IDEAMAP SUDAN

(IDeAMapSudan)

INTEGRATED DEPRIVATION AREA MAPPING SYSTEM FOR DISPLACEMENT DURABLE SOLUTIONS AND SOCIOECONOMIC RECONSTRUCTION IN KHARTOUM, SUDAN

FINAL SYMPOSIUM

FEBRUARY 2023

IDEAMAP SUDAN FINAL SYMPOSIUM

Artificial Intelligence (AI) and Earth Observation (EO data to fill data gaps in rapidly transforming cities

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Using results from : Y. Forget, N. Mboga

FEBRUARY 2023

Introduction : why EO and AI for sustainable urbanisation ?

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- Sustainable Development Goals → **232 indicators** to support setting up relevant policies to « leave no-one behind »
- Indicators should be **disaggregated** by income, sex, age, … and **geographic location**
- To achieve a sustainable urbanization, urban planning and land management, **need updated and geographically detailed data** → remains a challenge to find because of :
  - **Cost** of generating such data through traditional data
  - **Shortage of skilled professionals** in geospatial sciences → low national capacity of geospatial data production
  - Inertia regarding the **change of routine workflows** and adopting new practices that are not imposed through legal requirements

Introduction : why EO and AI for sustainable urbanisation ?

- EO capabilities can provide **useful information for decision making** for sustainable urbanisation
- EO can address the 2 first points :
  - EO data are **cheaper than field measures/observation** to produce similar data
  - **Training** such as with IdeaMapSudan can contribute to skilled professionals
- AI allows the **processing of big data sets,** such as EO data on urban areas with very high spatial resolution to map small houses

→ Presentation of results from some ANAGEO research projects (since 2014) using EO and AI using mainly Open Data and Software

EO and AI for mapping urbanisation

ULB ANAGEO

- Forget Yann (2021) uses **historical EO satellite data** to map the probability of urbanisation (1995-2015) for 45 African cities in the MAUPP project (https://maupp.ulb.ac.be/):
  - Much optical satellite data (i.e. in visible and infrared wavelength) existing since '70's
  - Much radar data (passes through clouds) since '87
  - Use of OpenStreetMap data to train the AI algorithms
  - Map built-up probabilities through time

MAUPP

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Forget, Y., Shimoni, M., Gilbert, M., & Linard, C. (2021). Mapping 20 years of urban expansion in 45 urban areas of sub-Saharan Africa. *Remote Sensing*, 13(3), 525. doi:10.3390/rs13030525

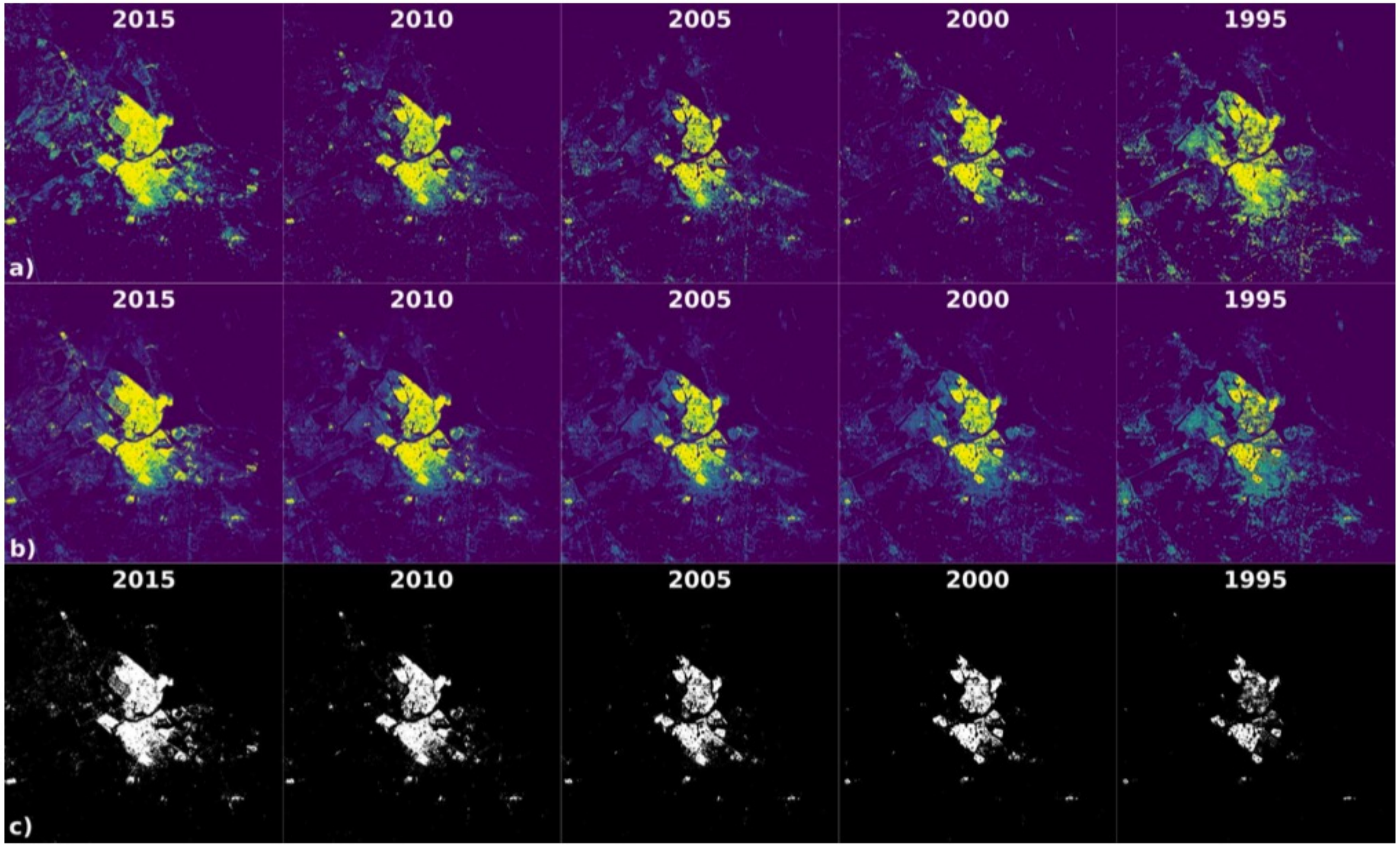


Figure 4.6: Post-processing of Ndola, Zambia. **a)** Raw RF built-up probabilities; **b)** Built-up probabilities after post-processing; **c)** Binary map (thresholded probabilities).

