EGU General Assembly 2020

JLU NEUE WEGE. SEIT 1607.

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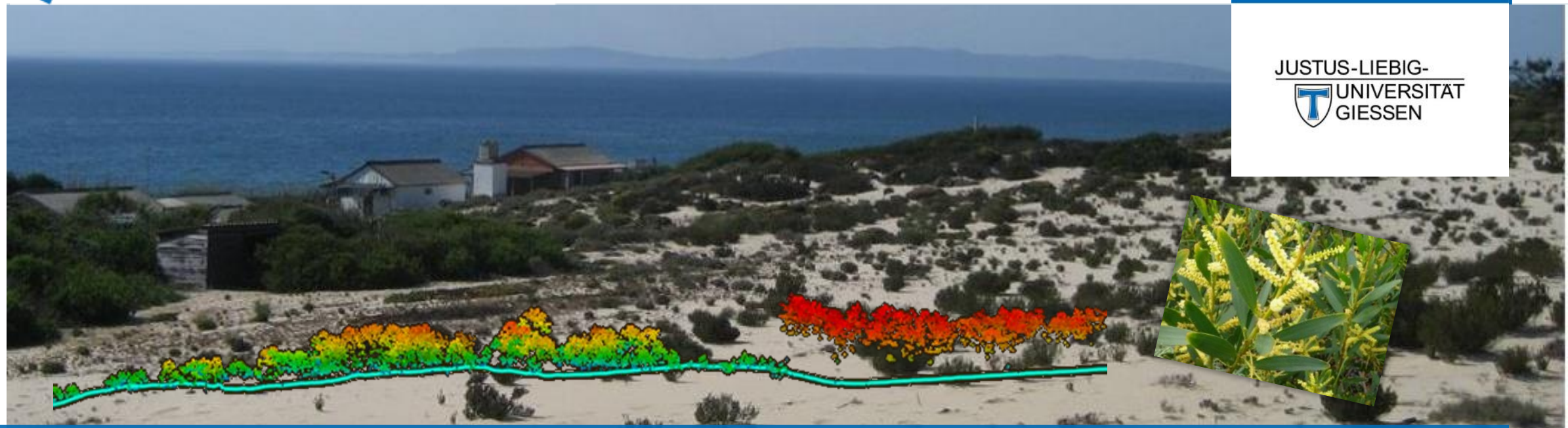


# Stable isotopes as early indicators of high impact after plant invasion: A remote sensing perspective

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



BG3.25 – Tracing Ecosystem Processes across Scales with Isotopes and other Novel Techniques

# Structure of the talk

- Introduction
  - Model invader and model system
- Scales and indicators
  - Leaf & Canopy: Trait dissimilarity
  - Stand: Spatial impact on N-cycle
  - Landscape: Invasion syndrome

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

# Model invader *Acacia longifolia*, Sydney Golden Wattle

Main characteristics of the invader

- Fabaceae native to SE Australia
- Tall shrub or tree
- Introduced to stabilise dunes
- Impacts on nutrient cycling and biodiversity

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

# Model invader *Acacia longifolia*, Sydney Golden Wattle

Alien range (Global invasive species database GISD)

ISSG Invasive Species Specialist Group

**GLOBAL INVASIVE SPECIES DATABASE**

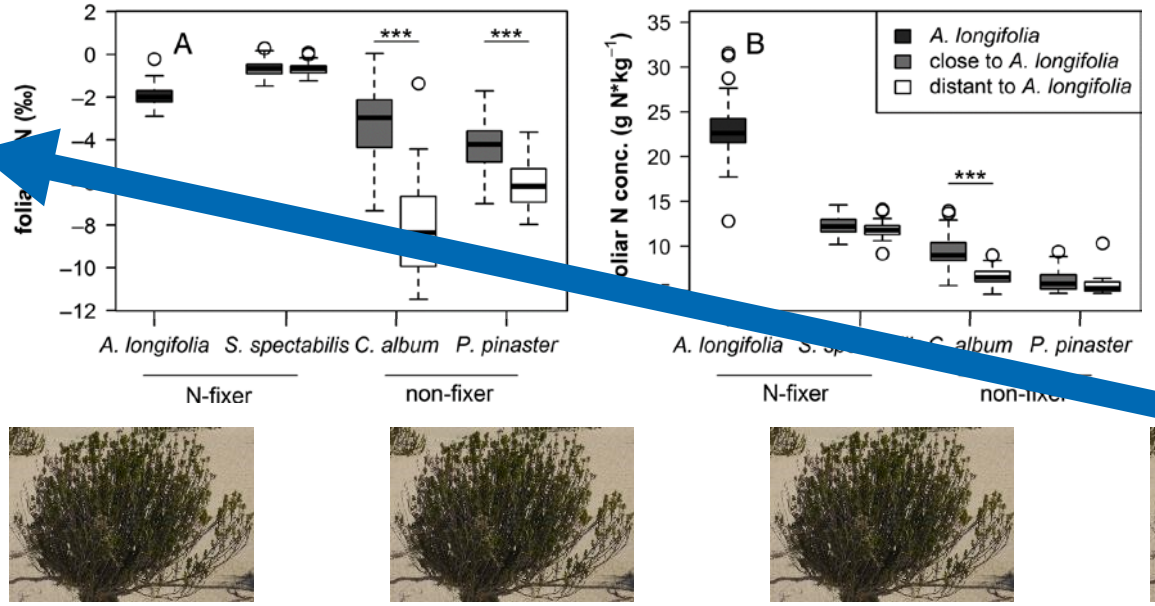
FULL ACCOUNT FOR: *Acacia longifolia*

[1] ARGENTINA
[1] BRAZIL
[1] DOMINICAN REPUBLIC
[1] INDONESIA
[1] ITALY
[1] MAURITIUS
[2] NEW ZEALAND
[1] REUNION
[1] SPAIN
[1] UNITED STATES
[3] AUSTRALIA
[1] COLOMBIA
[1] INDIA
[1] ISRAEL
[1] KENYA
[1] MYANMAR
[1] PORTUGAL
[3] SOUTH AFRICA
[1] SRI LANKA
[1] URUGUAY

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

# Model invader *Acacia longifolia*

Impact of *Acacia* on N cycling

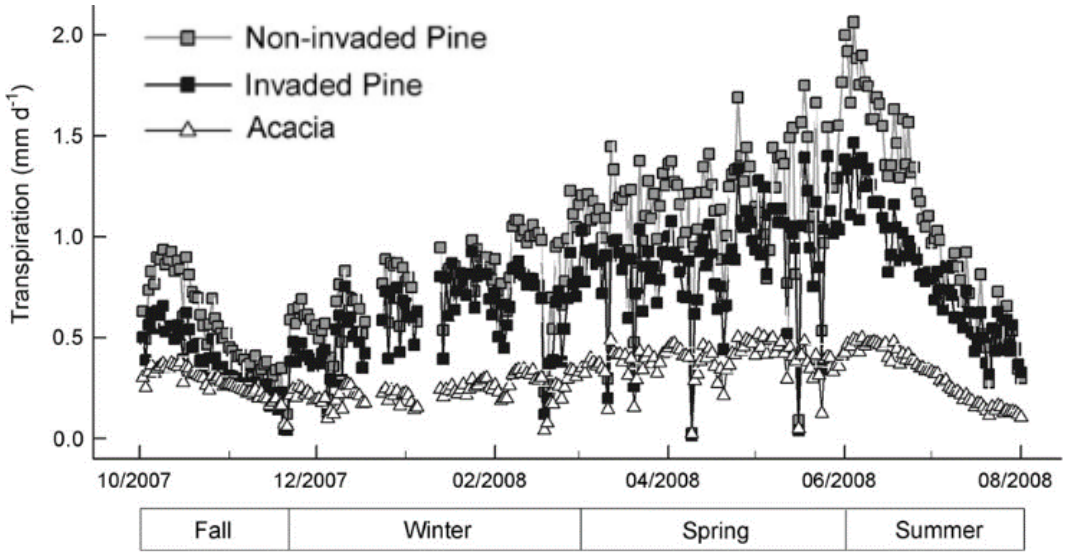

- Foliar N and $\delta^{15}N$ of the native shrub increases with vicinity to the N-fixing invader
- For mapping, topographic effects need to be considered

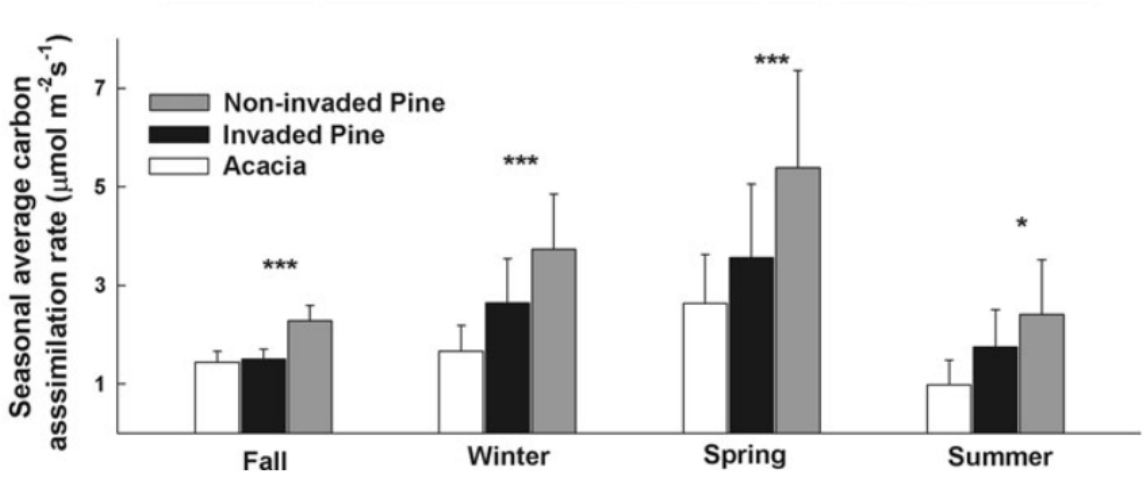
**Native Corema**
$N_{max}$: ~0.5%
$\delta^{15}N_{min}$: -12

Rascher et al. (2012) Community scale $^{15}N$ isoscapes: tracing the spatial impact of an exotic N2-fixing invader. Ecology Letters.

