Space-based impact assessment of invasive alien trees on evapotranspiration and water security in southern Africa

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Setting the scene

Setting the scene

- Biological invasions impact ecosystem function and biodiversity

Alien pines invading fynbos, Nicholas Coertze

Setting the scene for South Africa

- Biological invasions impact ecosystem function and biodiversity

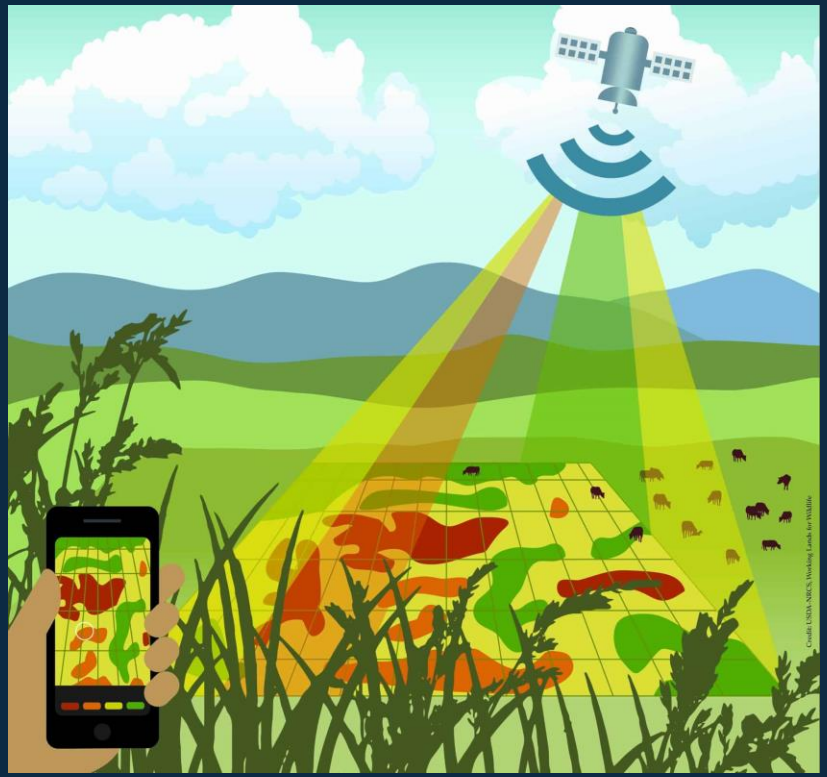
Setting the scene for South Africa

- Biological invasions impact ecosystem function and biodiversity
- Econonomic impacts
- Global South: limited resources
- Opportunity: freely available remote sensing data

Problem statement

Given limited funds, which invasions should be prioritized for clearing?

One way to prioritize is by quantifying water-related impacts.

