Taming the Long Tail

A Few-Shot Learning Approach to UAV-Driven Ecosystem Restoration

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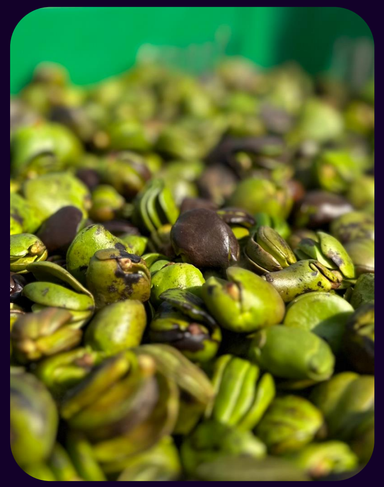
Overview

1. **Intro to Dendra Systems**
   - ➢ Case-Study: Mangrove Restoration

2. Flora Species Identification:
   A Long-Tailed Problem



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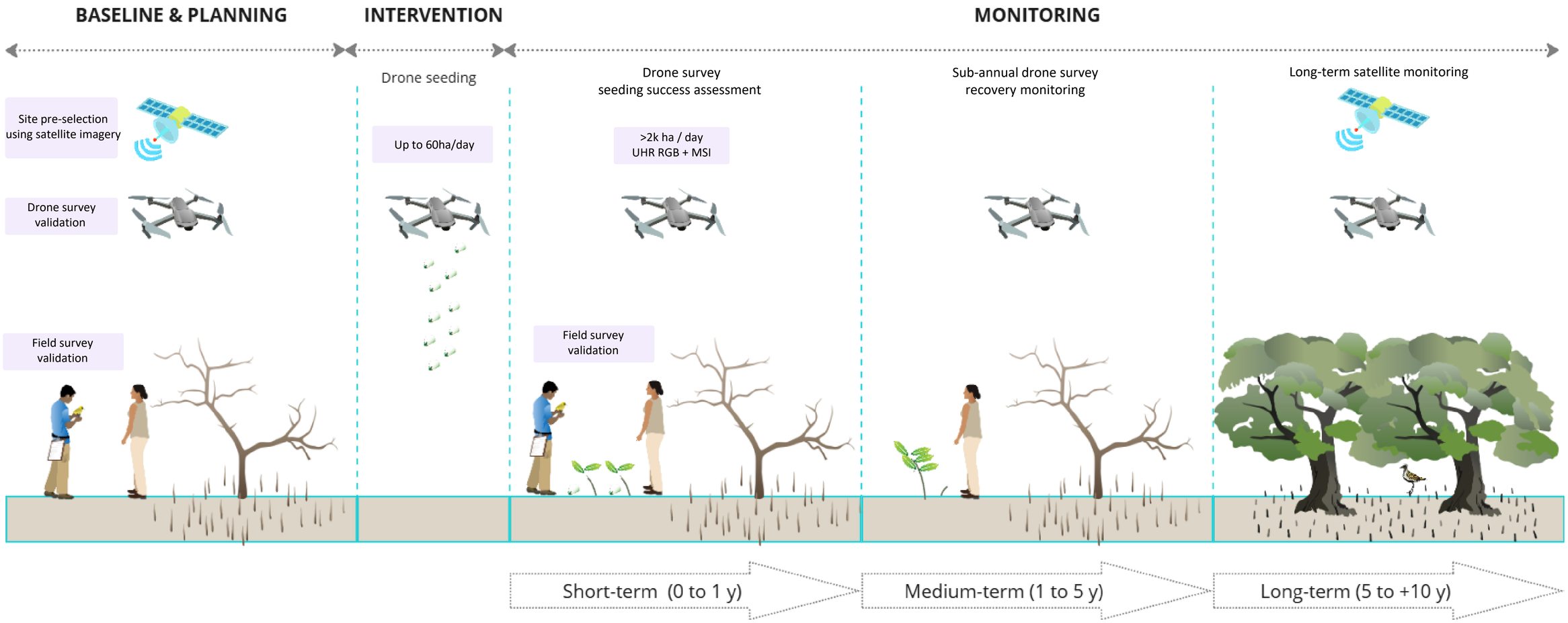
End-to-End Ecosystem Restoration: Core Operations



Poor site selection is one of the most common reasons for projects failing to meet goals[1].

