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Relationships among forest vegetation, plant diversity and some environmental factors in Türkmen Mountain (Eskişehir-Kütahya, Turkey)

Türkmendağı orman vejetasyonu ve bitki çeşitliliği ile bazı yetişme ortamı faktörleri arasındaki ilişkiler (Eskişehir-Kütahya, Türkiye)

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Abstract

The aim of this study is to determine the vascular plant diversity of forest vegetation in Türkmendağ and to reveal vegetation-environmental relationships. The sampling was done using the Braun-Blanquet method in 95 grids. Two subplots were sampled in each grid. Plant groups were determined by hierarchical classification clustering analysis. The relations between plant groups and environmental variables were examined by non-parametric test statistics. Alpha, beta and gamma (α, β, γ) values, which are the species diversity indices of plant groups and sample areas were calculated. The interrelationships among the diversity components (α, β_w and γ) of the sample areas, and the site factors were analysed by regression tree method. The best regression tree model was built by tree layer, shrub layer, slope, RI, limestone and altitude respectively. According to statistical analysis, the same variables played dominant roles for the distribution of plant groups. When we evaluate all three plant species diversity components together, plant groups endowed with the highest species diversity are Group 1, Group 2, Group 4 and Group 8.

Keywords: Species diversity, Diversity components, Forest vegetation, Site factors

Öz

Çalışmanın amacı, Türkmendağ'ı orman vejetasyonunun vasküler bitki çeşitliliğini örnek alanlar ve bitki grupları itibarıyla belirlemek ve bu grupların bazı çevresel faktörler ve meşcere parametrelerine göre ilişkilerini ortaya çıkarmaktır. Vejetasyon örneklemesi için Braun-Blanquet yöntemi kullanılmıştır. Örneklemeler 100 x 100 m²'lik 95 grid (100x100 m²) içindeki 2 alt örnek alanda gerçekleştirilmiştir. Bitki grupları, hiyerarşik sınıflandırma kümeleme analiziyle belirlenmiştir. Bitki gruplarıyla çevresel değişkenler arasındaki ilişkiler parametrik olmayan testlerle analiz edilmiştir. Bitki gruplarının ve örnek alanların alfa, beta ve gama tür çeşitlilik indisleri hesaplanmıştır. Örnek alanların α, β_w ve γ çeşitlilik değerleri ile yetişme ortamı faktörleri arasındaki ilişkiler regresyon ağacı yöntemiyle analiz edilmiş ve en yüksek açıklama payına sahip model değişkenleri ağaç ve çalı katı örtüşü bulunmuştur. Daha sonra eğim, radyasyon indeksi, kireçtaşı ve yükselti modelde yeterli kabul edilebilecek açıklama payına sahip değişkenler olarak belirlenmiştir. İstatistiksel analiz sonuçlarına göre bitki gruplarının dağılımında da aynı değişkenlerle önemli ilişkiler bulunmuştur. Her üç bitki tür çeşitliliği bileşenleri birlikte değerlendirildiğinde en fazla tür çeşitliliğine sahip bitki grupları Grup 1, 2, 4 ve grup 8 olmuştur.

Anahtar Kelimeler: Tür çeşitliliği, Çeşitlilik bileşenleri, Orman vejetasyonu, Yetişme ortamı faktörleri

1. Introduction

Biological diversity emerged in the late 1990s as a matter of political interest due to the increased extinction of species as a result of human activities (Ehrlich, 1991; Pausas and Austin, 2001). It is one of the fundamental characteristics of healthy nature. A diverse system is more stable, resilient and productive (Işık, 1999; Pourmajidian and Kavian, 2017). As long as the diversity and distribution of organisms in an ecosystem are not impaired, it is more resistant to the damaging factors and healthier (Özkan, 2010). Species diversity from biodiversity components can be measured as a variety of alpha (α, in an area), beta (β, between areas) and gamma (γ, across the whole area). Alpha and gamma diversity can also be directly calculated as species richness (Whittaker, 1960). It is important to calculate alpha, gamma and beta diversity indices in order to reach more accurate results in studies to be conducted on species diversity (Negiz et al., 2015).

Studies on species diversity, an area or a region having the changes in biodiversity reveal how we should approach the monitoring and measurement. (Kareiva, 1993; Prendergast et al., 1993; Gould and Walker, 1999). Within this framework, countries need to carry out biodiversity inventories in nature in order to ensure ecological sustainability as resources are exploited.

In Turkey, there are several floristic studies regarding plant species richness. However, they are not sufficiently detailed to answer questions as to which communities and habitats should be most protected at the planning stage. Plant species diversity varies across regions depending on the habitat conditions. Therefore, it is important to know the environmental factors affecting diversity while identifying the areas that are potentially rich in species (Gülsoy and Özkan, 2008).

Studies on plant species diversity usually associate the parameters of species diversity identified in sampling plots with environmental factors (Gimaret-Carpentier et al., 1998; Gould and Walker, 1999; Brewer et al., 2003; Pausas et al., 2003; McMaster, 2005; Özkan, 2006; Heydari and Mahdavi, 2009; Chytrý et al., 2010; Sfenthourakis and Panitsa, 2012). But there are also other studies that explored the relations between plant groups (communities) and species diversity and environmental factors (Gupta et al., 2008; Rad et al., 2009).

Türkmen Mountain is the study area of the present study. In this region, Akman et al. (1979) identified plant communities in the forest vegetation. In that study, 9 sampling plots in *Pinus nigra* subsp. *pallasiana* forests (Table 25), 3 sampling plots in *Carpinus betulus* stand (Table 21), 4 sampling plots in *Pinus sylvestris* forests (Table 34) and 7 sampling plots in *Fagus orientalis* forests (Table 36) were taken. However, it seems difficult to believe that the minimal samples they collected were adequate to identify the species diversity in Türkmen Mountain forest vegetation.

Unlike the study of Akman et al. (1979), the present study focuses on (1) the estimations and building models of diversity components (alpha diversity, beta diversity and gamma diversity), (2) examinations of the relationships between environmental factors and vegetation groups and, (3) comparisons among diversity components of sampling plots with species diversity indices of plant groups in Türkmen Mountain using a large inventory dataset.

2. Material and Method

2.1. Study area

Located in the Irano-Turanian flora zone at the Central Western Anatolia border of the Aegean Region (Zohary, 1973) Türkmen Mountain (1826m) is one of the mountains around the Central Anatolia Region (Figure 1). It is situated between Eskişehir and Kütahya provinces at 39°16’ – 39°38’ northern latitudes and 30°06’ – 30°36’ eastern longitudes in the steppe transition zone (Güner, 2008). The elevation of the study area where the samples were collected was 880-1760 meters. It is very close to the intersection of three phytogeographic regions (Irano-Turanian, Mediterranean and Euro-Siberian). The area accommodates a wide range of forest vegetation that has quite different ecological requirements. It hosts plant species that can grow under both semi-arid and humid climate conditions due to the effect of varying topographic structures and local climate conditions, different habitats and plant communities. The characteristic plant communities of Türkmen Mountain include coniferous Anatolian black pine (*Pinus nigra* subsp. *pallasiana)*, Scotch pine (*Pinus sylvestris*) and broad-leaved oriental beech (*Fagus orientalis*) forests. At lower elevations, there are oak trees (*Quercus cerris* var. *cerris, Q. pubescens*) from the secondary climax plant communities that were formed due to the destruction of black pine forests for many years. Oriental beech forests that are distributed in Turkey and Bulgaria are divided into 7 main groups while the 6th group is defined by the beech communities in the southern and western Anatolia under the effect of Mediterranean climate (Kavgacı et al., 2012). This group also covers the oriental beech forests in Türkmen Mountain.

