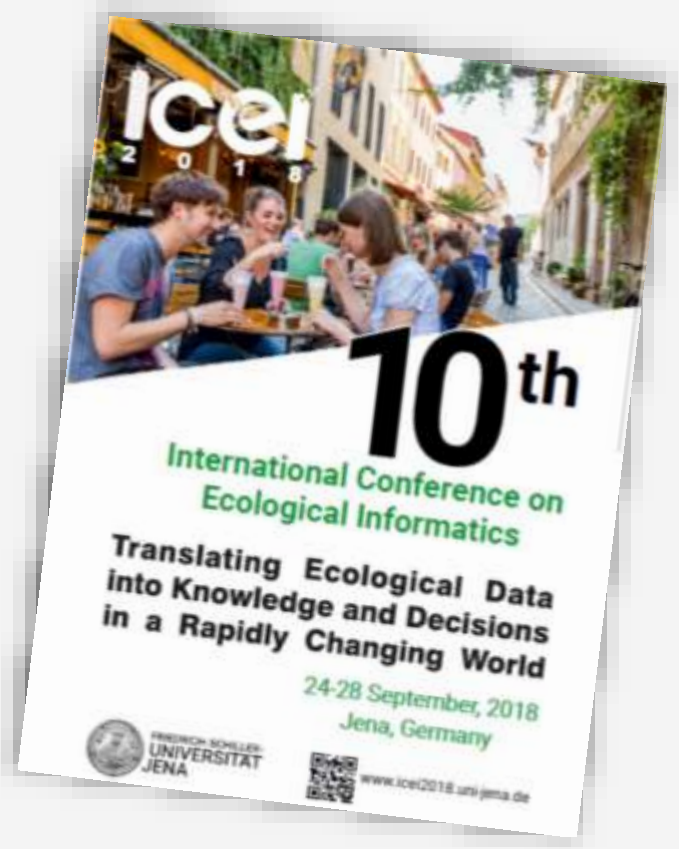
WWU
MÜNSTER

Early indicators of high impact of an invasive ecosystem engineer on ecosystem functioning from leaf to landscape scale

André Große-Stoltenberg, Christiane Hellmann, Jan Thiele,
Christiane Werner, Jens Oldeland



Structure of the talk

- Introduction
  - **Model invader and model system**
- Scales and concepts
  - **Stand: Functional tracers & Isoscapes**
  - **Landscape: Invasion syndromes**
  - **(Functional Traits)**

Mediterranean dune ecosystem in SW Portugal, NATURA2000 site Comporta/Galé.

Introduction

Stand: Isoscapes Landscape: Invasion syndromes

Model invader: *Acacia longifolia*, Sydney Golden Wattle

Profile

- **Fabaceae**
- **native to SE Australia**
- **Large shrub or tree**
- **Large phyllodes: 5-20cm long, 5-15mm wide**
- **Stabilising dunes, ornamental plant**
- **Impacts on nutrient cycling, biodiversity and fire regime**

Introduction

Stand: Isoscapes

Landscape: Invasion syndromes

Model invader: *Acacia longifolia*, Sydney Golden Wattle

Alien range
(Global invasive species database GISD)

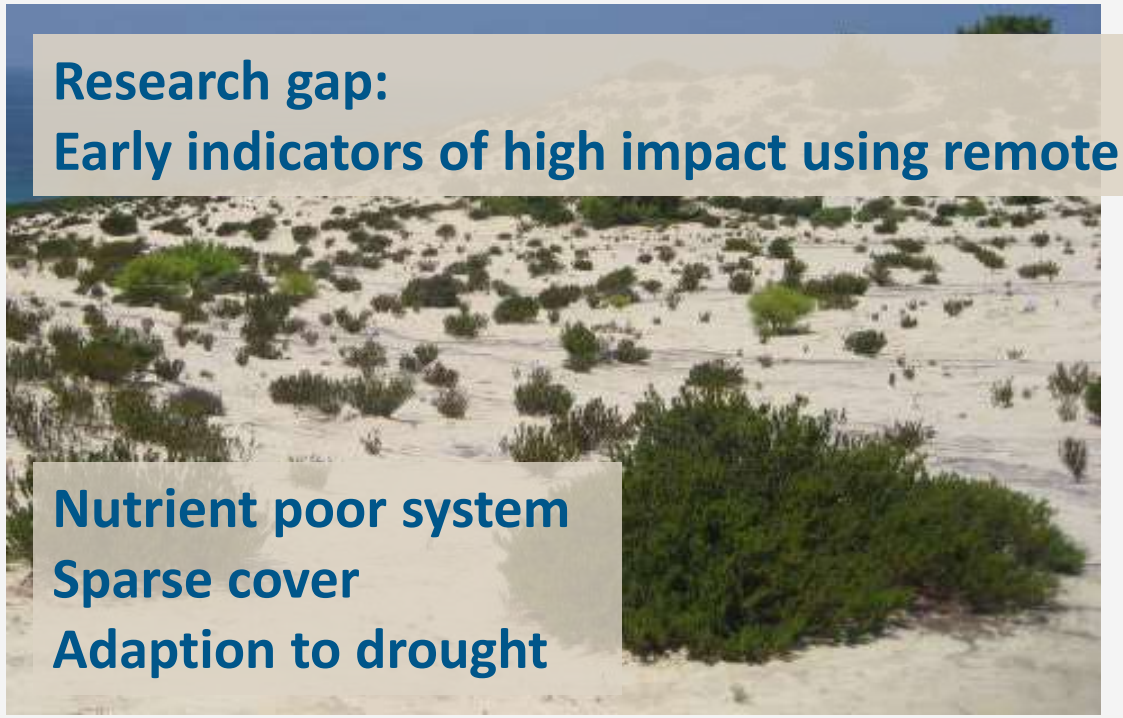
Argentina, Australia, Brazil, Colombia, Dominican Republic, India, Indonesia, Israel, Italy, Kenya, Mauritius, Myanmar, New Zealand, Portugal, Reunion, South Africa, Spain, Sri Lanka, United States, Uruguay

Introduction

Stand: Isoscapes Landscape: Invasion syndromes

Model system and model invader

Research gap:
Early indicators of high impact using remote sensing to enable continous monitoring