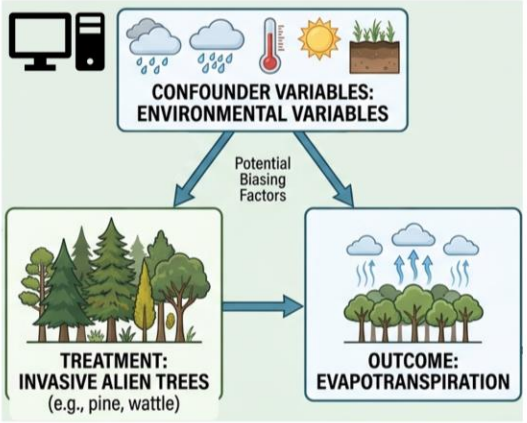


SATWAT

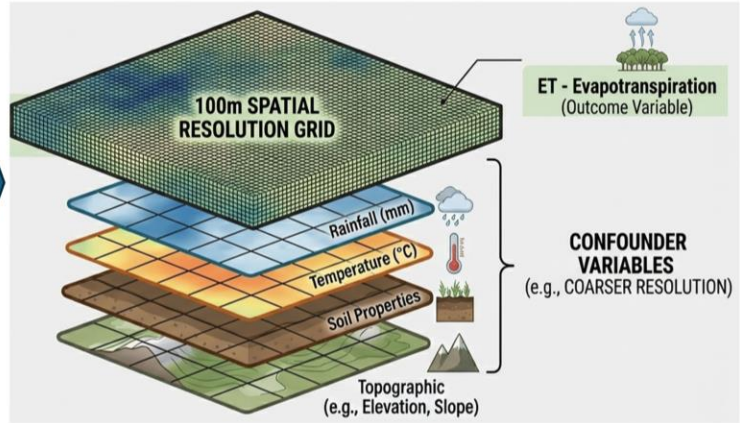
Space-based assessment of invasive alien trees on evapotranspiration and water security in southern Africa

AIM: Estimate and spatially map the direct impact of invasive alien trees on evapotranspiration, controlling for environmental confounders

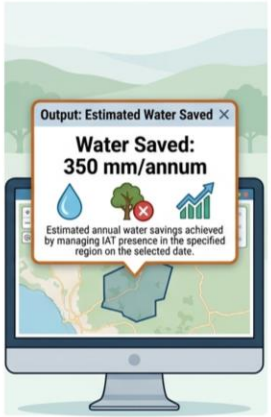
(1) Acquire freely available spatial datasets across six invaded catchments in southern Africa for the causal inference modelling framework



(2) Process the spatial datasets in preparation for causal inference modelling by resampling all confounder datasets to the evapotranspiration grid and ensure consistent projection and format



(3) Causal inference modelling and deploy a web application based on the resulting models



BioSCape: Impacts of Invasion on Biodiversity and Ecosystem Functioning in the Cape Floristic Region of South Africa

TREE 3356 No. of Pages 14 ARTICLE IN PRESS

Trends in
Ecology & Evolution

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Opinion

Scaling-up ecological understanding with remote sensing and causal inference

Elisa Van Cleemput [1,2,*], Peter B. Adler [3], Katharine Nash Suding [2], Alanna Jane Rebelo [4,5,6], Benjamin Poulter [7], and Laura E. Dee [2]

Decades of empirical ecological research have focused on understanding ecological dynamics at local scales. Remote sensing products can help to scale-up ecological understanding to support management actions that need to be implemented across large spatial extents. This new avenue for remote sensing applications requires careful consideration of sources of potential bias that can lead to spurious causal relationships. We propose that causal inference techniques can help to mitigate biases arising from confounding variables and measurement errors that are inherent in remote sensing products. Adopting these statistical techniques will require interdisciplinary collaborations between local ecologists, remote sensing specialists, and experts in causal inference. The insights from integrating 'big' observational data from remote sensing with causal inference could be essential for bridging biodiversity science and conservation.

Highlights

Current biodiversity policy goals demand large-scale conservation and management actions.

Ecological relationships operating in fine-scale experiments and observational datasets do not necessarily apply at management-relevant spatial scales.

Remote sensing offers a solution for understanding ecological relationships at scale, but inferring causality from remotely sensed data presents various

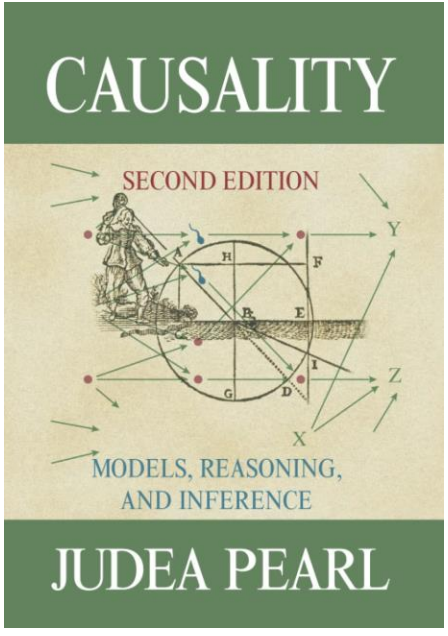
NASA BIOSCAPE Biodiversity Survey of the Cape

University of Colorado Boulder

Meghan Hayden et al. 2025. *In prep*

BioSCape: Impacts of Invasion on Biodiversity and Ecosystem Functioning in the Cape Floristic Region of South Africa

Can remote sensing reveal not just patterns—but causes and consequences?