# Model invader *Acacia longifolia*

Impact of *Acacia* on water cycling



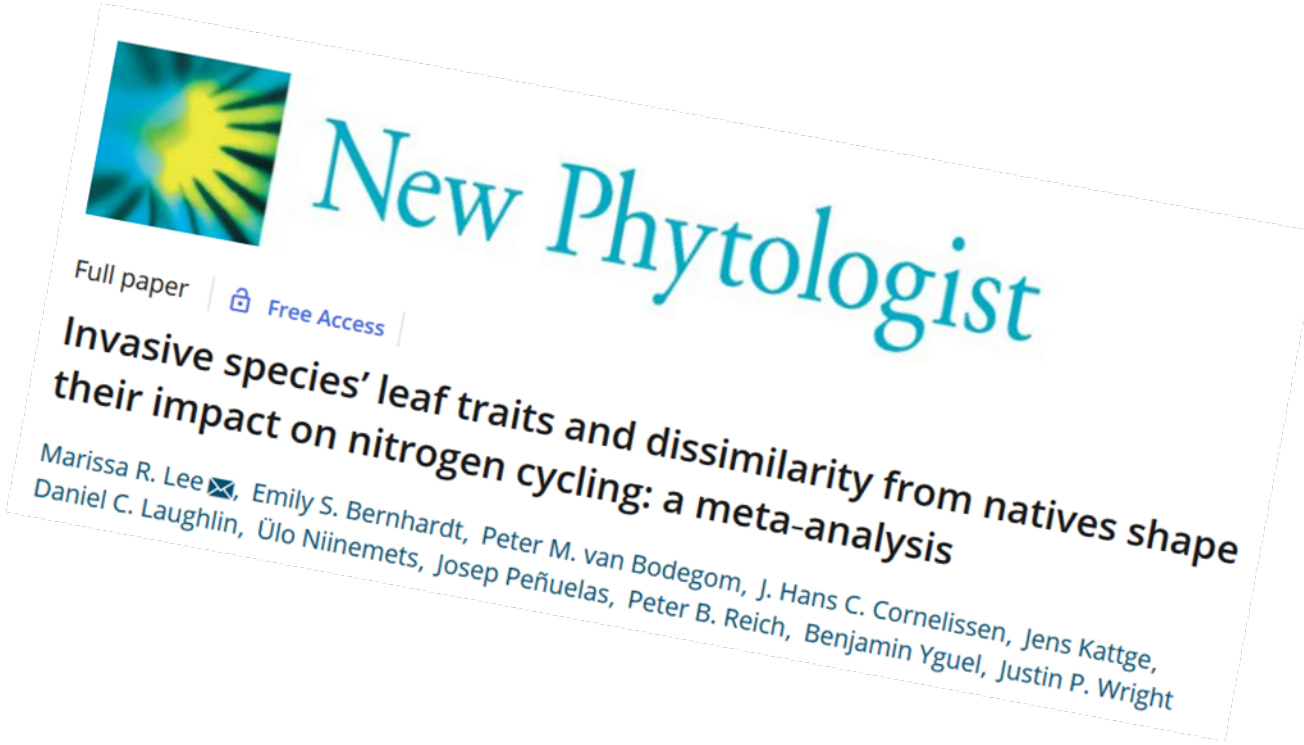

Rascher et al. (2011) Understory invasion by *Acacia longifolia* alters the water balance and carbon gain of a mediterranean pine forest. Ecosystems.

# Model invader *Acacia longifolia*

Research gap


# Concept „Trait dissimilarity“

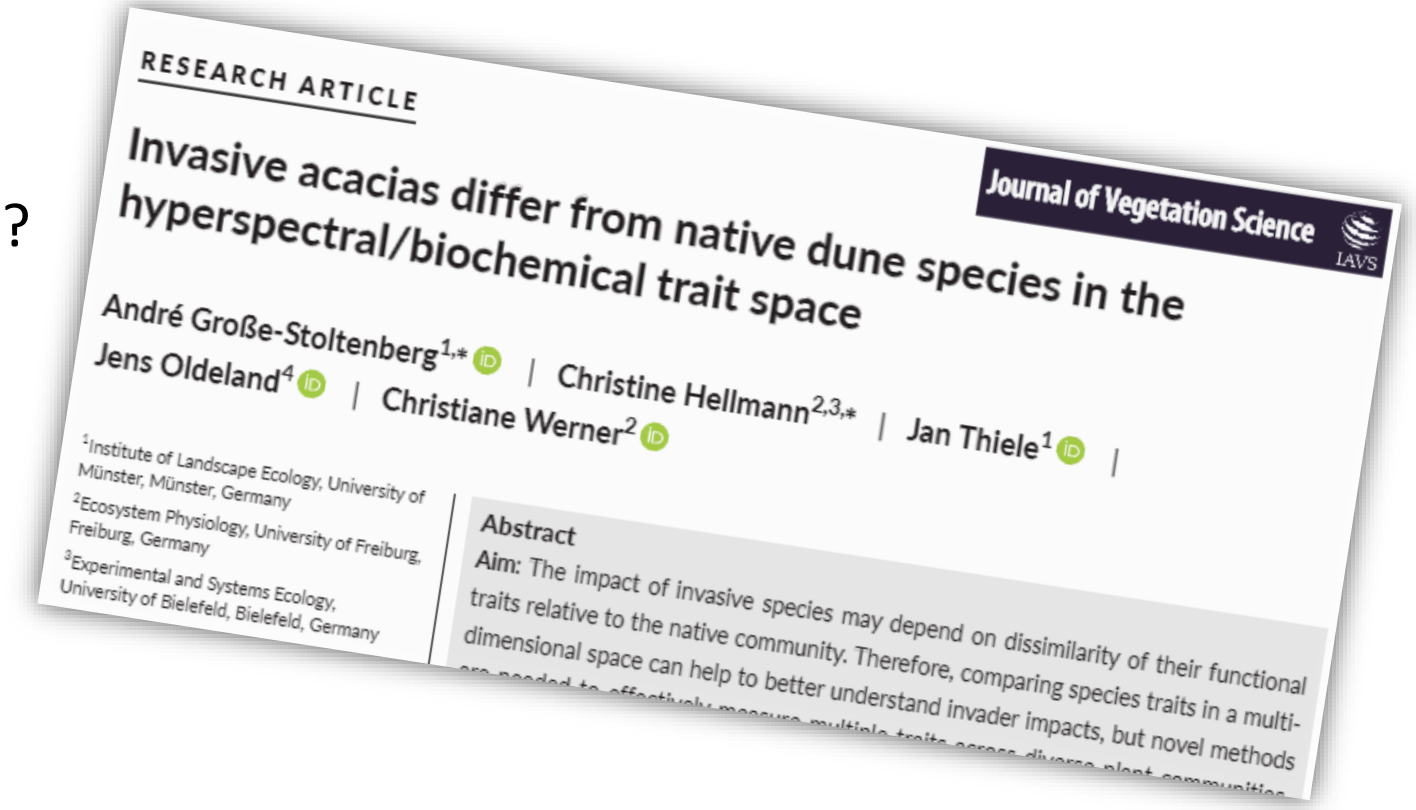
- Leaf and litter nitrogen (N) content, C:N ratio to assess invasive species’ impacts on N cycling
- Trait dissimilarities were better predictors than the trait values of invasive species alone
- Magnitude of impact increases with dissimilarity.




Lee et al. (2017) Invasive species’ leaf traits and dissimilarity from natives shape their impact on nitrogen cycling: a meta-analysis. New Phytologist.

# Research Question

- Are *Acacia longifolia*‘s leaf traits dissimilar from native species‘ traits?



RESEARCH ARTICLE

Invasive acacias differ from native dune species in the hyperspectral/biochemical trait space

Journal of Vegetation Science

André Große-Stoltenberg[1,*] | Christine Hellmann[2,3,*] | Jan Thiele[1] | Jens Oldeland[4] | Christiane Werner[2]

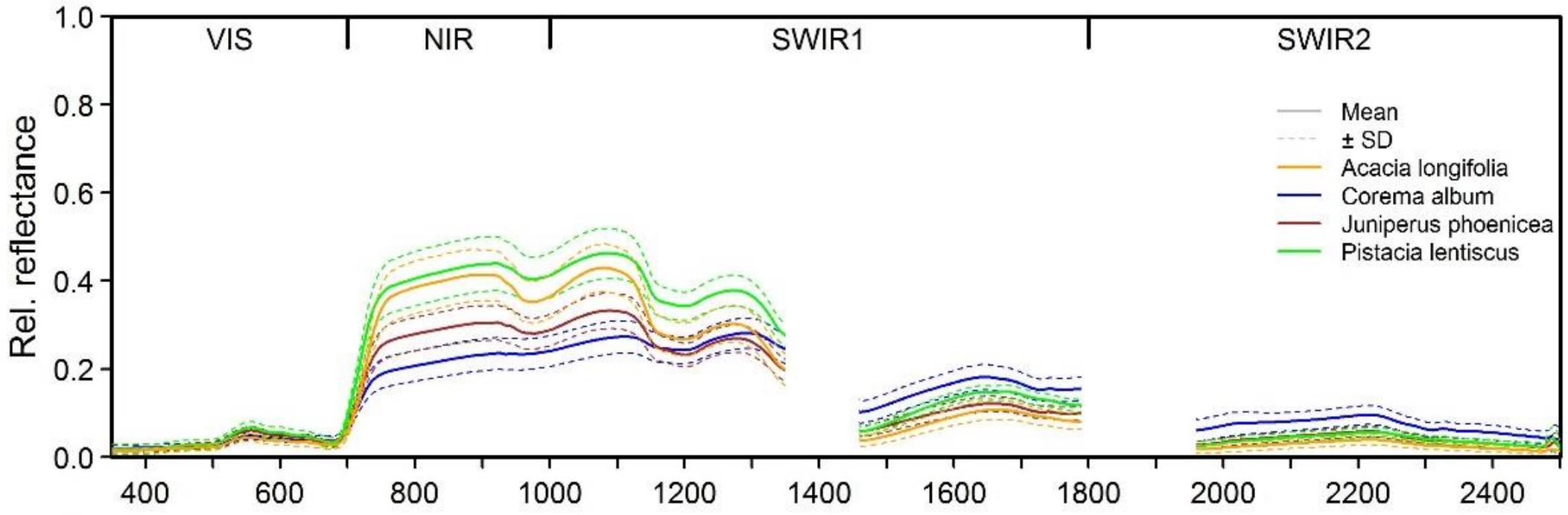
[1]Institute of Landscape Ecology, University of Münster, Münster, Germany
[2]Ecosystem Physiology, University of Freiburg, Freiburg, Germany
[3]Experimental and Systems Ecology, University of Bielefeld, Bielefeld, Germany

Abstract

Aim: The impact of invasive species may depend on dissimilarity of their functional traits relative to the native community. Therefore, comparing species traits in a multi-dimensional space can help to better understand invader impacts, but novel methods

Große-Stoltenberg et al. (2018) Invasive acacias differ from native dune species in the hyperspectral biochemical traits. Journal of Vegetation Science.

