

# ANALYSIS OF THE DYNAMICS OF URBANIZED SPACES BY SATELLITE APPLICATION TO FRENCH GUIANA (ADEUSA)

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Y. Fouzai, H. Albuquerque, N. Almeida, L. Demagistri, C. Bernard, T. Catry, C. Teillet, , B Pillot, C. Charron

To better understand the evolution of urbanized areas on the **Guiana Plateau**, develop a processing chain based on remote sensing data for dynamic monitoring of urban areas

## MACRO (Urban footprint - high resolution images)

Automatic delimitation for **11 cities selected** at 5 years time step + census year [1984 - 2022]



GeorgeTown (Guyana capital city)

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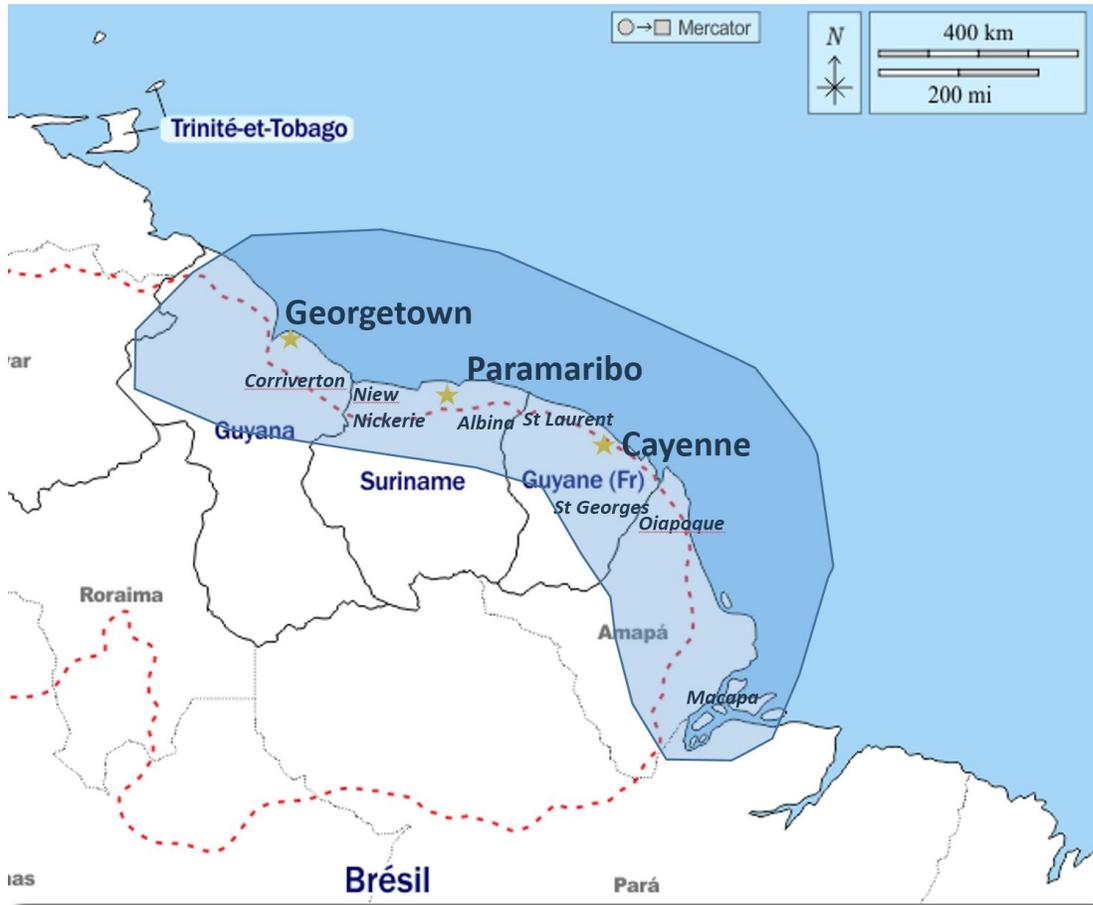
## MESO (Urban fabric - very high resolution)

Study for **limited number** of cities 6 intra-urban classes: dense, informal, discontinuous habitats, vegetation, water, roads



**4 countries, 11 selected cities**

**3 geographical contexts**



**Capital cities:** Georgetown (Gu), Paramaribo (Su)

**Regional capitals:** Kourou (Gf), Cayenne (Gf), Macapá (Br)

**Cross-border towns :**

Corriverton (Gu) – Nieuw Nickerie (Su)

Albina (Su)– St Laurent du Maroni (Gf)

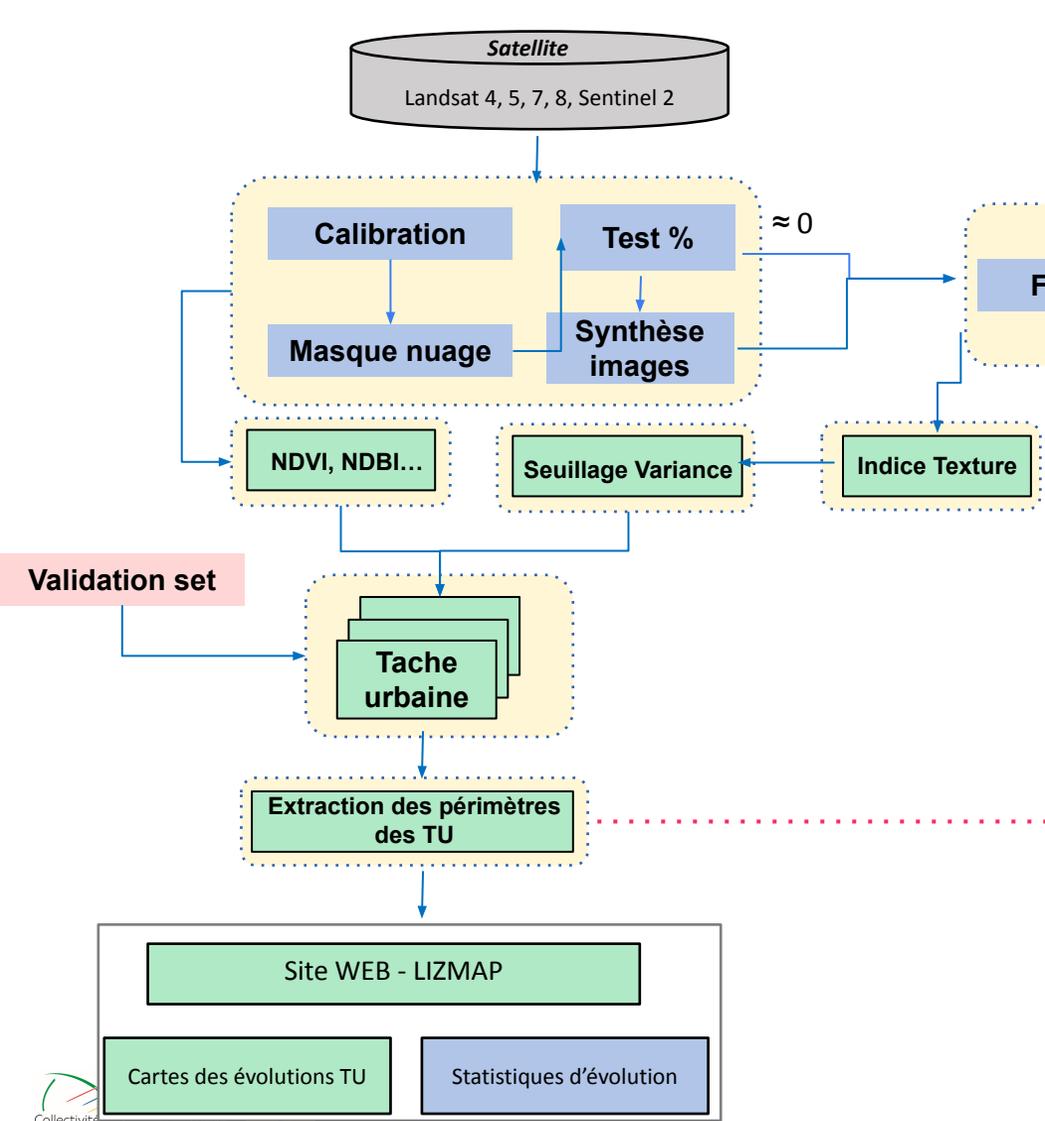
Saint Georges (Gf) – Oiapoque (Br)

Complex geographic entity. Low demographic density but ever-increasing urbanization

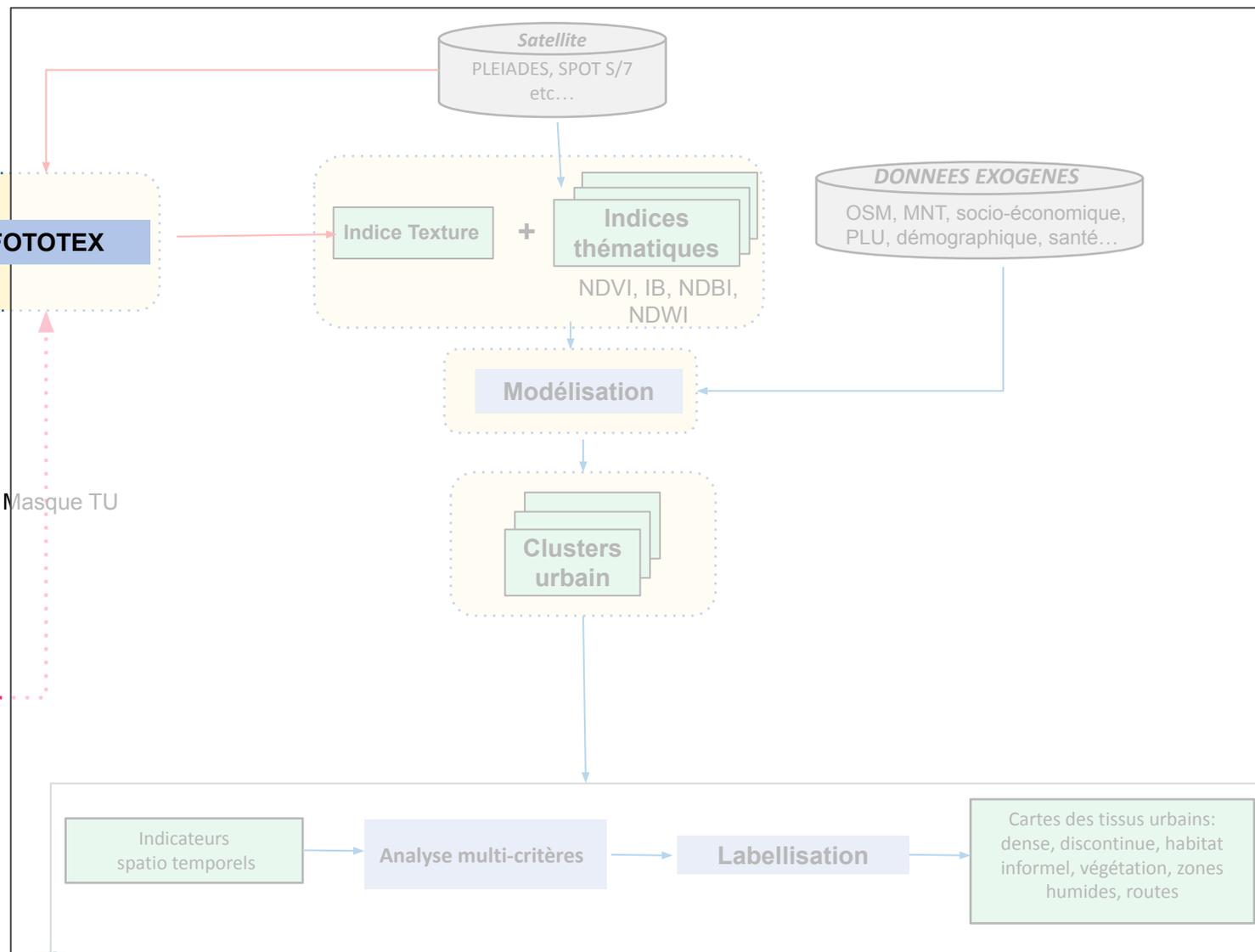
**PAYSAGES URBAINS du PLATEAU GUYANAIS**  
(Photos G. de Vilhena Silva)