[1] C. Lovelock et al., "Tackling the mangrove restoration challenge." *PLoS biology* 20.10 (2022)

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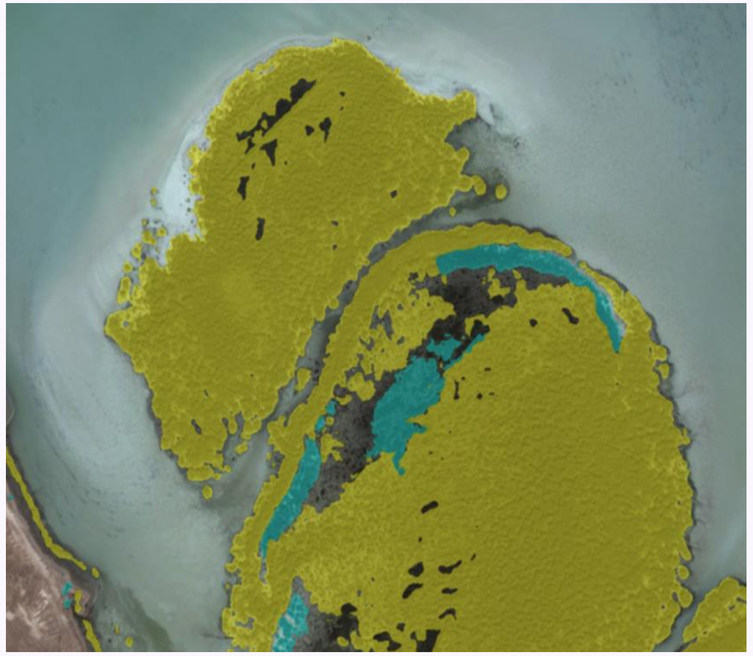
Case Study: Mangrove Seeding Success Monitoring

Satellites

Combine ranges of datasets derived from satellite imagery to pinpoint high-priority areas within extensive landscapes

Identifying suitable zones for intervention or monitoring and enabling more targeted, efficient resource deployment.



Mangrove & Saltmarsh habitat extent model generated on 30cm satellite RGB

Drones / Manned Aircraft

At 0.6 cm GSD, our RGB imagery combined with 5cm MSP data allows you to zoom from landscape level down to young saplings

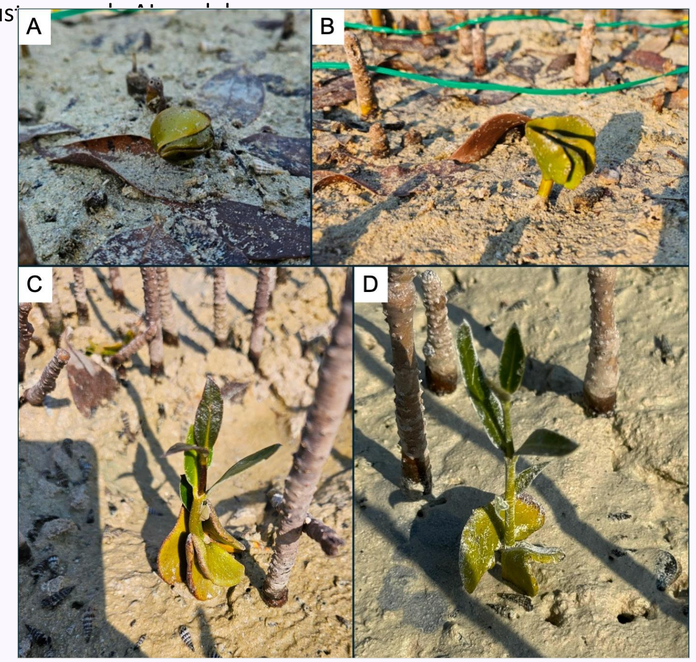
Empowering precise, landscape and ecosystem level monitoring with AI driven ecological insights to inform decision-making at scale.

