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VEGETATION-ENVIRONMENT RELATIONSHIPS IN THE AKDAĞ (BURDUR) REGION

ODNOSI VEGETACIJE I OKOLIŠA U REGIJI AKDAĞ (BURDUR)

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SUMMARY

In this study, the distribution of woody vegetation and the characteristics of the growing environment in the Akdağ (Burdur) region were determined, and forest site classification was established. Fieldwork was conducted on 85 sample plots, and 65 woody plant species were identified. Species with a frequency value below 5% in the vegetation data matrix were excluded and 56 species were included in the analysis. Additionally, environmental variables for each sample plot were obtained. Vegetation groups were obtained through clustering and two-way indicator species analysis methods during the vegetation classification stage. Subsequently, the most suitable discriminating group was identified using the multiple response permutation procedure (MRPP). It was observed that the clustering analysis based on Jaccard-Ward's method yielded the most suitable discriminating group. Furthermore, positive and negative indicator species were identified through indicator species analysis. Spearman correlation analysis between the best discriminating group and environmental variables revealed that elevation, temperature index, and solar radiation index variables exhibited a positive relationship, while parent material, Bio1 and Bio15 variables showed a negative relationship. Similar results were obtained in canonical correspondence analysis (CCA) applied to interpret the relationships obtained through correlation analysis using ordination methods. According to CCA, elevation was positively associated with plant distributions and vegetation groups, while Bio1 and Bio15 variables were negatively associated.

KEY WORDS: woody vegetation, forest site classification, Akdağ region, elevation

INTRODUCTION
UVOD

Forests are ecosystems formed by the coming together of living and non-living organisms such as trees, fungi, shrubs, mosses, wildlife, and insects, which cover vast areas in nature with their unique density and closeness (Aytuğ, 1976). Due to the longevity of the plant and wildlife species constantly interacting in this ecosystem, forests constitute the most resilient and complex ecosystems (Iqbal, 1993; Ticktin, 2004; Acarer, 2024). In addition to their distinctive functional and operational characteristics, forests also possess significant economic potential. This potential arises from the presence of numerous non-timber forest products within them. Cones, fruits, flowers, roots, leaves, barks, seeds, rubber, and resins, among many other forest products, constitute an important component of forest resources due to their economic value and contributions to various industries (Negiz et al., 2024).

In general, for the continued existence and sustainable utilization of the existing forested areas, it is necessary to establish the relationships among the factors constituting the forest ecosystem (Atalay, 1987; Baskent et al., 2005). In this context, inventory studies in forest ecosystems or the correlation of ecological factors with vegetation communities based on information about flora are conducted through various methods (Fontaine et al., 2007; Özkan and Gülsoy,

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2010). Flora elements are one of the fundamental components within the ecosystem integrity of forests. Generally, vegetation can be defined as units with similar habitat characteristics without being subject to systematic classification, or in other words, plant species found in a country or region (Çepel, 1982; 1985). In short, vegetation refers to plant communities formed ecologically and physiologically.

The classification of vegetation is carried out based on various criteria, such as plant species, plant form, plant density, leaf shedding and plant size. In order to classify vegetation correctly, it is necessary to conduct a proper and successful inventory process in the study (Grossman et al., 1998). Ecological factors used in studies aimed at vegetation classification include location, climate, landform, parent rock vegetation and soil (Kantarcı, 1978). Plant vegetation alone cannot be considered an indicator of ecological factors (Westman, 1981; Bailey and Hong, 1986). In many scientific studies, elevation, slope and aspect have been identified as the most effective ecological factors among the habitat characteristics, while particularly elevation has been emphasized due to climate change (Ayberk, 1982; Kantarcı, 1991; Acar et al., 2001; Karatepe, 2005; Özkan and Kantarcı, 2008; Negiz and Erfidan, 2023).

In this study, factors affecting the distribution, growth of plant species and the most suitable growing conditions for each species have been determined. The information obtained from the study will facilitate more effective and informed decision-making in forestry practices, assisting in the selection of species and origins during planting (Eser, 2014). Through vegetation classification, it becomes possible to conduct regional and local species inventories, determine species distribution and compile inventories of forest resources. Additionally, the distribution of rare, economically valuable, indicator and distinctive species, as well as endemic species, is determined through vegetation classifications. Therefore, the accuracy of habitat classification relies on vegetation classification and vegetation analyses (Özkan, 2002, 2003). In current conditions, it is anticipated that forestry activities planned without considering vegetation-environment relationships will lead to the inability to meet future demands for forest products, and even if met, they may not be increased. Moreover, it is predicted that the desired benefits from forest functions (such as ecotourism and recreation, nature conservation, hydrological, aesthetic and forest product production) cannot be achieved (Sevim, 1962; Günay, 1993; Çolak and Pitterle, 1999; Bakkaloğlu, 2003; Başkent et al., 2005; Karatepe and Gürlevik, 2005; Altun et al., 2008; Günlü et al., 2009). Following vegetation classification and the consequent forest site classification, data obtained from various disciplines, such as ecosystem planning and sustainability, as well as determination and conservation of biological diversity, become crucial for forestry. These data, derived from different disciplines, are utilized to support and enhance ecosystem management strategies and healthy functioning through interdisciplinary collaboration (Hepdeniz, 2007; Negiz, 2009).

The aim of this study conducted in the Akdağ region of the Burdur province is primarily to identify woody plant species and determine the relationships between these species and environmental factors, thereby classifying the habitat of the area based on these relationships. The goal of this study is to contribute to the conservation and sustainability of natural ecosystems by establishing a classification of habitats.