# Spectral signatures of selected species at canopy level




Große-Stoltenberg et al. (2016) Evaluation of continous VNIR-SWIR spectra versus narrowband hyperspectral indices to disciminate the invasive Acacia … . Remote Sensing.

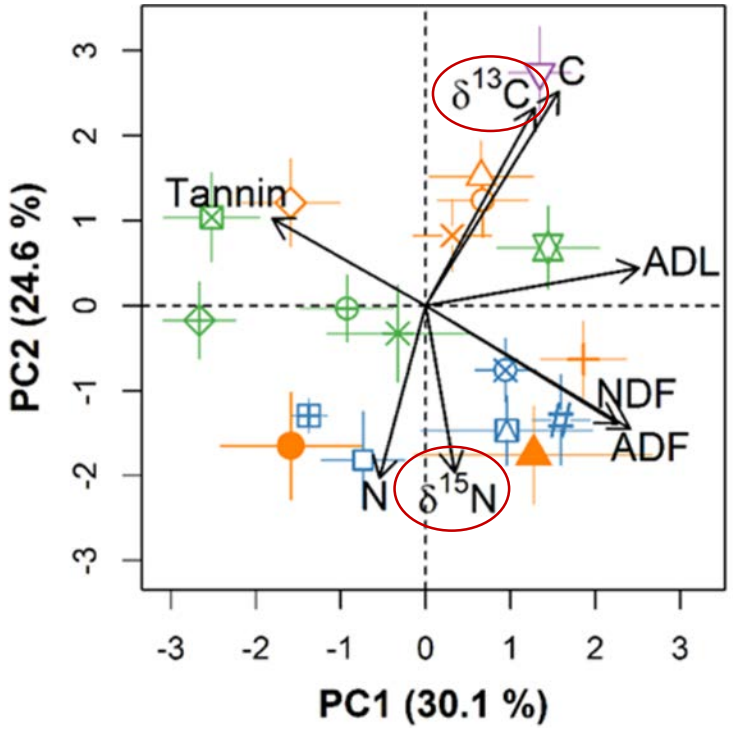
# Methods
## Species, functional groups, biochemical leaf traits, field spectra

- 18 species including *Acacia longifolia*
- 8 leaf traits together with leaf and canopy hyperspectral data (n = 162-218)

- Leaf biochemical traits
  - Carbon (C)
  - $\delta^{13}C$ (water use efficiency)
  - Nitrogen (N)
  - $\delta^{15}N$ (identification of N source)
  - Tannin (defense, decomposition)
  - Leaf Fibres (NDF, ADF, ADL, decomposition)

Große-Stoltenberg et al. (2018) Invasive acacias differ from native dune species in the hyperspectral biochemical traits. Journal of Vegetation Science.

# Results: PCA of leaf traits

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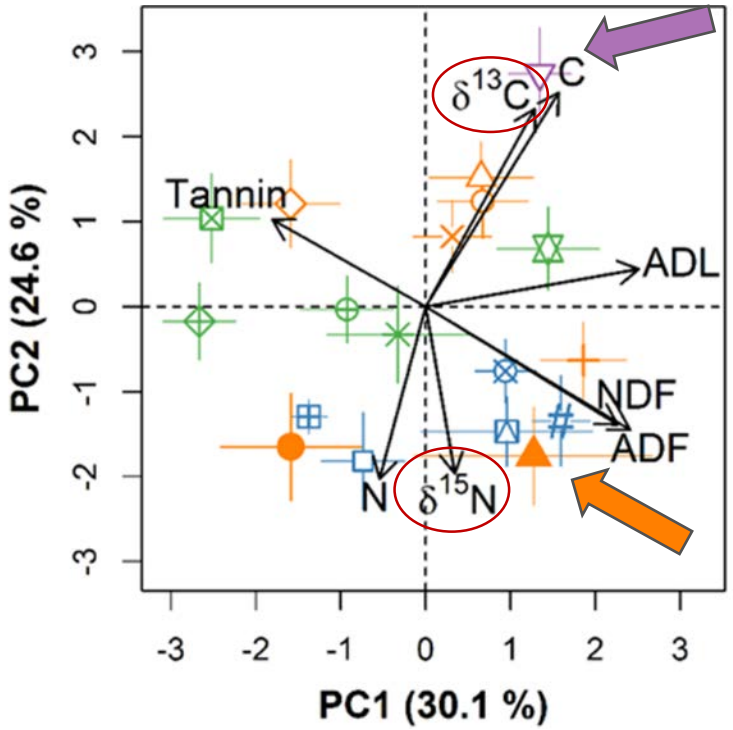



- *Acacia saligna*
- *Acacia longifolia*
- *Juniperus navicularis*
- *Juniperus phoenicea*
- *Pinus pinaster*
- *Phillyrea angustifolia*
- *Pistacia lentiscus*
- *Corema album*
- *Halimium calycinum*
- *Halimium halimifolium*
- *Cistus salviifolius*
- *Lavandula stoechas*
- *Rosmarinus officinalis*
- *Thymus camphoratus*
- *Thymus carnosus*
- *Helichrysum picardii*
- *Santolina impressa*
- *Corema album*

**invasive tall shrubs**

tall shrubs or trees

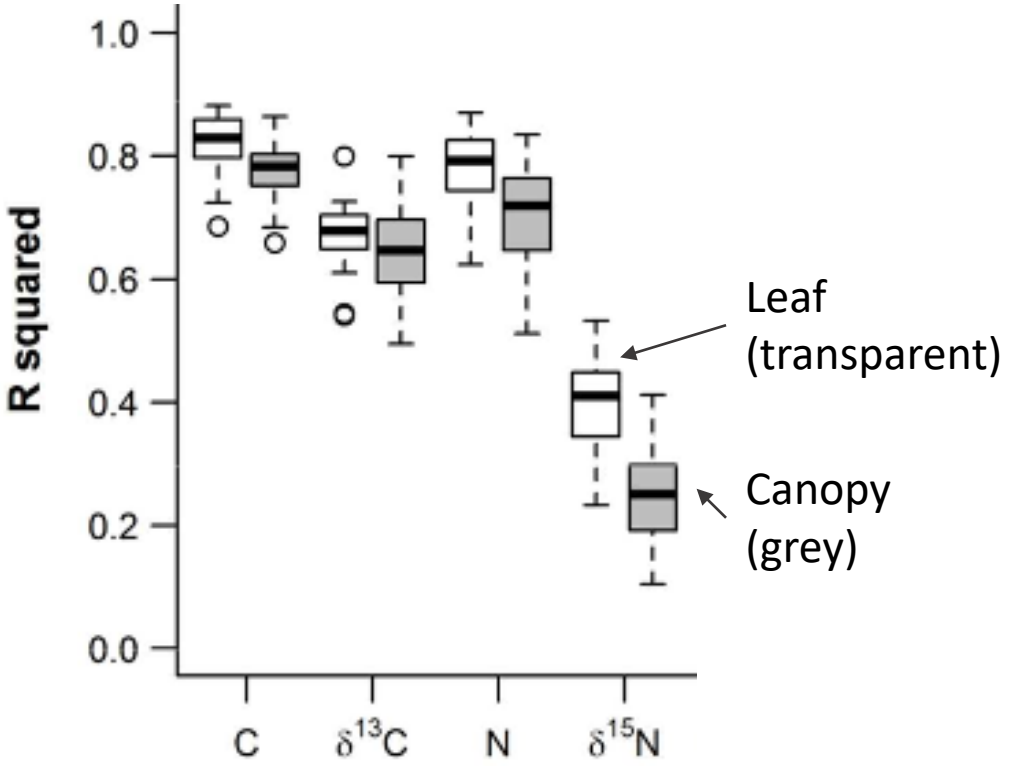
medium shrubs

dwarf shrubs

ericacean dwarf shrub

Große-Stoltenberg et al. (2018) Invasive acacias differ from native dune species in the hyperspectral biochemical traits. Journal of Vegetation Science.

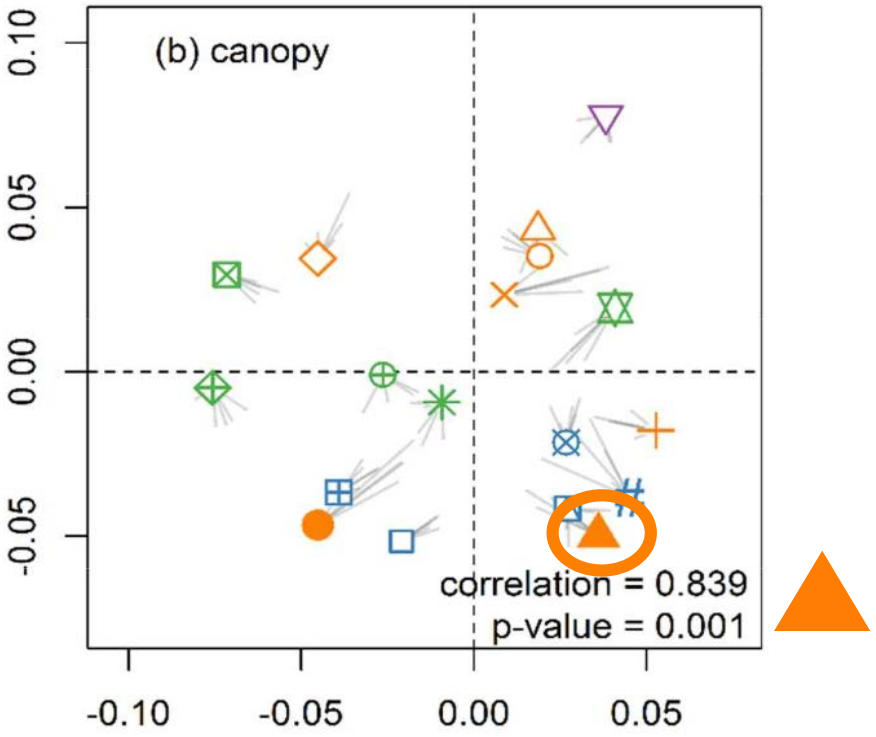
# Results: Prediction of traits based on spectral data




- $R^2$ slighty higher at leaf than at canopy level
- $R^2$ varies across leaf traits
- $R^2$ relatively high for $\delta^{13}C$, but relatively low for $\delta^{15}N$

Große-Stoltenberg et al. (2018) Invasive acacias differ from native dune species in the hyperspectral biochemical traits. Journal of Vegetation Science.