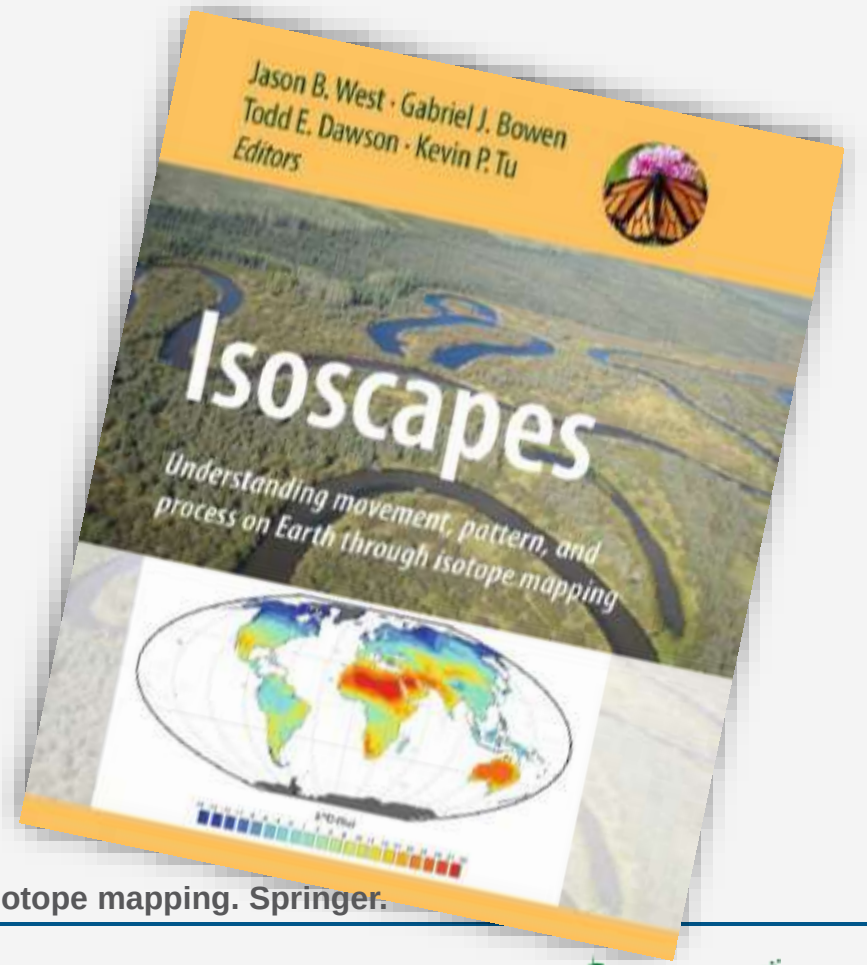


Nutrient poor system
Sparse cover
Adaption to drought

N_2 fixing
Dense thicket
Water spending

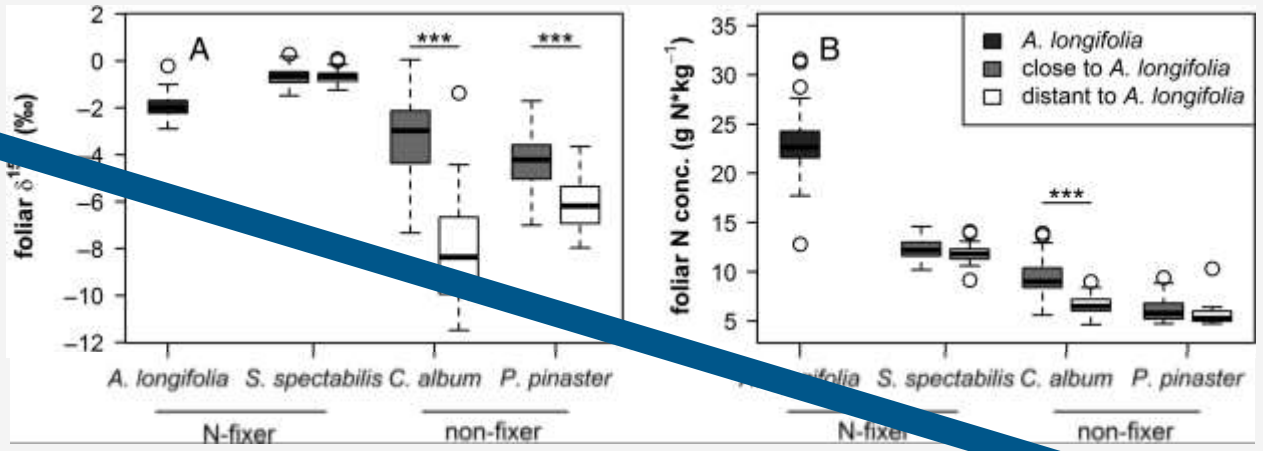
Concept „Isoscapes“

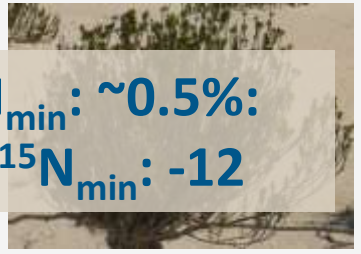
- Isotope + landscape: spatially explicit prediction of isotope ratios
- N_2-fixing species typically have greater foliar N content and $\delta^{15}N$ signatures closer to the atmospheric value (0) than non-fixing plant species (=> origin of plant nitrogen (e.g. atmospherically derived ver. soil derived))
- $\delta^{15}N_{sample} = (R_{sample}-R_{standard})/(R_{standard})$, $R_{sample} = {}^{15}N_{sample}/{}^{14}N_{sample}$



West et al. (2010) Isoscapes: Understanding movement, pattern, and process on Earth through isotope mapping. Springer.

Concept: Impact of the invader on N cycling





- Foliar N and $\delta^{15}N$ of the native shrub increases with vicinity to the N-fixing invader
- Topographic effects?

