A NEW OPERATIONAL APPROACH TO MULTI-SOURCE LANDSCAPE MAPPING BASED ON RADIOMETRIC INFORMATION

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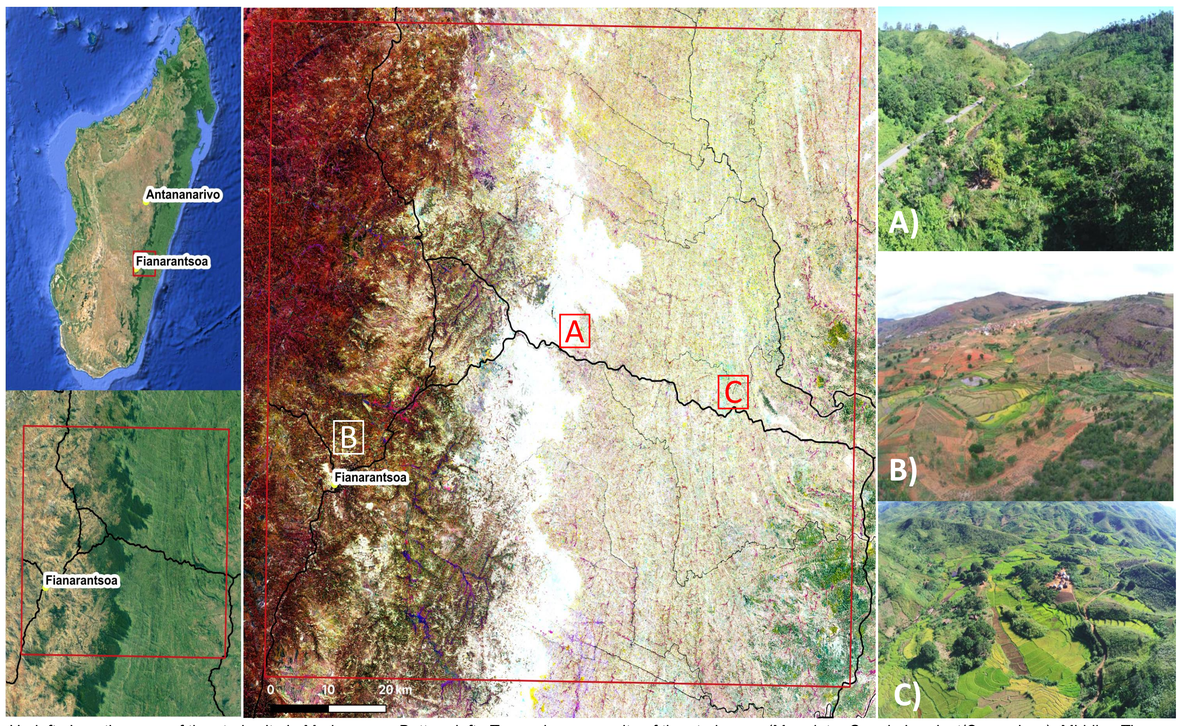
***Reference**: Lemettais, L., Alleaume, S., Luque, S., Laques, A. É., Alim, Y., Demagistri, L., & Bégué, A. (2024). Radiometric landscape: a new conceptual framework and operational approach for landscape characterisation and mapping. Geo-spatial Information Science, 1-23.* ***Contact:** alexandre.defossez@inrae.fr*

Contexte

This project aims to develop a **methodological framework** and operationalize a **spatial processing chain** to identify **landscape units** with the deployment of multi-source scales from **remote sensing.**

- *Our approach is based on the assumption that the primary components of the landscape can be extracted directly from the radiometric information of satellite images, especially from time series, and processed according to **geographic object-based image analysis (GEOBIA)*** concepts.