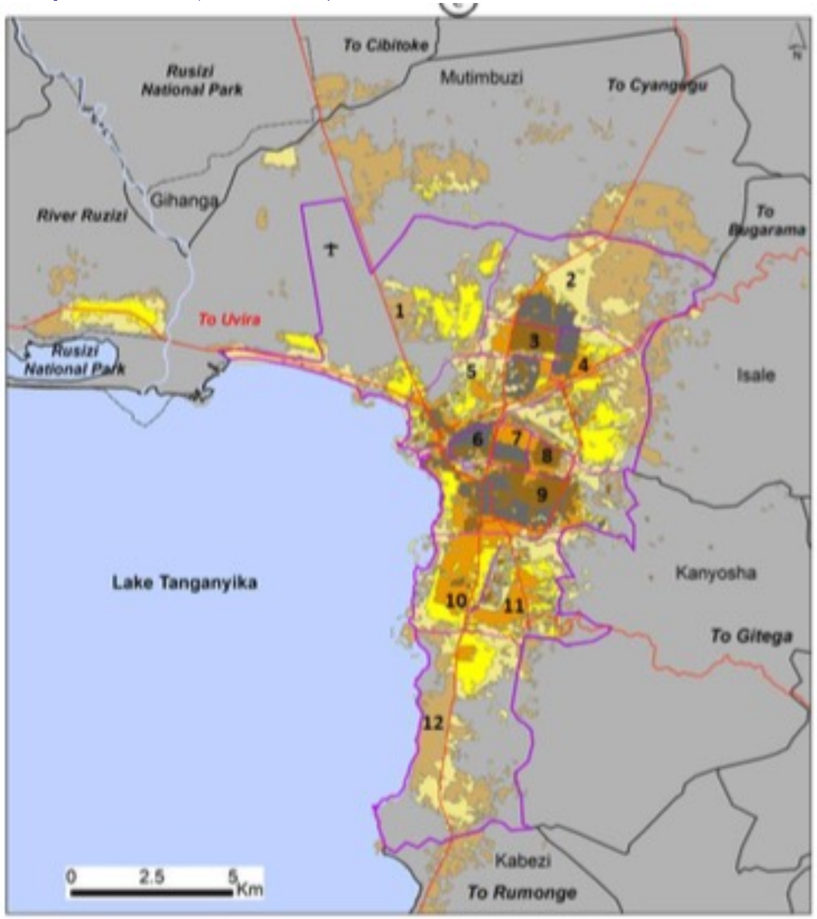
EO and AI for mapping urbanisation

- Mboga Nicholus (PhD thesis, ULB, 2021) :
  - uses **historical EO aerial** and recent satellite data
  - to map with AI (Deep-Learning) the **long-term urbanisation (1940-2020)**
  - For 3 cities in the Kivu region (Goma-Gisenyi, Bukavu, Bujumbura), Central Africa
  - in the PASTECA project (https://pasteca.africamuseum.be/)

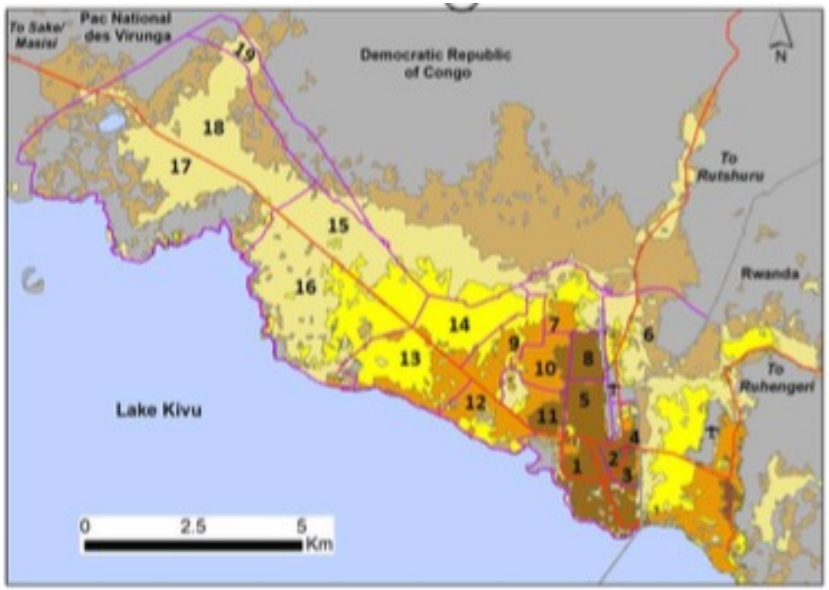
Mboga, N. O. (2021). *Long-term mapping of urban areas using remote sensing: Application of deep learning using case-studies of data from Central Africa* (Unpublished doctoral dissertation). Université libre de Bruxelles, Faculté des Sciences – Géosciences, Environnement et Société, Bruxelles.

Urbanisation mapped from old aerial photos and satellite data with AI (Deep Learning)

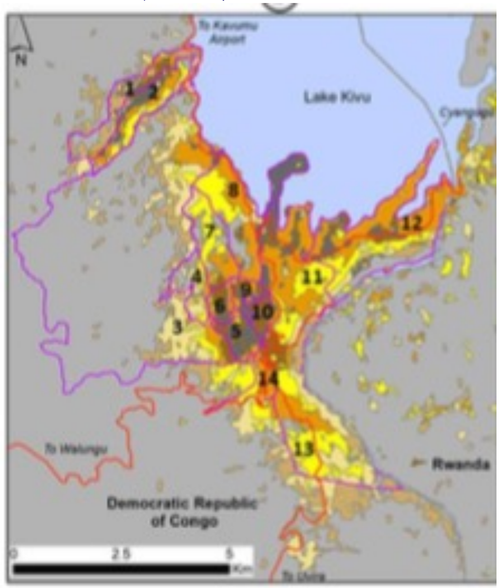
Bujumbura (Burundi)



Goma – Gisenyi (DRC)



Bukavu (DRC)



Year -1	Year -3	Year -5
Year -2	Year -4	Year -6

(a) Goma-Gisenyi	(b) Bukavu	(c) Bujumbura
Year 1 – (1947)	Year 1 – (1959)	Year 1 – (1959)
Year 2 – (1975)	Year 2 – (1975)	Year 2 – (1972)
Year 3 – (1990)	Year 3 – (1990)	Year 3 – (1990)
Year 4 – (2000)	Year 4 – (2001)	Year 4 – (2001)
Year 5 – (2010)	Year 5 – (2010)	Year 5 – (2010)
Year 6 – (2020)	Year 6 – (2020)	Year 6 – (2020)

Non built-up   Airport   Road

International boundary

PAStECA

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EO and AI for mapping detailed urban land use (LU) and land cover (LC)

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- Used of **very high resolution satellite imagery** (± 50 cm resolution, such as Pleaides) in combination with 3D views for
  - **Mapping detailed LC classes** on several African cities according to their spectral signatures and their height thanks to AI classification techniques
- **Mapping urban LU classes** on several African cities **at the street blocks level** thanks to AI classification techniques based on
  - Street block geometry (shape index, area)
  - EO-derived information (nDSM, NDVI)
  - LC-derived information (Landscape/Spatial metrics)
- Codes :
  - developped by T. Grippa during his PhD thesis
  - available on https://github.com/tgrippa
  - Documented in the
    MAUPP project's publications (https://maupp.ulb.ac.be/page/publications/) and
    REACT project's publications (https://react.ulb.be/publications)