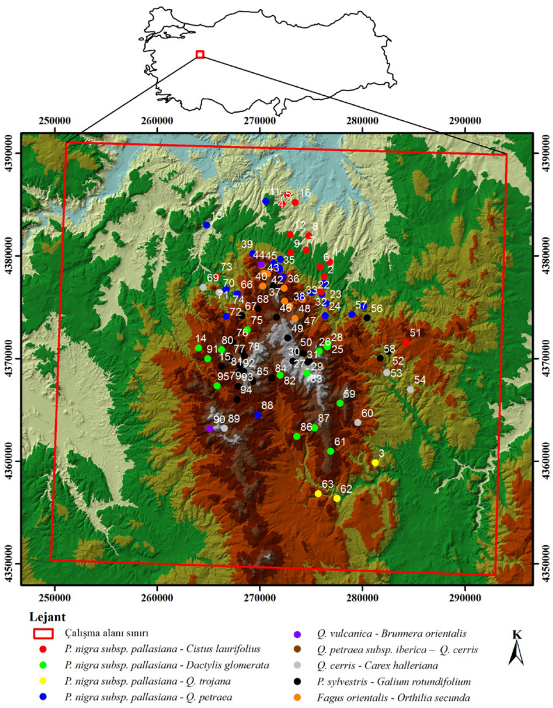

Figure 1. Distribution map of the sampling plots according to the plant groups in the study area
Şekil 1. Çalışma alanında bitki gruplarına göre örnek alanların dağılımı haritası

Total annual precipitation is 286 mm at Eskişehir Regional Station located at an elevation of 801 m and 565.5 mm at Kütahya station (969 m) according to the 1960-2015 data. The lowest precipitation is recorded in summer and fall. In summer, total precipitation is 44 mm in Eskişehir and 70.7 mm in Kütahya. According to the Emberger method (Akman and Daget, 1971; Akman, 1999), the Mediterranean bioclimatic type is usually observed in winter when it is usually very cold the semi-arid with low precipitation.

2.2. Data collection

The Braun-Blanquet method and scale (Braun-Blanquet, 1932; Akman et al., 2001) were used to identify plant communities and calculate species diversity in the forest vegetation. Türkmen Mountain was split into the grids of 100 × 100 m^2 on the map. The samples were collected from the plots in these grids. The number of sampling plots was determined in proportion to the areas of different plant communities on the ground. 2 sub-sampling plots were identified in each sampling plot (1 ha). The size of the sub-sampling plots was 400 m^2. Abundance-coverage values and habitat characteristics of vascular plants (elevation, aspect, inclination and slope position) in each of 190 sub-sampling plots were recorded during the field survey in 2013. The coordinates of the sampling plots were recorded with GPS. Plant species that could not be identified in the field were collected and dried according to standard herbarium techniques (Yaltırık and Efe, 1996). The geological map with a scale of 1/500.000 obtained from the Directorate General of Mineral Research and Exploration was digitized and the bedrocks of the sampling plots on the map was taken into account.

Plant species were identified according to the references such as "Flora of Turkey and the East Aegean Islands" and using stereo binocular microscope (Davis, 1965-1985; Davis et al., 1998; Güner et al., 2000; Duran and Ocak, 2005; Göktürk and Sümbül, 2014).

2.3. Statistical analysis

The vegetation data were tabularised in Microsoft Office Excel worksheets, stored in the TURBOVEG database (Hennekens and Schaminée, 2001, Kavgacı et al., 2008) and imported to JUICE software (Tichý, 2002) after the necessary adjustments. The plant groups were differentiated using PC-ORD software through hierarchical clustering analysis (Mc Cune and Meffords, 2006). In this analysis, the distance of the logarithmically converted values was analyzed with Jaccard distance measure formulation and flexible beta (-0,25) group linkage method.

Of the independent variables, elevation (m), inclination (°) and slope position were included in the numerical analyses by assigning categorical values from 1 to 5 (1: baseline plain; 2: lower slope; 3: hill plain or ridge plain; 4: middle slope; 5: upper slopes and ridges). Aspect was determined in degrees and transformed to the radiation index (*RI*) (Moisen and Frescino, 2002; Aertsen et al., 2010).

The plant species values of the plant groups in the sampling plots and the bedrock data out of the environmental factors were arranged in the form of present / absent data and used in numerical analysis. The associations between the plant groups and bedrock were calculated using Pearson Chi-square test statistic in SPSS 24 package software which is non-parametrical (Özdamar, 2009). In order to determine the direction of the relations, the inter-specific correlation analysis (Poole, 1974) was used. At this stage, C_3 formulation was preferred because it was thought that it had a better result in terms of interpretation during the calculation of correlation coefficient (Özkan, 2002).

At the second stage, SPSS 24 was used and Wilcoxon Rank Sum Test was applied to determine the relationships between vegetation groups (present / absent) and continuous and ordinal environmental variables (Özdamar, 2009).

Before calculating species diversity values of the plant groups and the sampling plots, the codes of the Braun-Blanquet scale were converted to values from 0 to 1 (r: 0.01; +: 0.02; 1: 0.04; 2: 0.15; 3: 0.375; 4: 0.625; 5: 0.875) (Fontaine et al., 2007). For each plant group, Shannon H (Wittaker, 1972; Rad et al., 2009, Özkan, 2016) and Simpson 1-D diversity indices (Simpson, 1949; Gülsoy and Özkan, 2008; Özkan, 2016) were used to determine alpha (α) diversity in Past 3 software (Hammer et al., 2001). To calculate the beta diversity, β_w formulation of Whittaker was used (Whittaker, 1972). The gamma (γ) diversity for each plant group was calculated directly as the number of species.

The α diversity values of the sampling plots were calculated separately for 95 sampling plots by taking the average of the sub-sampling plots (190). To calculate the differences in species diversity between the sampling plots, Whittaker's beta (β_w) diversity formulation was used (Whittaker, 1972; Gülsoy and Özkan, 2008; Özkan, 2016). Gamma diversity (γ) values are the sum of different species in a community; therefore, they were determined as the total number of individual species in the sub-sampling plots in 95 plots.

The regression trees method out of the multiple variable analysis methods in the DTREG software was used to model the species diversity values of the sampling plots according to the environmental factors (Breiman et al., 1984).

3. Results

3.1. Flora and vegetation analysis

In the present study, 242 genera and 477 taxa under 59 families were identified. 67 taxa are endemic (endemism rate 14%). Distribution according to the phytogeographical regions of the plant taxa in the forest vegetation were as follows; Euro-Siberian elements 90, Mediterranean elements 53, Irano-Turanian elements 44, whereas the phytogeographical regions of 290 taxa were unknown.

With the clustering analysis, the forest vegetation of Türkmen Mountain was divided into 9 different plant groups (Group 1. *Pinus nigra* subsp. *pallasiana* - *Cistus laurifolius* (23 sub-sampling plots); Group 2. *P. nigra* subsp. *pallasiana* - *Dactylis glomerata* subsp. *hispanica* (28 sub-sampling plots); Group 3. *P. nigra* subsp. *pallasiana* - *Quercus trojana* (6 sub-sampling plots); Group 4. *P. nigra* subsp. *pallasiana* - *Quercus petraea* subsp. *iberica* (45 sub-sampling plots); Group 5. *Quercus vulcanica* - *Brunnera orientalis* (3 sub-sampling plots); Group 6. *Q. petraea* subsp. *iberica* – *Quercus cerris* (5 sub-sampling plots); Group 7. *Q. cerris* - *Carex halleriana* (10 sub-sampling plots); Group 8. *Pinus sylvestris* - *Galium rotundifolium* (53 sub-sampling plots); Group 9. *Fagus orientalis* - *Orthilia secunda* (17 sub-sampling plots)) (Figure2).