University of Colorado Boulder

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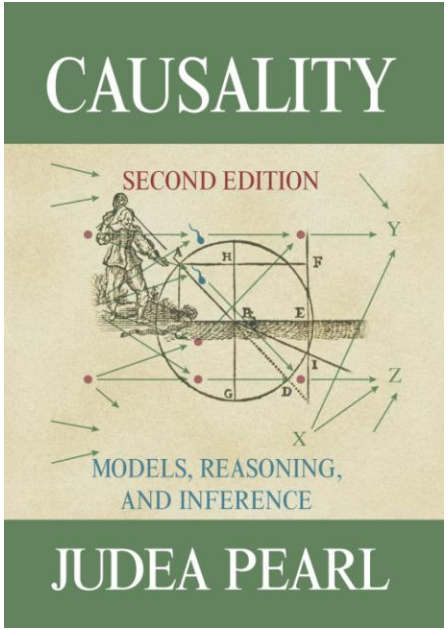
BioSCape: Impacts of Invasion on Biodiversity and Ecosystem Functioning in the Cape Floristic Region of South Africa

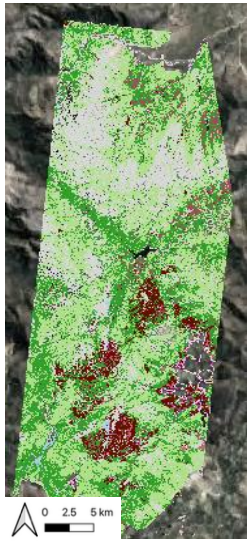
Research Question:

What is the magnitude of the effect of invasion on water use?



Meghan Hayden et al. 2025. *In prep*

Landscape-scale confounders



Classifier predictions (5 m) from AVIRIS-NG summarized as **percent IAT cover** at 100 by 100 m^2 region.

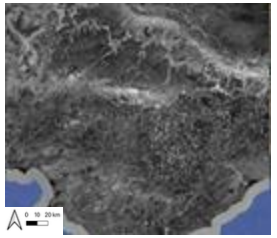
Fire history, climate, geology, soils, topography