REACT

MAUPP

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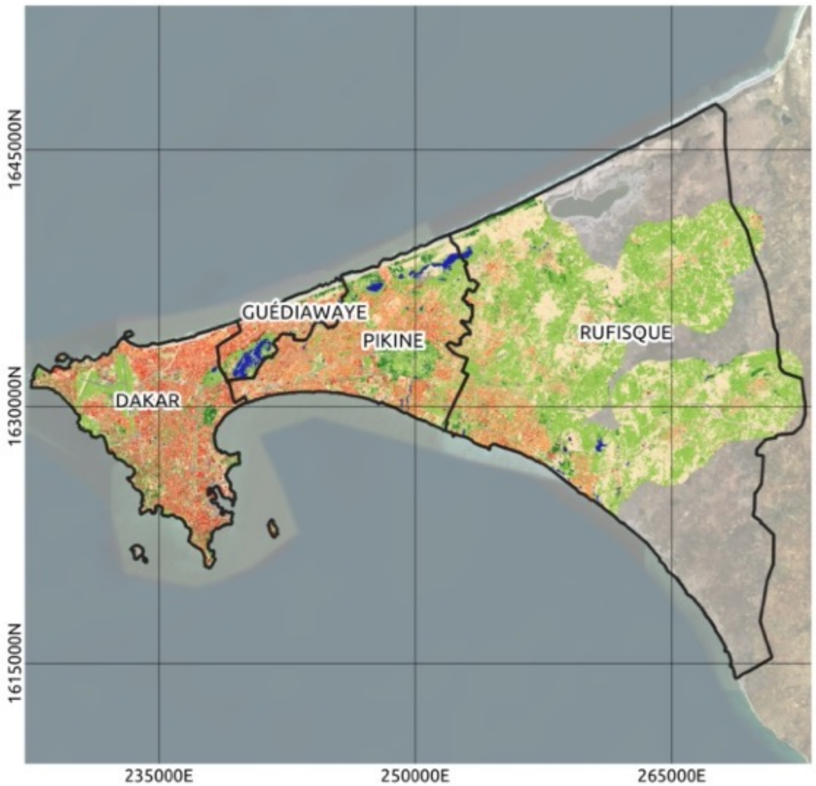
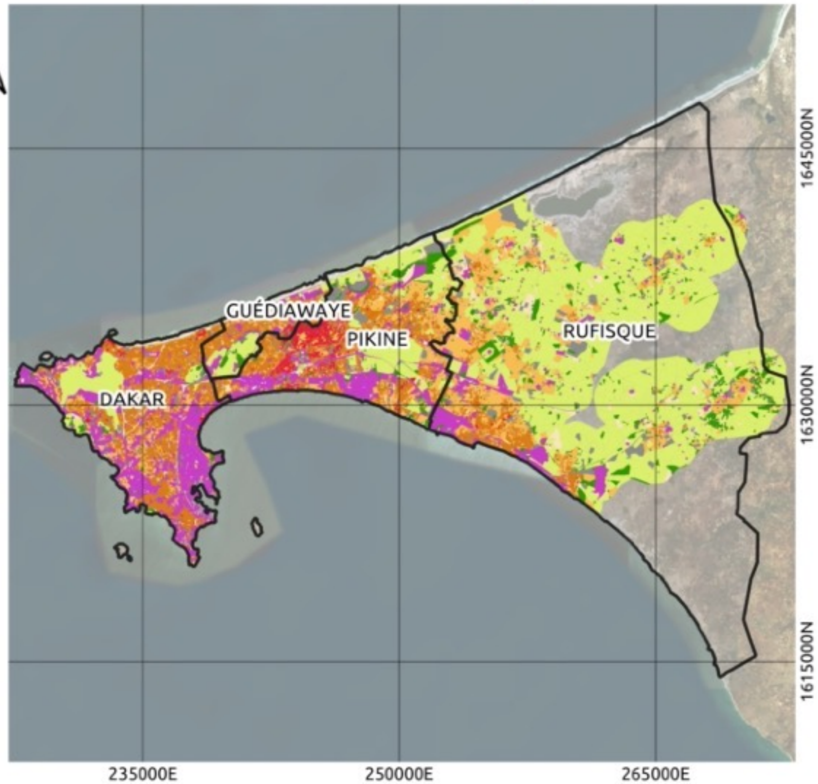
Dakar land cover and land use





Land Cover

- Artificial ground surface
- High vegetation / trees
- Low vegetation
- Water bodies
- Swimming pools
- Bare soil
- Low buildings (<5m)
- Medium buildings (5-10m)
- High buildings (>10m)

0 4 8 km

Level 2 Admin boundaries

Background: Bing Maps

Projection 32628 (WGS84, UTM zone 28N)

Land Use

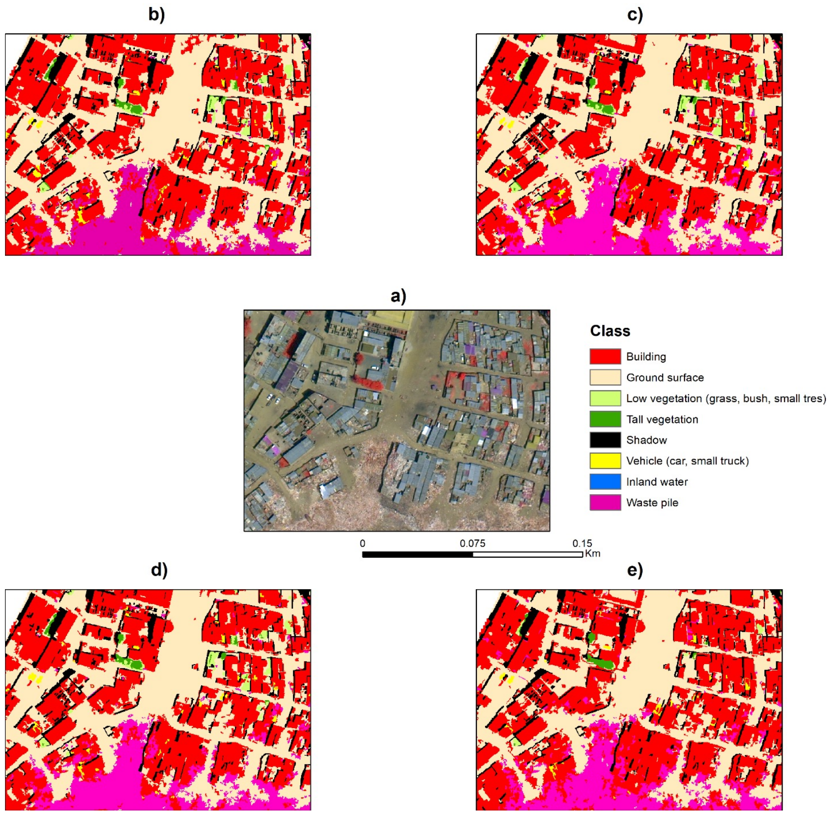
- Vegetation
- Agriculture
- Bare soil
- Non-residential built-up
- Uncertain
- Planned residential
- Planned residential - Low density
- Deprived residential

REACT project website: http://react.ulb.be/
Contact: WOLFF Eléonore
eleonore.wolff@ulb.ac.be

The REACT project was funded by BELSPO (Belgian Federal Science Policy Office) in the frame of the STEREO III program (contract SR/00/337)

EO and AI for mapping detailed urban land use (LU) and land cover (LC)

- In deprived urban areas ([Slumap project](https://slumap.ulb.be/) - https://slumap.ulb.be/) :
  - **Mapping land cover**
  - **Mapping waste piles**
  - Used as indicators of urban deprivation



S. Georganos, S. Vanhuysse, Á. Abascal and M. Kuffer, "Extracting Urban Deprivation Indicators Using Superspectral Very-High-Resolution Satellite Imagery," *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*, Brussels, Belgium, 2021, pp. 2114-2117, doi: 10.1109/IGARSS47720.2021.9554849.

EO and AI for mapping detailed urban land use (LU) and land cover (LC)

