Forest Ecology and Management 424 (2018) 483–493

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Predicting bird species richness and micro-habitat diversity using satellite data

Ibrahim Ozdemir[a,*], Ahmet Mert[a], Ulas Yunus Ozkan[b], Sengul Aksan[a], Yasin Unal[a]

[a] Department of Wildlife Ecology and Management, Faculty of Forestry, Suleyman Demirel University, 32260 Isparta, Turkey
[b] Department of Forest Management, Faculty of Forestry, Istanbul University, 34473 Sarıyer, Istanbul, Turkey

ARTICLE INFO

Keywords:
Remote sensing
Biodiversity
Spatial resolution
Wildlife
Habitat

ABSTRACT

Effective biodiversity management in forest ecosystems relies on the assessment of environmental indicators (surrogates) when attempting to measure total biodiversity. Bird species (BS) richness and micro-habitat (MH) diversity are two key features that are easily measured and can be utilized as biodiversity surrogates. Remote sensing technologies may be employed as a cost-efficient measure as well as accurately mapping diversity features across broad geographical areas. This study examined the possibilities of predicting BS richness and MH diversity using variables derived from satellite data in a brutian pine (*Pinus brutia Ten.*) forest ecosystem located in the Southwestern Mediterranean Region of Turkey. The study utilized 40 (90 × 90 m, 0.81 ha) sample plots. We used first, and second-order image texture measures calculated from RapidEye, SPOT-5 and Aster Normalized Difference Vegetation Index (NDVI) as explanatory variables for predicting these biodiversity surrogates at alpha (α) level. Stepwise linear regression analyses showed that BS richness and MH diversity can be estimated using image texture measures. According to the cross-validation test; BS richness was best predicted using standard deviation of Gray levels (STD) and Gray-Level Co-Occurrence Matrix (GLCM) Homogeneity of RapidEye NDVI ($R_{CV}^2 = 0.73$, $STE_{CV} = 4.321$), while MH diversity was best predicted using STD and GLCM Correlation of SPOT NDVI ($R_{CV}^2 = 0.73$, $STE_{CV} = 0.148$). In conclusion, the satellite-based diversity maps produced in this study can provide valuable data for forest managers and assist in formulating adaptive management plans for the ecologically sustainable management of brutian pine forest ecosystems.

1. Introduction

The conservation and maintenance of biodiversity in forest ecosystems are fundamental criteria for assessing and prescribing sustainable forest management plans. Several considerations and approaches have been presented and have revealed how biodiversity issues should be integrated into forest management plans. The opinion of diversification of forest structure is broadly accepted as a method to conserve and maintain biodiversity (Kuuluvainen, 2009). Namely, a structurally diverse forest (horizontally and vertically) may host a large number of plant and animal species (Harmon et al., 1986). However, silvicultural practices including clear-cut and commercial thinning leads to a decrease in heterogeneity within a forest stand. Therefore, important habitat features that are vital for many organisms and commonly found in old-growth forests are routinely destroyed in intensively managed forests (Kuuluvainen and Laiho, 2004; Vuidot et al., 2011; Regnery et al., 2013a, Treby et al., 2014). On the other hand, recent studies have shown that biodiversity-friendly timber management practices such as single-tree selection and group selection can produce a less destructive outcome on habitat attributes by retaining shrub cover and cavity-bearing trees (Ameztegui et al., 2018; Perry et al., 2018; Charchuk and Bayne, 2018).

