Studies on taxonomic diversity of plant communities and modeling its potential distribution in Yazılı Canyon Nature Park, Turkey

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Aim: The objective of the present study was to generate taxonomic diversity of plant communities and modeling its potential distribution in Yazılı Canyon Nature Park (Turkey).

Methodology: In the present study, taxonomic plant diversity were measured from the data obtained from 107 sampling plots and then modeled to visualize its' potential distribution by using regression tree technique (RTT) across the Yazılı Canyon Nature Park situated in the Mediterranean region, Turkey.

Results: Taxonomic diversity values were between 3.427 and 4.459. The variables made up the regression tree model were slope (%), distance to stream, solar illumination, altitude and aspect. The explained variances of tree models were unexpectedly found low with the values of 31.05% and 24.21% for training and testing data.

Interpretation: Even though tree model does not have high explanation ability, it was visualized to see the potential distribution of the taxonomic diversity in the study area. The distribution map illustrated that the places immediate environment to Yazılı stream and highly very steep places of the canyon has more taxonomic diversity values than its' other parts. This result was found meaningful since those places are more humid and include the plant species having more taxonomic distances from each other compared to its' other parts.

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Introduction

Various indices have been used in defining biodiversity in conservation biology and community ecology (Gülsoy and Özkan, 2008; Özdemir and Kamil, 2011). Those indices are divided mainly into two groups, which are traditional diversity indices and character based diversity indices. Among traditional diversity indices, the most popular ones are Shannon-Wiener entropy, Simpson dominance, Margalef index and Brillion index (Chiucchi et al., 2011; Svensson et al., 2012; Bandeira et al., 2013; Magurran, 2013). Character based diversity indices are known functional diversity and taxonomic diversity indices. Measuring functional diversity of living communities requires data about functional trails of the species. However, knowing the places in taxonomic hierarchy of the species is sufficient for measuring taxonomic diversity. In addition to this, taxonomic diversity is highly related to functional diversity, as well as species diversity of living communities (Özkan, 2012).


Even though advantages of taxonomic diversity has been well-explained by Warwick and Clarke (1995, 1998). Traditional diversity indices are still being used often in determining biodiversity than taxonomic diversity index. The reasons are probably due to fact that calculating taxonomic diversity is more complex than calculating biodiversity by using traditional diversity indices, preparing data for measuring taxonomic diversity is a long time consuming process, all species considered should be identified at species level to measure taxonomic diversity and the number of statistical package programs including measuring taxonomic diversity is insufficient. Due to these probable reasons, a study about modeling and mapping of taxonomic diversity has not been generated in forest ecosystems so far. On view of the above, the present study was carried out to generate taxonomic diversity of plant communities and modeling its potential distribution in Yazili Canyon Nature Park, Turkey.

Materials and Methods

Study area: The data was obtained from Yazili Canyon Nature Park, situated in the Mediterranean region of Turkey (Fig. 1). The study area has a typical Mediterranean climate (dry-hot summers/rainy winters), arith average annual precipitation if 950 mm. The most arid and hottest months are July and August (with an annual average temperature of 13.1° C, and 54 % average relative humidity). Heavy rains occur in November, December, January and February, while water deficit extends from June to mid-October (DMI, 2006). The canyon is a short (~6 km) deep limestone valley with a height varying between 100 m and 400 m. Topography is irregular. Major soil types are brown forest soil, reddish-brown Mediterranean soil and reddish Mediterranean soil. Brutian pine (Pinus brutia Ten.) and Oak species (Quercus spp.) are dominant species in the forest. The nature park is rich in endemic species with twenty four endemic plant taxa (Özkan and Süel, 2008).

One hundred seven sample plots were surveyed in the Park (Fig. 1) and total of one hundred eighty two plant taxa were identified. The coverage of vascular plant taxa was documented according to Braun Blanquet method and transformed according to Whittaker (1973). All the datas were arranged and stored in Excel files for statistical analysis.

