AN OPERATIONAL APPROACH TO MULTI-SOURCE LANDSCAPE MAPPING BASED ON ESSENTIAL LANDSCAPE VARIABLES (ELVs)

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1. Introduction

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.

- Landscape mapping: crucial for monitoring and understanding a wide range of processes, and for addressing challenges such as land-use planning and biodiversity assessment.

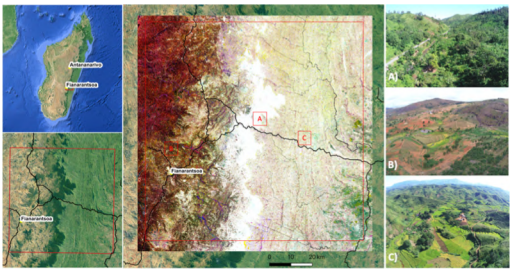


Fig 1: Up-left : Location map of the study site in Madagascar. Bottom-left : True color-composite of the study area (Map data: Google Landsat/Copernicus). Middle : Time composite image of Sentinel-2 NDVI images acquired in March 2019 (R), June 2019 (G), and November 2019 (B). Right : UAV-Photos of three typical landscapes of the study site (May 2022).

2. Essential Landscape Variables (ELVs)

Essential Landscape Variables (ELVs) are key components for the characterization and detection of landscapes using remote sensing. Here we considered: **Phenology**, (i.e vegetation production), **structure** and **composition** of landscape elements (Table. 1).

ELV	Remote sensing ELV	Data mobilized
Phenology	Time serie of vegetation index	• MODIS NDVI 16 days (2016-2020)
Vegetation productivity	Vegetation index (NDVI, max, annual integral)	• Mean MODIS NDVI (2016-2020) • PCA MODIS NDVI • NDVI Sentinel-2 (march/nov 2019)
Landscape structure and composition	Haralick indices, Fourier transform	• Mean of MODIS NDVI (2016-2020) • Sentinel-2 (march/nov 2019)

Table 1: Essential Landscape Variables (ELV), remotely sensed essential landscape variables and satellite data were mobilized.

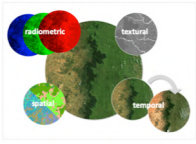
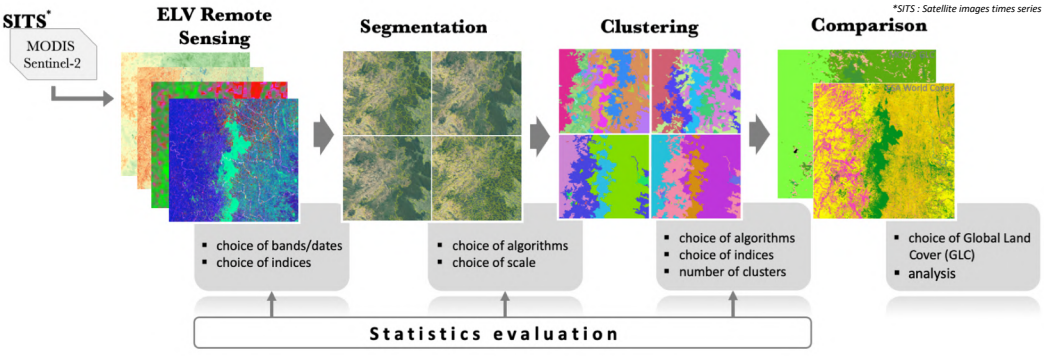


Fig 2: Four types of features (spatial, radiometric, temporal and textural) can be extracted from remote sensing data.

EVLs are determined with the help of multidisciplinary experts to reflect the different points of view and transcribe into remote sensing components. The four components are described in Fig. 2. They are: 1) The spatial component multi-scalar approach, to take advantage of the complementarity of spatial resolutions; 2) The temporal component characterizes the singular dynamics of each territory; 3) The radiometric component is used to explore and create general and specific indices; 4) The textural component represents the different homogeneities and heterogeneities on an image, calculated from gray level matrices.