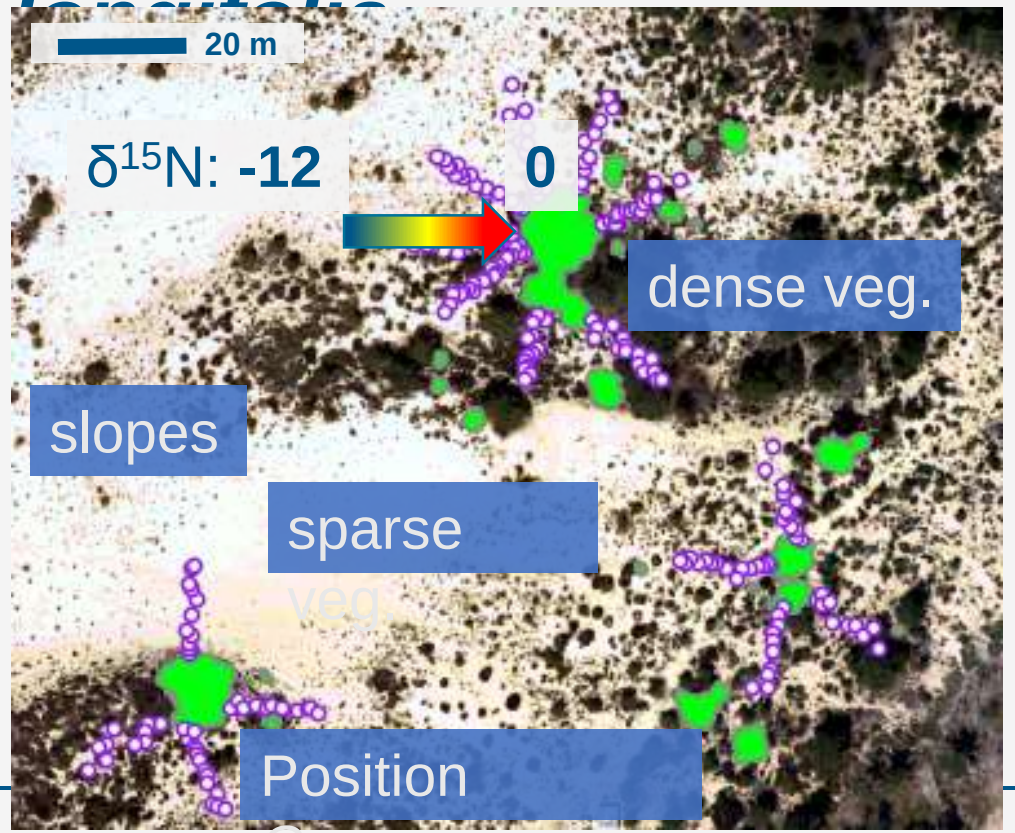
Rascher et al. (2012) Community scale ^{15}N isoscapes: tracing the spatial impact of anexotic N_2-fixing invader. Ecology Letters.

Research question

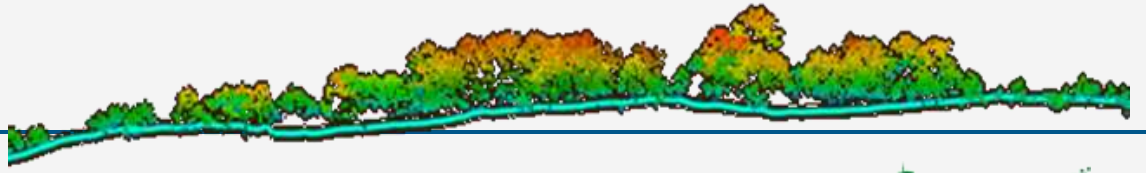
Can *Acacia longifolia*'s impact on N cycling be mapped using a functional tracer?

Hellmann et al. (2017) Heterogeneous environments shape invader impacts: integrating environmental, structural … . Scientific Reports

Methods: *Corema album* transects surrounding *Acacia longifolia*



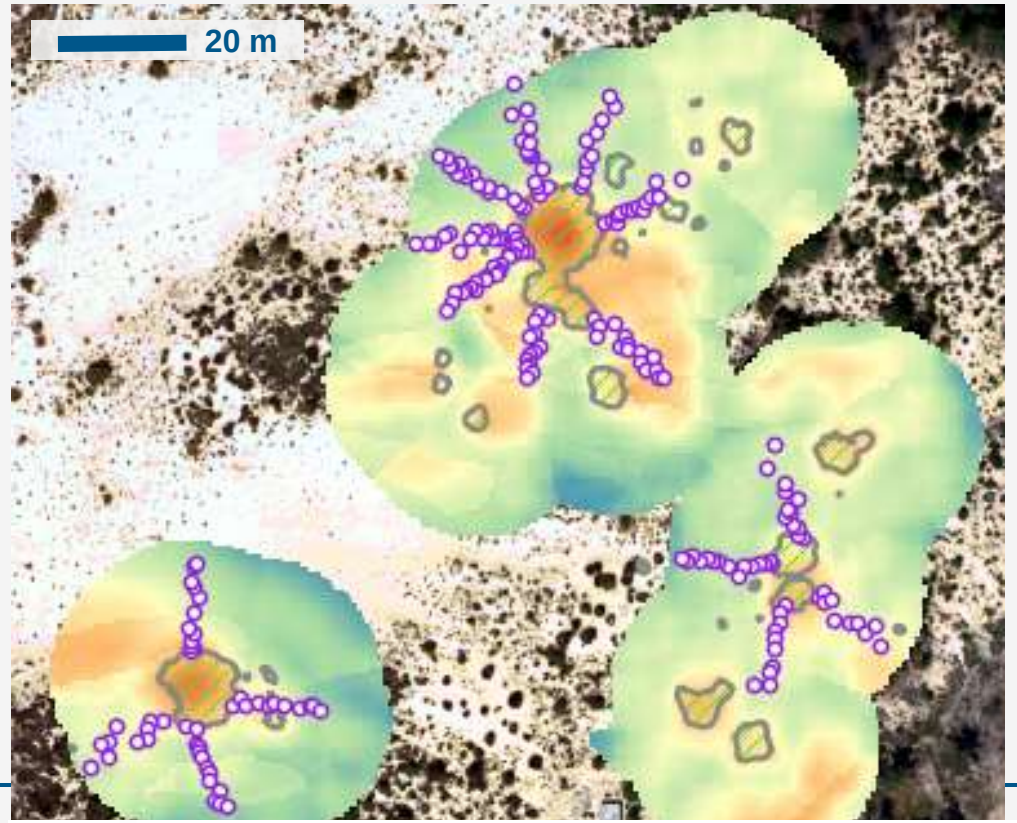
- **Data**
  - 5 sites
  - Map of the exotic, N-fixing *Acacia longifolia*
  - Transects of the native, non-fixing *Corema album*
  - Foliar $\delta^{15}N$ of Corema album (functional tracer of *Acacia* N fixation)
  - LiDAR data on topography and vegetation structure (environmental heterogeneity)



