RELATIONSHIPS BETWEEN ALPHA PLANT SPECIES DIVERSITY AND ENVIRONMENTAL VARIABLES IN DEDEGÖL (YENİŞARBADEMLİ) MOUNTAIN AREA

NEGİZ, M. G.[1*] – AYGÜL, E. Ö.[2]

[1]*Applied Sciences University of Isparta, Sütçüler Prof. Dr. Hasan Gürbüz Vocational School, Forestry Department, Sütçüler / Isparta, Turkey*
(phone: +90-555-694-5786; fax: +90-246-351-2901)

[2]*Yozgat Bozok University, Boğazlıyan Vocational School, Forestry Department Boğazlıyan / Yozgat, Turkey*
(phone: +90-354-290-3002; fax: +90-354-290-3003)

[*]*Corresponding author*
e-mail: mehmetnegiz@isparta.edu.tr; phone: +90-555-694-5786; fax: +90-246-351-2901

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Abstract. This study was conducted to determine the relationships between woody plant species alpha diversity (α) and environmental factors in Dedegöl (Yenişarbademli) Mountain area. The research data obtained from 103 sampling plots after the land inventory study was used to calculate the diversity variables. The coverage area and habitat characteristics of woody plant species in each sampling plot were recorded during the field work. Clustering analysis (CLA) was used to group the sampling plots base on the vegetation data matrix. Correspondence Analysis (CA) and detrended correspondence analysis (DCA) from the ordination techniques were applied in the study to the vegetation matrix in order to determine the distribution degree of the sampling plots on the ordination axis. As a result of the CA applied, surface stoniness was found to be the environmental factor that had the highest correlation. In conclusion, surface stoniness was found to have an important impact on the vegetation distribution. Furthermore, canonical correspondence analysis (CCA) was applied at the final stage of the study. In conclusion, Shannon-Wiener was the most effective index to calculate the alpha species diversity while surface stoniness and elevation were the most explanatory variables for alpha species diversity in the study site.
Keywords: *biodiversity, forest ecosistems, habitat factors, Shannon-Wiener index, ordination methods*

Introduction

Biological diversity is the degree of variation in the living organisms in a specific ecosystem, biome or in the entire world, referring to the variability in the species, functions and structures among the living organisms. Forest ecosystems constitute the most important sources of biological diversity as they contain 2/3 of the world's ecosystems (Thompson et al., 2009).

Biological diversity is a very broad concept that covers genetic diversity, species diversity and ecosystem diversity (Hunter, 1996; Aertsen et al., 2010; Negiz, 2013).

Species diversity is one of the most important elements to determine the biological diversity in forest ecosystems. Studies on forest ecology mainly focus on plant species diversity (Özkan, 2006; Özkan and Süel, 2008; Negiz, 2013; Özkan, 2016; Negiz and Aygül, 2019).

Species diversity is divided into three categories of alpha diversity (α), beta diversity (β) and gamma (γ) diversity (Gülsoy and Özkan, 2008). Alpha diversity is determined for a specific area while beta diversity is the measure of diversity amog areas. Gamma diversity refers to the total diversity of the relevant ecosystem covering these areas (Whittaker, 1972; Zhao et al., 2005; Mareno et al., 2006; Hashemi, 2010).

High species diversity is very important for a forest ecosystem. Ecosystems, which have a rich species diversity, are more resilient against any kind of adverse impacts. In other words, it plays a key role in the sustainability of ecosystems (Negiz, 2013).

On the other hand, there are important relationships between species diversity and habitat characteristics in forest ecosystems. It is clear that the areas with high potential in terms of species diversity can be identified if such relationships are known (Linder, 2001; Özkan, 2006).

Our study site – Dedegöl Mountains – (Yenişarbademli) region has a very rich forest asset. However, the amount of forestlands, which were degraded by people, is close to that of the actual forestlands. Potential areas should be identified to establish new forests. Therefore, it is important to determine the biological diversity of the area. This study was conducted in order to determine the relationships between the alpha diversity of Dedegöl Mountain (Yenişarbademli) region having a very high plant species diversity in the Mediterranean region and the habitat characteristics.

