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DEFINING VILLAGE BOUNDARIES IN NORTHERN AND CENTRAL BENIN: A SPATIAL APPROACH

O. Sedegnan, H. Sossou, L. Gazull, R. Gaetano, N. Ahoyo Adjovi, A. Begue



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- Pilot Observatory of Agricultural Landscapes and Dynamics in Benin



- DeSIRA European Union





- Earth observation (EO) data are increasingly used for various studies and applications.
- New research are emerging on **the use of EO data to derive socio-economic proxies** such as well-being, poverty, GDP, average income, etc. (*Watmough et al. 2016; Jean et al. 2016; Engstrom et al. 2017; Ehrlich et al. 2018; Steele et al. 2017; Watmough et al. 2019*)
- These are mainly **concentrated in urban areas with very high spatial resolution images** and tools (AI, cloud)
- However, **defining geographical objects of interest in relation to human activities represents a significant challenge for these research.**

- Most **socio-economic surveys in rural areas** are carried out at the **household or village community level**, which is **not directly visible on satellite images**.
- **Mapping territory occupied by a household is challenging** due to the fact that **households often cultivate multiple plots** that may be **distributed across a larger area** (*Entwisle et al., 1998*)
- **mapping village territories appears to be a more feasible undertaking.**
- Villages boundaries are **not widely available in Africa**, particularly in Benin, where **cadastral data is scarce and often incomplete.**

- **Requirement:**
 - Associate a set of pixels with a village type in terms of socioeconomic indicators.
- **Objective:**
 - **to develop an automatic method for delimiting village territories in northern and central Benin**
 - This approach **must be based on existing and available data to be deployed on a regional or national scale.**
 - Hypothesis: the spatial footprint of a village is a function of the size of its population.

- Benin, west Africa,
 - Northern and central region of Benin, which has a wide diversity of habitats and farming systems
 - Five agro-ecological zones
 - Six project sites

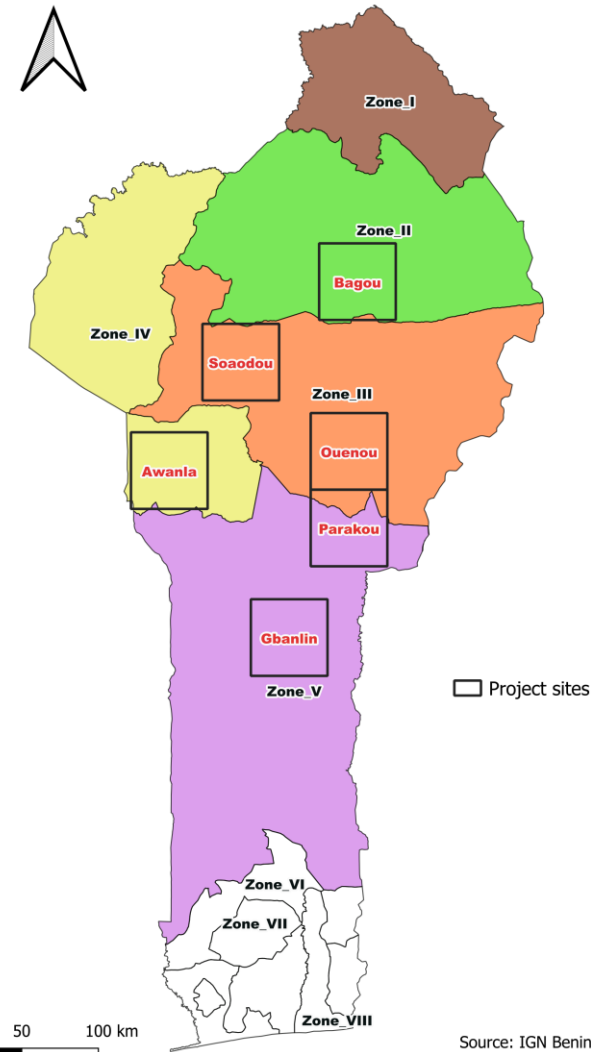
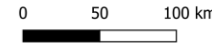


Figure 1: Study area
Source: IGN & MAEP Benin, 2018



Source: IGN Benin, 2018



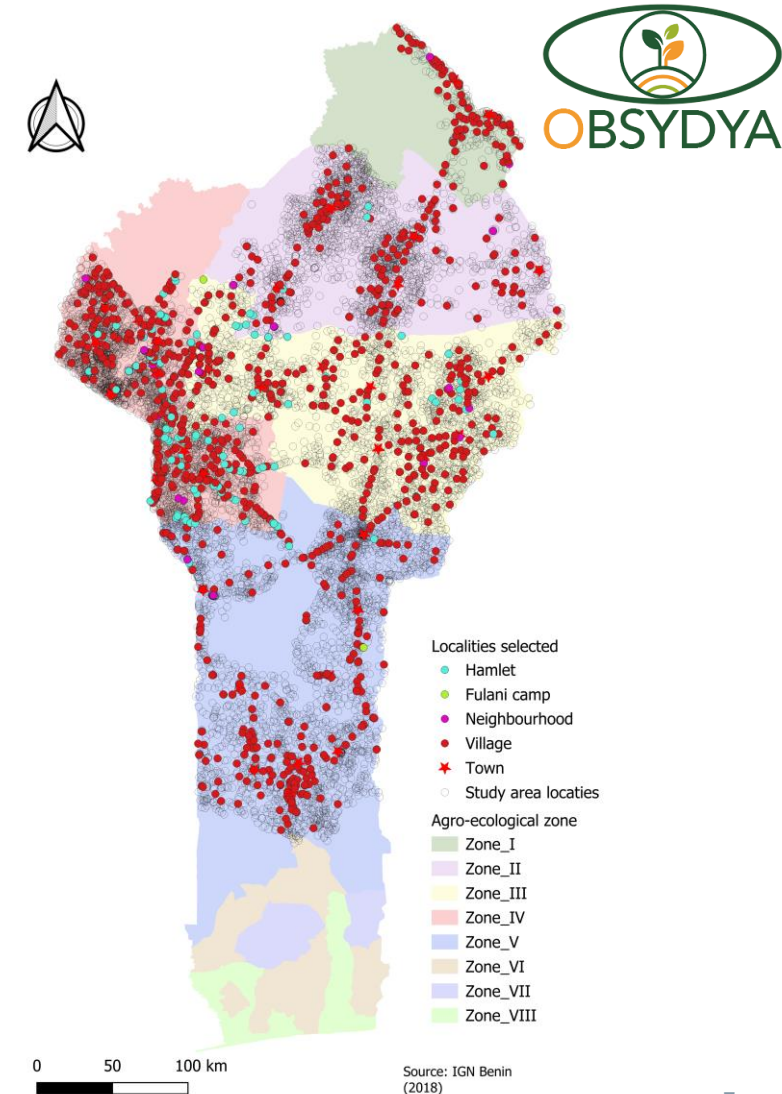
- Geographical database of localities in Benin produced in 2018 by the National Geographical Institute of Benin

- General population census database (RGPH) produced in 2013 by the National Institute of Statistics and Demography (INStaD)

- Raster product "Global Human Settlement Layer" for 2018 at 10 m spatial resolution and showing the percentage of built-up areas (<https://human-settlement.emergency.copernicus.eu/download.php>)

