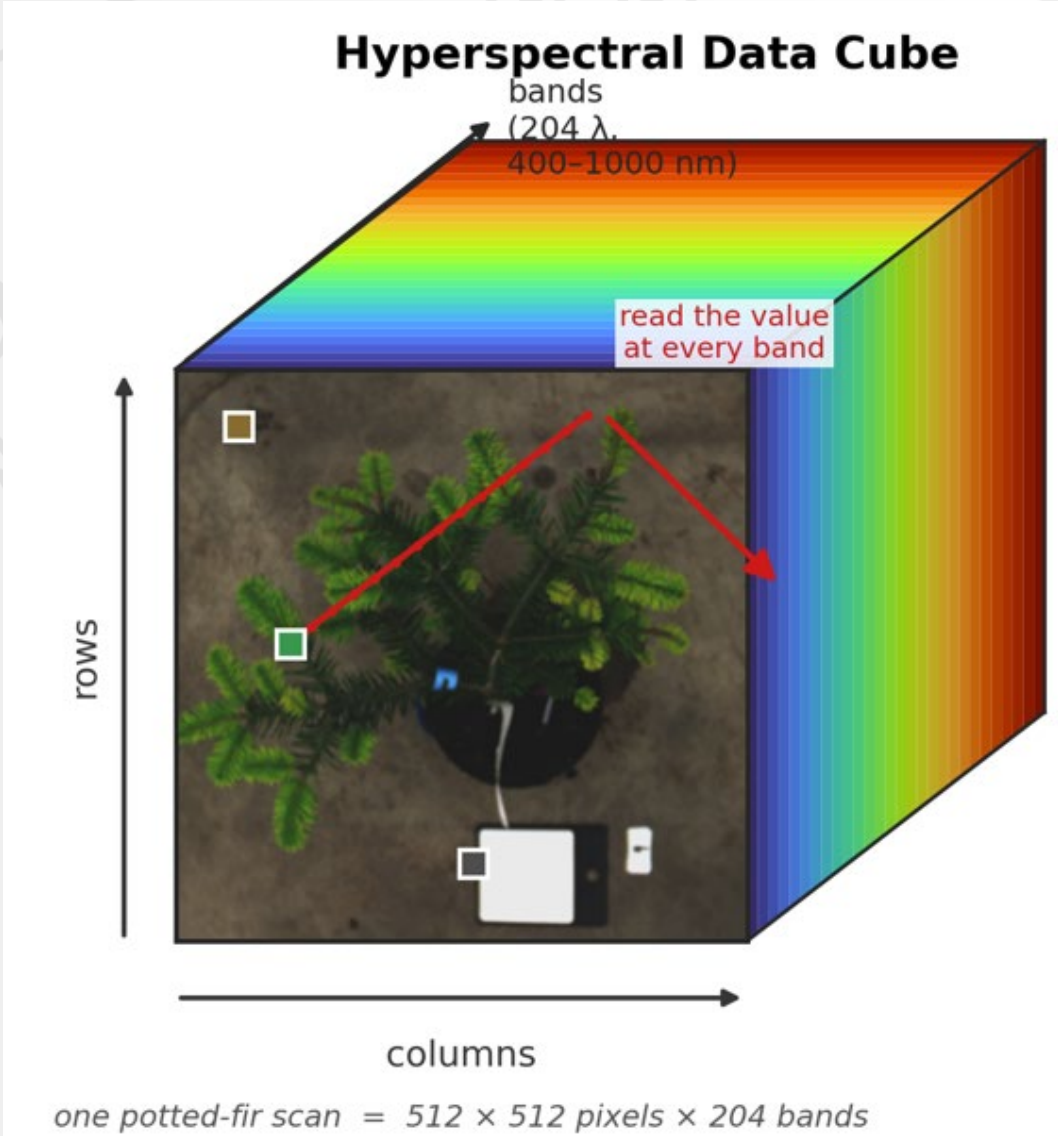
Detection of Silver Fir Woolly Adelgid Infestation in Abies Trees Using Hyperspectral and Multispectral Imagery

Department of Geosciences and Natural Resource Management（IGN）, University of Copenhagen

