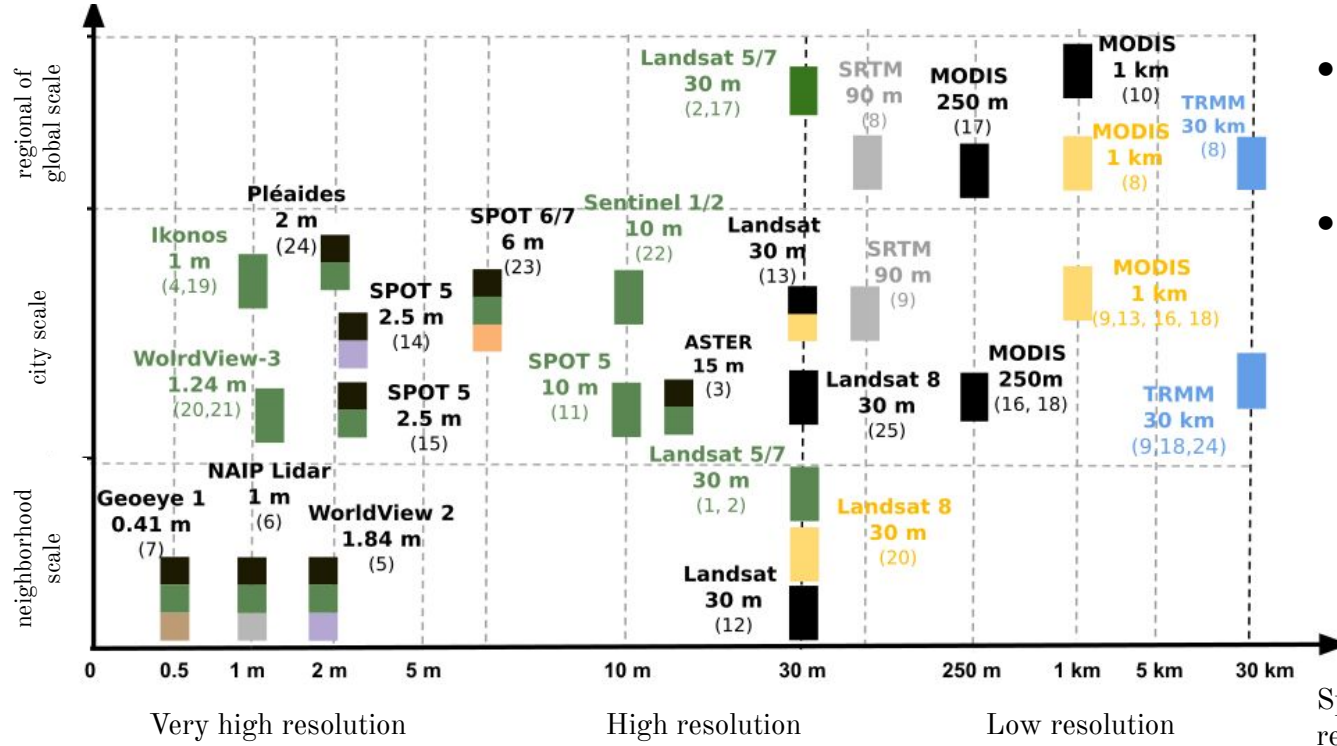




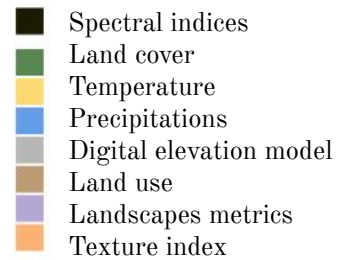
Axis 1: Urban variables from satellite imagery to characterise urban landscapes in relation to Aedes mosquitoes