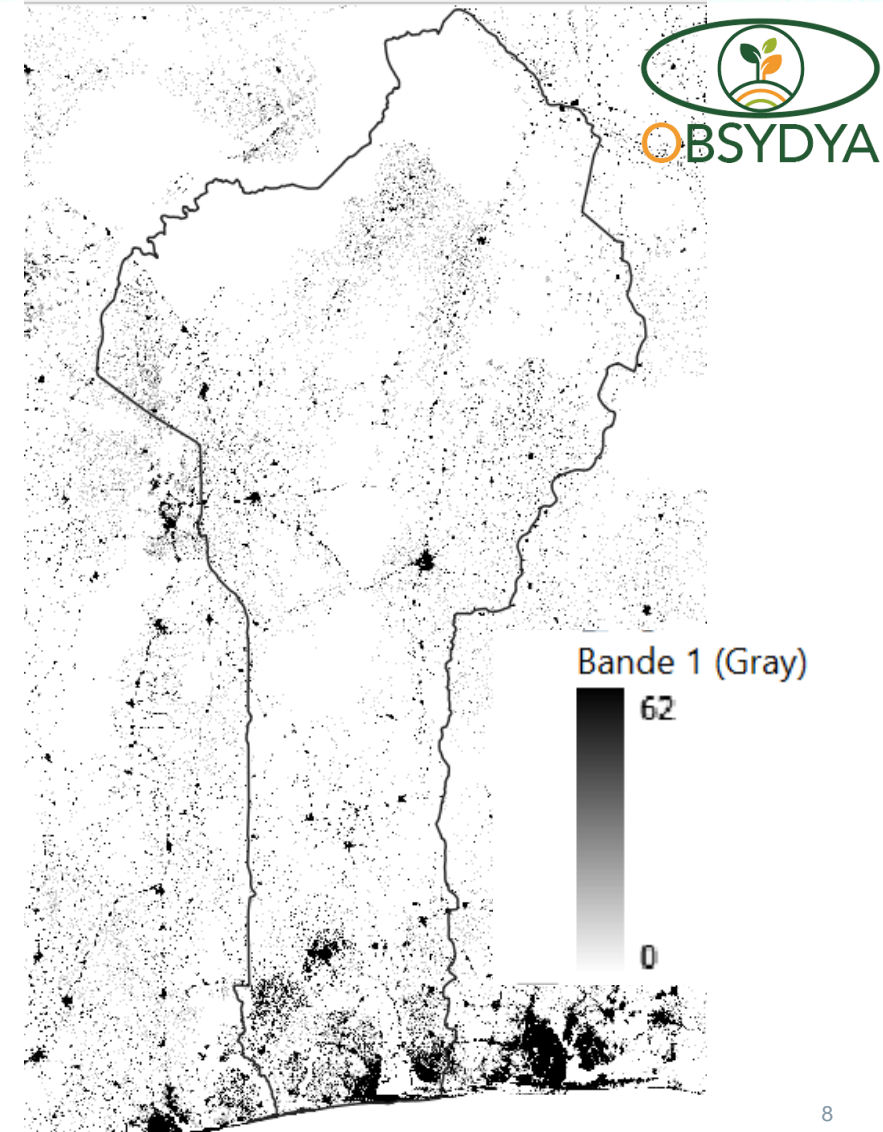
- National land use map 2015 produced by the project OSFACO

- A field survey conducted in selected villages in the northern and central Benin





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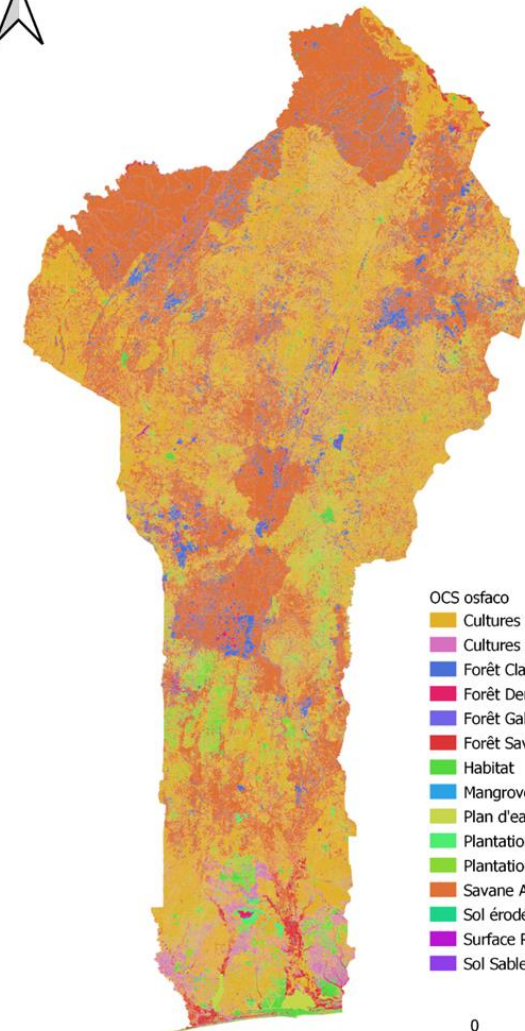
○ Geographical database of localities in Benin produced in 2018 by the National Geographical Institute of Benin

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○ **National land use map 2015 produced by the project OSFACO**

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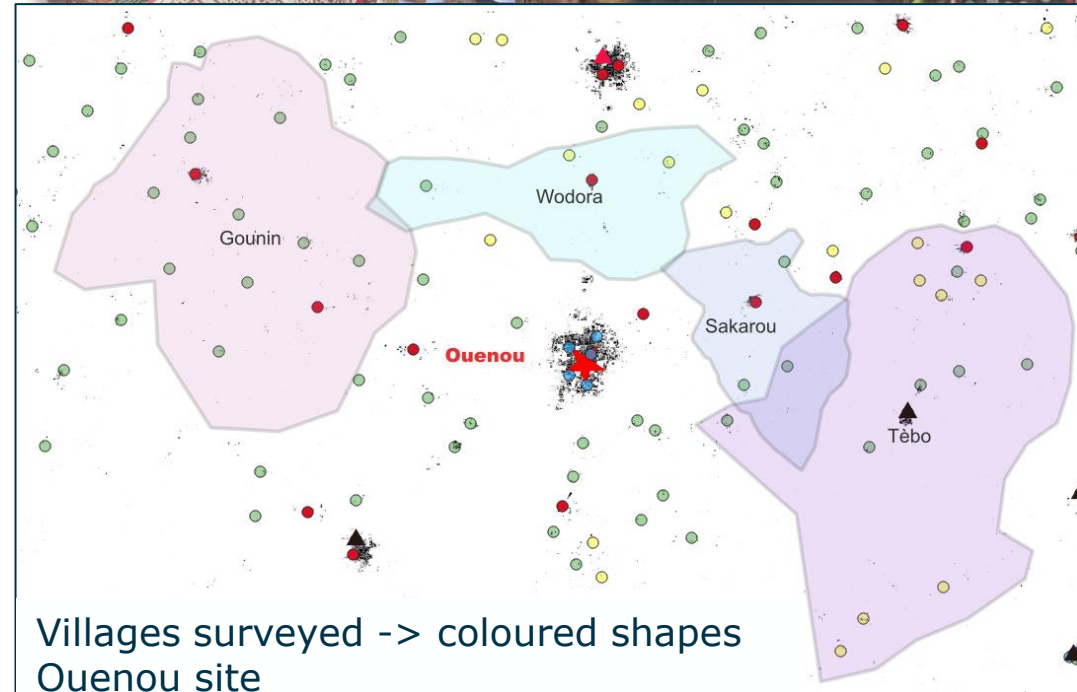