# Results: Prediction of traits based on spectral data




*Acacia longifolia*

- Even though $R^2$ ranges between 0.2 and 0.8, *Acacia longifolia*'s position in the trait space can be predicted accurately using hyperspectral data at both leaf and canopy level.

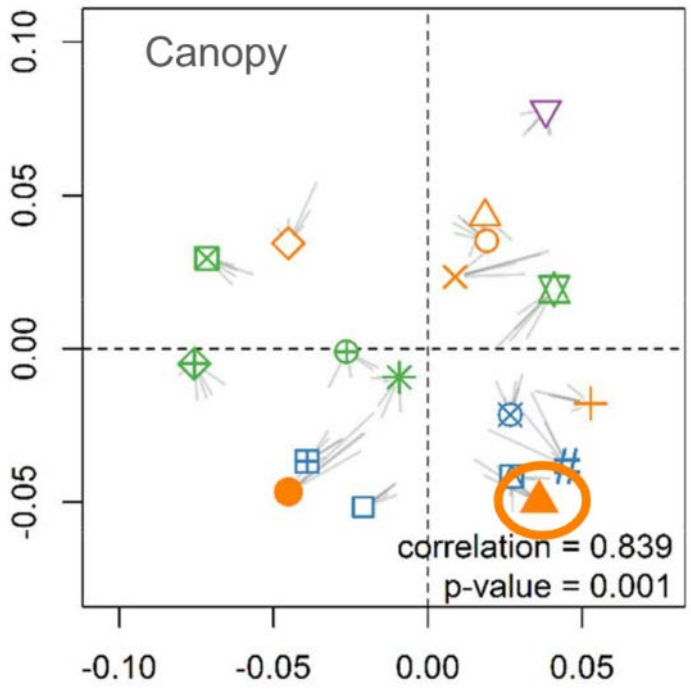
Große-Stoltenberg et al. (2018) Invasive acacias differ from native dune species in the hyperspectral biochemical traits. Journal of Vegetation Science.

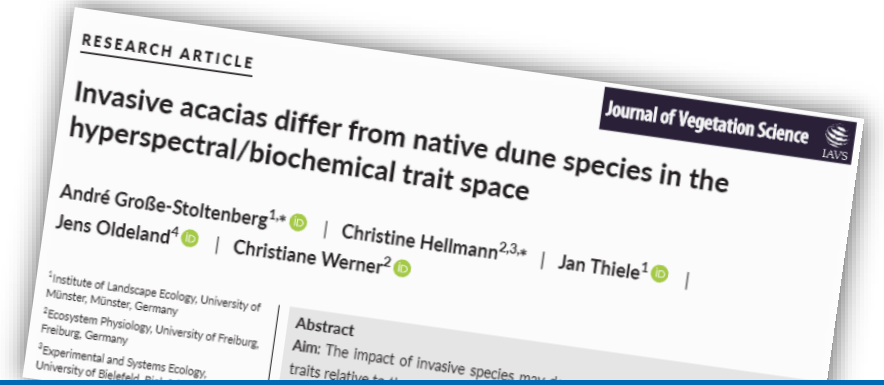
# Results: Prediction of traits based on spectral data


- There is potential nitrogen isotopic signatures from fresh leaf reflectance spectra.

Hellmann et al. (2015) Retrieving nitrogen isotopic signatures from fresh leaf reflectance spectra: disentangling $\delta^{15}N$ from biochemical and structural leaf properties. Front Plant Sci

# Conclusion

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Abstract

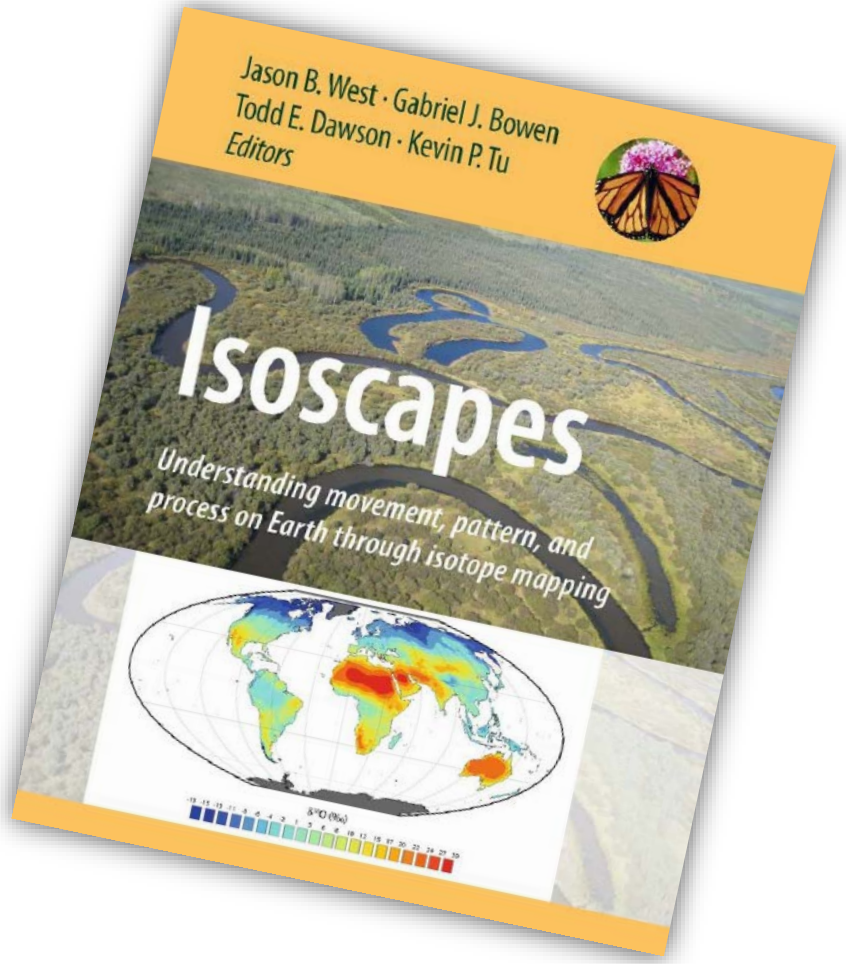
Aim: The impact of invasive species may ... traits relative to ...

*Acacia longifolia* is dissimilar from native species of the same growth form particular regarding leaf N content and including both $\delta^{13}C$ and $\delta^{15}N$.

This dissimilarity can be predicted using spectral data which indicates potential for mapping.

# 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))



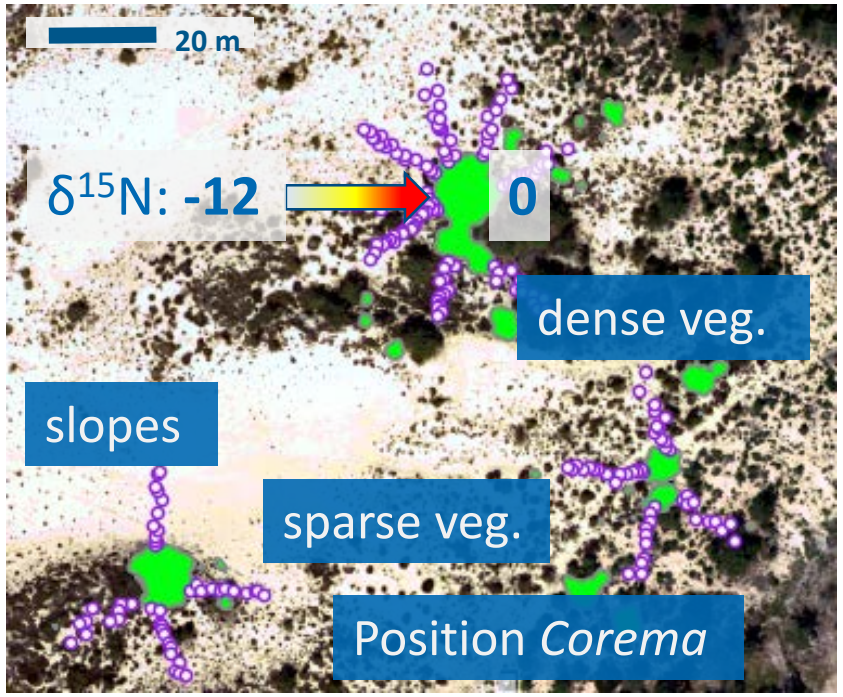

West et al. (2010) Isoscapes: Understanding movement, pattern, and process on Earth through isotope mapping. Springer.