Methods: Predictors derived from LiDAR

- Position of the native species relative to invader
- Landform (e.g. ridge, plain, valley)
- Topographic Wetness Index (related to slope)
- Vegetation cover

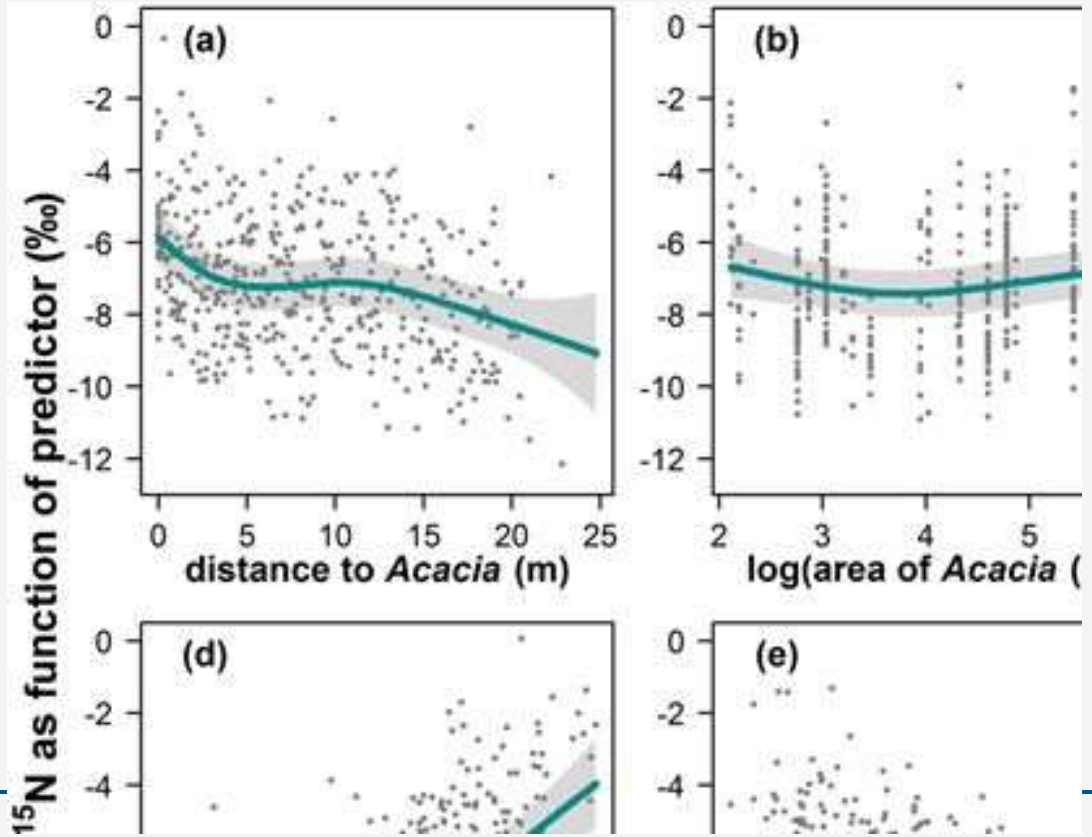
Results: Impact of *A. longifolia* and topography on $\delta^{15}N$



- **Important predictors (GAMM)**
  - Distance to *Acacia longifolia*
  - Landform, Position relative to *A. longifolia*, Vegetation cover, Topographical Wetness Index (LiDAR)
- **Model quality**
  - Median R^2: 0.6; Median RMSE: 1.82‰
- **Main findings**
  - ^{15}N enrichment by *Acacia* being evident in a range of approximately 5–8 m from the canopy

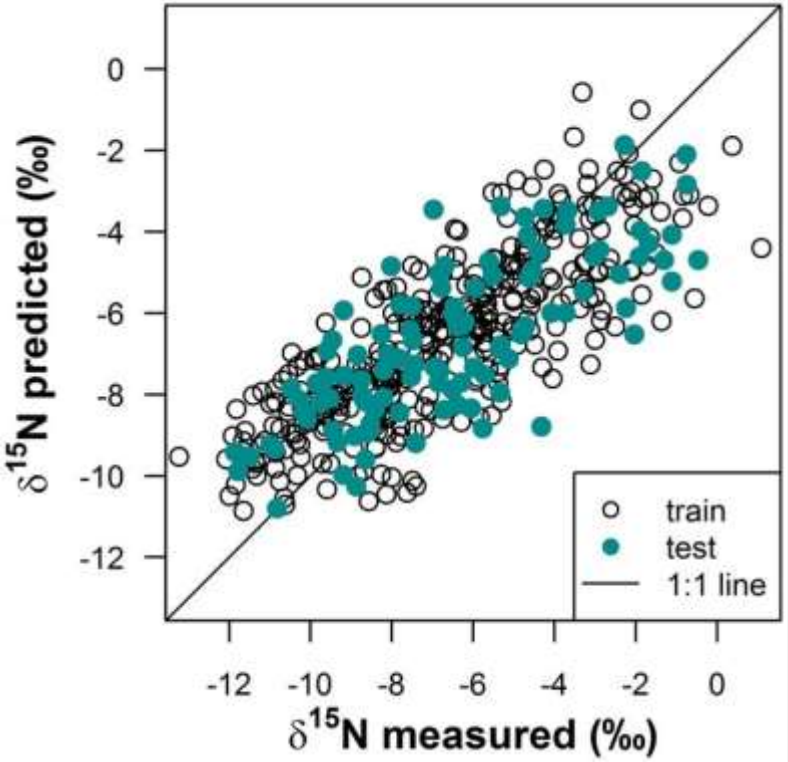
Hellmann et al. (2017) Heterogeneous environments shape invader impacts: integrating environmental, structural … . Scientific Reports

Results: Impact of *A. longifolia* and topography on $\delta^{15}N$



- **Important predictors (GAMM)**
  - Distance to *Acacia longifolia*
  - Landform, Position relative to *A. longifolia*, Vegetation cover, Topographical Wetness Index (LiDAR)
- **Model quality**
  - Median R^2: 0.6; Median RMSE: 1.82‰
- **Main findings**
  - ^{15}N enrichment by *Acacia* being evident in a range of approximately 5–8 m from the canopy