Material and Methods

Study area

The study site is located in the Dedegöl (Yenişarbademli) Mountain areas in Turkey at 37°38'35″ north an 31°21'17″ east coordinates. The study site is situated in the Lakes Region of the Mediterranean Region, in the west of Beyşehir Lake, and the vast majority of the site is contained in Isparta- Yenişarbademli and Isparta-Konya provincial boundaries (*Fig. 1*). The elevation of the region varies from 820 m to 2992 m. The mean monthly temperature during many years is 10.7 degrees. The total mean annual precipitation is 727 mm.

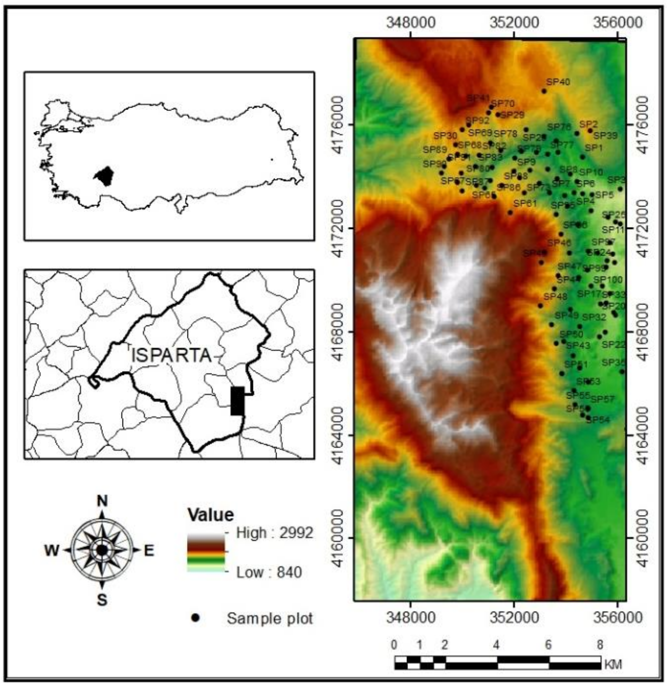

Figure 1. *Location Map of Dedegöl Mountain Region*

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Sampling method

In this study, 103 sampling plots were used. Studies on sampling areas were carried out between April and September, which was the vegetation period in 2016-2017. The sampling plots were selected randomly at a size of 20 m x20 m. The woody plant species in the sampling plots were identified and recorded in the inventory cards according to the Braun-Blanquet method.

From the environmental variables; latitude, longitudes and elevation were determined with global position sistems (GPS), while slope was determined with abney level and aspect was determined with a compass and slope position was determined in 5 classes (Valley Floor: 1, Lower: 2, Intermediate: 3, Upper: 4, Ridge: 5). Surface stoniness was calculated as the mean percentage (%) of 20 different points in the lower sampling plots with an iron bar and recorded to be associated with the alpha diversity inputs. Obtained environmental variables and the codes given to them for use in statistical analysis are given in *Table 1*.

Table 1. *Environmental variables and their codes*

Codes	Environmental variables
LATITU	Latitude
LONGTI	Longitude
ELEVATION	Elevation
ASPECT	Aspect
ALTITUDE	Altitude
SLOPOS	Slope Position
SURSTON	Surface Stoniness

Data analysis

First, the environmental variables were determined for alpha diversity. During the office work, firstly the coverage area of woody plant species was digitalized according to the method propose by Fontaine et al. (2007) and Özkan (2009) to calculate the alpha diversity (r:0.01, +:0.02, 1:0.04, 2:0.15, 3:0.375, 4:0.625, 5:0.875).

The climate data was obtained from 19 different climate data downloaded from http://www.worldclim.org (*Table 2*). This data was downloaded at the world scale, and was then reduced to the scale of the study site and made available to be used in the study.

The environmental variables were obtained through the digital elevation model. First the slope and aspect maps were created with ArcGIS software, then the topographic position index (TPI), ruggedness index (EI), roughness index (PI) and shading index (GI) were created. Following these stages, different equations were used to calculate the values of the aspect compliance index (AC), temperature index (TI) and radiation index (RI).

