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Determination the natural plant compositions and species distribution model in different habitat types of Düzce (Türkiye)

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FOREST ECOLOGY

ABSTRACT

Background: Türkiye is a very rich country in terms of the distribution and diversity of plants. Despite these current conditions, natural plant species are not sufficiently used in designing urban landscapes. The research aims to reveal an ecological model approach to urban planting by determining the ecological indicator values (EIV's) and coexistence in nature of the species detected in the natural vegetation, revealing the potential of plants to come together.

Results: Within the scope of research, natural areas in Düzce Plain and at the points touching the plain were determined according to the CORINE land cover classification, and 5 different habitat types were determined as forest habitat, riparian areas, rocky habitat, wetlands and meadow habitat. In this study, 420 plant taxa belonging to 89 families which were taken from 33 points and 168 sample areas, were identified. Both natural plant species determined by collecting plant species from the area and plant species diversity will be revealed by determining the ecological demands of the plants. After determining whether the coexistence of plant species collected and identified in these habitat types is distributed in an interdependent manner, scenarios regarding the coexistence of plants were constructed with the help of the latent variables model (LVM's) by R software program.

Conclusion: Some of the plant species with the highest percentage of presence according to the plant layers were selected, and plant compositions with high coexistence were proposed according to the LVM's.

Keywords: Coexistence; CORINE; Ecological indicator values; Latent variable model; Principal Component Analysis.

HIGHLIGHTS

Diverse species increase where trees, shrubs, and dense herbaceous layers coexist.
Species that grow in different habitat types can coexist in different areas.
Latent Variable Models guide ecological planting for selected plants and combinations.
Biodiversity hotspots are identified through links with environmental factors.

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INTRODUCTION

Landscape, as perceived by humans, is an area whose character is the result of the action and interaction of natural or human elements and is considered in two ways: natural and cultural (Déjeant-Pons, 2006). The natural landscape is composed of geographical elements such as different landforms, natural vegetation, soil structure, geology and hydrology. Vegetation is the most important element in the definition and sustainability of the natural landscape structures. Plants that form and shape the landscape can be formed into different life forms such as trees, shrubs and herbaceous plants (Raunkiaer, 1934). Plants can live both in and outside their natural environment under suitable ecological conditions (Keten et al., 2020; Kaya, 2022).

Native plants, as species best adapted to local conditions, contribute significantly to natural ecosystems (Walker, 1991; Hannebaum, 1998). In addition to their many aesthetic and functional qualities, native plants are also important in ecological planting design. Native species are considered to be better adapted to the local environment, because they grow more efficiently and require less maintenance (Sjöman et al., 2016; Alam et al., 2017). They also may provide better habitat resources for wildlife (Berthon et al., 2021). In addition to providing local adaptation, habitat permanence and support for native biodiversity, native plants can outperform recommended non-native species (Isaacs et al., 2009). Conservation of natural habitats, especially in riparian areas, is one of the most important parameters to increase bird diversity. in this context, the importance of natural plants is very important in terms of biodiversity (Engin et al., 2020).

In this context, it is important to have an understanding of the co-existence of plants avoiding plantings which may cause negative interacions or otherwise negatively affect the future co-existince of native species.

Especially since the 20th century, with the realization of the extent of damage to the natural environment due to global climate change, interest in natural plants has increased in many countries. The physical properties of the plant are related to the environmental and cultural factors of its habitat. In habitats such as forests, meadow, wetlands, and agricultural areas, increasing the density of biodiversity through vegetation and providing habitat for other organisms are important ecosystem services of vegetation (Eroğlu, 2012). There are many definitions of habitat, but in general it can be defined as the totality of physical conditions including land cover and climate (Kearney, 2006). Habitat loss is one of the leading causes of declining biodiversity (Joppa et al., 2016). Habitat information is critical for the design of landscape management plans, conservation planning, and analysis of past trends and future scenarios of species extinction risk (Visconti et al., 2016; Santini et al., 2019; Powers and Jetz, 2019).

Defining the ecological indicator values of species or communities is an issue that is considered necessary in plant design, application and repair phases and is the focus of all professional disciplines dealing with natural sciences seeking solutions to the ecological crisis experienced today (Blancas et al., 2013). Plants have a long history of being used as ecological indicators. However, it is also recognized that the associations of plants, known as ecological species groups, are more effective in providing information about growing environmental conditions than their individual ecological meanings (Ellenberg, 1948; Parker, 1982). Some of the environmental factors that have a significant impact on the survival and optimal growth of plants are light, temperature, continentality, moisture, pH of the soil, nitrogen, and salinity.