BIOLOGICAL INVASIONS

LANDSCAPE SCALE CONFOUNDERS

WATER USE

STRUCTURE & DIVERSITY



FAO's WaPOR **daily ET** at **100 by 100 m^2**

High

Low

Study 5

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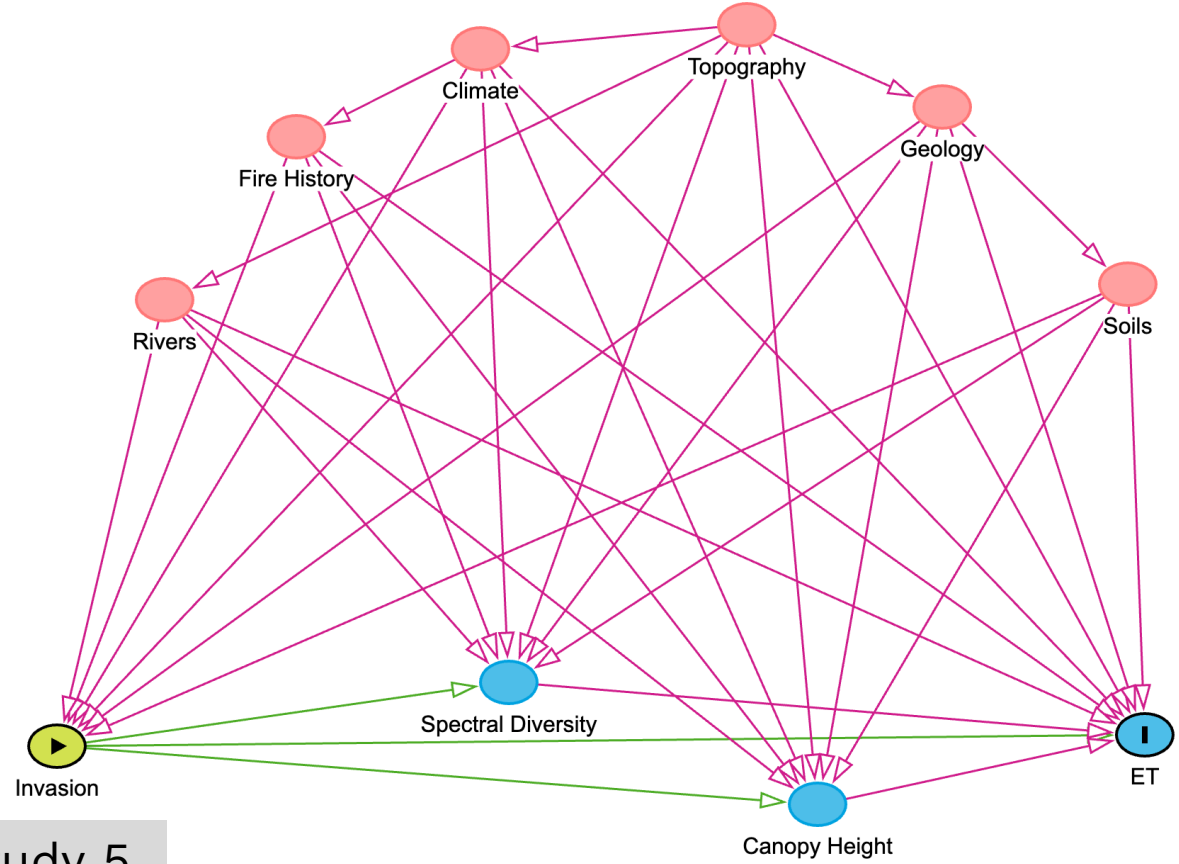
Causal diagram



Climate: Mean annual temperature and precipitation, Minimum and maximum temperature and precipitation, Temperature range, Temperature and precipitation seasonality