Examples of saplings obtained at 0.56cm drone RGB

Field

Combine the strengths of traditional field ecology with the scalability of spatial ecology

Precisely target areas and detect subtle changes across the habitat from an even closer perspective and to calibrate/validate our cust



Field ground truthing of mangrove saplings

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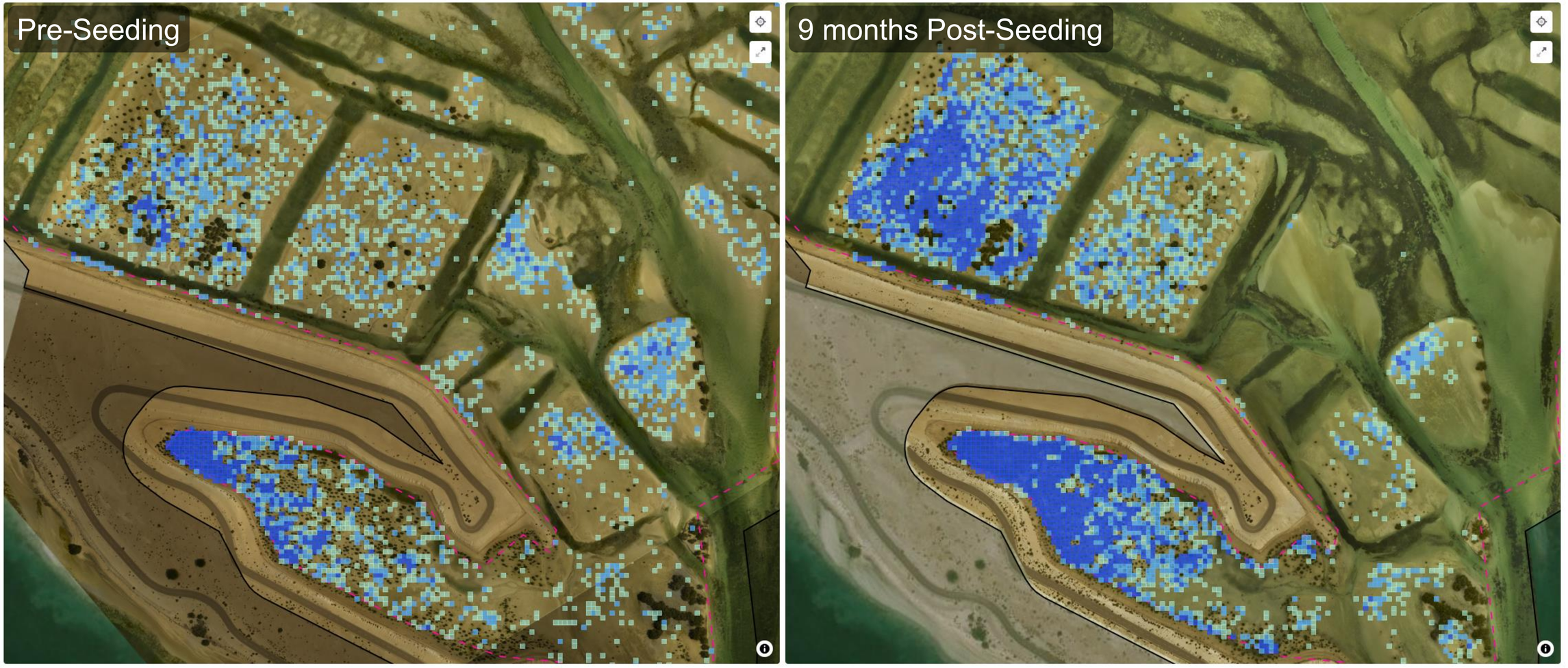
Automated Young Sapling Detection

Saplings insights

Compare intersection

Survey comparison

Sep 2023 | Maps | Jul 2024 | Maps



Class	Sep 2023	Jul 2024	Change
Saplings AI	6,900 (5,700 – 8,100)	12,300 (10,600 – 14,100)	+79%