Most plant species require different conditions to ensure optimal growth and production. The level of these conditions is also critical in determining whether a plant is healthy or not (Carroll et al., 2018). It is important to consider species that have similar relationships to the characteristics of the growing environment as ecological species groups for the sustainability of biodiversity. Ellenberg (1948) defined the concept of an ecological species group as a community of species that exhibit approximately similar behavior with respect to growing environment factors (Kavgacı et al., 2008). These habitat factors have been defined as Ellenberg's indicator values. In defining these groups, it is important to apply numerical methods in the classification of habitats, identification and classification of species, determination of environmental factors and integration of all these parameters. Ellenberg Indicators (EIVs) are the most common bioindicators in Europe (Szymura et al., 2014; Tyler et al., 2021; Tichý et al., 2023).They are often used to predict plant responses to environmental changes. Ecological indicators have been widely used in vegetation science for decades to predict difficult edaphic variables from plant species lists and abundances (Ellenberg et al., 1992; Schaffers and Sýkora, 2000; Ewald and Ziche, 2017; Tichý et al., 2023).

Türkiye has many different ecologies due to its different topographies and geographical conditions. This has resulted in a wide variety of biodiversity, including many different plant and animal species with diverse ecosystems and habitat differences (Uzun and Bayır, 2009). It is important that natural resources be used more accurately and that natural plant species be used in cities that have similar species diversity (Turgut and Yılmaz, 2020). In this context, it is necessary to determine the natural species and compositions in accordance with environmental parameters and their use in urban spaces. The aim of this study is to determine the EIV's of the species identified in natural vegetation and their coexistence in nature, and to determine the potential of plants in different habitats to come together and present an ecological model approach to urban vegetation.

• The hypotheses determined within the scope of the study are as follows;

• Plants that are found in different types of habitat can co-exist in a natural plant composition according to their ecological requirements and their presence.

• Plant diversity varies between plant layers depending on ecological indicator values in different habitat types.

• Ecological parameters are used to define natural plant compositions, which play an important role in defining the landscape.

MATERIAL AND METHODS

Study Area

The main material of the study was determined as Düzce Province, located in the western part of the Black Sea coastal mountains. As the border of the study area, the Düzce Plain boundaries were chosen due to its proximity to the city, the presence of natural species that can adapt more easily, and its existing boundary effect (Figure 1).

Düzce Province has a total surface area of 2,593 km², consisting of a 360.5 km² Düzce Plain and 2,233 km² of mountainous and rugged areas. The mountains are incised by deeply valleys in many places. Additionally, the river valleys outside the plain are generally characterized by deep canyons. The plain is surrounded by the Elmacık Mountains to the south and the Bolu Mountains to the east. From an elevation of 112 meters to the highest peak, which is 1,830 meters at Kardüz Plateau, there is a variation in altitude that provides a diversity (Özdede and Ak, 2022). Due to the influence of climatic, edaphic and physiographic factors, there are many different habitats in the study area where observed its unique landscape character.

Experimental design and sampling

In the study area, five different habitat types have been identified according to CORINE (2018), which include forests, meadow, riparian areas, wetlands and rocky areas. The distribution of sample areas in the study area was conducted using a random sampling method. This method is based on the principle of taking samples randomly in the field (Ozkan et al., 2022; Xiao et al., 2023).

A total of 168 sample areas were determined from 33 sample areas proportionally to the area covered by habitat types, indicating the vegetation status of the study areas (Figure 1). The sample plots were divided into four types of fields which are dimensions were determined according to the identified habitats as follows: 20*20 m for forest habitat type, 5*5 m for meadow and wetlands, 5*20 m for riparian areas, and 2*2 m for rocky areas. Except for the forest vegetation, the smallest sample areas were determined for other vegetation types, and plant taxa resulting from the species-area relationship were obtained. Braun-Blanquet Classification method was taken as basis in obtaining floristic data. (Braun-Blanquet, 2013; Kılınç, 2011; Kılınç et al., 2006).

Measurement of sample parameters

Defining of plant data

The identification of the collected plant samples was carried out by the experts of the Herbarium of the DUOF. Many different sources were used for identification. (Davis, 1965-1985; Davis, Mill and Tan, 1988; Ekim et al., 2000; Mueller-Dombois and Ellenberg, 1974; Güner et al., 2000; Güner et al., 2012; Ranunkiaer, 1934, Aksoy, 2006; Aksoy et al., 2018).

The Braun-Blanquet classification method was used to obtain floristic data (Dengler et al., 2008). The identified plants were coded as 1/0 (present - absent) in the

