Ecological Modelling 295 (2015) 107–112

Contents lists available at ScienceDirect

Ecological Modelling

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

Performance of methods to select landscape metrics for modelling species richness

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ARTICLE INFO

Article history:
Received 10 January 2014
Received in revised form 19 May 2014
Accepted 21 May 2014
Available online 19 June 2014

Keywords:
Variable selection
Biodiversity indicator
Ecological indicator
Landscape structure
Dadia National Park
Greece

ABSTRACT

Landscape metrics are commonly used indicators of ecological pattern and processes in ecological modelling. Numerous landscape metrics are available, making the selection of appropriate metrics a common challenge in model development. In this paper, we tested the performance of methods for preselecting sets of three landscape metrics for use in modelling species richness of six groups of organisms (woody plants, orchids, orthopterans, amphibians, reptiles, and small terrestrial birds) and overall species richness in a Mediterranean forest landscape. The tested methods included expert knowledge, decision tree analysis, principal component analysis, and principal component regression. They were compared with random choice and optimal sets, which were evaluated by testing all possible combinations of metrics. All pre-selection methods performed significantly worse than the optimal sets. The statistical approaches performed slightly better than random choice that in turn performed slightly better than sets derived by expert knowledge. We concluded that the process of selecting the most appropriate landscape metrics for modelling biodiversity is not trivial and that shortcuts to systematic evaluation of metrics should not be expected to identify appropriate indicators.

1. Introduction

Landscape structure has important influences on a wide range of ecological patterns and processes (Tscharntke et al., 2012) and ready availability of remote sensing and GIS are providing a wide array of landscape metrics for use within ecological research (e.g. Foody, 2008; Gillespie et al., 2008; McGarigal and Marks, 1995). These landscape metrics are increasingly used to assess patterns or changes of land use/cover, and habitat or regulation functions of landscapes (see review by Uuemaa et al., 2013). Recent studies have applied landscape metrics to various issues such as landscape aesthetics (Frank et al., 2013), urban fragmentation (Fan and Myint, 2014), effects of scale and data resolution (Lechner et al., 2013; Morelli et al., 2013; Roces-Diaz and Díaz-Varela, 2014), systematic reserve design and landscape planning (Kati et al., 2010; Turetta et al., 2013), and indication of sustainability (Renetzeder et al., 2010). Hundreds of metrics are easily calculated (McGarigal and Marks, 1995) and to avoid including a large list of redundant variables, which is particularly problematic with small data sets, a pre-selection of metrics is often required (Dormann et al., 2013). As with the selection of other environmental variables (cf. Synes and Osborne, 2011), the selection of landscape metrics can be based on theoretical considerations (Leitão and Ahern, 2002; Li and Wu, 2004), expert knowledge (Morelli et al., 2013; Roces-Diaz and

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http://dx.doi.org/10.1016/j.ecolmodel.2014.05.012
0304-3800/