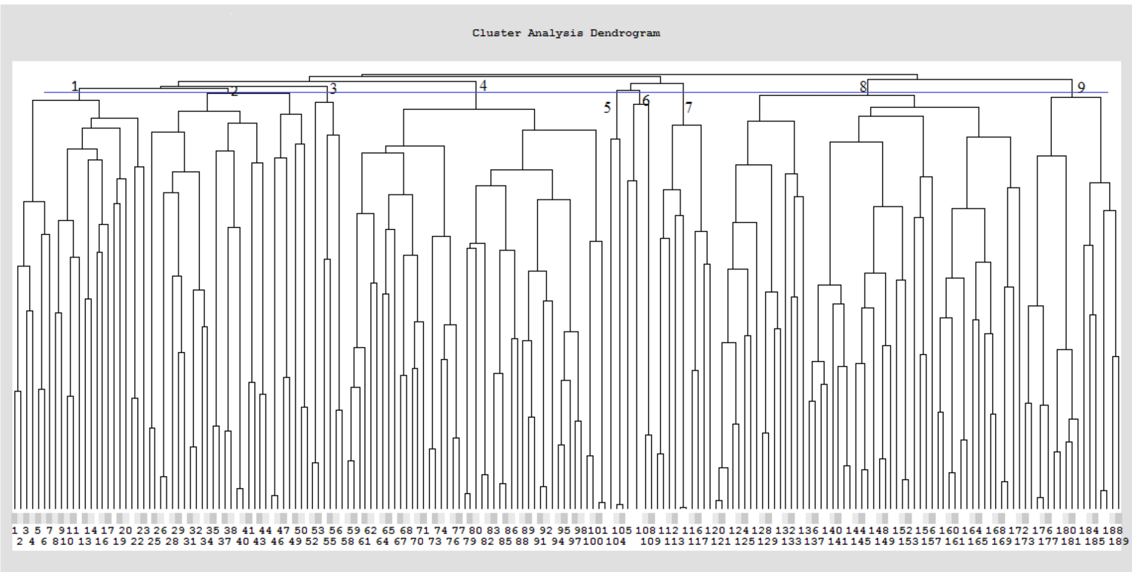

Figure 2. Cluster analysis according to Relative Euclidean formulation and Flexible Beta (-0.25) method
Şekil 2. Relative Euclidean formülü ve grup bağlantı yöntemlerinden Flexible Beta (-0,25) metodu ile yapılan kümeleme analizi

3.2. Relationships between plant groups and site area

According to the statistical analysis results the relationship between the plant communities and bedrocks, there were significant relationships at P<0,05 level with all groups except Group 6 and Group 7 from plant groups and ophiolitic bedrocks (Table 1). Groups 1, 4 and 9 preferred pyroclastic bedrock, while Groups 2, 3 and 8 did not. Group 3 was not found on this bedrock while Groups 2 and 8 preferred it less. Groups 1 and 4 had a negative association with limestone while Groups 3 and 8 had a positive association with it. Metaflysh had a positive relationship with Groups 2 and 5 but a negative relationship with Group 4. Unaltered volcanite had a negative relationship with Group 4 while it had a positive relationship with Group 8. Basalt bedrock had a contrary relationship. The fact that the relationships were negative means that where there is one group, another group does not exist or exists in lower amounts, while positive relationship shows the contrary. There were statistically significant differences between the environmental factors and plant groups except Group 7 in terms of elevation, tree, shrub coverage, inclination and radiation index (RI) (Table 2). In this study, slope position was not found to be an effective variable in differentiating the plant groups.

Table 1. The results of Pearson Chi-square and the interspecific correlation analysis belong to the relationships between the plant communities (groups) and bedrock types in Türkmen Mountain
Tablo 1. Türkmendağı bitki toplumları (grupları) ile ana kaya tipleri arasındaki ilişkilere ait Pearson ki kare test istatistiği ve nitelikler arası ilişki analizi sonuçları

Plant group	Bedrock	a	b	c	d	χ^2	p	C3
Group1	Pyroclastic	103	64	3	20	19.39	0.000	0.38088
	Limestone	122	45	23	0	8.12	0.004	-0.21222
Group2	Pyroclastic	82	80	24	4	11.92	0.001	-0.34966
	Metaflysh	149	13	17	11	21.14	0.000	0.21404
Group3	Pyroclastic	100	84	6	0	4.91	0.027	-0.11138
	Limestone	145	39	0	6	19.96	0.000	0.14308
Group4	Pyroclastic	90	55	16	29	9.79	0.002	0.36000
	Limestone	103	42	42	3	9.45	0.002	-0.31817
	Unaltered Volcanite	122	23	45	0	8.12	0.004	-0.21222
	Basalt	143	2	34	11	28.66	0.000	0.24068
	Metaflysh	122	23	44	1	5.789	0.016	-0.18147
Group5	Metaflysh	165	22	1	2	8.06	0.005	0.04335
Group8	Pyroclastic	64	73	42	11	16.40	0.000	-0.50122
	Limestone	112	25	33	20	8.03	0.005	0.27227
	Unaltered Volcanite	132	5	35	18	33.00	0.000	0.36531
	Basalt	124	13	53	0	5.40	0.020	-0.13967
Group9	Pyroclastic	102	71	4	13	7.88	0.005	0.22111

a: number of sampling plots where neither of them (defined plant group and bedrock) exists; **b:** number of sampling plots of the other plant groups where only the defined bedrocks exists; **c:** number of sampling plots on the other bedrock/s where only the defined plant group exist; **d:** number of sampling plots where both exist

Elevation had a negative relationship with Groups 1 and 4 while it had a positive relationship with the Groups 2, 5, 8 and 9 that were located at higher elevations. Inclination was a negative significant indicator for Group 1 (P<0.001) whereas it had a positive relationship with Group 6. RI had a positive relationship with Group 8 that was located at a higher elevation (sunny aspects), while it had a negative relationship with Group 9 (shady aspects). Tree coverage was a negative indicator for Group 1 (P<0.001) and Group 3 (P<0.05) and Anatolian black pine was the dominant plant of these groups. These groups are differentiated by their lower tree coverage rate than the other plant groups. The overall coverage rate of the shrub layer is a very important positive indicator for the differentiation of Group 1. Tree layer coverage is a very important positive indicator to differentiate the oriental beech (Group 9) that forms the shady forest community. General tree layer coverage rate is an important positive indicator to differentiate the Scotch pine plant group (Group 8). Compared to the other communities, they have higher tree coverage.

The shrub layer coverage had a very significant relationship with Group 8 (P<0.001), while it had a less significant negative relationship with Group 2 (p=0.042). Both groups had low shrub layer cove-

Table 2. Wilcoxon tests regarding the relationship between plant groups and environmental variables and present/absent data regarding the direction of differences
Tablo 2. Bitki grupları ile çevresel değişkenler arasındaki Wilcoxon testi ve farklılık yönünü belirleyen var/yok değerleri

Plant group	Independent variables	Wilcoxon rank sum test			Present			Absent		
		W	Z	P	Min.	Max.	Mean	Min.	Max.	Mean
1	Elev.(m)	469.0	-6.987	0.000	935	1323	1046.4±103.3	985	1753	1384±172
	Icn (º)	1220.5	-3.951	0.000	2	17	9.3±4.6	0	45	16±8
	T.C.(%)	1239.0	-3.897	0.000	10	80	56±19	15	98	71±14
	S.C.(%)	14675.5	-5.154	0.000	5	75	39±24.2	0	80	12.9±16.9
2	Elev.	14542.5	-3.456	0.001	1300	1752	1461.2±105.5	935	1753	1322.8±204.3
	S.C.	2127.0	-2.038	0.042	0	39	8±9.7	0	80	17.5±20.8
3	T.C.	306.50	-2.023	0.043	43	70	59±12	10	98	70±15
4	Elev.	2617.5	-5.213	0.000	985	1510	1219.1±110	935	1753	1381.7±204.7
	S.C.	12653.0	-3.710	0.000	1.3	70	21.6±18.7	0	80	14.4±19.9
5	Elev.	17667.5	-2.021	0.043	1530	1563	1550±17.6	935	1753	1339.9±198.7
6	Inc.	17380.5	-2.368	0.018	12	45	29±14	0	37	14.6±7.2
8	Elev.	10763.0	-6.826	0.000	1178	1753	1500.2±141.3	935	1752	1282.4±184.4
	T.C.	12170.5	-2.702	0.007	30	90	74±12	10	98	68±16
	S.C.	3125.5	-5.701	0.000	0	50	6.1±10.8	0	80	20±21.1
	RI	12232.5	-2.504	0.012	0.002	1	0.511±0.331	0	1	0.388±0.331
9	Elev.	16010.5	-2.362	0.018	1256	1585	1450.3±101.7	935	1753	1332.6±203.1
	T.C.	15342.0	-5.483	0.000	65	98	88±9	10	90	68±14
	RI	1108.5	-2.381	0.017	0	0.883	0.220±0.211	0	1	0.442±0.338

If the man value of those that are present is lower than the mean value of those that are absent, the relationship is negative, while it is positive if the mean value is higher, Elev: Elevation; Inc.: Inclination; T.C.: Overall tree layer coverage; S.C: Overall shrub layer coverage

rage. Shrub layer coverage of Black Pine– Macedonian oak plant group (Group 4) was 21%, which is why it is a very important positive indicator for the differentiation of the group.