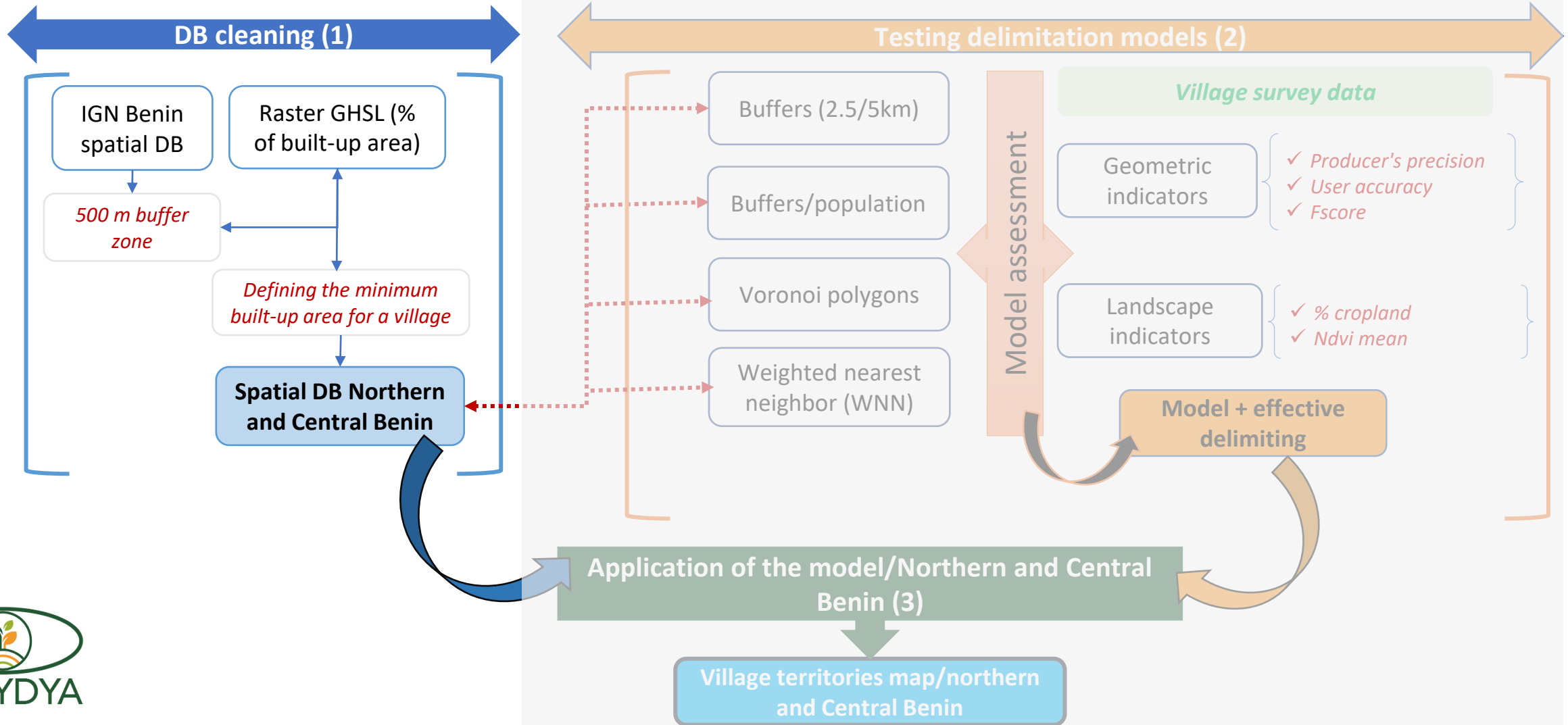
- OCS osfaco
- Cultures et Jachères
- Cultures et Jachères sous Palmier
- Forêt Claire et Savane Boisée
- Forêt Dense
- Forêt Galerie et Formation Ripicole
- Forêt Savane Marécageuse
- Habitat
- Mangroves
- Plan d'eau
- Plantation forestière
- Plantation Fruitière
- Savane Arborée et Arbustive
- Sol érodé
- Surface Rocheuse
- Sol Sableux

0 50 100 km



- **A field survey conducted in selected villages in the northern and central (2023-2024) : 25**
- Village focus group with 10-15 representative adult men and women (producers, breeders, processors, elders, religious and administrative authorities, etc.).
- Interviews based on an interview guide and a map (satellite image of the village) overlaid with roads and infrastructure (school, health centre, etc.).
- The village boundaries are delimited on the basis of the identification of localities belonging to the village and whose land is farmed by the inhabitants.





Results: DB cleaning (1)

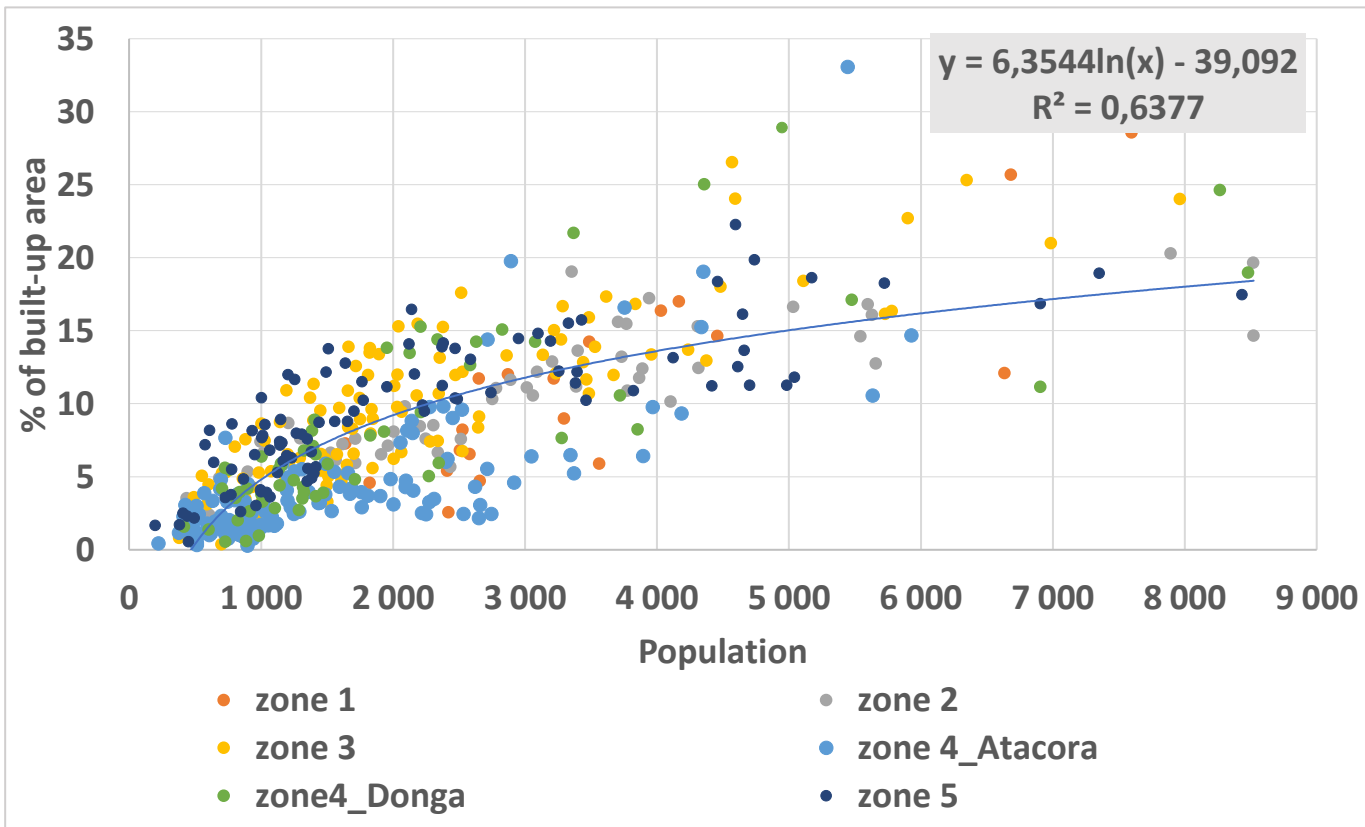


- IGN Benin spatial database (2018): **no population data, more localities, different labels from the RGPH database**
- RGPH population database (2013): **not georeferenced**



➤ **Need population data -> find a population proxy**

➤ **GHSL (2018, 10m)**

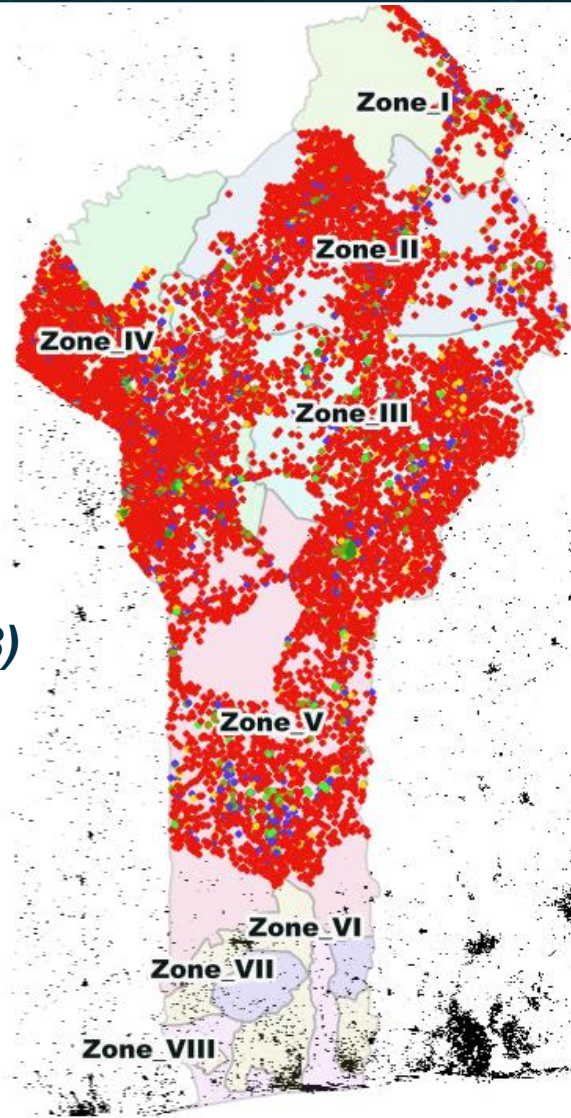


- In Benin, a **village** is defined by a minimum population size of **1 000**
- On average, this corresponds to **5% of the built-up area in 500 m buffer**
- **Deletion of localities not complying with this percentage**