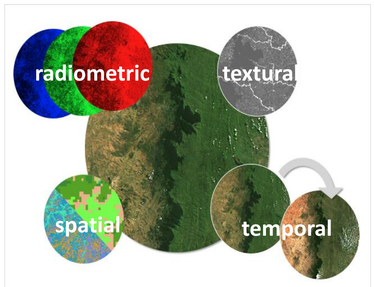


Up-left : Location map of the study site in Madagascar. Bottom-left : True color-composite of the study area (Map data: Google Landsat/Copernicus). Middle : Time composite image of Sentinel-2 NDVI images acquired in March 2019 (R), June 2019 (G), and November 2019 (B). Right : UAV-Photos of three typical landscapes of the study site (May 2022).

Essential Landscape Variables

Essential Landscape Variables (ELVs) are key components for the characterization and detection of landscapes using remote sensing.

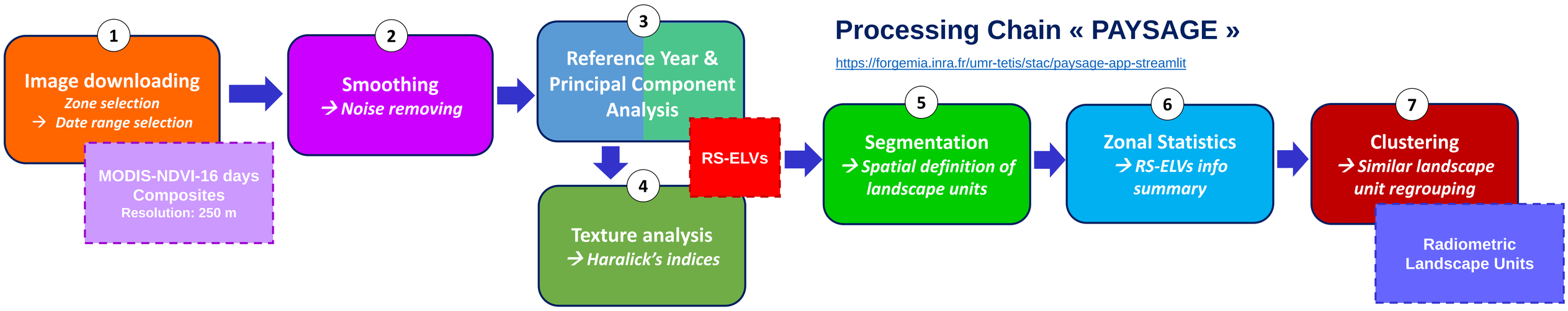
Here we used ELVs to characterise: 1) the landspace temporal variations related to **seasonality** 2) the landscape **composition** and 3) landscape **structure**. Furthermore, the **spatial variability** of the landscape is considered indirectly through the spatial variations of the other three components.



ELVs	Landscape information	RS-ELVs	Data mobilized
Phenology, climate, cropping calendar and practices…	Temporal (seasonality)	Principal Components	MODIS « reference year »: 2016-2020 *(mean for each NDVI 16 days composite)*
Land cover, biomass, vegetation conditions, soil type…	Spectral (composition)	Vegetation Indices	MODIS « reference year »: 2016-2020 *(mean for each NDVI 16 days composite)* • Sentinel-2 seasonal NDVI, NDWI *(wet: 11 Avril; dry: 28 October 2019)*
Landscape structure and composition, hydrographic network…	Textural (composition, structure)	Haralick indices	• MODIS « reference year »: 2016-2020 *(mean for each NDVI 16 days composite)* • Sentinel-2 seasonal NDVI *(wet: 11 Avril; dry: 28 October 2019)*