## Macro : Urban Footprint

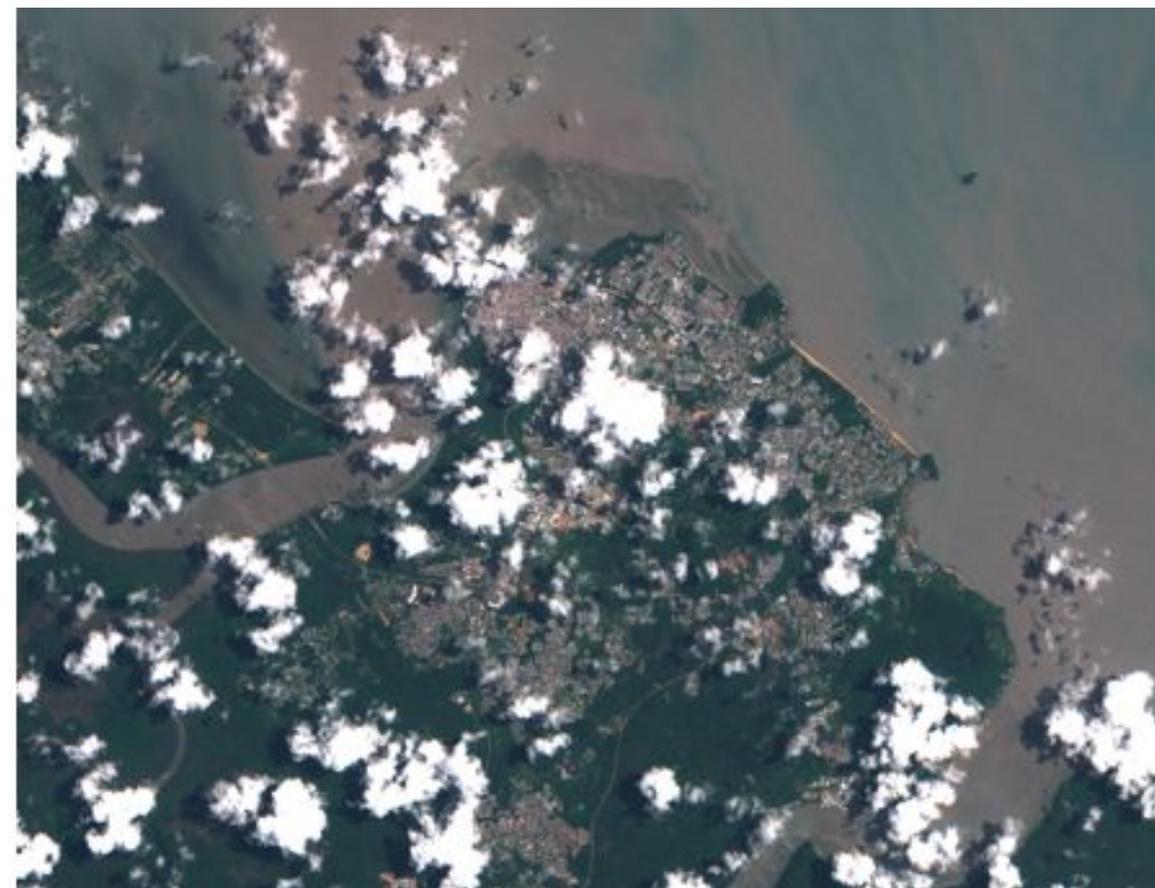
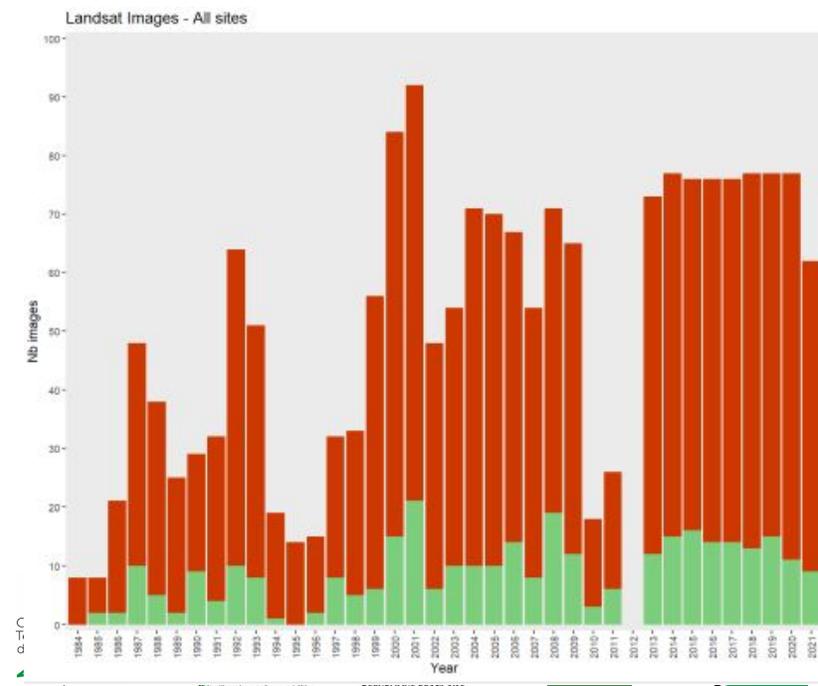


## Meso : urban fabric



## STEP 1 : IMAGES REPOSITORY

Saison sèche (JJASO)			
Satellite	Dates	Nb d'images disponibles	Couverture Nuages < 20%
Landsat 4,5,7,8	1987-2022	1896	327
Sentinel 2	2015-2022	2822	688



Cayenne - Sentinel 2 image : cloud cover  $\leq$  2.9 %

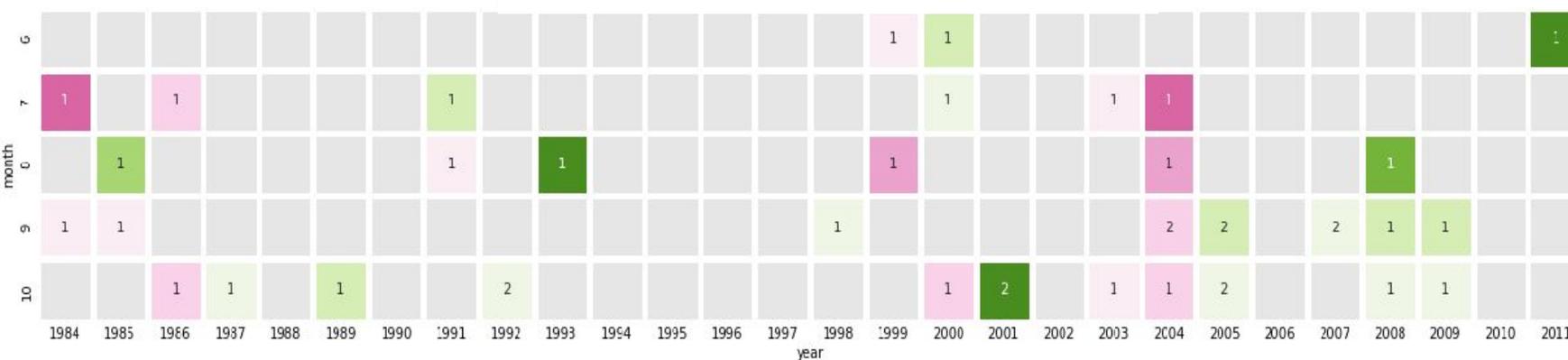
## Scripts / Modules development (python, R) to :

(C. Bernard)

- assist satellite images selection,
- determine a common analysis time step,
- visually compare studied sites.



Macapa



Landsat 4-5  
1984 - 2011

St Georges  
/ Oiapoque

## STEP 2 : PRE-PROCESSINGS

### Lots of experiments performed ...

#### Images Calibration :

- Reflectances computation and atmospheric corrections :  
landsat (USGS, SCP); Sentinel (Sen2cor, MAJA), Sen2lasrc-NASA

#### Cloud masks evaluation and computation :

- Landsat 4 / 5 , 7 et 8 (USGS)
- Sentinel (MAJA - CESBIO),
- Sentinel (Sen2cor -ESA)
- Sen2lasrc (Fmask, S2cloudless )

#### According to cloudiness :

- IF  $\approx 0$  THEN GOTO next processing,
- ELSE images synthesis (gap filling, Composite, WASP)
- ELSE try Radar data (S1)

some tests performed on Macapa for 2 dates : data synthesis over 1 year needed in order to filter speckle.

... and meetings and workshops with experts

**R. Gaetano,  
J.B. Feret  
F.de Boissieu,  
A. Defossez,  
J. Fozzani  
C. Charron,  
O. Hagolle ...**

## STEP 3 : PROCESSINGS

What is **UrbanFootprint** and Which **Common definition**?