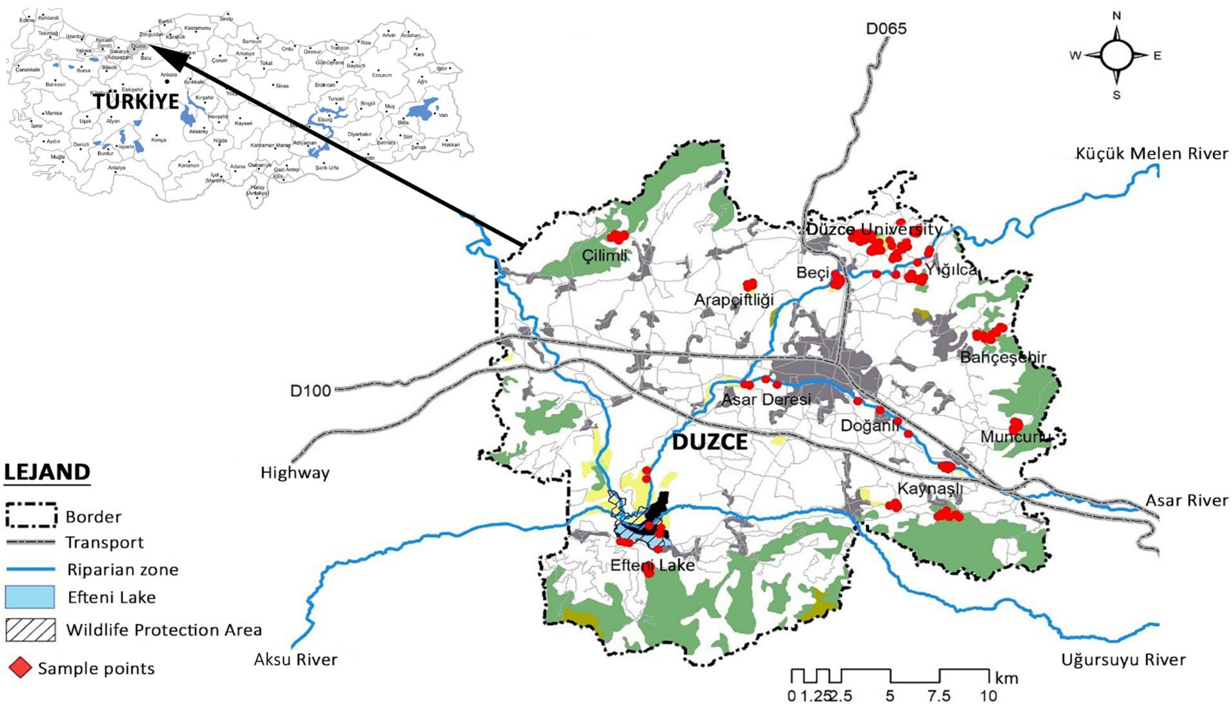


Figure 1: Location map of the study area (Kaya, 2022).

sample areas where they were found and digitized using the program Excel 2016 (Microsoft, USA). In addition, the areas covered by the plants in the field were processed as percentages and these data were plotted according to the Braun-Blanquet cover-abundance scale.

Measurement of Ellenberg Ecological Indicator Values

Soil samples were also taken from the sampling areas of the species in order to determine the habitat characteristics accurately. Soil samples were taken from the first 30 cm depth of the mineral soil after the dead cover layer was removed. Samples were taken from 3 random points representing the area for each site and subjected to analysis in 3 replicates. As a result of the soil sample analysis, total nitrogen, pH and electrical conductivity (salinity) data were obtained from ecological indicator values. In addition, the moisture and light measurements taken in the field are discussed under pH, EC and total nitrogen analysis. Air-dry soil samples were separated from their skeletons, air-dry soil samples were mixed with 1/2.5 of pure water and pH meter to determine the reaction of the soil as solution acidity (Schofield and Taylor, 1955; Thomas, 1996). To determine the electrical conductivity of the soil, air-dry soil samples were mixed with 1/5 of pure water and readings were taken with the help of a probe (Rhoades, 1996). Total nitrogen in the soil was determined by the semi-micro Kjeldahl method (Bremner, 1996).

Soil moisture (%VWC) content at 0-30 cm soil depth was measured by TDR method to reflect the ecological characteristics of the habitats of the species whose soil moisture content was determined.

Light (μmol m-2 s-1) was measured at representative points according to the field characteristics of the species distributed in the sample areas determined at noon in cloudless weather (between 12-14 hours) by quantum meter.

Environmental Variables and Taxonomic diversity

Variables were recorded for each plot to assess the influence of environmental conditions and ecological parameters on plant composition (Westhoff and van der Maarel, 1978; Dengler et al., 2008). Using 12.5 m resolution ALOS PALSAR (Alaska Satellite Facility), DEM (Digital Elevation Model) data, slope map, elevation map, NDVI (Normalized Difference Vegetation Indices), radiation index map, and aspect suitability index map were generated. Although there are many indices used to determine alpha species diversity, species richness (S), Shannon-Wiener index and Simpson's D index were calculated using the PAST program in this study.

Table 1: Analyses and formulas within the scope of the study.

Biodiversity dimension	Index	Formula	Programme	Paramater meaning
Topographic Variables	Radiation Index	$RI = \left[1-\cos\left(\left(\frac{\pi}{180}\right)(Q-30)\right)\right]/2$	ArcGis	*Q* represents the aspect value. Radiation index values range from 0 to 1. While the areas in the north-northeast direction, which is the coldest and rainiest, converge to 0, the values approach 1 towards the hotter and drier south-southwest direction (Moisen and Frescino, 2002; Aertsen et al., 2010; Özdemir and Çınar, 2023).
	Aspect Suitability Index	$BUI = \cos(A_{max} - A) + 1$	ArcGis	A represents the aspect value, A_{max}, represents to the aspect value of 202.5°. Aspect suitability index values range from 0 to 2. It refers to aspects that receive more rainfall and are more humid, especially as the value approaches 2 (Huebner and Vankat, 2003).
	Normalized Difference Vegetation Indices	$NDVI = (NIR - R)/(NIR + R)$	ERDAS	*NIR*: Near Infrared reflectance, *R*: Red reflectance The *NDVI* value typically falls within a range of -1 to +1
Taxonomic diversity	Species richness	$S = \sum_{i}^{S_i} S_i$	PAST	*S* represents the number of species, p_i represents the proportion of importance of theith species in the total set of species, *N* is the individual number of species in the community
	Shannon-Wiener diversity index	$H' = -\sum p_i lnp_i$	PAST	
	Simpson diversity index	$\lambda = \sum_{i=1}^{S} p_i^2$	PAST	