Response data: Taxonomic diversity index (∆*) is empirical relationship with Shannon –Wiener diversity but it has an added component of taxonomic separation. This index, as defined in Equation 1 was firstly employed by Warwick and Clarke (1995).

\[ \Delta = \frac{\sum w_{x,x}^{i,j}}{\sum x_{x} + \sum(x - 1)/2} \]

where, \( x \) and \( x_{i} \) refers to numerical statement of the species abundances (e.g. number of individuals) and \( w \) refers to ‘distinctness weight’ given to the path length linking species \( i \) and \( j \) in the hierarchical classification.

Taxonomic diversity values of sample plots were calculated by Paleontological Statistics (PAST) software version 1.89 (Hammer et al., 2001).

Environmental data: All environmental variables were provided from digital elevation model belonging to study area. In this context, Digital elevation model (ELEVATION) was taken from General Directory of Forestry (OGM). Slope % (SLOPE) and aspect (ASPECT) were created from the elevation built function provided using ArcGIS. Topographic position index (TPI) and landform category (LFC) maps were made from the elevation map by placing “tpi_jen.avx” file into the Arcview extensions directory (Weiss, 2001). Solar illumination index (SOLAR) map was derived using elevation map by Topography tools extension in ArcGIS 10.2. (Lyatsky et al., 2001). Distance to stream index (STREAMDS) map was obtained by calculating the distance from the points in the sampling design to nearest stream line in ArcGIS. Thereafter, these maps were resampled with a resolution of 20 m by 20 m grids using nearest neighbour interpolation as simplest technique for assigning pixel values to the new grid.

Radiation index (RI), used in the present study as an explanatory variable, was calculated for each pixel by the following equation (McCune and Keon, 2002):

\[ RI = \frac{[1 - \cos(\pi / 180)Q - 30)]}{2} \]

where, \( \theta \) is an azimuth value measured from true north. This assigns a value of zero to land oriented in the north-north...
Modeling potential distribution of taxonomic diversity

The estimated values obtained from tree model were calculated at each grid (20×20 m). All grids were digitalized to form a niche based distribution map of taxonomic diversity.

Results and Discussion

One hundred eighty two species recognized in the sample plots were represented by 152 genus, 59 family, 41 order, 3 class and 2 phylum in taxonomic hierarchy. The numerical values transformed according to Westhoff and van der Maarel (1973) of the species varied between 9 and 48 per plot (mean=29). The most highly speciose family was Asteraceae (23 species). Of the 182 species encountered, Daphne, Salvia, Sideritis, Trifolium and Verbascum were dominant.

Taxonomic diversity values varied between 3.427 and 4.459. RTT was applied for modeling the distribution of taxonomic diversity (response variable) by means of environmental factors (explanatory variables). The optimal regression tree of taxonomic diversity produced a tree with 6 terminal nodes and 4 splits (Fig. 2). The explained variances of tree model were 31% and 24% for training and testing data. Özkan and Berger (2014) studied the Yukangökdere forest district in the mountain zone of the Mediterranean region. To build a distribution model of species diversity, the researchers used RTT, and reported the explained variance of the distribution model as 63%. Dogan and Dogan (2006) modeled plant species richness using by Simpson D diversity index with multiple regression analysis in the Nallihan district of Turkey. As a result of the study, a distribution model with an explanation rate of 59% was obtained. When comparing the results of the studies done by Özkan and Berger (2014) and Dogan and Dogan (2006), the explained variance value of the distribution model obtained from the present study seems to be remained insufficient. One of the reasons of insufficiency of the distribution model we obtained is probably related to scale of the study area. Because Yukangökdere Forest district and Nallihan district are correspond to middle scale-area and large scale area, respectively. However Yazılı Canyon Nature Park is a small-scale area.