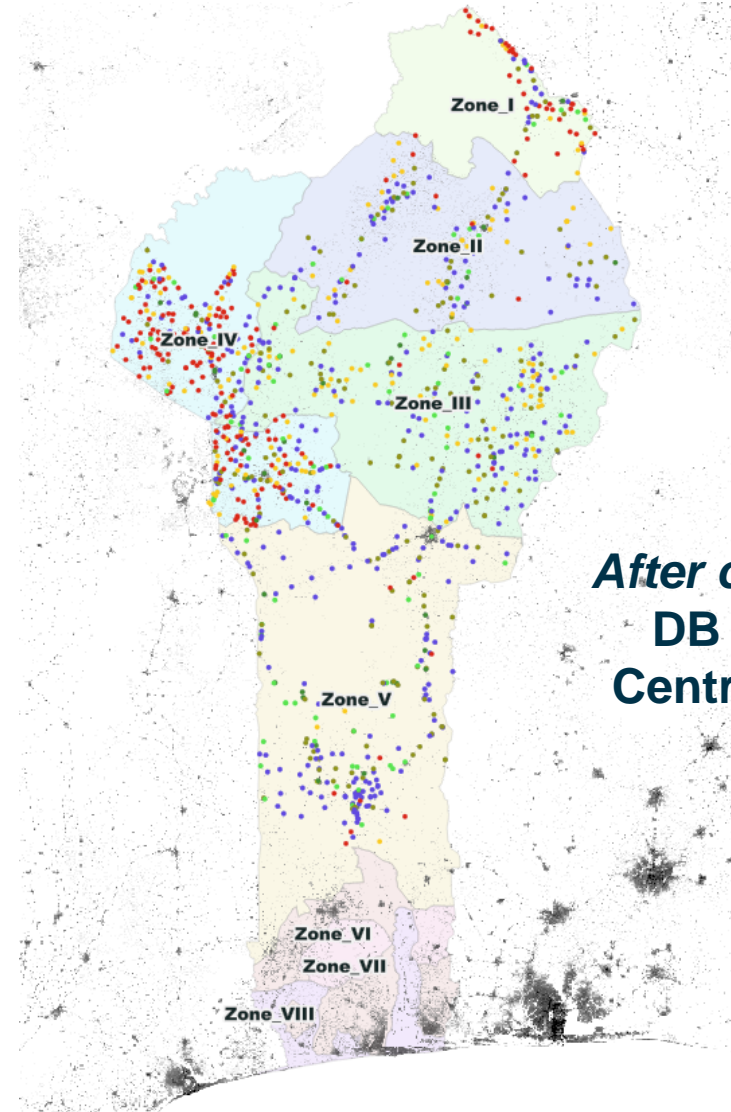
For the forthcoming clean-up, a protocol was defined for the elimination of overlapping localities:

Neighborhoods and hamlets that overlap with villages were removed	District capitals were retained, taking precedence over smaller villages	Removing the village named after the first	Urban localities were deleted, save for designated town markers
Before cleaning	Before cleaning	Before cleaning	Before cleaning
After cleaning	After cleaning	After cleaning	After cleaning

Results: DB cleaning (1)