The researchers have developed indexes to calculate the alpha species diversity such as Shannon- Wiener, Brillouin, Simpson, Margalef D and Berger- Parker (Shannon, 1948; Simpson, 1949; Berger and Parker, 1970; Clifford and Stephenson, 1975; Pielou, 1975; Özkan, 2016). Basic components analysis was applied with the help of SPSS software so as to decide which of these indexes should be used. In order to determine the relationships between the alpha values and environmental factors, spearman rank correlation analysis and regression analysis were applied with the help of SPSS software. Clustering analysis was performed according to the Ward's method through the Past program to divide the vegetation groups by using the woody plants identified in the sampling plots. The

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relationship analysis among the qualities was performed via the SPSS software in order to determine the indicator species of the groups which were divided with the clustering analysis. Ordination methods (DCA; CCA; CA) were used with the help of PC-ORD for more clear interpretation of the relationships between the woody vegetation identified in the sampling plots and the environmental factors.

Table 2. *Climate variables and their codes*

Codes	Climate variables
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range
BIO3	Isothermality
BIO4	Temperature Seasonality
BIO5	Max Temperature of Warmest Month
BIO6	Min Temperature of Coldest Month
BIO7	Temperature Annual Range
BIO8	Mean Temperature of Wettest Quarter
BIO9	Mean Temperature of Driest Quarter
BIO10	Mean Temperature of Warmest Quarter
BIO11	Mean Temperature of Coldest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality
BIO16	Precipitation of Wettest Quarter
BIO17	Precipitation of Driest Quarter
BIO18	Precipitation of Warmest Quarter
BIO19	Precipitation of Coldest Quarter

Results and Discussion

The data obtained from 103 sampling plots were used. The species that had the highest presence in the study site were *Pinus nigra* (98.06%), *Cistus laurifolius* (57.28%), *Verbascum glomeratum* (57.28%).

As a result of the basic components analysis (BCA) performed to determine the representative diversity index out of the alpha diversity indexes; Taxa_S (0.937), Simpson_1-D (0.917), Shannon-Wiener index (0.950), Shannon-Wiener index were found to have the highest coefficient.

In many studies on biodiversity, usually Shannon-Wiener index was used to calculate the alpha diversity index while the results were consistent with that finding (Gorelick, 2006; Ohsawa and Nagaike, 2006; Liang et al., 2007; Gülsoy and Özkan, 2008; Negiz, 2013).

As a result of the basic components analysis (BCA) performed to reduce the climate variables or select the most suitable representative climate variables; two components with a variance greater than and variance contribution greater than 10% were found. The variance contribution of the first component was 83.3% while that of the second component was 12.7% and the rate of these two components in the total variance was 96%.

According to the Spearman rank correlation analysis that showed the relationships between the alpha species diversity and environmental factors; the alpha species diversity (Shannon_H) had a significantly positive correlation with BIO1 (r_s=0.269 and $p<0.01$), BIO2 (r_s=0.278 and $p<0.01$), BIO4 (r_s=0.273 and $p<0.01$) and BIO10 (r_s=0.274 and

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p<0.01); BIO11 (r_s=0.273 and p<0.01); ALTITUDE (r_s=0.292 and p<0.01) and SURSTON (r_s=0.359 and p<0.01) while it had a negative relationship with BIO12 (r_s= -0.360 and p<0.01) and ELEVATION (r_s= -0.220 and p<0.05).

The alpha diversity values had positive correlations with several climate variables selected as the representative climate variables whereas it had a negative relationship with only annual precipitation (BIO12). As mentioned above, heavy snow and snow thickness at especially higher elevations in the region can be suggested as the most important reason for that. Another important aspect of the Spearman rank correlation analysis results was that the alpha diversity variables had a positive correlation with SURSTON while it had a negative relationship with ELEVATION. The positive correlation with surface stoniness can be explained by the fact that the areas with high surface stoniness were located in the south-eastern parts of the study site and thus the sunshine duration was longer in those area compared to the others.

According to the results of the multiple regression analysis performed to model the alpha diversity; R^2 value of the best model was 0.272 and its standard error was 0.348. That is, the model explained 27.2% of the variance and it is significant at the level of p<0.01. This model was constituted with SURSTON, ELEVATION, BIO5, TPI. The variance inflation factors of the model were lower than 5. Its tolerance values were closer to 1. The significance level of all variables including the model's constant was lower than 5%. Beta value indicates the significance of the variables in the model. In this context, ELEVATION was the most important variable.

The relationships with ELEVATION were negative as those in the Spearman rank correlation analysis. This shows that the alpha diversity was higher at lower elevations.