METHODS
METODE

Study area – *Područje istraživanja*

This study is located between the boundaries of Isparta Regional Directorate of Forestry, Ağlasun Forestry Management Chiefdom and Çukur Forestry Management Chiefdom. The study area, covering approximately 5917 ha, is situated between the north latitudes of 37° 37' 01" and 37° 40' 41' and the east longitudes of 30° 48' 23" and 30° 35' 57". The place where the Isparta Stream flows within the study area represents the lowest (403 m) elevation, while the Kapıkaya peak represents the highest (1734 m) elevation region (Figure 1).

Although the study area comprises a diverse range of rock formations, the majority are composed of limestone (Hacısalihoğlu et al., 2010). Additionally, the soil structure in the study area generally consists of calcareous soils (CSB, 2011; Ceylan, 2015). Eleven different types of rock formations have been identified within the study boundaries: alluvium, old alluvium, sandstone-mudstone, sandstone-mudstone-limestone, mélanges, olistostromes, trachybasalt, volcanics, sedimentary rocks, slope debris-cone accumulations and gravel. Within the boundaries of the Ağlasun Forestry Management Chiefdom, 52% of the study area is covered by forests consisting mainly of pine species, predominantly *Pinus brutia* Ten. (19500 ha), *Pinus nigra* Arn. (2500 ha), *Quercus coccifera* L. (11000 ha) and *Juniperus* spp. (6000 ha). Additionally, approximately 900 ha are covered by *Cedrus libani* A. Rich. species.

Analysis of long-term average temperatures collected from stations shows variations around Burdur/Merkez (13.5°C), Tefenni (11.6°C), and Kemer (12.1°C). When examining total average rainfall for long-term periods, December for Burdur and January for Tefenni and Kemer were identified as the wettest months (Burdur/Centre 432 mm, Tefenni 377 mm, Kemer 593 mm).

Data collection – *Prikupljanje podataka*

Field studies were conducted in 85 sample areas with dimensions of 20x20 m (400 m^2) (Fontaine et al., 2007; Özkan,

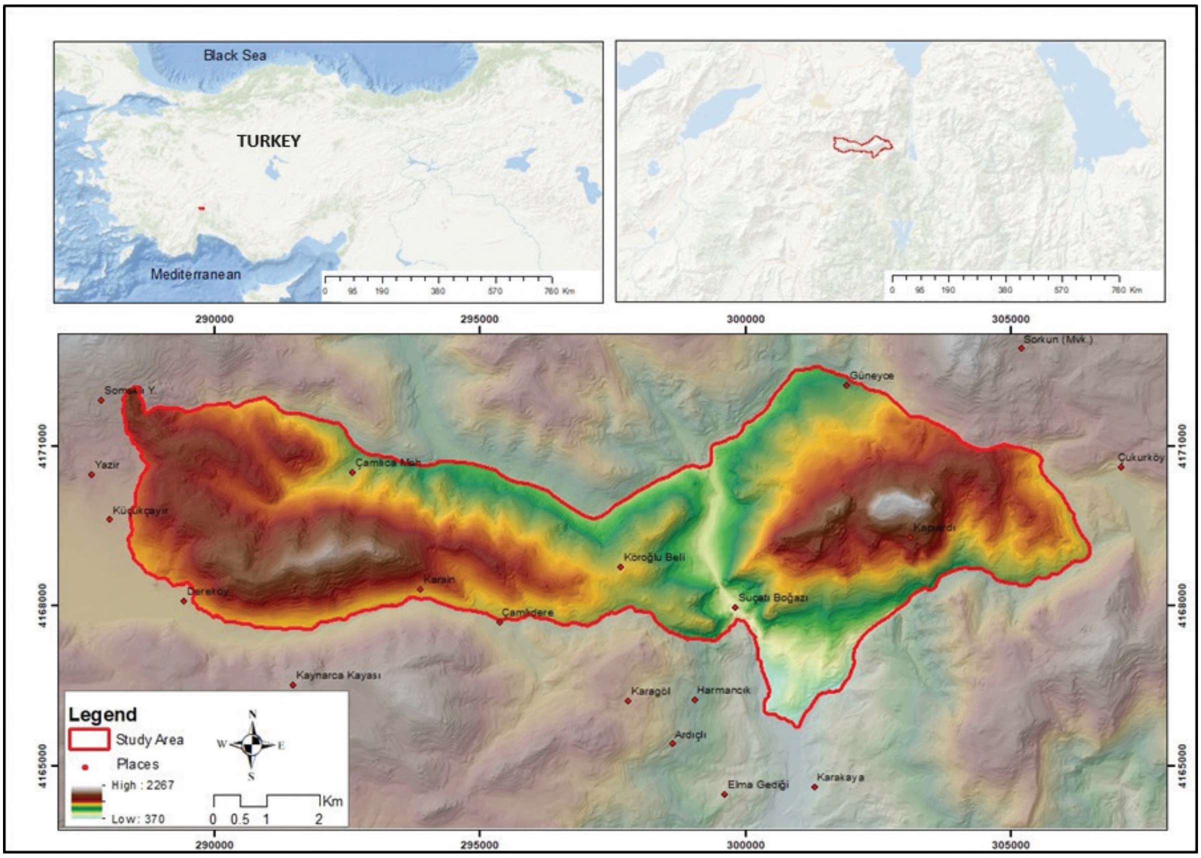

Figure 1. Location map of the study area in the Akdağ region
Slika 1. Karta područja istraživanja u regiji Akdağ