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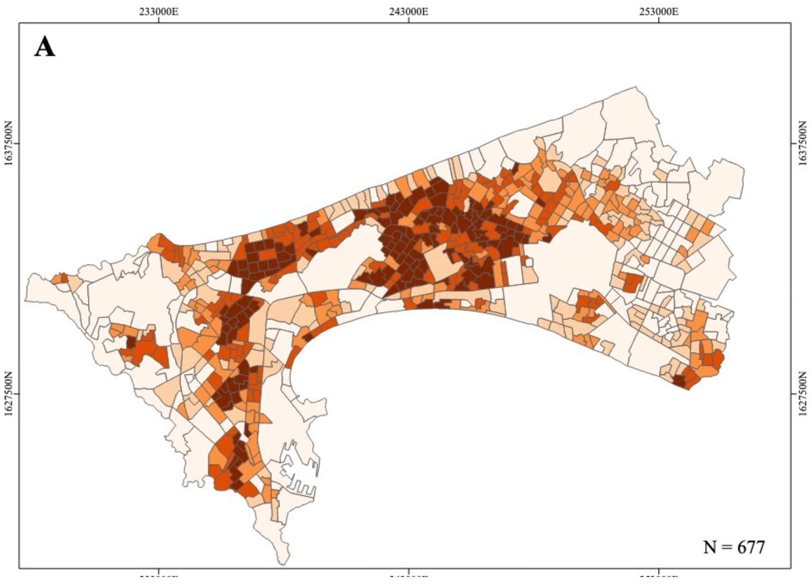
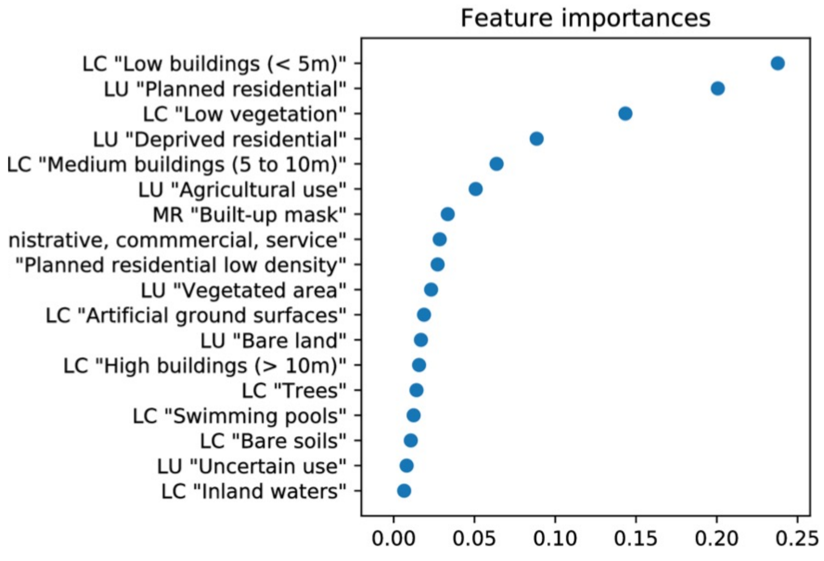
- Mapping such detailed LC and LU :
  - Required the **acquisition of VHR data (full price >10$/sqkm)**
  - Once the codes are developed, the **processing is heavy** Ouagadougou example
    - 615 km² (>95% LC publication deal with <3km²)
    - +200 Gb data in total
    - +15 10^6 segments
    - +50 Gb tabular file (csv)
    - Segmentation: ±10 days using 17 cores
    - Segment stats and classification: ±2 days
    - Post-classification: ±1,5 days
    - Land use: ±2 days

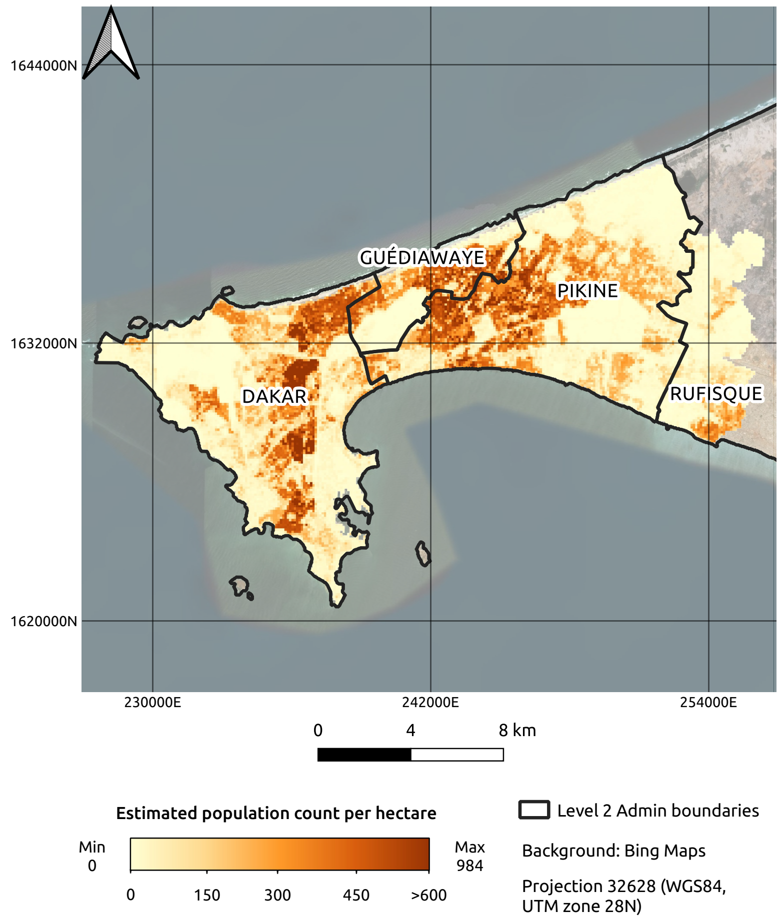
EO and AI for mapping detailed population estimation

- Use of the **LC and LU maps with census population statistics** at the finest administrative level
- to **estimate and map population densities** thanks to AI techniques (REACT project - https://react.ulb.be/ – publications, data available)





Dakar population estimates



Background: Bing Maps

Projection 32628 (WGS84, UTM zone 28N)

REACT project website: http://react.ulb.be/

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http://react.ulb.be/

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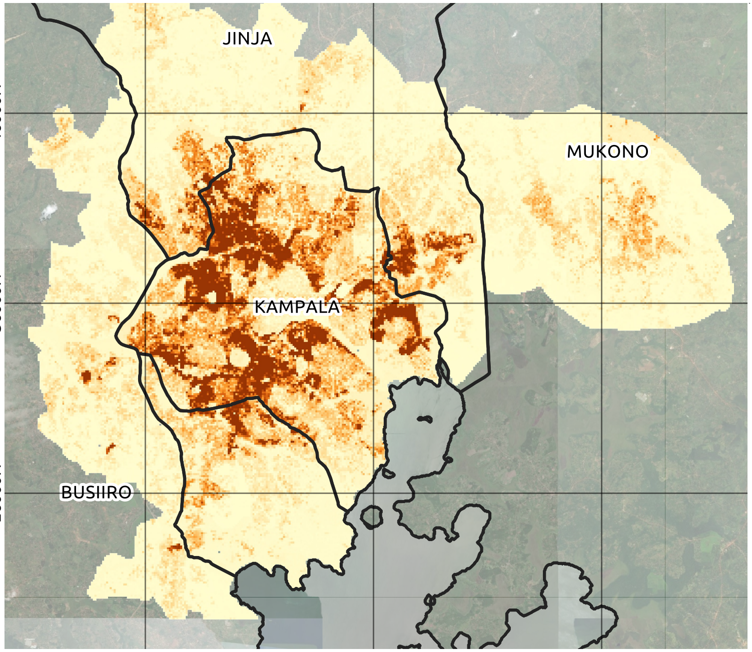
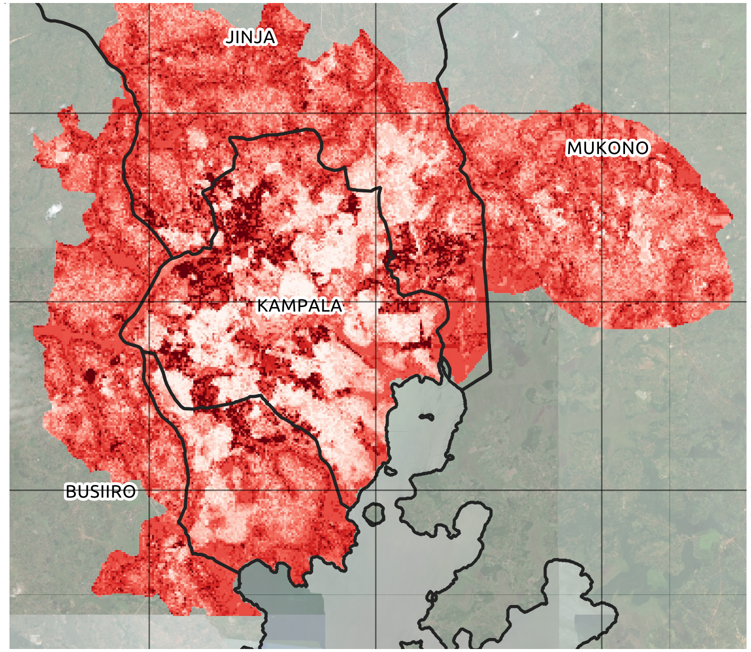
Kampala population and malaria estimates

