Monitoring post-fire vegetation recovery using UAV:

A successional analysis from the Ankarafantsika National Park, Madagascar

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1. Context

The dry dense forests of western Madagascar are among the most threatened ecosystems in the world. Ankarafantsika National Park, a major biodiversity refuge, is losing its vegetation cover to fires, the leading cause of degradation after clearing (MEEF, 2014).

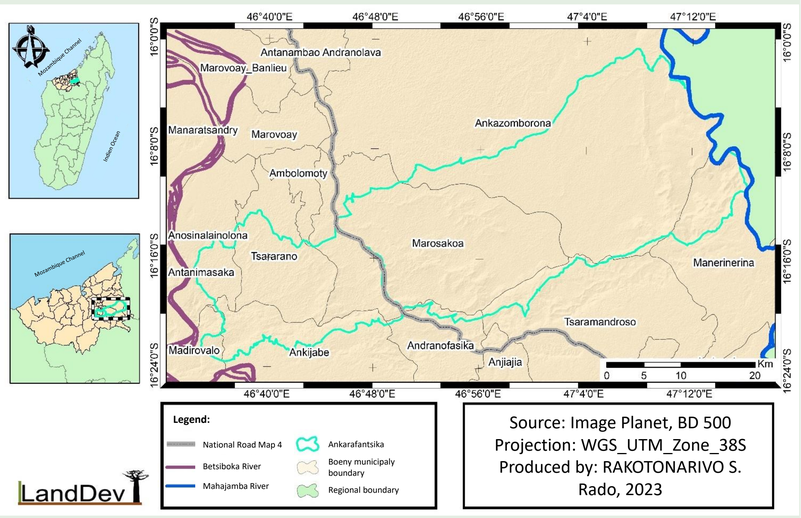
Conventional forest inventories remain costly and difficult to scale up over large areas. Drones (UAVs), combined with 3D photogrammetry, offer a fast and accurate alternative for monitoring vegetation succession after a fire disturbance.

➢ Objective

To identify post-fire vegetation successions in Ankarafantsika National Park, in order to propose effective restoration strategies.

Synchronic approach (Space for Time Substitution): successional stages are analyzed simultaneously using transects of different ages, compared with an unburned reference ecosystem.

2. Study Area



Location of Ankarafantsika National Park, Boeny region

- Dense dry deciduous forest, mosaic of savannas and thickets
- > 800 plant species, 48% endemic to Madagascar
- 8 lemur species, 129 bird species

3. Material

Three series of satellite images were used to locate burned areas from 2001 to 2022:

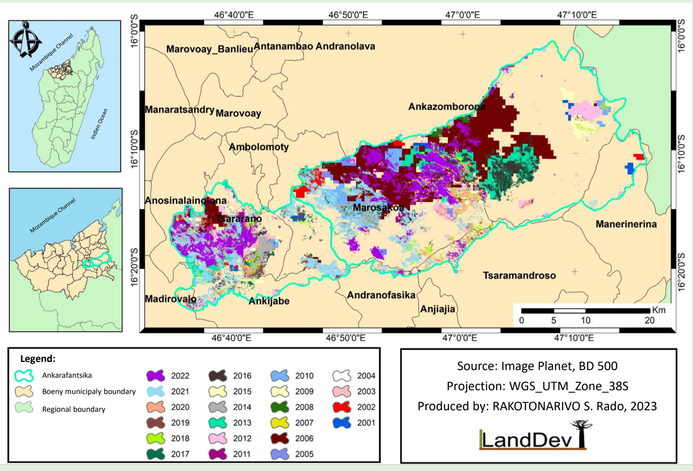
- MODIS (MCD64A1, 500 m)
- 2001-2013 / LANDSAT-8 OLI (30 m)
- 2014-2022 / SENTINEL-2 (10 m) — 2016-2022

A Planet basemap (5 m) was applied to verify forest regrowth after fire.
DJI Mavic 2 Pro drone (RGB) — flight at 80 m altitude, 90%/80% overlap, speed 2.9 m/s (Sarron *and al.,* 2018).
Processing: ArcGIS 10.3, Agisoft Metashape (photogrammetry), and RStudio (dense clouds, statistics).