It is widely accepted that the biodiversity of a geographic area is evaluated by determining its species diversity. However, predicting overall species diversity is a difficult task as it is costly and requires a range of specialists with differing skill sets that are necessary for accurate taxonomic identification of organisms (Michel and Winter, 2009). Therefore, biodiversity managers use proxies or surrogates which can reflect the distribution of biodiversity, and, are readily observable and quantifiable. Bird species (BS) richness and micro-habitat (MH) diversity are the most preferred surrogates in this regard. It has been shown that when MH diversity increases within a forest, various organisms are then able to find the necessary resources requited for shelter, feed, and roosting sites within this habitat (Winter and Möller, 2008). Meanwhile, MH diversity is highly correlated with BS richness (Urban and Smith, 1989; Gil-Tena et al. (2010a, 2010b); Regnery et al.,

* Corresponding author.
E-mail addresses: ibrahimozdemir@sdu.edu.tr (I. Ozdemir), ahmetmert@sdu.edu.tr (A. Mert), uozkan@istanbul.edu.tr (U.Y. Ozkan), sengulaksan@sdu.edu.tr (S. Aksan), yasinunal@sdu.edu.tr (Y. Unal).

https://doi.org/10.1016/j.foreco.2018.05.030
Received 21 February 2018; Received in revised form 7 May 2018; Accepted 12 May 2018

2013b). Therein, higher BS richness is associated with higher biodiversity (Howard et al., 1998; Bibby et al., 1992; Burgess et al., 2002). Furthermore, changes in bird populations are correlated with ecological and environmental changes (Järvinen and Väisänen, 1979; Jiguet et al., 2007). Ultimately, forest planners can use MH diversity and BS richness as biodiversity indicators when managing and monitoring biodiversity in a forest planning unit.

Effective biodiversity management requires accurate spatial data on the status of biodiversity and in particular, where and how it changes over time. Plot-level inventories for MH diversity and BS richness is rarely feasible because ground-based works are costly and time consuming across broad geographic areas. Satellite remote sensing can play an important role in providing spatial information on a continuous basis across broad-scales. The most distinct advantage of satellite data is that it allows for wall-to-wall mapping of biodiversity (Mao et al., 2018). A wall-to-wall map with continuous values of diversity for each cell (pixel) is an important planning tool for biodiversity conservation and monitoring in forest ecosystems.

Recent researches have sought to increase the accuracy when estimating the attributes of forest structure using image texture measures derived from satellite data (Ozdemir and Karnieli, 2011; Gallardo-Cruz et al., 2012; Ozdemir and Donoghue, 2013). The image texture measures (first and second order) have also been examined to estimate BS richness in limited studies. To date, the modeling undertaken for BS richness and abundance data using texture measures, revealed differing results depending on study sites, methods, and satellite data. The image texture calculated from aerial photos (infrared air photo and digital orthophoto quarter-quadrangles -DOQQs) explained variance of 54–57% (Wood et al., 2013; St.Louis et al., 2006) while image texture derived from Landsat explained variance of 15–82% in BS richness (Wood et al., 2013; Culbert et al. 2012; St.Louis et al., 2009). The effects of spatial resolution of satellite image in estimating BS richness have not been studied, yet. After undertaking an extensive literature review, we believe that this paper presents the first in-depth results concerning the image texture performance in the estimation of MH diversity.

Thus, the goal of this paper was to examine the ability of image texture variables derived from RapidEye, SPOT-5, and Aster data to predict BS richness and MH diversity in a brutian pine (*Pinus brutia Ten.*) forest ecosystem located in the Southwestern Mediterranean Region of Turkey. Our specific objectives were to: (i) understand the effects of spatial resolutions of satellite data (5 m, 10 m, and 15 m), (ii) compare the performance of first, and second-order texture measures in predicting these biodiversity surrogates, (iii) determine the relationships between BS richness and MH diversity, and (iv) to generate a satellite-based diversity map characterizing biodiversity for the study area.