3. Methods



We mobilized 2 Time Series of Satellite Images MODIS (2016-20) and Sentinel-2 (2019). The information was extracted from each of the different components of the objects. The objects are segmented according to different parameters, and then classified according to the parameters chosen with the **K-means method** by an **object approach** (OBIA). Finally, each object was confronted to other GLCs.

4. Results

Landscape units in 6 clusters

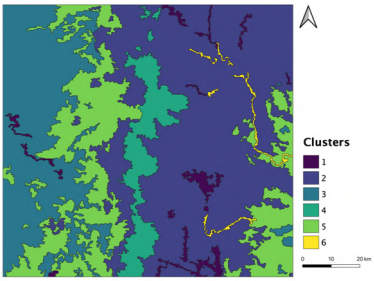


Fig 3: Mapping of landscape units based on MODIS and Sentinel-2 data obtained with the combination of MODIS NDVI PCA between 2016 and 2020 and two texture methods (Haralick and FOTOTEX) applied on NDVI of Sentinel-2 data, in 6 clusters at two different dates March and November in 2019. Haralick's Correlation and Entropy are the two indices used for the first method (Haralick).

Information by vegetation and texture indices

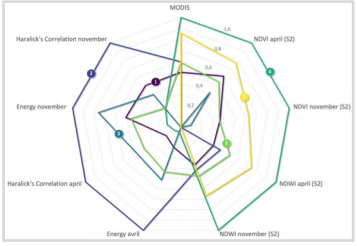


Fig 5: Radar chart composed of 9 vegetation and texture indices , for the 6 clusters. Means are normalized between 0 and 1 by 0,1.

- The highest averages values were obtained in clusters 2 and 4.
- Clusters 4 and 6 showed the highest average NDWI.
- Cluster 2 showed high average values for all 4 Haralick indices. Index 2 showed strong correlation (i.e. class 4 had large areas of similar intensities).

Distribution of NDVI

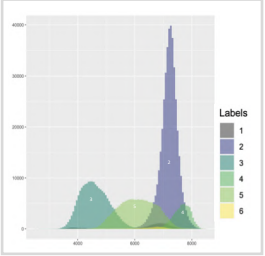


Fig 4: Distribution of mean MODIS NDVI according to the 6 clusters. Strong discretization between clusters 3 ,5 , 2. Clusters 2 and 4 are characterized by high NDVI values.

Landscape analysis in terms of land cover

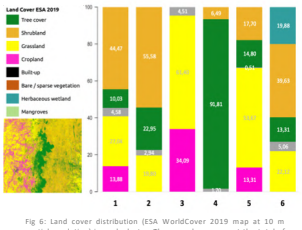


Fig 6: Land cover distribution (ESA WorldCover 2019 map at 10 m spatial resolution) in each cluster. The gray clas represent the total of land cover classes showing less than 5% of the cluster area.

- Cluster 4 was mostly composed of tree cover and corresponded to the **ecological corridor**.
- Cluster 3 was mostly composed of **grassland and cropland,** while Cluster 5 is **highly heterogeneous**.
- Clusters 1 and 2 are dominated by **shrubland**, with the presence of **cropland** in Cluster 1.
- Cluster 6 was the only miwed landscape with herbaceous **wetland**.

5. Conclusion & prospects

- Segmentation and clustering were able to highlight **typical characteristic areas**, such as ecological corridors, contrasting landscapes from East to West as a results of differentiated climate conditions.
- Results of this approach allowed to map landscape units.
- ELVs approach provided a **multi-temporal baseline** considering **both seasonal** and **multi-year variations**.
- Work based on multi-source satellite data (i.e. MODIS and Sentinel-2), highlighted the complementarity of different sensors at different resolutions working at different scales (multi-scalar).
- Perspectives for the future to consider to undertake **the approach to develop a processing chain** and to test and evaluate the approach through field missions in other regions of Madagascar and test the reproducibility in some areas of Brazil.

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