# Research question „Isoscapes“

- 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

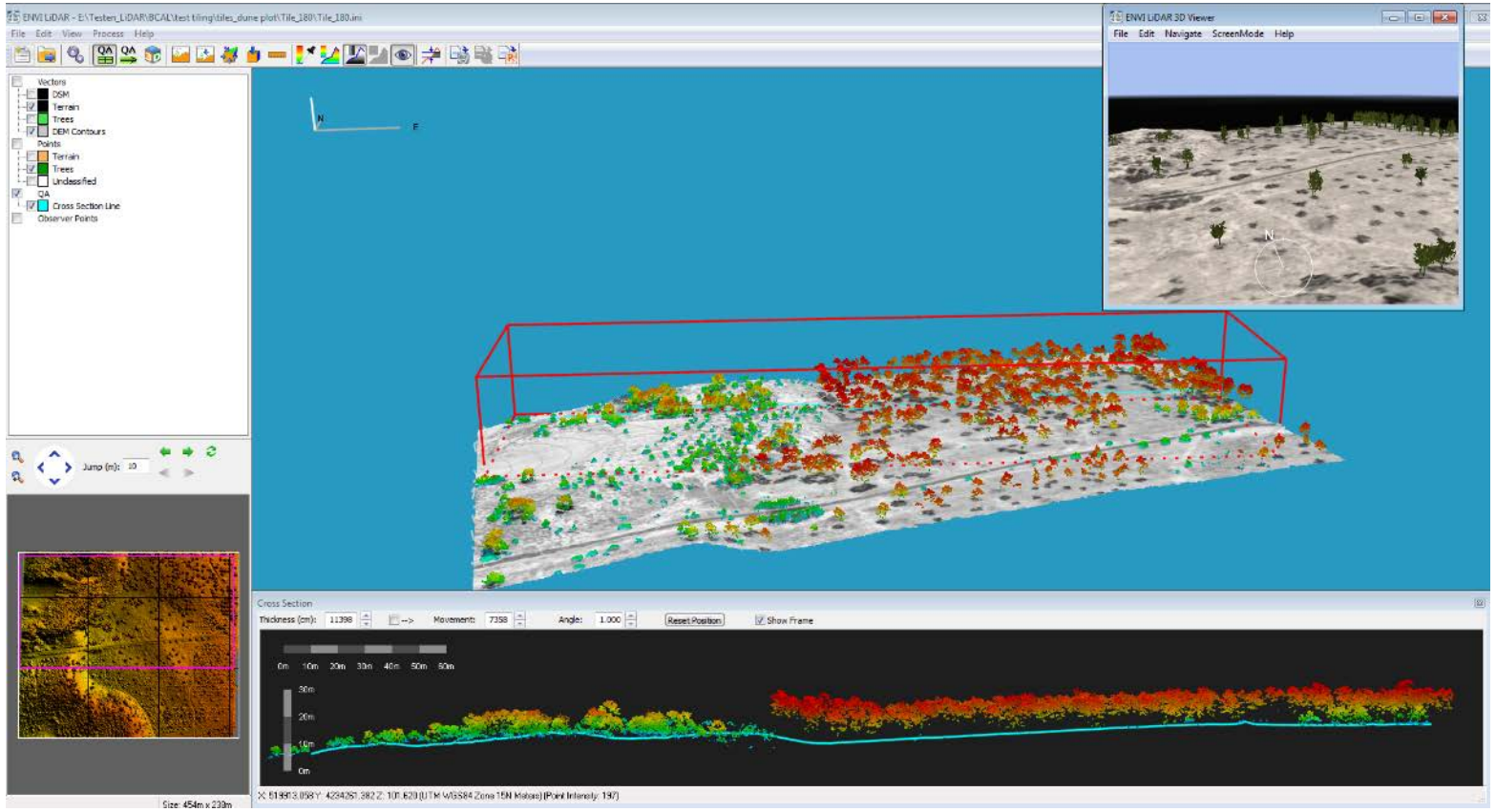
# Methods
## Native *Corema album* transects surrounding *Acacia longifolia*




- Data for 5 sites (one site shown here)
  - Map of the N-fixning *A. longifolia*
  - Transects of the native, non-fixing *Corema album*
  - Foliar $\delta^{15}N$ of C. album as a functional tracer of *Acacia* N-fixation
  - LiDAR data on topography and vegetation structure (environmental heterogeneity)

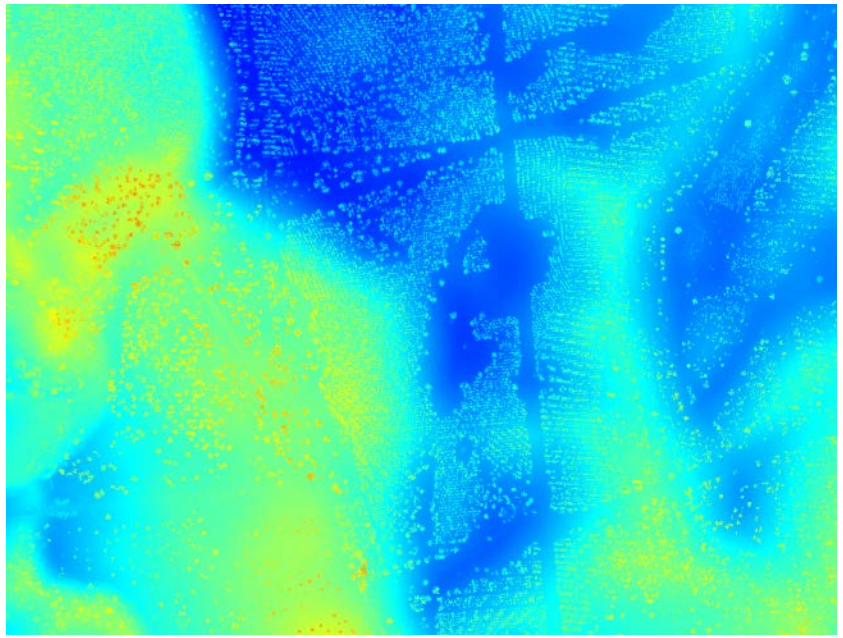
Hellmann et al. (2017) Heterogeneous environments shape invader impacts: integrating environmental, structural … . Scientific Reports.

# Methods
# Spatial predictors derived from airborne LiDAR

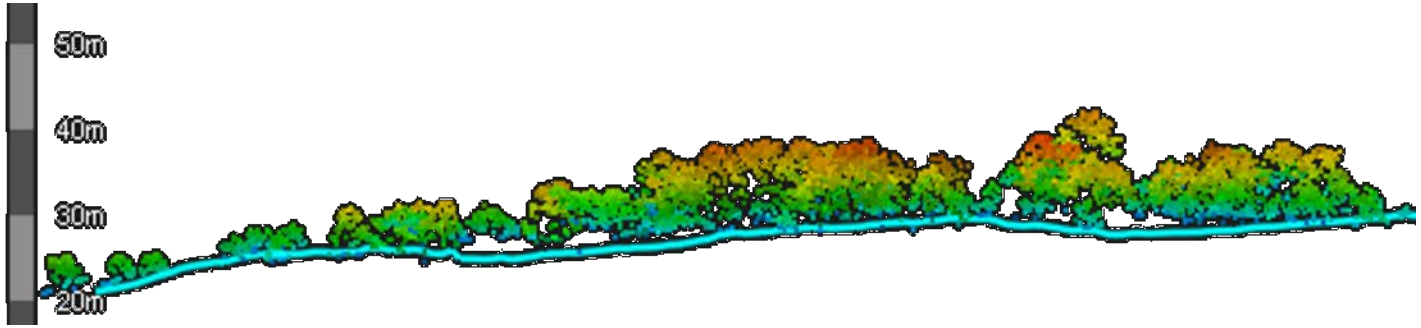


# Methods
## Spatial predictors derived from airborne LiDAR

Digitial Surface Model (DSM)



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



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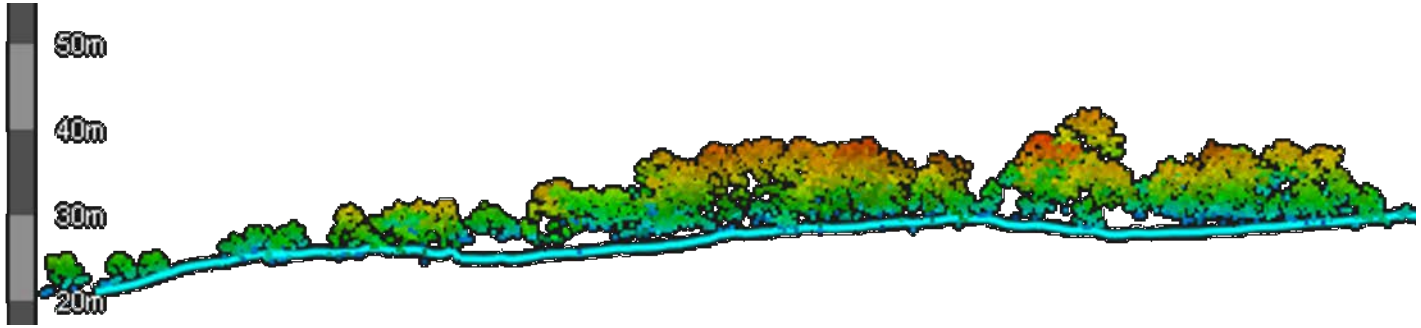
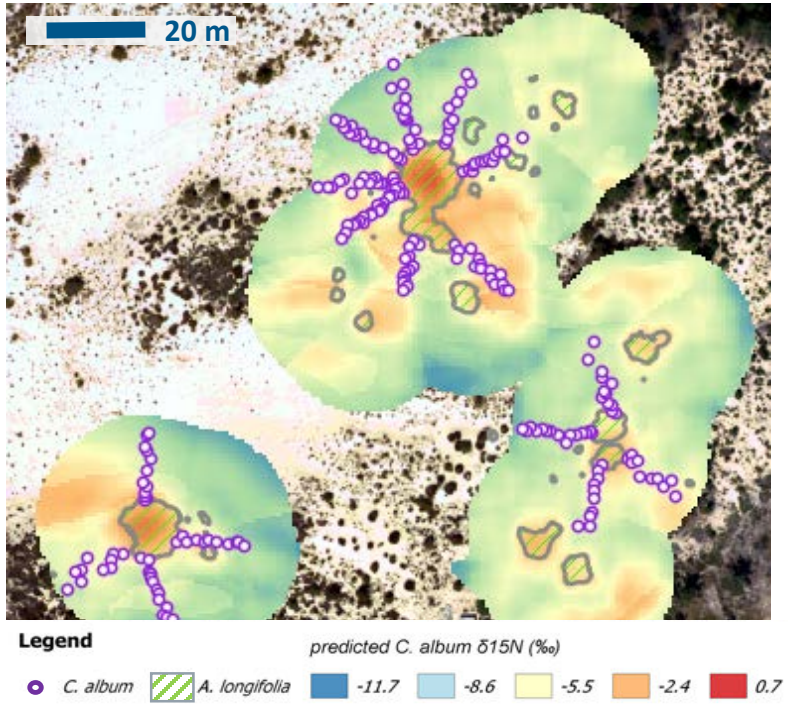


# Results
# Impact of *A. longifolia* and topography on $\delta^{15}N$




- Important predictors (GAMM)
  - Distance to *Acacia longifolia*
  - Landform, Position relative to *A. longifolia*, Vegetation cover, Topographical Wetness Index (LiDAR)
- Model quality ($\delta^{15}N$ map)
  - Median $R^2$: 0.6; Median RMSE: 1.82‰
- Main finding
  - $^{15}N$ 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. Scientific Reports.