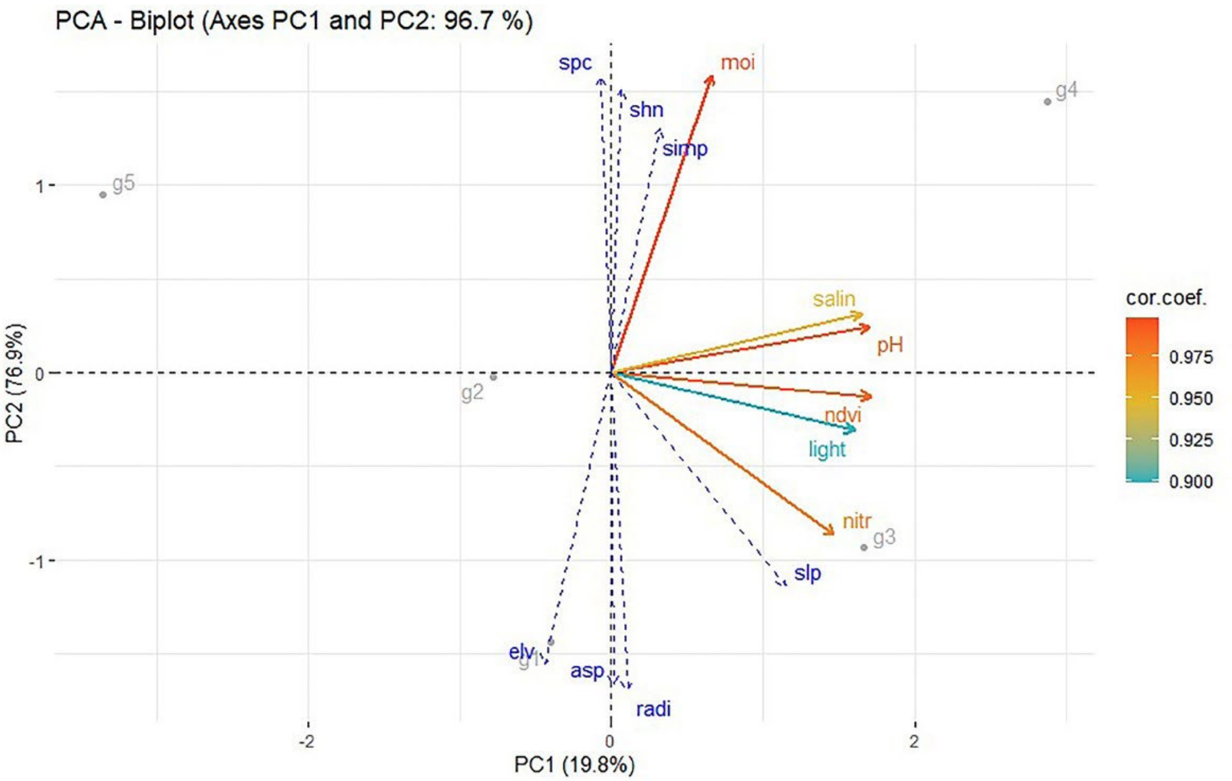
Statistical-Data Analysis

In order to determine whether the factors influencing the parameters identified in the study differed significantly among the habitat types, an analysis of variance (ANOVA) was performed in the SPSS 20 package program (IBM). After identifying the plant species belonging to the study areas, the orientations of these plant species in terms of EIV's were revealed. The PCA analysis was performed using the R version 4.1.2 program (R Core Team, 2021) and is shown in Figure 2. In this context, the light, temperature, humidity, pH, nitrogen and salinity values of each species were determined using the EIV's prepared by Pignatti (2005) for the European flora. In addition, PCA analysis was performed to determine the relationship between EIV parameters and environmental parameters with 5 different habitat types identified in the study area (Figure 3).

Latent variable models (LVM's) were used to assess how plant composition was affected by EIV values (Hui et al., 2015; Warton et al., 2015). LVM's provide a generalized linear model framework for studying the abundance of many taxa, and facilitate the specification of general statistical models. The presence/absence of all plant species in plot groups was modeled simultaneously, assuming binomial responses with a probit link function. A total of 93 plant species were included in the model (22% of all plants recorded), above the 10% occurrence rate of plants recorded in all habitat types.

The covariates include parameters (i.e. pH, EC, N light, moisture in plot groups) that have been identified as important for habitat selection by plants. In addition, the model itself includes two latent variables that mediate residual correlations between taxa, i.e. variation that is not due to shared environmental responses, and can recover errors (Warton et al., 2015).