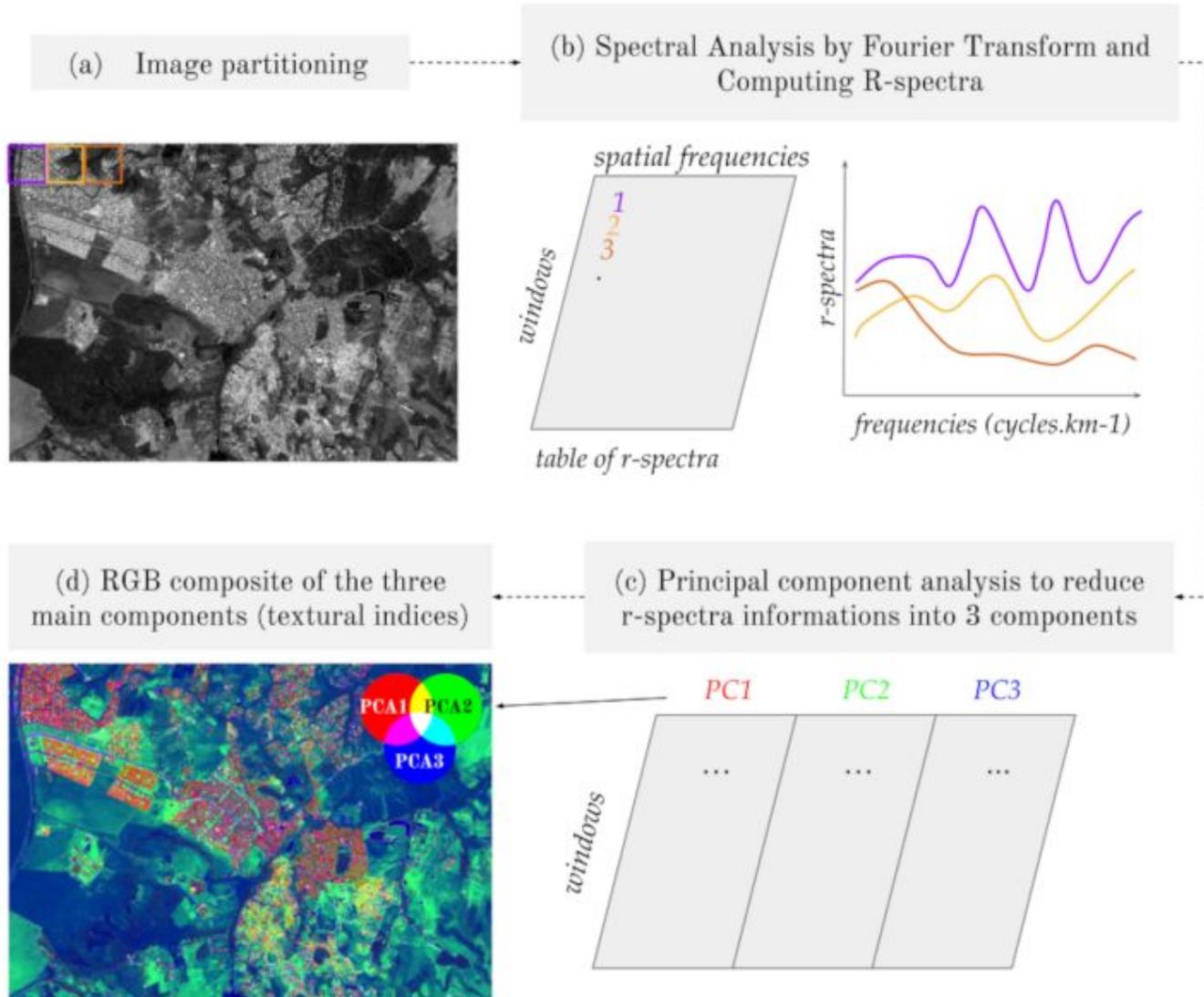
There is no official definition, but the term evokes the physical inscription of urbanization within a territory.

**PROGYSAT PRODUCT : Urban footprint = every habitated/constructed area than can be detected on the image = main center + all peripheral centers at a given distance (according to the size of the city)**

**=> 2 levels = main center + peripheral urban**

**=> every enduser will refine the urban footprint according to local (country level, municipo level) laws or public policies...**

## STEP 3 : PROCESSINGS



**A- Image partitioning for generating analysis windows :** block or moving windows

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

**C- PCA of the spatial frequencies matrix :**  
analysis windows are characterised by vectors of frequency components (pattern repetition). This step consists in dimensionality reduction of those vectors.

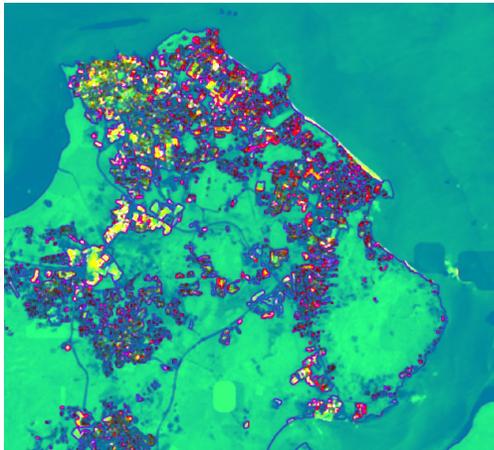
**D- RGB composite :**  
Spatial representation of the distribution of initial image frequencies  
R=PC1, G=PC2, B=PC3

## STEP 3 : PROCESSINGS

### Calculation of texture indices via FOTOTEX

( <https://framagit.org/espace-dev/fototex> )

Teillet et al., 2021 - Adaptation of the FOTO method to the urban context



based on Couteron et al., 2006; Proisy et al., 2007; Lang, 2019



Article

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

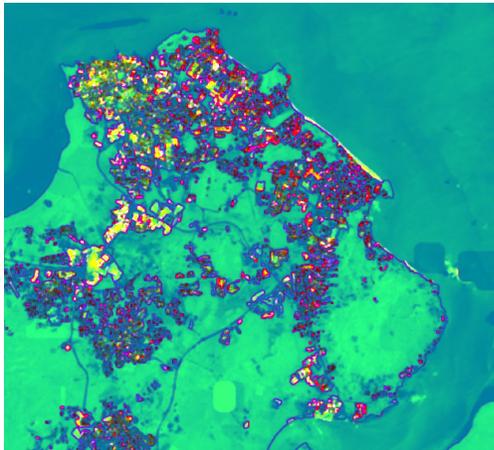
Claire Teillet <sup>1,\*</sup>, Benjamin Pillot <sup>1</sup>, Thibault Catry <sup>1</sup>, Laurent Demagistri <sup>1</sup>, Dominique Lyszczarz <sup>2</sup>, Marc Lang <sup>3</sup>, Pierre Couteron <sup>4</sup>, Nicolas Barbier <sup>4</sup>, Arsène Adou Kouassi <sup>5,6</sup>, Quentin Gunther <sup>7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

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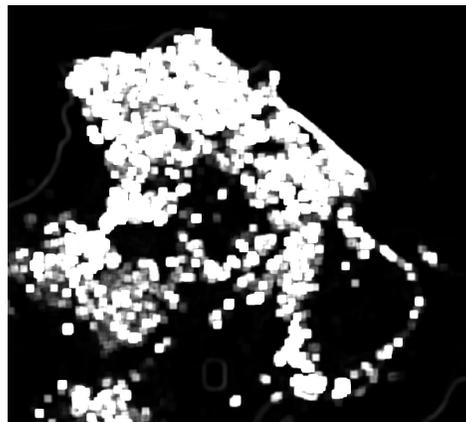


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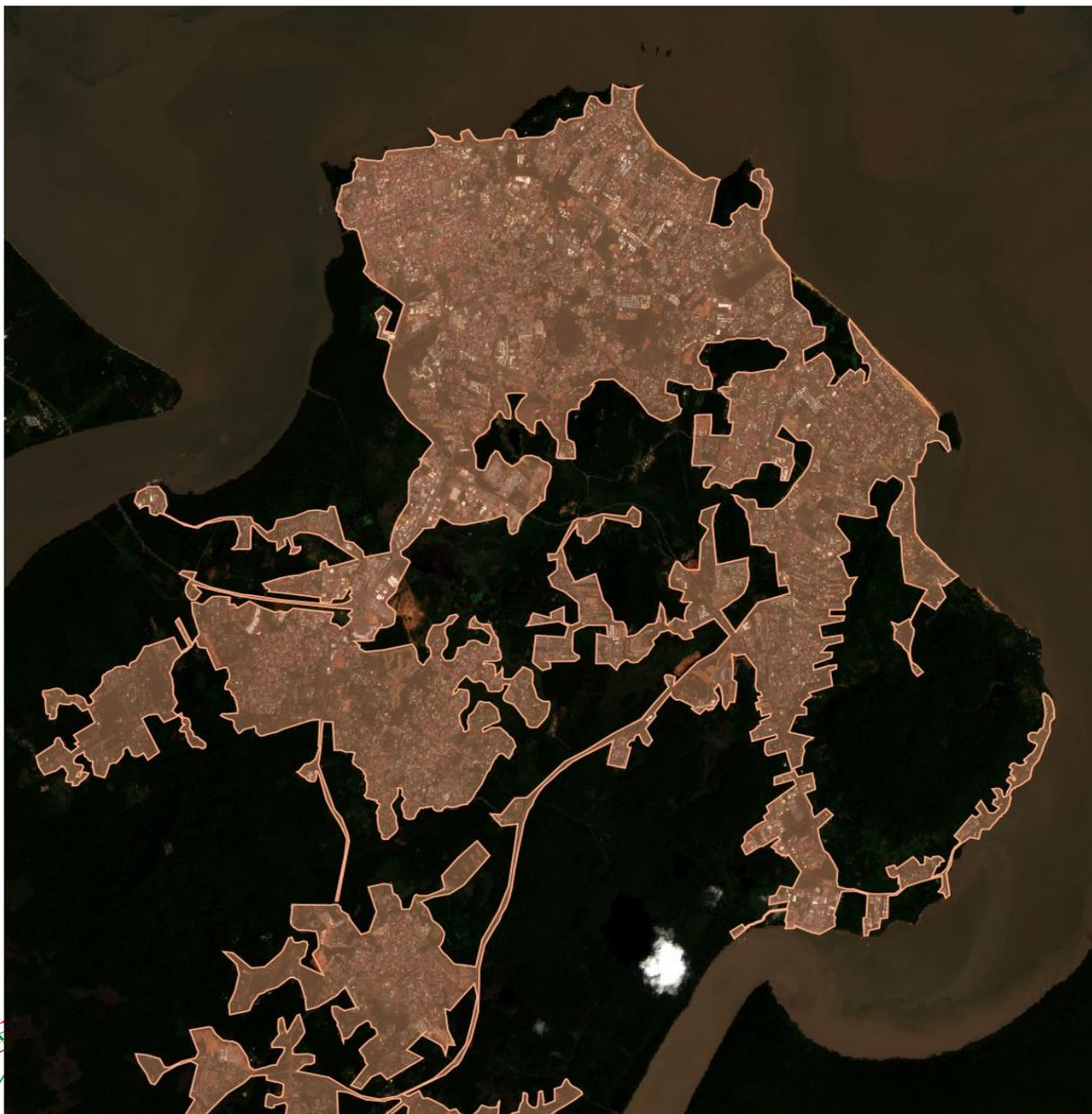
### Moving window variance applied on one of the output channels



