Spatio-temporal vegetation indicators of Southern European floodplain forests vulnerability

Changements spatio-temporels de la végétation comme indicateurs de la vulnérabilité des forêts alluviales du Sud de l'Europe

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RÉSUMÉ

Ce projet vise à caractériser les tendances des variations spatio-temporelles à long terme de la structure et du fonctionnement des communautés végétales des forêts alluviales du Sud de l'Europe, afin d'identifier les indicateurs de vulnérabilité de l'écosystème, transférables à d'autres régions. La zone d'étude est située dans le Parc National de Doñana (sud-ouest de l'Espagne) qui présente la zone de forêt alluviale ibéro-atlantique la plus grande et la mieux préservée avec un climat Méditerranéen. L'étude comprend (i) un suivi à long terme, basé sur un réseau de placettes permanentes, de la réponse des communautés végétales et des relations fonctionnelles des espèces fondatrices avec les changements environnementaux, (ii) l'identification des patrons spatio-temporels et des signatures spectrales des principales espèces fondatrices en utilisant des approches de télédétection (depuis 1984), (iii) le développement de nouvelles méthodologies pour classifier et suivre la dynamique de la dominance et de la structure de la végétation. Les résultats préliminaires montrent des changements temporels dans la composition et la structure des forêts, avec un décalage dans la dominance entre *Salix* et *Fraxinus*, probablement associé à une réduction des apports de la nappe phréatique. Les signatures temporelles et spectrales bien distinctes suggèrent la potentialité de cartographier les changements historiques, d'interpréter les ajustements spatio-temporels observés par rapport à la dynamique naturelle de la forêt ou à des perturbations anthropiques, et de développer des nouvelles approches de gestion adaptative sur la base du degré de complexité et de prédictibilité des séries temporelles étudiées.

ABSTRACT

Our research aims at characterizing the long-term spatial and temporal variation trends in the plant community structure and function occurring in Southern European floodplain forests in order to identify indicators of the whole ecosystem vulnerability applicable to other regions. The study area is located at National Park of Doñana (SW Spain), which harbors the largest well preserved area of ibero atlantic floodplain forests under Mediterranean climate. The study includes (i) maintaining a long-term monitoring of riparian vegetation based on an established network of permanent plots to track plant community responses and functional relationships of foundation tree species to environmental change; (ii) Identifying spatio-temporal vegetation patterns and spectral signatures for the main foundation tree species by means of remote sensing (1984 to present), (iii) developing and testing novel classification methods for vegetation structure and dominance. Preliminary field results revealed temporal changes in forest composition and structure, revealing a dominance shift between *Salix* and *Fraxinus*, likely associated with water table lowering. The distinct spectral and temporal species signatures observed suggest potential ability for mapping historical changes, for the interpretation of spatio-temporal adjustments associated with forest natural dynamics or anthropic disturbances, and for developing new approaches for adaptive ecosystems management based on the level of complexity and predictability of the studied temporal series.

KEYWORDS

Foundation species, global change, riparian dynamics, spatial patterns, wetland forests

1 INTRODUCTION

Long term monitoring of riparian plant communities is critical, not only to track biological responses to local and global environmental changes but also to identify early warning signals of prospective changes in the whole ecosystem functioning and services. Dominant trees in floodplain forests act as foundation species modulating ecosystem processes through specific characteristics with strong impact in local conditions affecting other species (Grady et al 2005). Doñana National Park (DNP), in South-western Spain (Figure 1), harbours the largest area of well-preserved Ibero-Atlantic floodplain forest under Mediterranean climate (Rodríguez-González et al 2008). In 2002 we launched a multiscale long-term monitoring protocol of riparian vegetation formations from DNP, within the Doñana LTSER Platform. In this project, we aim at characterizing the spatio-temporal variation trends in the community structure and function occurring in Southern European floodplain forests in order to identify indicators of the whole ecosystem vulnerability, a key issue for riparian ecosystems adaptation to global change.

Specific goals are i) Field-based monitoring of community composition and structure, ii) Identifying temporal patterns and spectral signatures for the main foundation tree species by means remote sensing approaches, iii) Developing and testing novel classification methods for the intermediate scale remote sensing of population structure.

Figure 1. Study area

2 METHODS

We are carrying out quinquennial inventories of foundation tree populations (*Fraxinus angustifolia* and *Salix atrocinerea*) and forest plant communities' composition and structure since 2004 in an established network of 11 permanent LTSER sites within DNP floodplain forest area. The long-term monitoring program includes for each site: floristic relevés (61 plots), tree inventories in 200m^2 plots (tree height, number of dead and alive stems per tree, stem diameters, architectural parameters) and local environmental variables (geomorphic, soil parameters and water level in summer).

Aiming at characterizing both spectral and temporal signatures for the floodplain forest dominant species our approach used different data sources. On the one hand, NDVI (Normalized Difference Vegetation Index; Díaz-Delgado et al. 2010) values were computed from a long time series of Landsat TM and ETM+ images (1984 to 2014) for 42 ground-truth locations inside the study area. Landsat images provide periodic acquisitions, every 7 to 16 days, at 30 m pixel size enabling temporal analysis of NDVI as a proxy for plant cover, biomass and Leaf Area Index (LAI).
On the other hand we looked for better spatial and spectral resolution to identify dominant species by using AHS (Airborne Hyperspectral Sensor) images captured from a plane flown in 2013 over the study area (similar flight campaigns are also available for 2004, 2005, 2008, 2010 and 2011). Pixels of 6 m size were used to extract hyperspectral signatures (reflectance from 0.4-2.5 μm) for the 42 ground-truth locations sparsely distributed across the floodplain forests of DNP.
Finally, for the 42 field locations we measured LAI using AccuPAR LP-80 ceptometer (Decagon Devices, Pullman, WA, USA). LAI variability largely contributes to spectral response thus sampling across a LAI gradient we may be able to find the critical reflectance differences between the dominant species. Ancillary structural information was also collected such as plant and bare soil percent cover, forest stratification and species dominance per strata, tree recruitment and damages.