As a result of the clustering analysis performed according to the Ward's method; groups of 2 (T:-31.7211; A:0.05868; P:0), 3 (T:-29.3821; A:0.078724; P:0), 4 (T:-32.8804; A:0.107194; P:0) and 5 (T:-30.6251; A:0.68298; P:0) were used. In order to decide the most suitable group separation, MRPP analysis was conducted with PC-ORD program. According to the MRPP analysis; it was decided that the group of 4 had the most effective results in terms of T, A and P values.

A relationship analysis between qualities was performed to determine the indicator plant species of the groups. The analysis revealed that the most important indicator species in Group A were *Cistus laurifolius* and *Rosa canina*, while *Cistus laurifolius*, *Euphorbia* sp., *Juniperus excelsa*, *Laurus nobilis*, *Populus tremula* and *Thymus samius* were the most important indicator species in Group B. The most important indicator species of Group C were *Cistus laurifolius*, *Euphorbia* sp., *Juniperus oxycedrus* subsp. *oxycedrus*, *Rosa canina* and *Verbascum* sp. while *Sambucus ebulus* and *Abies cilicica subsp. isaurica* were the most important indicator species in Group D.

The results of the Spearman rank correlation analysis performed to investigate the relationships between the abovementioned groups and the alpha species diversity (Shannon_H). Group A (Correlation Coefficient: 0.358; Significance Level:0) and Group D (Correlation Coefficient: 0.281; Significance Level:0.004) had a positive relationship with the groups whereas Group C (Correlation Coefficient: -0.384; Significance Level:0) had a negative relationship with the groups.

In conclusion, the sampling plots in Group A were located at the intermediate elevations in the study site (1226-1694). *Rosa canina* and *Cistus laurifolius* that were the indicator species in Group A verify this finding. Group A had a higher alpha diversity than the other groups. This leads to the conclusion that the species diversity is higher at intermediate elevations in the study site. It was found that the species diversity decreased

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as the elevation increased in the study site. This can be explained by the fact that there were some snow-covered locations at high elevations in the study site with heavy snow for a long time (approximately 6 months a year). Many plant species in the region preferred low elevations due to the snow cover (Özkan, 2006; Özkan and Negiz, 2011).

The ranking and association analysis were conducted according to the ordination methods. First, the location of the vegetation communities on the axis was determined according to different ordination methods. Furthermore, the groups identified according to the clustering analysis were transferred to the ordination axis at this point to demonstrate the relationship between the groups and the distribution of vegetation communities. Finally, the environmental variables included in the data as the second matrix were associated with the ordination axis so that the vegetation-environment relationships on the axis were interpreted.

Correspondence Analysis (CA) was the first ranking-association analysis to have been applied in the study. The vegetation data matrix was evaluated with the correspondence analysis. The location of the sampling plots was identified on the ordination axis. 3 axis were obtained with this analysis, while Axis 1 (0.339; 7.72), Axis 2 (0.261; 5.93), Axis 3 (0.238; 5.43) were identified according to the Eigenvalue coefficient and variance explanation power of the axis. This indicates that Axis 1 had the highest Eigenvalue coefficient and variance explanation power. Therefore, it was decided to include only the Axis 1 in the analysis. The location of the sampling plots on Axis 1-2 is shown in *Fig. 2*.

The correlation coefficients of the relationships between the Axis 1-2 and plant species in the vegetation data matrix were found to be *Cirsium arvense* subsp. *vestitum* (0.519), *Euphorbia* sp. (0.664), *Populus tremula* (-0.564) and *Thymus samius* (0.550) while the plant species had the highest correlation with Axis 1.