Scientific paper in progress

- <https://forge.ird.fr/espace-dev/personnels/fouzai/progysat>

## STEP 3 : RESULTS

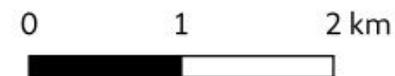


### Urban footprint (TU) delineation

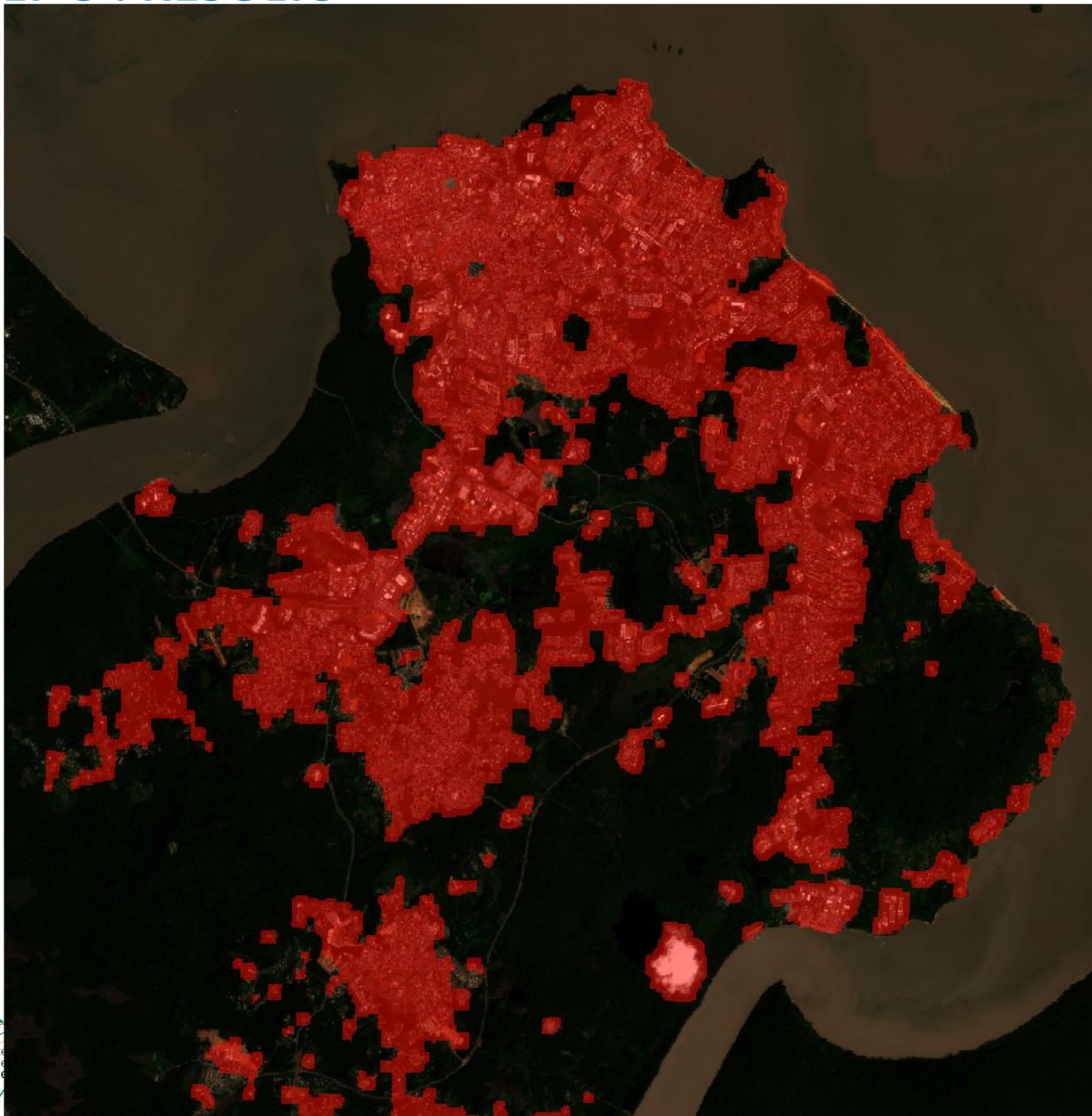
Cayenne  
Sentinel 2 image



Photo-interpretation by expert



## STEP 3 : RESULTS



### Urban footprint (TU) delineation

Cayenne  
Sentinel 2 image

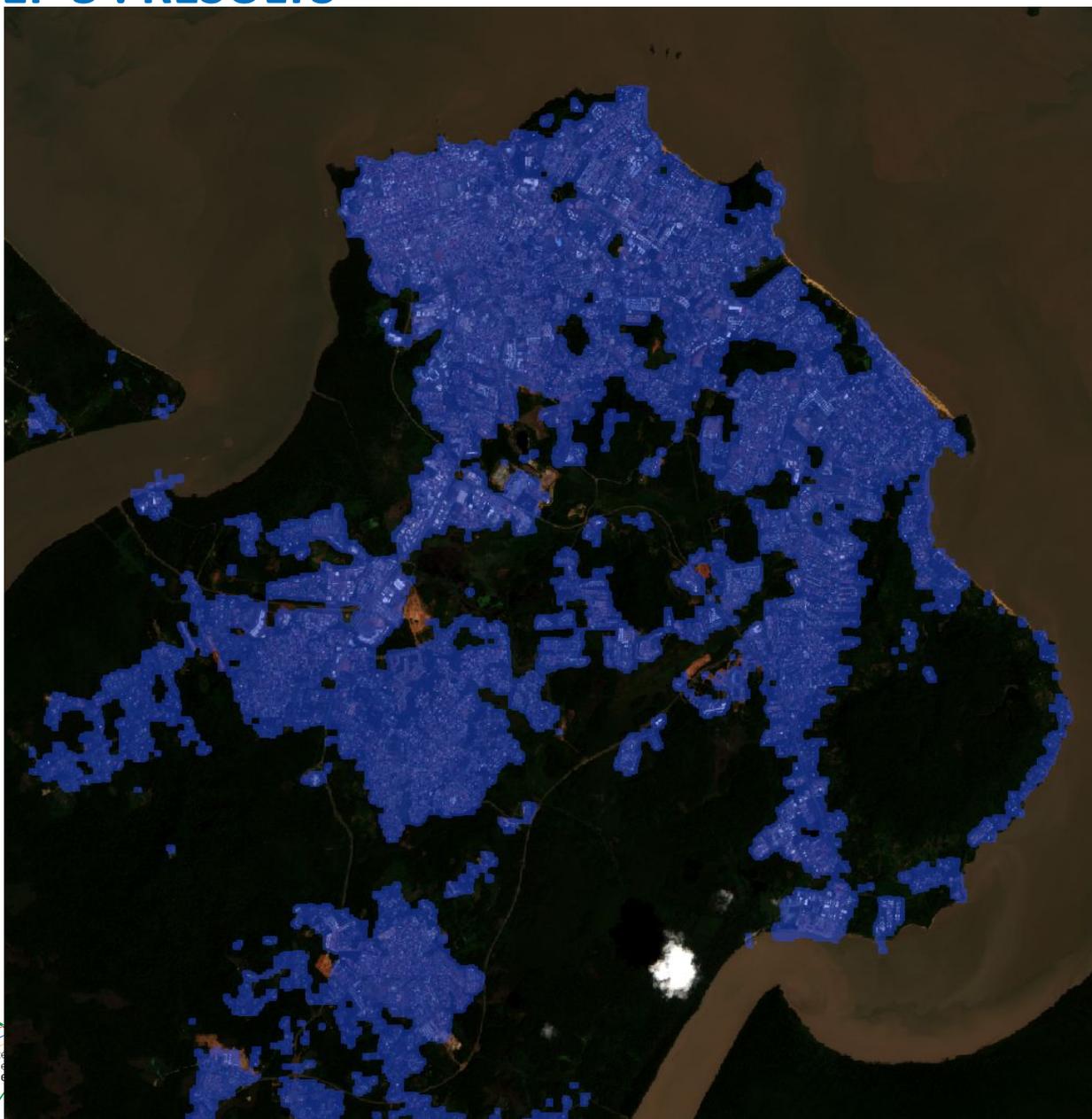


Automatic process

0 1 2 km



## STEP 3 : RESULTS

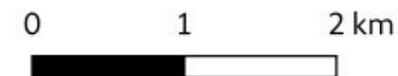


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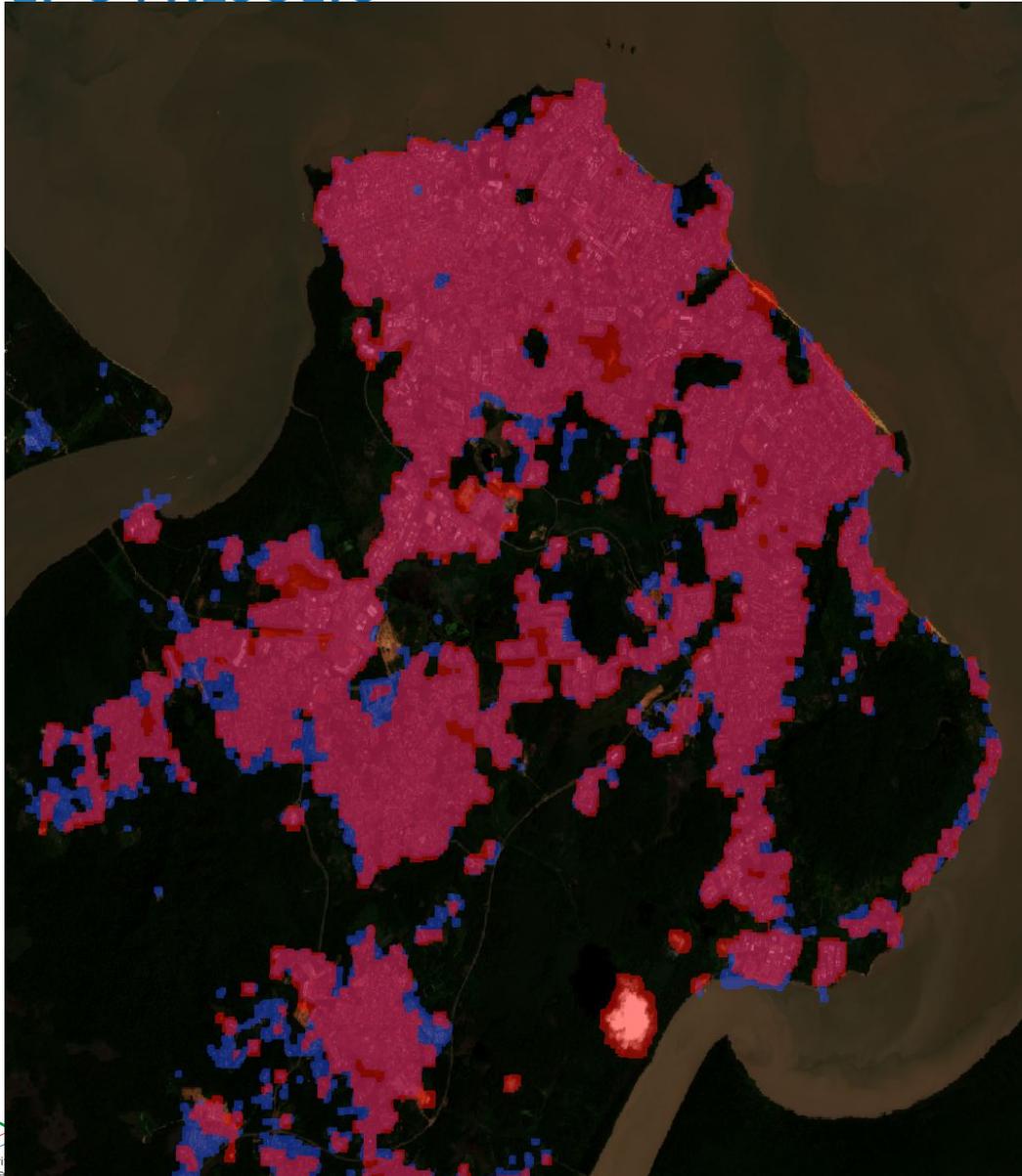
Cayenne  
Sentinel 2 image



Global Human Settlement Layer  
(GHSL - <https://ghsl.jrc.ec.europa.eu/>)