4. Methodology

1. **Detection of burned areas**
   Spectral indices NBR, BAI (Landsat-8), and BAIS-2 (Sentinel-2); MODIS "Burn Date" layer (Tahintsoa *and al.,* 2022)
2. **Age attribution of formations**
   Age = years elapsed since the last fire event (year zero: 2023)
3. **Stratified sampling**
   20 transects of 300 m × 200 m (Semeki Ngabinzeke *and al.,* 2020): 19 successions (1 to 21 years) + 1 reference ecosystem
4. **Drone acquisition and photogrammetry**
   DJI Mavic 2 Pro, dense point cloud → DSM, DTM, and CHM (Agisoft, 2017)
5. **Individual Tree Detection (ITD)**
   Local Maximum Filter with variable window (lidR); validated against orthophoto (Lisein *and al.,* 2013)
6. **Structural analysis and modeling**
   Heights, vertical profiles, age-height correlation, reconstruction model

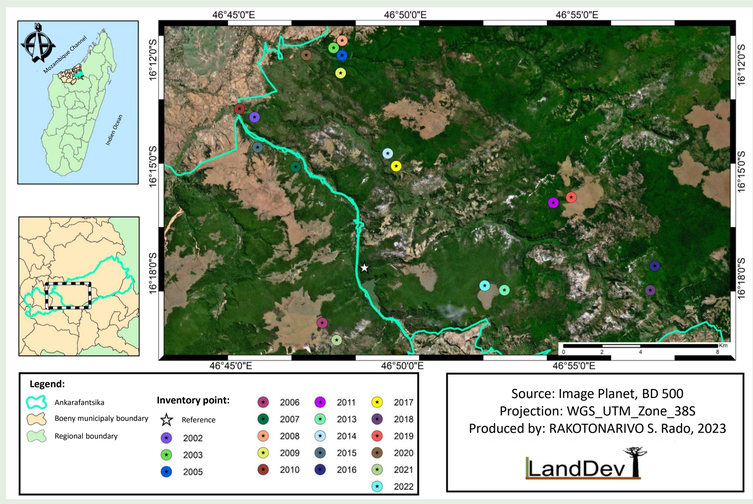
5. Fires: Location and Frequency (2001-2022)



Burned areas, 2001-2022

- 40,707 ha : Peak burned area in 2006 (31.3% of the Park)
- 1 to 16 passes
- Increasing frequency from East to West

6. Transect Location



Location of the 20 inventory transects (19 successions + 1 reference)

7. From Reference to Burned Ground

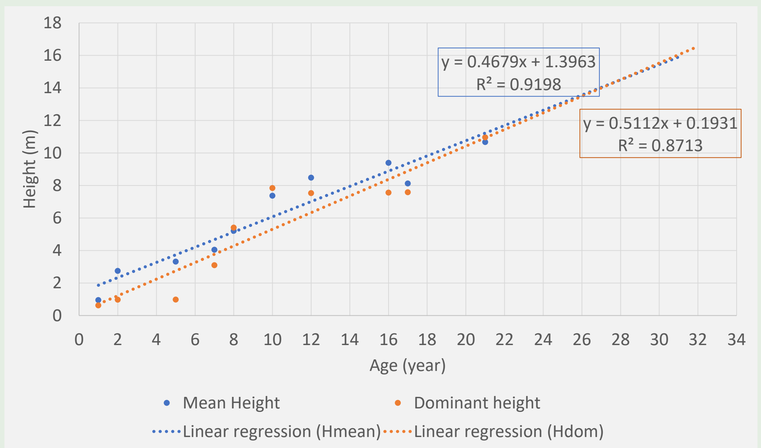
Reference (intact forest) *Formation aged 1 year*

Drone orthophotos reveal a clear difference in cover: bare soil and sparse vegetation shortly after the fire, versus continuous, overlapping canopy in the reference.