Kun Zhang, Jing Xu, Saiful Azim & Ole Kim Hansen

UNIVERSITY OF COPENHAGEN



Adelgids damage evaluation methods

Scores

0= no damage

1= some damage

2= severe damage

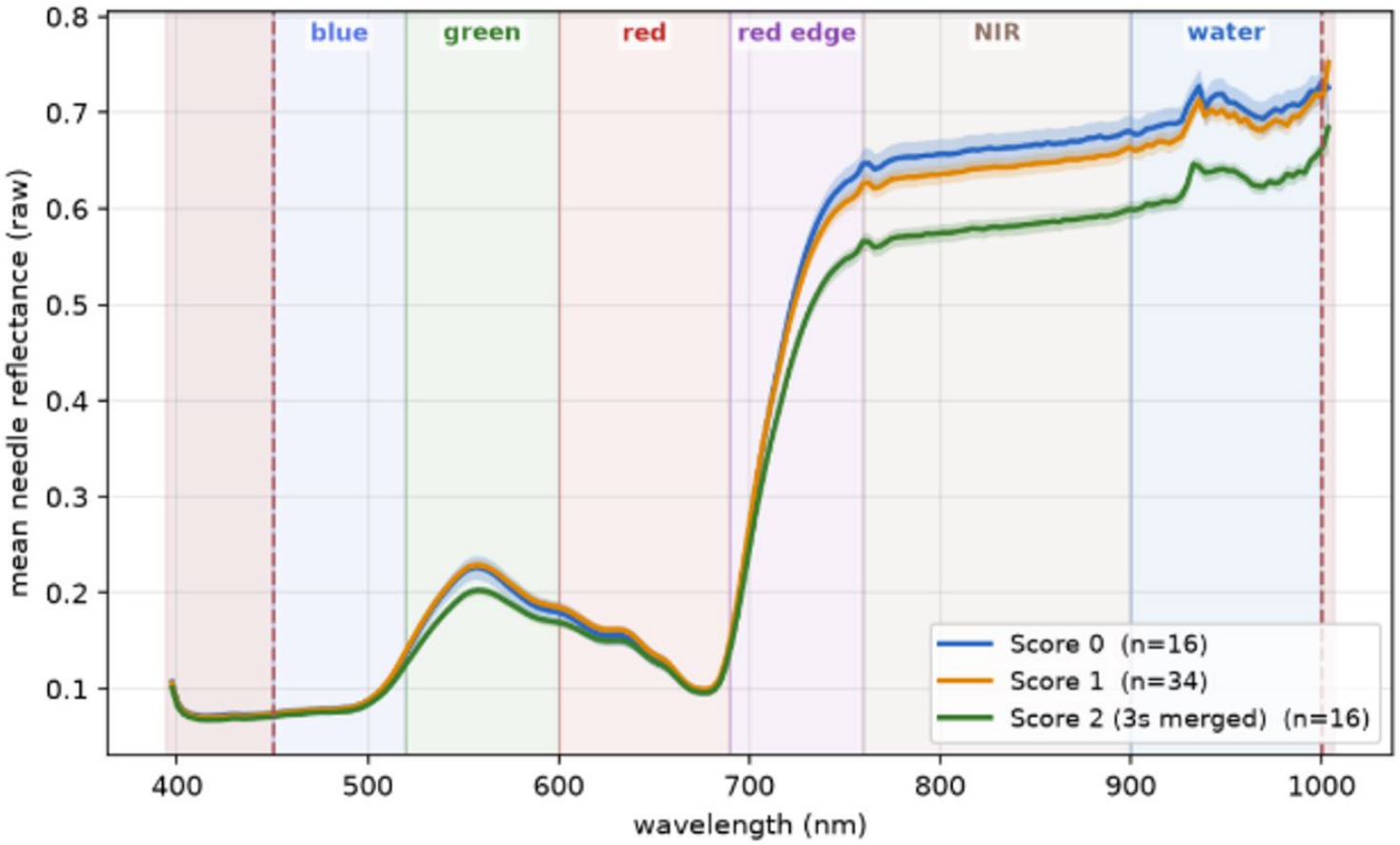


Counting

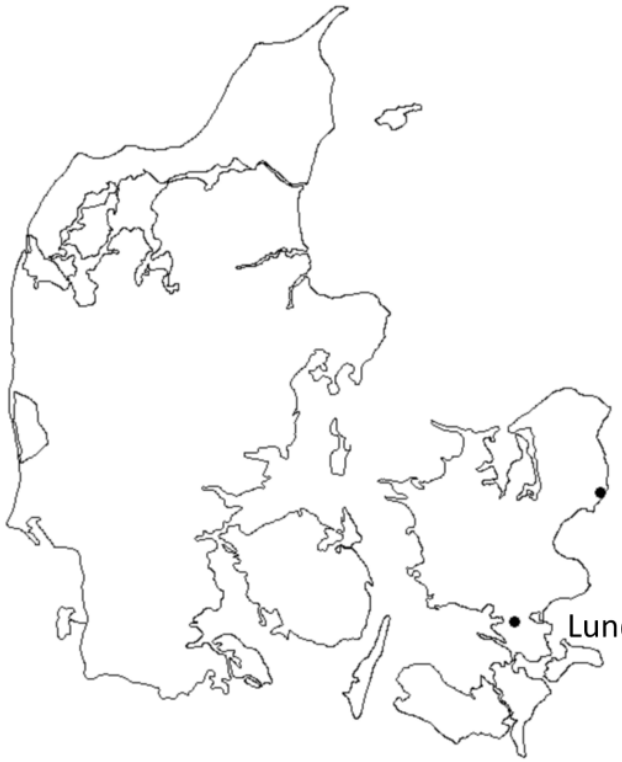


Aim

Identify the wavelength fingerprint of adelgids damage in Nordmann fir trees



Experiment design







SPECIM IQ camera

400-1000 nm
204 spectral bands



Outdoor Validation of Greenhouse-based Hyperspectral Models
17-04-2026

- 2026-01-16
- 2026-01-30
- 2026-02-12
- 2026-02-23
- 2026-03-13

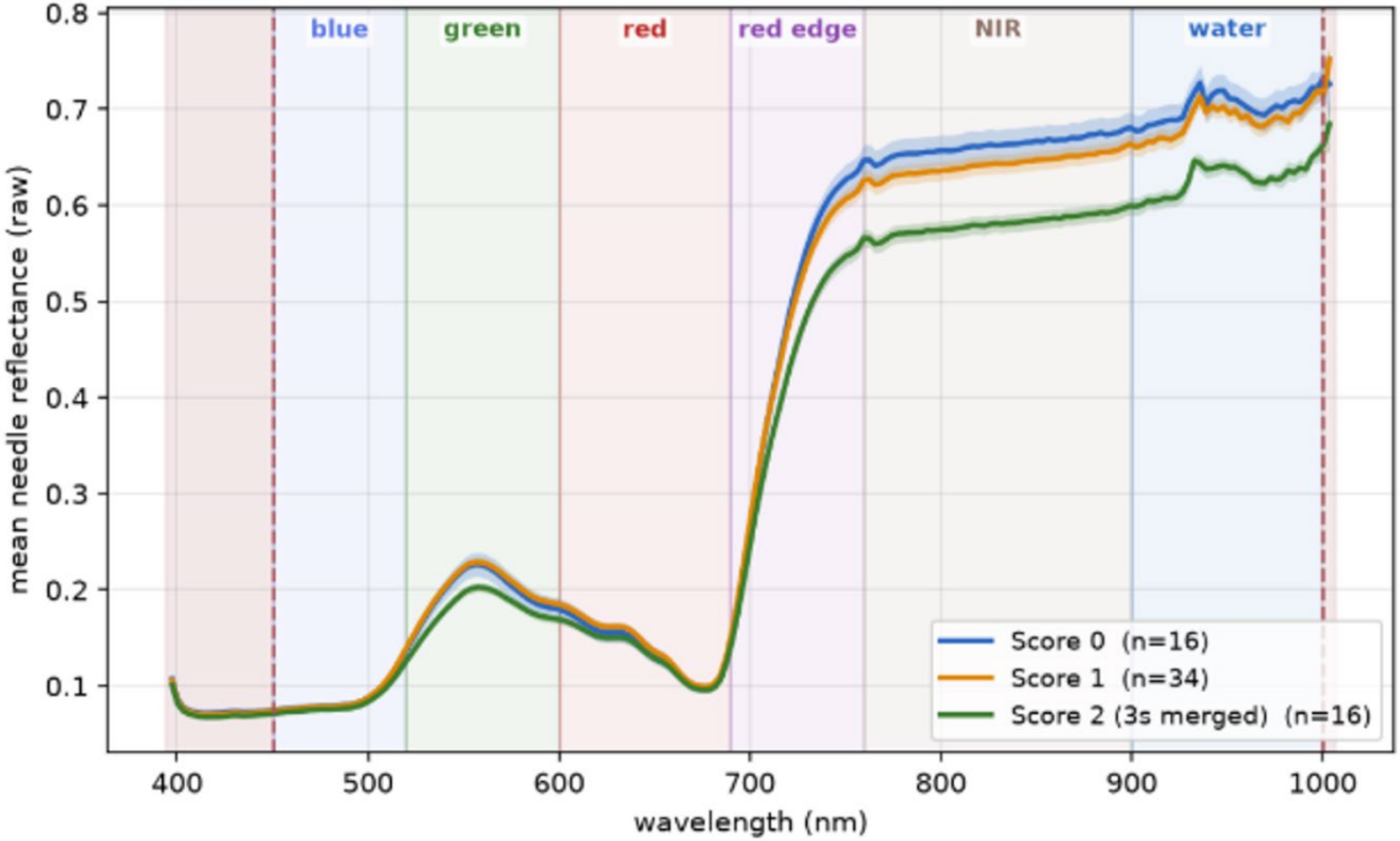
38 trees

- 2026-03-24
- 2026-04-01
- 2026-04-06
- 2026-04-17
- 2026-04-23
- 2026-04-28
- 2026-05-01

66 trees

Band trim

Based on the noise-to-signal per band across the sensor range, of the 204 bands, 183 are used, range from 452.25–997.40 nm.



Analysis pipeline: six steps

1. Segmentation

Find the needles — most of the image is concrete, pot and soil.

2. Extraction

Pull needle pixels into a compact table, so the 214 MB cubes are read once.

3. Preprocessing

Remove sensor noise and brightness differences so needles are comparable.

4. Features

Summarise thousands of pixels into a few numbers per tree.

5. Modelling

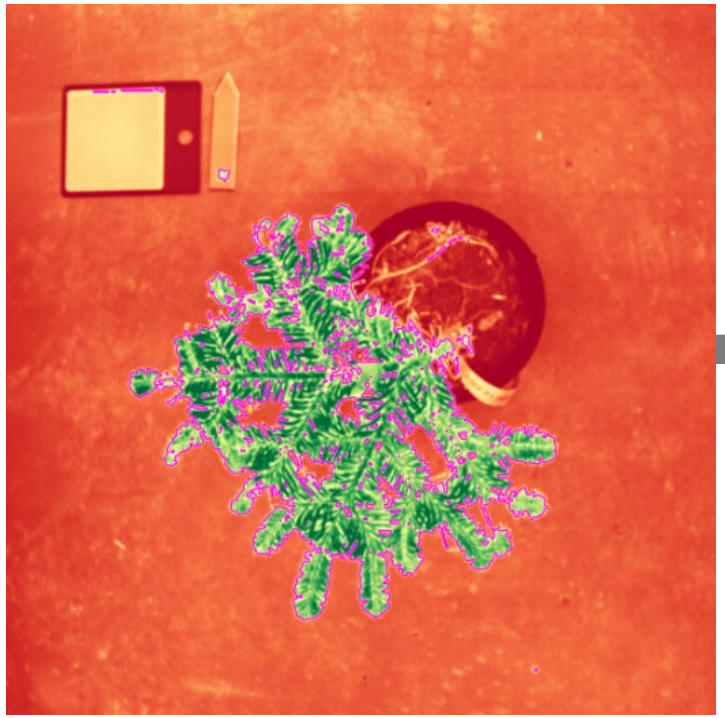
Learn the mapping from spectra to damage; test on unseen trees.

6. Validation

Could pure noise have produced this? Two conclusions changed.