Processing Chain « PAYSAGE »

https://forgemia.inra.fr/umr-tetis/stac/paysage-app-streamlit

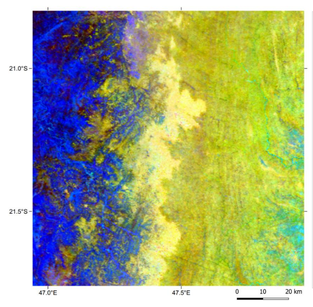


Application: landscape analysis in Madagascar

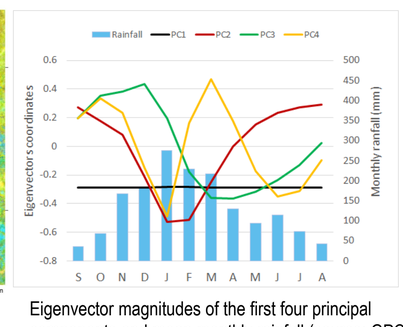
Three RS-ELV datasets are assessed to map the landscape units over the study area

Dataset	RS-ELV	Variable number
A	*MODIS mean annual NDVI + MODIS PC2, PC3, PC4*	4
B	*Dataset A + 2 MODIS Haralick's indices*	6
C	*Dataset A + 2 NDVI Sentinel-2 Haralick's indices (two dates)*	8

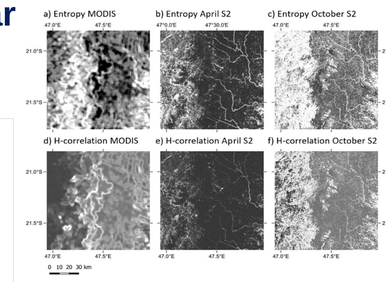
MODIS NDVI PCA calculated over the reference year (2016–2020)



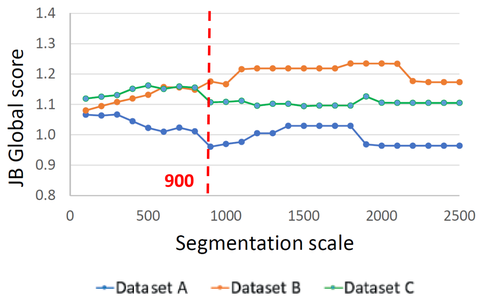
PC1 in red, PC2 in green, PC3 in Blue.



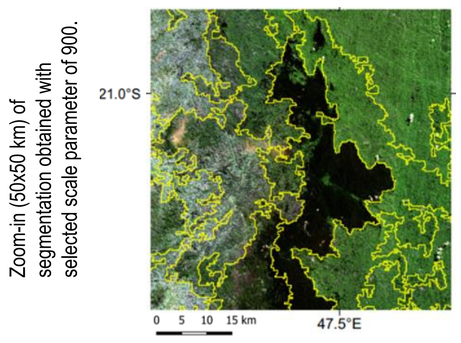
Eigenvector magnitudes of the first four principal components and mean monthly rainfall (source: GPCP data) over a climatic year.

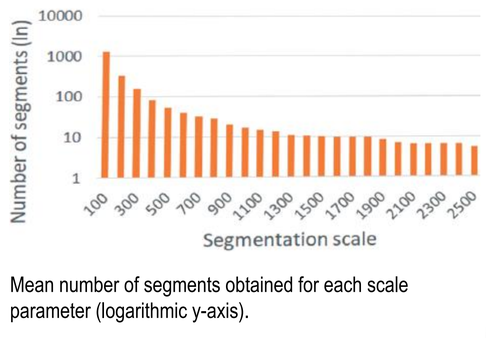


Entropy (up line) and H-correlation (bottom line) images calculated for MODIS annual NDVI (a and d, respectively), NDVI Sentinel-2 April (b and e, respectively) and NDVI Sentinel-2 October (c and f, respectively).