- Analysis of sensors and remote sensing variables used in modelling

Analysis scale



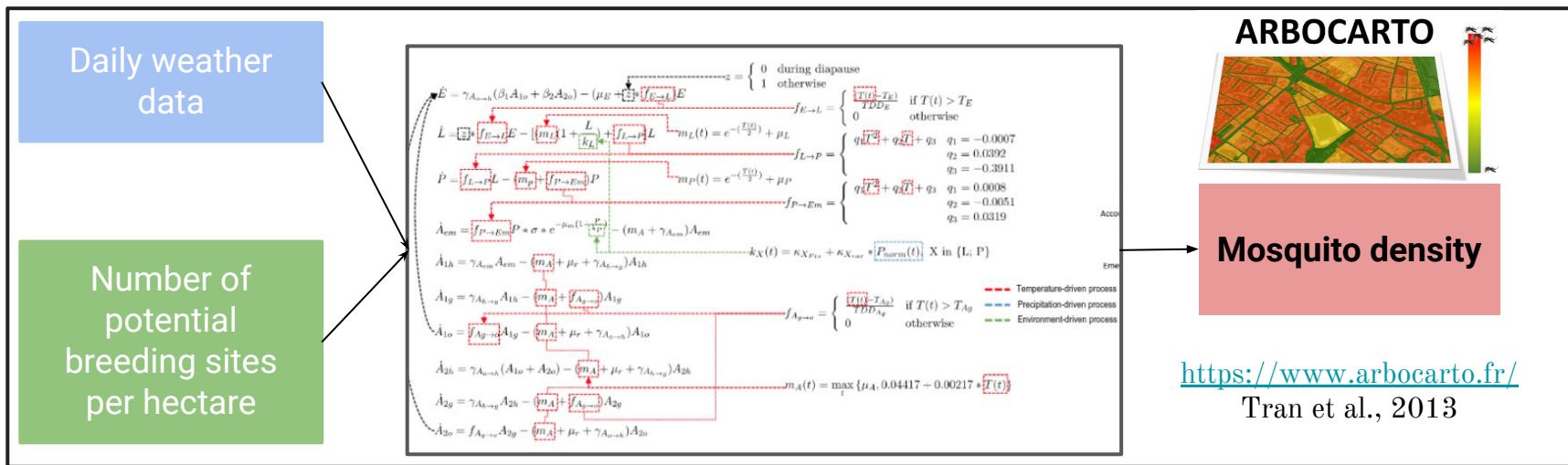
- Imagery allows to study urban landscapes at different scale
- Majority of sensors allows to work at the city scale but much less at neighborhoods scale which can be interesting for health studies
- Climatic variables is at low spatial resolution no matter the scale of analysis, other variables depends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



→ **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 different images at different scales



Article

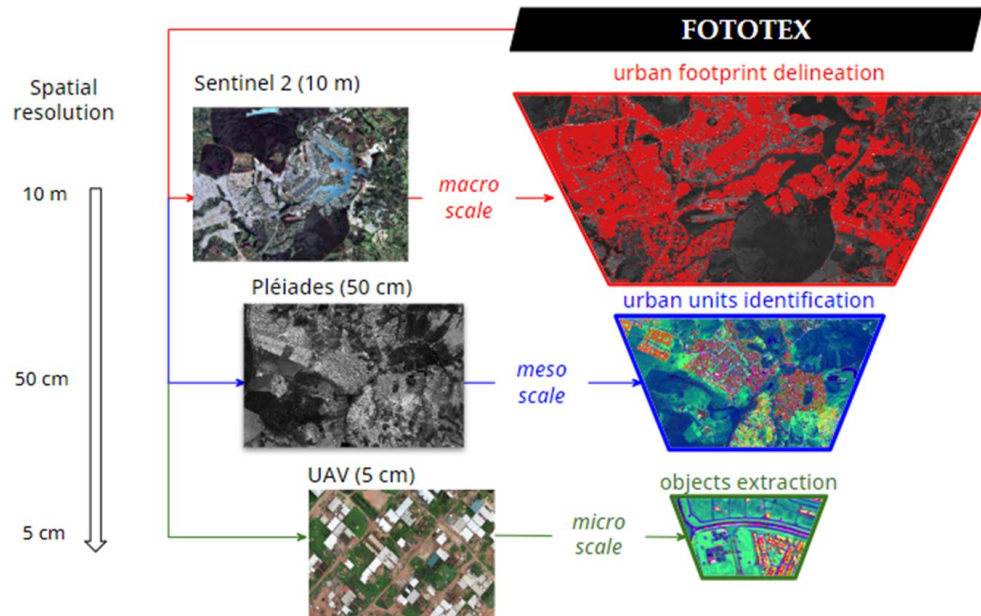
Fast Unsupervised Multi-Scale Characterization of Urban Landscapes Based on Earth Observation Data