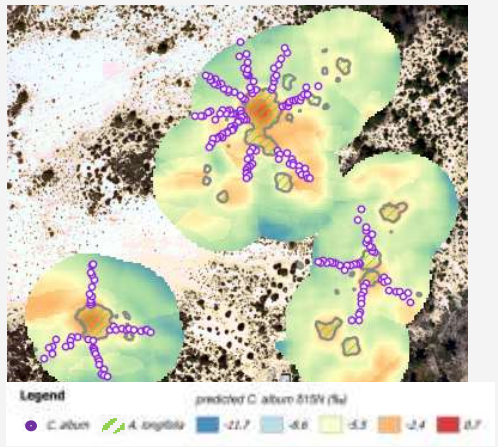
Results: Impact of *A. longifolia* and topography on $\delta^{15}N$



- **Important predictors (GAMM)**
  - Distance to *Acacia longifolia*
  - Landform, Position relative to *A. longifolia*, Vegetation cover, Topographical Wetness Index (LiDAR)
- **Model quality**
  - Median R^2: 0.6; Median RMSE: 1.82‰
- **Main findings**
  - ^{15}N enrichment by *Acacia* being evident in a range of approximately 5–8 m from the canopy

Conclusion

Isoscapes linked with remote sensing can be applied to map invader impact on N cycling, and can serve as an early indicator for high impact.

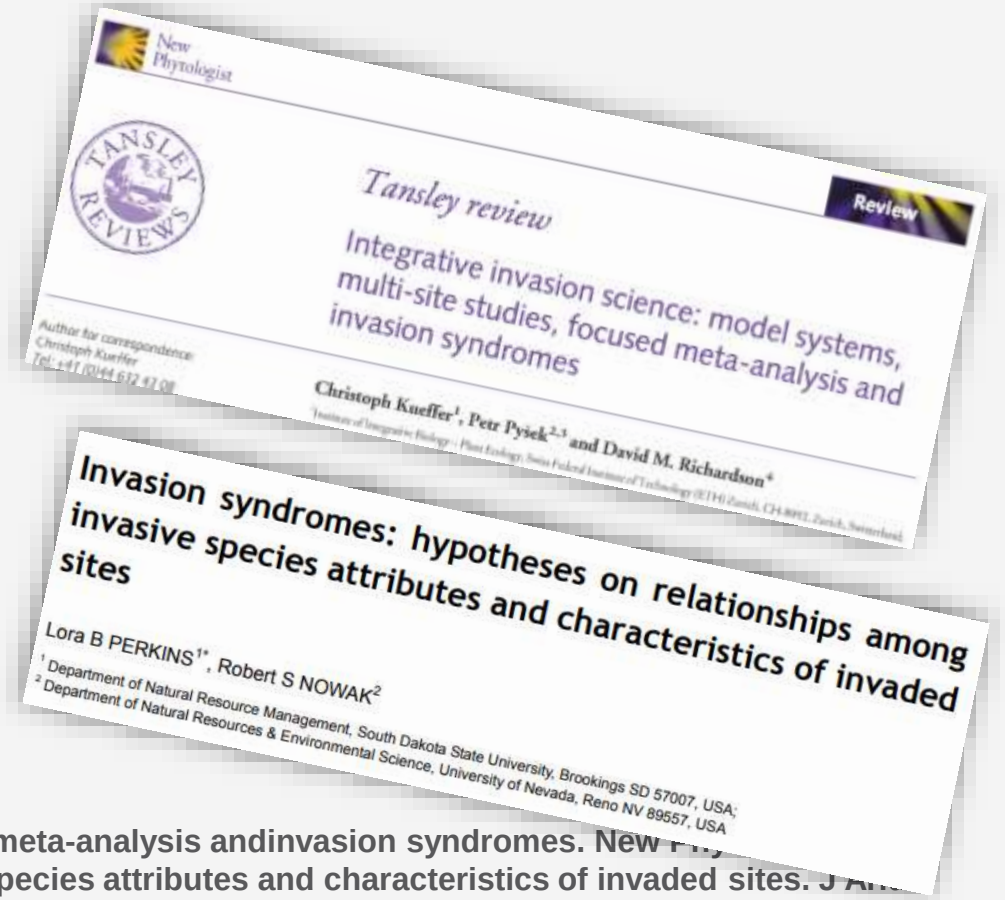


Hellmann et al. (2017) Heterogeneous environments shape invader impacts: integrating environmental, structural … . Scientific Reports

Concept

Invasion syndromes

- **Typical recurrent associations of species biology and invasion dynamics with particular invasion contexts such as invaded habitat.[1]**
- **Sites with relatively low resource abundance and low diversity should be vulnerable to invasion by species with niche construction ability.[2]**



[1]Kueffer et al. (2013) Integrative invasion science: model systems,multi-site studies, focused meta-analysis andinvasion syndromes. New Phy...
[2]Perkins & Nowak (2013) Invasion syndromes: hypotheses on relationships among invasive species attributes and characteristics of invaded sites. J Ar... Land.

Introduction Stand: Isoscapes **Landscape: Invasion syndromes**

Research question

How can *Acacia longifolia*‘s impact on ecosystem structure and functioning be mapped at the landscape scale?


Remote Sensing of Environment 209 (2018) 780–792
Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

Early detection of GPP-related regime shifts after plant invasion by integrating imaging spectroscopy with airborne LiDAR

Große-Stoltenberg A.[a,*], Hellmann C.[b,c], Thiele J.[a], Werner C.[c], Oldeland J.[d]

[a] Institute of Landscape Ecology, University of Münster, Heisenbergstraße 2, 48149 Münster, Germany
[b] Ecosystem Physiology, University of Freiburg, Georges-Köhler-Allee 53/54, 79110 Freiburg, Germany
[c] Experimental and Systems Ecology, University of Bielefeld, Universitätsstraße 25, 33615 Bielefeld, Germany
[d] Biodiversity, Ecology and Evolution of Plants, Biocentre Klein Flottbek and Botanical Garden, University of Hamburg, Ohnhorststraße 18, 22609 Hamburg, Germany