Figure 2: The distribution of plant species and its correlation based on EIV's (percent of explained variability: PCA1 = 72.9%, CCA2 = 11.2%).



For graph, codes correspond to the sampling plots, and colours of the codes represent to plant layers (Habitat Types: g1. Forest, g2. Meadow, g3. Rocky, g4. Wetland, g5. Riparian Area).

Figure 3: *PCA plot of axis 1 and axis 2* based on the distribution of 168 sample plots in the urban area of Duzce, Turkey, and the relationship between plant species richness, plant species diversity, environmental parameters, and EIV parameters.

LVM's are calculated using the Boral package in R (Hui, 2016), which uses Bayesian Markov chain Monte Carlo estimation implemented by JAGS (Plummer, 2003).

RESULTS

Ecological Indicator Values for Plant Diversity

The EIV's prepared by Pignatti (2005) for the European flora were determined and PCA analysis was performed and the trends of plant species are given in Figure 2 for easier visual perception. Figure 2 shows that there is a negative correlation between temperature and light parameters and N, EC, pH and moisture values. pH has the highest correlation coefficient and light indicator type has the lowest correlation coefficient.

Environmental variables and EIV's for Habitat Features

One-way analysis of variance (ANOVA) was performed to determine whether the factors affecting plant richness and plant species diversity differed significantly among habitat types. As a result of the ANOVA test; significant differences were found between habitat types and all parameters except the radiation index (Table 2).

Examining the graph obtained as a result of the analysis, it can be seen that the parameters that influence plant species diversity are pH and slope, as in the correlation analysis. In addition, although it has a very low correlation coefficient, the NDVI value also has a significant relationship with plant species richness. The information on these correlations is also very important in order to identify areas with high values in terms of potential species diversity (Table 2).

Figure 3 is a visualisation of the relationship between habitat types and environmental parameters. As can be seen from Figure 3, areas where the soil moisture structure and plant layers vary reflect riparian areas; areas where nitrogen is high and layering is low reflect rocky areas. In addition, areas where plant layers are dense, light demand is low and nitrogen and moisture are low represent forest areas. It also shows areas of plant species richness and diversity. Alpha diversity was found to be high in riparian areas with dense layers of trees, shrubs and herbs. The main reason for this is the abundance of plant species growing in areas under trees and in areas with light penetration. It was observed that alpha diversity was high in wetlands close to the road. Human factors rather than ecological factors are thought to be the main reason for this. It is predicted that the presence of ruderal plants along with aquatic plants in these areas formed by degraded areas will increase the diversity. Alpha diversity was also found to be high in some forest edge areas. In addition to the high altitude and slope in these areas, it can be said that the presence of some herbaceous species in the borders increases diversity due to the proximity to hazelnut areas. When we evaluated the areas where alpha diversity was low; diversity was low in meadows with dense shrub cover and forest habitats with dense tree shrub cover. In these areas, it is predicted that diversity decreased as a result of the decrease in light due to high closure.

Table 2: Results obtained from the ANOVA test between habitat types and environmental parameters.

Variable	Habitat Types	N	(x̄)	(σ)	HG	(F)	p-value (p*)
	1	78	375.44	68.58	e		
	2	53	244.71	43.56	c		
Elevation	3	10	329.50	108.50	d	68.43	0.000*
	4	9	157.27	4.03	a		
	5	18	203.14	22.74	b		
	1	78	28.84	19.70	b		
	2	53	13.29	8.96	a		
Slope	3	10	32.70	24.85	b	14.65	0.000*
	4	9	12.68	13.57	a		
	5	18	4.47	3.29	a		
	1	78	0.57	0.34	a		
	2	53	0.54	0.37	a		
radnx	3	10	0.62	0.32	a	1.97	0.101
	4	9	0.36	0.38	a		
	5	18	0.37	0.28	a		
	1	78	0.91	0.59	a		
	2	53	1.10	0.62	ab		
Aspect_suix	3	10	1.41	0.36	b	2.64	0.036*
	4	9	0.75	0.66	a		
	5	18	0.83	0.64	a		
	1	78	29.85	14.47	ab		
	2	53	21.42	5.97	a		
S	3	10	31.70	7.60	b	10.42	0.000*
	4	9	41.44	18.76	c		
	5	18	41.67	21.47	c		
	1	78	2.87	0.50	ab		
	2	53	2.66	0.32	a		
Shannon_H	3	10	3.05	0.23	bc	9.23	0.000*
	4	9	3.30	0.53	c		
	5	18	3.29	0.59	c		
	1	78	0.92	0.04	ab		
	2	53	0.91	0.03	a		
Simpson_1-D	3	10	0.94	0.01	bc	4.77	0.001*
	4	9	0.94	0.03	c		
	5	18	0.94	0.05	bc		
	1	78	0.86	0.14	c		
	2	53	0.72	0.16	b		
NDVI	3	10	0.72	0.19	b	12.58	0.000*
	4	9	0.80	0.17	bc		
	5	18	0.60	0.23	a		

Continue...

Table 2: Continuation.