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>





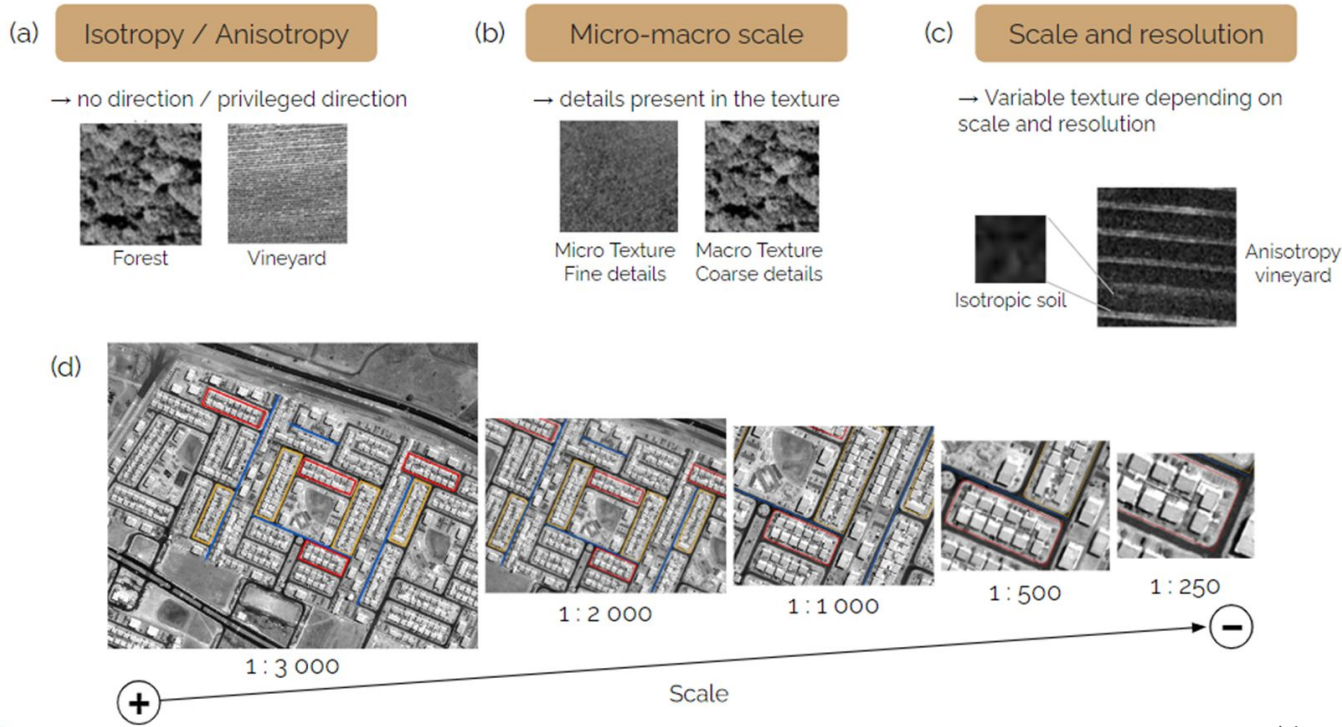
Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of *Aedes* mosquitoes

- 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

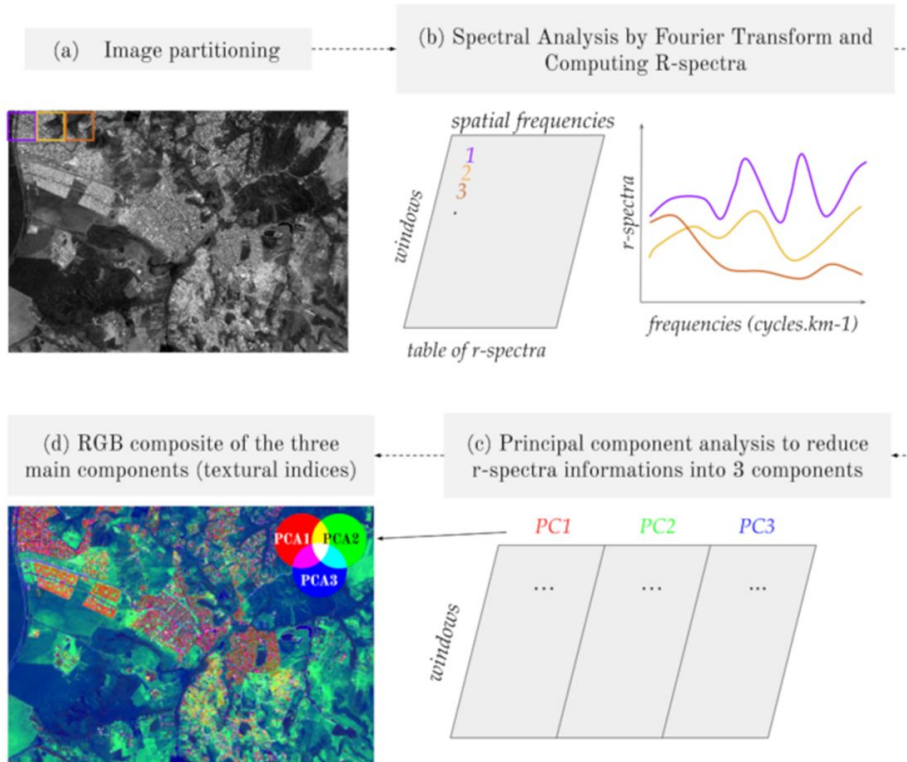
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Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of *Aedes* mosquitoes