2009; Özkan and Negiz, 2011; Güner et al., 2011). Using Global Positioning System (GPS), the latitude, longitude, and elevation of the sample areas were determined. Additionally, based on field observations, slope position (base terrain, lower slope, lower midslope, upper midslope, upper slope and ridge), land surface shape (flat, concave, convex, undulating) and land surface form (flat soil surface, rocky terrain) data were recorded (Çepel, 1995). Woody plants were identified in each sample area, and the data were processed according to the Braun-Blanquet method using previously prepared inventory sheets (r, +, 1, 2, 3, 4, 5) (Braun-Blanquet, 1932). The measurements conducted in the field

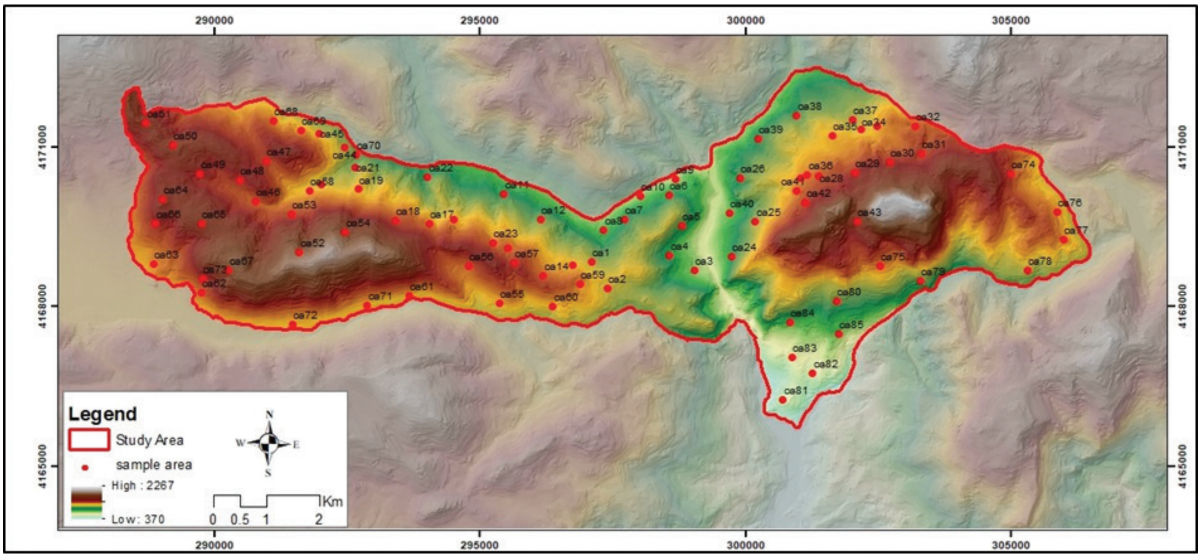

Figure 2. Locations of sample areas in the Akdağ region
Slika 2. Lokacije uzorkovanih područja u regiji Akdağ

were stored in Microsoft Office Excel format to be correlated with the distribution of target species in the study area. The positions of the sample areas within the study area boundaries are shown in Figure 2.

Statistical evaluation – *Statistička analiza*

The data obtained from woody plant species in the field, along with environmental variables, were processed in the Microsoft Office Excel program to make them statistically ready for analysis. The data matrix for woody plant species was prepared in a presence/absence format (Fontaine et al., 2007; Özkan, 2009; Negiz, 2009). The dataset for plant species was evaluated using clustering and two-way indicator species analysis to obtain vegetation classifications. In this study, two clustering analyses (Euclidean-Ward's and Jaccard-Ward's) were conducted based on Euclidean and Jaccard distance measurements (McCune and Grace, 2002; Negiz, 2009; Yatman, 2022). Cut-off levels were determined as suggested by Özkan and Negiz (2009) for clustering analysis. Additionally, four different two-way indicator species analyses were conducted from a single indicator level to four indicator levels, following the recommendation by Hill (1979). Thus, a total of six analyses were performed for vegetation classification and the resulting subgroups were saved in a Microsoft Office Excel file.

All obtained subgroups were subjected to the multiple response permutation procedures (MRPP) test, as performed by Fontaine et al. (2007) and Negiz (2009), to determine the significance of differences between groups and within-group homogeneity. The method, cut-off level, and vegetation classification determined to be most suitable by MRPP analysis were accepted. The indicator species for the best group differentiation in vegetation classification were determined through indicator species analysis (Özkan, 2002; Özkan, 2006; Çelik et al., 2006; Negiz, 2009; Gülsoy et al., 2013; Özdemir et al., 2014).

Then, environmental variables were created using ArcMap software. Elevation layer was downloaded from Earth Explorer database at 30 m resolution. Radiation index, heat index, topographic position index, topographic humidity index, solar radiation index, solar illumination index, hillshade index, landform position index and slope variables were produced using elevation. Bioclimatic variables were downloaded from the worldclim database at a resolution of 30 arc seconds (~1 km). Finally, each sample area was applied to the obtained digital maps and the values corresponding to the sample areas were determined (Özdemir and Özkan, 2016; Acarer, 2024).

To minimize potential issues of multicollinearity between climate and other environmental variables, factor analysis was applied to 19 bioclimate variables (Özdamar, 2004). Subsequently, Spearman correlation analysis was used to explore the relationships between the selected best group distinction in vegetation classification and environmental characteristics (Spearman, 1904). Following factor analysis, climate variables deemed relevant and showing high correlation with environmental variables through Spearman correlation analysis (a total of 17 variables), along with the data matrix consisting of woody plant species, were transferred to ordination methods. This facilitated the visualization of relationships between vegetation and environmental characteristics.

At this stage, canonical correspondence analysis (CCA) was applied, working with both vegetation and environmental data matrices (Braak, 1986; Ulusan, 2016; Negiz and Kurt, 2017).

Statistical analyses were conducted using the SPSS, PC-ORD, and CAP package programs (SPSS, 2004; McCune and Mefford, 2011).