## STEP 3 : RESULTS



### Urban footprint (TU) delineation

Cayenne  
Sentinel 2 image



Automatic process

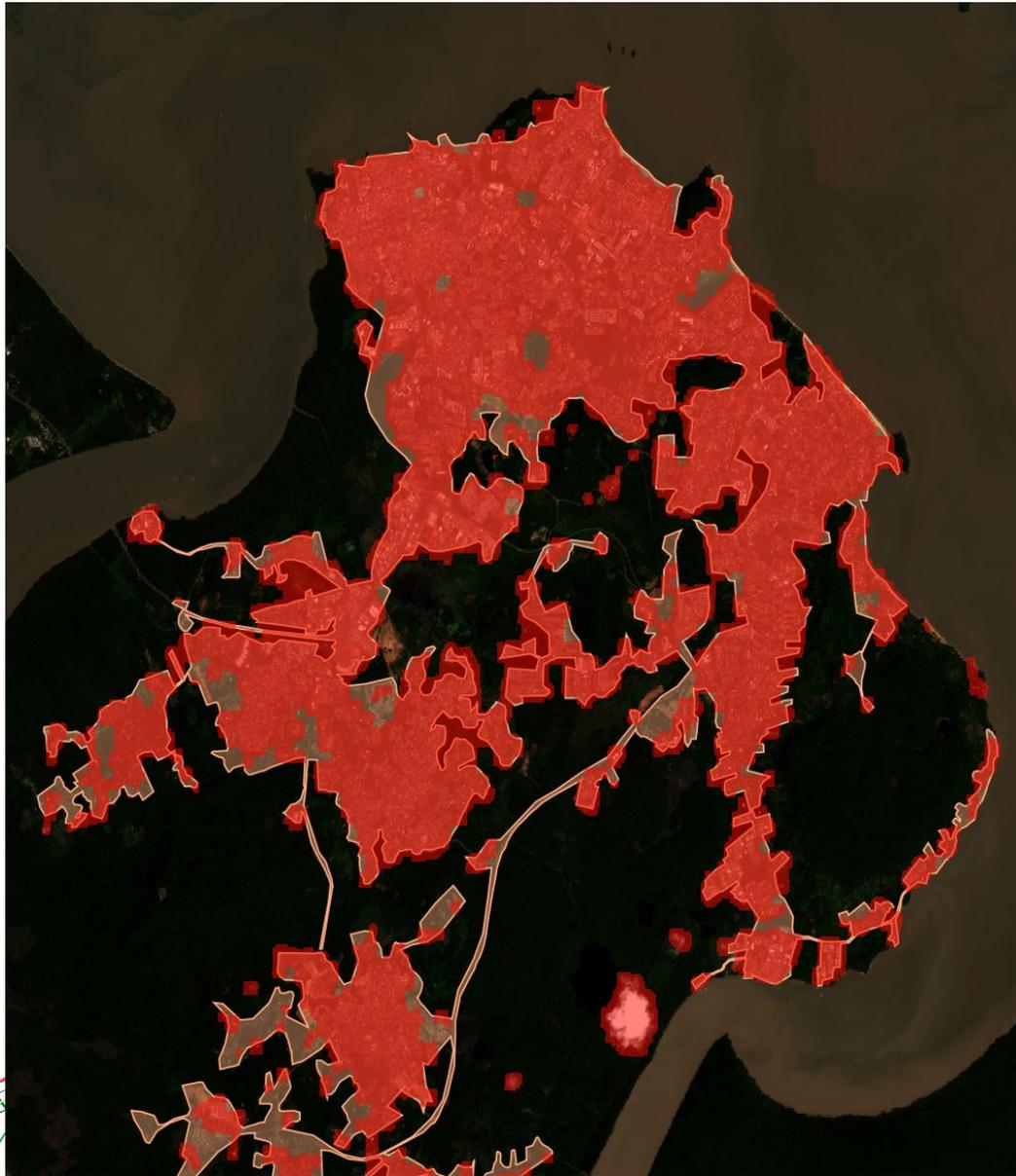


Global Human Settlement Layer  
(GHSL - <https://ghsl.jrc.ec.europa.eu/>)

0 1 2 km



## STEP 3 : RESULTS



### Extraction Tache Urbaine (TU)

Cayenne

Image Sentinel 2 :



Automatic process

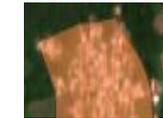
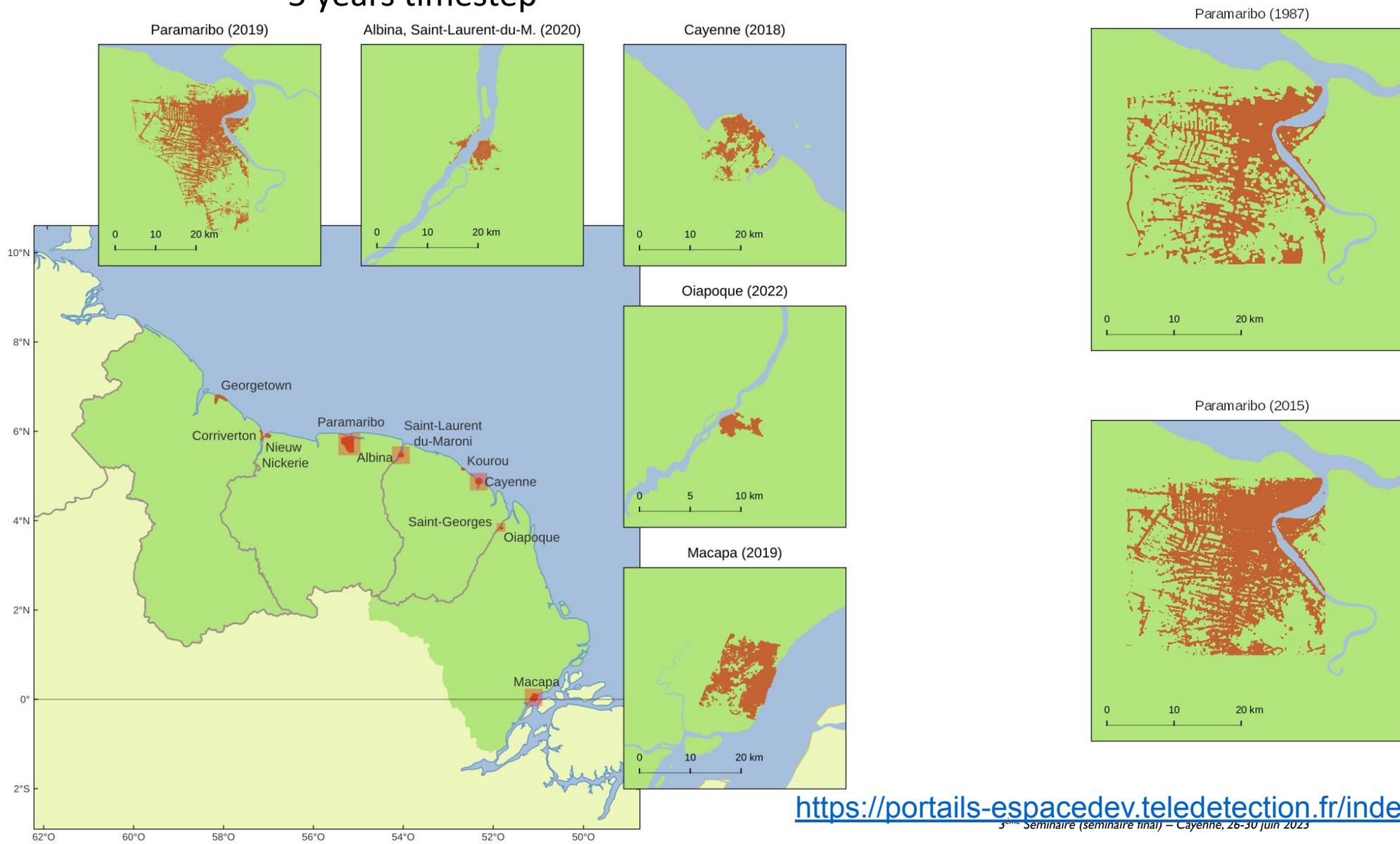


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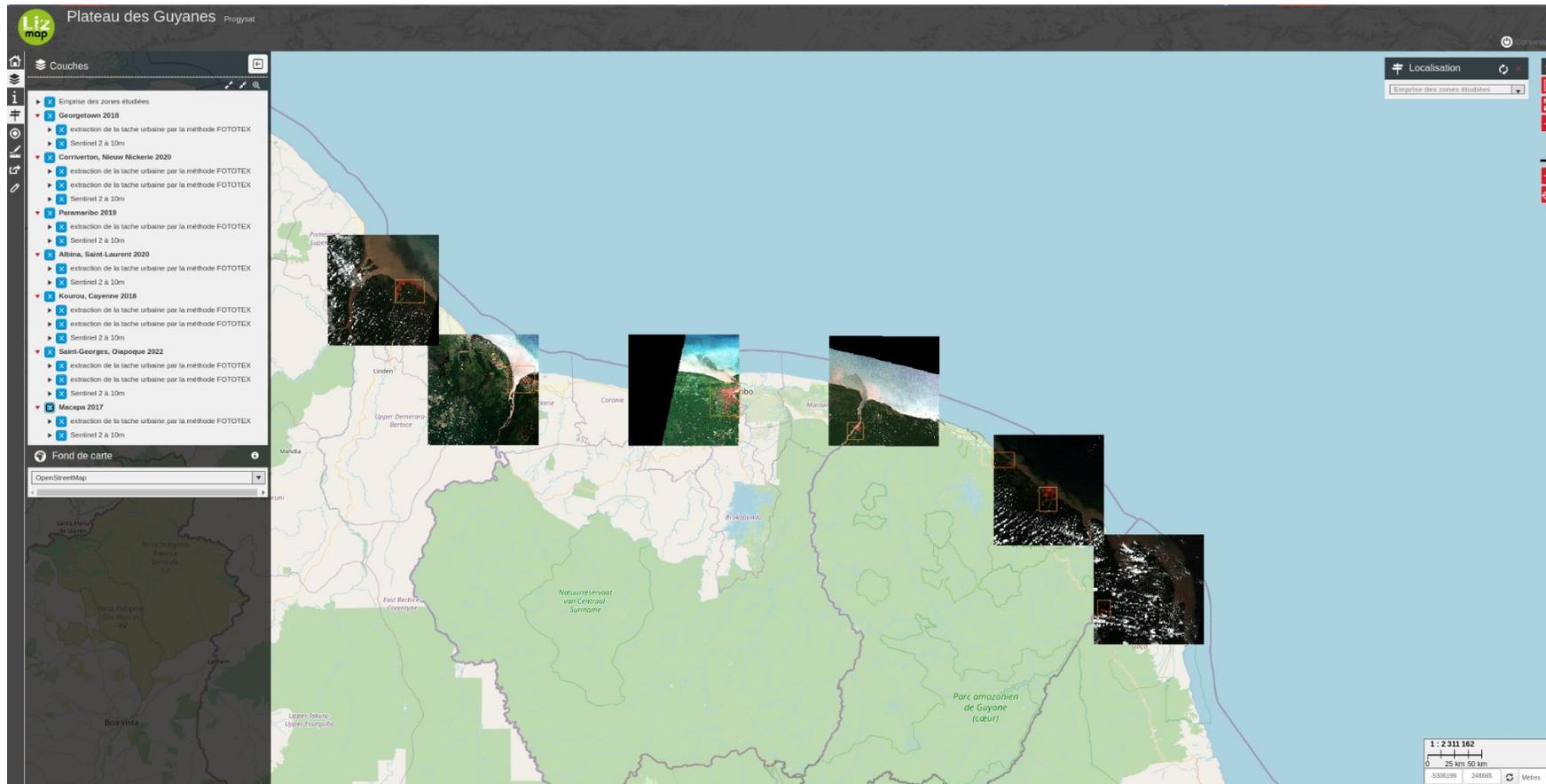


