Mapping baobab populations across savanna landscapes: evidence for an optimal intermediate spatial grain

Chafika Phiri

Supervisors: Dr Andrew Cunliffe, Dr Hugh Graham, Dr. Sarah Venter, Dr Dawn Cory-Toussaint, Prof. Dave Hodgson.

MOTIVATION

- Millions of people across Africa depend on baobabs for income, nutrition and traditional medicine.
- Concerns of increased threats by land-use change, climate change and overutilisation.
- Information on their spatial distribution is crucial to support sustainable management.

Image source: Sarah &ABA

MOTIVATION

- Acquiring information at scale is challenging

Field Surveys

Slow

Costly

Limited

✓ Stakeholders are interested in knowing population estimates to inform production

- **But landscape-scale information remains scarce**

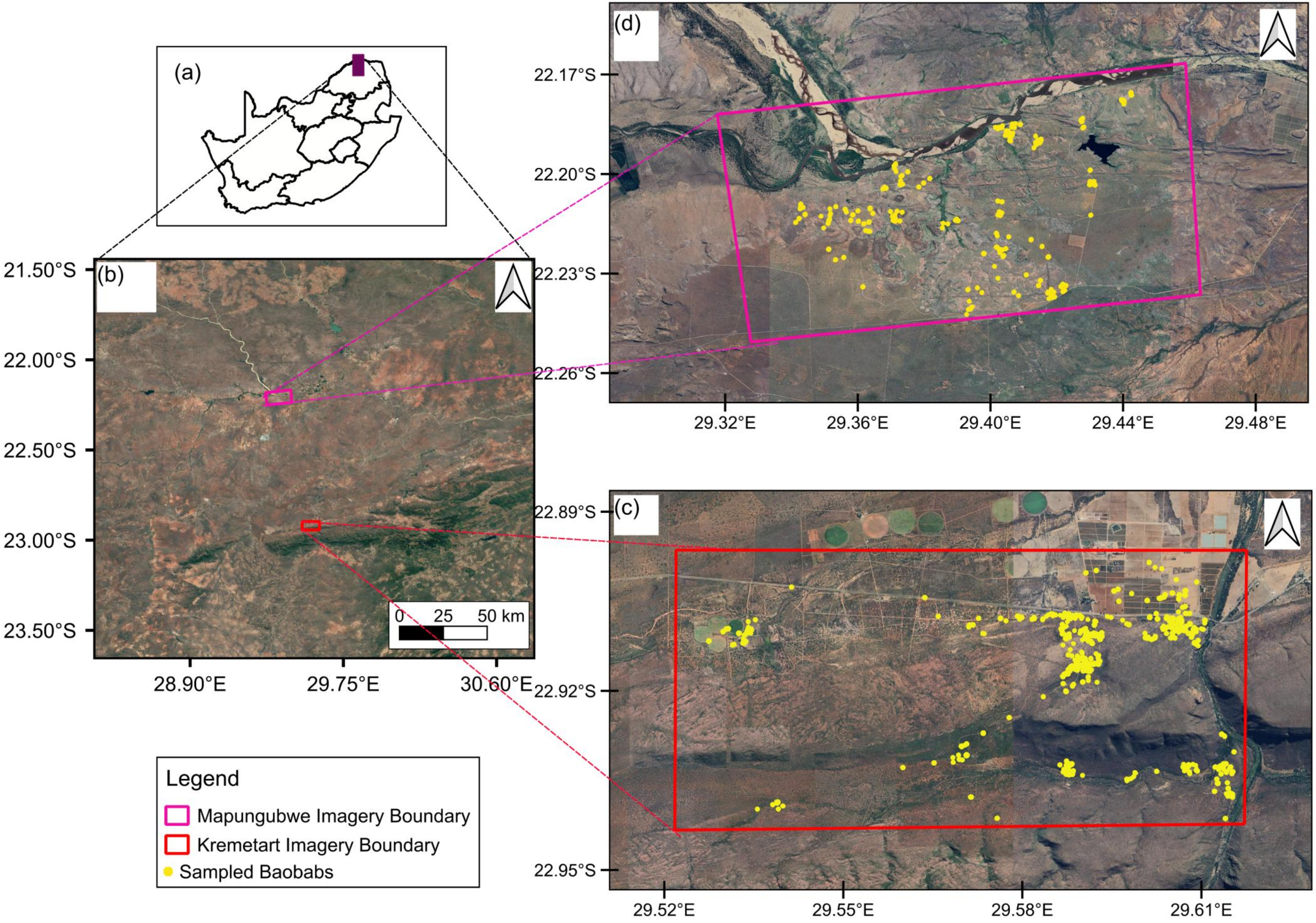
AIM

- To evaluate machine learning (U-Net) modelling approaches and satellite data to map baobab distribution

Research Questions

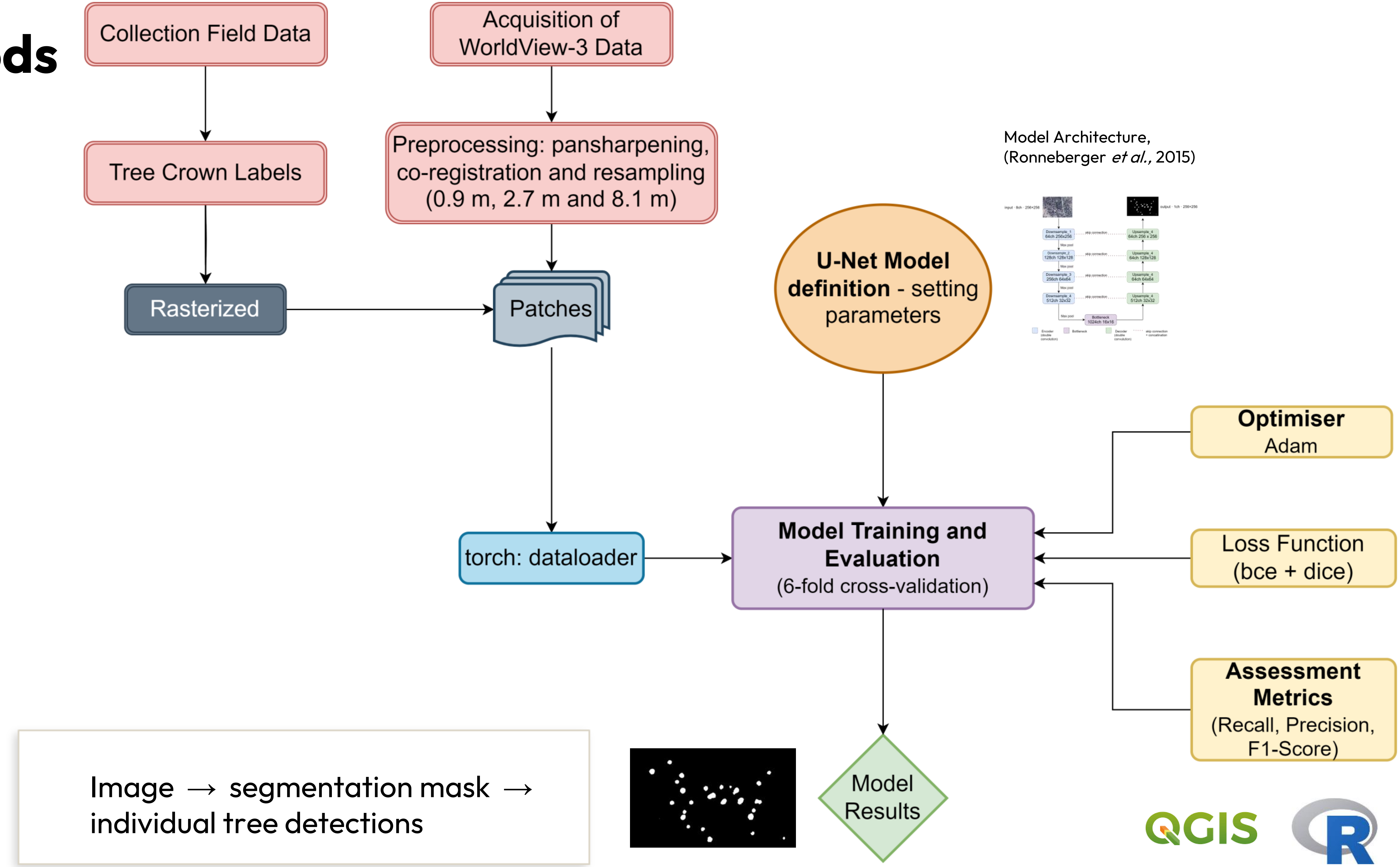
1. Does the U-Net model's performance differ with the spatial grain of imagery?
2. Does baobab canopy size influence U-Net model performance?
3. Does using multi-seasonal imagery improve the U-Net model performance?
4. Does the landscape complexity influence the U-Net model performance?

Study Sites



(a)
(b)
(c)
(d)
21.50°S
22.00°S
22.50°S
23.00°S
23.50°S
28.90°E
29.75°E
30.60°E
0 25 50 km
22.17°S
22.20°S
22.23°S
22.26°S
29.32°E
29.36°E
29.40°E
29.44°E
29.48°E
22.89°S
22.92°S
22.95°S
29.52°E
29.55°E
29.58°E
29.61°E
Legend
Mapungubwe Imagery Boundary
Kremetart Imagery Boundary
Sampled Baobabs

Methods


Collection Field Data
Acquisition of WorldView-3 Data
Tree Crown Labels
Preprocessing: pansharpening, co-registration and resampling (0.9 m, 2.7 m and 8.1 m)
Rasterized
Patches
Model Architecture, (Ronneberger et al., 2015)
U-Net Model definition - setting parameters
torch: dataloader
Model Training and Evaluation (6-fold cross-validation)
Optimiser Adam
Loss Function (bce + dice)
Assessment Metrics (Recall, Precision, F1-Score)
Model Results
Image → segmentation mask → individual tree detections

Experiments run across four factors with Worldview -3 imagery

Multiple spatial grains

Canopy-size classes

Seasonal combinations

Three land use types

➢ Same model — only one factor varied at a time.

Experiments run across four factors with Worldview -3 imagery

- Multiple spatial grains
- Canopy-size classes
- Seasonal combinations
- Three land use types

➢ Same model — only one factor varied at a time.

How we measured performance

Precision

Of the detected trees, how many are real?

Recall

Of real trees, how many did we find?

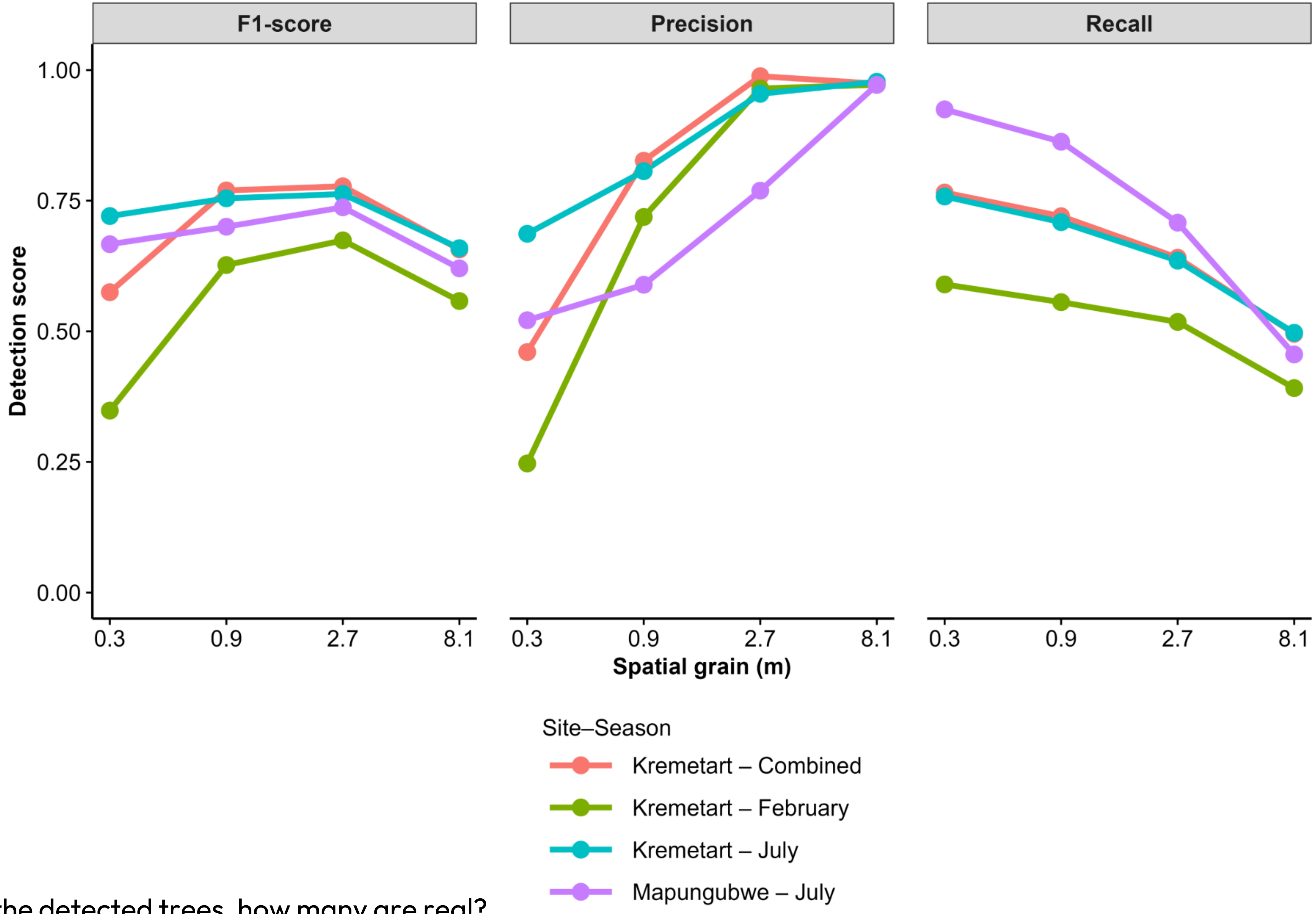
F1-score

Harmonic mean of the two

RESULTS

Finding 1

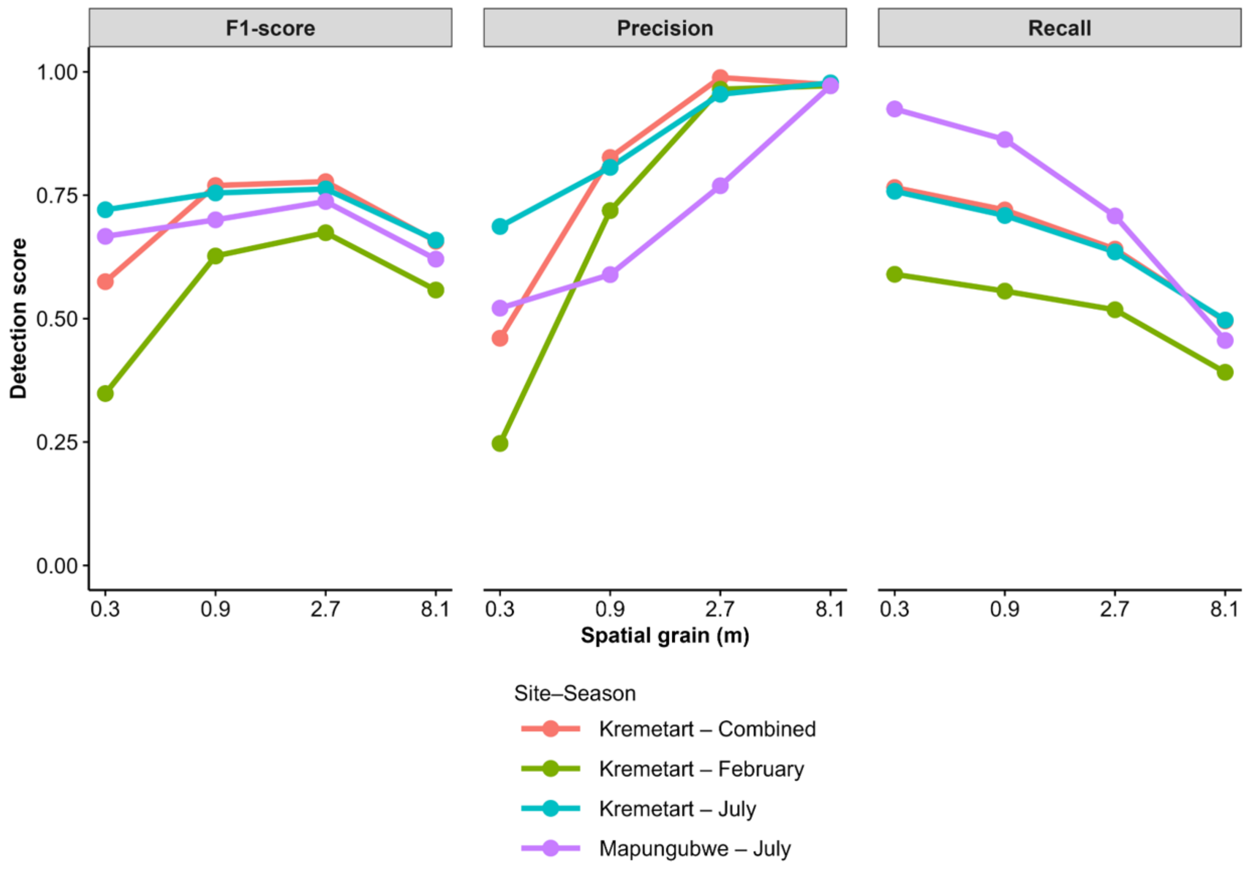
U-Net baobab detection performance peaks at intermediate spatial grain



Precision = Of the detected trees, how many are real?
Recall = Of real trees, how many did we find?
F1-Score = Harmonic mean of the two

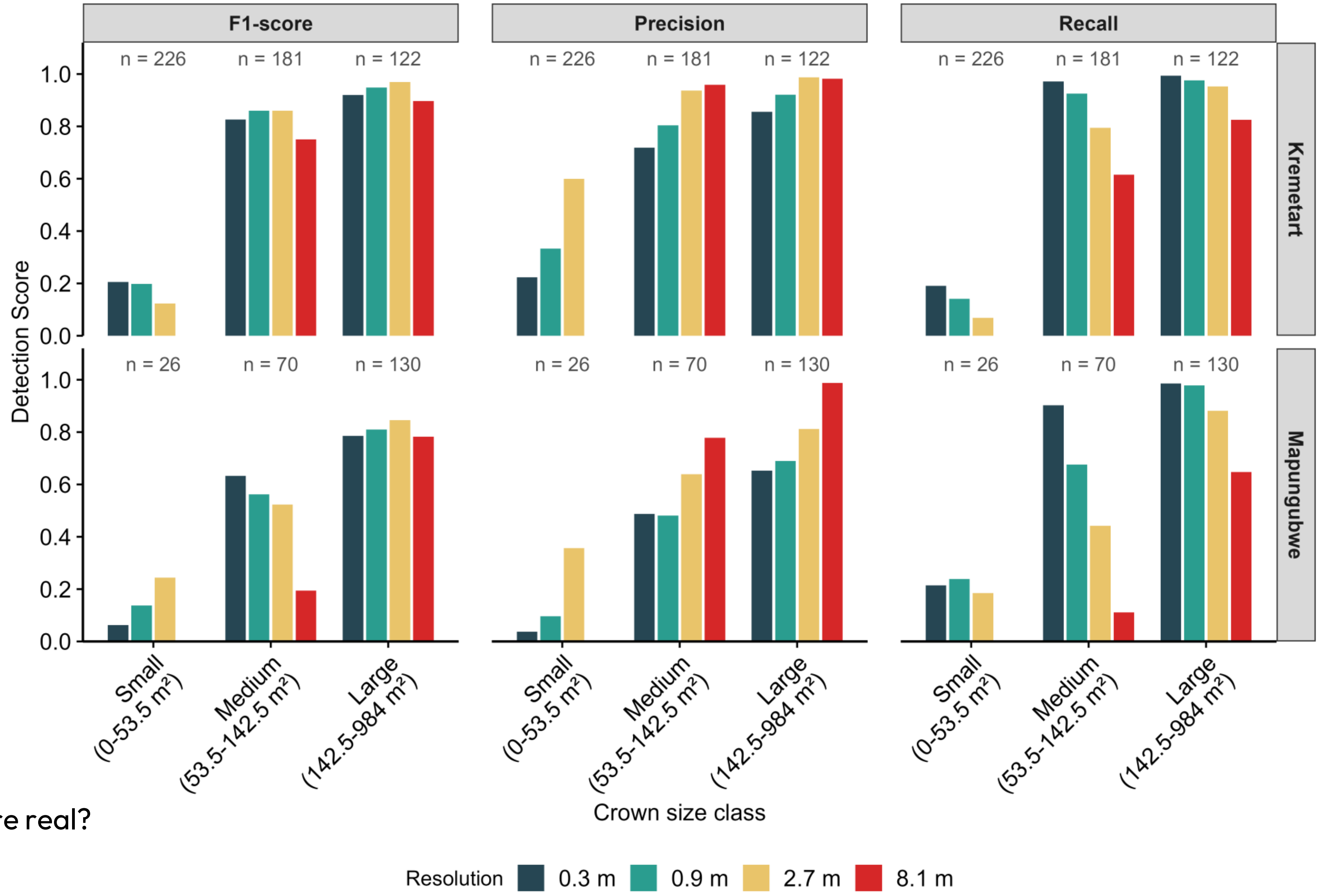
Ecological Implications

- Long-term baobab population monitoring.
  - ➢ Choosing the wrong spatial grain can lead to: Underestimation of populations, misleading ecological interpretations



Finding 2

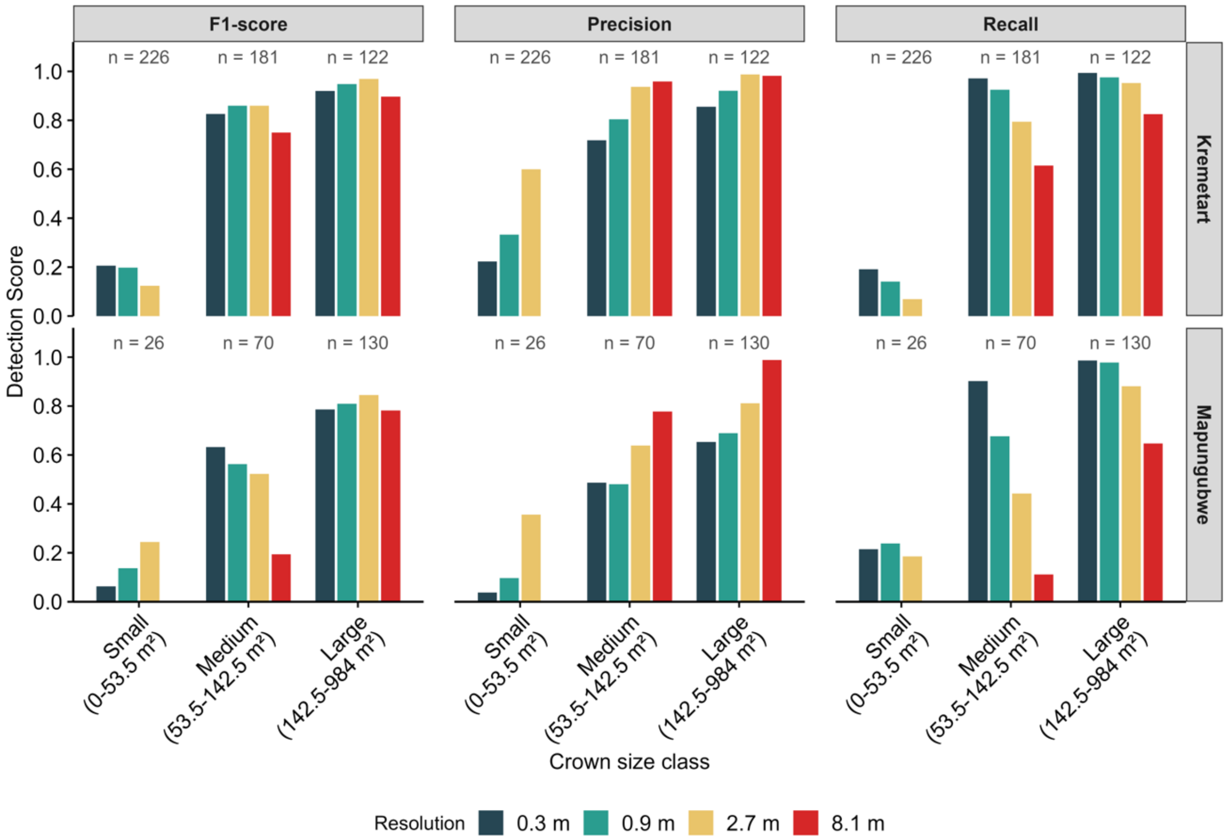
- Large crowns are detected reliably (F1 ≥ 0.85).
- Small crowns are often missed (F1 ≤ 0.2, roughly 80% go undetected)



Precision = Of the detected trees, how many are real?
Recall = Of real trees, how many did we find?
F1-Score = Harmonic mean of the two

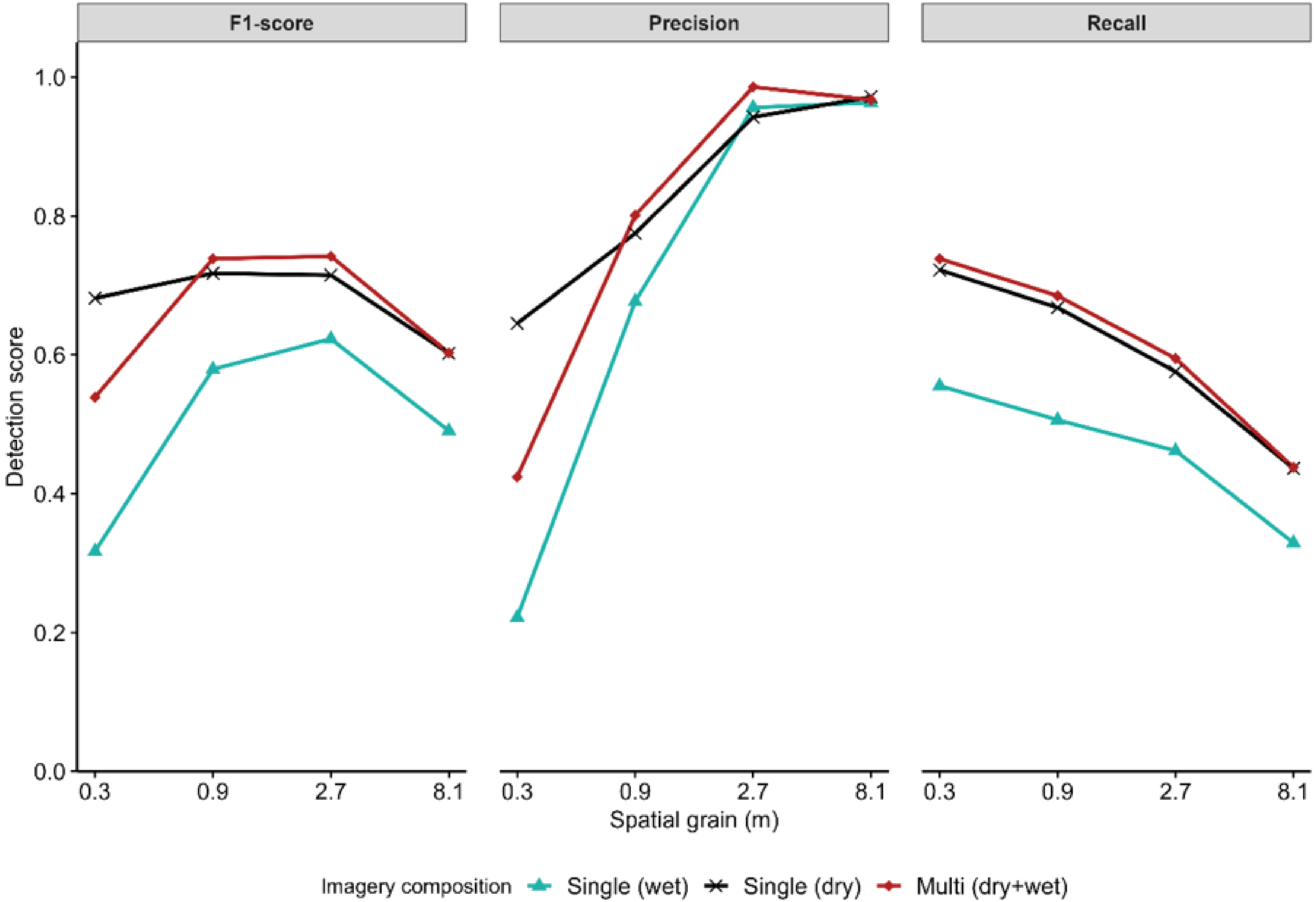
Ecological Implications

- Recruitment assessment and Population structure analysis
  - ➢ Juvenile/smaller trees missed → regeneration may appear weaker than it is



Finding 3

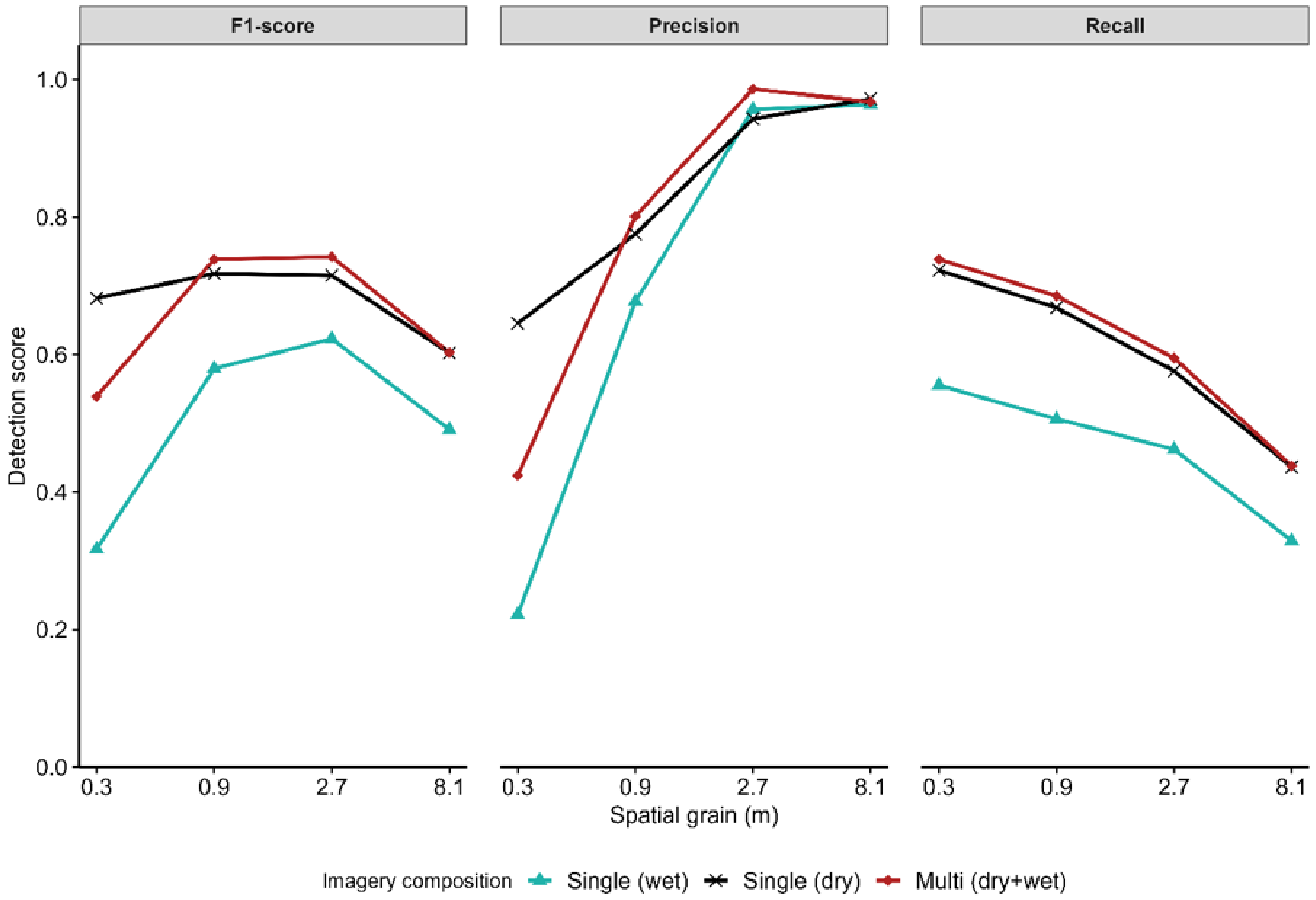
Multi-season imagery provides the highest baobab detection performance at moderate spatial grain



Precision = Of the detected trees, how many are real?
Recall = Of real trees, how many did we find?
F1-Score = Harmonic mean of the two

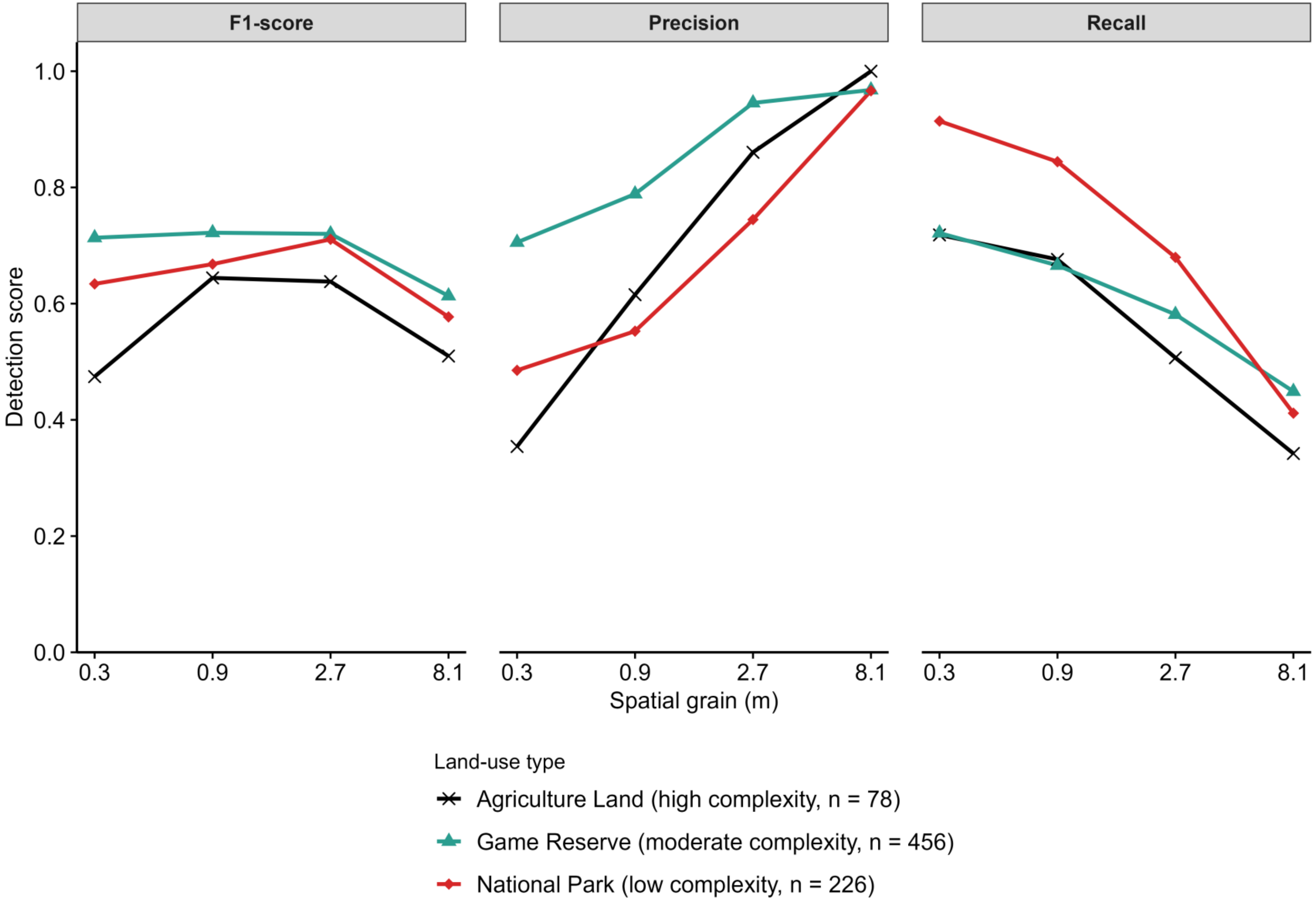
Ecological Implications

- Baobab phenological stages.
  - ✓ Pheno-phases aid detection.



Finding 4

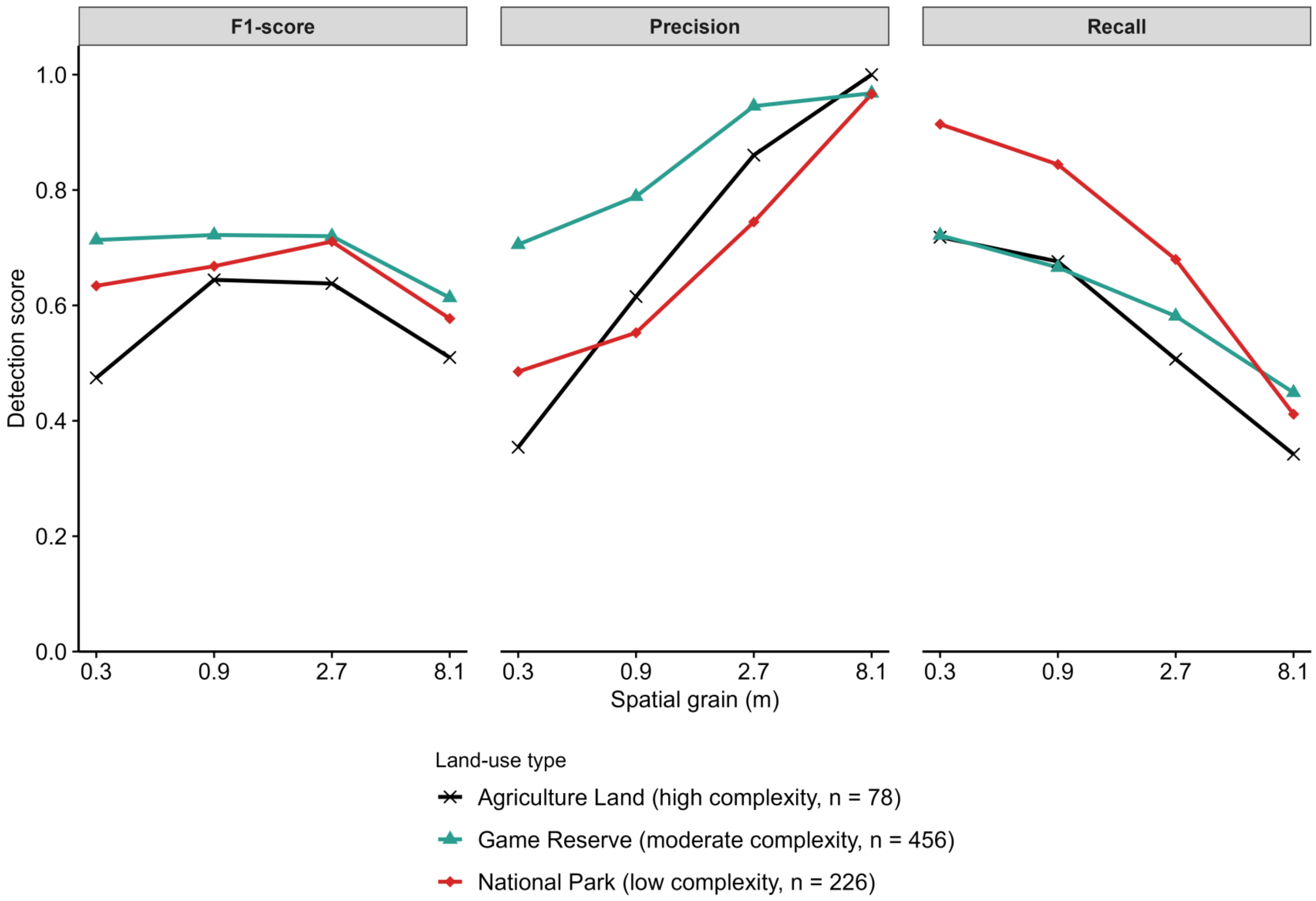
Intermediate spatial grains maximise baobab detection performance across landscapes differing in complexity



Precision = Of the detected trees, how many are real?
Recall = Of real trees, how many did we find?
F1-Score = Harmonic mean of the two

Ecological Implications

Threats in human-dominated areas can be underestimated.



Precision = Of the detected trees, how many are real?
Recall = Of real trees, how many did we find?
F1-Score = Harmonic mean of the two

Summary

- ✓ Intermediate spatial grain optimises model performance
- ✓ U-net model performance depends on crown size
- ✓ Combined-season imagery improves baobab detection.