3.3. Species diversity of plant groups

Alpha, beta and gamma (α, β, γ) values, which are the species diversity indices of plant groups, are shown in Figure 3 (A, B, C, D). Simpson index had the maximum values with 0.91 in Group 3 and 0.72 in Group 4 in the communities dominated by black pine (Figure 3A). The lowest Simpson value (0.63) was found in Group 9 dominated by oriental beech. The Shannon indices values (Figure 3B) of the plant groups were nearly similar to Simpson indices values. Group 1 had the maximum gamma value (Figure 3C). This was followed by Group 2 and Group 8, which had different habitat conditions and a wide distribution area. From the black pine communities, Group 4 ranked the 4th with 174 species while it was one of the communities with the highest beta diversity (Figure 3D). Group 3 was distributed in a narrower area and had lower topographic heterogeneity. Group 4 was distributed in a wider area and had a higher topographic heterogeneity.

3.4. Plant species diversity in the forest vegetation of Türkmen Mountain

From the alpha diversity indices, Shannon and Simpson indices had a similar result in the top 10 values (Table 3). The 5 sampling plots with the highest alpha diversity (Shannon H, Simpson 1-D) were in Group 1 and Group 3. The plant communities with the highest gamma diversity were in Groups 1, 3 and 4. The highest B_w value (0.85) was found in the sampling plots that had plant groups in Group 4 and Group 5. The second highest B_w value (0.76) was found in the sampling plots with different plant groups (Group 4, Group 7).

3.5. Modelling of factors affecting species diversity

Here we report the results of the regression tree analysis conducted for the relationships between diversity indexes and environmental factors**:**

Gamma diversity: The proportion of variance explained was R^2= 0.2678 while its variables were inclination and tree coverage (Figure 4). In areas where the tree coverage was less than or equal to 66.25% and inclination was lower than or equal to 11.5°, gamma diversity had the highest value in the model with 66.5. The maximum value of the gam-

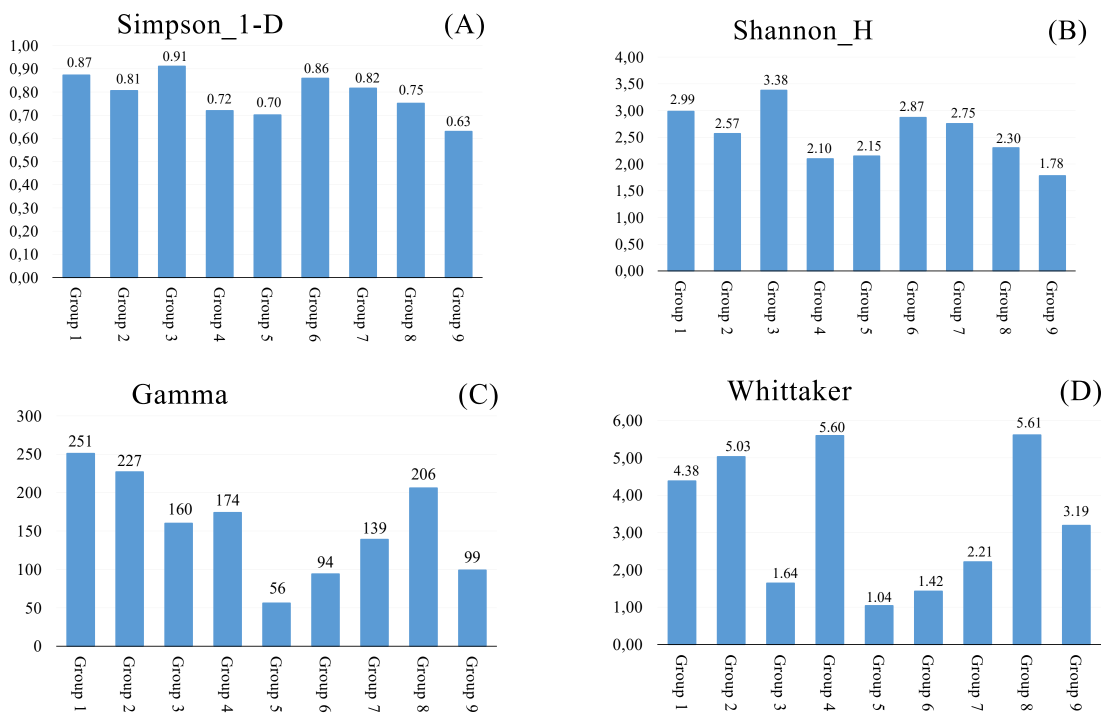

Figure 3 (A, B, C, D). Graphs of species diversity indices values of plant groups
Şekil 3 (A, B, C, D). Bitki gruplarının tür çeşitliliği indis değerlerine ilişkin grafikler

Table 3. Top 10 highest values of species diversity in each sampling plot
Tablo 3. Örnek alanlar için belirlenen tür çeşitlilik değerlerinin en yüksek ilk 10 değerleri

Sub-sampling plots	Plant group	Simpson1-D	Shannon H	Whittaker	Gamma
13-14	Group 1	0.938	3.721	0.347	101
125-126	Group 3	0.936	3.599	0.241	72
5-6	Group 3	0.937	3.548	0.205	88
31-32	Group 1	0.911	3.352	0.504	85
15-16	Group 1	0.908	3.107	0.391	64
57-58	Group 8	0.907	3.216	0.404	66
149-150	Group 2	0.903	2.999	0.341	55
101-102	Group 1	0.898	3.095	0.333	56
163-164	Group 2	0.879	3.138	0.299	63
93-94	Group 8-Group 6	0.878	3.069	0.505	73
17-18	Group 1	0.874	2.956	0.495	68
41-42	Group 1-Group 4	0.870	2.967	0.596	75
91-92	Group 8	0.867	3.001	0.261	58
111-112	Group 8	0.861	2.845	0.495	71
123-124	Group 3	0.858	2.987	0.469	72
11-12	Group 1	0.818	2.739	0.540	67
69-70	Group 4	0.810	2.360	0.621	47
65-66	Group 9	0.782	2.427	0.616	59
165-166	Group 2-Group 8	0.753	2.302	0.710	53
151-152	Group 8	0.702	2.107	0.625	39
107-108	Group 7-Group 4	0.690	1.930	0.760	44
87-88	Group 4-Group 5	0.679	2.131	0.846	48
103-104	Group 8	0.679	1.739	0.600	28
45-46	Group 4	0.654	1.806	0.632	31
35-36	Group 4	0.620	1.700	0.619	34

ma indices of the sampling plots was 101, and the minimum value was 14.