Population's estimates = denominator for mapping malaria parasite rate





0 4 8 km

Population

Estimated population count per hectare

Min 0 — Max 804

0 32 63 95 >126

Level 2 Admin boundaries
Background: Bing Maps
Projection 32636 (WGS84, UTM zone 36N)

Malaria

Standardised *Plasmodium falciparum* parasite rate in 2 – 10yr olds (%)

Min 2.6 — Max 15.2

<3.6 5.4 7.2 8.8 >10

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EO and AI for mapping wealth

- Attempts to **estimating and mapping wealth in urban areas** from:
  - DHS Wealth Index (WI) computed from
    - the detailed data of the **Demographic and Health Surveys** (DHS)
    - Data available for points which are dislocated of $\pm$ 1 km
  - Satellite-derived VHR **land-use/land-cover** (LULC) datasets

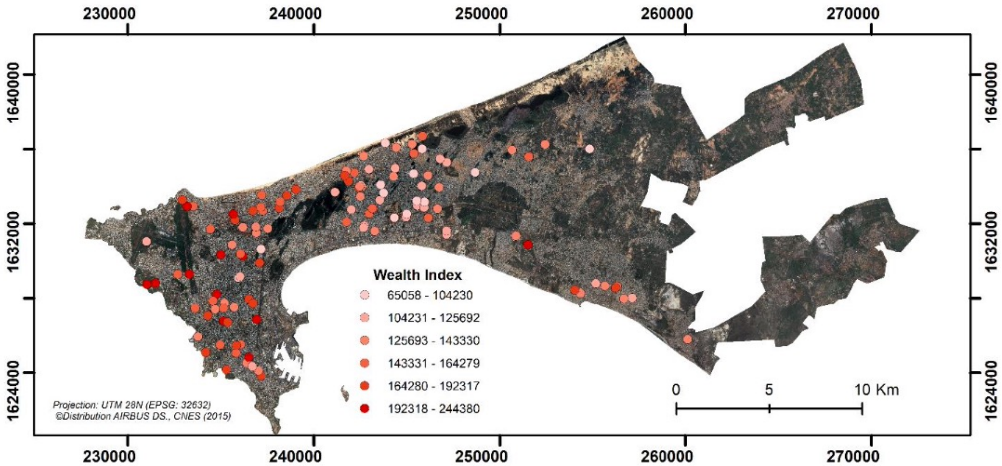

Figure 2. Demographic and Health Surveys (DHS) Wealth Index across Dakar between 2008–2016.

Reference article : Georganos, S.; Gadiaga, A.N.; Linard, C.; Grippa, T.; Vanhuysse, S.; Mboga, N.; Wolff, E.; Dujardin, S.; Lennert, M. Modelling the Wealth Index of Demographic and Health Surveys within Cities Using Very High-Resolution Remotely Sensed Information. *Remote Sens.* **2019**, *11*, 2543. https://doi.org/10.3390/rs11212543

Encouraging results but needs to be refined

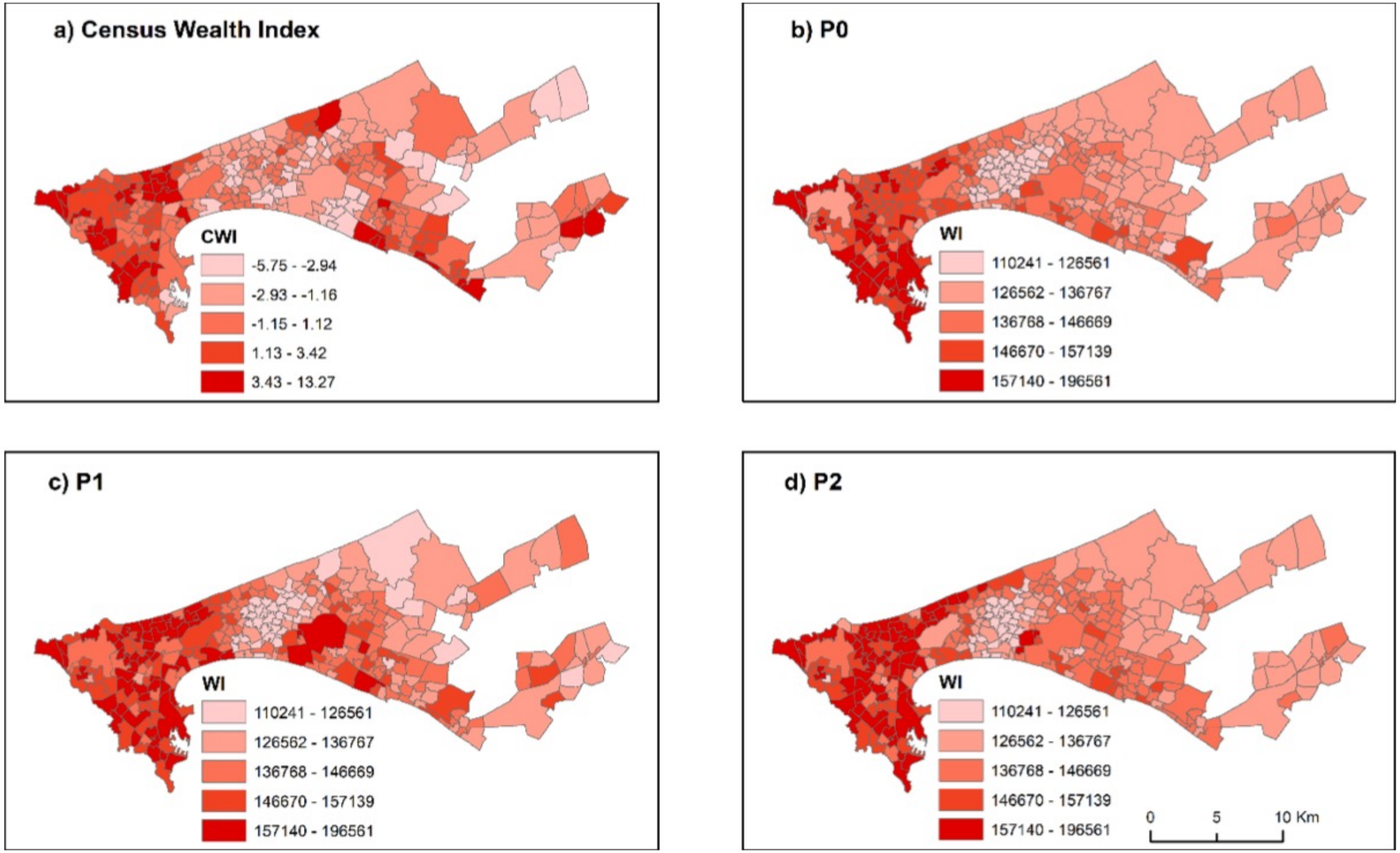

Figure 13. Census data and model predictions at a scale of 300 admin units. (**a**) Census Wealth Index (CWI), (**b**) predicted DHS WI (PO), (**c**) predicted DHS WI (P1), (**d**) predicted DHS WI (P2).