RESULTS
REZULTATI

During the field inventory stage, a total of 65 woody plant species (in tree and shrub forms) were recorded across 85 different sample areas. It was observed that the occurrence rates (%) of nine of these woody plant species fell below the 5% frequency threshold in the sample areas. Consequently, these species were excluded from the vegetation data matrix in the statistical analysis stages due to their low representation levels. Therefore, analyses were conducted on 85 sample areas and 56 woody plant species.

In the clustering analysis applied to the vegetation data matrix using two different distance measurements (Euclidean-Ward's and Jaccard-Ward's), vegetation groups were identified at 8 different cutting levels, including 2, 3, 4, and 5. Through the clustering analysis and two-way indicator species analysis, a total of 16 different cutting levels were determined. In the clustering analysis conducted according to Euclidean- Ward's method, for the first cutting level, referred to as the 2-way separation (Group 2a), 41 sample areas were separated in the first group and 44 in the second group. Similarly, in the 3-way separation (Group 3a) of the same method, the first group of the cutting level consisted of the same sample areas as the first group in the previous cutting level. Therefore, the number of sample areas in the first group of the 3-way separation remained 41, while in the second group, there were 30, and in the third group, there were 14. For the 4-way separation (Group 4a) of the clustering analysis, the first group consisted of 20 sample areas, the second group of 21, the third group of 26 and the fourth group of 7 sample areas. In the 5-way separation (Group 5a), the first group comprised 20 sample areas, the second group 21, the third group 25, the fourth group 5 and the final group consisted of 14 sample areas.

In the clustering analysis conducted according to Jaccard-Ward's method, for the first cutting level, referred to as the 2-way separation (Group 2j), 41 sample areas were allocated to the first group and 44 to the second group. Similarly, in the 3-way separation (Group 3j) of the same method, the first group consisted of 40 sample areas, the second group of 30, and the third group contained 15 sample areas. For the 4-way separation (Group4j) of the clustering analysis, the first group consisted of 20 sample areas, the second group of 21, the third group of 26 and the fourth group of 7 sample areas. In the 5-way separation (Group 5j), the first group comprised 20 sample areas, the second group 21, the third group 25, the fourth group 5 and the final group consisted of 14 sample areas.

As mentioned earlier, a total of four two-way indicator species analyses were applied to the vegetation data matrix as suggested by Hill (1979), ranging from a single indicator level to four indicator levels. Similar to the clustering analysis, in the two-way indicator species analysis, group differentiations were obtained from two different cutting levels: 2-way and 4-way. Thus, vegetation groups were separated based on sample areas at a total of 8 cutting levels for the two-way indicator species analysis. In the single-indicator application of the two-way indicator species analysis, the 2-way separation resulted in 27 sample areas in the first group and 58 in the other group. At the next separation level, a 4-way group separation occurred. In this separation, the first group consisted of 15 sample areas, the second group of 12, the third group contained 36, and the fourth and final group included 22 sample areas. In the two-indicator application of the two-way indicator species analysis, both 2-way and 4-way group separations were observed. At the 2-way separation, the first group comprised 27 sample areas, while the other group had 58 sample areas. For the 4-way separation with two indicators, the first group contained 15 sample areas, the second group 12, the third group 36 and the fourth group 22 sample areas.

In the three-indicator application of Twinspan analysis, two different separation levels were determined: one with single and two indicators, resulting in two 2-way and 4-way separations. At the first separation level of the 2-way separation, the first group comprised 27 sample areas, while the other group had 58 sample areas. For the 4-way separation, the first group contained 14 sample areas, the second group 12, the third group 39 and the fourth group 20 sample areas. In the four-indicator two-way indicator species analysis, at the first separation level of the 2-way separation, the first group consisted of 35 sample areas, while the other group had 50 sample areas. For the 4-way separation, the first group contained 18 sample areas, the second group 17, the third group 30 and the fourth group 20 sample areas.

Table 1. MRPP Analysis Results: T, A, and P-values (expected delta: 3.5708374)

Tablica 1. Rezultati MRPP analize: T, A i P vrijednosti (očekivana delta: 3,5708374)

Group Discrimination *Grupna diskriminacija*	T	A	P
Kgroups2a	-16.317	0.025	0.000
Kgroups3a	-18.320	0.041	0.000
Kgroups4a	-21.387	0.058	0.000
Kgroups5a	-21.873	0.071	0.000
Kgroups2j	-18.868	0.029	0.000
Kgroups3j	-20.466	0.046	0.000
Kgroups4j	-23.554	0.065	0.000
Kgroups5j	-24.367	0.080	0.000
Tgroups2one	-18.567	0.029	0.000
Tgroups4one	-19.894	0.055	0.000
Tgroups2two	-16.718	0.026	0.000
Tgroups4two	-19.894	0.055	0.000
Tgroups2 three	-18.567	0.029	0.000
Tgroups4 three	-18.941	0.052	0.000
Tgroups2 four	-20.349	0.031	0.000
Tgroups4 four	-21.817	0.060	0.000

To determine the most suitable group differentiation among the total of 16 group differentiations resulting from clustering and two-way indicator species analyses in the vegetation classification stage and thus identify the most appropriate analysis method, the multiple response permutation procedures (MRPP) test was applied. The results of the MRPP analysis are shown in Table 1. In the MRPP analysis, the T-values represent inter-group distance, while the A-values represent within-group distance. In the selection process of the most suitable group differentiation and analysis method based on MRPP analysis, it would be appropriate to choose the analysis method and group differentiation where the T-value is the smallest and the A-value is the largest. For the different differentiations calculated at 16 cutting levels, the T-values range from -16.32 to -24.37, while the A-values range from 0.026 to 0.081.