● 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

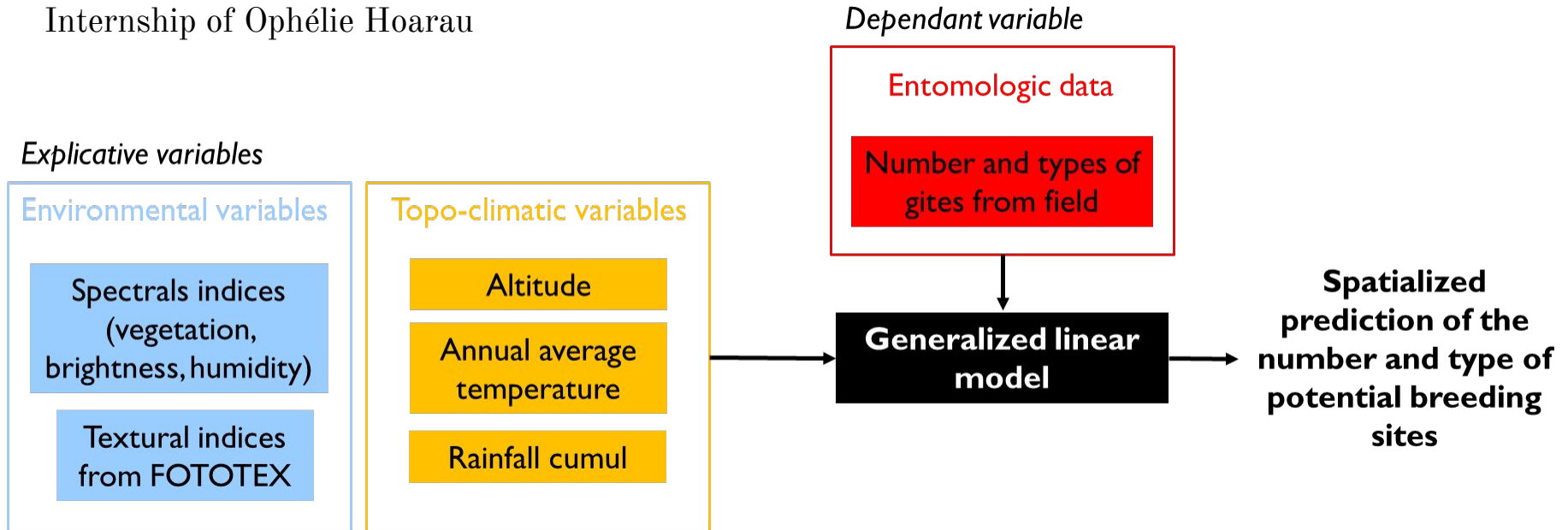
D- RGB colour composition
Spatial representation of the distribution of the frequencies that make up the initial image
 $R=PC1, G=PC2, B=PC3$



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)