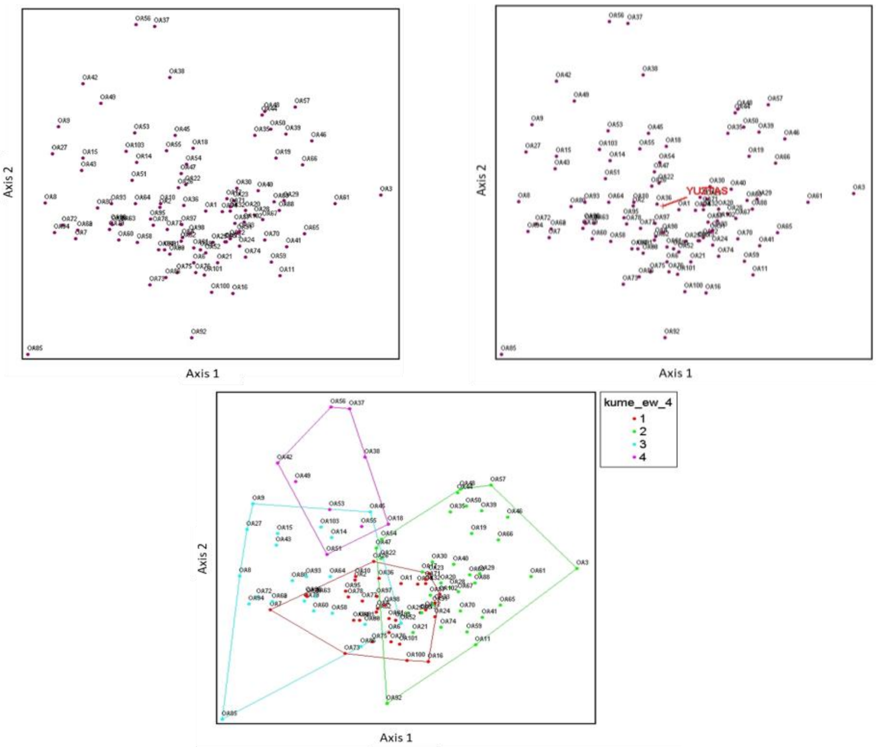

Figure 2. *Location of sampling plots on Axis 1-2 according to the correspondence analysis, location of environmental variables and Euclidean-Ward's 4 groups according to the clustering analysis*

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As regards the correlation coefficients of the environmental variables according to the association between the axis and environmental data matrix; SURSTON (0.368) were found to be the environmental factor that had the highest correlation with the axis while it had a positive correlation with Axis 1. The location of the statistically significant environmental variables on the axis is shown in *Fig. 2*.

When the results relating to the vegetation data matrix and those of the environmental variables were interpreted together on Axis 1, it was understood to have a positive correlation with *Cirsium arvense* subsp. *vestitum*, *Euphorbia* sp., *Populus tremula*, *Thymus samius*.

At the next stage, the location of the groups identified at the Euclidean-Ward's 4 Groups separation stage in the clustering analysis according to the results of the grouping analyses was transferred to the Axis 1-2 identified in the correspondence analysis (*Fig. 2*).

The detrended correspondence analysis (DCA) was another ranking-association analysis applied in the study. With this analysis, 3 axis were identified, which were Axis 1 (0.339; 3.155), Axis 2 (0.234; 2.567) and Axis 3 (0.182; 2.193) according to their Eigenvalue coefficients and variance explanation power. Axis 2 had the highest Eigenvalue coefficient and variance explanation power. Therefore, it was decided to include only the Axis 1 in the analysis. The location of the sampling plots on Axis 1-2 is shown in *Fig. 3*.

The correlation coefficients of the relationships between Axis 1-2 and the plant species in the vegetation data matrix were found to be *Cirsium arvense* subsp. *vestitum* (0.531), *Euphorbia* sp. (0.678), *Juniperus excelsa* (0.508), *Populus tremula* (-0.562) and *Thymus samius* (0.552) while the plant species had the highest correlation with Axis 1.

As regards the correlation coefficients of the environmental variables according to the association between the axis and environmental data matrix; SURSTON (0.375) were found to be the environmental factor that had the highest correlation with the axis while it had a positive correlation with Axis 1. The location of the statistically significant environmental variables on the axis is shown in *Fig. 3*.

When the results relating to the vegetation data matrix and those of the environmental variables were interpreted together on Axis 1, it was understood that there was a positive correlation with *Cirsium arvense* subsp. *vestitum*, *Euphorbia* sp., *Juniperus excelsa*, *Populus tremula* and *Thymus samius*.

At the next stage, the location of the groups identified at the Euclidean-Ward's 4 Groups separation stage in the clustering analysis according to the results of the grouping analyses was transferred to the Axis 1-2 identified in the correspondence analysis (*Fig. 3*).

The canonical correspondence analysis (CCA) was another analysis applied in the study. With this analysis, 3 axes were identified, which were Axis 1 (0.179; 4.7), Axis 2 (0.151; 4), Axis 3 (0.118; 2.9) according to their Eigenvalue coefficients and variance explanation power. This indicates that Axis 1 had the highest Eigenvalue coefficient and variance explanation power. Therefore, it was decided to include only the Axis 1 in the analysis. The location of the sampling plots on Axis 1-2 is shown in *Fig. 4*.