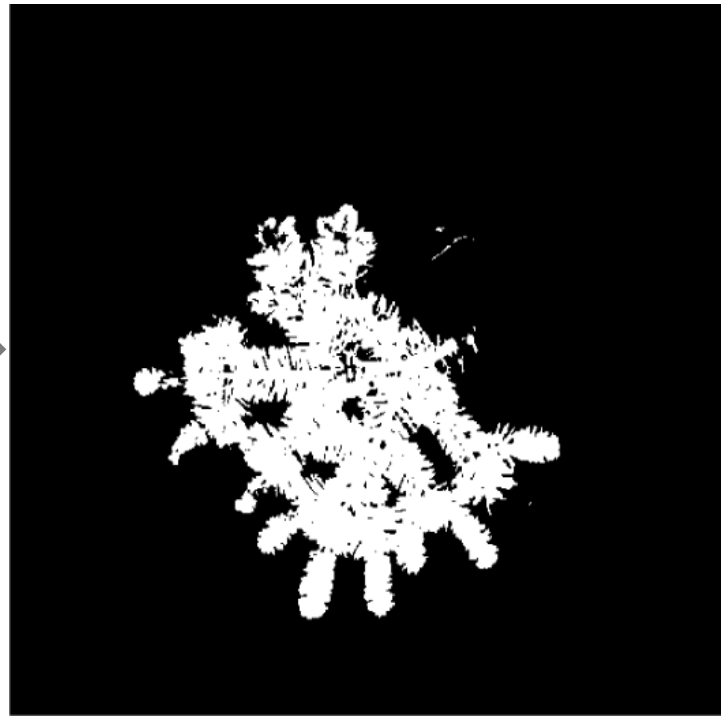
1-Image processing – tree segmentation

A Global PCA mask



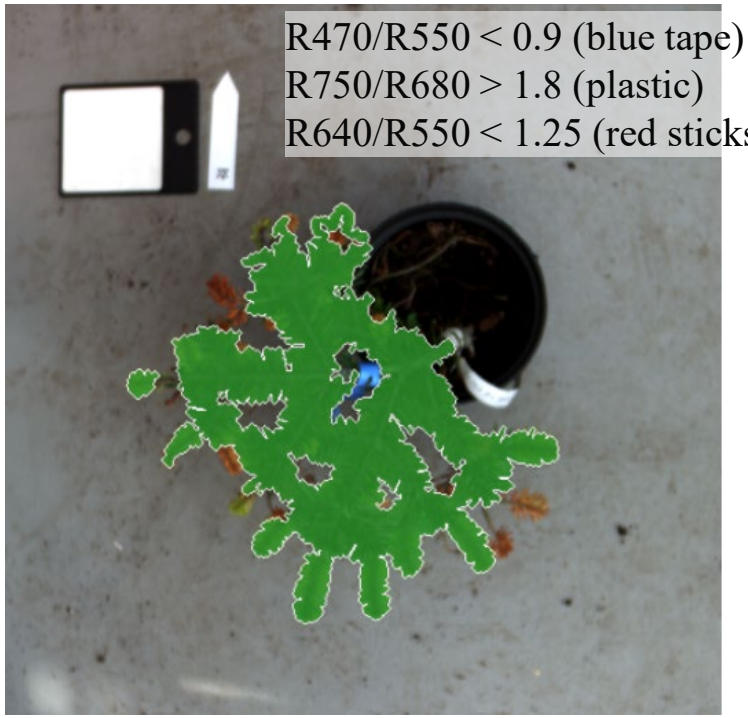
Otsu on the vegetation-correlated PC of the whole image; keeps needle-tip pixels, drops moss/soil/pot.

B NDVI threshold

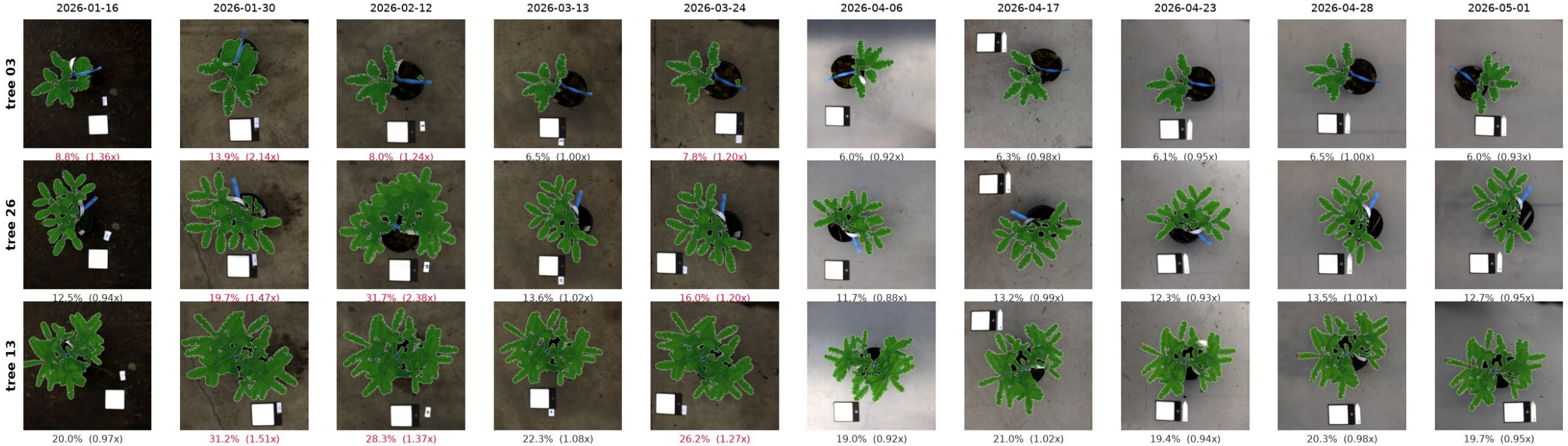


NDVI > 0.30 removes non-living leftovers

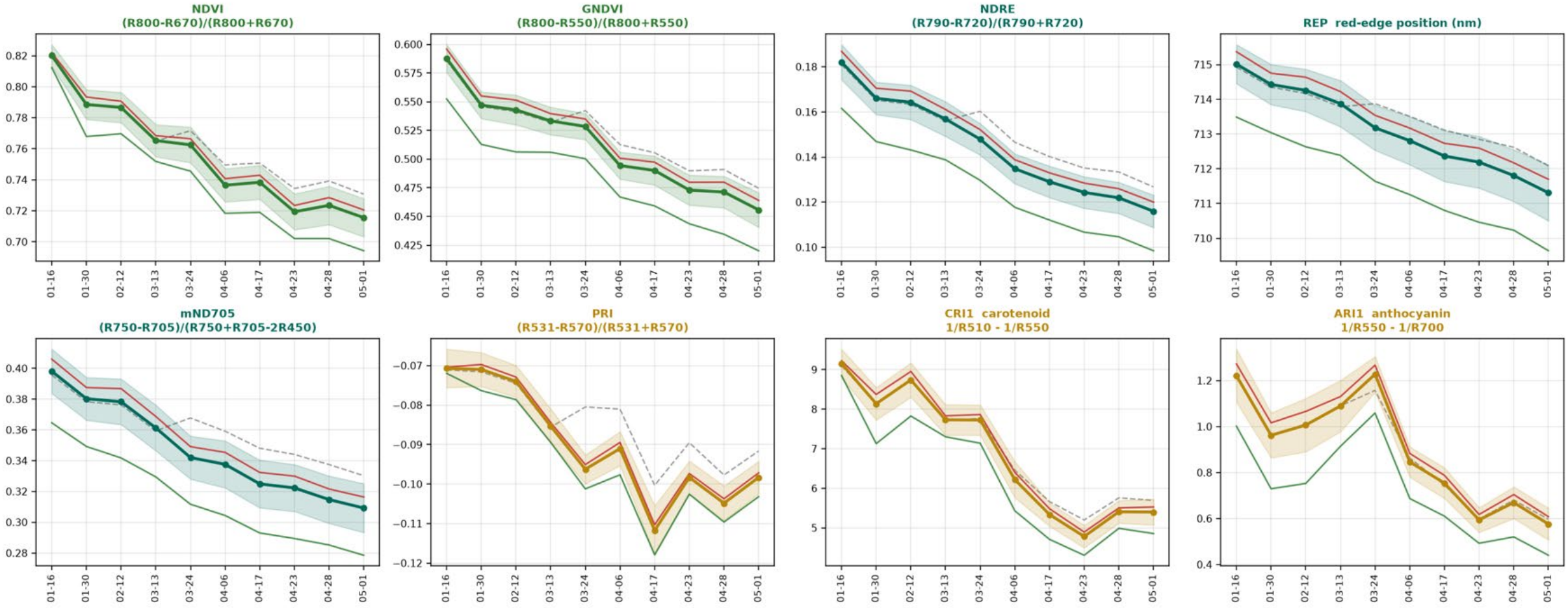
C Ratio rules



Three ratio rules that living needles always satisfy; removes blue tape and red sticks.