The second reason of the weakness of the model is probably related to considerable potential contribution of topographical heterogeneity to the distribution model. As explained by several researchers (MacArthur and MacArthur, 1961; Tilman, 1982; Palmer, 1992; Huston, 1994; Vivian-Smith, 1997; Crawley and Harral, 2001; Willis and Whittaker, 2002; Steiner and Köhler, 2003; Dufour et al., 2006), increasing biodiversity is often associated with greater environmental or topographical heterogeneity. In this regard, we may postulate that the variation of taxonomic diversity is not very sensitive in the variations of environmental variables among the sample plots level but environmental heterogeneity within sample plot. Unfortunately we did not measure the data belonging to micro habitat heterogeneity even though the study area has a high topographical variability due to its’ irregular, karstic structure. That
Fig. 1: Location of Yazili Canyon Nature Park in the Mediterranean Region, Turkey

Legend

- Yazili Canyon Nature Park
- Stream
- Lake
- Sample plot

Keywords: Environmental Biology, Mediterranean Region, Turkey.
is why we do not know how much micro habitat (topographical) heterogeneity within sample plot is significant to explain the variations of taxonomic diversity.

As Warwick and Clarke (1998), Heino et al. (2007) and Gwali et al. (2010) pointed out, taxonomic diversity index is appropriate to demonstrate the effect of anthropogenic disturbance and degradation of biotic communities. In this sense, it might be thought that insufficiently explanation variance of the distribution model is related to degradation. However; Yazılı Canyon Nature Park is a well-managed protected area, not subjected to anthropogenic disturbance for a long time.

On the context of the explanations above, to better explain the interrelationships between environmental factors and taxonomic diversity, further studies of taxonomic diversity-environmental relations are clearly needed.

The tree model was created by slope %, distance to stream, solar illumination, aspect and altitude. The highest Δ* value occurred on plots with more than 81.825 of slope % and solar illumination greater than 108.5. Regarding the least Δ* value, the environmental variables played roles were slope % (less than 81.825), distance to stream (less than 15.255) and aspect (less than 20.56). Model based map of taxonomic diversity is shown in Fig. 2. As seen in the distribution map, the places immediate environment to middle and upper areas and very steep places of the canyon showed richer in taxonomic diversity values than other parts. According to a study carried out on endemic plant species in the Yazılı Canyon Nature Park (Özkan and Süel, 2008), estimating species diversity obtained from Simpson Reciprocal Index was found higher in the lower part, in particular, valley bottom of the Yazılı Canyon. As compared to the results of Özkan and Süel (2008) to the result of the present study, a negative correlation between species diversity and taxonomic diversity was noted. It is well-known that taxonomic diversity is calculated by using taxonomical distances (Desrochers and Anand, 2004; Da Silva and Batalha, 2006; You-Hua and Zhi-Bo, 2009; Koperski, 2010; Gwali et al., 2010) among the species, whereas species diversity is calculated by considering the number of species and their relative values when Shannon-Wienner Index (Shannon, 1948) or Simpson reciprocal index (Simpson, 1949) are used. Such a negative relationship between taxonomic diversity and species diversity was not new, since woody and herbaceous species shows approximately uniform distribution (well-balanced

Fig. 2 : Fitted regression tree and estimated values of taxonomic diversity
distribution) in the upper part of the Canyon whereas majority of the species composed of herbaceous species in lower part of valley bottom of the study area.

Turkey resigned biodiversity convention in 1996 (Glowka et al., 1996). After signing this convention, the studies dealing with measuring biodiversity, examining biodiversity-environment relationships, and modeling and mapping of biodiversity using remote sensing data and GIS gained much more importance (Maddock and du Plessis, 1999; Özdemir and Donoghue, 2013; Özdemir, 2014). As mentioned before, diversity has been studied in different ways (Clarke and Warwick, 2001; Shimatani, 2001; Petchey et al., 2004; Özkan, 2012; Negiz et al., 2015). Unlike the traditional diversity indices, taxonomic diversity is calculated considering the places in taxonomic hierarchy of the species. That is why taxonomic diversity is not related only to species diversity but also to functional diversity and genetic diversity among the species and structural diversity of vegetation communities (Özkan, 2012).

As a conclusion, taxonomic diversity index is a more suited equation to explain biodiversity than traditional diversity indices (Vane-Wright et al., 1991; Izsák and Papp, 1995; Somerfield et al., 1997). The distribution maps of taxonomic diversity are, therefore, one of the most essential information layers intended for preparing and implementations of conservation and management plans to enable sustainability of the ecosystems.

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