ARTICLE INFO
Keywords:
Acacia
Ecosystem engineer

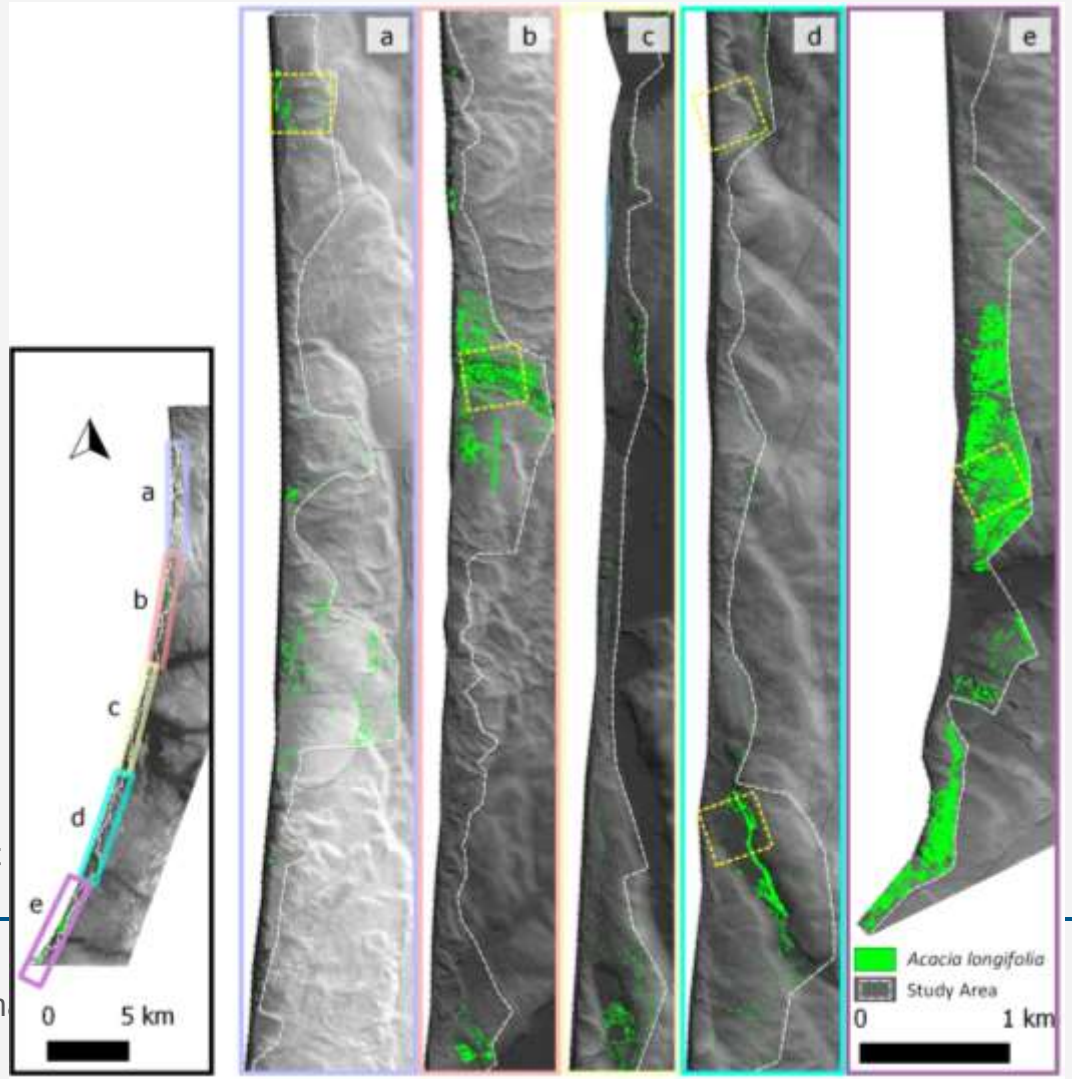
ABSTRACT
Invasive plant species can have high, self-reinforcing impacts on ecosystem structure and functioning that induce permanent changes of ecosystem properties. Therefore, early detection and timely management is required to alleviate ecosystem consequences of invasion. Integrating airborne hyperspectral imagery with LiDAR data can

Große-Stoltenberg et al. (2018) Early detection of GPP-related regime shifts after plant invasion by integrating imaging spectroscopy with airborne LiDAR. Rem Sens Env.

Introduction Stand: Isoscapes **Landscape: Invasion syndromes**

Approach: Mapping the invader

- Airborne hyperspectral and LiDAR data (2m)
- 119 vegetation indices and 71 LiDAR derivatives
- Random Forest with Recursive Feature Elimination (15 VIs, 1 LiDAR derivative)
- Model accuracy: Sensitivity 0.79; PPV 0.81



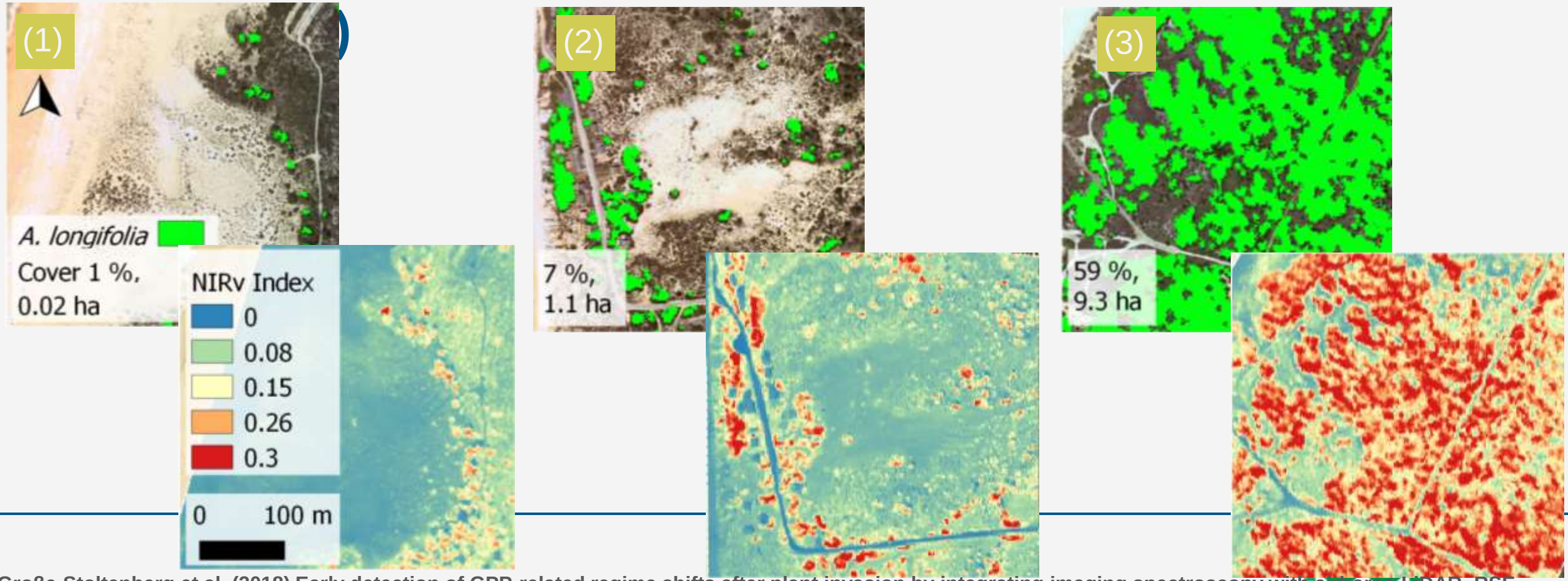
Große-Stoltenberg et al. (2018) Early detection of GPP-related regime shifts after plant invasion by integrating imaging spectroscopy with airborne LiDAR. Rem Sens Env.