Topography: Elevation, Aspect, Landform

Soils: pH, N, P, K

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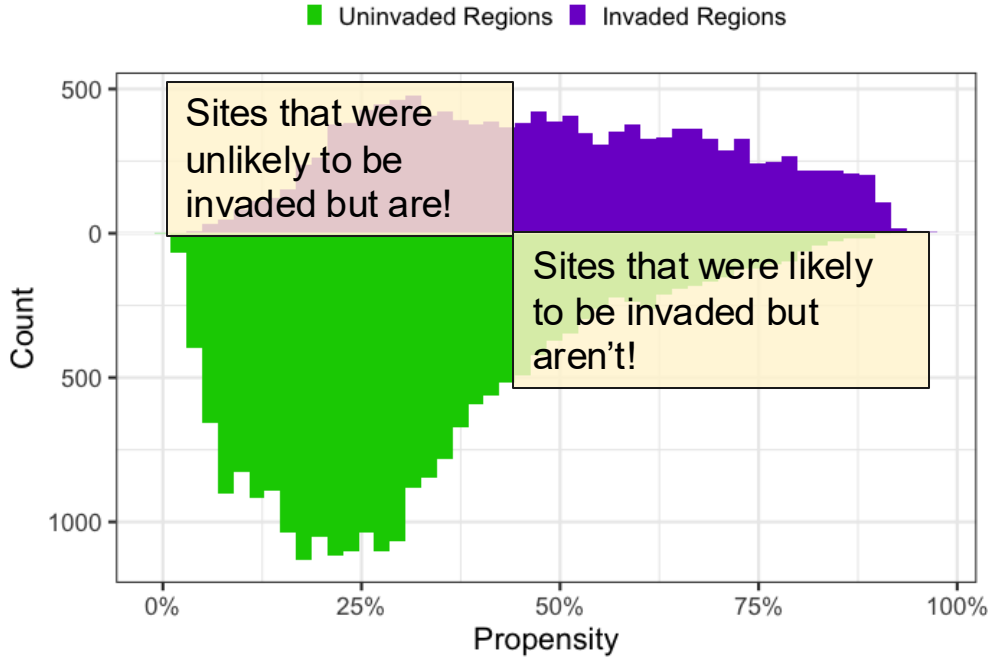
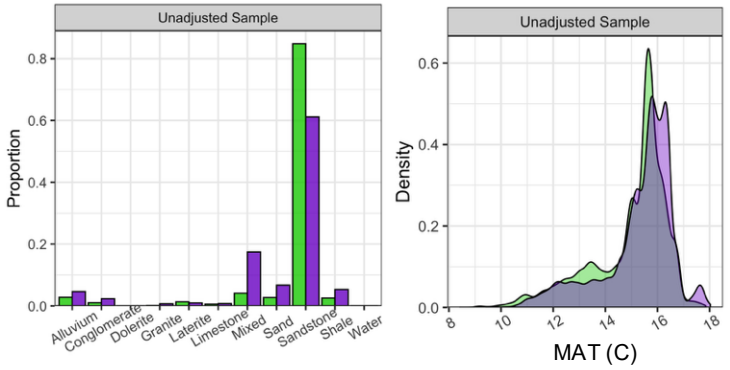
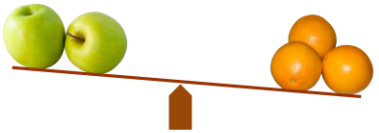
Selection Bias: Propensity of being invaded