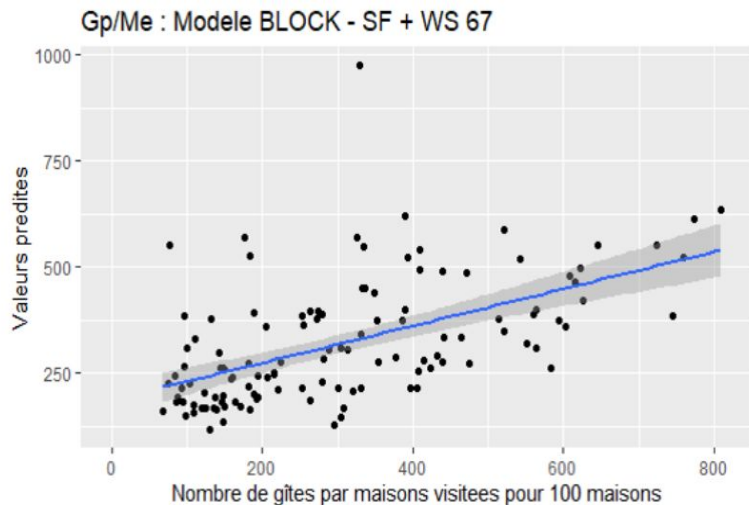
Internship of Ophélie Hoarau





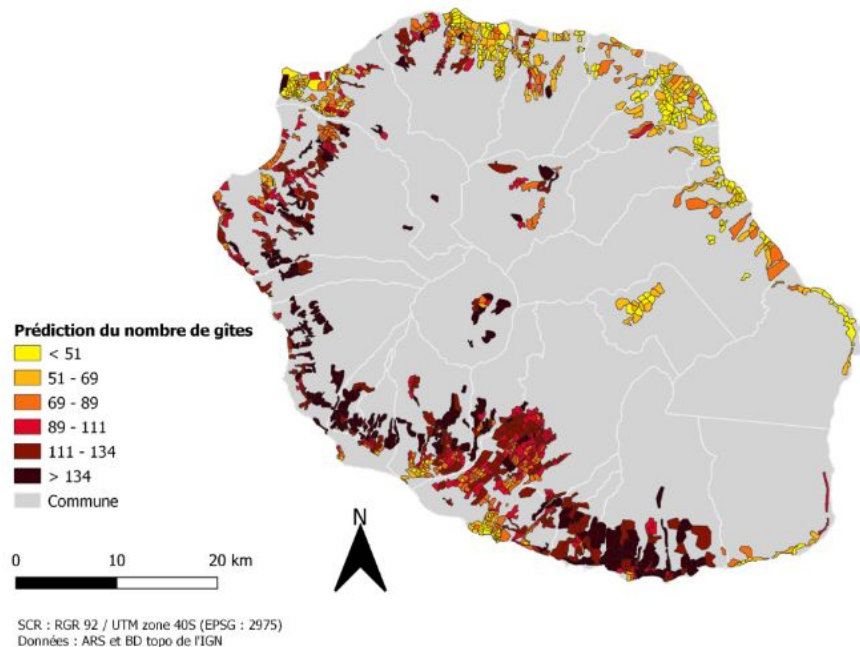
Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of *Aedes* mosquitoes

- **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

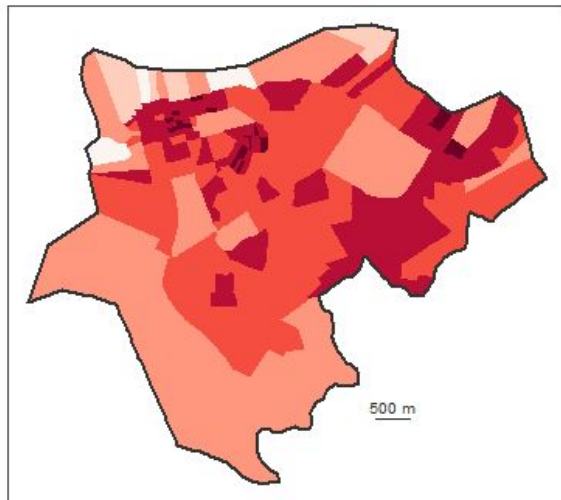
Estimation du nombre de gîtes prédits dans chaque zone ALIZES