Approach: Estimation of productivity

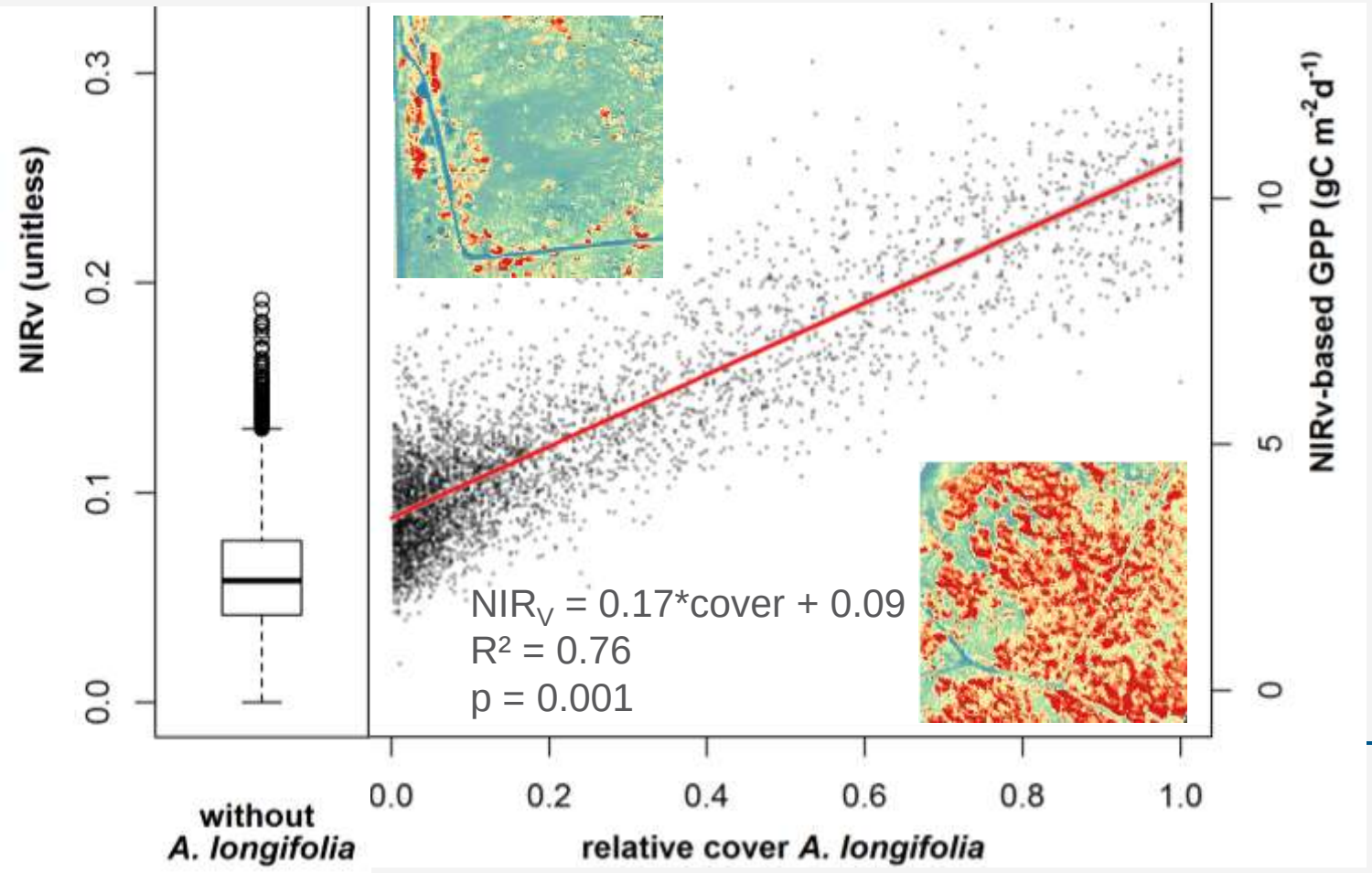
Near-Infrared Vegetation Index (NIR_V) (Badgley et al. 2017)

- **New vegetation index that relates to productivity (Gross Primary Production (GPP))**
- **Valid across ecosystems and vegetation types even if vegetation cover is low**
- **calibrated against multi-year monthly averages of eddy-covariance data from 105 FLUXNET sites**
- $NIR_V = NDVI \times N_T$
  - $NDVI = (R_{800} - R_{680}) / (R_{800} + R_{680})$
  - N_T : **NIR reflectance** **Badgley et al. (2017) Canopy near-infrared reflectance and terrestrial photosynthesis . Science Advances**

Results: Map of Acacia longifolia and NIR_V index



Results: Cover *Acacia longifolia*, NIR_V index, and GPP



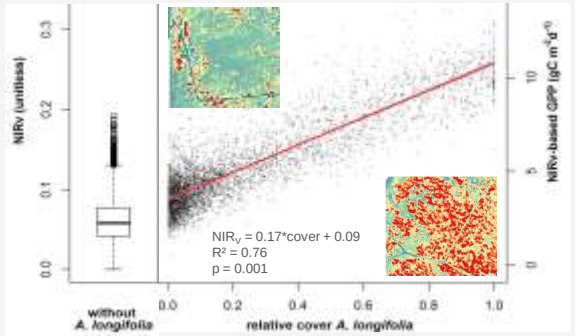
- **Productivity (NIR_V-based GPP) increases with invader cover.**
- ***Acacia longifolia*, an invader with niche construction ability, induces a regime shift from dune to forest type ecosystem.**