## STEP 3 : RESULTS : Urban footprints for 11 cities of the Guyana plateau region [1984 – 2022] ~ 5 years timestep



## STEP 3 : RESULTS

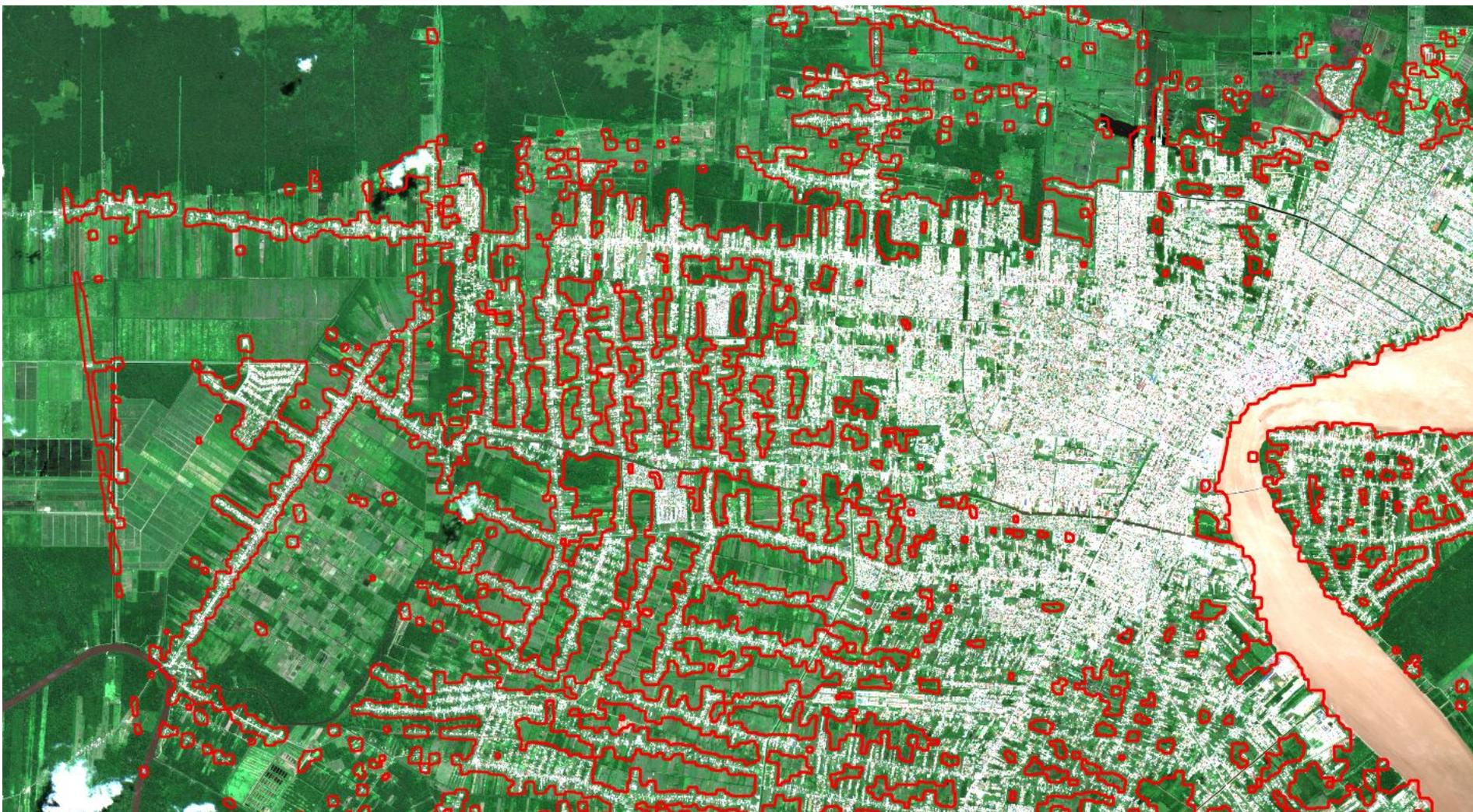
### LIZMAP web portal (data visualization)



<https://portails-espacedev.teledetection.fr/>

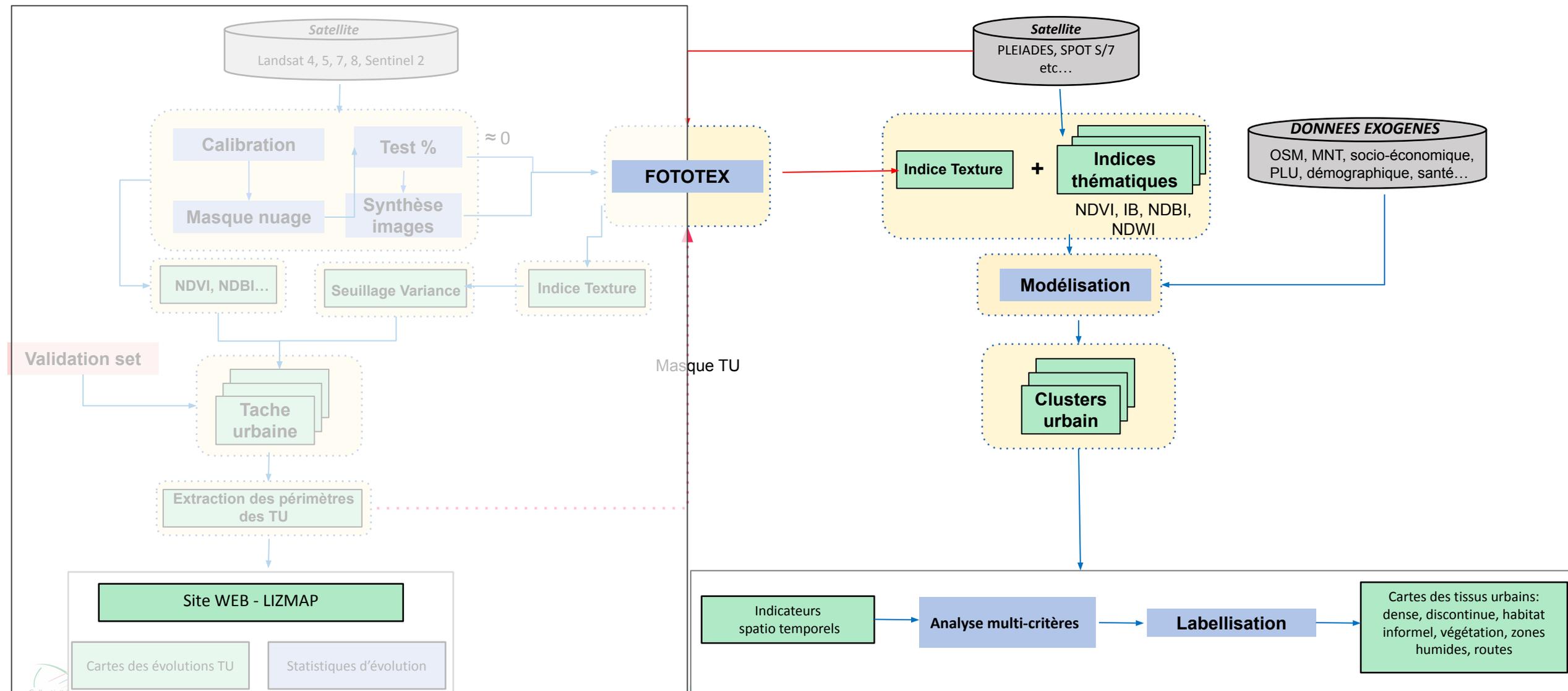
## STEP 3 : RESULTS

LIZMAP web portal (data visualization)



## Macro : Urban Footprint

## Meso : urban fabric



## Public institutions responsible for (or working on) urban typologies and urban areas action plans

Country	Research or public Institution / partners
<b>Guyana</b>	Guyana University, Embassy
<b>Surinam</b>	Anton de Kon University, Embassy
<b>French Guyana</b>	CTG, AudeG, DGTM (ex DEAL) en lien IGN (Photo), Université de Guyane, Consulat du Brésil, EPFA (ex EPAG), OHM
<b>Brazil</b>	<b>UFPA, IBGE, IEPA, IDS:</b> Instituto de Desenvolvimento Social. Ambassade, SEPLAN-Amapá; SETEC; Prefeitura de Oiapoque (Secretaria de Relações Internacionais), Instituto de Pesquisa, Planejamento Urbano e Desenvolvimento Sustentável de Redenção -IPPUR, Ministère des Relations Extérieure (MME), Ministério do Meio Ambiente (MMA), Observatório de Clima e Saúde/ICICT/FIOCRUZ; INDE (Infraestrutura Nacional de Dados Espaciais), INPE.

Public institutions responsible for (or working on) urban typologies and urban areas action plans

Inventory of available exogenous data and urban typologies



Fonte: IBGE, Diretoria de Geociências, Coordenação de Geografia.

Table: Brazilian example (IBGE) - Definition of classes closely related to living conditions

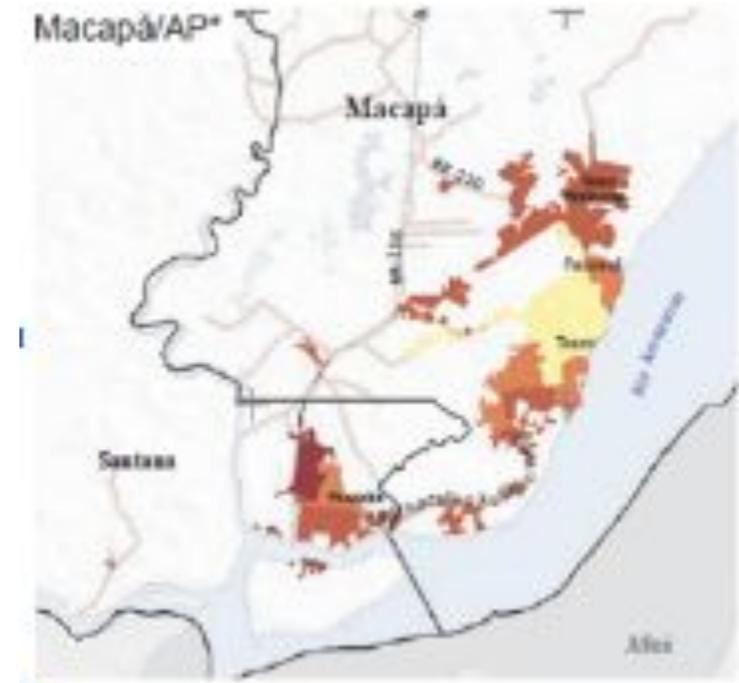


Figure : Intra-urban typology, Macapa (Source, IBGE)

## PROGYSAT - INTRA-URBAN

### Discussions and definitions with partners :

- Habitat dense,
- Habitat discontinu ou lâche
- Habitat informel (habitat informel dense = Favelas) ; (= illégal = sans autorisation)
- Nouvelle extension urbaine (déterminée par l'historique)
- Infrastructures (ports, zones industrielles etc.)
- Végétation (hors agriculture)
- Eau / Zones inondables
- Routes (goudronnée, en terre)