2026-01-16
2026-01-30
2026-02-12
2026-03-13
2026-03-24
2026-04-06
2026-04-17
2026-04-23
2026-04-28
2026-05-01
tree 03
8.8% (1.36x)
13.9% (2.14x)
8.0% (1.24x)
6.5% (1.00x)
7.8% (1.20x)
6.0% (0.92x)
6.3% (0.98x)
6.1% (0.95x)
6.5% (1.00x)
6.0% (0.93x)
tree 26
12.5% (0.94x)
19.7% (1.47x)
31.7% (2.38x)
13.6% (1.02x)
16.0% (1.20x)
11.7% (0.88x)
13.2% (0.99x)
12.3% (0.93x)
13.5% (1.01x)
12.7% (0.95x)
tree 13
20.0% (0.97x)
31.2% (1.51x)
28.3% (1.37x)
22.3% (1.08x)
26.2% (1.27x)
19.0% (0.92x)
21.0% (1.02x)
19.4% (0.94x)
20.3% (0.98x)
19.7% (0.95x)

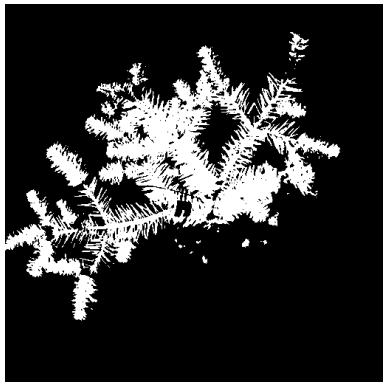
Vegetation indices development across dates

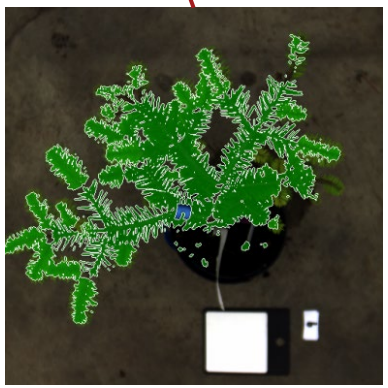


Adelgid Infestation Severity (AIS)

$$AIS = \frac{N_{adelgids}}{A_{plant}}$$

No. pixels





Level	AIS	Plant condition
0	0-20	Healthy plants with no visible pest damage, or only a few scattered adelgids; leaves show no curling, wrinkling, or chlorosis.
1	20-150	Some leaves exhibit curling or wrinkling symptoms caused by adelgid infestation.
2	>150	Most leaves show severe curling and wrinkling, and plant growth is significantly inhibited.

Classification criteria for AIS

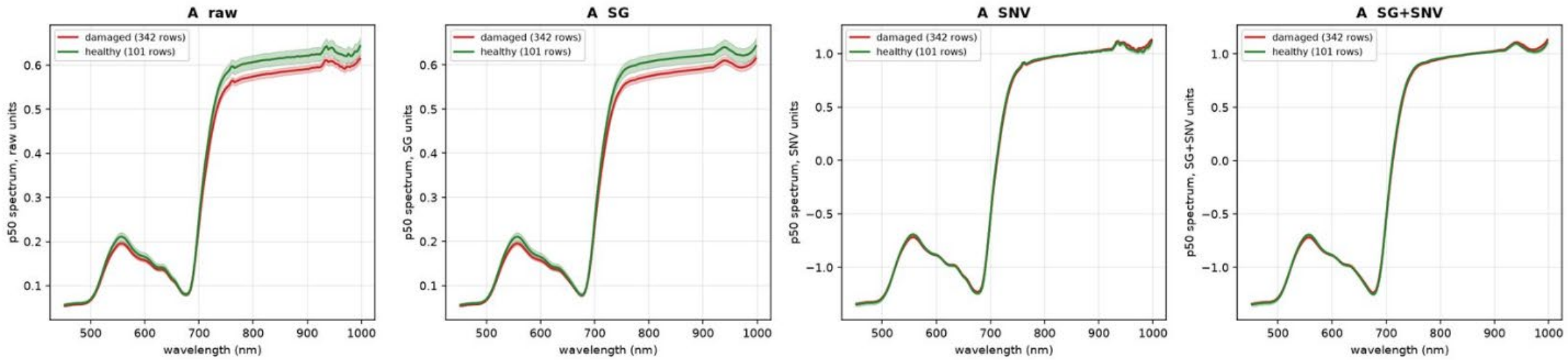


Representative examples of adelgid infestation severity levels in Abies plants.
(A) Level 0; (B) Level 1; (C) Level 2.

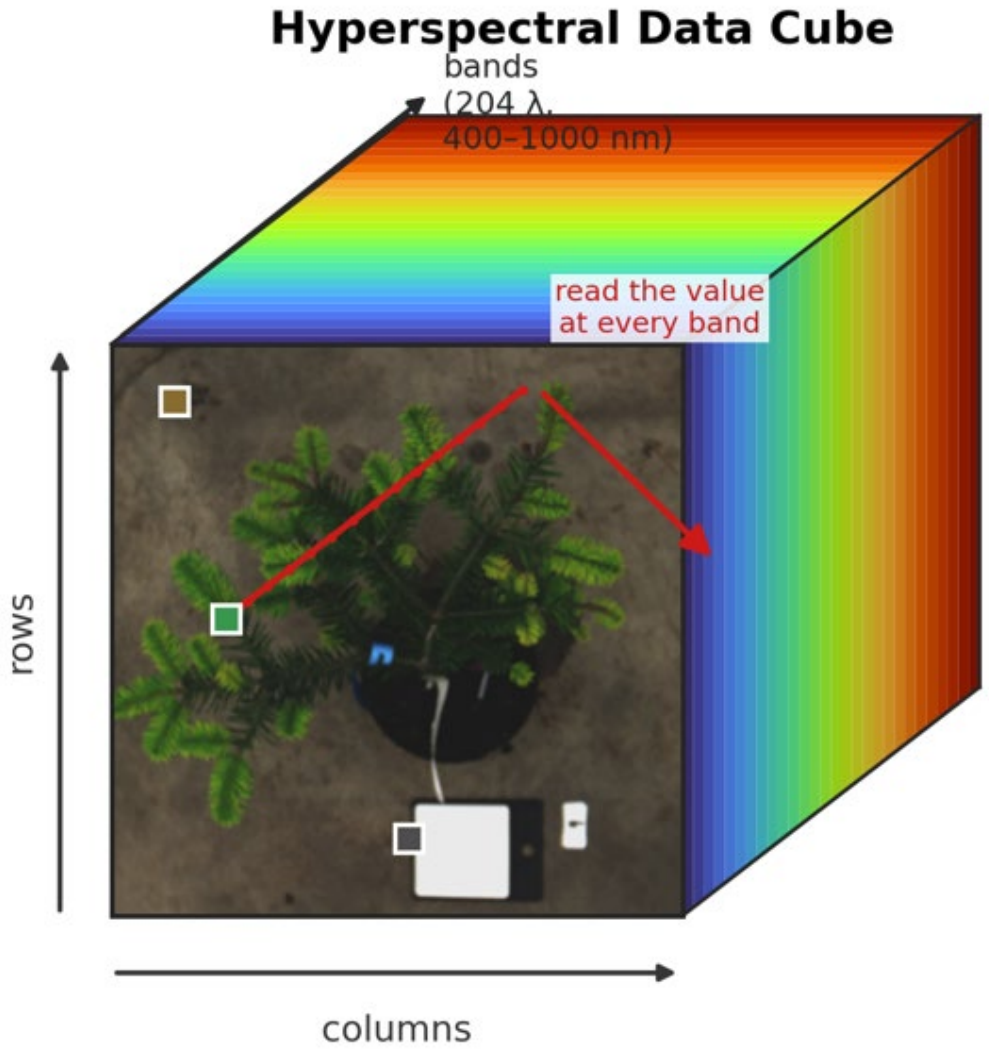
Preprocessing

In raw units the two classes separate mostly by NIR brightness- set by how the canopy happened to be lit and oriented that day.

- **SG smoothing (Savitzky–Golay)** remove noise, neighboring wavelength bands jitter up and down randomly, making the curve spiky.
- **SNV (Standardized Normal Variate)** remove brightness differences between pixels/samples that have nothing to do with chemistry. x_snv = (x - mean(x)) / std(x)



From mask to model input



183 bands

The mask yields tens of thousands of needle pixels per tree, and the model needs one row.

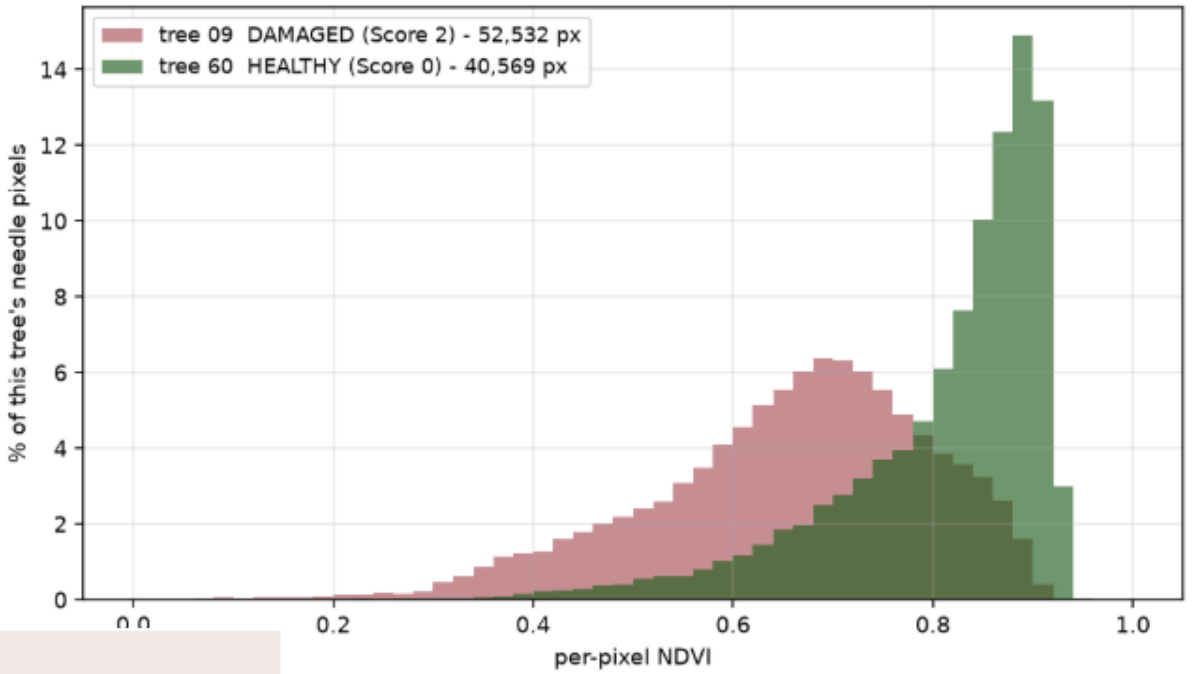
Adelgid damage is patchy. A tree is not uniformly sick; parts of its canopy are. Averaging the needle pixels therefore destroys the signal.

Damaged-pixel fraction

Fraction of canopy below a threshold.

50 bin heights: what % of pixels fall in 0.00–0.02, 0.02–0.04, and so on.

50 × 6 indices = 300 columns.



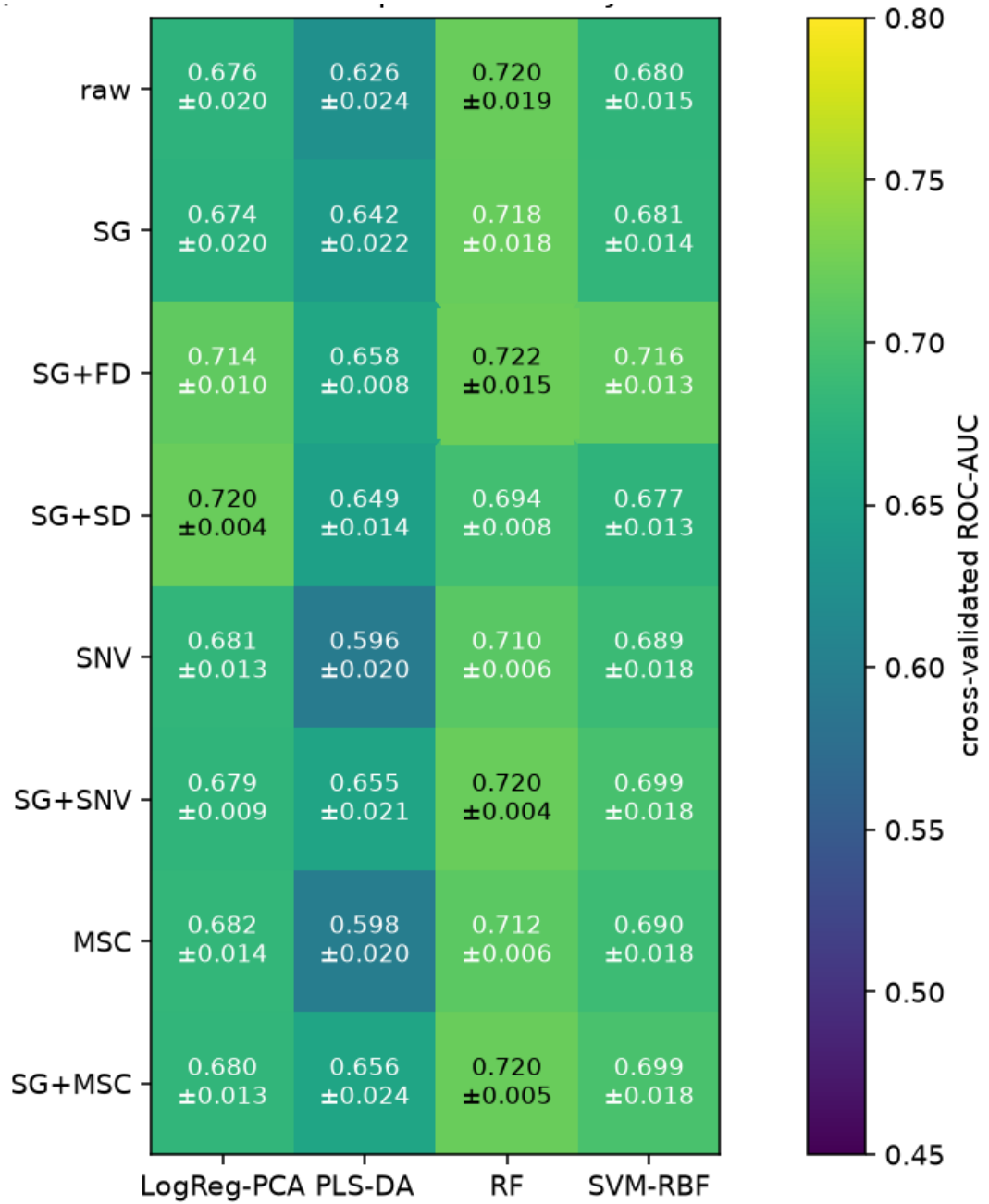
Index	Potential information
NDVI	vegetation vigor/greenness
GNDVI	chlorophyll-related vegetation response
NDRE	chlorophyll/stress, particularly useful in dense vegetation
mND705	red-edge/chlorophyll sensitivity
PSRI	senescence/stress-related pigment changes
PRI	photosynthetic/light-use-efficiency-related changes

Modeling

A Random Forest (RF) is an ensemble machine-learning model made up of many decision trees.

the model is essentially learning:
Given the distribution of spectral-index values across a tree's canopy, how likely is that tree to be adelgid-damaged?

A Random Forest does not rely on one tree. It builds many trees, each seeing somewhat different training observations and subsets of variables.

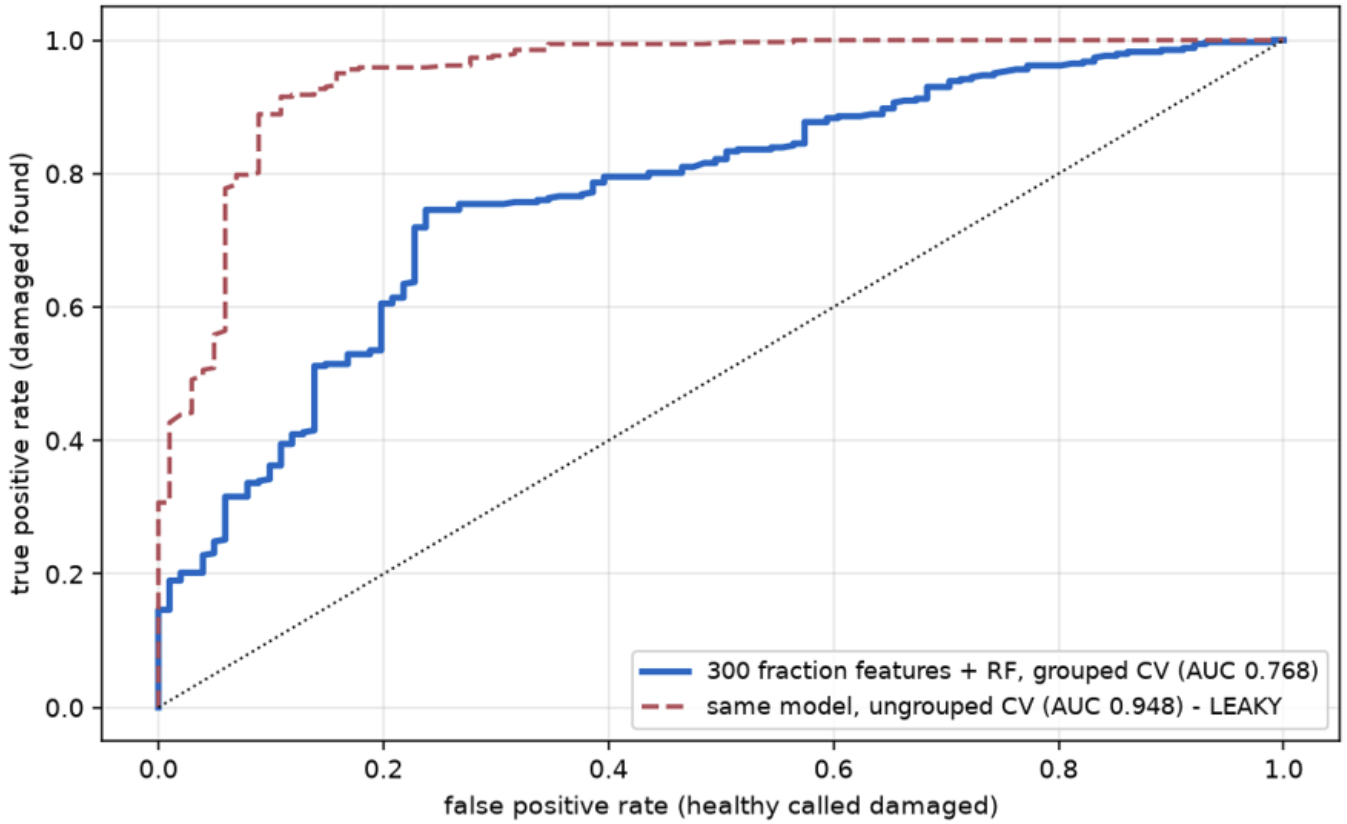


Validation

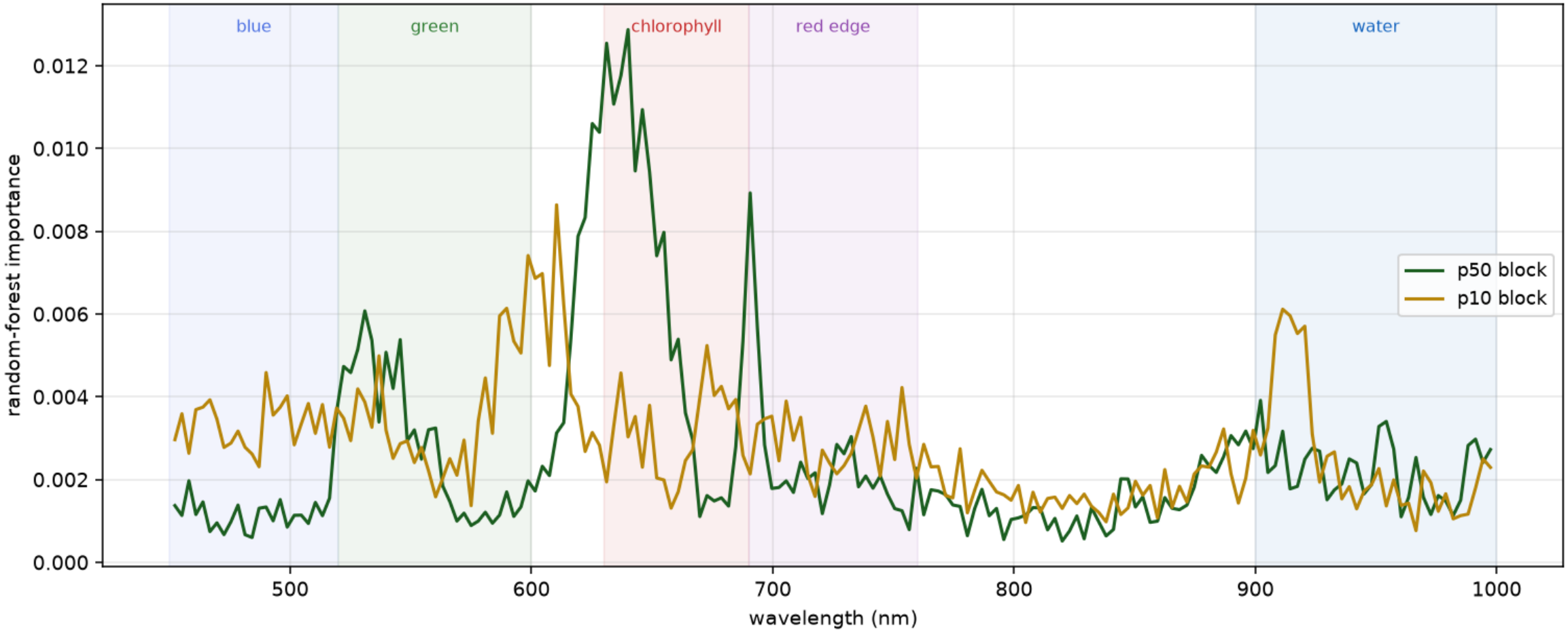
Validation strategy: GroupKFold

- Split: 5 folds

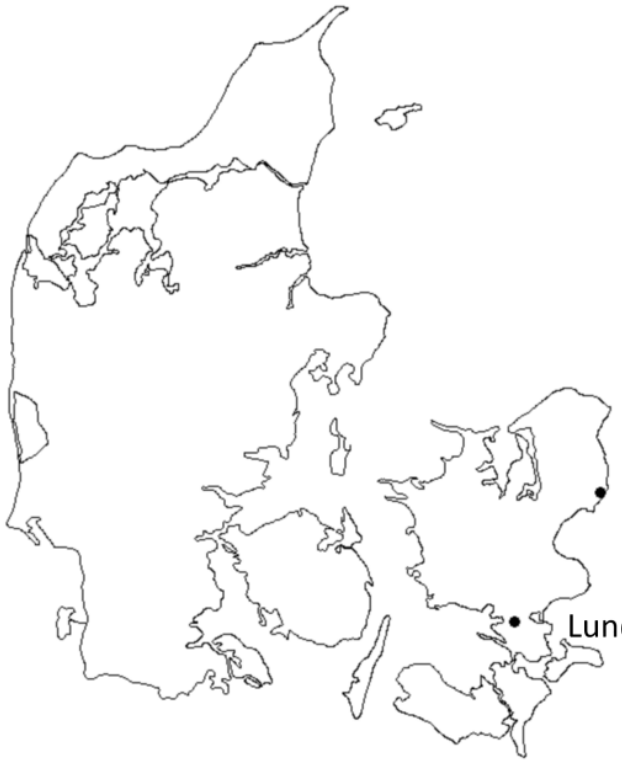
- AUC = 0.768 (76.8% of random (damaged, healthy) pairs are ordered correctly