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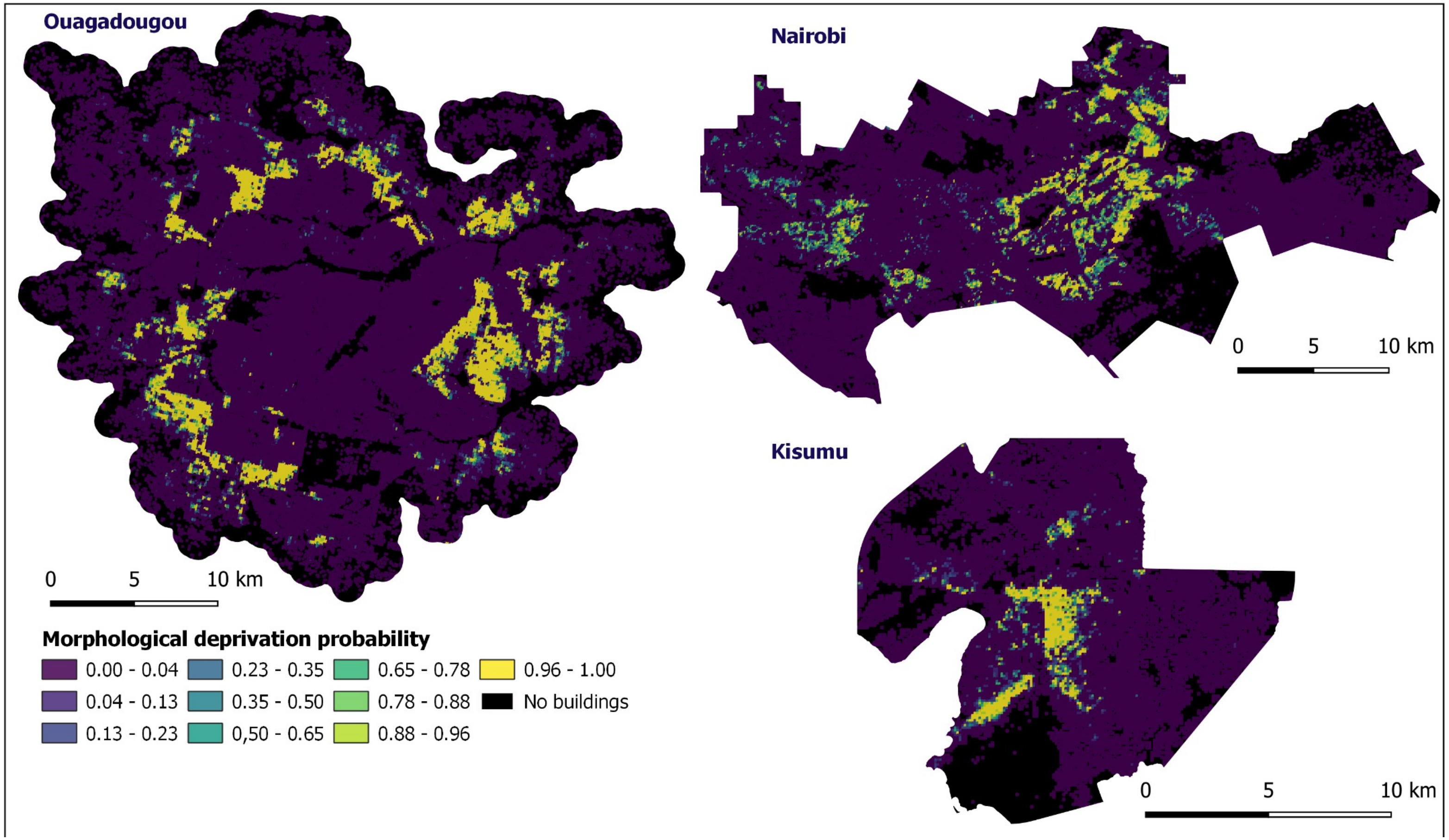
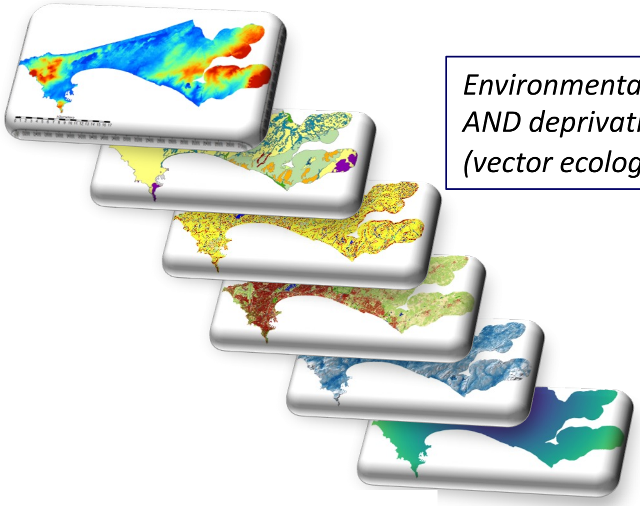
EO for mapping deprivation probability

Machine Learning and a mix of open data -> gridded probability maps (100m x 100m)

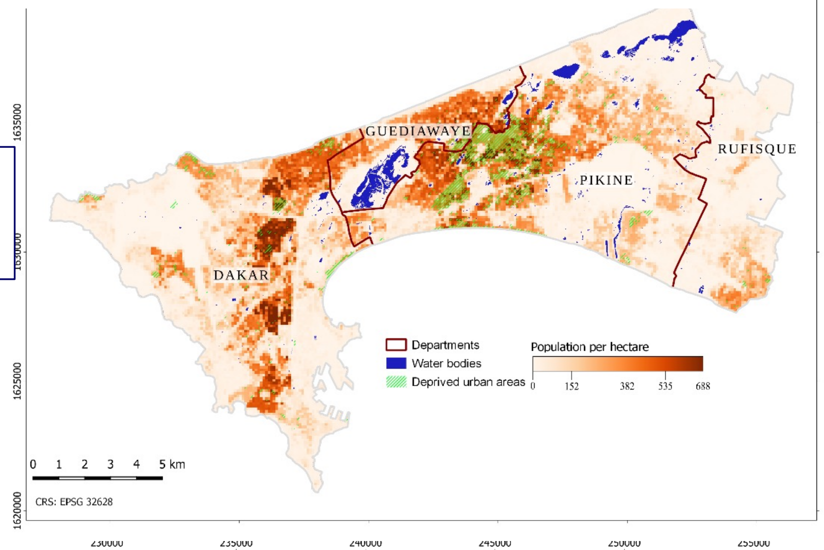


EO and AI for **mapping urban malaria and its associated risk**

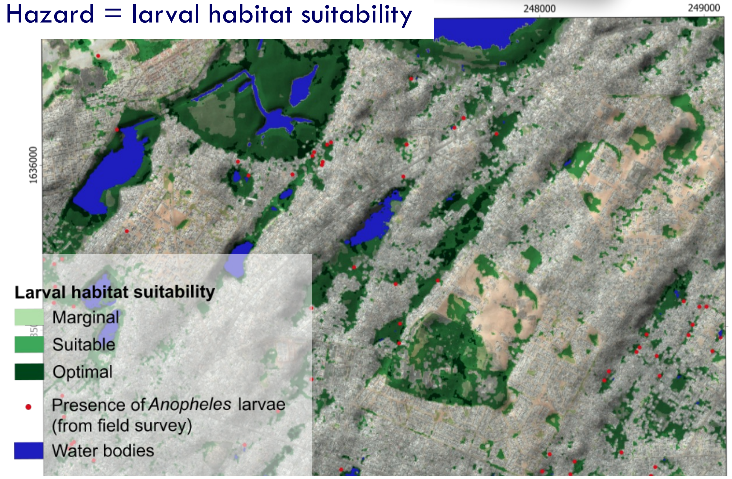


Environmental factors AND deprivation (vector ecology approach)