2. Material and methods

2.1. Study area

A geographical area jointly covered by three satellite data (RapidEye, SPOT-5, and Aster) was selected as our study area. The study area is 22.2 km^2 and located between latitudes 36°44′24″N and 36°46′42″N, longitudes 29°05′19″E and 29°08′48″E (Fig. 1). The climate of the study area is Mediterranean, with wet winters and dry, hot summers. This area is composed of mainly brutian pine stands, and

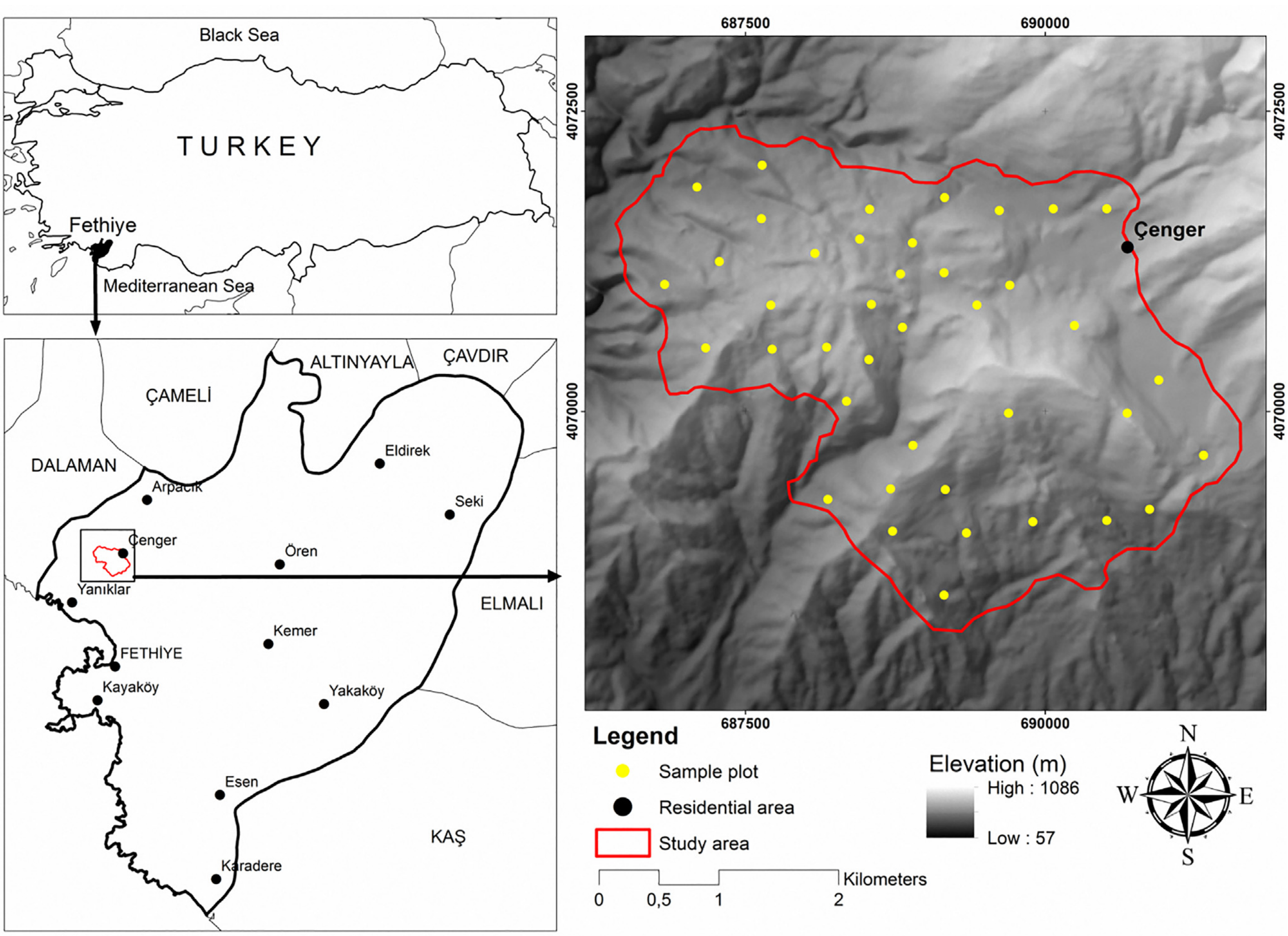

Fig. 1. Study area.