Variable	Habitat Types	N	(x̄)	(σ)	HG	(F)	p-value (p*)
Light	1	78	589.09	641.07	a	64.28	0.000*
	2	53	1924.58	75.07	c		
	3	10	1708.80	510.63	bc		
	4	9	1955.22	118.60	c		
	5	18	1472.72	652.07	b		
Humidity	1	78	24.32	14.51	a	18.14	0.000*
	2	53	43.26	21.14	bc		
	3	10	34.62	21.88	ab		
	4	9	63.10	30.28	d		
	5	18	52.97	18.19	cd		
pH	1	78	6.02	0.73	a	8.81	0.000*
	2	53	6.38	0.49	ab		
	3	10	6.65	0.25	b		
	4	9	7.22	0.06	c		
	5	18	5.98	1.12	a		
N	1	78	0.20	0.13	b	10.32	0.000*
	2	53	0.24	0.08	b		
	3	10	0.35	0.21	c		
	4	9	0.23	0.06	b		
	5	18	0.08	0.04	a		
EC	1	78	74.87	56.61	a	5.20	0.001*
	2	53	104.65	58.41	ab		
	3	10	132.45	79.88	b		
	4	9	156.53	27.96	c		
	5	18	87.86	102.89	ab		

N: Frequency, x̄: Mean value, σ: Standard deviation, HG: Homogeneity group F: F-value, p: Significance level, *: at p<0.05 level of significance, Habitat Types: 1. Forest, 2. Meadow 3. Rocky, 4. Wetland, 5. Riparian Area (radnx: Radiation Index, aspect_suix - Aspect Suitability Index, S: Species Richness, N: Nitrogen, EC: Electrical Conductivity – Salinity).

Coexistence modeling of plant taxa

Figure 4 visualises the model in terms of the co-occurrence of plant taxa. The plant species with the strongest correlation in each plant layer were selected and shown in Table 3. Warton et al. (2015) also identified the relationship between environmental variables and plant availability using the LVM's. Vegetation richness plays an important role in both diversity and habitat use (Bitani et al., 2023). Especially in areas with a high diversity of tree species, functional diversity has been found to be high. In this context, creating vegetative compositions according to the combination of species will allow habitats to be more sustainable.

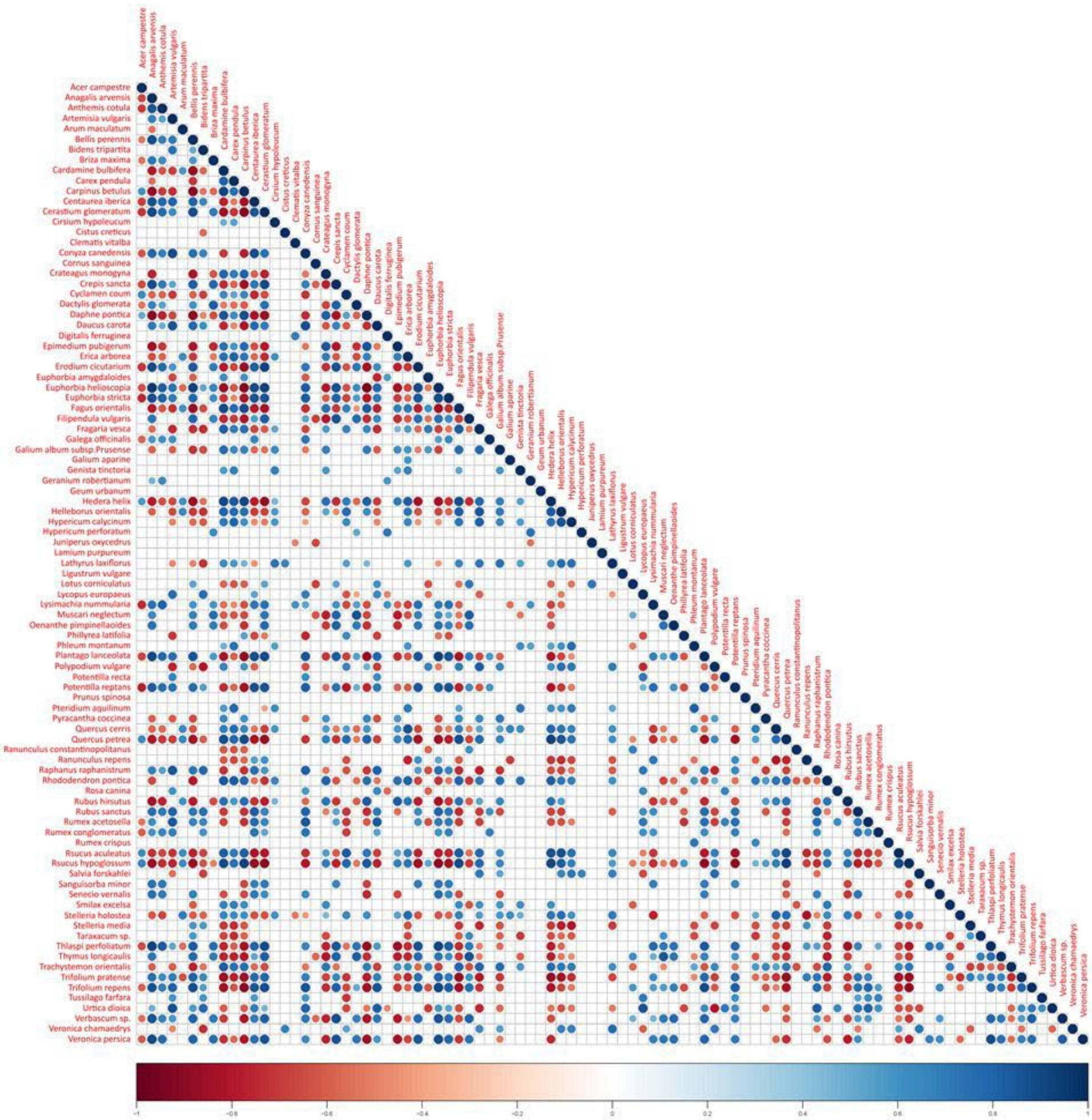
In the study, one plant species from each plant layer was considered and the positive correlation values of a total of 5 plant species with the highest percentage of occurrence were divided into 5 groups according to the LVM's (very weak, weak, medium, strong, very strong). In this context, the plant species were classified into 4 layers (tree, shrub, herbaceous, twining/climbing), and the plant species with high correlation with each other are shown in Table 3.