F-score ITD : 0.80 – 0.89
Reliability of individual tree detection (20 transects)

8. Reconstruction Speed

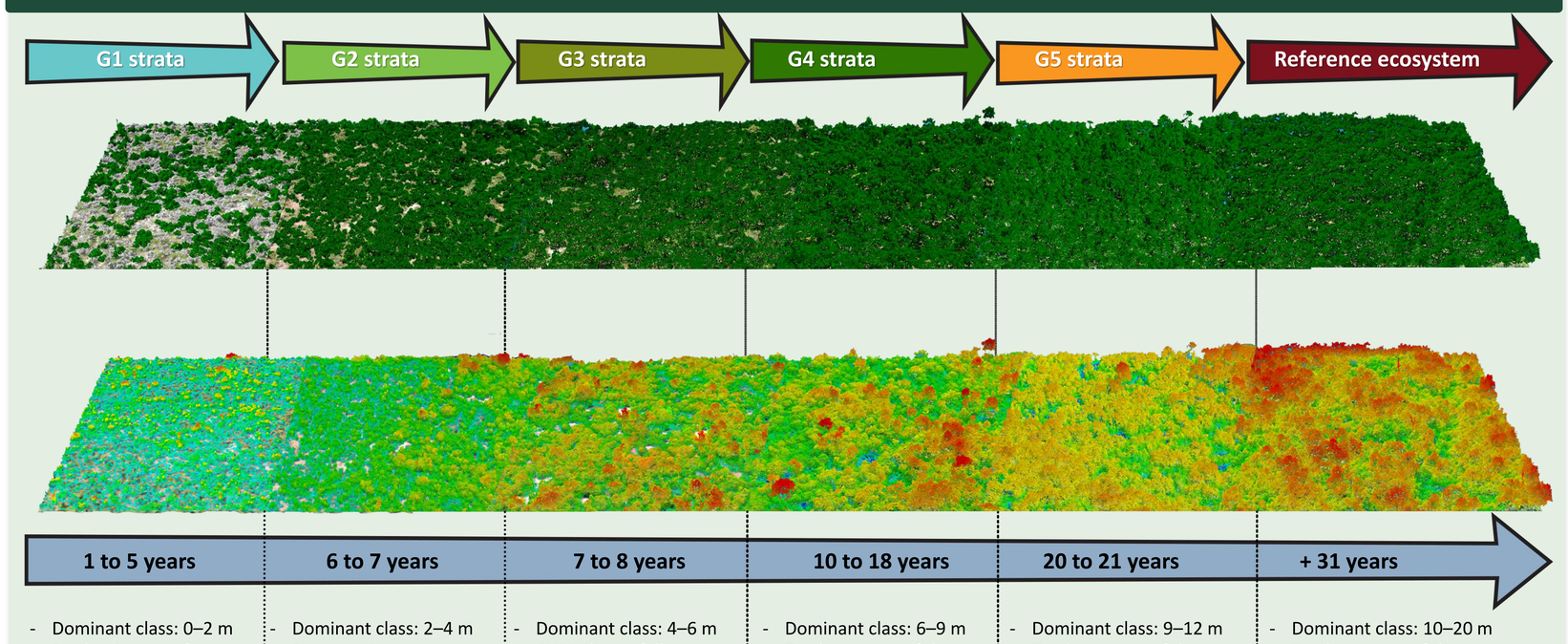
Both mean height and dominant height are strongly correlated with the age of post-fire vegetation regrowth.



Dominant height growth curve as a function of pos-fire vegetation age (G1 to G5)

- 21 years after the fire, the vertical structure of the successions has not yet reached that of the reference.
- Regression model projections indicate that the **reference's mean** and **dominant heights** will be reached at **around 31 and 30 years post-fire**, respectively.

9. Forest Reconstruction Model After Fire



Structural reconstruction trajectory of post-fire vegetation in Ankarafantsika, from strata G1 to G5 up to the reference ecosystem

10. Conclusion and Recommendations

Burned forests can recover naturally if recurrent fires are prevented, although structural recovery requires about 30 years.

- Prioritizing fire prevention in the western and northern parts of the park
- Prioritizing young vegetation successions (under 10 years) due to high vulnerability
- Monitoring with drones for a rapid and cost-effective assessment of large-scale forest regeneration.

11. References

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