Which wavelengths separate trees



Materials







Experimental Site

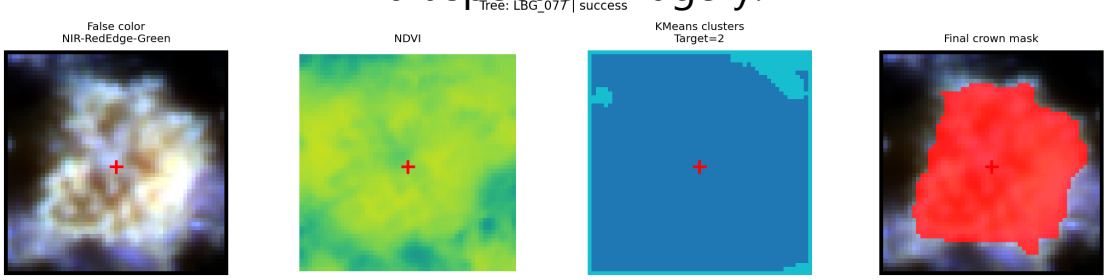


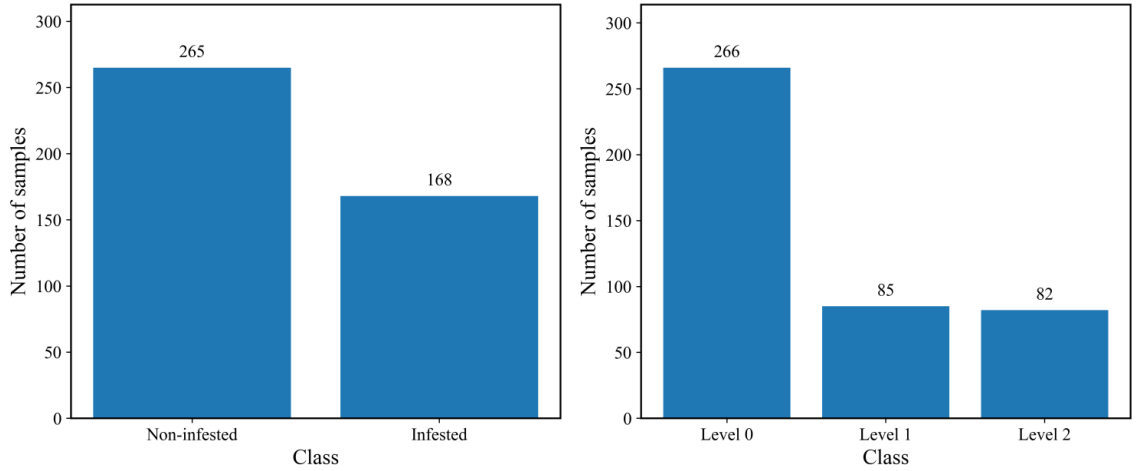
DJI Mavic 3M

UAV Multispectral Image-based Classification of adelgid Infestation

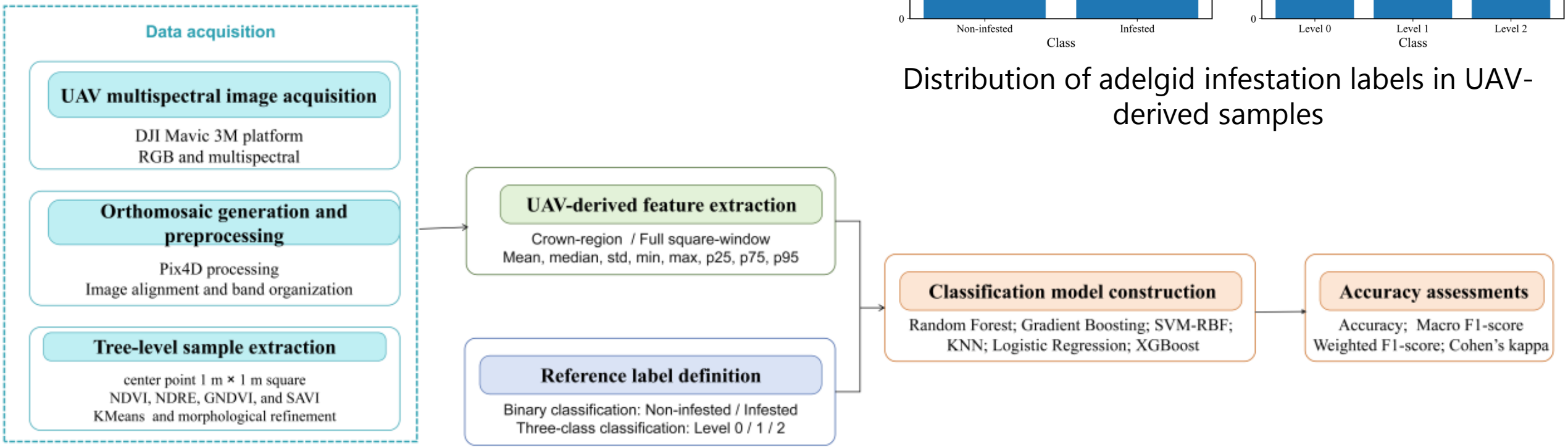
Workflow

Example of tree-level sample extraction from UAV multispectral imagery.





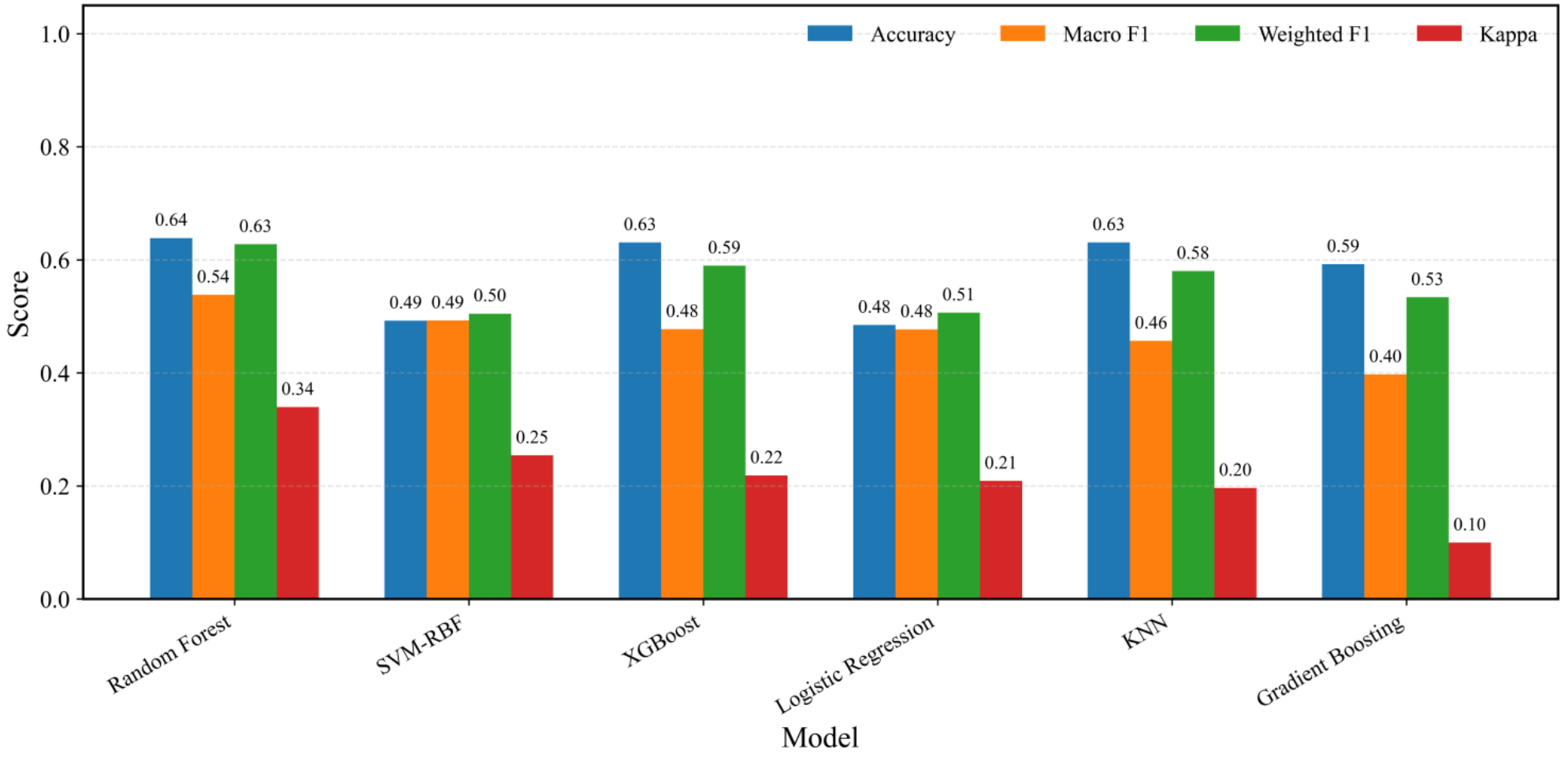
Distribution of adelgid infestation labels in UAV-derived samples