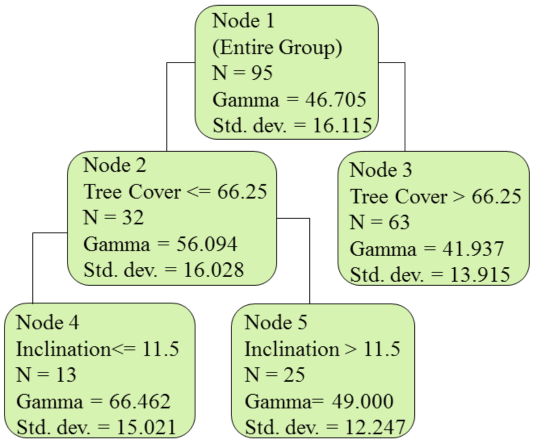

Figure 4. Regression tree model of gamma diversity
Şekil 4. Gama çeşitliliğine ait regresyon ağacı modeli

The model obtained by the regression tree analyses applied to the relationship between Shannon H values and environmental factors was explained by tree layer coverage, inclination, limestone and elevation (Figure 5). The explanation coefficient of the model was R^2= 0.463. In areas where the inclination was lower than 12.5°, tree layer coverage was lower than or equal to 63.75%, Shannon diversity (H) had the maximum value with 2.965. At the second stage, tree coverage was 63.75% - 81.25% in the model and the bedrock limestone was represented with H value of 2.62. Its' maximum and minimum values in the sampling plots were 3.7205 and 0.9057, respectively.

According to the regression tree analysis applied to the relationship between the Simpson 1-D index values and environmental variables, the proportion of variance explained of the model was R^2= 0.3040 (Figure 6). The maximum Simpson 1-D index value was 0.9383, while its minimum value was 0.3574 in the sampling plots. In areas where the tree layer coverage, which was the model's variable was lower than or equal to 81.25, Simpson index had the maximum value with 0.7913.

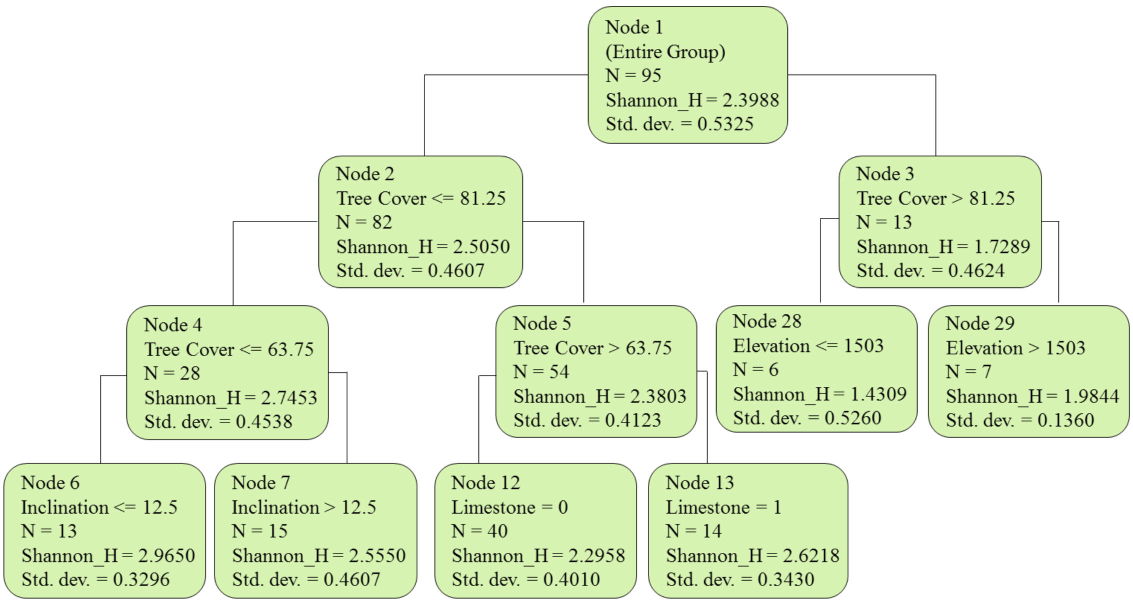

Figure 5. Regression tree model of Shannon H diversity
Şekil 5. Shannon H çeşitliliğine ait regresyon ağacı modeli

According to the regression tree analysis applied to the relationship between the Whittaker's beta diversity index (β_w) values (maximum: 0.84615; minimum: 0.11765) and environmental variables, the model's explanation coefficient was R^2= 0.187 which was very low (Figure 7).

In areas where the shrub layer coverage was greater than 19.25%, the beta value was the highest with 0.4725. The model with the second highest explained proportion was the one in which the shrub layer coverage was lower than or equal to 19.25% and the radiation index value was greater than 0.56 (sunny aspects between NW and SE).

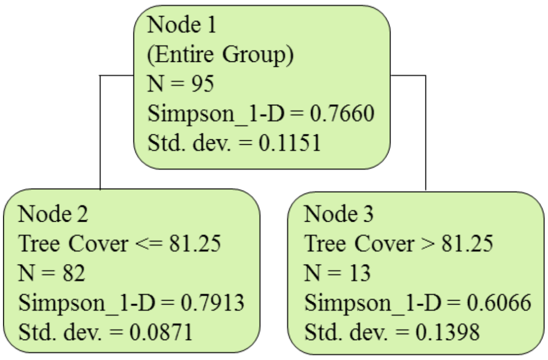

Figure 6. Regression tree model of Simpson 1-D index
Şekil 6. Simpson 1-D indisine ait regresyon ağacı modeli

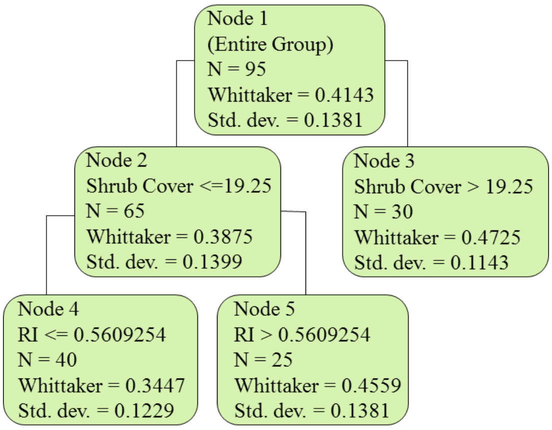

Figure 7. Regression tree model of Whittaker beta index
Şekil 7. Whittaker beta indisine ait regresyon ağacı modeli

4. Discussion and Conclusion

4.1. Plant groups and environmental factor

Türkmen Mountain is an important district consisting of different tree species and other plant taxa as well as numerous plant communities as a result of different habitats. It is surrounded by steppe, and the endemism rate of its forest vegetation is 14%. As a matter of fact, the endemism rate of Kalabak basin in the mountain alone is 13.9% (Ocak et al., 2008).

The numerical analyses applied to the relationships between plant groups and some environmental factors revealed that elevation, bedrock, shrub layer coverage, inclination, radiation index and tree layer coverage were the most important variables in differentiating plant groups. Slope position and ophiolitic bedrock did not play a significant role in differentiating the plant groups. Studies conducted in different regions found that elevation was the most important factor in the distribution of plant communities (Poulos et al., 2007; Fontaine et al., 2007; Özkan and Kantarcı, 2008; Kavgacı et al., 2010a; Kavgacı et al., 2010b; Özkan and Negiz, 2011). Sultandağı in Çarıksaraylar locality, the vegetation between the elevations from 1200 to 2000 meters was divided into three plant groups with clustering analysis and the most important variables were elevation and bedrock according to the correlation analysis performed with site factors (Şentürk et al., 2013). In our study, bedrock was found to be the most important variable after elevation.

4.2. Species diversity of the sampling plots and the modelling of factors affecting species diversity

To examine the results of the species diversity indices (alpha, beta and gamma) of 95 sampling with species diversity indices of plant groups were closely found each other.

