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Can we predict habitat quality from space? A multi-indicator assessment based on an automated knowledge-driven system

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ABSTRACT

There is an increasing need of effective monitoring systems for habitat quality assessment. Methods based on remote sensing (RS) features, such as vegetation indices, have been proposed as promising approaches, complementing methods based on categorical data to support decision making.

Here, we evaluate the ability of Earth observation (EO) data, based on a new automated, knowledge-driven system, to predict several indicators for oak woodland habitat quality in a Portuguese Natura 2000 site.

We collected in-field data on five habitat quality indicators in vegetation plots from woodland habitats of a landscape undergoing agricultural abandonment. Forty-three predictors were calculated, and a multi-model inference framework was applied to evaluate the predictive strength of each data set for the several quality indicators.

Three indicators were mainly explained by predictors related to landscape and neighbourhood structure. Overall, competing models based on the products of the automated knowledge-driven system had the best performance to explain quality indicators, compared to models based on manually classified land cover data.

The system outputs in terms of both land cover classes and spectral/landscape indices were considered in the study, which highlights the advantages of combining EO data with RS techniques and improved modelling based on sound ecological hypotheses. Our findings strongly suggest that some features of habitat quality, such as structure and habitat composition, can be effectively monitored from EO data combined with in-field campaigns as part of an integrative monitoring framework for habitat status assessment.

Introduction

Assessing habitat quality, namely habitat resilience and ability to support biodiversity and ecosystem services (Buffa and Villani, 2012), is crucial for the conservation of European native woodlands (Brumelis et al., 2011; Jamoneau et al., 2011), which are expected to expand in the future (Navarro and Pereira, 2012). The assessment of woodland quality has focused on habitat composition (Buffa and Villani, 2012), structure (Liira and Sepp, 2009) or function (Thompson et al., 2013), depending on the observation extent. At

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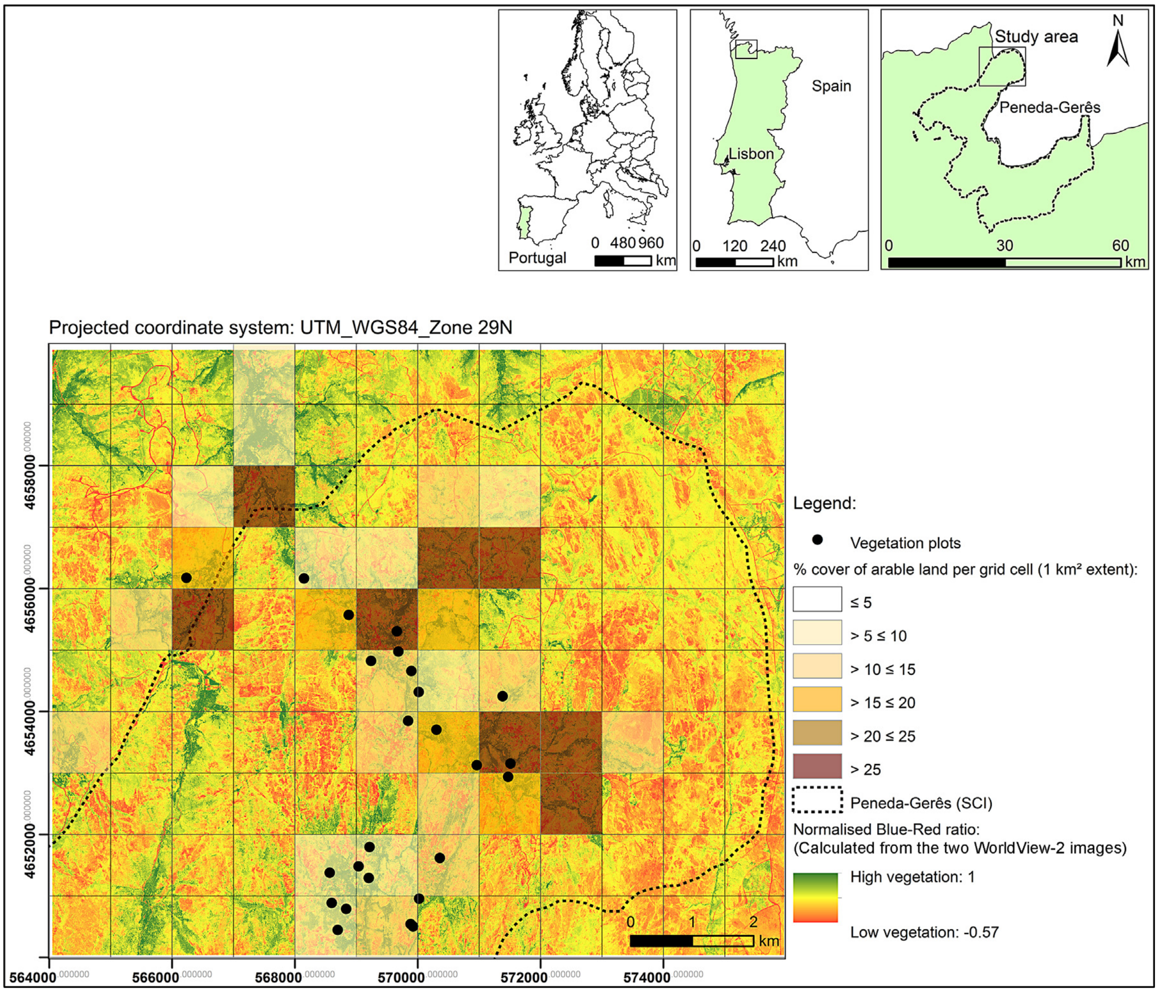