Automated Young Sapling Detection

Saplings insights

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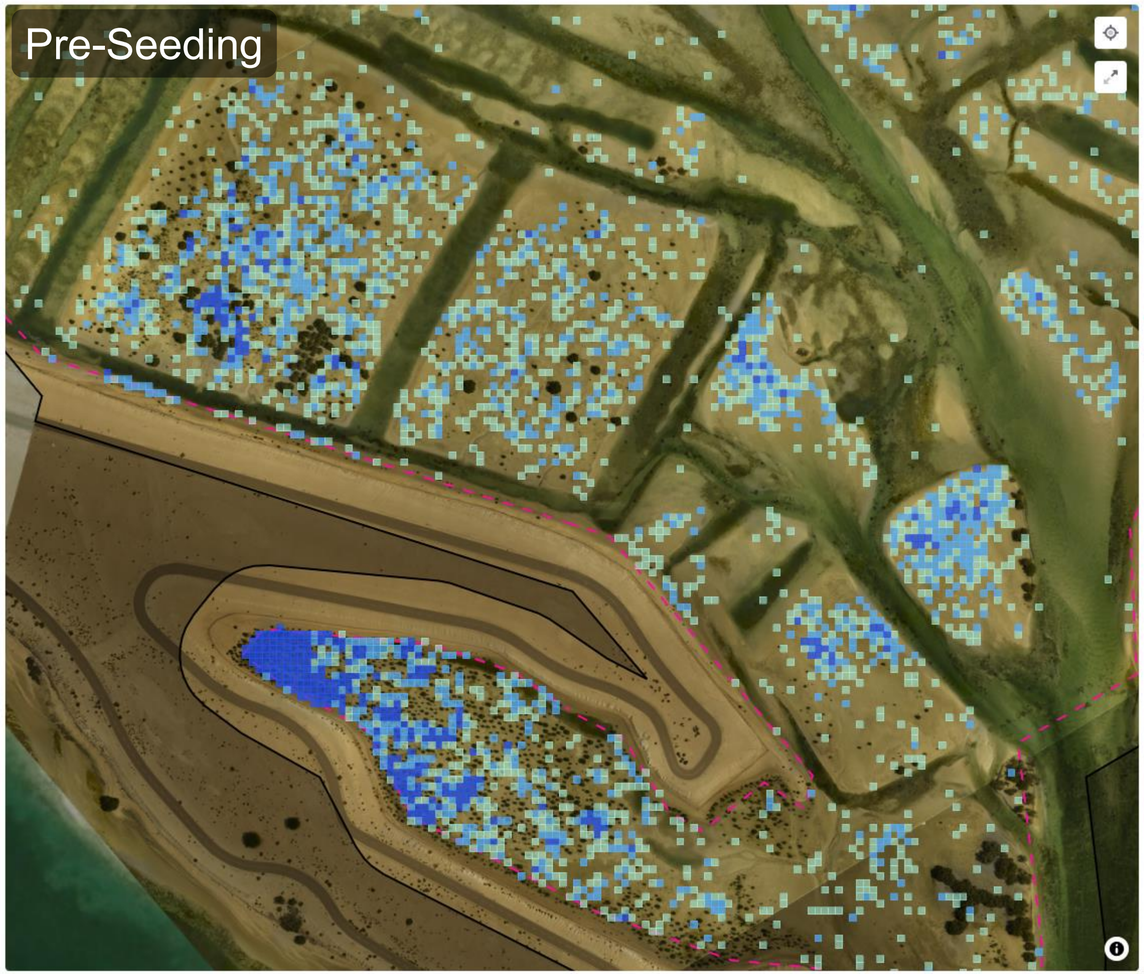

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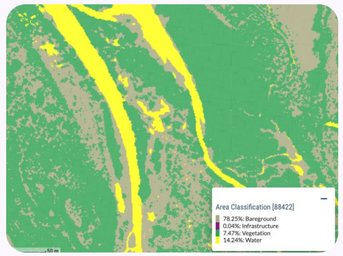
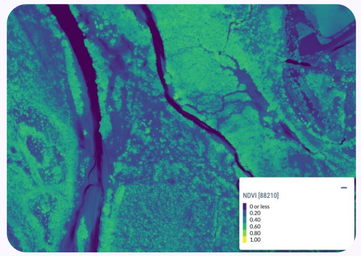
Remote sensing analyses and insights – long-term monitoring