In light of the explanations provided, it has been observed that the T and A-values of the groups obtained through MRPP analysis were evaluated on tables and figures. When evaluated, clustering analysis applied using Jaccard-Ward's method for 5-group differentiation indicated better results. Therefore, it was decided to focus on the 5-group differentiation applied by clustering analysis using the Jaccard-Ward's method in the vegetation classification stage, and ecological interpretations were made at this level (Figure 3).

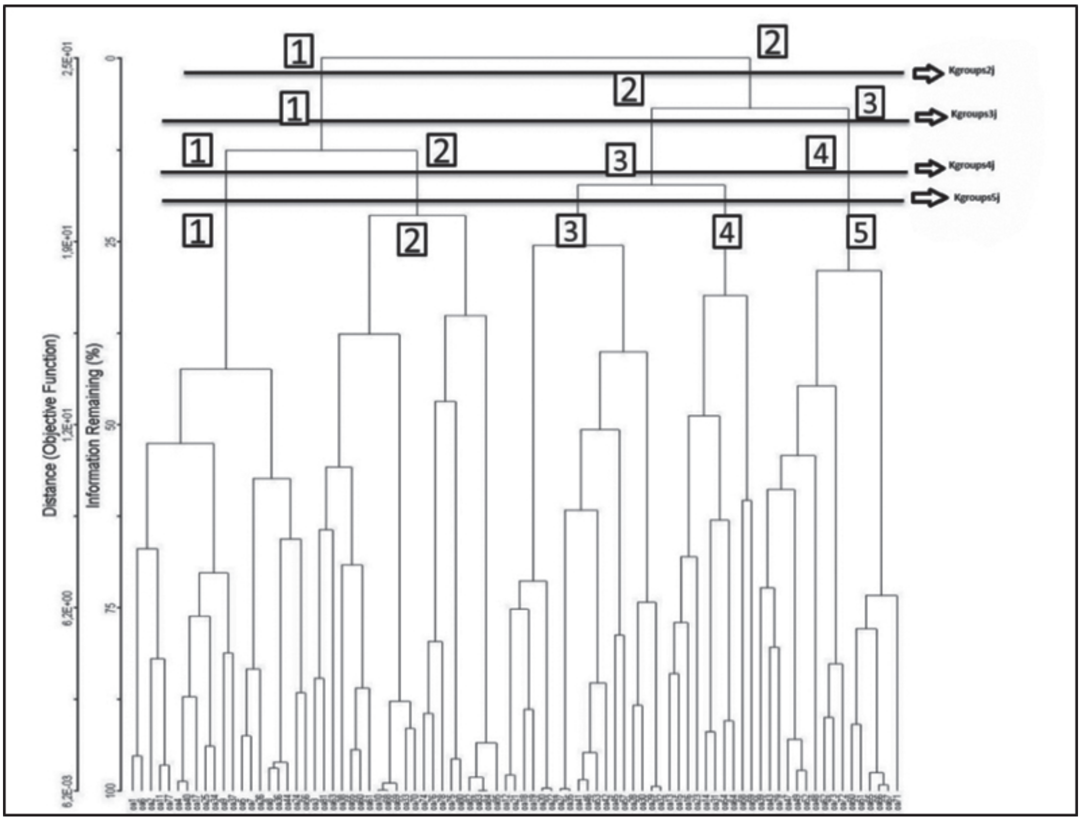

Figure 3. Group differentiation of clustering analysis according to the Jaccard-Ward's method, Kgroup5j
Slika 3. Grupna diferencijacija analize klasteriranja prema Jaccard-Wardovoj metodi, Kgroup5j

Following the classification of plant communities, the relationships between vegetation groups and vegetation data with other environmental variables were established. The correlation phase will allow for an ecological interpretation of the forest-growing environment classification of the study area. However, before proceeding to the correlation phase, a preliminary process is required to select the most suitable environmental variables. This is because environmental variables, especially climate variables, evaluated among them, can exhibit very high correlations (Negiz, 2013; Eser, 2014). In particular, significant relationships can be detected between precipitation and temperature variables and dependent variables of plant communities. Selecting the most suitable climate variables among the environmental variables will minimize problems such as multicollinearity, which may arise in subsequent statistical evaluations. Based on these explanations, the results of the factor analysis applied to determine representative climate variables are shown in Table 2.

As seen in Table 2, as a result of factor analysis, more than one component with a variance greater than 1 has emerged. Here, the contribution rate to the variance of the first component is 66.573%, the second component is 22.338%, and the third component is 8.820%. Statistically, it is expected that the contribution rate of components with a variance greater than 1 should be more than 10%. However, in the factor analysis applied to climate variables relevant to our study area, although the variance of the last component is greater than 1, the contribution rate to the variance is less than 10%. Nevertheless, the coefficient values for these three components are provided in Table 3 to determine the representative climate variable. The variables Bio15 and Bio1 with the highest coefficients of 0.990 and 0.989 in the first component have been identi-

Table 2. Variance and variance contribution (%) values of the factor analysis applied for the reduction of climate variables
Tablica 2. Vrijednosti varijance i doprinosa varijance (%) faktorske analize primijenjene za smanjenje klimatskih varijabli

Components *Komponente*	Variance *Varijanca*	Variance % *Varijanca %*	Cumulative Variance % *Kumulativna varijanca %*
1	**12.649**	**66.573**	**66.573**
2	**4.244**	**22.338**	**88.911**
3	1.676	8.820	97.731

Table 3. Component coefficients of climate variables from factor analysis
Tablica 3. Koeficijenti komponenti klimatskih varijabli iz faktorske analize