The correlation coefficients of the relationships between Axis 1-2 and the plant species in the vegetation data matrix were found to be *Cistus laurifolius* (-0.557), *Cirsium arvense* subsp. *vestitum* (0.501), *Euphorbia* sp. (0.609), *Laurus nobilis* (0.540) and *Thymus samius* (0.549) while the plant species had the highest correlation with Axis 1.

As regards the correlation coefficients of the environmental variables according to the association between the axis and environmental data matrix; SURSTON (0.477) and BIO12 (0.393) were found to be the environmental factor that had the highest correlation

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with the axis while they had a positive correlation with Axis 1. The location of the statistically significant environmental variables on the axis is shown in *Fig. 4*.

When the results relating to the vegetation data matrix and those of the environmental variables were interpreted together on Axis 1, it was understood that there was a positive correlation with *Cistus laurifolius*, *Cirsium arvense* subsp. *vestitum*, *Laurus nobilis*, *Thymus samius*, *Euphorbia* sp., SURSTON and BIO12.

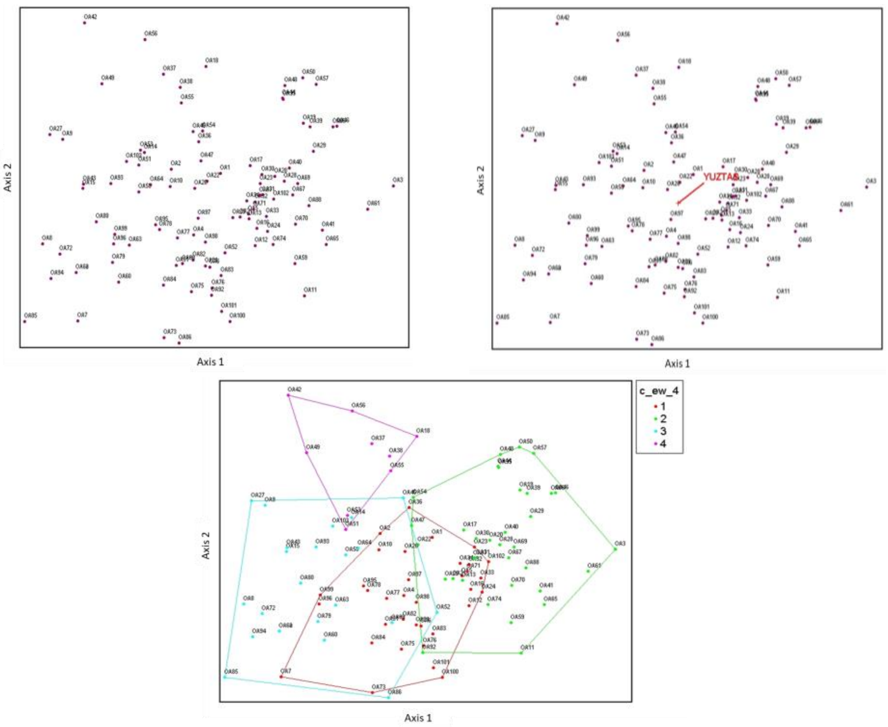

Figure 3. *Location of sampling plots on Axis 1-2 according to the detrended correspondence analysis, location of environmental variables and Euclidean-Ward's 4 groups according to the clustering analysis*

At the next stage, the location of the groups identified at the Euclidean-Ward's 4 Groups separation stage in the clustering analysis according to the results of the grouping analyses was transferred to the Axis 1-2 identified in the correspondence analysis (*Fig. 4*).

The relationships between the results of these analyses (ordination axis values of sampling plots) and habitat characteristics were tested with the Pearson correlation analysis. The results of the ordination analysis were similar concerning the statistical significance of the environmental variables. The structured groups were transferred to the graphical result of each ordination analysis and the conformity of the sampling plots with their respective groups was tested in their distribution in the ordination axis.

The results of DCA, one of the ordination methods applied, demonstrated that four groups identified in the clustering analysis were more clearly separated compared to the other ordination methods (CA, CCA) to explain the vegetation-environment relationships in Yenişarbademli.