Land cover, multispectral & relief mapping

5cm MSI + LiDAR

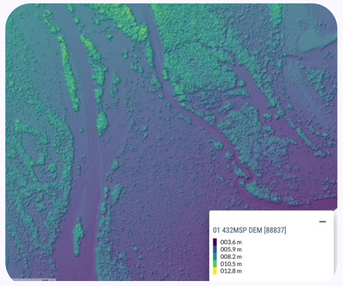


Area Classification



NDVI

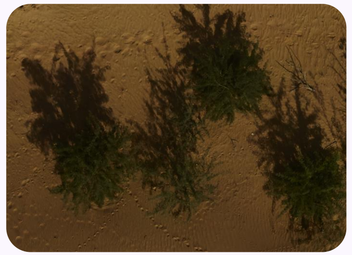
Erosion Heatmaps



Digital Elevation Model

Flora and fauna species identification

0.6cm RGB

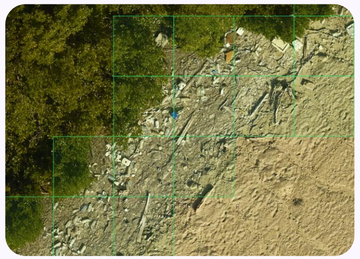


Native flora species & invasives / weeds mapping

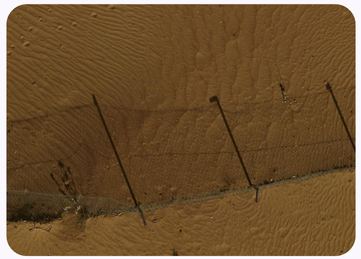
Native & invasive fauna identification

Human impact assessment

0.6cm RGB



Litter



Infrastructure

Contamination barrier

Dredging

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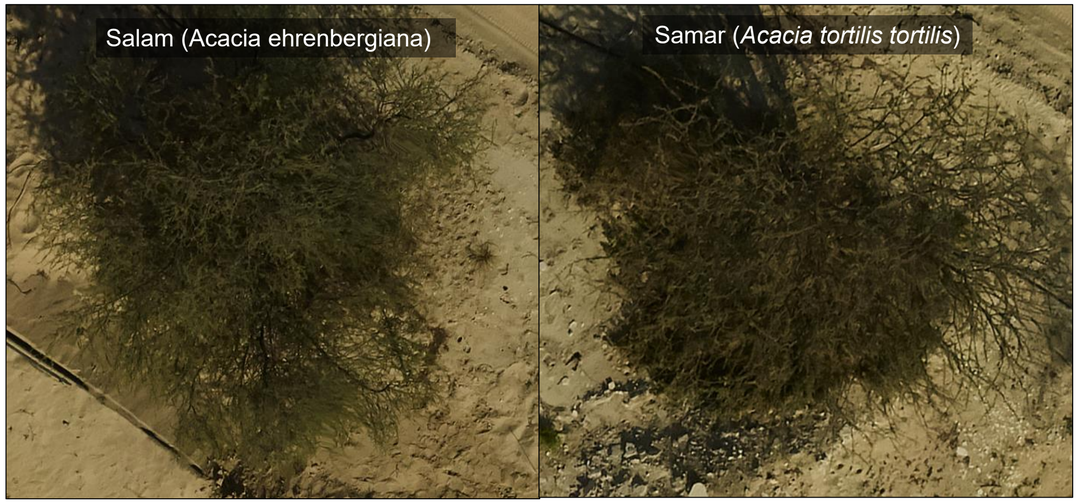
Flora Species Identification: A Long-Tailed Problem

Visually similar species



Morphological variations within a subspecies

- Approx. 440,000 known flora species globally[(2)]

  [(2)] Govaerts R (2025). The World Checklist of Vascular Plants (WCVP). Royal Botanic Gardens, Kew

- Morphological variations of individual (sub)species
  - Growth stage
  - Climate / biome
  - Seasonal effects (flowering)
  - Site management (irrigation)

- (Lack of) distinguishing features
  - Related (sub)species with visually similar appearance
  - Convergent evolution of unrelated species
  - Observability in remote sensing imagery

- Effects of imaging conditions
  - Sensor GSD / artefacts
  - Illumination conditions
  - Sensor colour calibration

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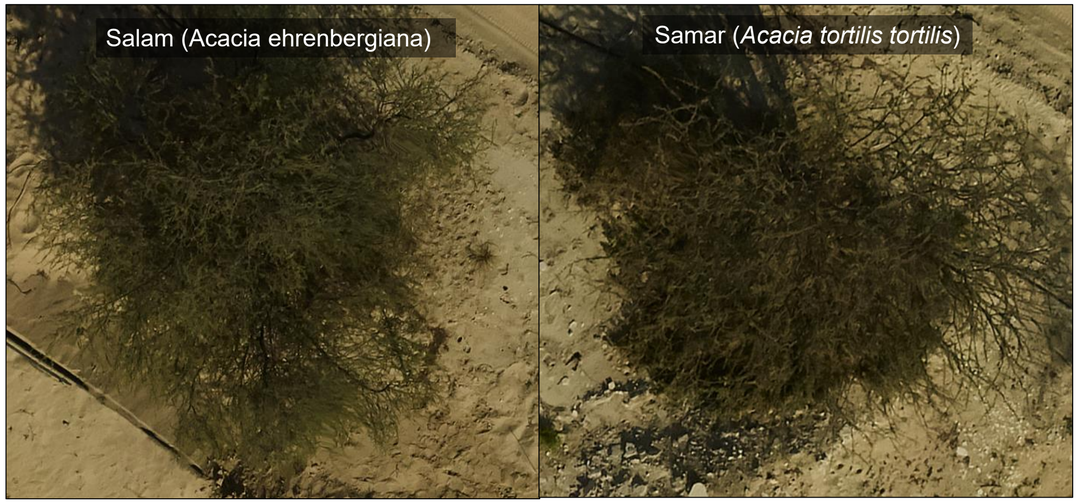
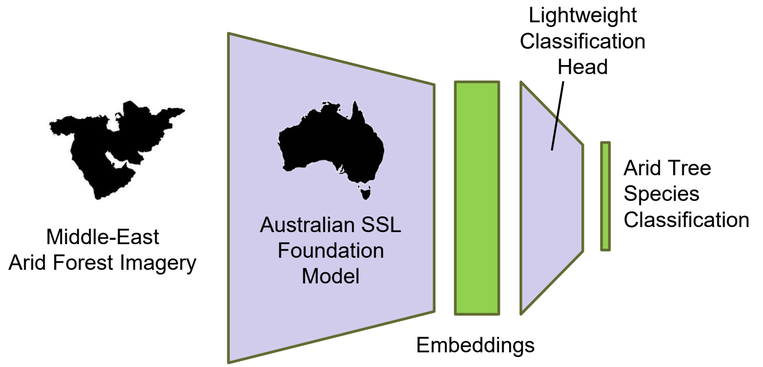
Unseen Acacia Species Identification

Visually similar species



Morphological variations within a subspecies

Demonstrating foundation model generalisation capabilities for fine-grained out-of-distribution tasks



Species	Precision	Recall	F1 Score	Support
Ghaf (Prosopis cineraria)	0.77	0.93	0.85	29087
Arak (Salvadora persica)	0.81	0.74	0.77	7666
Samar (Acacia tortilis tortilis)	**0.76**	**0.78**	**0.77**	**2605**
Sidr (Ziziphus spina-christi)	0.81	0.81	0.81	2276
Damas (Conocarpus)	0.84	0.87	0.86	1916
Ghuwaif (Prosopis juliflora)	0.81	0.84	0.82	1603
Radina (Acacia nilotica)	**0.76**	**0.78**	**0.77**	**984**
Salam (Acacia ehrenbergiana)	**0.61**	**0.64**	**0.62**	**478**
Talha (Acacia tortilis raddiana)	**0.44**	**0.44**	**0.44**	**434**