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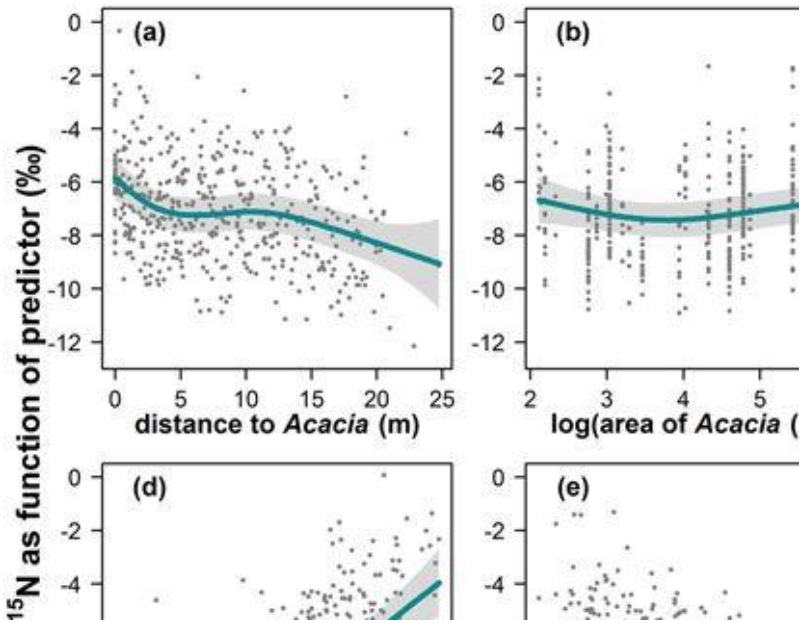


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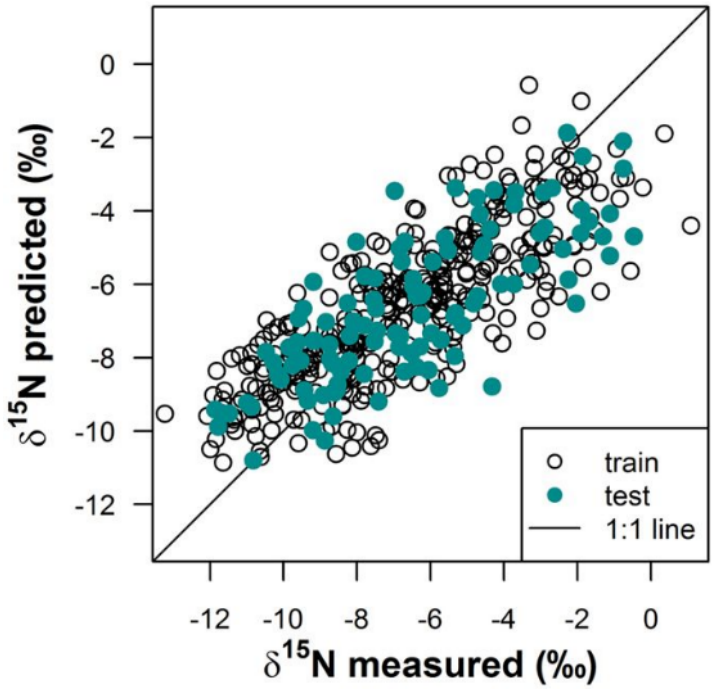


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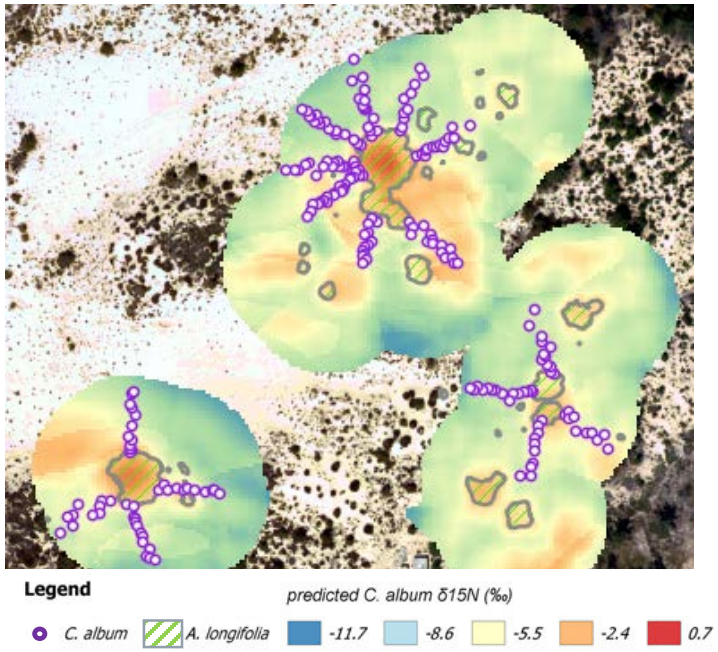
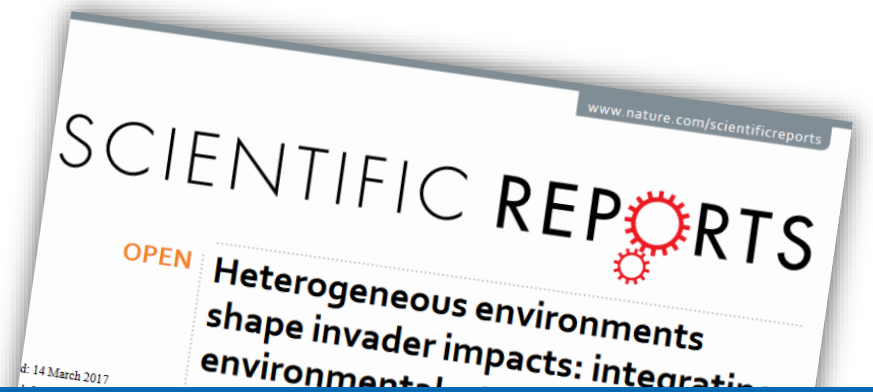
# Conclusion



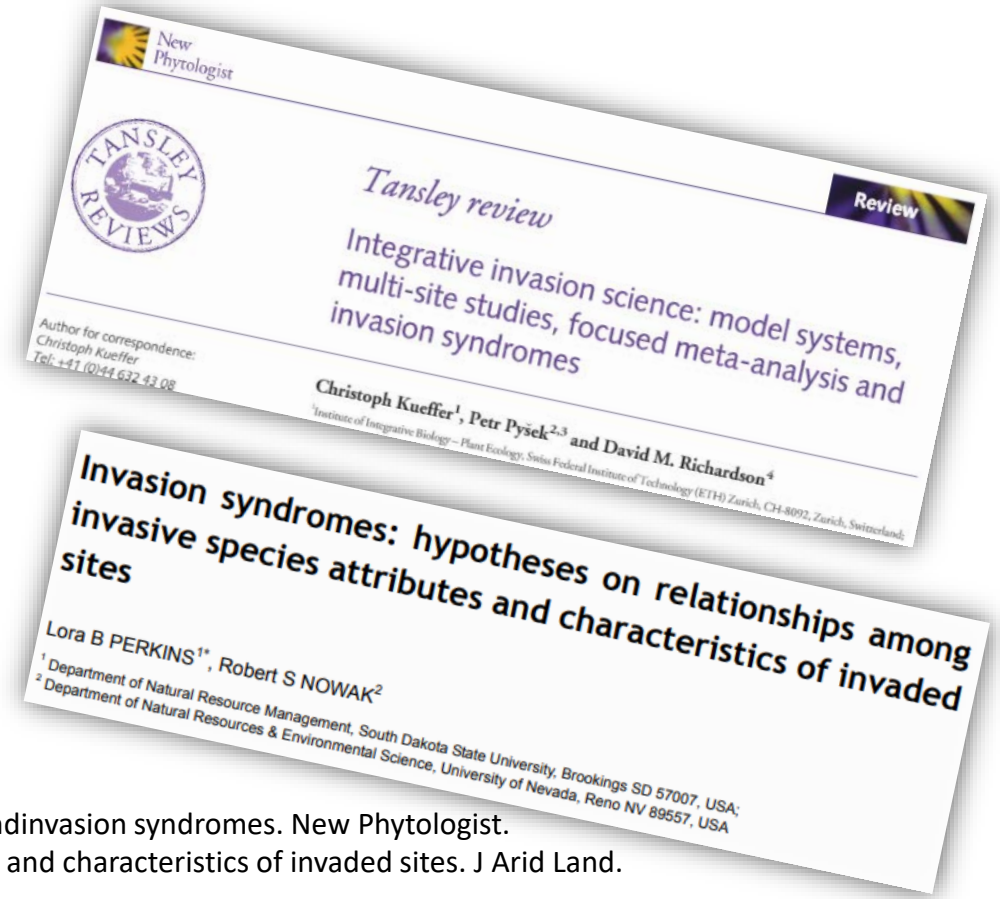




Isoscapes linked with remote sensing can be applied to map invader impact on N cycling.

They can serve as an early indicator for high impact.

# Concept „Invasion syndromes“

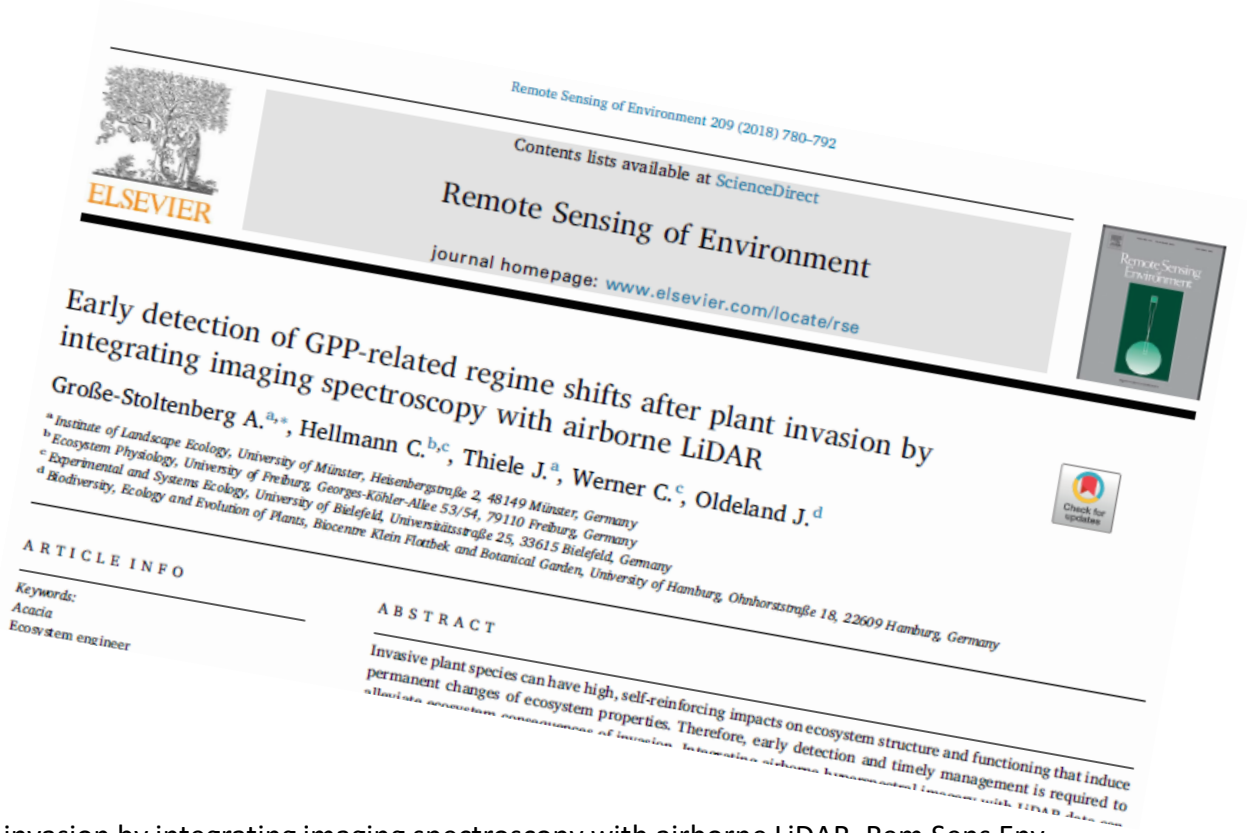
- Typical recurrent associations of species biology and invasion dynamics with particular invasion contexts such as invaded habitat.[1]
- Sites with relatively low resource abundance and low diversity should be vulnerable to invasion by species with niche construction ability.[2]




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

# Research question

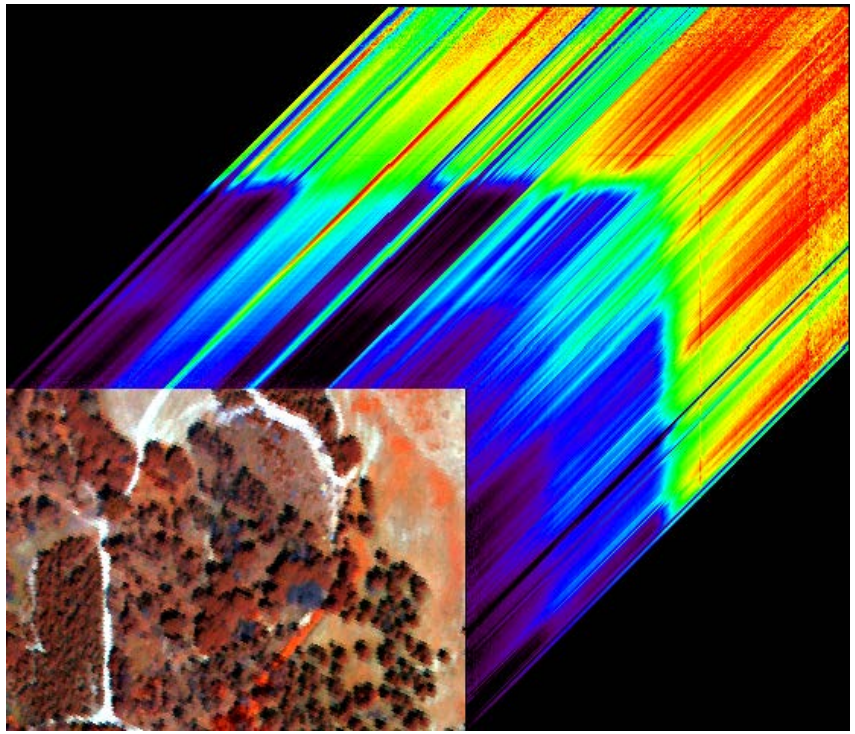
How can *Acacia longifolia*‘s impact on ecosystem structure and functioning be mapped at the landscape scale?




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: 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



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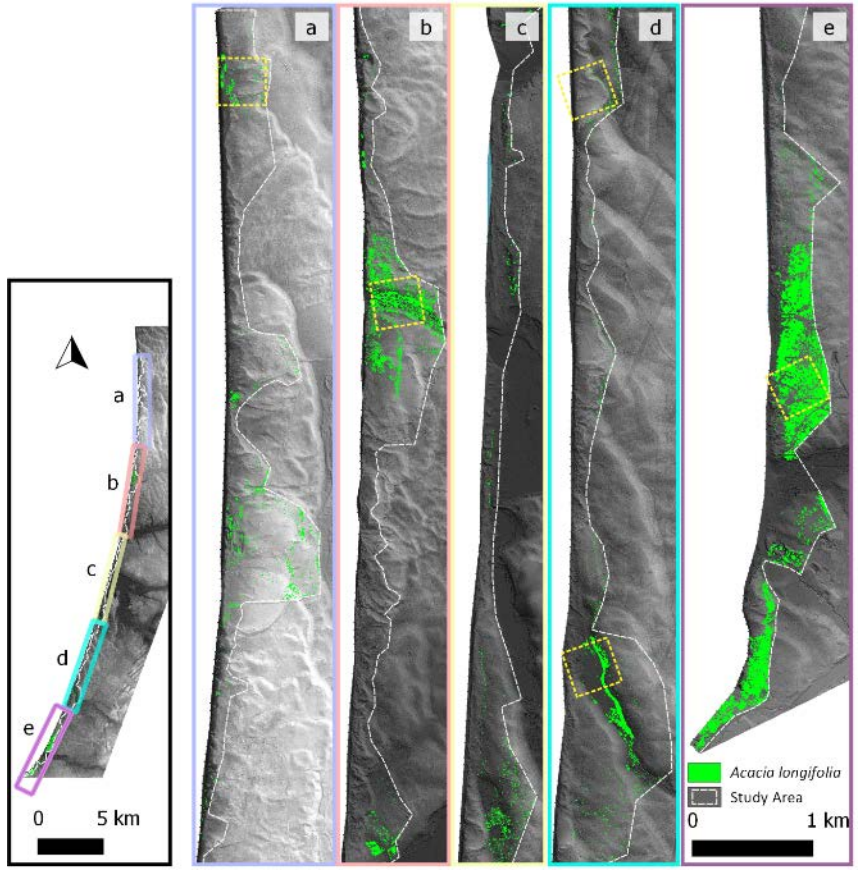


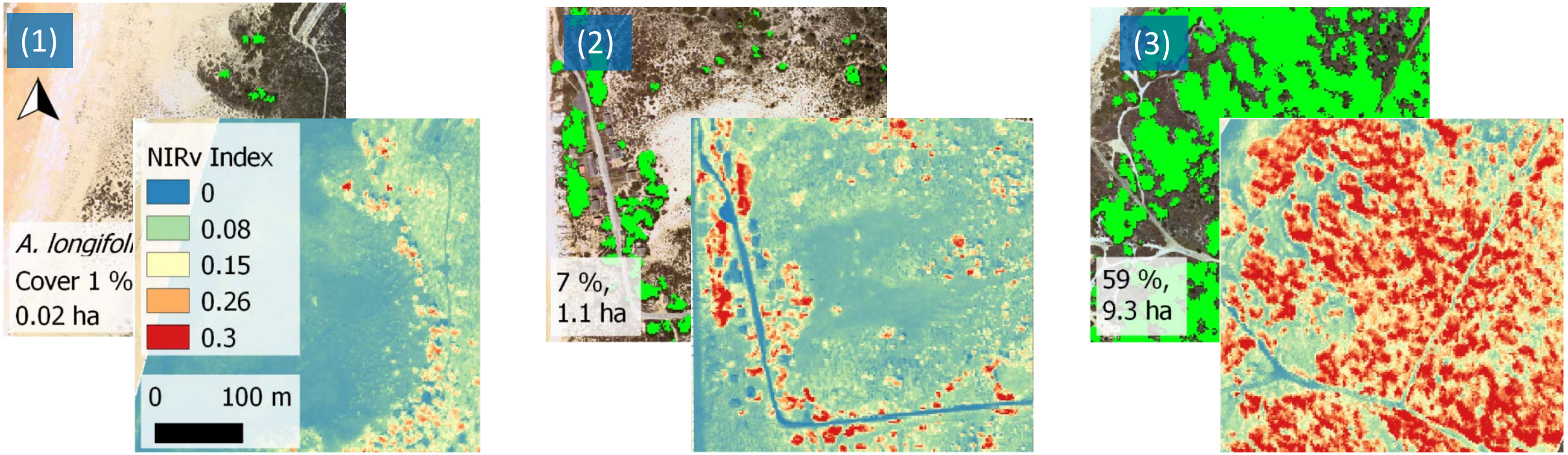

Große-Stoltenberg et al. (2018) Early detection of GPP-related regime shifts … .RSE

# Approach: Estimation of productivity

- Near-Infrared Vegetation Index (NIRV) (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
- $NIR_V = NDVI \times N_T$, $NDVI = (R800 - R680)/(R800 + R680)$; $N_T$ : NIR reflectance

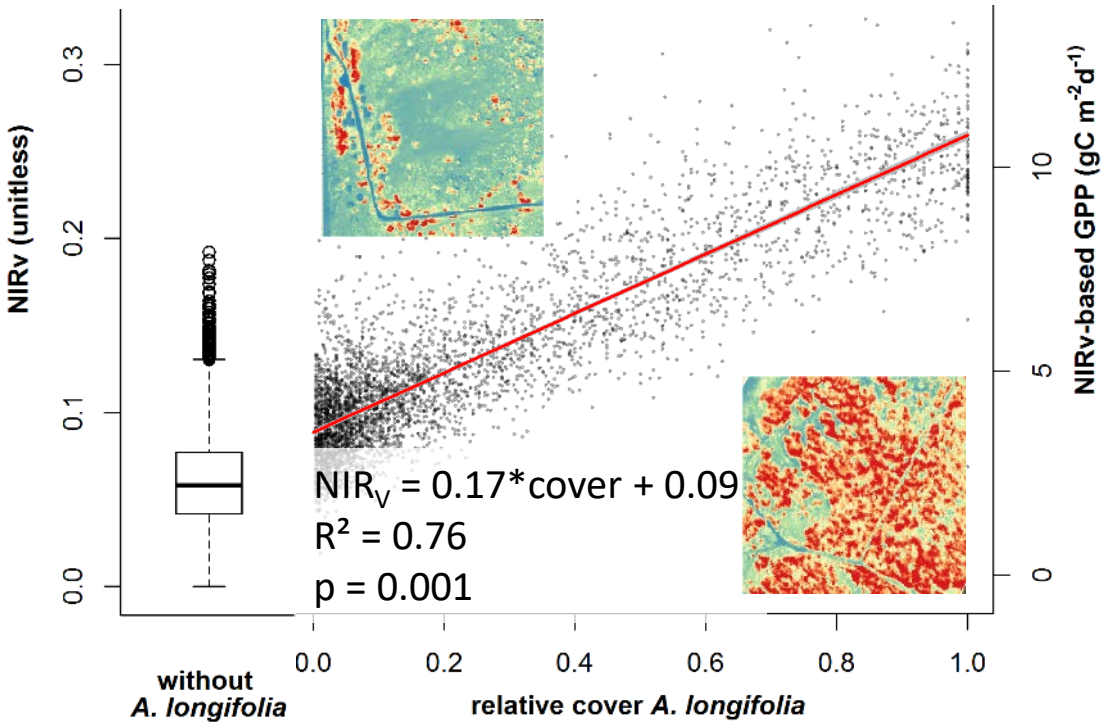
Badgley et al. (2017) Canopy near-infrared reflectance and terrestrial photosynthesis . Science Advances

# Results: Map of *Acacia longifolia* and $NIR_v$ index (productivity)




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.