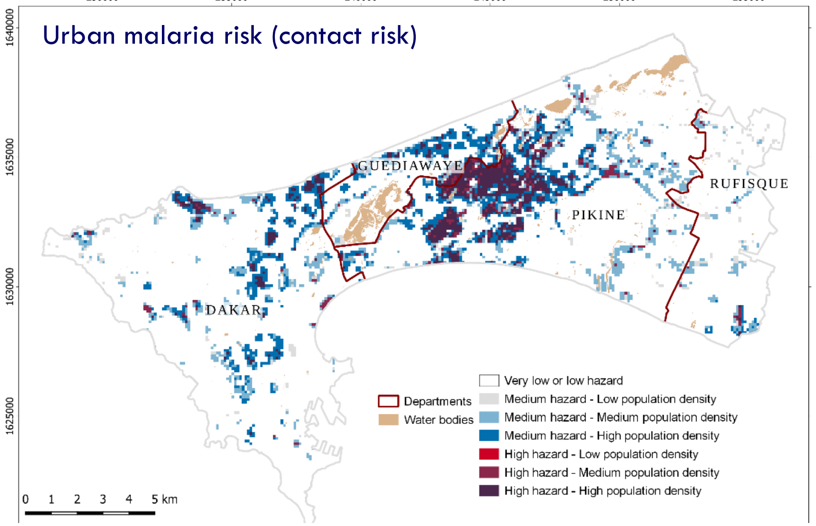
Element at risk = population and its vulnerability = deprivation



Hazard = larval habitat suitability



Urban malaria risk (contact risk)



Vanhuysse et al. , 2022. Fine-scale mapping of urban malaria exposure under data scarcity: an approach centred on vector ecology. Malaria Journal (Under review).

MOSQUIMAP

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EO and citizen science to map **perceived deprivation in slums**

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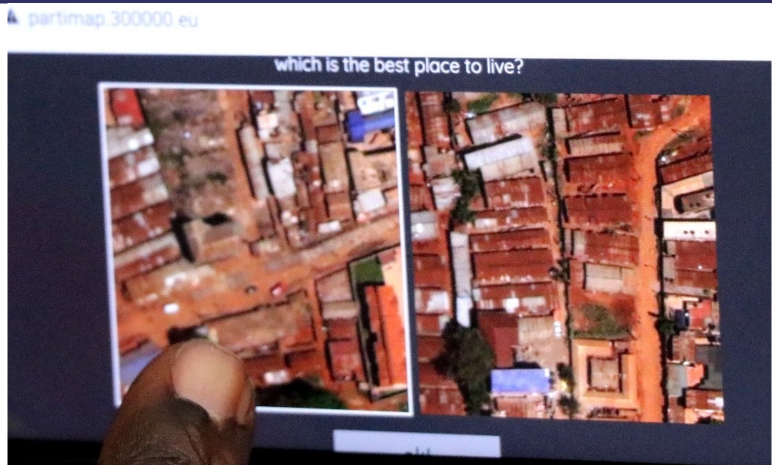
- **Citizen science :**
  - Participation of people from **7 deprived areas** in Nairobi
  - Selecting on their smart-phones the **best place to live,** between two satellite or street views



- EO and GIS data :
  - **Land cover classes, extracted buildings, OpenStreetMap data** (roads, rivers, …)
- Ai processing → map of perceived deprivation in slums

PARTIMAP

Abascal, A., Rodríguez-Carreño, I., Vanhuysse, S., Georganos, S., Sliuzas, R., Wolff, E., & Kuffer, M. M. (2022). Identifying degrees of deprivation from space using deep learning and morphological spatial analysis of deprived urban areas. *Computers, environment and urban systems*, 95, 101820. doi:10.1016/j.compenvurbsys.2022.101820

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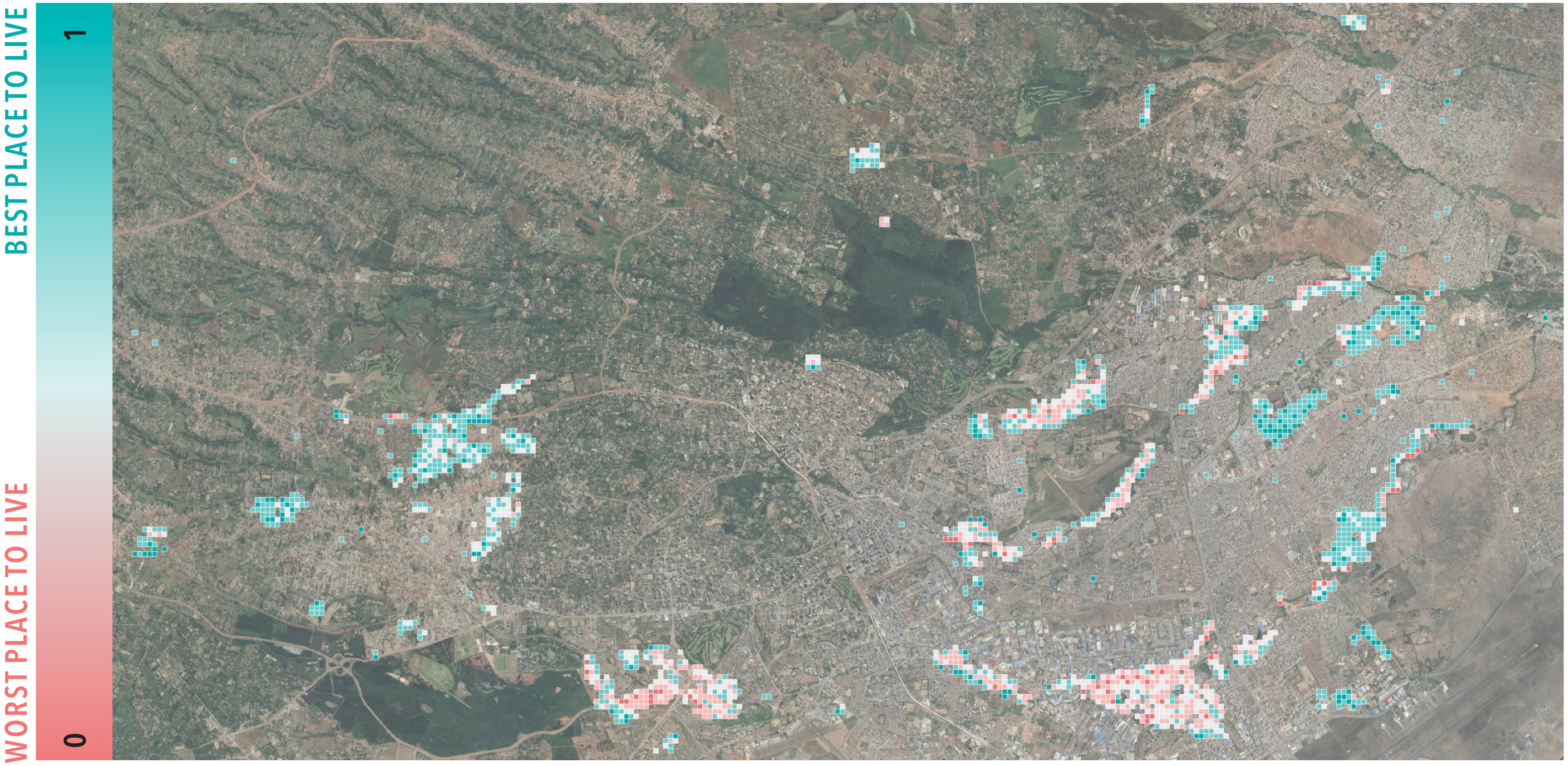
EO and citizen science to map perceived deprivation in slums