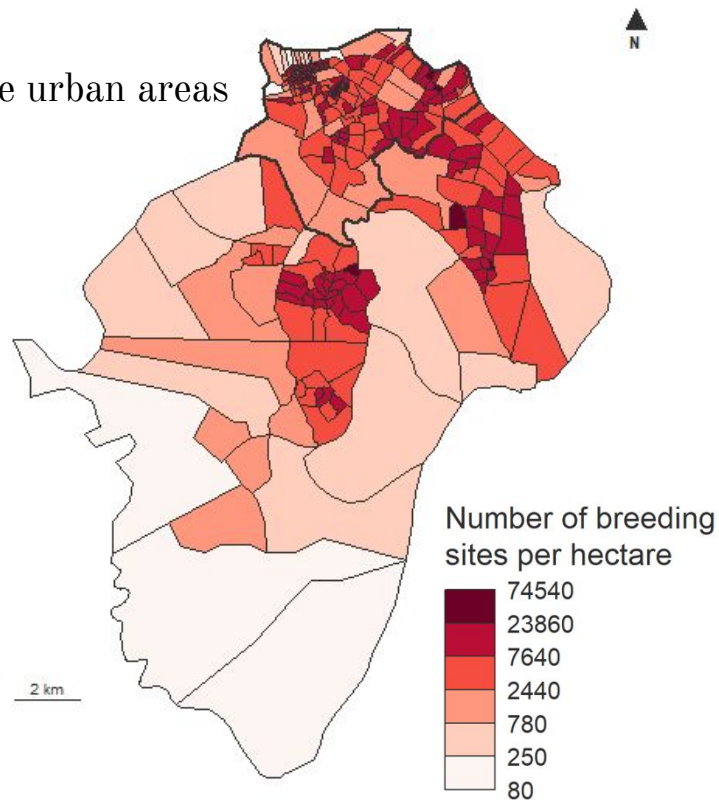


Axis 2: Using urban variables to estimate the number of potential breeding sites and the density of *Aedes* mosquitoes

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



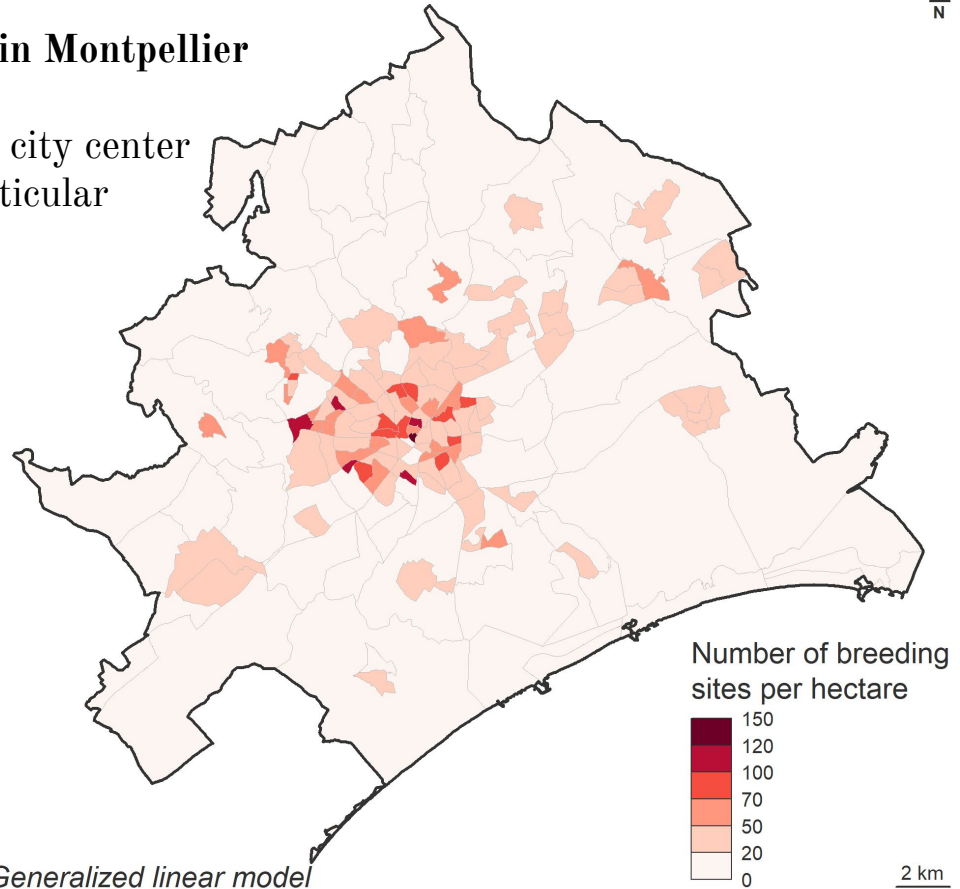
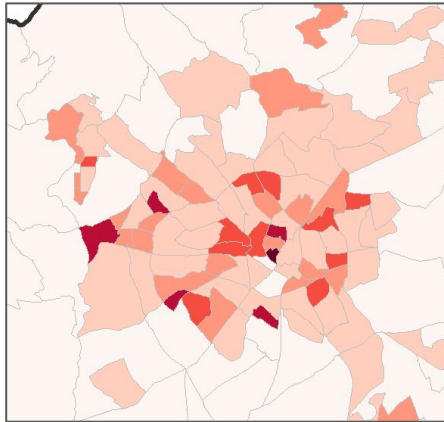
Generalized linear model