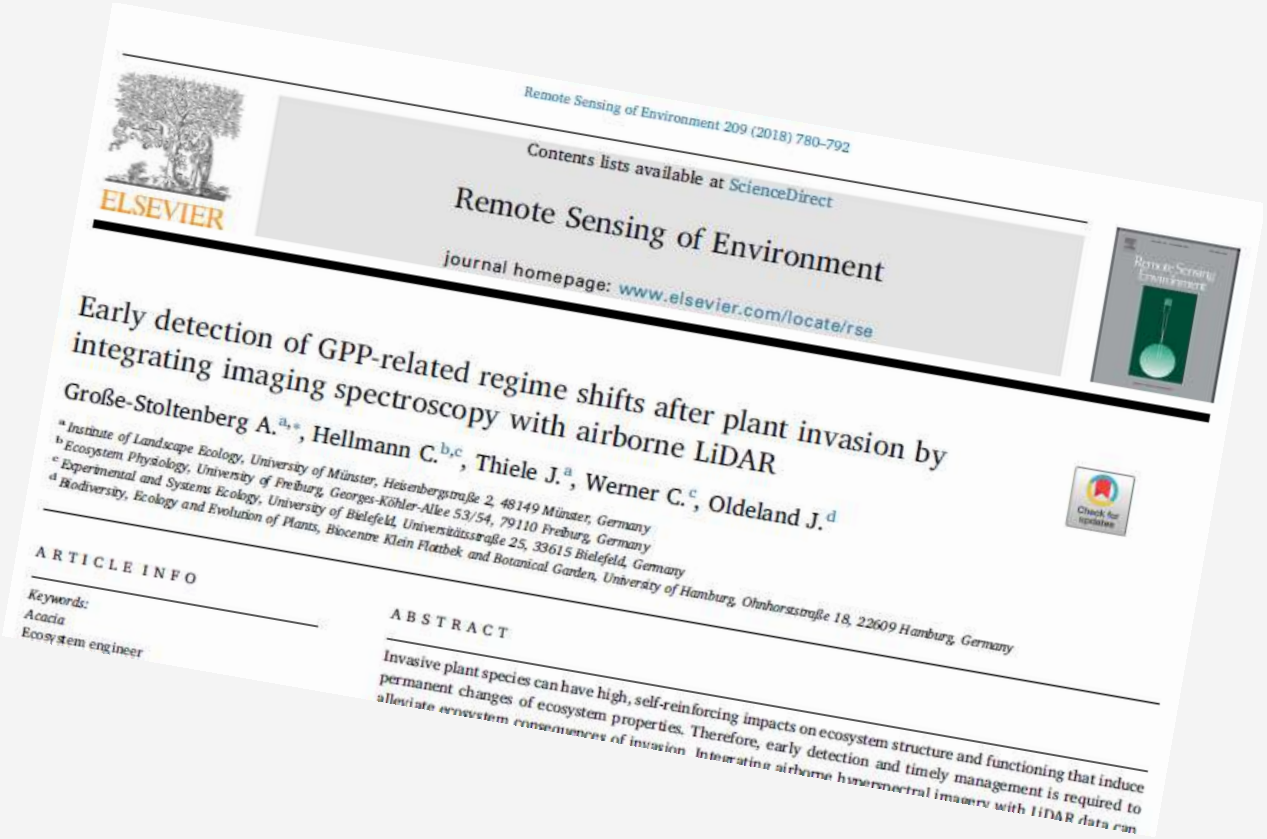
Große-Stoltenberg et al. (2018) Early detection of GPP-related regime shifts after plant invasion by integrating imaging spectroscopy with airborne LiDAR. RSE

Introduction | Stand: Isoscapes | **Landscape: Invasion syndromes**

Conclusion

Invader induced modifications of productivity (GPP) can be mapped even at early stages of invasion. The NIR_V index could be a remote sensing “model metric” to track this typical invasion pattern (“syndrome”).




Remote Sensing of Environment 209 (2018) 780–792

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Early detection of GPP-related regime shifts after plant invasion by integrating imaging spectroscopy with airborne LiDAR

Große-Stoltenberg A.[a,*], Hellmann C.[b,c], Thiele J.[a], Werner C.[c], Oldeland J.[d]

[a] Institute of Landscape Ecology, University of Münster, Heisenbergstraße 2, 48149 Münster, Germany
[b] Ecosystem Physiology, University of Freiburg, Georges-Köhler-Allee 53/54, 79110 Freiburg, Germany
[c] Experimental and Systems Ecology, University of Bielefeld, Universitätsstraße 25, 33615 Bielefeld, Germany
[d] Biodiversity, Ecology and Evolution of Plants, Biocentre Klein Flottbek and Botanical Garden, University of Hamburg, Ohnhorststraße 18, 22609 Hamburg, Germany

ARTICLE INFO

Keywords:
Acacia
Ecosystem engineer

ABSTRACT

Invasive plant species can have high, self-reinforcing impacts on ecosystem structure and functioning that induce permanent changes of ecosystem properties. Therefore, early detection and timely management is required to alleviate ecosystem consequences of invasion. Integrating airborne hyperspectral imagery with LiDAR data can

Große-Stoltenberg et al. (2018) Early detection of GPP-related regime shifts after plant invasion by integrating imaging spectroscopy with airborne LiDAR. RSE

N_2-fixing invasive ecosystem engineer alters ecosystem structure and functioning!

LEAF, CANOPY

Trait dissimilarity
Leaf traits differ between invader and invaded community, especially leaf N. This dissimilarity can be predicted using spectral data (mapping).

STAND

Isoscapes
Invader impact on N cycling can be mapped by combining LiDAR with spatial data on functional tracer foliar $\delta^{15}N$.

LANDSCAPE

Invasion syndromes
Airborne RS enables early detection of regime shift from a dune to forest type ecosystem; NIR_V as a model metric to track this syndrome.

ECOPHYSIOLOGY — REMOTE SENSING

Acknowledgments

DFG Deutsche Forschungsgemeinschaft

EUFAR European Facility For Airborne Research

DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service

Studienstiftung des deutschen Volkes

SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS