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

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

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Highlights

• The invasive *Acacia longifolia* was successfully mapped in a heterogeneous ecosystem.
• Combination of airborne hyperspectral and LiDAR data was used to map the invader.
• Invader causes GPP related shifts from dune to forest ecosystem.
• High impact on productivity detected at early stage of invasion.
• NIR_V index suggested as a “model metric” to track this typical invasion pattern.

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 deliver spatially explicit information on invader occurrence and ecosystem transformations even at early stages of invasion. However, relevant “model invaders” and well-characterized ecosystems need to be identified to both increase predictive power of invasion theory and prioritize management. In addition, there is still a knowledge gap regarding sensor-based approaches that are valid in space and time to assess the impact of invasive engineers on ecosystem functioning as well as the potential to induce regime shifts. In this study, occurrence and spatio-temporal impact of the invasive N_2-fixing shrub, *Acacia longifolia*, was assessed in a

heterogeneous, Mediterranean dune ecosystem. The invader was mapped using vegetation indices derived from airborne hyperspectral images as well as airborne LiDAR data using Random Forest classification with a Sensitivity of 0.79, a Positive Predicted Value (PPV) of 0.81, and Cohen's Kappa of 0.77. Invaded sites varied between early stages with low cover, where isolated patches were detected, to heavily infested *A. longifolia* thickets. Analysis of historical images showed that the invader could establish under the harsh conditions of open dune plains, possibly triggered by human interference. The recently developed Near-Infrared Vegetation Index (NIR_V), which is related to Gross Primary Production (GPP), increased linearly and significantly with increasing invader cover. This indicated a GPP-related regime shift induced by the invader, changing ecosystem productivity representative of open shrublands to that of forests. Such a shift could even be identified at early stages of invasion. Thus, the NIR_V index may provide an appropriate sensor-based "model metric" to assess impacts of invasive engineers. This offers the opportunity to predict and anticipate regime shifts as a basis for timely management.

Abbreviations

ASTER GDEM, Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model; DEM, Digital Elevation Model; dGPS, differential Global Positioning System; DSM, Digital Surface Model; fPAR, Fraction of absorbed Photosynthetic Active Radiation; GPP, Gross Primary Production; LAI, Leaf Area Index; LiDAR, Light Detection And Ranging; nDSM, normalized Digital Surface Model; NDVI, Normalized Difference Vegetation Index; NIR, Near-infrared; NIR_V, Near-Infrared Vegetation Index; N_T, reflectance in the near-infrared part of the spectrum; OOB, Out-Of-Bag (error); PPV, Positive Predicted Value; PRI, Photochemical Reflectance Index; RFE, Recursive Feature Elimination; UAV, Unmanned Aerial Vehicle; VI, Vegetation Index

Keywords

Acacia; Ecosystem engineer; Hyperspectral; Impact; Invasion syndrome; LiDAR; Mediterranean; Monitoring; NIR_V; Transformer species; Vegetation indices