Example of selection bias →



Propensity of being invaded = $\Pr(T_i=1|X_i)$



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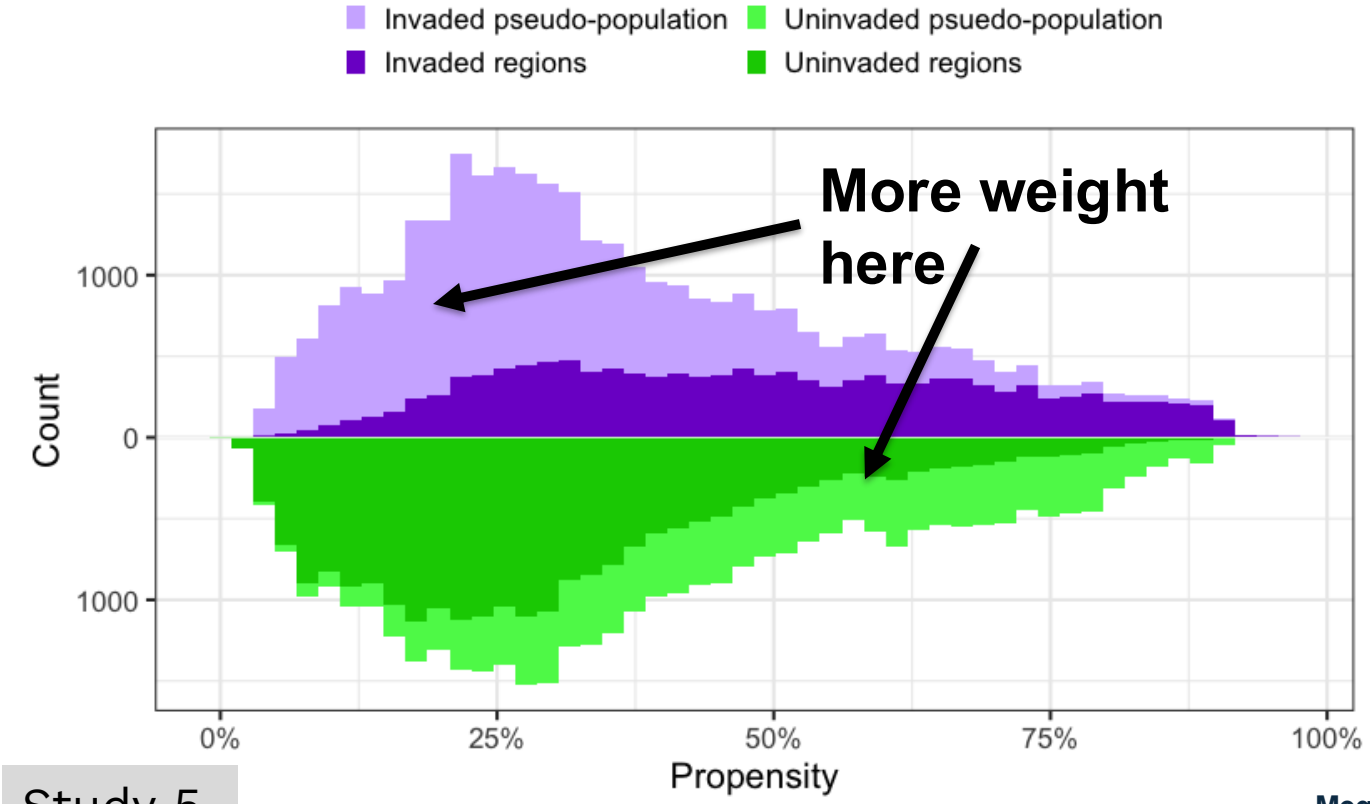
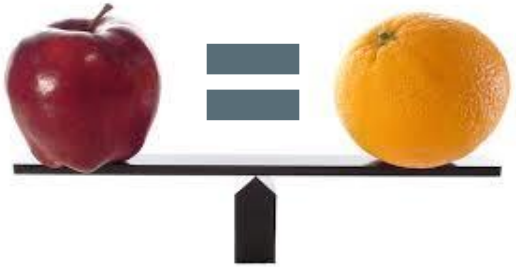
Analysis Design: Inverse Probability Weighting