In summary, Table 3 shows that climbing species can coexist with plant species from all layers. *Oenanthe pimpinellaoides*, which has the highest occurrence in the herbaceous layer, is generally associated with plants that have the characteristics of wet meadow vegetation, while at the same time it can be associated with plant species such as *Filipendula vulgaris* that prefer more arid meadows. Among the shrub species, *Rubus sanctus* is found in the tree layer with species more common in aquatic areas (*Salix alba, Ulmus minor*), while in the herbaceous layer it is found with species more common in roadsides and disturbed areas (*Conyza canadensis, Raphanus raphanistrum*, etc.).

DISCUSSION

Species composition in habitats and their distribution across the habitat surface can be strongly influenced by their topographic, climatological and ecological requirements for environmental resources (water, nutrients, light and temperature) and their sensitivity to stress conditions and threats (Schulze et al., 2005, Gurevitch et al., 2002; Kutbay and Sürmen, 2022). In other hand, Huseyinova (2021), Aksoy and Çoban (2017) and Tunçkol et al. (2020) calculated EIVs in their studies on different habitat types and investigated their relationships with environmental parameters (slope, altitude, radiation index).

Topography is one of the most important determinants of plant species diversity. It allows many local species to enrich and form a composition. Small changes in topography cause changes in soil moisture and many other environmental variables (Vivian-Smith, 1997; Silvertown et al., 1999; Økland et al., 2008; Moeslund et al., 2013). In the forested areas that make up the study area, species diversity is limited by environmental factors such as low light penetration and low soil moisture. However, the presence of species correlated



**Positive values (blue) indicate that species are likely to occur within the same plot groups, and negative values (red) indicate that species are likely not to occur together. The size of the circular shapes indicates the level of correlation, with larger circles representing higher correlation and smaller circles representing lower correlation. . The significance values are shown with asterisk (*p < 0.05, **p < 0.01, ***p < 0.001). Only significant correlations (95%) are included in the plot.*

Figure 4: Species co-occurrence patterns of predicted species using LVM's including the covariates EIV's parameters, and two latent variables.

Table 3: The co-occurence of preferred plants according to their percentage of presence according to LVM's model.

Species	Tree	Shrub	Herbaceous	Twining-Climbing
Twining-Climbing Layer				
Hedera helix L.	*Carpinus betulus* L.	*Daphne pontica* L.	*Cardamine bulbifera* L. Crantz	*Smilax excelsa* L.
	Fagus orientalis	*Ruscus aculeatus* L.	*Carex pendula* Huds.	*Epimedium pubigerum* (DC.) C.Morren & Decne.
	Quercus petraea (Matt.) Liebl.	*Rhododendron ponticum* L.	*Fragaria vesca* L.	
	Acer campestre L.	*Hypericum calycinum* L.	*Helleborus orientalis* Lam.	
	Castanea sativa Mill.	*Erica arborea* L.	*Doronicum orientale* Hoffm.	
Herbaceous Layer				
Oenanthe pimpinellaoides L.			*Verbascum* L. *sp*	*Convolvulus arvensis* L.
			Anagallis arvensis L.	
			Cerastium glomeratum Thuill.	
			Filipendula vulgaris Moench	
			Crepis sancta (L.) Bornm.	
Shrub Layer				
Rubus sanctus Schreb.	*Salix alba* L.	*Ligustrum vulgare* L.	*Centaurea iberica* Trev. ex Spreng.	*Convolvulus arvensis*
	Ulmus minor Mill.		*Euphorbia helioscopia* L.	
			Raphanus raphanistrum L.	
			Conyza canedensis (L.) Cronquist	
			Trifolium resupinatum L.	
Tree Layer				
Fagus orientalis Lipsky	*Carpinus betulus*	*Daphne pontica*	*Cardamine bulbifera* (L.) Crantz	*Hedera helix*
	Castanea sativa	*Ilex colchica* Pojark.	*Doronicum orientale* Hoffm.	*Smilax excelsa*
	Quercus petraea	*Genista tinctoria* L.	*Fragaria vesca*	*Epimedium pubigerum*
	Sorbus torminalis (L.) Crantz	*Ruscus aculeatus*	*Helleborus orientalis*	
		Pyracantha coccinea M. Roem.	*Trachystemon orientalis* (L.) G.Don	