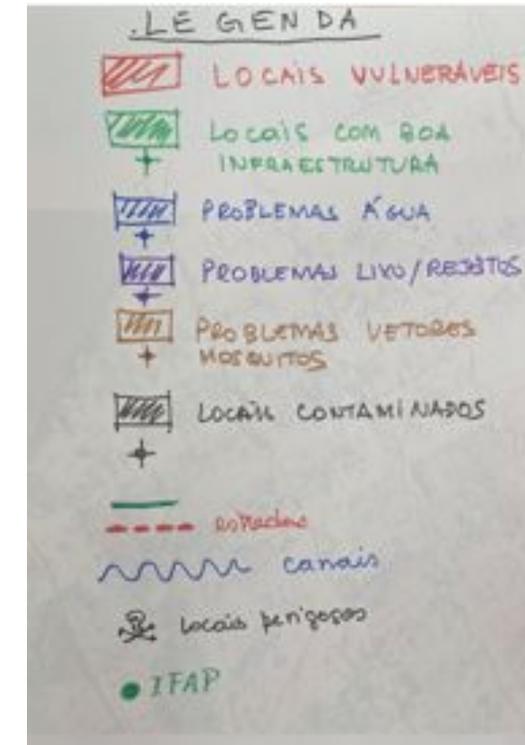


**UNIFAP**  
Universidade Federal do Amapá

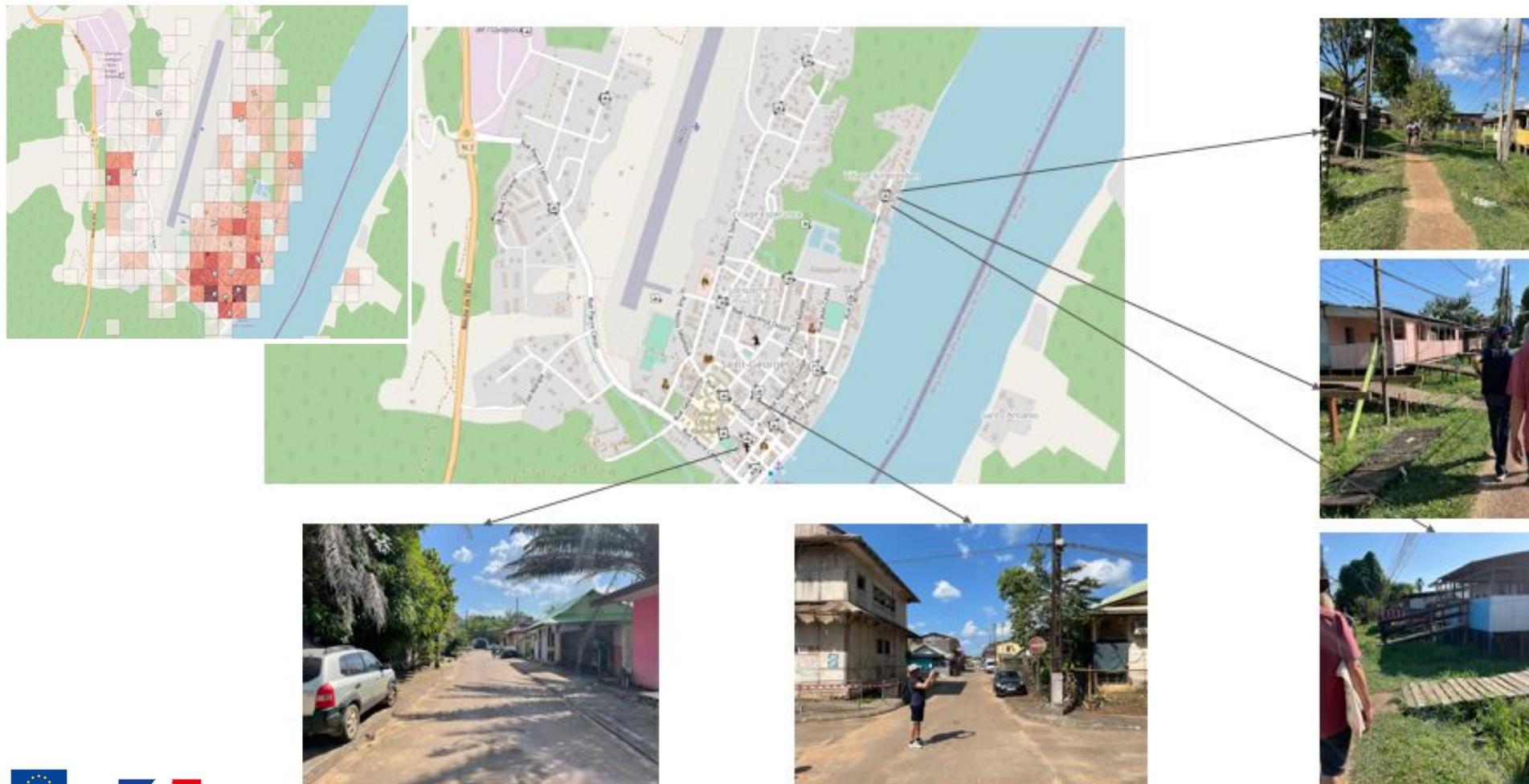


## PROGYSAT - INTRA-URBAN

**Discussions with representatives of Guyanese and Brazilian communities :**  
natives, fishermen, butchers, health workers...

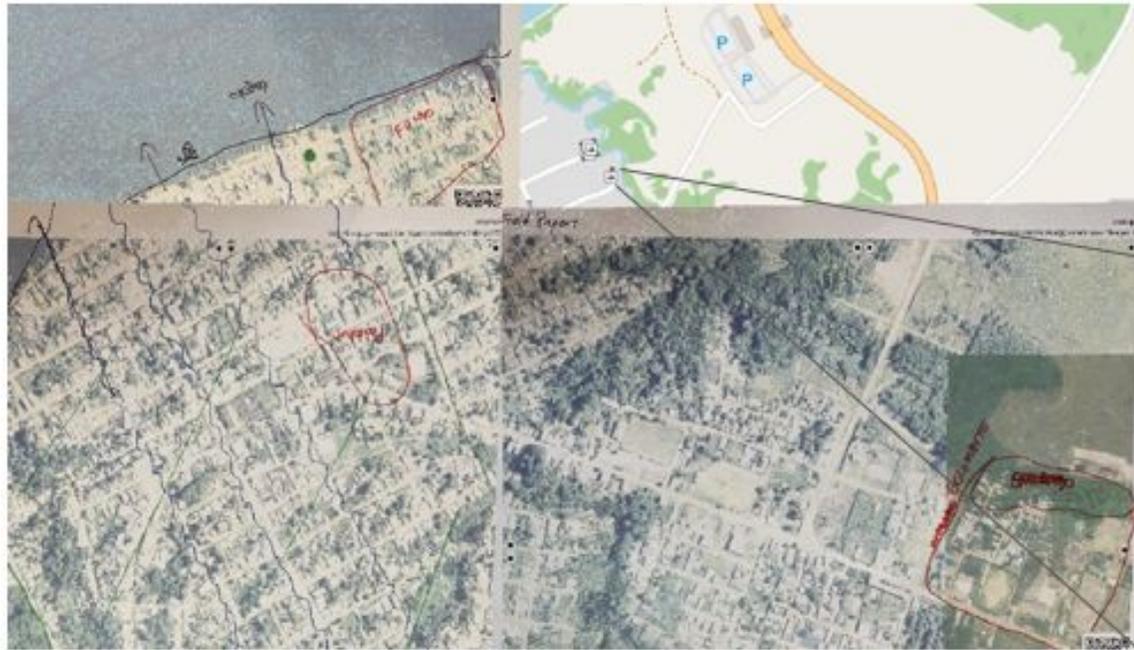


**Field mission :** ground control points (GPS, Photos) ; sampling based upon building density (OpenStreetMap)



## Field mission (Fr. Guyana, Brazil) :

- (i) sampling based upon building density (OpenStreetMap) and the targeted urban classes
- (ii) locate sensitive areas and neighbourhoods with the help of community representatives (Brazil)