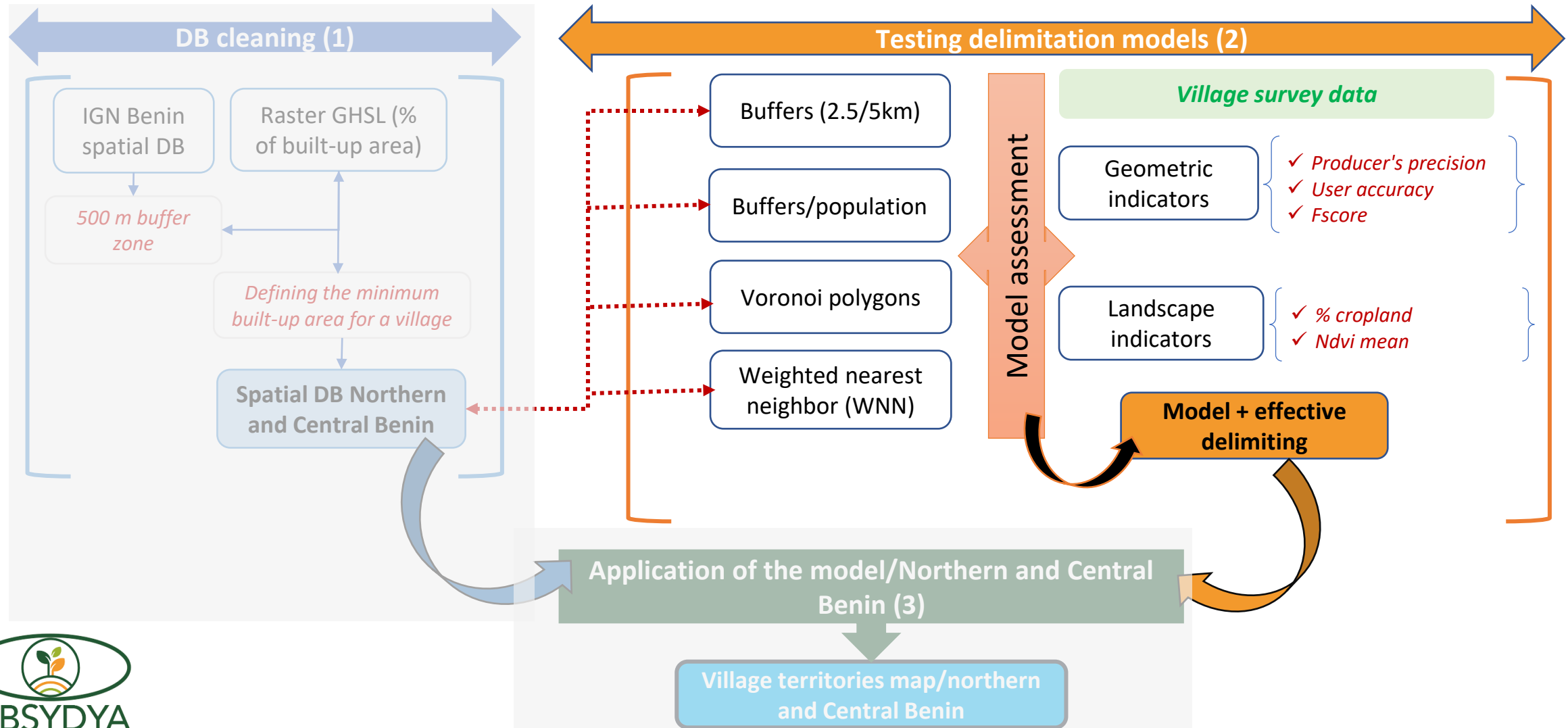


*Before cleaning:
spatial BD (10 948)*

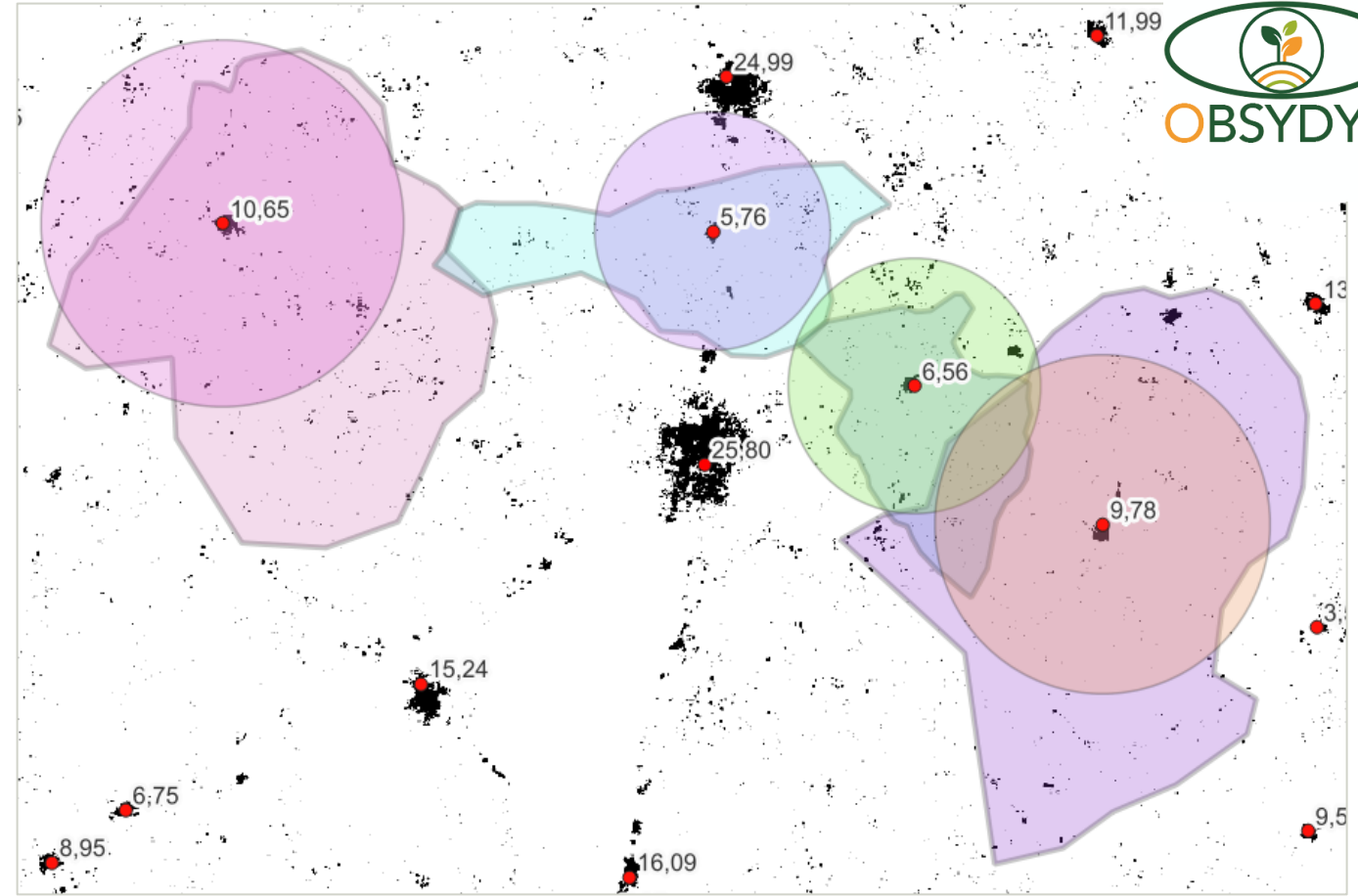
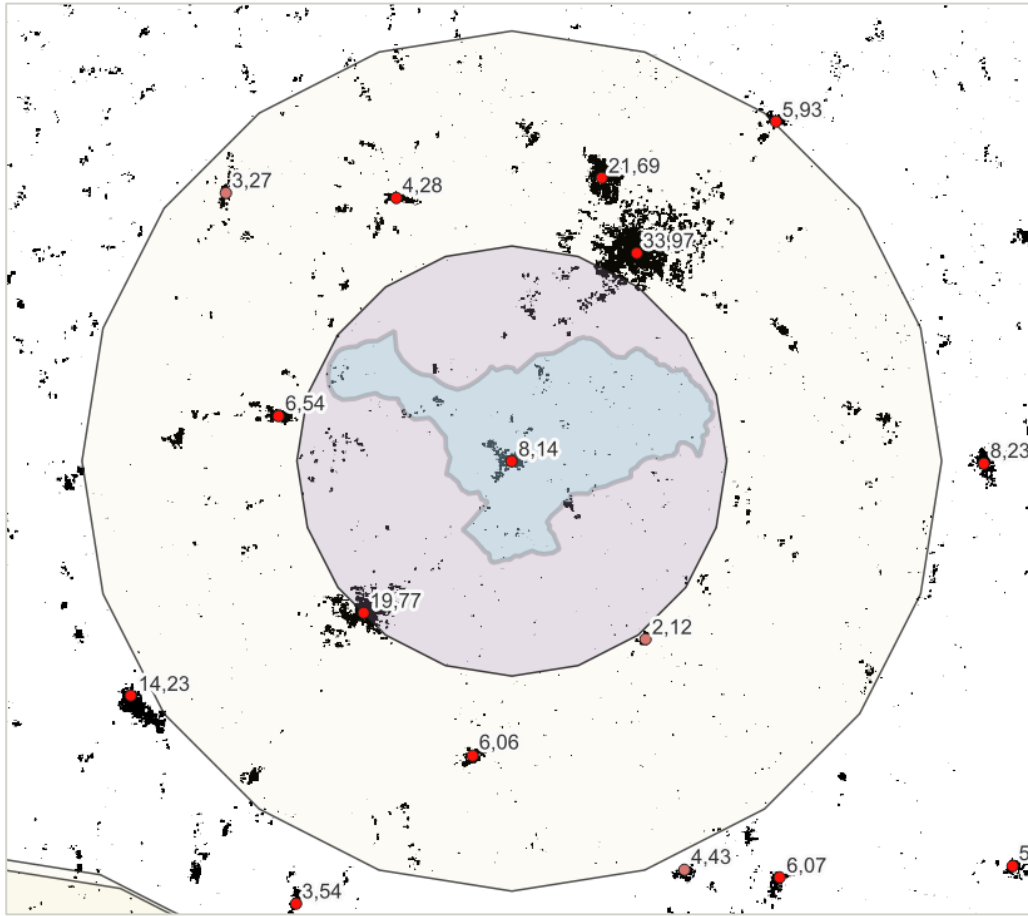


*After cleaning : Spatial
DB Northern and
Central Benin (1 092)*





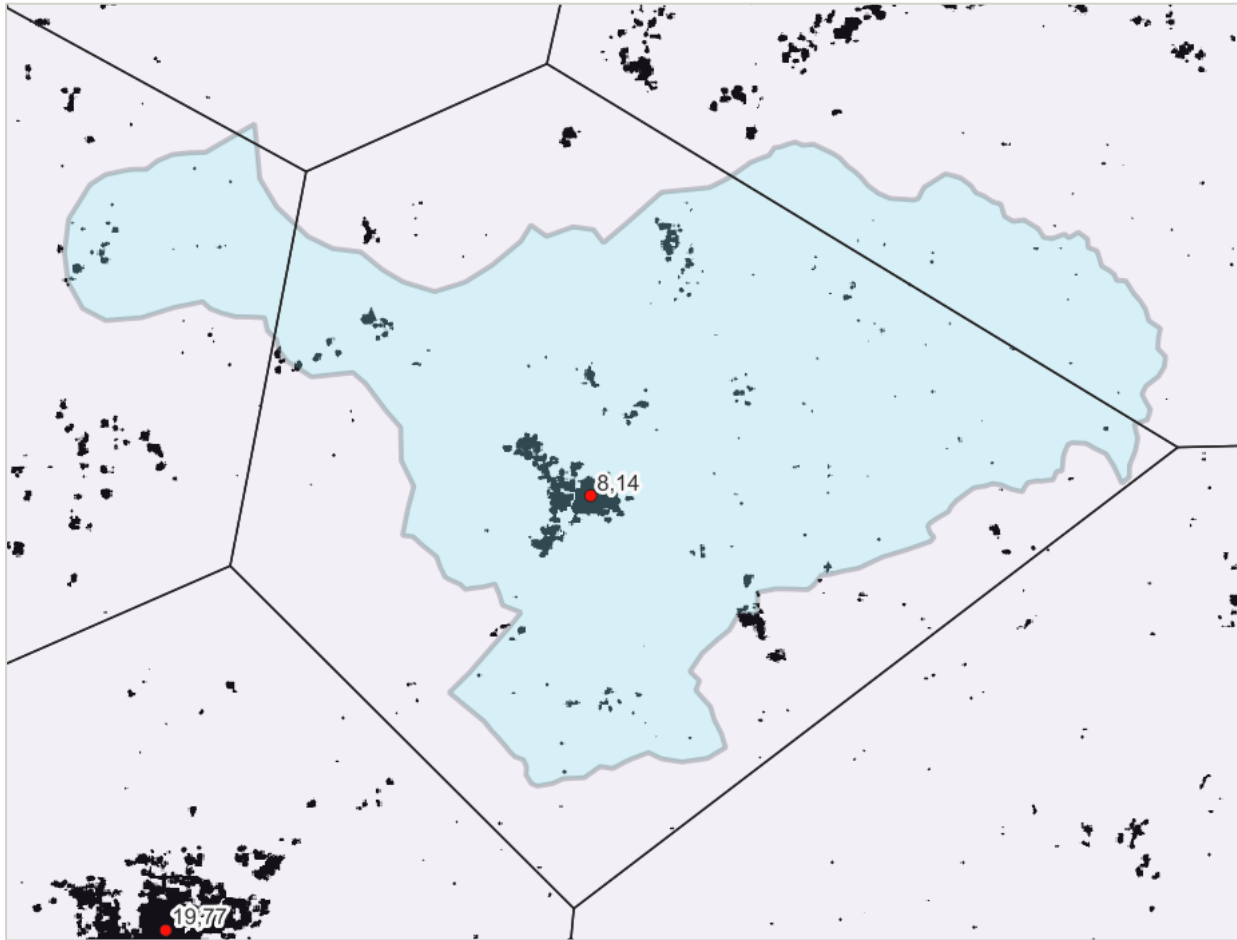
Testing delimitation models (2)