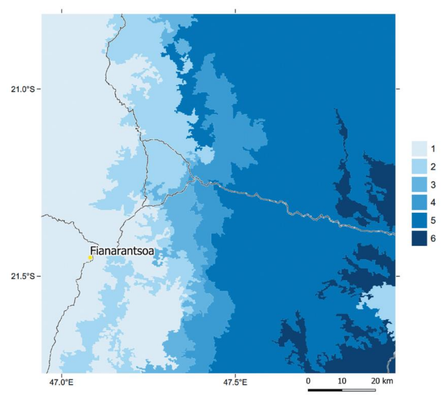


Results for the global JB scores (Böck *et al.*, 2017) calculated for the set of test segmentations. **Dataset A is selected for clustering (min value = 900).**





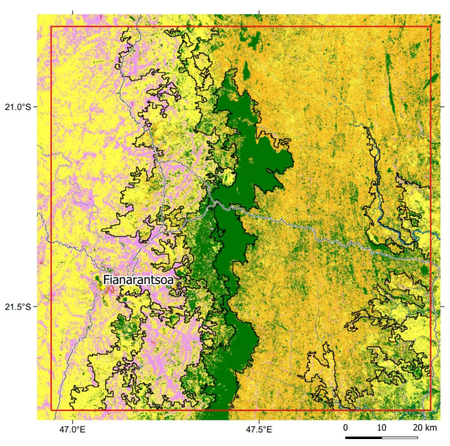
Mean number of segments obtained for each scale parameter (logarithmic y-axis).



The final radiometric landscape map in six classes (the grey lines represent the roads network).

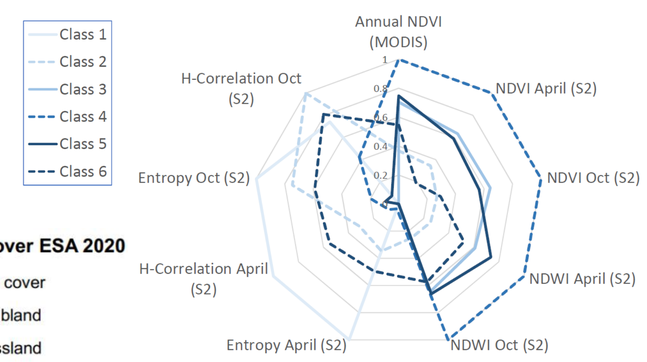
Landscape unit characterisation

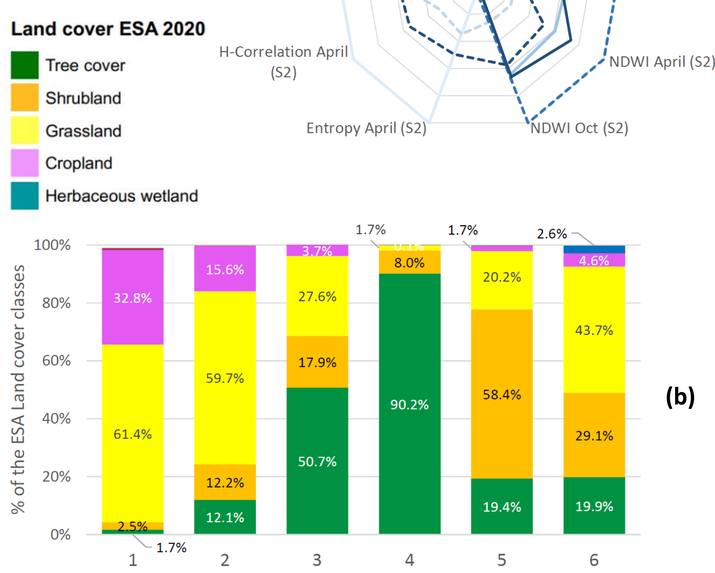
Landscape type characterisation in terms of land cover : **(a)** ESA World cover map (2020) with cluster boundaries; **(b)** Frequency distribution (%) of the ESA global cover land cover classes (2020), by landscape class (labels of the LULC classes representing less than 1% are not shown).