3 RESULTS AND DISCUSSION

Our field data revealed temporal shifts in forest composition and structure. For the period 2004-2010, we registered (i) a general decrease in stems/ha which was significant (p=0.0069) in *Salix* and (ii) opposite temporal trends in Basal Area (m^2/ha) across species with increase in *Fraxinus* and decrease in *Salix* dominated plots (Figure 2). These results suggest a forest senescence tendency in DNP, together with an inversion trend in tree dominance, likely associated to changes in hydrology regime (Díaz-Delgado et al. 2010), and intense herbivory damages observed on *Salix* young vegetative stems (pers. obs.) leading to large mortality and unsuccessful population regeneration in *Salix* populations.

Spectral and temporal signatures of dominant species were found different enough suggesting a good potential for mapping historical changes in species distribution and enabling the interpretation of spatio-temporal adjustments associated with forest natural dynamics and disturbances. Figure 3 shows preliminary results at 4 representative ground truth sites with the two dominant species with extreme LAI values (2 and 6) and plant percent cover (70%-95%). Temporal signatures (Figure 3A)

show clear phenological differences between both species, *Salix* showing largest vegetative period than *Fraxinus*. Phenological signature should enhance species identification and long-term structural changes detection. Also, separability between the two species spectra (Figure 3B) is evidenced in spite of LAI and percent cover variation among study sites.

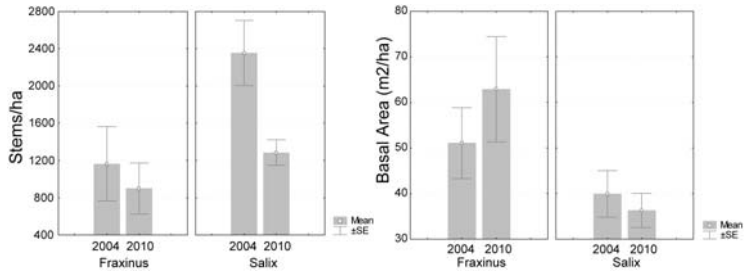

Figure 2. Stems/ha and Basal area (m^2/ha) in *Salix* and *Fraxinus* dominated plots during the period 2004-2010.

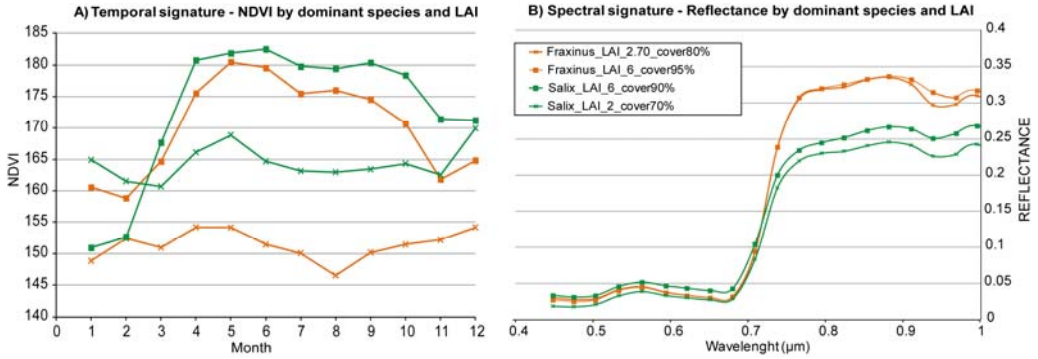

Figure 3. A) Monthly average NDVI values (linear transformation to 0-255 scale); B) Spectral signatures (0.4-1 µm) for *Salix* and *Fraxinus* dominated sites from AHS images of May 2013.

Next steps entail mapping species dominance through AHS image classification procedures. Validation will be done by means of ground-truth stations. The process may easily be replicated over the other flight campaigns what will aid to determine dominance changes in the last decade. According to NDVI temporal patterns, historical reconstruction of species dominance can go back up to 1984 with the time series of available images. Particularly with the observed phenological differences through NDVI values we expect to be able to identify retrospectively changes in species dominance. Finally, a novel classification method using an unmanned aerial vehicle (UAV) is being developed for identification of spatial patterns in population structure within foundation species, which we expect will refine results to the intraspecific level structure dynamics.

4 CONCLUSIONS

Preliminary field results revealed temporal shifts in forest composition and structure likely associated to recent environmental changes. The distinct spectral and temporal species signatures suggest potential ability for mapping historical changes in the structure and function of these foundation species formations. Such information will enable to reconstruct and interpret spatio-temporal adjustments associated with forest natural dynamics or anthropic disturbances, and to develop new monitoring approaches based on the level of complexity and predictability of the studied temporal series, with application for the adaptive management of riparian forests face to global change.

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