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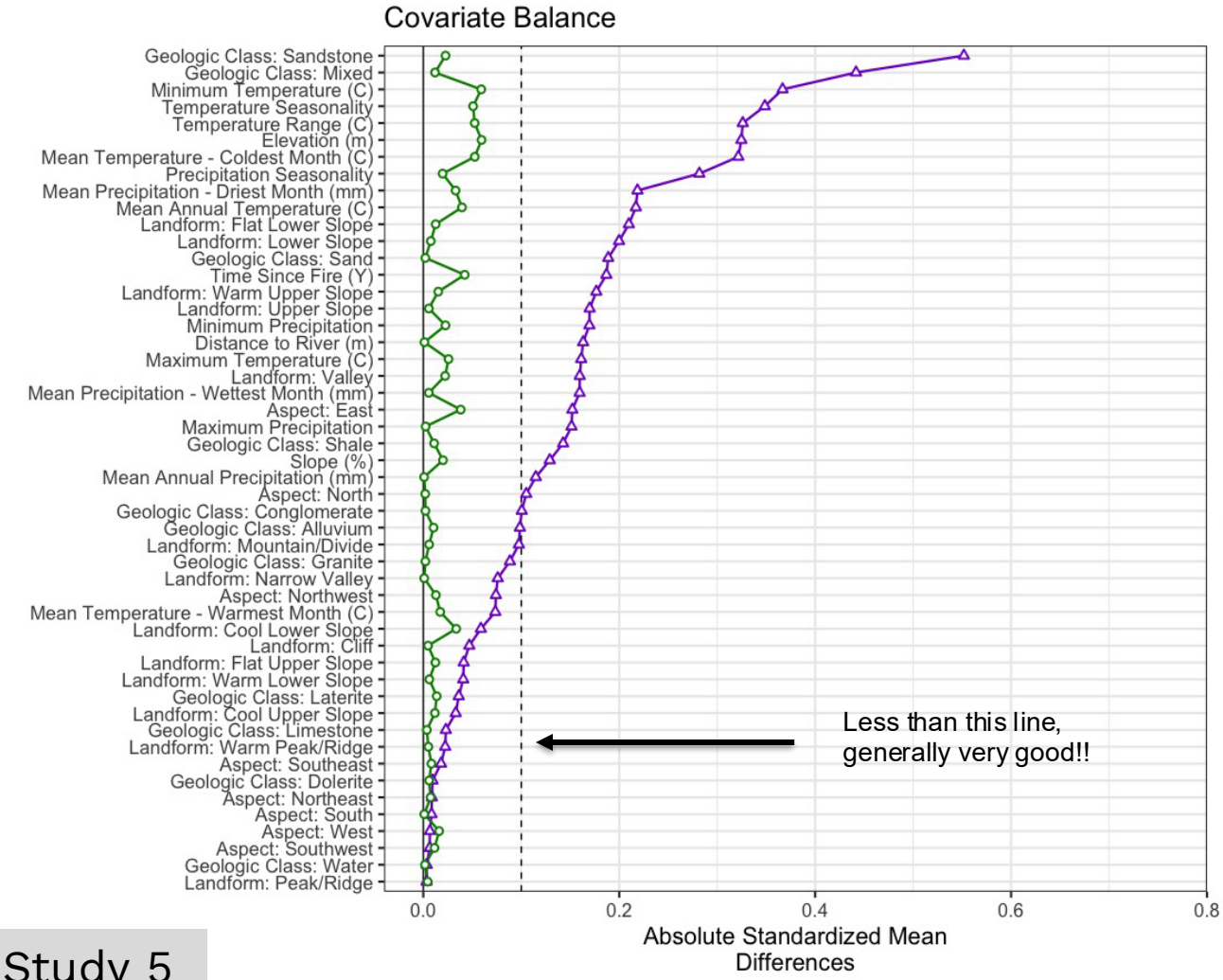

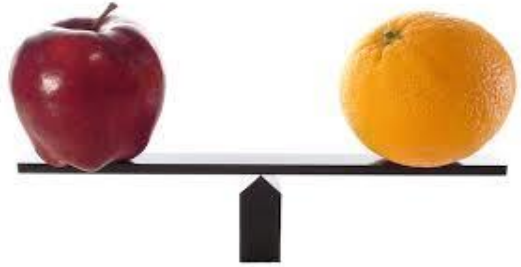

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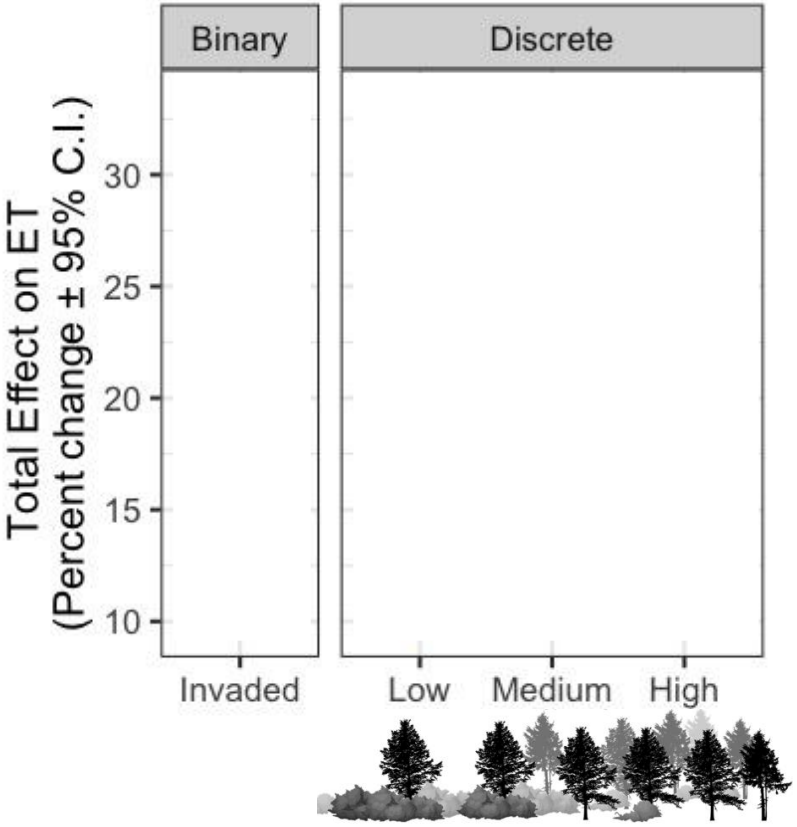
Results: Invasion increases water use