(a)

Radar chart composed of the normalised mean values of MODIS and Sentinel-2 ELVs, for the six classes of the radiometric landscape map:





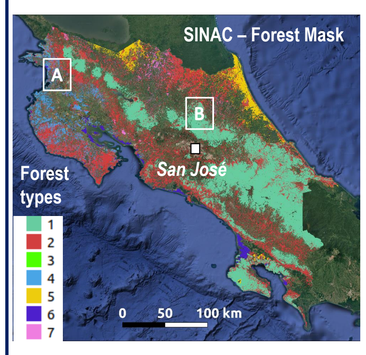
(b)

Take home message

- **Segmentation and clustering** were able to highlight typical **characteristic areas**, such as ecological corridors, **contrasting landscapes** from East to West as a result of differentiated climate conditions.
- **ELVs approach** provided **a multi-temporal baseline** considering both seasonal and multi-year variations.
- The method presented here can serve as a first step towards **a generic framework for producing radiometric landscapes**

Testing the replicability of the method in Costa Rican forests

- **Objectives**: (1) to verify **the replicability of the method** in a different geographical and ecological context (2) to adapt the **processing chain** to make it as **generalisable** as possible to different landscape types, regions and spatial scales.
- **Study site**: The present study concentrated on the forest landscapes of Costa Rica. We used a mask from the National System of Conservation Areas (SINAC - *Sistema Nacional de Áreas de Conservación*) to filter out landscape units with at least 25% of the total forested area.



1) **Mature evergreen forest**
2) **Secondary evergreen forest**
3) **Mature deciduous forest**
4) **Secondary deciduous forest**
5) **Palm plantations**
6) **Mangroves**
7) **Forestry plantations**

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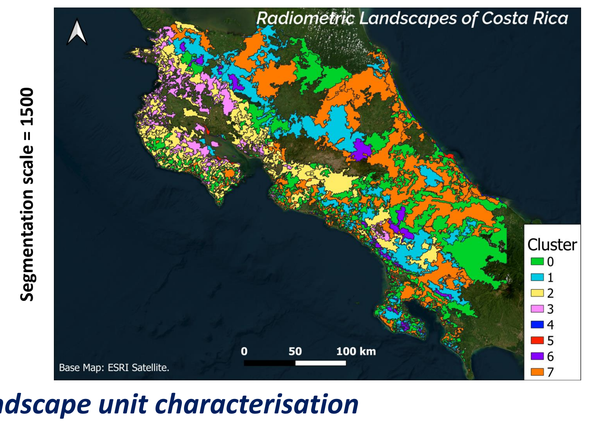
Dataset selected to map the forested landscape units

MODIS reference year	RS-ELV	Variable number
• 2020-2022 *(mean for each NDVI 16 days composite)*	*MODIS PC1, PC2 + 2 MODIS Haralick's indices (entropy and H-correlation)*	4



Landscape unit characterisation

Forest class	1	2	3	4	5	6	7	other
Cluster 0	37.1	26.2	0.0	0.8	1.8	1.3	0.7	32.1
Cluster 1	43.1	17.4	0.0	0.0	1.9	0.8	0.5	36.3
Cluster 2	2.7	32.4	0.1	14.6	0.0	0.1	0.7	49.4
Cluster 3	0.4	21.5	0.1	16.6	0.0	1.1	0.3	60
Cluster 4	5.3	23.3	0.1	1.8	23.3	9.6	0.7	35.9
Cluster 5	4.3	12.9	0.0	2.2	6.6	19.8	0.1	54.1
Cluster 6	70.2	6.6	0.0	0.1	0.0	0.4	0.0	22.7
Cluster 7	27.3	21.3	0.0	0.1	6.3	0.4	1.3	43.3

- **Conclusions**: 1) Our results suggest that our method can be replicated in different geographical and ecological contexts; 2) Upscaling may require adaptations to the processing chain, particularly at the segmentation step (parametrization). 3) Landscape unit characterization is highly dependent on the quality of the reference maps. The use of thematic maps, produced at regional scales to address specific requirements, may be preferable to the use of global maps (*e.g.* ESA World Cover map).