The alpha diversity indices of the sampling plots had similar results to the plant groups (Table 3). Concerning the alpha diversity index values, it was found that the top 5 sampling plots with the highest value were in the Anatolian black pine communities with the highest alpha diversity values (Group 3 and Group 1). Similarly, the sampling plots with the highest gamma diversity were found to be in the Anatolian black pine communities (Groups 1, 3, 4). The sampling plots with the highest beta value matched with the groups with the highest beta value (Group 4 and Group 8). B_w values were found to be higher in the sampling plots with different plant communities.

Beta diversity was calculated as compared to two subplots which were selected in 1 hectare. Therefore, in this area, topographic heterogeneity was very low. As a result, beta diversity values were lower than the beta diversity values of the plant groups.

Beta diversity explains the differences in diversity between ecosystems or areas (Klinka, 1997). It is also known as the most important diversity component especially in studies on forest ecology, which may show the differences between habitats in an ecosystem (Negiz et al., 2015). Increasing differences between and number of communities in an area is associated with increased heterogeneity of that area (Gould and Walker, 1999). It is claimed that the species diversity on 19 islands on the Aegean Sea does not result from local differences but from the heterogeneity of communities (Sfenthourakis and Panitsa, 2012). In our study, area heterogeneity had a significant impact on B_w while it can be suggested that different plant groups affected the beta diversity. As a matter of fact, B_w was found to be higher in the sampling areas where different plant groups existed together. The grass layer was also rich in the sampling plots that had tree and shrub layers consisting of different species. The beta diversity was also high in those plots. It can also be argued that different plant groups increased beta diversity from floristic perspective.

A comparison between the model's variables identified for the gamma, alpha and beta diversity and the factors that influenced the differentiation of the plant groups that had the highest diversity values (Groups 1, 3 and 4 and Group 8) revealed similar results. When all diversity indices and the regression tree models were assessed together, it was understood that the species diversity and richness were higher in the sampling plots with a tree layer coverage less than 66%, inclination lower than 12.5°, shrub layer coverage greater than 19, limestone presence and RI higher than 0.56. The structural complexity of stands should be included in the studies related to plant species diversity as an important parameter (Poulos et al., 2007). In fact, tree layer coverage and shrub layer coverage were the most important variables that influenced the species diversity in our study and the shrub layer and grass layer coverage and richness both increased as the tree layer coverage decreased. Increased heterogeneity of the forest upper layer also increases the forest lower layer's woody species richness (Pausas, 1994).

In a study conducted in the Çarıksaraylar locality of the Beyşehir lake basin, it was found that alpha woody species diversity was higher on northern aspects, while tree and shrub layer species diversity was higher on the high mountainous areas (Özkan, 2006). In our study, the sampling plots and plant groups with maximum alpha and gamma diversity were located in areas with lower inclination and elevation.

4.3. Plant groups and species diversity

Türkmen Mountain has pure and mixed stands consisting of different species and varying topographic conditions. The plant communities with low beta diversity have a narrow distribution area in Türkmen Mountain. Beta and gamma diversity are lower in areas with fewer differences in habitat and plant species in plant communities represented by fewer sampling plots. Therefore, area heterogeneity is lower. The plant communities with higher beta diversity are distributed in wider areas; thus, they may have different habitat characteristics. This increases the beta diversity of plant groups.

Group 8 and Group 4 had the highest beta value. Group 8 that represented the Scotch pine forest community is distributed at an elevation of 1178 - 1700 meters on Türkmen Mountain and forms the uppermost community of the forest vegetation. It is found in different physiographic factors and productivity classes such as different elevations, inclinations and aspects (Güner, 2008). Elevation, shrub and tree layer coverage and radiation index were the important variables in differentiating Group 8. Group 4 was differentiated by lower elevation and higher shrub layer coverage. Both groups were distributed in a wide area. Such areas had a high topographic heterogeneity, which also increased the species richness. As a matter of fact, Group 8 ranked the 3rd and Group 4 ranked the 4th in terms of gamma diversity. However, these groups were not rich in alpha diversity. Similar results were reported in a study conducted on the islands between coastal areas of the Northeast America and Southeast Canada. The natural vascular species richness increased in direct proportion to the surface area and physiological factors had a significant impact on plant species richness (McMaster, 2005). In the study conducted in the islets in Greece, it was found that geographic variables had a significant effect on plant species diversity (Iliadou1 et al., 2014). According to the regression tree model applied in a study in California, shrub species richness was found to be maximum at higher elevations with steep slope where topographic humidity index was low and the bedrock was on the surface (Moody and Meentemeyer, 2001). In another study conducted in Iran-Melah Gavan conservation zone, the highest species diversity was found in the climate zone at 1400-1500 m whereas the lowest species diversity was found in the climate zones at higher elevations (1800-2000 m) (Heydari and Mahdavi, 2009). In our study area, however, the forest community was distributed up to 1800 meters. The plots where the shrub layer coverage was greater than 19.25% in the regression tree model, those with shrub layer lower than or equal to 19.25% and with RI greater than 0.56 in the second model (sunny aspects between NW and SE) and plots with less shrub layer and higher RI in the third model were the best models for beta value. This is consistent with these results compared to the communities with the highest beta value. Group 8 had a low shrub layer coverage and preferred areas with higher RI value. The second maximum beta value was found in Group 4 that was differentiated with highs shrub layer coverage, which was a very important indicator.

In a study conducted in Scotch pine forests, bedrocks with calcium carbonate (such a limestone) had much higher species diversity compared to those without carbonate (such as granite, schist, sandstone) (Pausas and Carreras, 1995). In our study area, Group 8 that preferred limestone and unaltered volcanite ranked 3rd in terms of gamma species diversity as it had different habitat conditions and stand coverage. It had a lower alpha diversity value compared to the other plant groups. In a study conducted in Scotch pine forests of Türkmen Mountain, Shannon-Wiener diversity was found to be higher in areas with higher productivity (Güner et al., 2011). In our study, the index values of the alpha species diversity decreased with increased inclination, elevation and tree layer coverage. In fact, compared to the other plant communities, Group 8 and Group 9 had the highest average tree layer coverage (74%; 88%) and average elevation (1500; 1450 m). There was a negative relationship between these environmental variables (elevation and tree layer coverage) and species diversity while they had a positive impact in differentiating Group 8 and 9.

According to the alpha, beta and gamma diversity indexes calculated for each plant community, Simpson and Shannon alpha diversity indexes had similar results. However, Shannon index values were much higher and revealed the differences better; therefore, it can be suggested that this index explains the differences in species diversity between plant communities in a better way. Groups 9, 5, 4 and 8 had the lowest alpha diversity values and had higher tree layer coverage and higher elevation except Group 4. This finding shows that the alpha diversity decreased as shade and elevation increased. Group 3, Group 1, Group 6 and Group 7 had the highest alpha diversity, respectively. Group 3, 6 and 7 that were represented by a low number of sampling plots had similar habitat characteristics and higher alpha diversity since the presence and coverage of plant taxa in these groups were higher. Therefore, Group 3 ranked the 5th in gamma diversity (species richness) with 160 species in only 6 sampling plots whereas it had the highest alpha diversity value as the species had a higher coverage rate and frequency. In fact, Gimaret-Carpentier et al., (1998) reported that diversity indices reflected abundance which was the distribution of different species groups that compose a population and the theoretical explanation of Shannon (H') and Simpson (D) diversity indices was based on the relative frequency of the species in a population. The lowest alpha diversity was found in the plant group dominated by oriental beech (Group 9). In that plant group, the tree layer cover percentage was very high; therefore, there were fewer species in the herb layer while their coverage was lower. There were oriental beech shrubs trees that grew from shoots rather than different shrub species in the Group 9. For that reason, Group 9 was found to have the lowest alpha diversity. In a study that took the number of species into account, the number of plant taxa contained in pure *Fagus orientalis* stands was about 30% lower compared to the ones in *Picea orientalis* and *Pinus sylvestris* stands (Küçük, 1998). Although the number of species in Group 9 was not high, it ranked the 5th with its beta diversity of 3.19. This group was mixed with Scotch pine, Anatolian black pine and occasionally hornbeam, and so increased the beta value due to the presence of different species in the sampling plots. In a study conducted in deciduous forest communities, Rad et al. (2009) found that the species diversity of *Querco-Carpinetum betulii,* and *Carpinetum-Fagetum* communities was significantly higher than that of *Rusco-Fagetum* and *Fagetum orientalis* communities and thus species diversity had an inverse relationship in the stands where dominated shadow-resistant climax species.