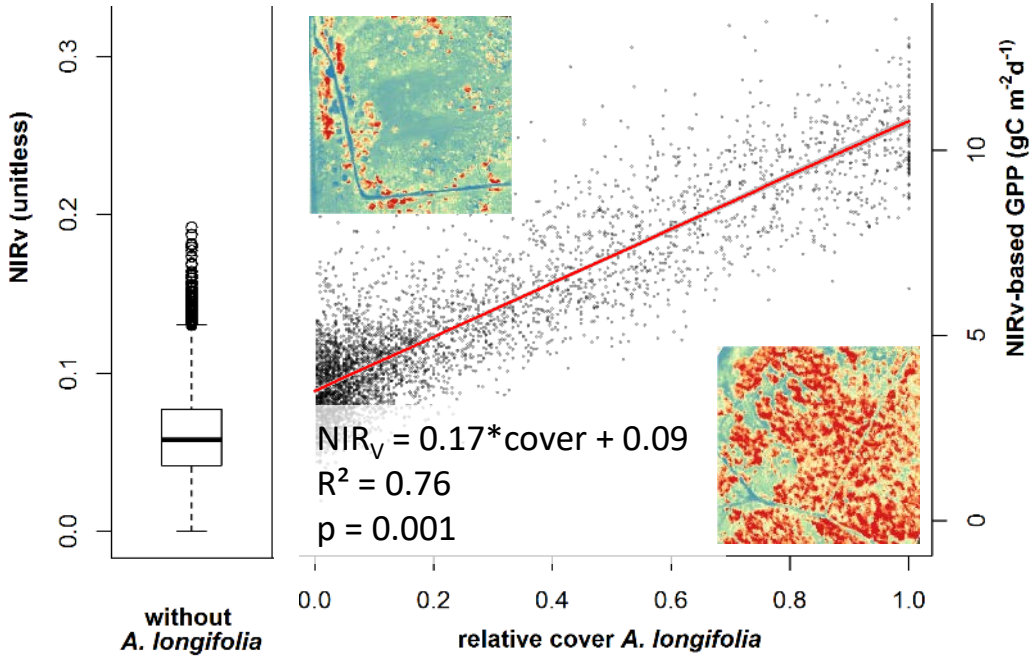
# Results: Cover *Acacia longifolia,* $NIR_V$ index, and GPP

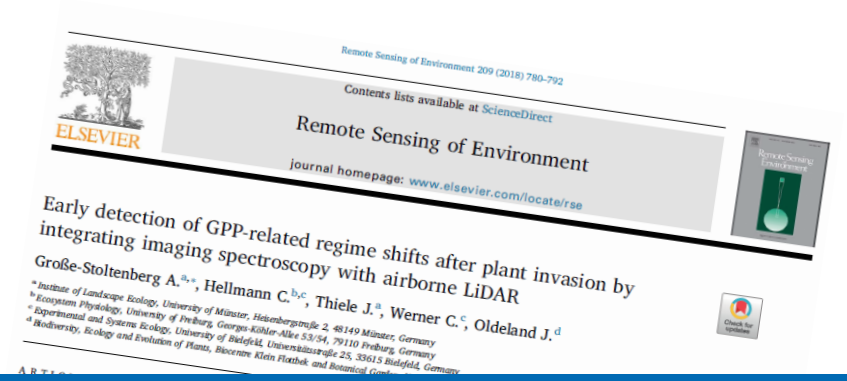



- Productivity ($NIR_V$-based GPP) increases with invader cover.
- *Acacia longifolia*, an invader with niche construction ability that changes both nitrogen and water cycling, induces a regime shift from dune to forest type ecosystem.

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

# Conclusion

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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]

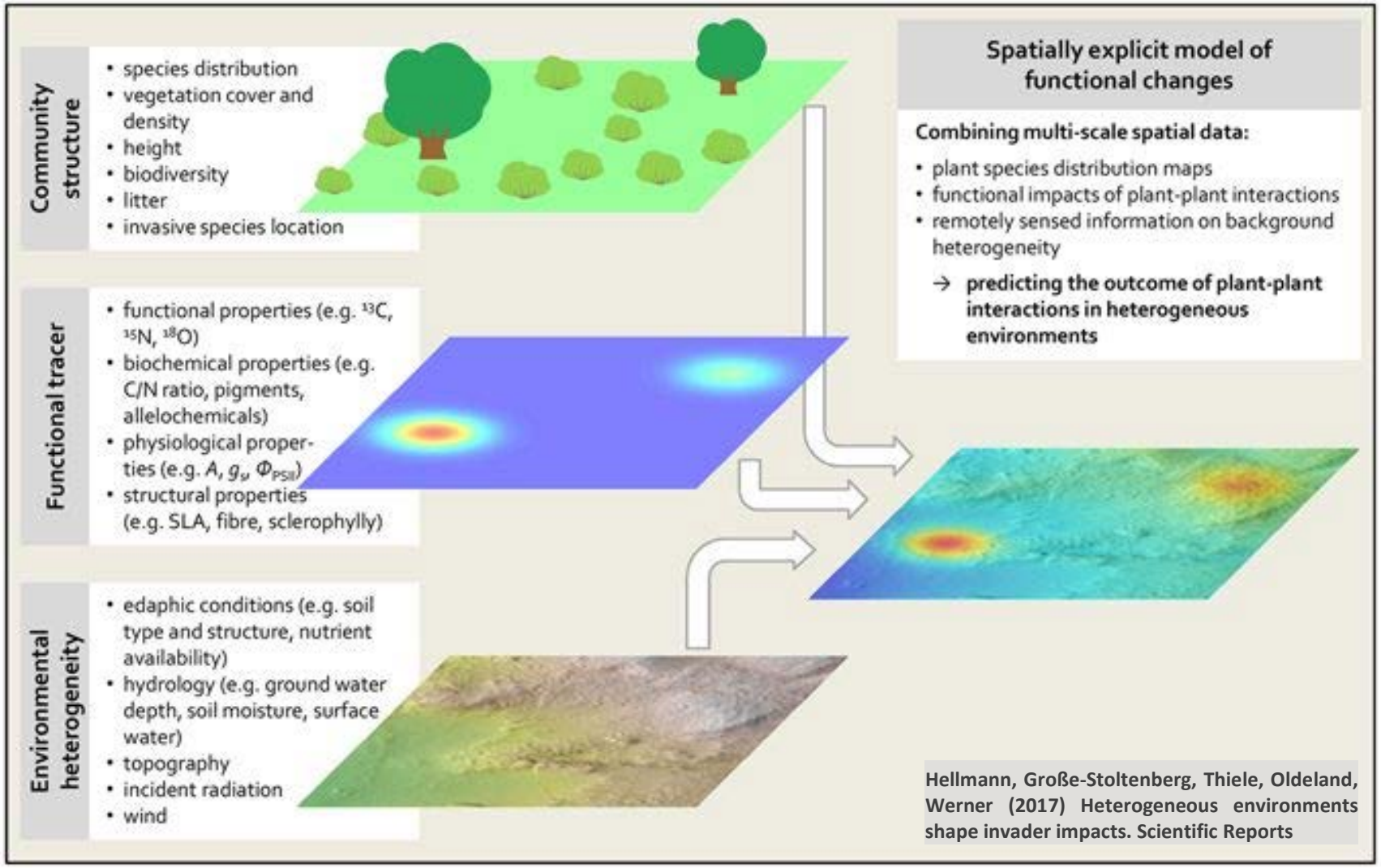
[a] Institute of Landscape Ecology, University of Münster, Heisenbergstraße 2, 48149 Münster, Germany
[b] Ecosystem Physiology, University of Freiburg, Georges-Köhler-Allee 53/54, 79110 Freiburg, Germany
[c] Experimental and Systems Ecology, University of Bielefeld, Universitätsstraße 25, 33615 Bielefeld,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

Invader induced modifications of productivity (GPP) can be mapped even at early stages of invasion.

The NIRV index could be a remote sensing “model metric” to track this typical invasion pattern (“syndrome”).

Introduction Leaf&Canopy: Traits Stand: Spatial Impact **Landscape: Invasion Syndrome**

# Stable isotopes as early indicators of high invader impact: Remote sensing perspective



DFG Deutsche Forschungsgemeinschaft

DAAD Deutscher Akademischer Austauschdienst
German Academic Exchange Service

EUFAR European Facility for Airborne Research

Studienstiftung des deutschen Volkes

SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS

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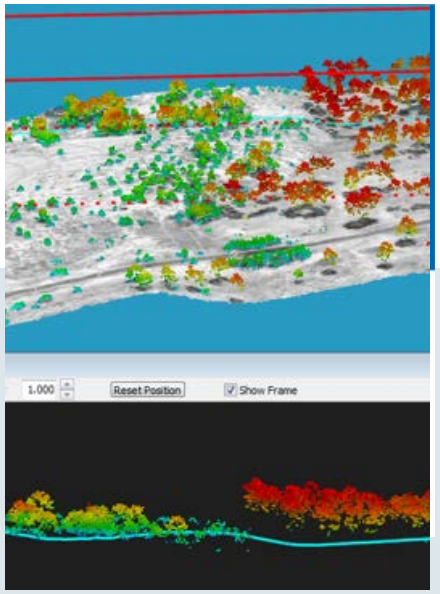


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