

# Close-range drone imagery for mapping tree canopy seed fertility in European temperate forest

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## Background

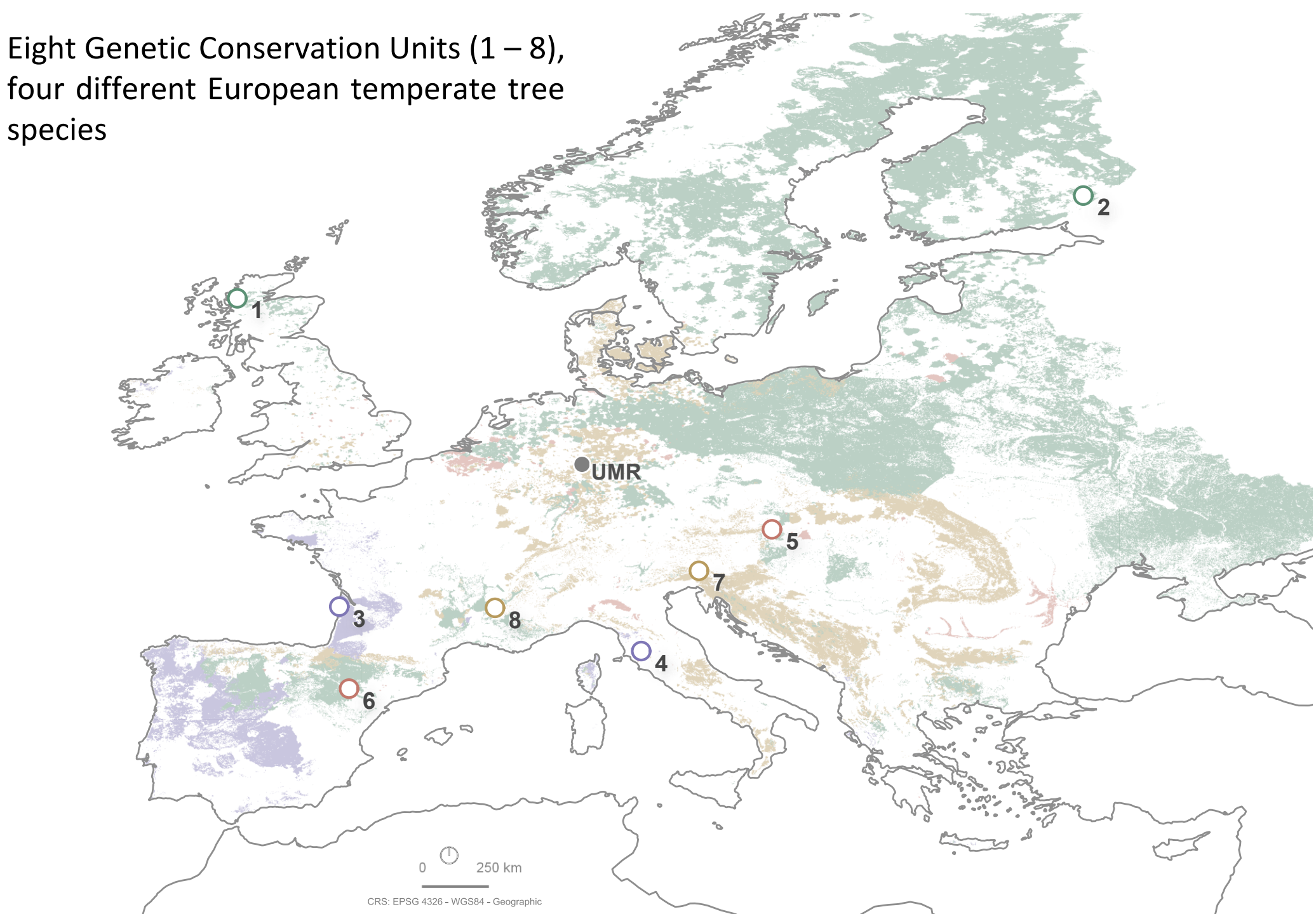
- Variation in seed production among adult trees controls their genetic contribution to the next generation, shaping effective population size, gene flow and forest resilience.
- Tree-level seed counts over whole stands are logistically demanding, species-dependent and rarely feasible beyond small plots.
- Close-range RGB imagery from low-cost drones offers a scalable way to turn crown observations into spatial fertility maps for genetic monitoring and sampling design.

## Hypothesis

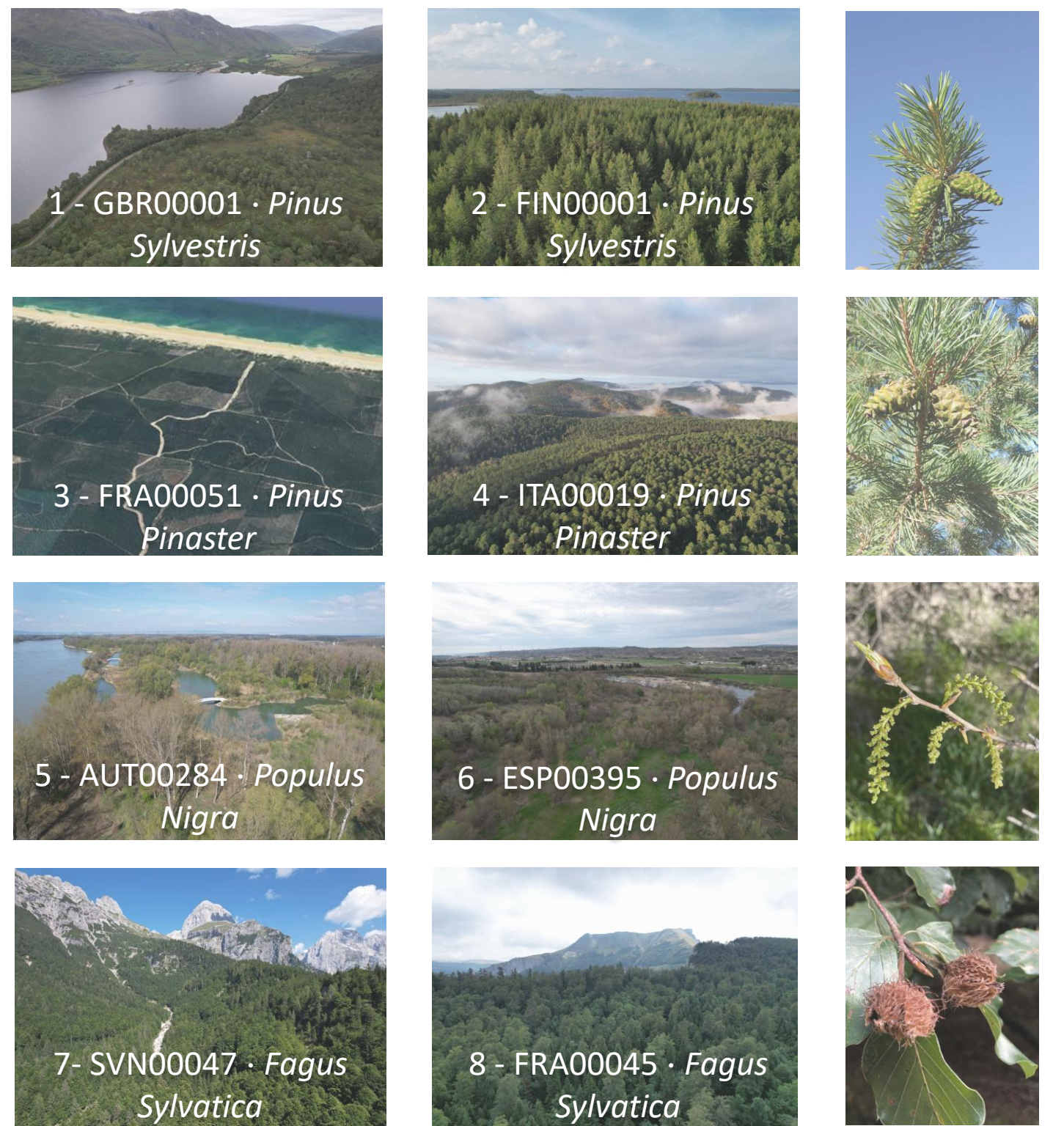
- Under favourable weather and flight conditions, high-resolution drone RGB imagery, analysed with Machine Learning (ML) or visual scoring, yields crown fertility classes reliable enough to map seed fertility from individual crowns to stand scales.

## Study sites

Eight Genetic Conservation Units (1 – 8), four different European temperate tree species



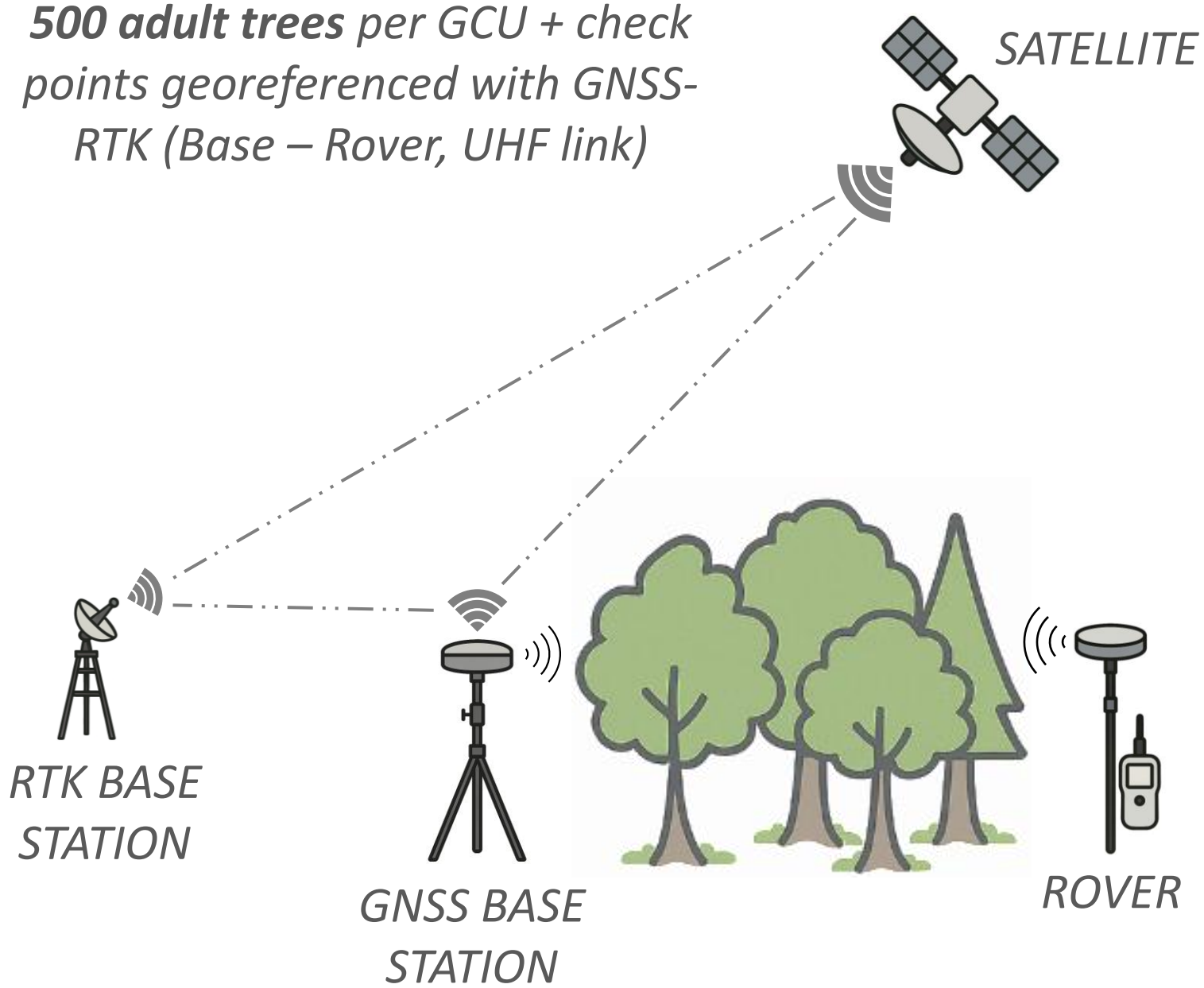
Aggregated forest map showing the dominant species at 1x1 km [1]:  
● Pinus sylvestris   ● Populus nigra   ● Pinus pinaster   ● Fagus sylvatica  
● UMR (Philips-Universität Marburg)



## Study design

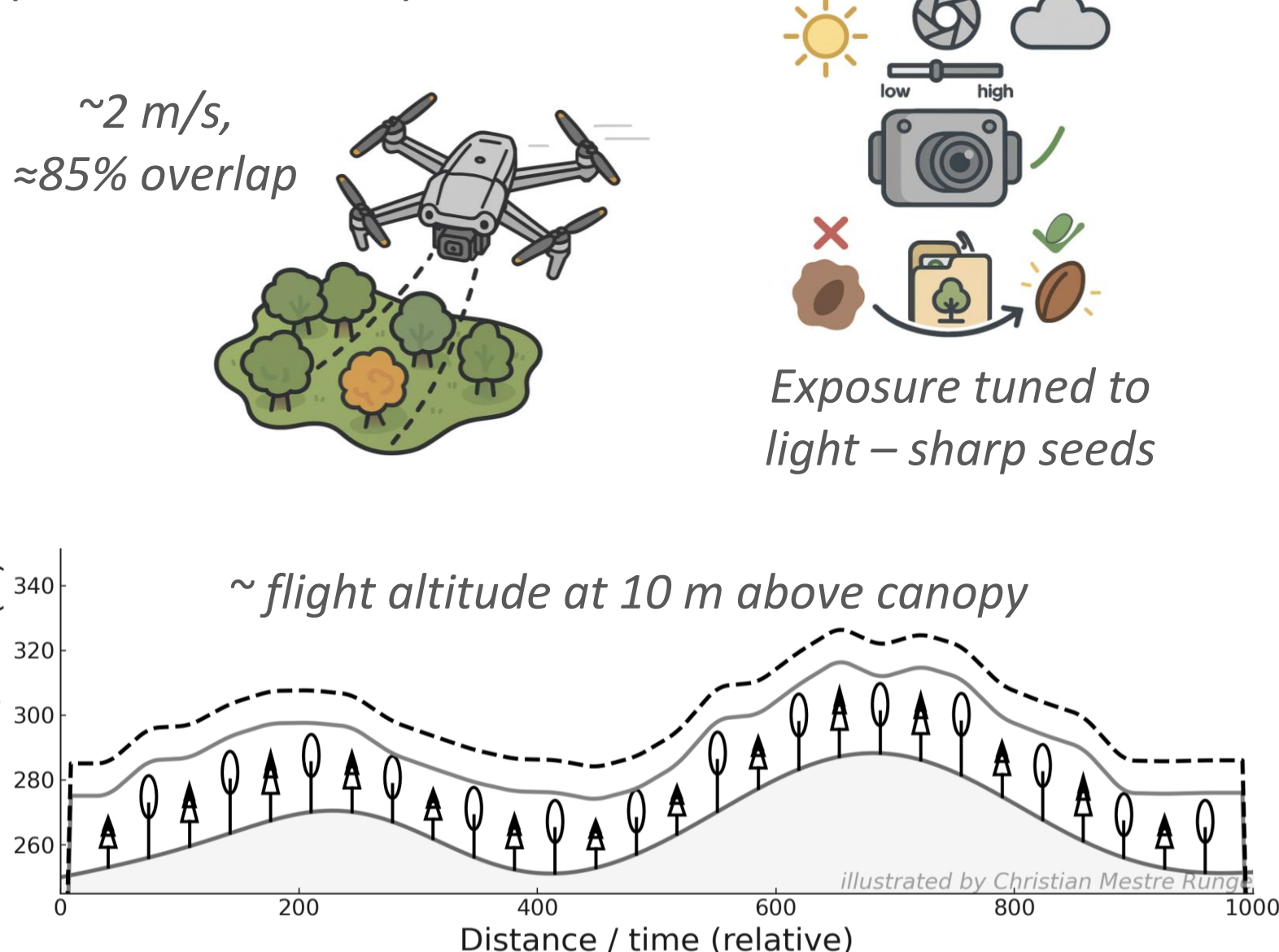
### Step 1 – Georeferencing adult trees

**500 adult trees per GCU + check points georeferenced with GNSS-RTK (Base – Rover, UHF link)**

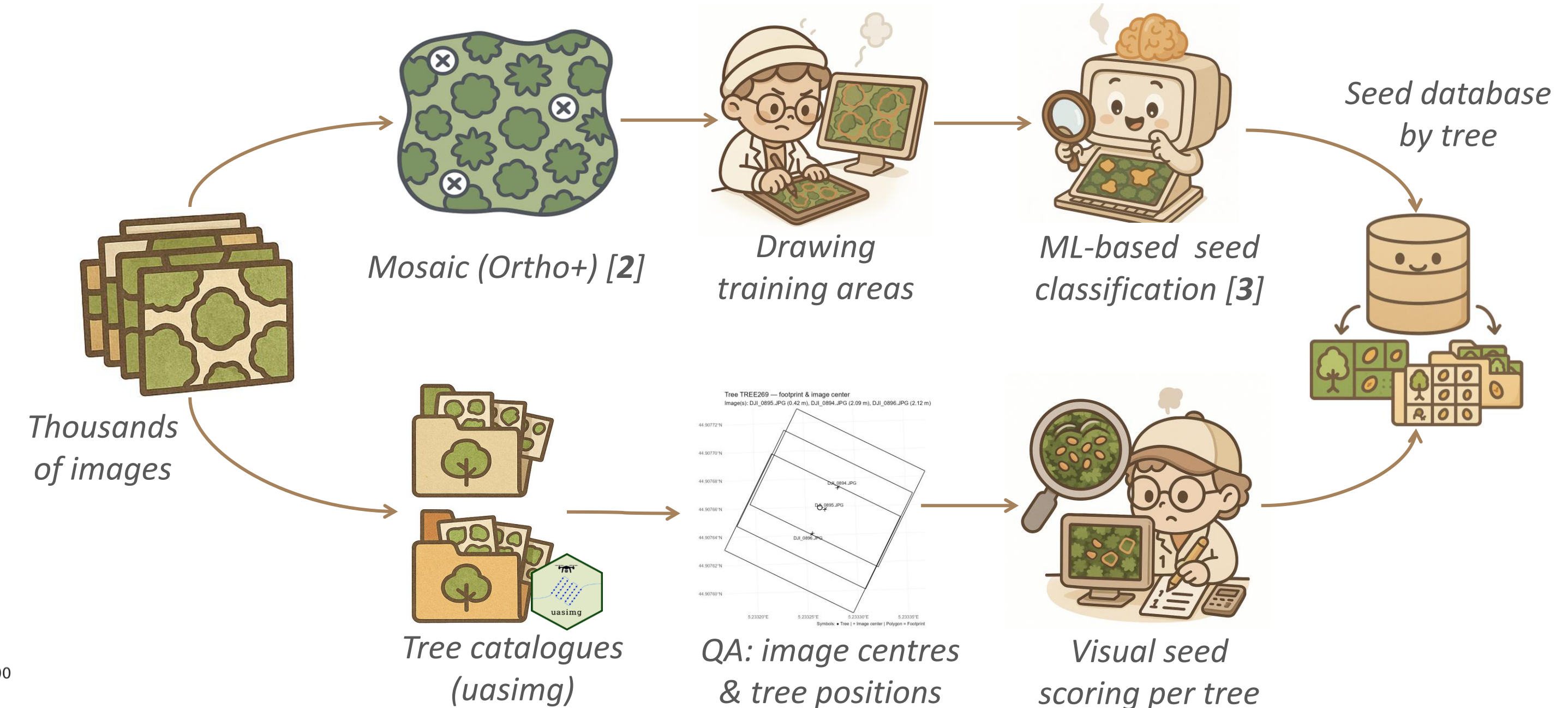


### Step 2 – Close-range RGB imaging

Three drones (DJI Air2S, Mavic Pro, Mavic 3M); parameters tuned per GCU:

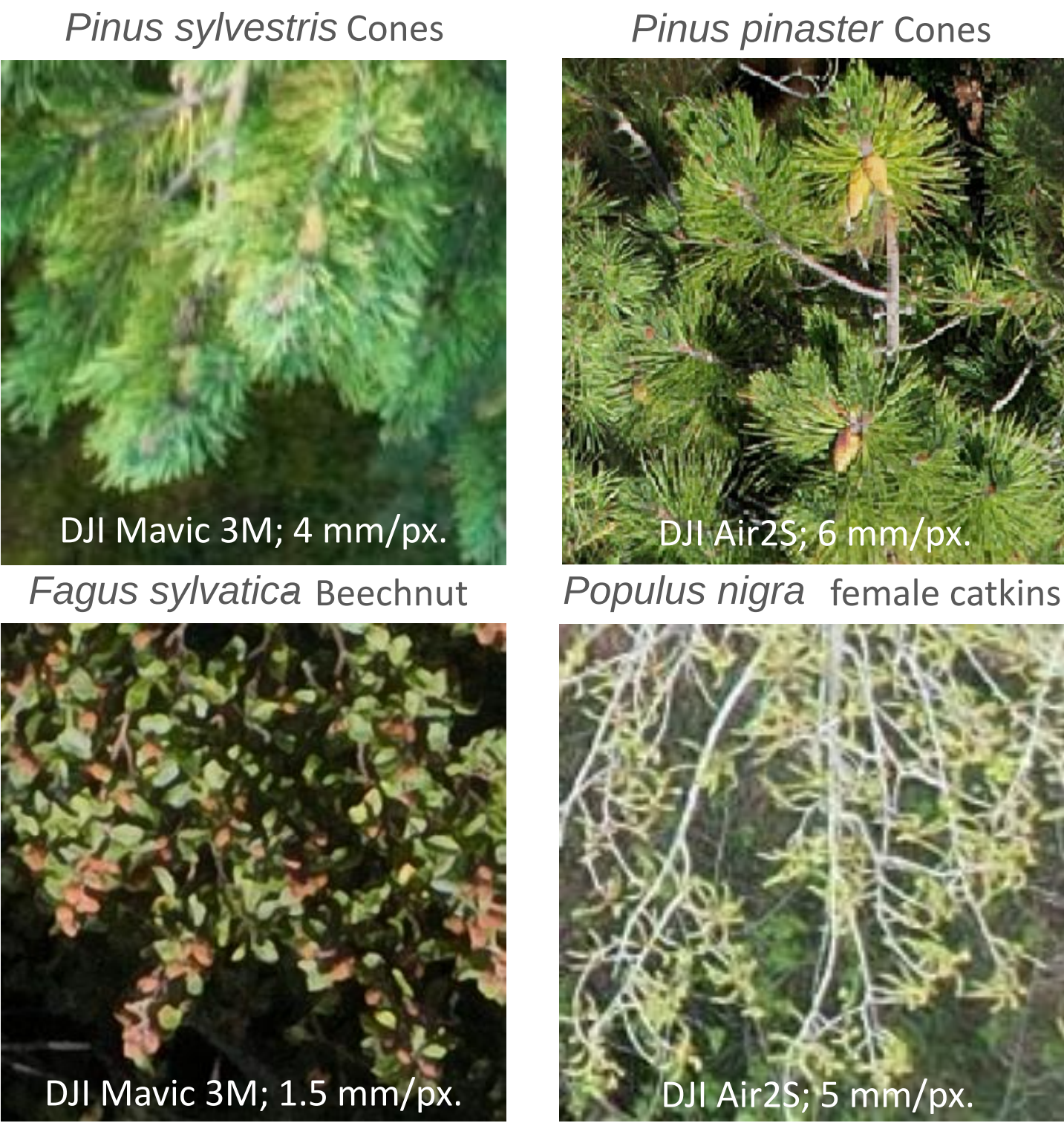


### Step 3 – Image Processing & Seed database by tree

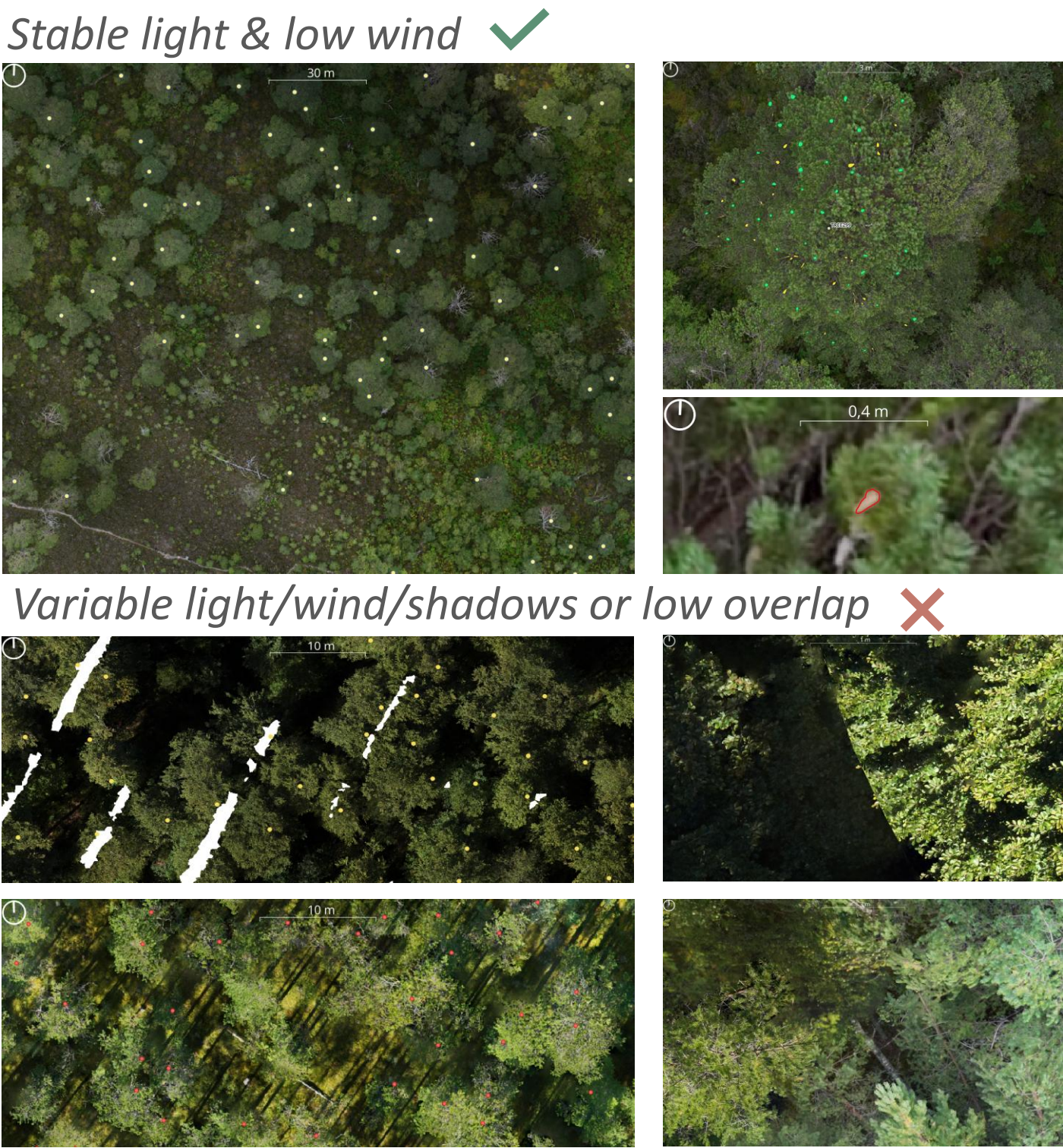


## Results

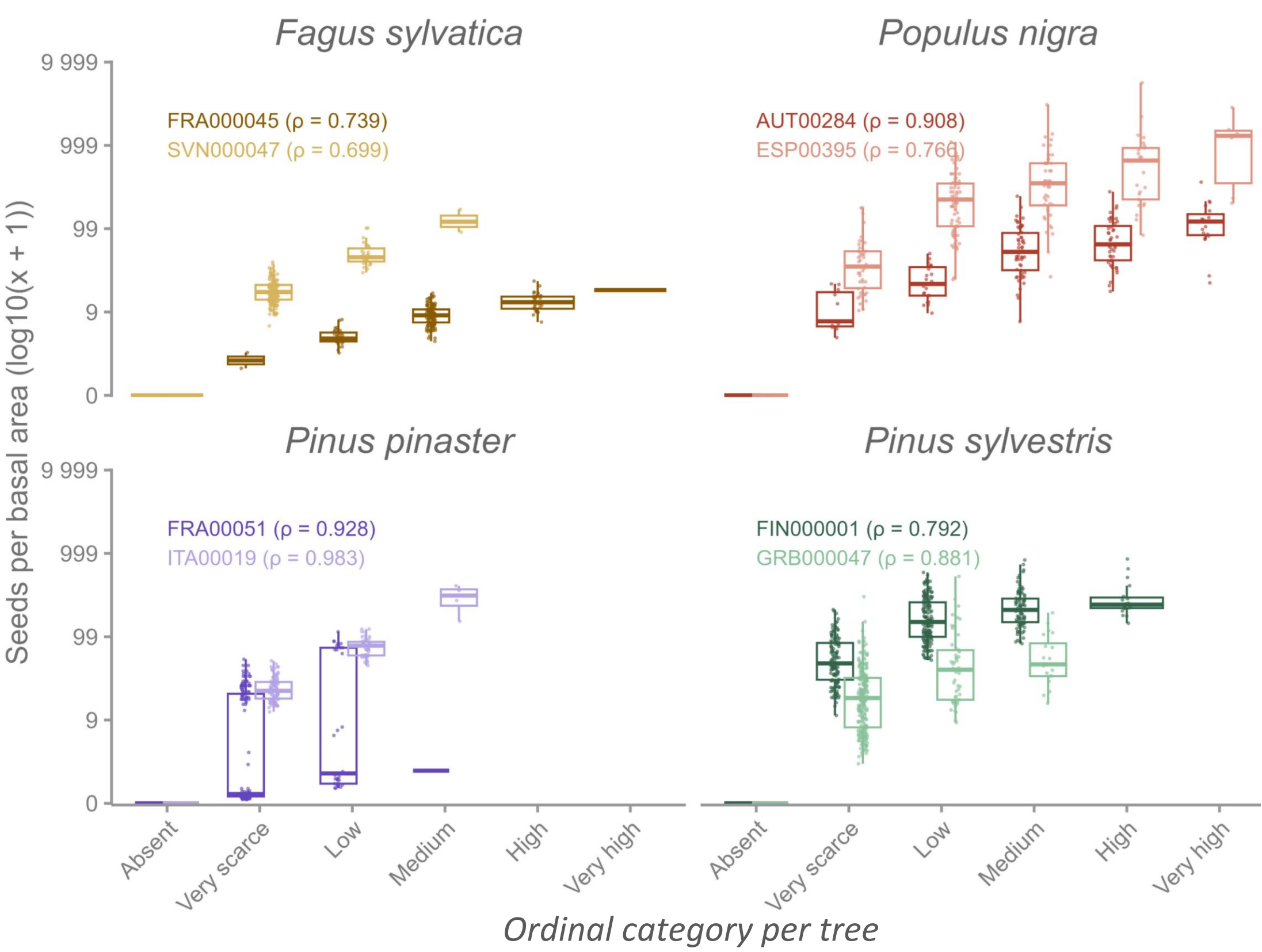
### How seeds look in the images



### Mosaic Quality



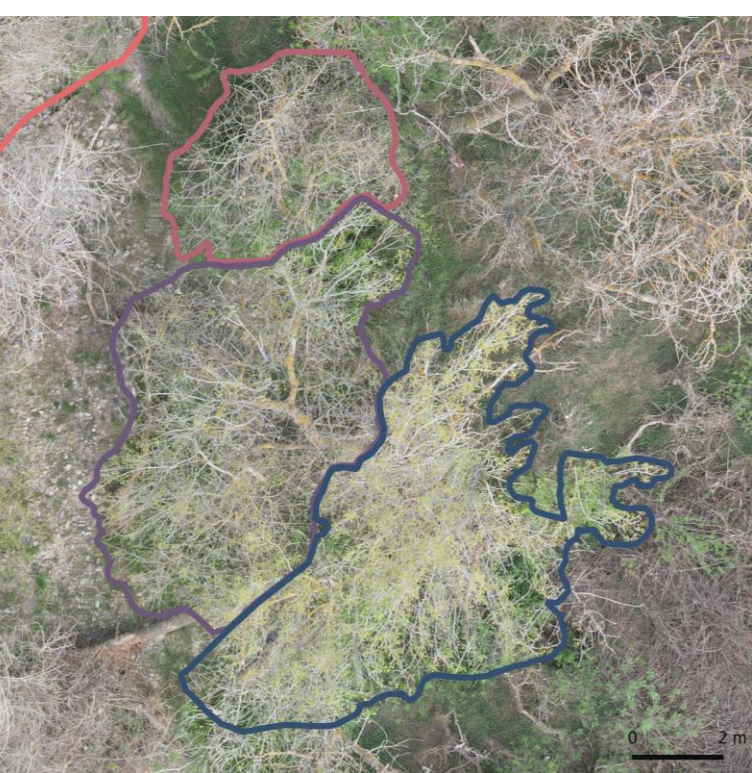
### QA – do image-based fertility classes match seed/BA ratio?



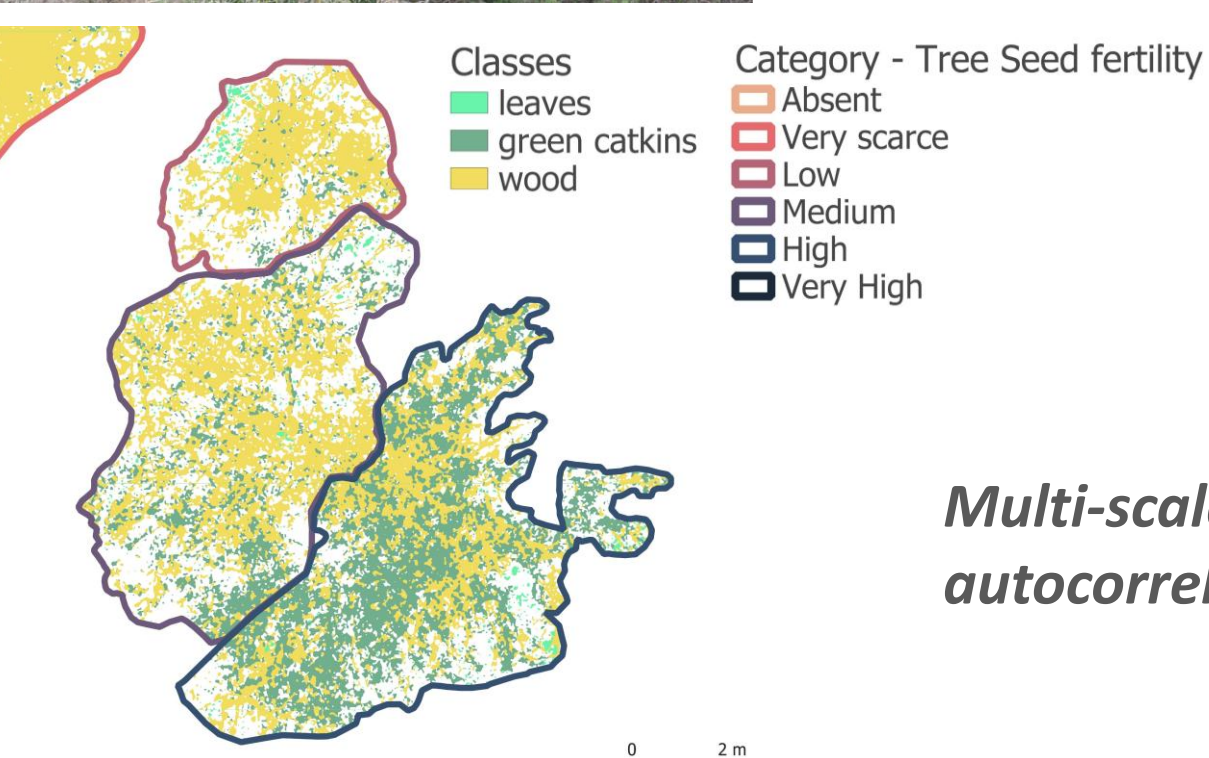
Seeds/BA ratio increases monotonically across fertility classes & species (Spearman  $p = 0,7-0,9$ )

### Seed-fertility maps from crown to stand scale – basis for spatial sampling and genetic interpretation

SPA, Populus Nigra – ML approach

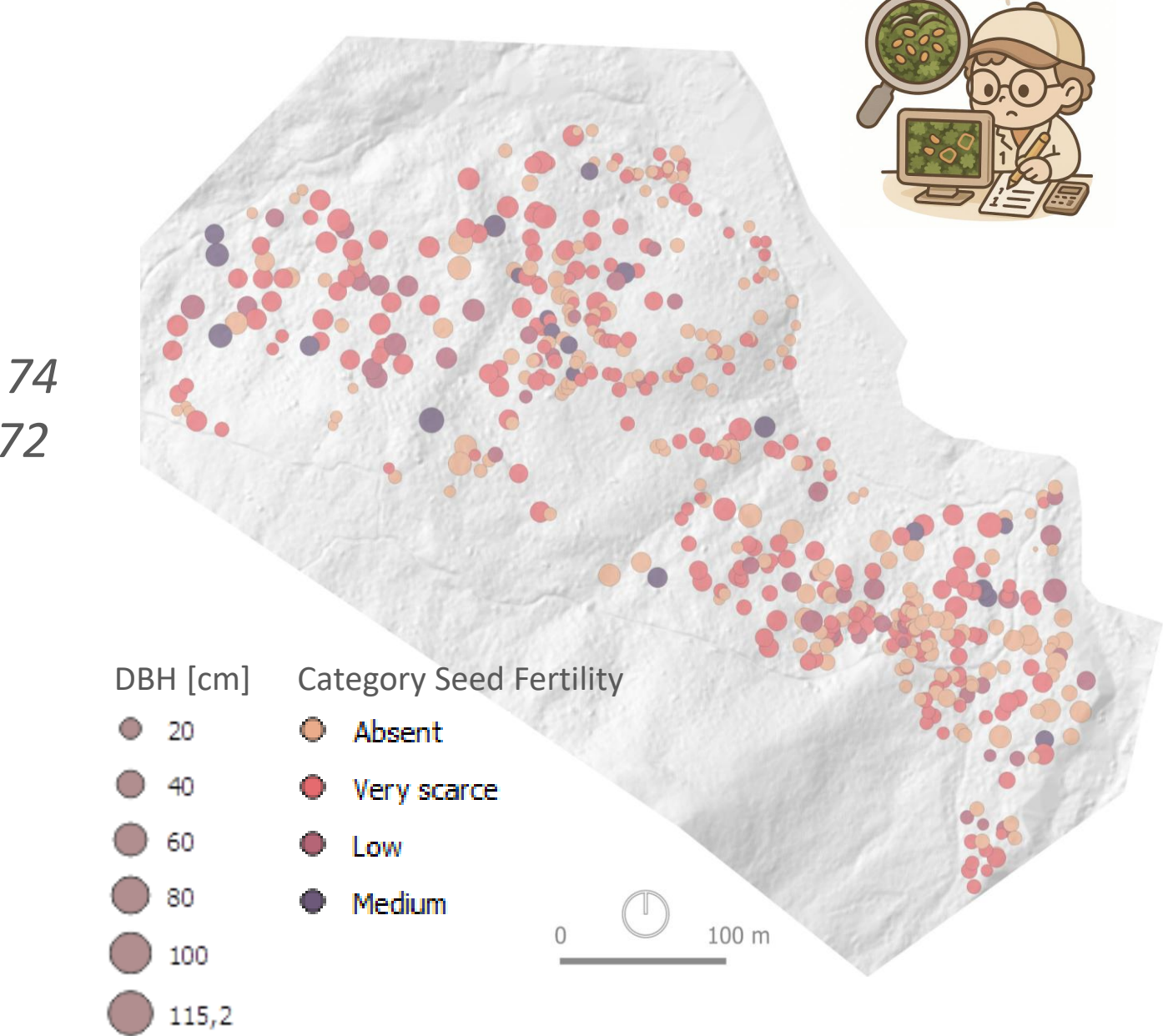


**ML Performance**  
Accuracy: 0.79 | Kappa 0.74  
Precision: 0.73 | Recall 0.72  
F1-Score: 0.72



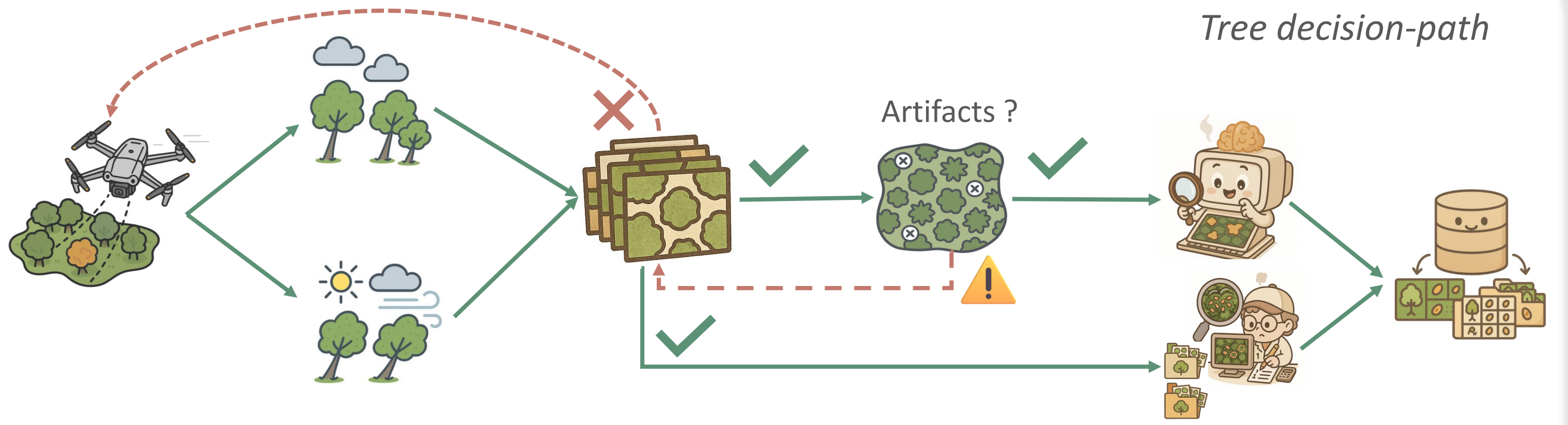
**Multi-scale seed autocorrelation?**

GBR, Pinus Sylvestris – Visual Scoring



**Visual Scoring Performance**  
Fertility categories from semantic interpretation – visual ground truth; subjective by definition

## Outlook



Drone seed mapping is powerful but fragile – it only works in a narrow “good condition” window  
Fertility classes are consistent with seeds counts – higher class means more seeds per basal area across species  
Multiscale seed-fertility maps reveal intra-stand aggregation and provide spatial priors for genetic analysis

### References

- [1] Schuck, A., Van Brusselen, J., Päivinen, R., Häme, T., Kennedy, P., Folving, S., 2002. Compilation of a calibrated European forest map derived from NOAA-AVHRR data. EFI Technical Report 13, European Forest Institute.
- [2] Reudenbach, C. (2022). MetashapeTools: Scripts, utilities and optimized workflows for Agisoft Metashape Software. GitHub. Available at: <https://github.com/gisma/MetashapeTools>
- [3] Meyer, H., & Pebesma, E. (2021). Predicting into unknown space? Estimating the area of applicability of spatial prediction models. Methods in Ecology and Evolution, 12(9), 1620-1633. <https://doi.org/10.1111/2041-210X.13650>

All cartoon-style illustrations were edited using Bilbtree Art Designer

Two pinecone photographs used in the Study Site figure were obtained from iNaturalist.

Aerial images of the study site figure were acquired with our drones, except for site FRA0051, which is a Google Earth Pro screenshot

Forgenius website



Populus Nigra - Gitlab



Pinus Pinaster - Gitlab