Longname *Puno ime*	Shortname *Skraćeno ime*	Unit *Jedinica*	1st Component *1. komponenta*	2nd Component *2. komponenta*
Mean diurnal air temperature – *Srednja dnevna temperatura zraka*	**Bio1**	°C	**0.989**	0.305
Mean annual air temperature range – *Raspon srednje godišnje temperature zraka*	Bio2	°C	–0.367	0.734
Isothermality – *Izotermnost*	Bio3	°C	–0.065	0.701
Temperature seasonality – *Sezonalnost temperature*	Bio4		–0.800	0.428
Mean daily maximum air temperature of the warmest month – *Srednja maksimalna dnevna temperatura zraka najtoplijeg mjeseca*	Bio5	°C/100	0.873	0.480
Mean daily minimum air temperature of the coldest month – *Srednja minimalna dnevna temperatura zraka najhladnijeg mjeseca*	Bio6	°C	0.967	0.233
Annual range of temperature – *Godišnji raspon temperature*	Bio7	°C	–0.648	0.665
Mean daily air temperature of the wettest quarter – *Srednja dnevna temperatura zraka najvlažnijeg tromjesečja*	Bio8	°C	0.963	0.259
Mean daily air temperature of the driest quarter – *Srednja dnevna temperatura zraka najsušeg tromjesečja*	Bio9	°C	0.939	0.334
Mean daily air temperature of the warmest quarter – *Srednja dnevna temperatura zraka najtoplijeg tromjesečja*	Bio10	°C	0.932	0.354
Mean daily air temperature of the coldest quarter – *Srednja dnevna temperatura zraka najhladnijeg tromjesečja*	Bio11	°C	0.963	0.259
Annual precipitation amount – *Godišnja količina padalina*	**Bio12**	Kg m^{-2} $year^{-1}$	0.155	**–0.866**
Precipitation amount of the wettest month – *Količina padalina najkišovitijeg mjeseca*	Bio13	Kg m^{-2} $month^{-1}$	0.809	–0.520
Precipitation amount of the driest month – *Količina padalina najsušeg mjeseca*	Bio14	Kg m^{-2} $month^{-1}$	–0.860	0.069
Precipitation seasonality – *Sezonalnost padalina*	**Bio15**	Kg m^{-2} $month^{-1}$	**0.990**	–0.083
Mean monthly precipitation amount of the wettest quarter – *Srednja mjesečna količina padalina najvlažnijeg tromjesečja*	Bio16	Kg m^{-2} $month^{-1}$	0.787	–0.547
Mean monthly precipitation amount of the driest quarter – *Srednja mjesečna količina padalina najsušeg tromjesečja*	Bio17	Kg m^{-2} $month^{-1}$	–0.843	–0.363
Mean monthly precipitation amount of the warmest quarter – *Srednja mjesečna količina padalina najtoplijeg tromjesečja*	Bio18	Kg m^{-2} $month^{-1}$	–0.949	–0.278
Mean monthly precipitation amount of the coldest quarter – *Srednja mjesečna količina padalina najhladnijeg tromjesečja*	Bio19	Kg m^{-2} $month^{-1}$	0.787	–0.547

Table 4. Results of Spearman correlation analysis between Kgroup5j and environmental variables
Tablica 4. Rezultati Spearmanove korelacijske analize između Kgroup5j i okolišnih varijabli

Environmental Variable – *Okolišna varijabl*	R	P	Environmental Variable – *Okolišna varijabla*	R	P
Bedrock – *Osnovna stijena*	**–0.342****	**0.001**	Landform position index – *Indeks položaja reljefa*	0.203	0.063
Radiation index – *Indeks zračenja*	0.157	0.151	Hillshade index – *Indeks sjene*	–0.189	0.083
Heat index – *Indeks topline*	**0.229***	**0.035**	Aspect – *Orijentacija*	–0.065	0.553
Elevation – *Nadmorska visina*	**0.593****	**0.000**	Solar illumination index – *Indeks sunčeve svjetlosti*	–0.066	0.546
Topographic position index – *Indeks topografskog položaja*	**0.306****	**0.004**	**Bio1**	**–0.641****	**0.000**
Topographic humidity index – *Indeks topografske vlažnosti*	–0.167	0.127	Bio12	0.158	0.148
Solar radiation index – *Indeks sunčevog zračenja*	**0.246***	**0.023**	**Bio15**	**–0.583****	**0.000**
Slope – *Nagib*	–0.059	0.590			

r: Correlation coefficient, p: Significance level, *0.01>p>0.05, **0.01>p

Table 5. Eigenvalue coefficients of canonical correspondence analysis axes
Tablica 5. Koeficijenti svojstvenih vrijednosti osi u kanoničkoj analizi korespondencije

Axis *Os*	Eigenvalue Coefficients *Koeficijenti svojstvenih vrijednosti*
1st axis - *1. os*	0.426
2nd axis - 2. *os*	0.362
3rd axis - *3. os*	0.196

fied as representative climate variables. It is observed that selecting the Bio12 variable with a coefficient of -0.866 in the component matrix table is appropriate for the second component. It has been decided that there is no need to use other climate variables for the selection of annual average temperature (Bio1), total annual rainfall (Bio12) and seasonal rainfall (Bio15) variables for use in the correlation stage.

In the vegetation classification section, the results of the Spearman correlation analysis applied between the environmental variables and the best group differentiation identified as Kgroup5j are presented in Table 4. Here, it was determined that there is a positive relationship between Kgroup5j and Si, Slope, Tpi and Sri variables, while there is a negative relationship with Aspect, Bio1 and Bio15 variables.