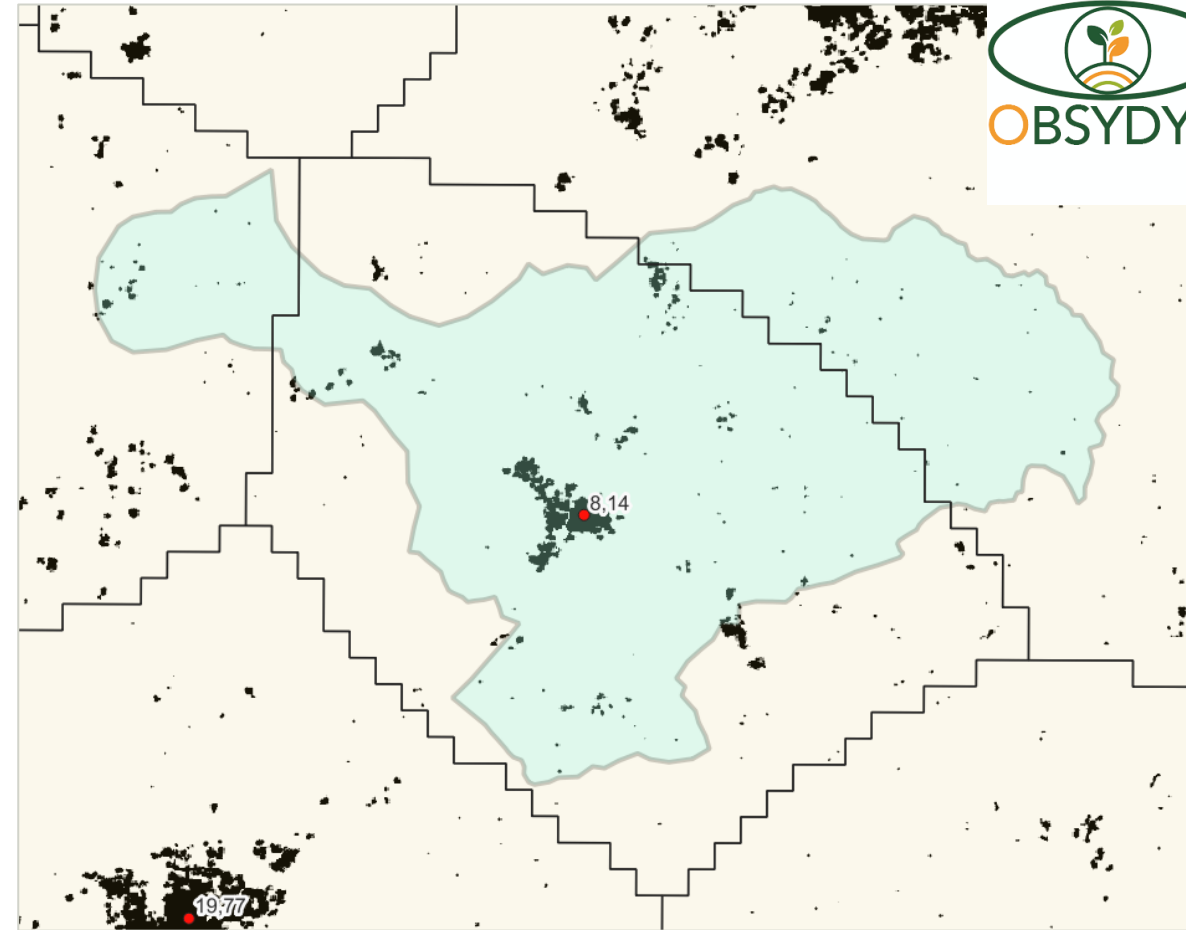
1. Circular buffer (2.5 et 5 km) – Outline of the village surveyed

2. Variable Buffer as a function of population size – Outline of the village surveyed





3. Voronoi polygon - Outline of the village surveyed



4. Weighted nearest neighbor (WNN) – Outline of the village surveyed

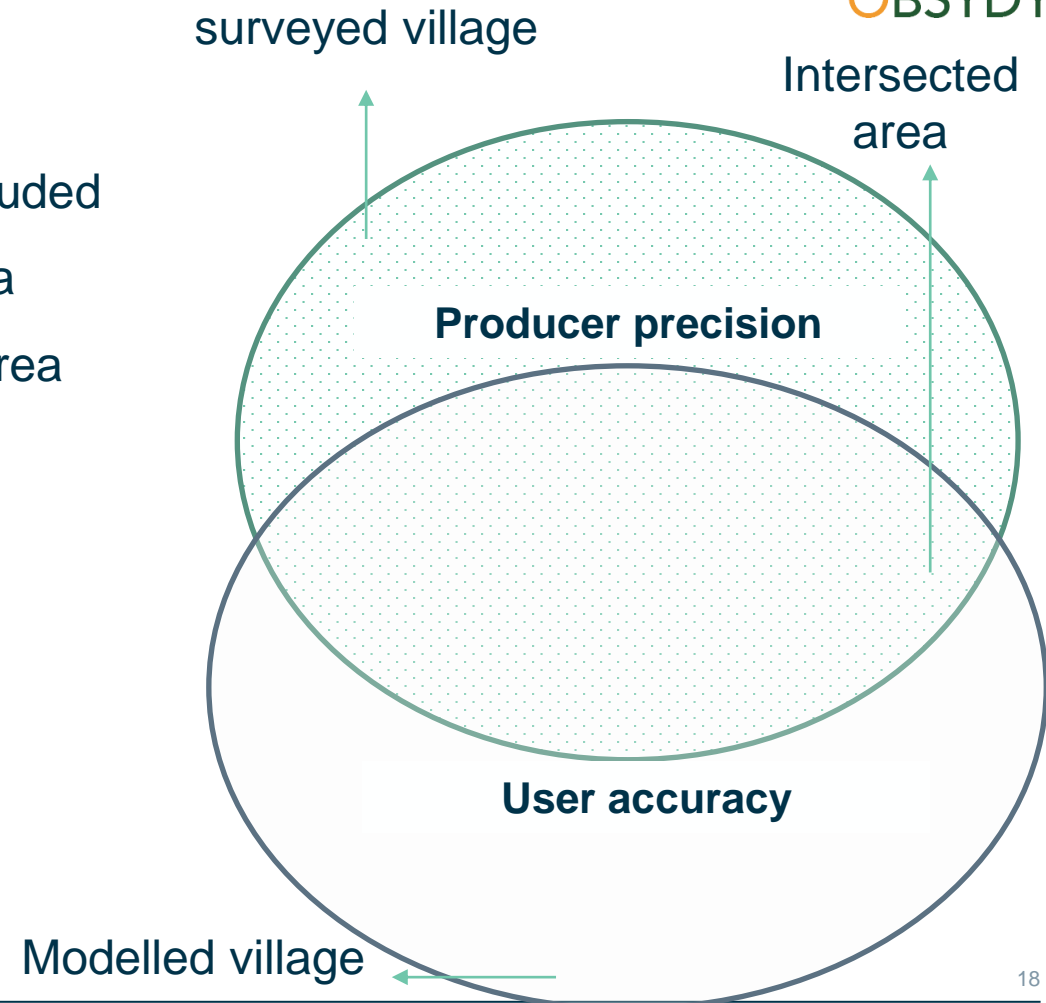
Evaluation of the models

1. Geometric indicators

- **Producer accuracy (PA)** = % of modelled village area included in surveyed village = $\text{intersected area} / \text{surveyed village area}$
- **User accuracy (UA)** = $\text{intersected area} / \text{modelled village area}$
- **F-score** = $(2 \times \text{PA} \times \text{UA}) / (\text{PA} + \text{UA})$