In conclusion, tree layer coverage, shrub layer coverage and inclination, respectively, were the most important factors that affected plant species diversity. Regression tree models showed that species diversity and richness were higher in areas where tree layer coverage was lower than and equal to 81% and inclination was lower than and equal to 12.5°, and shrub layer coverage was lower than 19.5%. It can be suggested that topographic heterogeneity, stand structure (coverage) and heterogeneity of plant communities had an impact on beta diversity. From the alpha diversity indices, the Shannon index better revealed the species diversity differences between the plant communities. When we assessed all diversity components (alpha, beta and gamma) according to the plant groups, *Pinus nigra* subsp. *pallasiana – Cistus laurifolius* (Group 1) was the common plant group that all three components were found to be the highest. It was understood that the factors affecting the differentiation of this group were the same as the significant variables in the regression tree model. The other plant groups with high species diversity were Group 2 (*Pinus nigra* subsp. *pallasiana – Dactylis glomerata* susbp. *hispanica*), Group 4 (*Pinus nigra* subsp. *pallasiana - Quercus petraea* subsp. *iberica*) and Group 8 (*Pinus sylvestris – Galium rotundifolium*). In conclusion, the variables in the model created for the sampling plots were similar to the variables that affected the differentiation of the vegetation. Furthermore, the sampling plots with the highest species indices values were similar to the plant groups that had the highest diversity indices values. In this context, the planning according to species diversity indices of plant groups will make efforts easier.

According to the findings of the study and the results of the analyses, the following points should be taken into consideration in planning the areas rich in species diversity on the basis of plant groups and sampling plots:

- Plant communities should be composed of different tree species,
- Tree and shrub layer coverage should not be too high,
- There should be different plant species on the bottom layers, especially the grass layer,
- There should be different plant communities or groups in the transition zones,
- Areas with different topographic structure should not be ignored.

Moreover, it was concluded that it would be appropriate to use the alpha, gamma and beta diversity indices all together according to the results of the studies.

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References

Aertsen, W., Kint, V., Van Orshoven, J., Özkan, K., Muys, B., 2010. Performance of modelling techniques for the prediction of forest site index: a case study for pine and cedar in the Taurus mountains. XIII World Forestry Congress, 18 – 23 October 2009, Buenos Aires, Argentina.

Akman, Y., Daget, P. H., 1971. Quelques Aspects Synoptiques des Climats de la Turquie. *Bulletin de la Société Languedocienne de Géographie* 5(3): 269-300.

Akman, Y., Barbéro, M., Quézel, P., 1979. Contribution a’l’étude de da dégétation forestiére d’anatolie Méditerranéenne. *Phytocoenologia* 5(2): 189-276.

Akman, Y., 1999. İklim ve Biyoiklim (Biyoiklim Metodları ve Türkiye İklimleri). Kariyer Matbaacılık, Ankara.

Akman, Y., Ketenoğlu, O., Geven, F., 2001. Vejetasyon Ekolojisi ve Araştırma Metodları. Ankara.

Braun-Blanquet, J., 1932. Plant Sociology (Translated: Fuller, D. G. and Conard S. H. 1983). West Germany.

Breiman, L., Friedman, J., Olshen R., Stone, C.J., 1984. Classification and Regression Trees. Wadsworth, Belmont.

Brewer, S.W., Rejmánek, M., Webb, M.A.H., Fine, P.V.A., 2003. Relationships of phytogeography and diversity of tropical tree species with limestone topography in southern Belize. *Journal of Biogeography* 30(11): 1669–1688.

Chytrý, M., Danihelka J., Axmanová I., Božková, J., Hettenbergerova, E. , Li, C-F., Rozbrojová Z., Sekulová, L., Tichý, L., Vymazalová, M., Zeleny, D., 2010. Floristic diversity of an eastern Mediterranean dwarf shrubland: the importance of soil pH. *Journal of Vegetation Science* 21(6): 1125–1137.

Davis, P. H., 1965-1985. Flora of Turkey and the East Aegean Islands. Edinburg University Press, Vol: 1-9, Edinburg.

Davis, P. H., Mill, R. R., Tan, K., 1998. Flora of Turkey and the East Aegean Islands (Supplement 1). Edinburg University Press, Vol: 10, Edinburg.

Duran A., Ocak, A., 2005. Hesperis turkmendaghensis (sect. Hesperis) (Cruciferae/Brassicaceae), a new species from the Central Anatolia region, Turkey. *Botanical journal of the Linnean Society* 147(2): 239-247.

Ehrlich, P.R., 1991. Biodiversity studies: science and policy. *Science* 253(5021): 758-762.

Fontaine, M., Aerts, R., Özkan, K., Mert, A., Gülsoy, S., Süel, H., Waelkens, M., Muys, B., 2007. Elevation and exposition rather than soil types determine communities and site suitability in Mediterranean mountain forests of southern Anatolia, Turkey. *Forest Ecology and Management* 247((1-3): 18-25.

Gimaret-Carpentier, C., Pélissier, R., Pascal, J.P., Houllier, F., 1998. Sampling strategies for the assessment of tree species diversity. *Journal of Vegetation Science* 9(2): 161-172.

Gould, W.A., Walker, M.D., 1999. Plant communities and landscape diversity along a Canadian Arctic river. *Journal of Vegetation Science* 10(4): 537-548.

Göktürk, R.S., Sümbül, H., 2014. A taxonomic revision of the genus Cephalaria (Caprifoliaceae) in Turkey. *Turk Journal of Botany* 38(5): 927-968.

Gupta, A., Joshi, S.P., Manhas, R.K., 2008. Multivariate analysis of diversity and composition of weed communities of wheat fields in Doon Valley. India, *Tropical Ecology* 49(2): 103-112.

Gülsoy, S., Özkan, K., 2008. Tür çeşitliliğinin ekolojik açıdan önemi ve kullanılan bazı indisler. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi* 1: 168-178.

Güner, A., Özhatay, N., Ekim, T., Başer, K.H.C., 2000. Flora of Turkey and the East Aegean Islands (Supplement 2). Edinburg University Press, Vol: 11, Edinburg.

Güner, Ş.T., 2008. Bozkıra Geçiş Bölgesindeki Sarıçam (*Pinus sylvestris* L. ssp. *hamata* (Steven) Fomin.) Ormanlarının Gelişimi ile Bazı Yetişme Ortamı Özellikleri Arasındaki İlişkiler, Çevre ve Orman Bakanlığı, Orman Toprak ve Ekoloji Araştırmaları Enstitüsü Müdürlüğü Yayını, Bakanlık Yayın No: 358, Müdürlük Yayın No: 3, 41 s., Eskişehir.

Güner, Ş.T., Özkan, K., Yücel, E., 2011. Sarıçam ormanlarının verimliliği ile vejetasyon ve tür çeşitliliği arasındaki ilişkiler: Türkmen Dağı örneği. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi* 12(1): 1-6.

Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. "Past: paleontological statistics software package for education and data analysis", *Palaeontologia Electronica*, 4(1).

Hennekens, S.M., Schaminee, J.H.J., 2001. TURBOVEG a comprehensive data base management system for vegetation data. *Journal of vegetation science* 12(4): 589–591.

Heydari, M., Mahdavi, A., 2009. Pattern of Plant Species Diversity in related to physiographic factors in Melah Gavan Protected Area, Iran. *Asian Journal of Biological Sciences* 2(1): 21-28.

Iliadou, E., Panitsa, M., Raus, T., Dimopoulos, P., 2014. Flora and factors affecting species diversity in the islet groups of the protected" Natura 2000" sites of the Amvrakikos Gulf and Mesolongi Lagoon (Ionian area, Greece). *Willdenowia*, 44: 439-450.

Işık, K., 1999. Çevre Sorunları Biyolojik Çeşitlilik ve Orman Gen Kaynaklarımız, TEMA (Türkiye Erozyonla Mücadele, Ağaçlandırma ve Doğal Varlıkları Koruma Vakfı Yayınları 25, Doyuran Matbaası, İstanbul.

Kareiva, P., 1993. No shortcuts in new maps. *Nature* 365: 292-293.

Kavgacı, A., Carni, A., Silc, U., 2008. Bitki çosyolojisi çalışmalarında kullanılan sayısal metotlar ve bazı bilgisayar programları. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi* A(2): 188-201.

Kavgacı, A., Başaran, S., Başaran, M. A., 2010a. Cedar forest communities in Western Antalya (Taurus Mountains, Turkey). *Plant Biosystems* 144(2): 271-287.

Kavgacı, A., Čarni, A., Tecimen, B., Özalp, G., 2010b. Diversity and ecological differentiation of oak forests in NW Thrace (Turkey). *Archives of Biological Science*, 62(3): 705-718.

Kavgacı, A., Arslan M., Bingöl M.Ü., Erdoğan N., Čarni A., 2012. Classification and phytogeographical differentiation of oriental beech forests in Turkey and Bulgaria. *Biologia* 67(3): 461-473.

Klinka, K., 1997. *Plant diversity in old-growth and second-growth stands in the coastal rainforests of British Columbia*. 1997. PhD Thesis. University of British Columbia.

Küçük, M., 1998. Kürtün (Gümüşhane) Örümcek Ormanlarının Florası ve Saf Meşcere Tiplerinin Floristik Kompozisyonu. Doğu Karadeniz Ormancılık Araştırma Enstitüsü Teknik Bülten No: 5, Trabzon, 120 s.

Mc Cune, B., Mefford, M.J., 2006. PC-ORD 5, Multivariate analysis of ecological data. MjM Sofware Design, Gleneden Beach, Oregon.

McMaster, R.T., 2005. Factors influencing vascular plant diversity on 22 islands off the coast of eastern North America. *Journal of Biogeography* 32(3): 475–492.

Moisen, G. G., Frescino, T. S., 2002. Comparing five modelling techniques for predicting forest characteristics. *Ecological Modelling* 157(2-3): 209-225.

Moody, A., Meentemeyer, R. K., 2001. Environmental factors influencing spatial patterns of shrub diversity in chaparral, Santa Ynez Mountains, California. *Journal of Vegetation science* 12(1), 41-52.

Negiz, M.G., Gülsoy, S., Özkan, K., 2015. Orman ekosistemlerinde tür çeşitlilik bileşenlerinin belirlenmesinde kullanılabilecek bir arazi envanter yaklaşımı. *Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü Dergisi* 19(2): 198-204.

Ocak, A., Hüner, G., Ataşlar, E., 2008. The flora of Kalabak basin (Eskişehir, Turkey). *Turk Journal of Botany* 32(5):381-410.

Özdamar, K., 2009. Paket Programlar ile İstatistiksel Veri Analizi, 7. Baskı, Kaan Kitabevi, Eskişehir.

Özkan, K., 2002. Türler arası birlikteliğin interspesifik korelasyon analizi ile ölçümü. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi* A(2): 71-78.

Özkan, K., 2006. Beyşehir Gölü Havzası Çarıksaraylar yetişme ortamı yöreler grubunda fizyografik yetişme ortamı faktörleri ile ağaç ve çalı tür çeşitliliği arasındaki ilişkiler analizi. *Anadolu Üniversitesi Bilim ve Teknoloji Dergisi,* 7(1): 157-16.

Özkan, K., Kantarcı, M.D., 2008. Beyşehir Gölü Havzası'nın orman yetişme ortamı alt bölgeleri ve yöreleri grupları. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi*, A(2): 123-135.

Özkan K., 2010. Orman ekosistem çeşitliliği haritalama çalışmaları için ekolojik alan çeşitliliğinin belirlenmesi üzerine bir öneri. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi* A(2): 136-148.

Özkan, K., Negiz, G.M., 2011. Isparta Yukarıgökdere Yöresi'ndeki odunsu vejetasyonun hiyerarşik yöntemlerle sınıflandırılması ve haritalanması. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi* 12(1): 27-33.

Özkan, K., 2016. Biyolojik Çeşitlilik Bileşenleri(Alfa, Beta ve Gama) Nasıl Ölçülür? Süleyman Demirel Üniversitesi Orman Fakültesi Yayın No: 98, Isparta.

Pausas, J.G., 1994. Species richness patterns in the understorey of Pyrenean *Pinus sylvestris* forest. *Journal of Vegetation Science* 5(4): 517-524.

Pausas, J.G., Carreras, J., 1995. The effect of bedrock type, temperature and moisture on species richness of Pyrenean Scots pine (*Pinus sylvestris* L.) forests. *Vegetatio* 116(1): 85- 92.

Pausas, J.G., Austin, M.P., 2001. Patterns of plant species richness in relation to different environments: An appraisal. *Journal of Vegetation Science* 12(2): 153-166.

Pausas, J.G., Carreras, J., Ferré, A., Font, X., 2003. Coarse-scale plant species richness in relation to environmental heterogeneity. *Journal of Vegetation Science* 14(5): 661-668.

Poole, R.W., 1974. An Introduction to Quantitative Ecology. McGrawHill, Inc., New York.

Poulos, H.M., Taylor, A. H., Beaty, R.M., 2007. Environmental controls on dominance and diversity of woody plant species in a Madrean, Sky Island ecosystem, Arizona, USA. *Plant Ecology*, 193(1): 15-30.

Pourmajidian, M. R., Kavian, H., 2017. Assessment of plant biological diversity and soil characteristics in the pure ash tree stand and in mixture with beech (a case study of Lavij-Noor, Iran). *Journal of Forest Science*, *63*(10): 443-448.

Prendergast, J.R., Quinn, R.M., Lawton, J.H., Eversham, B.C., Gibbons, D.W., 1993. Rare Species, the Coincidence of Diversity Hotspots and Conservation Strategies. *Nature* 365: 335-337.

Rad, J.E., Manthey, M., Mataji, A., 2009. Comprasion of Plant Species Diversity with Different Plant Communities in Decidious Forests. *International Journal of Environmental Science & Technology* 6(3): 389-394.

Sfenthourakis, S., Panitsa M., 2012. From plots to islands: species diversity at different scales. *Journal of Biogeography* 39(4): 750–759.

Simpson, E. H., 1949. Measurement of diversity. *Nature* 163: 688.

Şentürk, Ö., Ulusan, M.D., Eser, Y., Şenol, A., Özkan, K., 2013. Sultan Dağları-Çarıksaraylar Yöresi'nde vejetasyon ile yetişme ortamı faktörleri arasındaki ilişkiler. 3rd International Geography Symposium – GEOMED, Kemer-Antalya, s. 597-607.

Tichý L., 2002. JUICE, software for vegetation classification. *Journal of Vegetation Science* 13(3): 451–453.

Yaltırık, F., Efe, A., 1996. Otsu Bitkiler Sistematiği. II. Baskı, İstanbul Üniversitesi Yayın No: 3940, Orman Fakültesi Yayın No: 10, 518 s., İ.Ü. Basımevi ve Film Merkezi, İstanbul.

Whittaker, R.H., 1960. Vegetation of the Siskiyou Mountains, Oregon and California. *Ecoogycal Monographs* 30(3): 279-338.

Whittaker, R.H., 1972. Evolution and Measurement of species diversity. *Taxon* 2: 213-251.

Zohary, M., 1973. Geobotanical Foundatitons of the Middle East. Vol: 1-2, Gustav Fisher Verlag, Stuttgrad.