Canonical correspondence analysis (CCA) involves the simultaneous evaluation of vegetation and environmental data matrices. Three axes are determined in this analysis and the eigenvalue coefficients of these axes are provided in Table 5. As shown in Table 5, the eigenvalue coefficient of the 1st axis is higher than that of the 2nd and 3rd axes. Therefore, it would be more appropriate to base evaluations on the 1st axis. However, since the graphical interpretation of the analysis results is presented on a graph with two axes, the resulting graph is displayed on the 1st and 2nd axes. The locations of the 85 sample sites according to the CCA analysis are provided in Figure 4.

The correlation coefficients of environmental variables with respect to the axes obtained from canonical correspondence analysis are presented in Table 6, while their representation on the axes is shown in Figure 5. It was found that the variables Bio1 and Bio15 exhibited significant positive correlations, whereas elevation and shadowing index variables showed significant negative correlations.

Figure 4. Species distribution on axes (1-2) according to CCA analysis of sample areas
Slika 4. Raspodjela vrsta na osi (1-2) prema CCA analizi uzorkovanih ploha

Table 6 Correlation coefficients of environmental variables with respect to the axes in CCA analysis
Tablica 6. Koeficijenti korelacije okolišnih varijabli s obzirom na osi u CCA analizi

Environmental Variables *Okolišne varijable*	1st axis *1. os*	2nd axis *2. os*
	R	r
Bedrock – *Osnovna stijena*	0.150	0.485
Radiation index – *Indeks zračenja*	0.423	–0.379
Heat index – *Indeks topline*	0.368	–0.135
Elevation – *Nadmorska visina*	–0.537	–0.787
Topographic position index – *Indeks topografskog položaja*	–0.448	–0.306
Topographic humidity index – *Indeks topografske vlažnosti*	0.028	0.177
Solar radiation index – *Indeks sunčevog zračenja*	0.408	**–0.472**
Slope – *Nagib*	0.012	0.101
Landform position index – *Indeks položaja reljefa*	0.029	–0.338
Hillshade – *Sjena*	**–0.528**	0.170
Aspect suitability index – *Indeks prikladnosti orijentacije*	0.066	0.165
Solar illumination index – *Indeks sunčeve svjetlosti*	0.022	0.039
Bio1	**0.583**	**0.743**
Bio12	0.396	**–0.485**
Bio15	**0.679**	**0.589**

DISCUSSION AND CONCLUSIONS
RASPRAVA I ZAKLJUČCI

There are almost no natural forests in the world that are not affected by anthropogenic activities. It is evident that areas with natural characteristics and intact genetic structures harbor significantly more biodiversity and provide habitat for a greater variety of species compared to areas affected by human intervention (Ticktin, 2004; Negiz, 2013; Yatman, 2022). Additionally, it is known that undisturbed natural areas host a higher abundance of species classified as relicts, rare, and endemic species (Dublin et al., 2004). Given the negative impacts caused by global climate change, rapid population growth, and human-induced disturbances, as mentioned above, the importance of maintaining natural forests has become increasingly recognized. Therefore, there is a growing need for studies that examine the relationships between vegetation, flora-related data, and habitat characteristics, especially in natural forest areas and protected areas, with the aim of mitigating or minimizing the adverse effects mentioned (Guisan and Theurillat, 2000). It is crucial to adhere to the principle of sustainability during the implementation of ecosystem-based multipurpose planning activities in natural and protected forest areas. Therefore,