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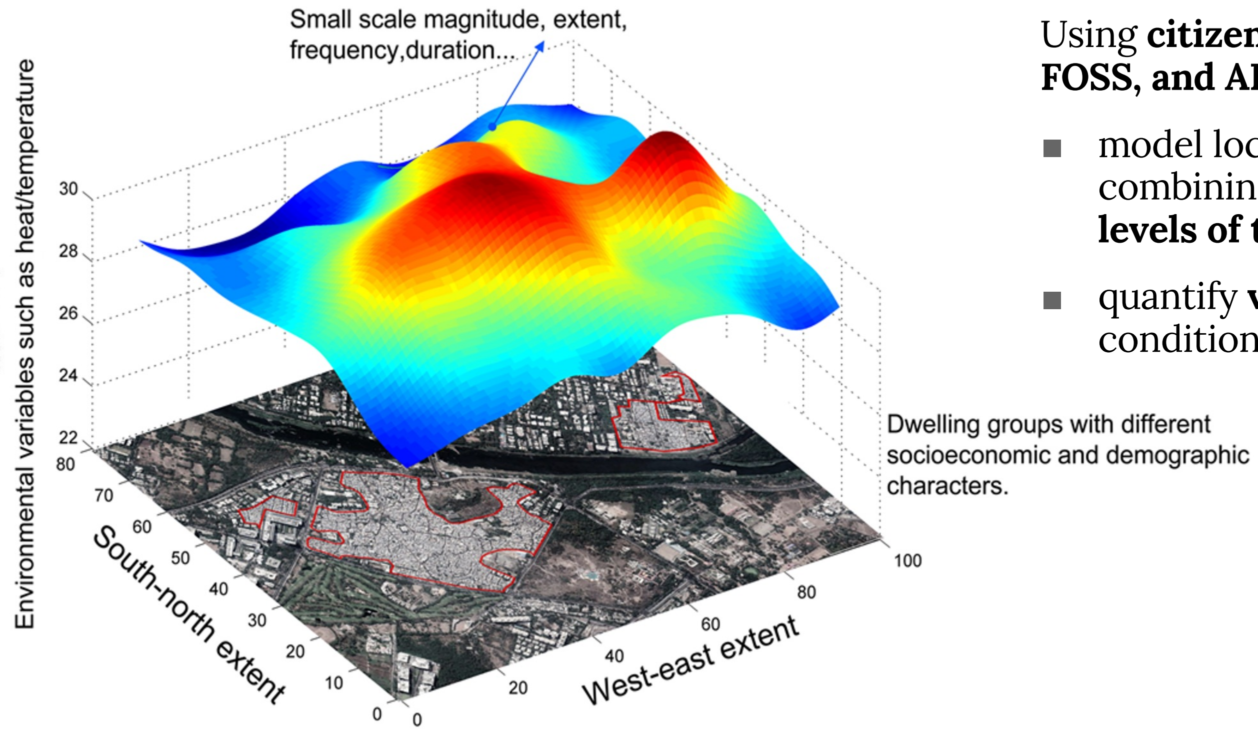
Recently started project : exposure to temperature variations and extreme heat (ONEKANA)

Research question: How and why are **urban dwellers with different levels of deprivation divergently exposed to variations of temperatures and extreme heat ?**



Hypothesis

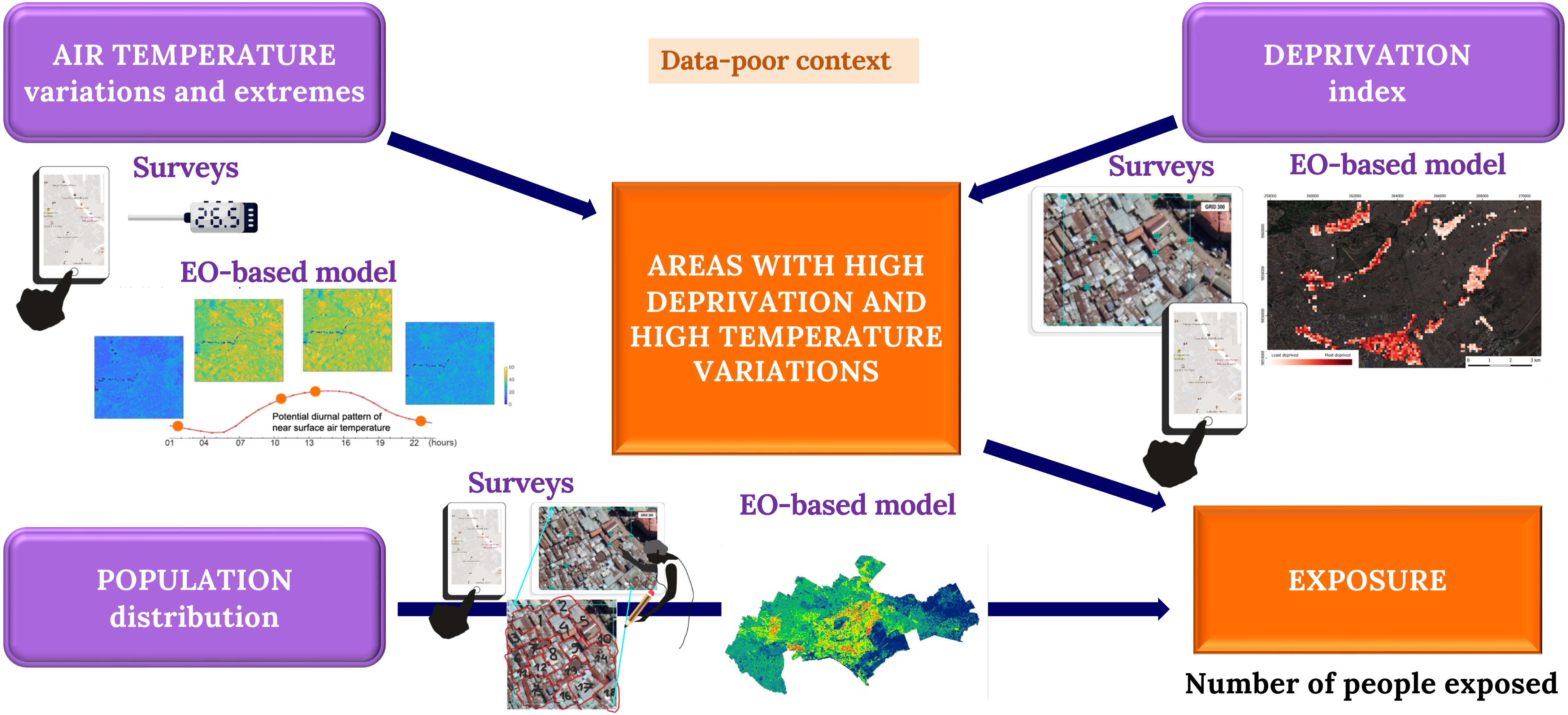
Using **citizen science & open or low-cost satellite images**, **FOSS, and AI,** it is possible to:

- model location, extent and characteristics of areas combining both **high levels of deprivation and high levels of temperature variation/extreme heat)**
- quantify **vulnerable populations** exposed to such conditions

Methodology

Recently starting project : exposure to temperature’s variations and extreme heat (ONEKANA)

Methodology | **Citizen science & Earth Observation-based modelling (AI)**



Conclusion

- EO data regularly **covers large areas** → allows **regular updates**
- EO data :
  - Are **open and free of charge** up to a 10m resolution
  - Are **costly for sub-metric resolution** but **much cheaper than the equivalent data collected on the field**
  - Processed images available for free in the case of disasters (e.g. Floods) with the Charter activation by local authorities (https://disasterscharter.org/)
- **Crucial data source** to
  - Maps of land cover, urbanisation, urban morphology, urban deprivation, …
  - Combine with statistical data using spatial models to estimate and map urban population, urban malaria hazards and risks,
  - Combine with socio-economical household survey data to estimate and map wealth using spatial models
  - …

Thank you for your attention

Questions ?