Study 5

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In closing

- SATWAT aims to provide a user-friendly open-access tool to simulate the effect of invasion on water resources for various scenarios.
- The project will demonstrate how EO data, combined with advanced causal modelling, can inform nature-based solutions and strengthen regional water security.

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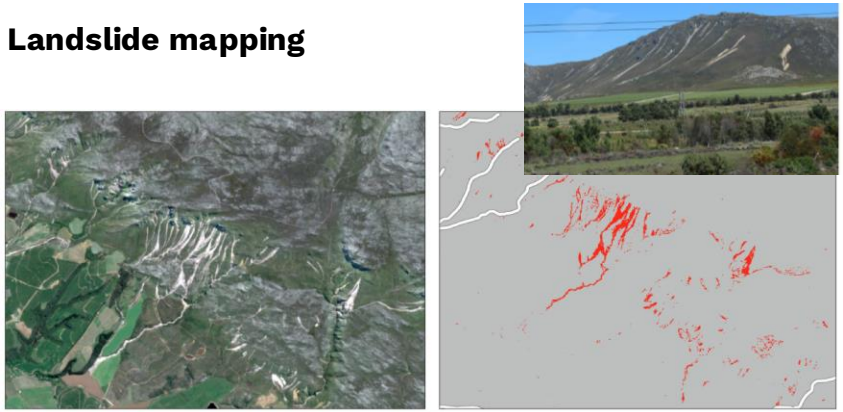
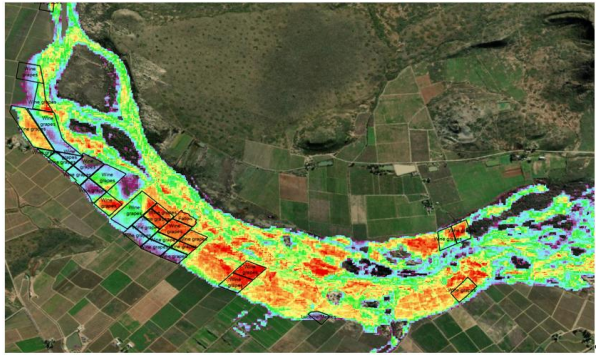
Landslide mapping



Flood mapping



ET quantification/plant water-use

Remote Sensing Applications: Society and Environment 38 (2025) 101612

Contents lists available at ScienceDirect

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Evaluating the performance of satellite-derived evapotranspiration products across varying bioclimates in South Africa

Liam S. Cogill [a,b,c,*], Michele Toucher [e,f], Piotr Wolski [g], Karen J. Esler [b,d], Alanna J. Rebelo [a,b,c]

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Biomass mapping – green biofuels to fund restoration

Ecological Informatics 95 (2026) 103756

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Supporting ecological restoration: leveraging satellite data and machine learning to map invasive alien tree biomass

Liam S. Cogill [a,b,c,*], Karen J. Esler [b,d], Laven Naidoo [e,f], Alanna J. Rebelo [a,b,c]

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Take home messages

- Ground-truthing
- Uncertainty quantification/propagation

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