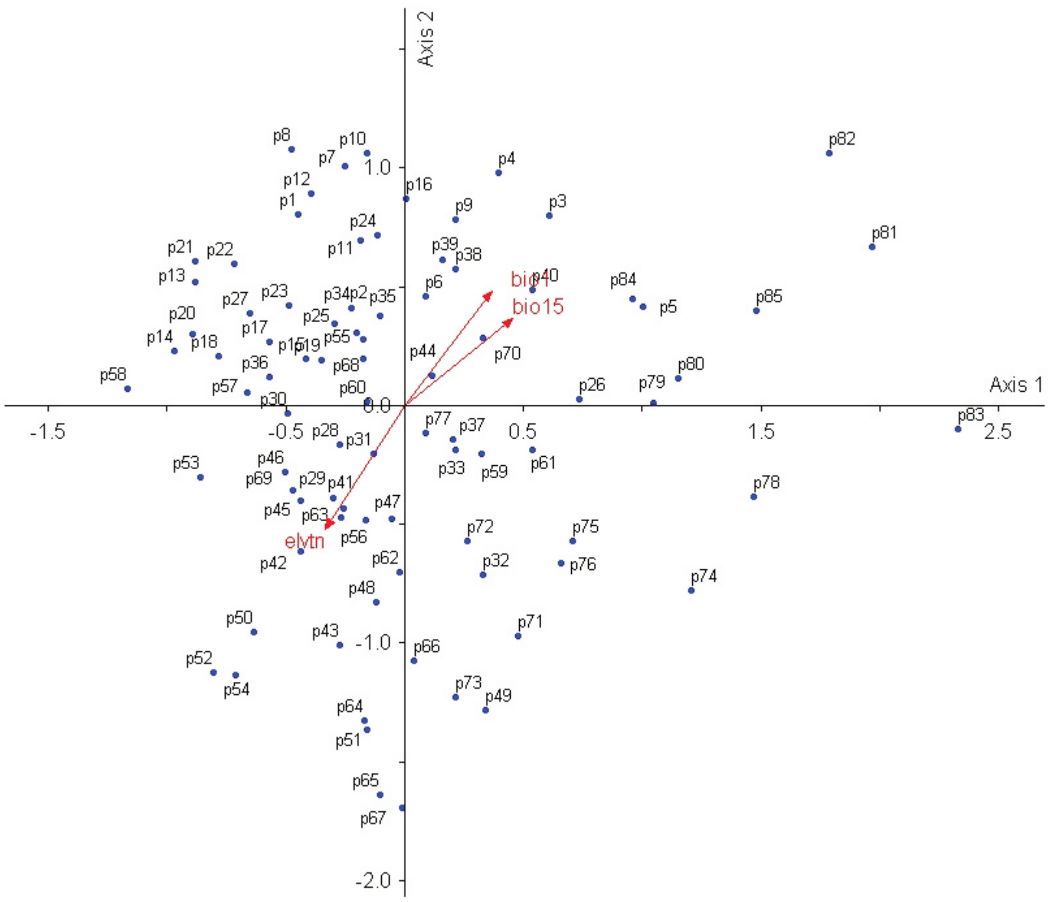

Figure 5. Distribution of sample sites and environmental variables on axes (1-2) according to CCA analysis
Slika 5. Distribucija uzorkovanih ploha i okolišnih varijabli na osi (1-2) prema CCA analizi

planning is necessary for the conservation of resources, followed by their utilization in all activities carried out in forest ecosystems. Thus, the determination and classification of vegetation groups will contribute to achieving a balance between conservation and utilization, thereby fulfilling the principle of sustainability (Fontaine et al., 2007). By creating flora or vegetation groups and correlating these data with habitat characteristics, the results and maps obtained will contribute to the planning and management stages of forestry activities (Özkan and Mert, 2011).

In light of the above-mentioned explanations, this study was conducted in the Akdağ region with the primary aim of classifying woody vegetation and correlating it with environmental variables. The ultimate goal was to obtain the necessary information for forest site classification at the local, national, and regional scales, and thus to provide recommendations that would contribute to activities in forest ecosystems.

In this study, the classification of woody plant communities in the Akdağ region was initially conducted. Within this scope, clustering and two-way indicator species analyses were employed. The best group differentiation in clustering analysis, performed using Jaccard-Ward's method resulting in a 5-group differentiation (Kgroup5j), was obtained by MRPP.

In the Akdağ region, Spearman correlation analysis was initially conducted to determine the effects and directions of environmental variables on the vegetation group differentiations obtained for forest site classification. Subsequently, CCA, a commonly preferred ordination method in the literature, was employed (Spearman, 1904; Ulusan, 2016). Prior to Spearman correlation analysis, factor analysis was applied to 19 climatic variables obtained at the regional scale to eliminate potential issues arising from high correlations among them. As a result of factor analysis, it was decided to include the Bio1, Bio12 and Bio15 climate variables in the correlation phase. Thus, with these three climate variables added to the other environmental variables, a total of 15 variables were used for the correlation between woody plant species and vegetation groups.

Spearman correlation analysis conducted between the environmental variables and the vegetation group differentiation obtained Kgroup5j as the best group differentiation , revealing that elevation, temperature index and solar radiation index variables showed positive relationships with vegetation group differentiation, while aspect, Bio1 and Bio15 variables exhibited negative relationships. These relationships were further supported and visually presented through CCA, which enabled more detailed interpretations. According to the outputs of CCA, elevation had a positive effect on plant distributions and vegetation group differentiations, while Bio1 and Bio12 variables had negative effects. The positive effect indicated that as elevation increased, the distribution groups of plant species also changed, while the negative effect suggested that the distribution of species changed or became more distinct at points where Bio1 and Bio12 variable values decreased (Table 6).

In summary, understanding the effects of habitat characteristics on the distribution of plant communities is of great importance. Therefore, this study, conducted in the natural forest areas of the Akdağ region, aimed to classify and correlate plant communities based on the habitat characteristics that influence their distribution. The recommendations presented based on the results of the study are believed to be beneficial for various applications and scientific studies focusing on living communities, especially forestry practices, at the local, regional and global levels.

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SAŽETAK

U ovom istraživanju određene su distribucija drvenaste vegetacije i karakteristike biljnog okoliša u regiji Akdağ (Burdur) te je uspostavljena klasifikacija šumskih staništa. Terensko istraživanje provedeno je na 85 ploha, pri čemu je identificirano 65 vrsta drvenastih biljaka. Vrste s učestalošću manjom od 5% u matrici vegetacijskih podataka bile su isključene. Također, dobivene su okolišne varijable za svaku uzorkovnu plohu. Grupiranje vegetacije i analiza indikatorskih vrsta provedeni su tijekom faze klasifikacije vegetacije. Naknadno je identificirana najprikladnija diskriminirajuća grupa korištenjem postupka višestruke permutacije odgovora (MRPP). Primijećeno je da je analiza klasteriranja temeljena na Jaccard-Wardovoj metodi dala najprikladniju diskriminirajuću grupu. U sljedećoj fazi, kreirane su distribucijske karte biljnih zajednica za odabranu diskriminirajuću grupu. Nadalje, pozitivne i negativne indikatorske vrste identificirane su kroz analizu međuatributnih odnosa. Spearmanova korelacijska analiza između najbolje diskriminirajuće grupe i okolišnih varijabli otkrila je da varijable nadmorske visine, indeksa temperature i indeksa sunčevog zračenja pokazuju pozitivnu korelaciju, dok su varijable vezane uz matični materijal, Bio1 i Bio15 pokazale negativnu korelaciju. Slični rezultati dobiveni su u kanoničnoj analizi korespondencije (CCA) primijenjenoj za tumačenje odnosa dobivenih putem korelacijske analize korištenjem metoda ordinacije. Prema CCA, nadmorska visina pozitivno je povezana s distribucijom biljaka i vegetacijskim grupama, dok su varijable Bio1 i Bio15 negativno povezane.

KLJUČNE RIJEČI: drvenasta vegetacija, klasifikacija šumskog staništa, regija Akdağ, nadmorska visina