2. Landscape indicators

- % of cropland
- NDVI mean (MODIS 2015-2019)



Testing delimitation models (2)

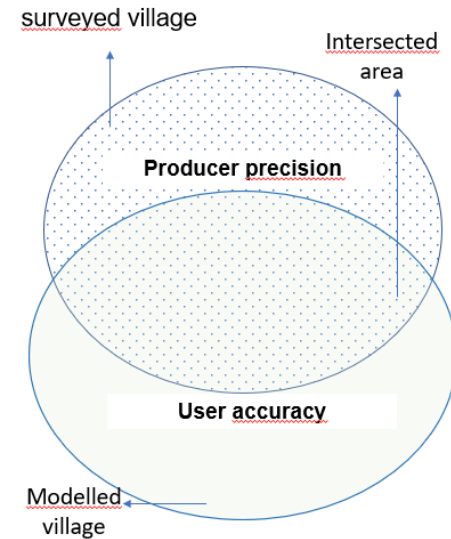
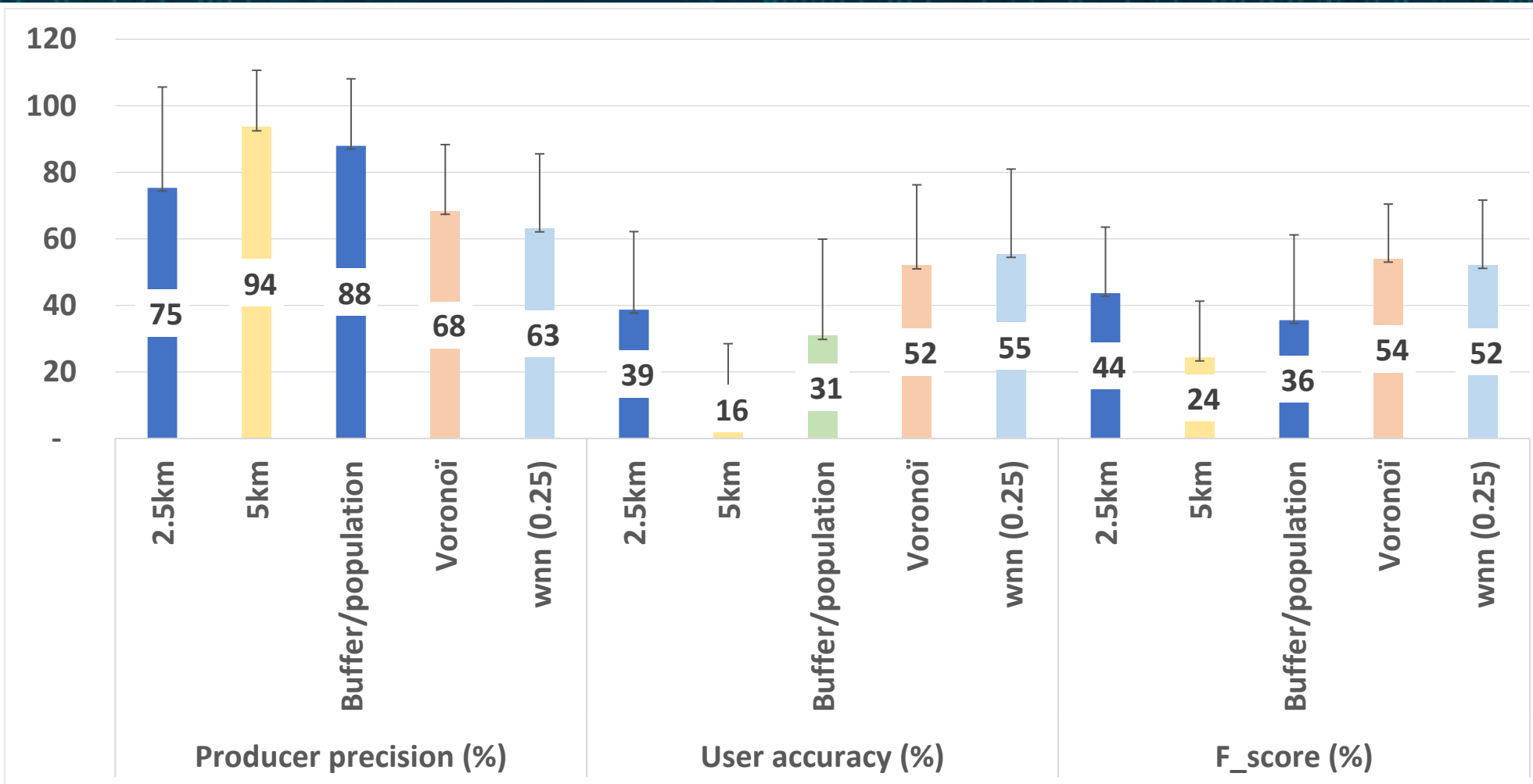






Figure: Geometric indicators

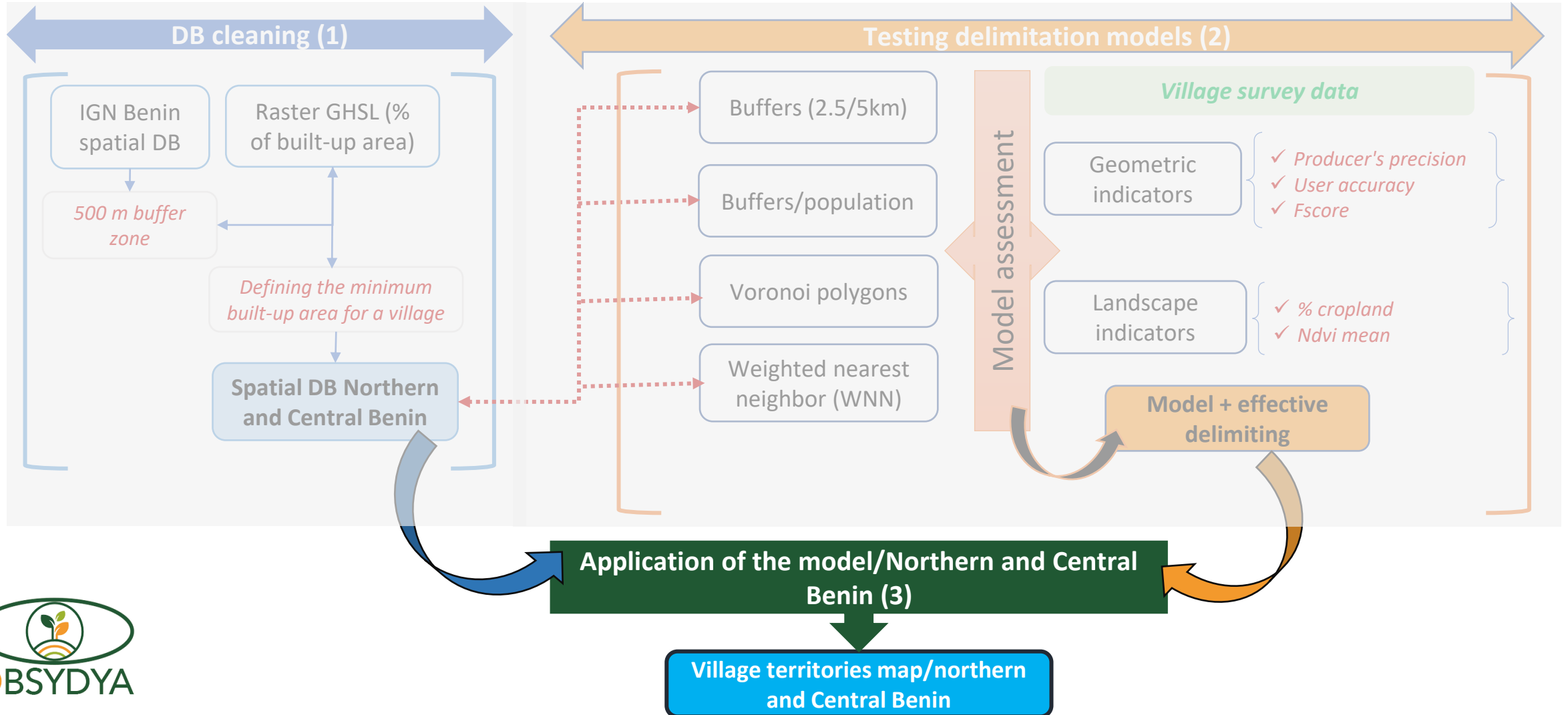
Source: IGN Benin 2018, OBSYDYA 2024 survey data