DCA results also showed that SURSTON had the highest positive correlation with especially Axis 1 regarding the location of the sampling plots. Similarly, SURSTON was the environmental variable that had the strongest positive relationship also in RA and

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CCA. Several studies conducted in the Mediterranean region found that elevation was the most important habitat factor that had an impact on the vegetation distribution (Fontaine et al., 2007; Özkan et al., 2009; Şentürk et al., 2013). The reason why SURSTON was found to be the most important variable in this study was that the areas with high surface stoniness were located in the southeast part of the study site as in the Spearman rank analysis and multiple regression analysis and thus the duration of sunlight in these areas was higher than the other locations.

As regards the CCA process, the relationships between the environmental variables demonstrate that SURSTON, BIO4, BIO12 had high relationships with one another. Therefore, the distribution of vegetation was denser especially in the southeast locations with high surface stoniness as the annual precipitation and seasonal temperature in the region increased.

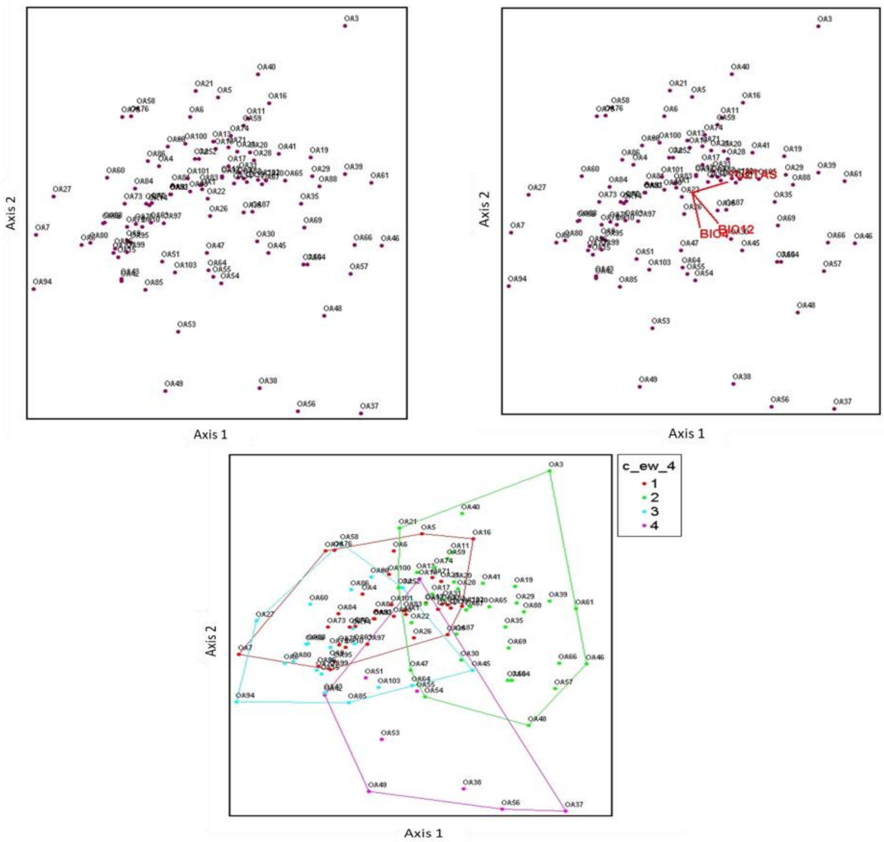

Figure 4. *Location of sampling plots on Axis 1-2 according to the canonical correspondence analysis, location of environmental variables and Euclidean-Ward's 4 groups according to the clustering analysis*

Conclusions

In summary, this study demonstrated that the sampling plots had a higher alpha diversity when the elevation variability was lower and surface stoniness variability was higher. It was also found that the distribution of vegetation was denser in areas where the seasonal temperature and annual precipitation were higher.

The study area was mountainous and carstic, which played a significant role in these findings. This information is also important to determine the areas with high potential for

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the components of species diversity. The Lakes Region was one of the oldest settlements in Yenişarbademli while the ecosystem had been destroyed by people for a long time (Vanhaverbeke and Waelkens, 2003; Karaca, 2005; Özkan et al., 2010). Most of the forests have been degraded due to the destruction; therefore, it is important to understand/predict the potential of especially the destroyed areas with the help of the actual information.

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