Fig. 1. Location map of the Peneda-Gerês National Park and the study area, with the sampled grid cells represented along a gradient of agricultural use.

small spatial extents, indicators (sensu Thompson et al., 2013) measured in the field include structural and compositional features and disturbance impacts (Alessandro and Marta, 2012; Winter, 2012). At larger extents, the applicability of landscape pattern indices (LPIs) relies on the assumption that decreases of habitat quality are captured by landscape and woodland configuration changes (Forman and Godron, 1986; Guirado et al., 2008).

LPIs and habitat quality can be related based on categorical land cover (LC) data (Yamaura et al., 2008; Nagendra et al., 2015), which often does not adequately capture detailed structural attributes, such as canopy density, or functional dynamics, such as light interception (Cord et al., 2014). This information can be obtained in a pre-categorical level from Earth observation (EO) data, such as spectral indices, captured from distinct techniques (Cord et al., 2014; Frazier et al., 2013). For example, light detection and ranging (LiDAR) provides information on forest three-dimensional structure and hyperspectral sensors give insights into species composition and vegetation functioning (Dubayah and Drake, 2000), though data from both sensors is expensive to acquire and repeat coverage is often not achieved (Nagendra et al., 2013). Although expensive to acquire if used routinely, multi-spectral data from very high resolution (VHR) spaceborne sensors (e.g. WorldView-2) shows greater availability, mapping campaign independence and regular coverage, especially when acquired at different seasons according to plant phenology (Cord et al., 2014; Nagendra et al., 2013).

The Biodiversity Multi-SOurce Monitoring System: From Space To Species (BIO_SOS) project (funded by the European Community's Seventh Framework Programme), addressed the integrated use of EO and in-field data to develop tools and models for consistent multi-annual monitoring of protected areas and their surroundings. Within this project, the Earth Observation Data for Habitat Monitoring (EODHaM) system was developed based on VHR imagery and RS techniques (Lucas et al., 2015). This study aims at evaluating the ability of RS techniques, and in particular of RS information and indices, for inferring on (in-field) observed indicators of woodland habitat quality at relevant spatial extents. The predictive strength of several predictors obtained by distinct sources (manual delimitation and classification of aerial photos versus automated, rule-based systems) is also discussed for woodland monitoring in a Portuguese Natura 2000 landscape.

Methods

Study area and focal habitat type

The study area (120 km^2) is a traditional rural landscape located in Peneda-Gerês National Park, northwest Portugal (42°1′39.04″ N, 8°9′35.377″ W; Fig. 1). The climate is temperate to sub-Mediterranean and the total mean annual rainfall is 2000 mm. Elevation ranges from 524 to 1332 m, and the geology is dominated by granite (Honrado, 2003). Oak woodlands correspond to the 9230 Annex I habitat type from the Habitats Directive (Council Directive 92/43/EEC). In the study area, until the 1960s, forest harvesting for farming and fuel wood reduced oak woodlands to scattered fragments. Currently, population out-migration