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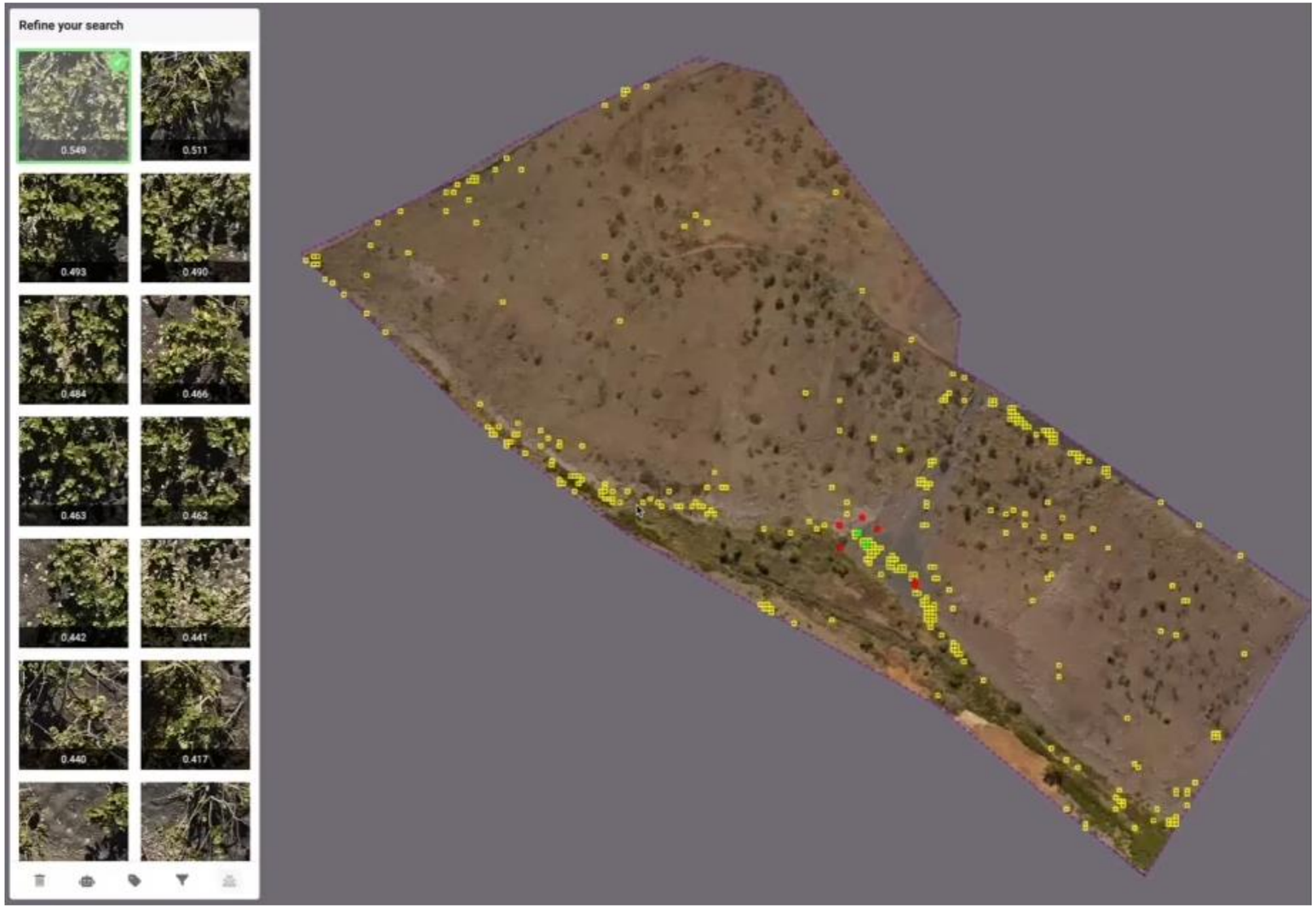
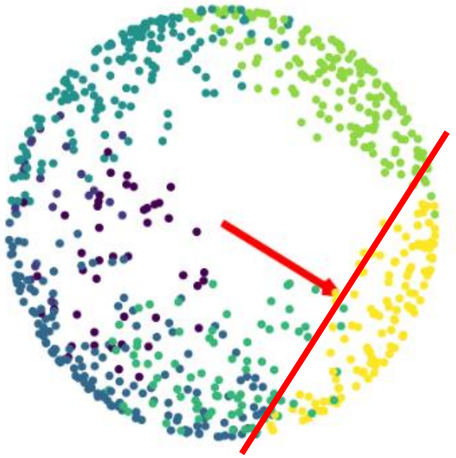
Disposable Few-Shot Classifiers for Scalable Species Identification

Training a Rubber Bush (Calotropis Procera) classifier
in **50 seconds** with just **2 positive** and **5 negative** samples



Extremely lightweight binary classifiers
provide real-time semantic search capabilities



Key observations:

- Embedding richness is critical for achieving useful levels of specificity and recall
- Efficient production infrastructure unlocks new tooling for both ecology teams and customers
- Enables quick assessment of the “classifiability” of new species or imagery

Conclusions

- The task of flora species identification from even sub-cm remote sensing imagery is a highly challenging long-tailed problem which cannot be addressed at scale with monolithic modelling approaches.
- Specialised foundation models can be paired with extremely lightweight classifiers to perform fine-grained tasks beyond their training domains with minimal additional supervisory overhead.
- Implementing few-shot models as support tools for ecologists can provide significantly more flexibility and value than end-to-end-automated DL pipelines.

Thanks to the whole Dendra team!