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



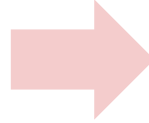
Generalized linear model



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

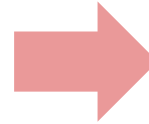
- Exploratory approach to estimate the number of potential breeding sites over study sites

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

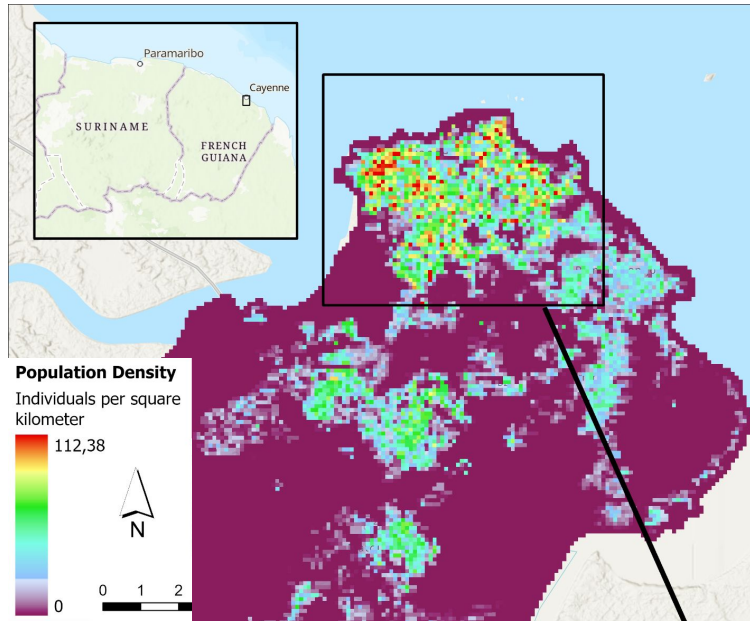


Ameliorate experts estimation by adding more information of urban landscapes knowledge



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

distribution and population density factors in relationship to population exposure have been found in literature