with soil moisture requirements in the high moisture plain may have allowed the development of moisture richness with species composition. Climbing plants, for example, need to attach to an external support (usually neighbouring plants) in order to grow significantly vertically and increase light acquisition. This has been observed in forests (Putz, 1984; Stansbury et al., 2007), open habitats and controlled environments. Hedera helix, for example, is highly tolerant of different light preferences (Mercer, 2003) and forms compositions with different plant layers (Table 3).

The pH requirements of plant species may increase when their genetic line is threatened and protect their genetic line, while they may be the result of general diversity when they are not threatened (Pärtel et al., 2004). The high correlation of pH requirements with species diversity in the study may be a general indicator of the richness of plant species diversity in the area, rather than being due to threats in these areas. However, analyses of pollution in habitats can be a guide to general threats.

In terms of nitrogen (N) value, it was observed that the areas with the highest N value were rocky areas, while the areas with the lowest N value were riparian areas. Welti et al. (2012) stated that low groundwater in flooded areas increases nitrogen retention, while in the study area it is assessed that the nitrogen capacity is low due to seasonal high groundwater at certain times. The high nitrogen content in the rocky areas of the study area may be due to the undisturbed litter layer rich in organic matter and incompletely dissolved soil properties (Çepel, 1988; Sarı and Acar, 2015).

It is also emphasised that nitrogen is the dominant variable affecting riparian species richness. This richness in riparian zones, which have been reported in studies on this topic as the source of local plant species diversity and the most developed areas of diversity (Naiman et al., 1993; Richardson et al., 2007), can be attributed to the enrichment of the soil by nitrogen fixers in the area and the important role played by some nutrients transported from other habitats, especially in the retention and transport of nitrogen and phosphorus (Pinay et al., 2018). In other habitat types in the area, other environmental parameters are likely to limit species diversity.

Significant differences in salinity (EC) were found, and salinity was higher in marsh areas compared to other areas. However, since areas with salinity values below 1000 are considered as salt-free areas, this parameter was not interpreted.

In general, the results of the study show the possibility of coexistence of species characterised in different habitat types and the determination of natural plant composition in different layers. Dupre and Ehrlen (2002) stated that different plant species can be found in different habitat types. As shown in Figure 4, it was found that there are strong relationships between species found in different habitats. By creating plant compositions on both a layer and species basis, natural species can be used together and biodiversity can be ensured. Plant species living together have different niches, and these differences are one of the important factors in providing species richness of plant communities (Shmida and Ellner, 1984). From this point of view, the use of species growing together in different habitat types will be valuable for the sustainability of biodiversity. In addition, many studies mention that species will move from their natural ranges to different habitats over time, especially due to climate change (Davis and Shaw, 2001; Scheffers and Pecl, 2019). In this context, species from different habitat types in urban ecosystems are expected to represent ecological innovation and succeed in urban environments (Lundholm and Marlin, 2006).

CONCLUSIONS

When evaluated in terms of plant layers, it was observed that among the areas with tree, shrub and herbaceous layers, species diversity increased especially in areas with dense herbaceous layers. It can be said that the species diversity is not high in areas where the layers are singular or where there are at most two layers. It can be said that the main factor for the low diversity despite the dense stratification is the monotonous presence of plants due to the proximity.

Looking at the ecological indicator values as a result of the analyses, it can be said that the diversity increases in areas where the moisture in the soil structure increases and the light transmittance is high. In addition, in some areas with high nitrogen levels, species diversity was found to be high. This situation is parallel to the results found in the literature.

Areas with moist soil structure and variable plant stratification correspond to riparian areas, whereas areas with high nitrogen and low stratification correspond to rocky areas. In addition, areas with dense plant stratification, low light demand, low nitrogen, and low moisture reflect forested areas.

As a result of digital elevation models and field observations, the natural plant composition along the riparian corridor, which is one of the areas where slope varies, shows different plant stratifications. This has resulted in species diversity being differentiated between riparian areas. However, in the forest habitats, it was also found that the average slope within the plots varied greatly and this affected the species diversity.

As a result, determining the structure of natural vegetation by revealing the plant species diversity in natural areas and the parameters that affect it is extremely important in terms of transferring these areas into the future without degradation. Knowing the relationships between species diversity and environmental parameters allows the identification of areas with high potential in terms of species diversity and is also very important for the conservation, sustainability and restoration of these areas.

AUTHORSHIP CONTRIBUTION

Project Idea: SK; EE

Funding: SK; EE; NB; AA; AHD

Database: SK; EE; NB

Processing: SK; EE; NB; AA; AHD

Analysis: SK; AHD

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Review: SK; AA; AHD

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