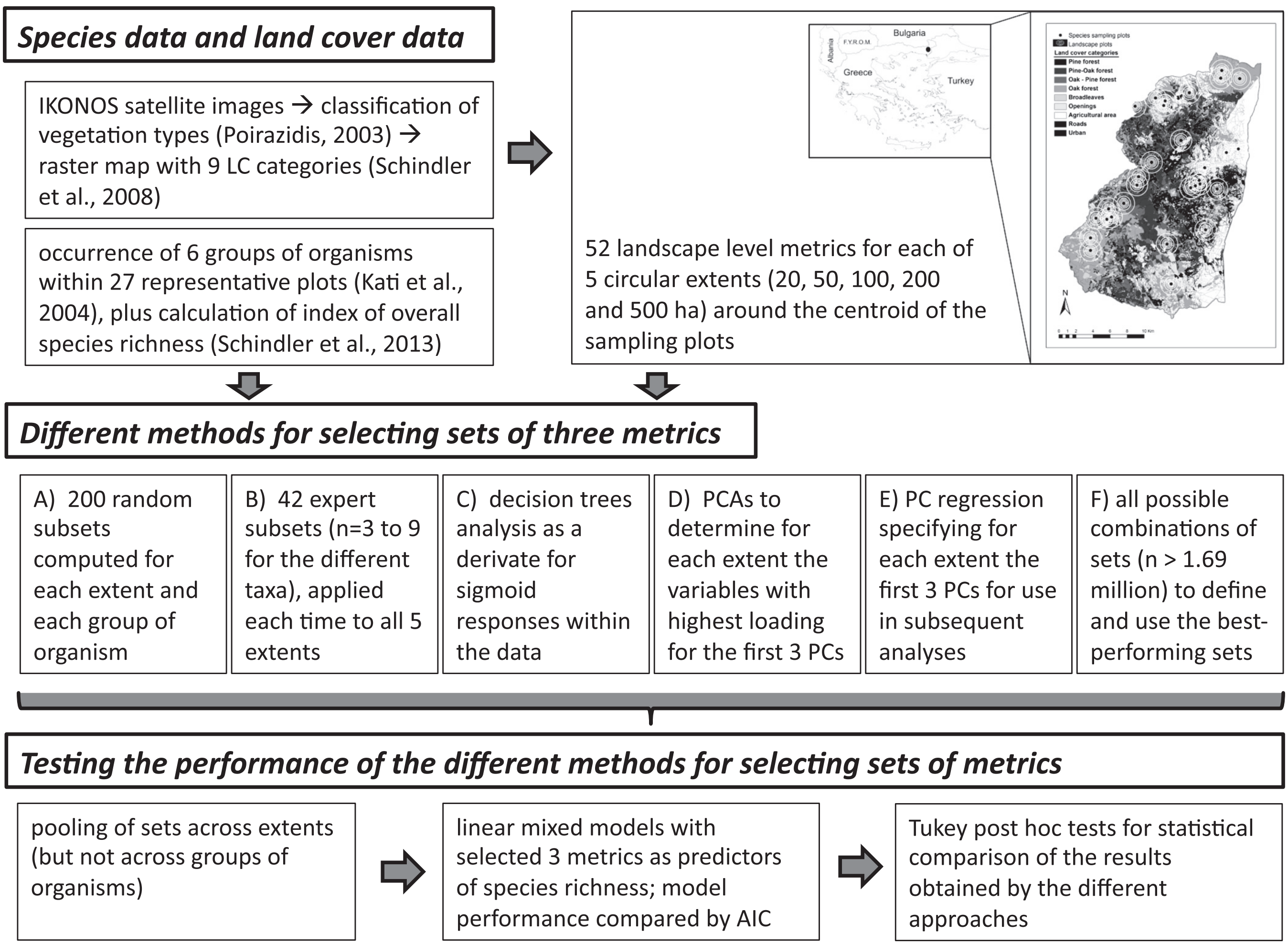

Fig. 1. Flow chart outlining the steps used in data analyses. Included is a map showing the study area in north-eastern Greece and the locations of sampled points.

Díaz-Varela, 2014), previously published studies from other areas (Frank et al., 2013; Höbinger et al., 2012; Lechner et al., 2013), or the same study area (Kati et al., 2010), and statistical approaches aiming at elimination of redundant variables (Beja et al., 2014; Schindler et al., 2008; Turetta et al., 2013).

In ecological models, landscape metrics are often integrated as predictors (e.g. Beja et al., 2014; Schindler et al., 2013). Because habitat reduction and land use change are widely acknowledged causes of species decline (Ewers and Didham, 2006; Sala et al., 2000), landscape metrics are supposed to be relevant indicators of biodiversity (Kati et al., 2010; Lindenmayer et al., 2002; Schindler et al., 2013). However, there are no universally appropriate indicator variables, because their performance depends on the landscape context and the targeted taxon (Cushman et al., 2008; Fahrig, 2003; Schindler et al., 2013; Torras et al., 2008; Walz, 2011; Yamaura et al., 2008). Thus, in the absence of prior knowledge for a specific study system, a pre-selection of landscape metrics is a challenging task for conservationists and policy-makers interested in identifying indicators of biodiversity (Walz, 2011).

Taking as a case study a well investigated protected area of high species and landscape diversity in northeastern Greece, we have tested the performance of different methods for preselecting sets of landscape metrics for modelling the species richness of six groups of organisms, namely woody plants, orchids, orthopterans, amphibians, reptiles, and small terrestrial birds, as well as overall species richness. The pre-selection methods that we considered were expert choice, and the frequently applied statistical approaches decision tree analyses, principal component analyses (PCA), and principal component regression (Dormann et al., 2013). Our objective was to compare the performance of these methods to each other and against models with randomly selected metrics, as well as to an optimal model with the best performing set of metrics.

2. Methods

2.1. Study area, species data and land cover data

Our case study area, the Dadia–Lefkimi–Soufli National Park (hereafter Dadia NP) covers 430 km^2 and is located in north-eastern Greece (Fig. 1). The area is dominated by extensive pine and oak forest, but also contains a variety of other habitats such as pastures, arable land, torrents and stony hills. Dadia NP is a local biodiversity hotspot and has a successful history of monitoring, research and management for the conservation of biodiversity (Catsadorakis and Källander, 2010; Kati et al., 2004a,b; Schindler, 2010; Schindler et al., 2011; Zografou et al., 2014).

Our data on species and landscapes are described by Schindler et al. (2013) (cf. Fig. 1) who assessed for the study area the performance of individual metrics as indicators of species richness. Species data on the occurrence of six groups of organisms were sampled within 27 representative plots of 20 ha or less (Kati et al., 2004a), and included 48 woody plant species, 19 orchid sp. (Kati et al., 2000), 38 orthoptera sp. (Kati et al., 2004b), 18 amphibian and reptile sp. (Kati et al., 2007), and 66 small terrestrial bird sp. (Kati and Sekercioglu, 2006). These six data sets of 189 species in total were complemented by an index of overall species