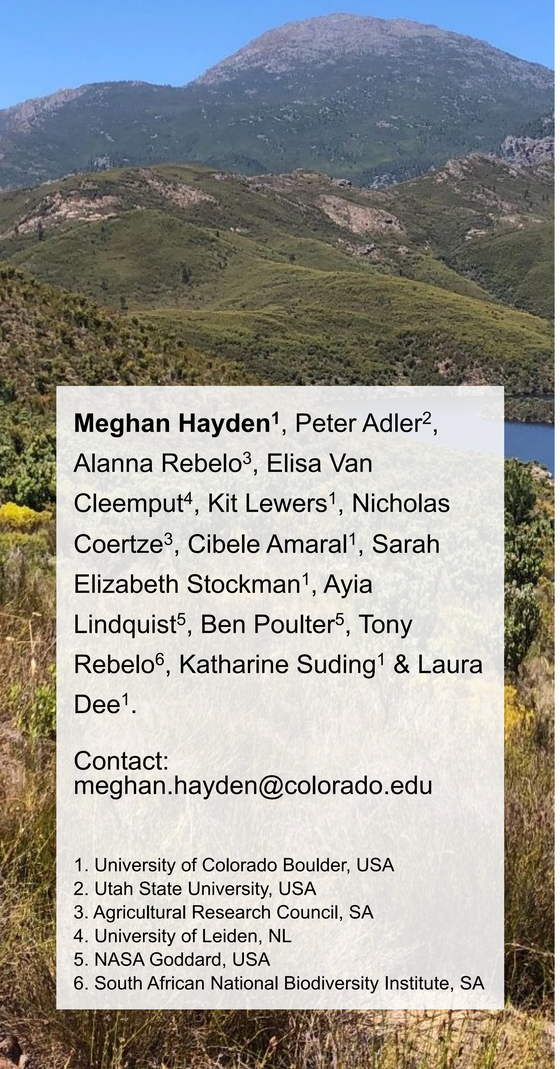
Impacts of Invasive Alien Trees on Biodiversity and Ecosystem Functioning in the Greater Cape Floristic Region



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Background & Motivation

- Global change drivers impact biodiversity and ecosystem functioning at large scales, requiring large scale conservation and management efforts.
- Here, **we attempt to scale up our understanding of causal ecological relationships by integrating remote sensing and causal inference to address a pressing global change problem: invasion.**
- We use the Greater Cape Floristic Region (GCFR) of South Africa as a case study, due to the significant threat the region faces from invasive alien trees and due to access to data from an unprecedented biodiversity survey.

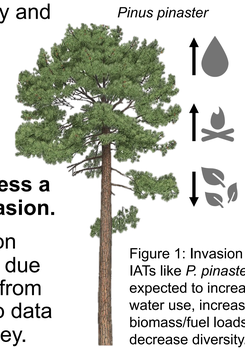


Figure 1: Invasion of IATs like *P. pinaster* is expected to increase water use, increase biomass/fuel loads and decrease diversity.

Research Questions

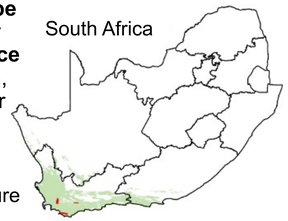
1. What is the magnitude of the effect of **invasion on ecosystem functioning** (here, water resources)?

2. What is the magnitude of the effect of **invasion on biodiversity** (here, spectral diversity)?

3. How does the **direct effect** of invasion on ecosystem functioning compare to **indirect effects** via mediation by biodiversity and functional traits?

Methods

We used data collected as part of **BioSCape** surveys in Fall 2023, including 2400 survey locations paired with **AVIRIS-NG reflectance data** (5 m spatial resolution; 380 - 2510 nm, ~5 nm resolution) to map IATs and test their effects on spectral diversity and evapotranspiration.



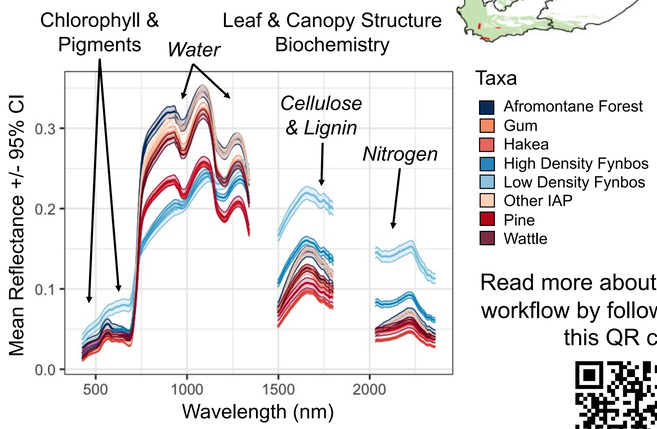


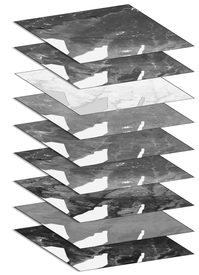
Figure 2: Reflectance of mapped taxa (n = 300 per class) from AVIRIS-NG. *Top: Training data represent three sites (red) in the GCFR of South Africa.*

Read more about our workflow by following this QR code

Mapping Invasive Alien Trees (IATs) with Hyperspectral Imagery

Hyperspectral imagery allows for high accuracy in distinguishing invasive alien trees from native vegetation in the GCFR. Discrimination was primarily challenged by Afromontane forest due to its spectral similarities with some IAT taxa.

- Random Forest outperforms Gradient Boosted Regression Trees, Support Vector Machine and Partial Least Squares Discriminatory Analysis algorithms for classifying IATs.
- "Area of Applicability" approach prevents predictions outside of training space.



Feature importance:
1. PC7 (*0.02% var. explained*)
2. Greenness Index
3. Leaf Carotenoid Content
4. PC6 (*0.03% var. explained*)
5. Water Based Index
6. PC1 (*82% var. explained*)
7. Moisture Stress Index
8. Red-SWIR
9. Narrow Red Edge
10. NDVI

Figure 3: Features contributing the most to classification.

Table 1: F1 scores (weighted) from Random Forest model evaluated with different training splits.

	Stratified Random Sampling (n = 100)	**Spatial cross-validation (k = 45)**
Overall	**0.900** [0.897 – 0.902]	**0.742** [0.671 – 0.811]
IAT vs. Native	**0.967** [0.965 – 0.969]	**0.889** [0.828 – 0.950]
Intra-IAT	**0.906** [0.904 – 0.909]	**0.738** [0.667 – 0.811]

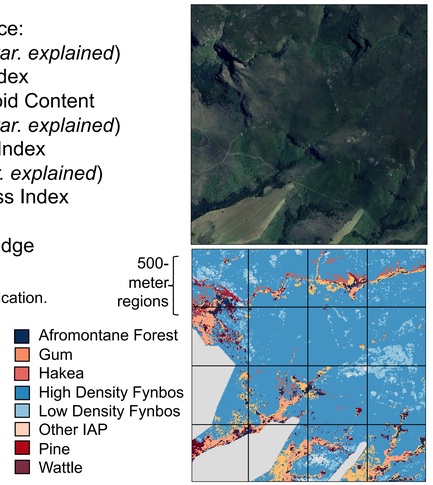


Figure 4: Predicted taxa for a 4-km^2 sample area with agriculture masked out (grey). *Top: True color image of the sample area.*

Estimating Effects of Invasion Using a Casual Inference Framework

- *Characterizing uncertainty:* We create a series of maps sampling from the probability distributions of pixel predictions to estimate robustness of our results to classifier uncertainty.
- *Reducing bias:* We use Inverse Probability Weighting to create balance in confounding variables across invaded and uninvaded units.
- *Estimating effects:* We use mediation analysis to partition the direct and indirect effects of invasion on water use.

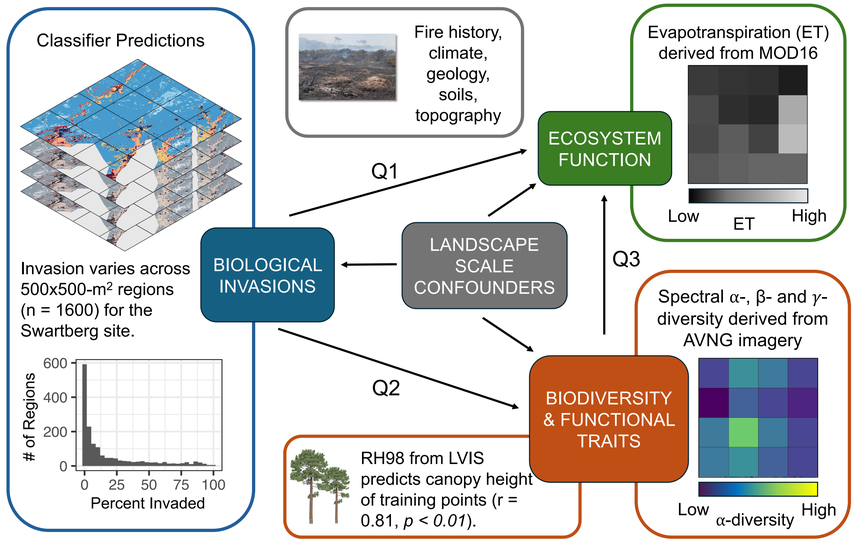


Figure 5: Workflow for assessing outcomes of invasion for ecosystem function and biodiversity.

Next Steps

We will use the layers created in this workflow to **estimate the causal effects on invasion on water use**, both directly and via changes to diversity and functional form.

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