UAV Multispectral Image-based Classification of adelgid Infestation

Result

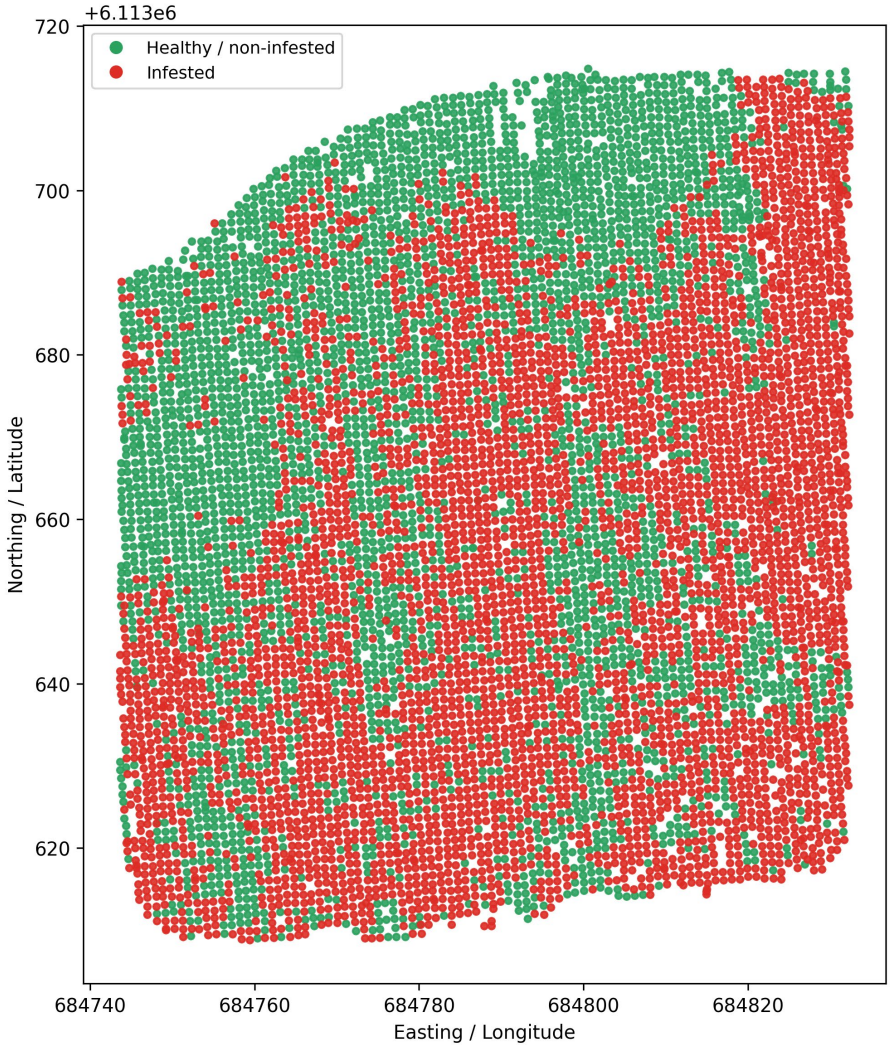
Three-class Classification of Adelgid Infestation Severity



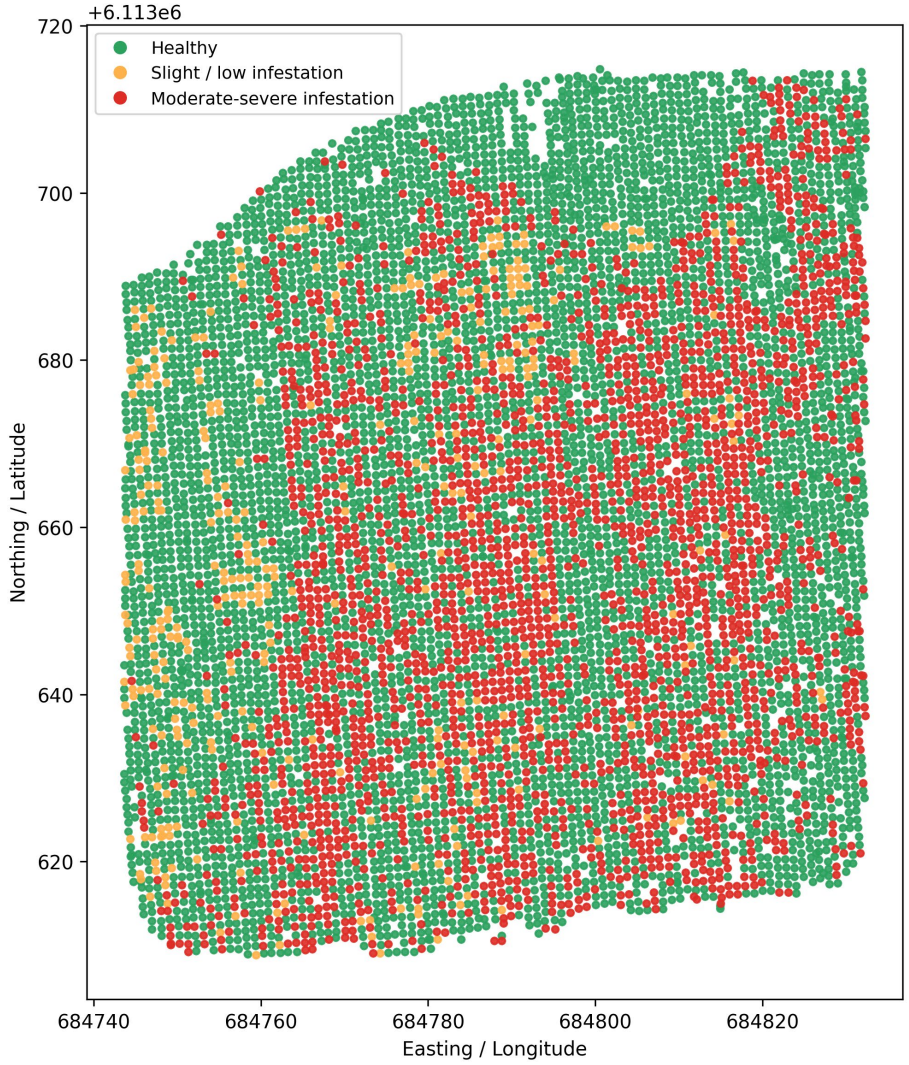
UAV Multispectral Image-based Classification of adelgid Infestation

Tree-level Prediction Map of Adelgid Infestation

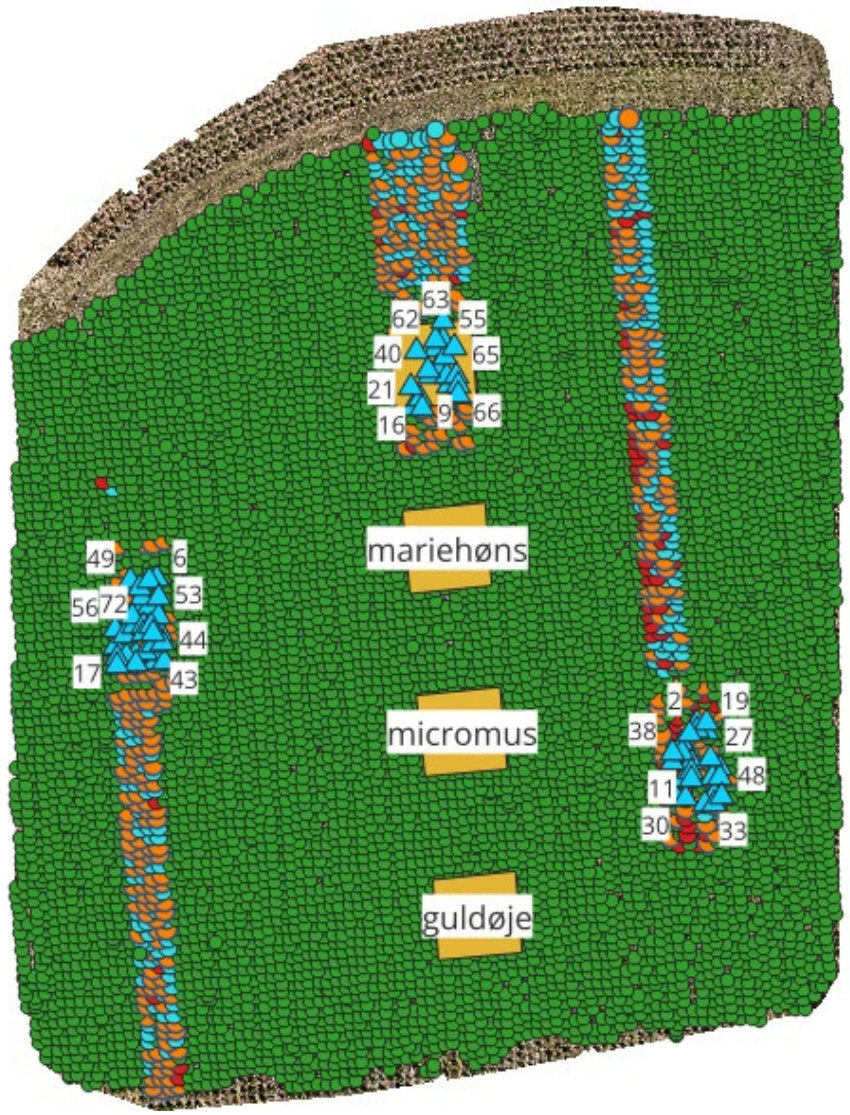
Binary Classification



Three-class Classification






63
62
55
40
65
21
9
66
16
mariehøns
49
6
56
72
53
44
17
43
micromus
2
19
38
27
48
11
30
33
guldøje