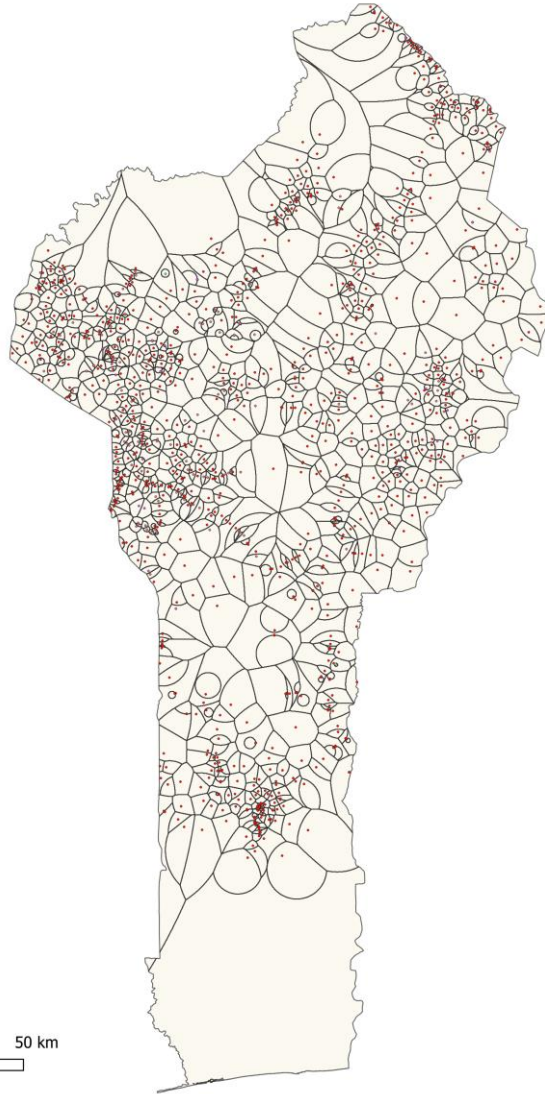
Tableau: landscape indicators

Indicateurs	Villages (A)	Delimitation Models				
		Buffer 2.5km (B)	Buffer 5km (C)	Buffer/population (E)	Voronoi (D)	Wnn (F)
% of cropland	63 (19)	62 (19)	58 (18)	60 (22)	61 (24)	61 (24)
NDVI mean (ACP)	1 603 (46)	1 604 (41)	1 609 (36)	1 612 (39)	1 605 (47)	1 606 (48)

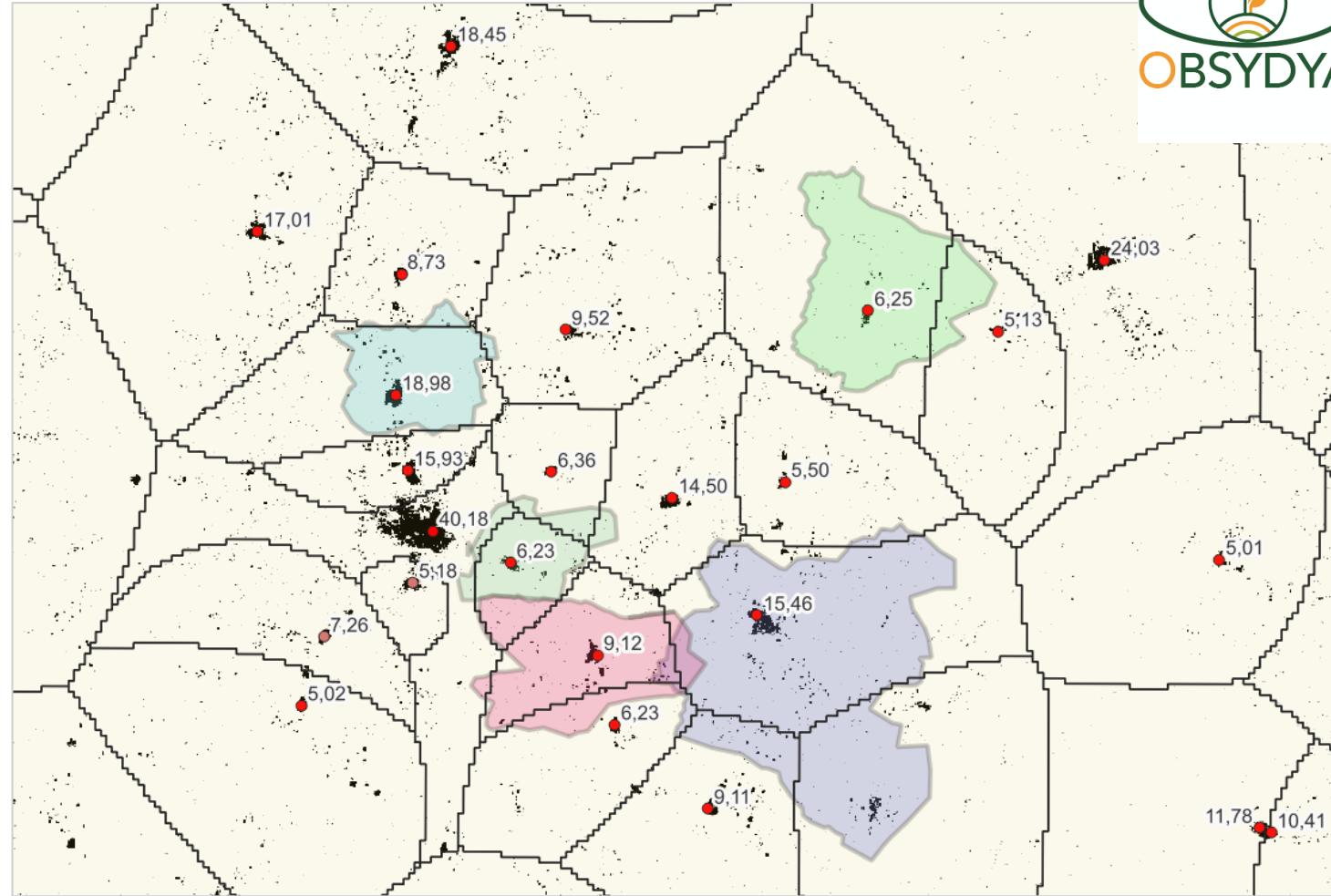
-  Significant at 1% level
-  Significant at 5% level
-  Significant at 10% level
-  No significant difference



Application of the model/Northern and Central Benin (3)



0 25 50 km





Conclusions

- The Voronoi polygon model is the best in terms of Fscore.
- However, for linking socio-economic and EO data, the "wnn" method seems best because it shares the most area with the surveyed village (**user accuracy is the most highest**).
- The choice of delimitation models depends on the objectives for constructing these terroirs.

Perspectives

- Enhance the village survey database in order to increase the sample size of field villages for a better comparison of indicators.
- Deepen the preliminary results obtained by testing the models by agro-ecological zone.



Thanks for your attention



SEDEGNAN AURELLE

sedegnanaurelle@yahoo.com