Types of habitats

Shops



Intermediate housing



Collectif housing



Atlas des tissus urbains, AUDEG, 2019

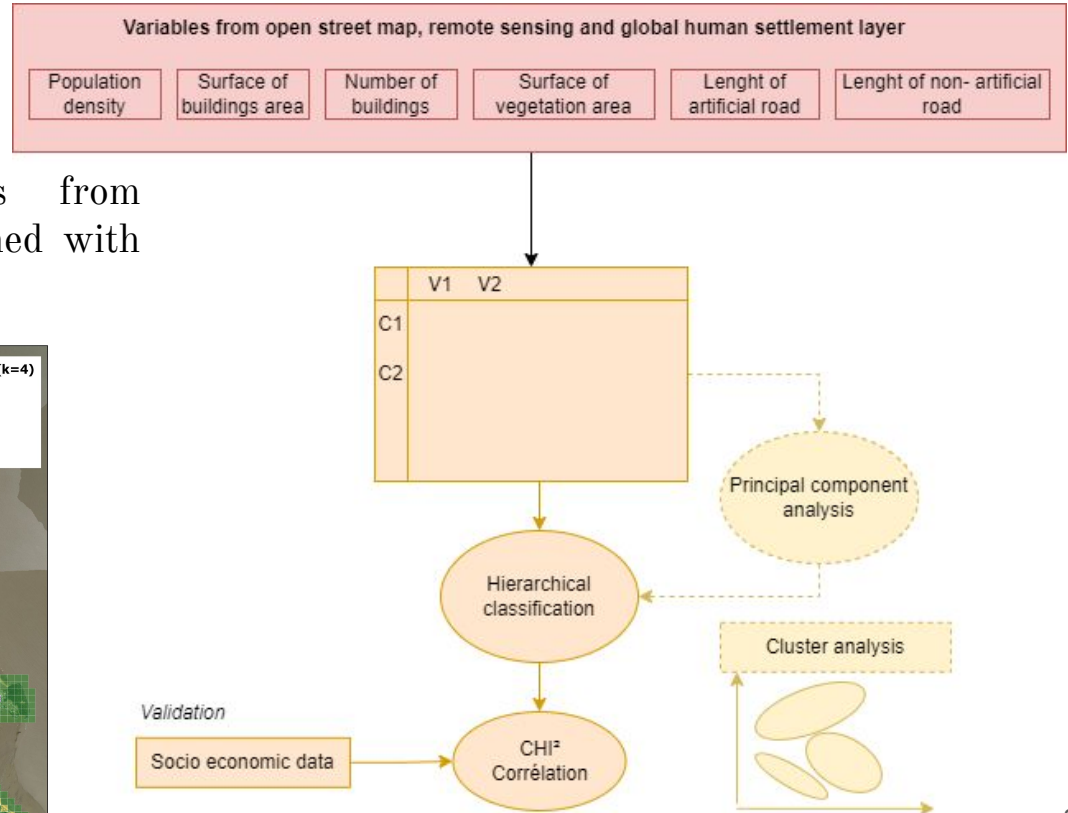
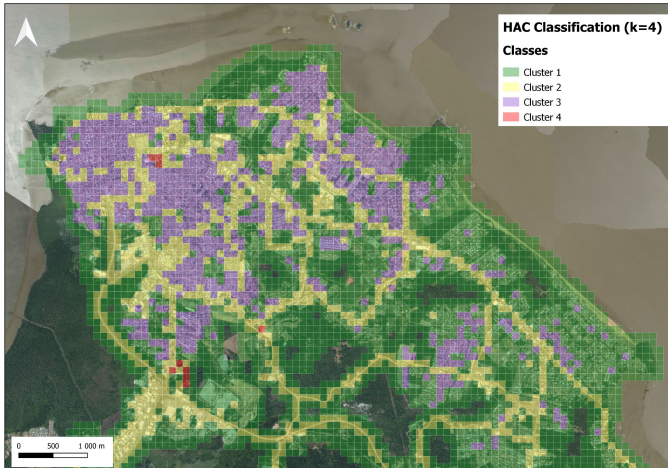
→ **Objective** : Integrate more information on population exposure into modelling risk



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)

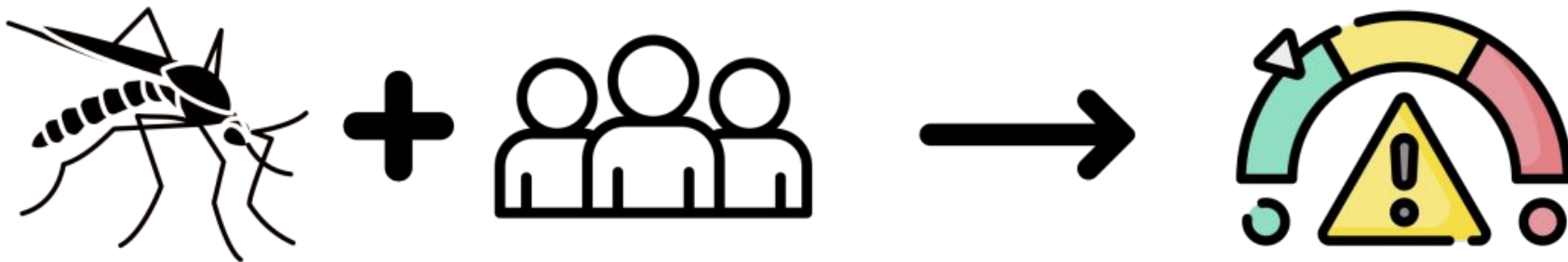
- Creating socio-economic classes from remote sensing information combined with OSM data and global data (GHSL)





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



TÉLÉDÉTECTION ET MODÉLISATION SPATIALE

Applications à la surveillance et au contrôle
des maladies liées aux moustiques

Annetise Tran, Éric Daudé, Thibault Catry, coord.



éditions
Quæ

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