## Informal urban settlements : preliminary results



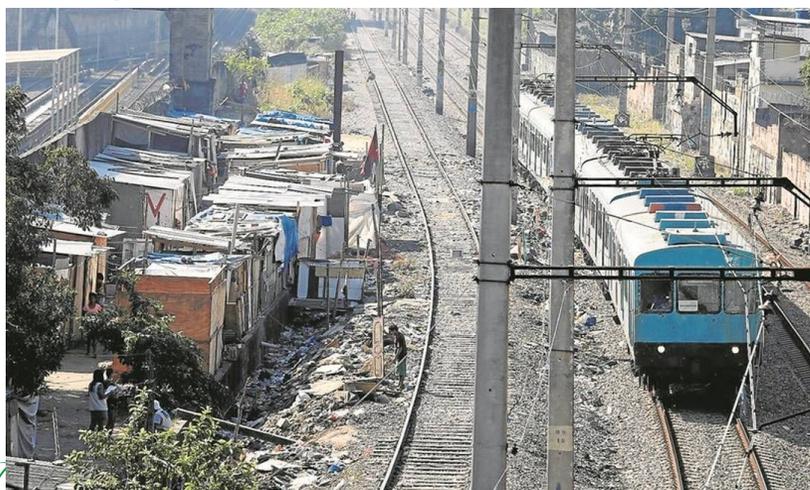
Slope



Plain or floodable areas



High-voltage lines

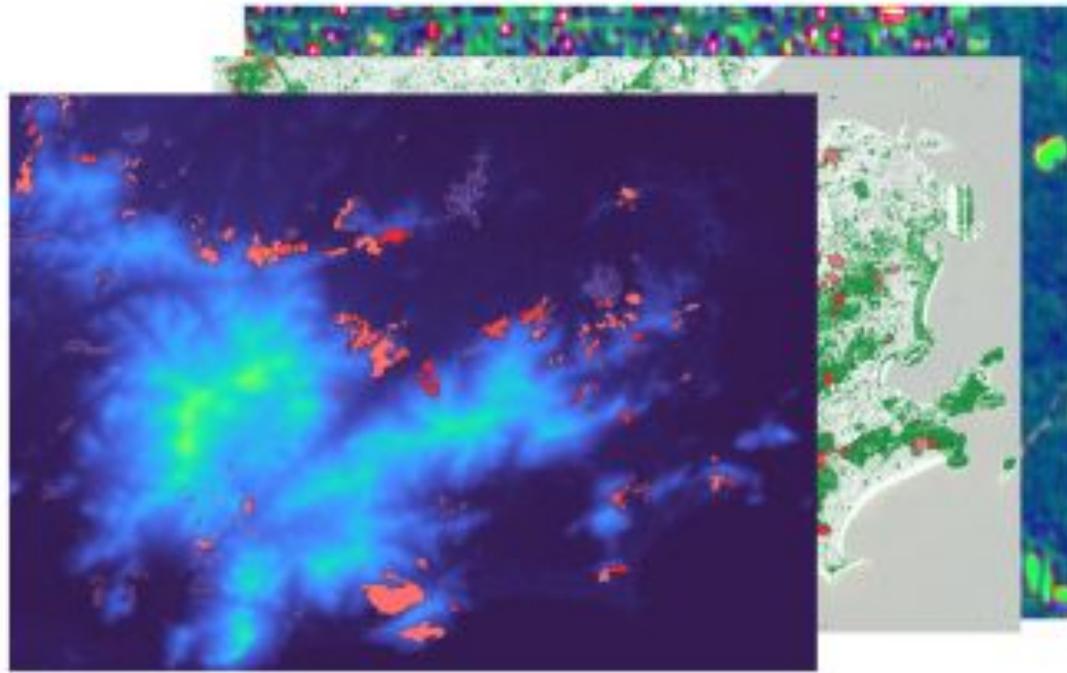


Geographic location

⇒ social inequality  
regarding access to healthcare

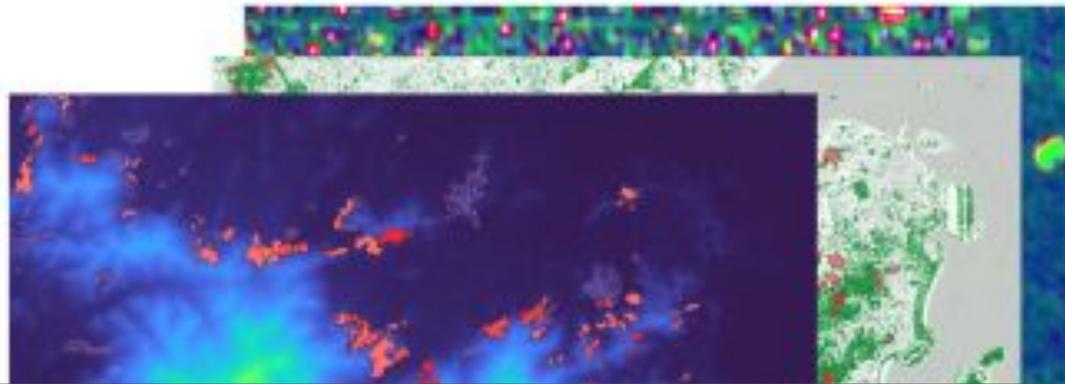
## Informal urban settlements : preliminary results

Image descriptors computation based on satellite or exogenous data :



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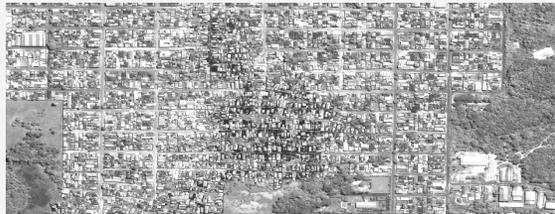
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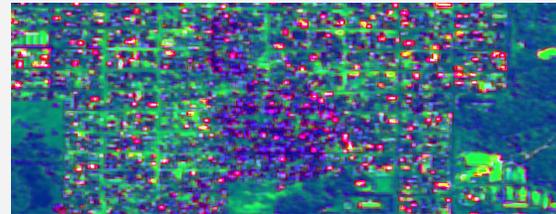
### Textural Descriptors

Distinction of intra-urban units using the FOTOTEX unsupervised texture analysis algorithm (based on Fourier transforms - <https://framagit.org/benjaminpillot/fototex>).

Favelas areas seem highlighted and appear in purple spatial clusters.



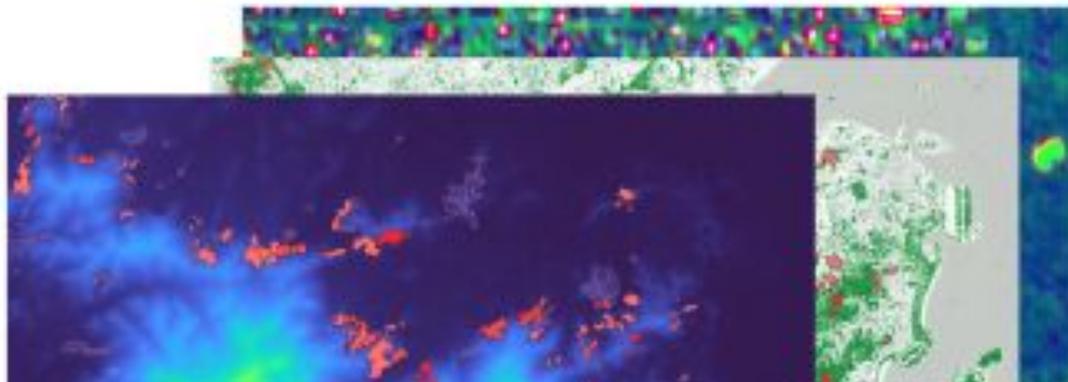
Picture detail of a panchromatic channel - Pléiades Macapa



Colour composite of FOTOTEX output channels

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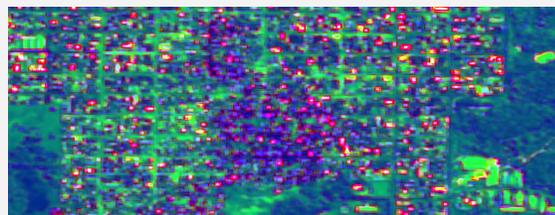
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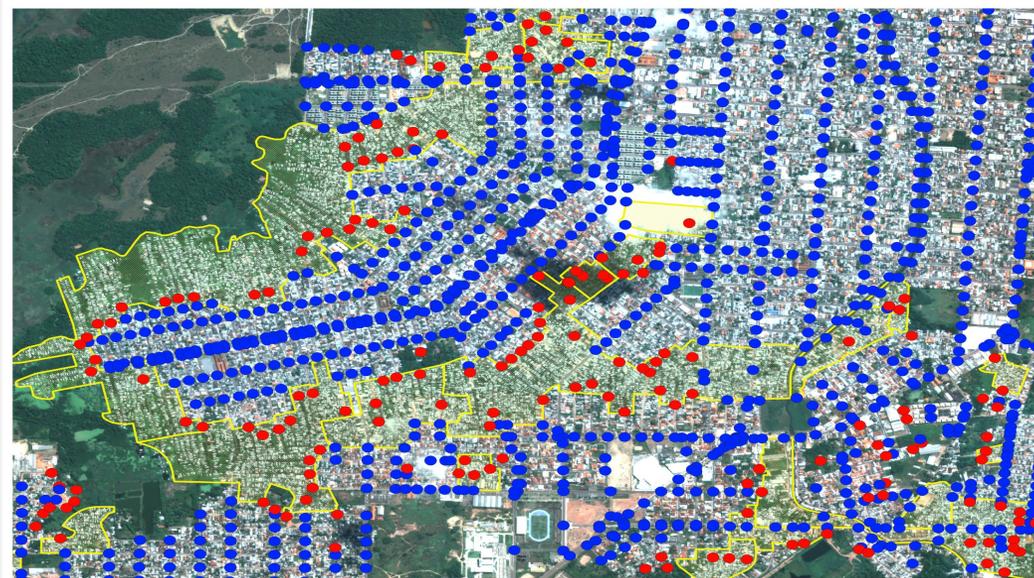


Picture detail of a panchromatic channel - Pléiades Macapa



Colour composite of FOTOTEX output channels

### Descriptors from road network



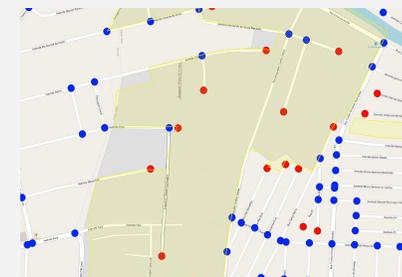
On each node of the road network (OpenStreetMap) calculation of the number of connections. Separation of nodes according to the number of connections :

- **RED**  
1 or 2 connections

**Nodes frequently connected to favelas**

- **BLUE**  
≥ 3 connections

**Alignments & regularity could be associated to residential urban areas**



## Scientific and technical activities

- **Data processing chains**

- Python library for automatic delineation of urban footprint from satellite images :

- <https://forge.ird.fr/espace-dev/personnels/fouzai/progysat>

- **Maps**

- Urban footprints for 11 cities : *Georgetown-2018, Corriverton-2020, Nieuw Nickerie-2020, Paramaribo, Albina-2020, Saint-Laurent-2020, Kourou-2018, Cayenne-2018, Saint-Georges-2022, Oiapoque-2022, Macapa*

- Urban Footprint history : *Paramaribo 1987-2019, Macapa 1985-2017*

- **Web platforms fed continuously by the project results**

- LIZMAP web portal for maps and data visualization : <https://portails-espacedev.teledetection.fr/index.php/view>

- DataSuds repository : <https://dataverse.ird.fr> - *vector files deposit in progress*

## Scientific and technical activities

- **Articles, communications, conferences, posters**

Communication 1 : Peiter P., Vilhena Silva G., Dessay N., **Fouzai Y**, Albuquerque H., Almeida N., Demagistri L., Bernard C., Catry T., Teillet C., Pillot B., Charron C., Dessay N., Analysis of the dynamics of urbanized spaces by satellite application to French Guiana, 27-30 Septembre 2022, Paramaribo – Suriname.

Communication 2 : **Fouzai Y**, Demagistri L., Teillet C., Catry T., Bernard C., Pillot B., Dessay N., Suivi de la dynamique spatio-temporelle de la tâche urbaine pour onze villes du plateau guyanais par approche texturale. Télédétection pour l'Etude du Milieu Urbain (TEMU), 2-3 février 2023, Montpellier

Poster : **Fouzai Y**, Demagistri L., Teillet C., Catry T., Bernard C., Pillot B., Peiter P., Roux E., Gracie R., Dessay N., Caractérisation des favelas par imagerie satellitaire pour un meilleur suivi sanitaire des populations, Télédétection pour l'Etude du Milieu Urbain (TEMU), 2-3 février 2023, Montpellier

Article 1 : Délimitation automatique des taches urbaines par imagerie satellitaire (*en cours de rédaction - revues de Télédétection ciblées : JAG ou JSTARS*)

Article 2 : Análise de dinâmicas dos principais centros urbanos da região das Guianas (1985-2022) (*en cours de rédaction - revue : Revista Ponto de Vista - <https://periodicos.ufv.br/RPV/index>*)

## Scientific and technical activities

- **Capacity building**

- Youssef FOUZAI : *fixed-term contract IRD - dec. 2021 to dec. 2022 - 13 month - Algorithm Development*
- Hermano Gomes Albuquerque : *fixed-term contract IOC/FIOCRUZ - fevr. 2022 to sept. 2022 - 6 month part-time. Scientific bibliography regarding urban typologies. Support for the analysis of urbanisation documents identified for cities in Brazil, French Guiana and Guyana ; Fieldwork.*
- Nataliel de Almeida Costa : *fixed-term contract UNIFAP - fevr. 2022 to juil. 2022 - 6 month. Structure data for each city as QGIS projects with all the associated available data - Fieldwork for validation*

- **Training and awareness workshops**

- PROGYSAT closing seminar : Workshop on Urban footprint delineation and spatio-temporal dynamic analysis
  - presentation, tools, demonstration
  - intra-urban preliminary results (indicators, discussions and perspectives)
  - assistance with installing python modules

- **Tutorials, trainings and workshops materials**

- Python notebooks for training in urban footprint delineation tools:

<https://forge.ird.fr/espace-dev/personnels/fouzai/progysat/-/tree/main/notebook>



Merci de votre attention

