www.biodicon.com Biological Diversity and Conservation

ISSN 1308-8084 Online ISSN 1308-5301 Print

Research article/Araştırma makalesi
DOI: 10.46309/biodicon.2024.1384960
17/3 (2024) 206-215

Prediction of potential geographic distribution of *Capparis spinosa*

Alican ÇIVĞA *[1], Serkan ÖZDEMIR[1], Serkan GÜLSOY[2]
ORCID: 0000-0003-4975-8878; 0000-0002-9425-3724; 0000-0003-2011-8324

[1] Sütçüler Prof. Dr. Hasan GÜRBÜZ Vocational School, Department of Forest Engineering, Isparta University of Applied Sciences, 32950 Sütçüler, Isparta, Turkey
[2] Faculty of Forestry, Department of Forest Engineering, Isparta University of Applied Sciences, 32200 Isparta, Turkey

Abstract

Capparis spinosa is a medicinal plant with economic (e.g., food, animal breeding, medicine) and ecological (e.g., erosion control, fighting wildfires) importance that is distributed in the western and southern coastal regions of Turkey. The MaxEnt model was used to simulate potential distribution areas of *C. spinosa* with the effect of environmental conditions. The results showed that the potential suitable area of *C. spinosa* is 6109 hectares, mainly distributed below 1000 meters in Babadağ Region. It was determined that the variables contributing to the model were bedrock, elevation, topographic position index and hillshade index, respectively. The acquired model presented excellent performance according to its AUC values (Training AUC: 0.909 and test AUC: 0.906). It is thought that the results revealed in the study will provide an insight for future investigations to be carried out for the species.

Keywords: Caper, habitat suitability, MaxEnt, species distribution modeling

---------- * ----------

Capparis spinosa'nın potansiyel coğrafi dağılımının tahmini

Özet

Capparis spinosa, Türkiye'nin batı ve güney kıyı bölgelerinde yayılış gösteren, ekonomik (örneğin gıda, hayvancılık, ilaç) ve ekolojik (örneğin erozyon kontrolü, orman yangınlarıyla mücadele) öneme sahip tıbbi bir bitkidir. Çevre koşullarının etkisiyle *C. spinosa*'nın potansiyel dağılım alanlarını simüle etmek için MaxEnt modeli kullanılmıştır. Sonuçlar, *C. spinosa* için potansiyel uygun alanın 6109 hektar olduğunu ve Babadağ Bölgesi'nde çoğunlukla 1000 metrenin altında dağıldığını göstermiştir. Modele katkı sağlayan değişkenlerin sırasıyla ana kaya, yükselti, topoğrafik pozisyon indeksi ve gölgelenme indeksi olduğu belirlendi. Elde edilen model, AUC değerlerine (Eğitim AUC: 0,909 ve test AUC: 0,906) göre mükemmel performans sergiledi. Çalışmada ortaya çıkan sonuçların türe yönelik ileride yapılacak araştırmalara ışık tutacağı düşünülmektedir.

Anahtar kelimeler: Kapari, habitat uygunluğu, MaxEnt, tür dağılım modellemesi

1. Introduction

* *Corresponding author* / Haberleşmeden sorumlu yazar: Tel.: +905548604459; Fax.: +905548604459; E-mail: alicancivga@isparta.edu.tr
 Received: 02.11.2023; Published: 15.12.2024 BioDiCon. 1129-021123

Non-wood forest products (NWFP) are among the biological elements whose sustainability has been under threat in recent years due to reasons such as population growth, deforestation, and climate crisis. Globally, the market share of NWFP has been reported as approximately 7.1 billion dollars. NWFP also has a large market share in Turkey. As of 2019 data, there is an 880 million dollars market share for 250 distinct taxa in an area of 1.7 million hectares in Turkey [1]. Among these species, taxa belonging to the genus Capparis attract attention due to their multifunctional benefits.

The genus Capparis is represented by about 250 species in a wide area, including Southern Europe, Northern and Eastern Africa, Madagascar, Western, central, and southeast Asia. Among these species, *Capparis spinosa* L. (C. spinosa) and *Capparis ovata* L. (*C. ovata*) are widely distributed in Turkey with a total of 5 varieties [2]. Varieties of *C. spinosa* are mostly distributed in the western and southern coastal regions, while varieties of *C. ovata* distribute in Central Anatolia, Eastern Anatolia, Southeastern Anatolia and locally in some parts of the Black Sea [3].

The name caper, which is based on Greek, is commonly used for the *C. spinosa*, which is also known by names such as kebere, gebreotu, cat's nail among the local people. Caper is a species having a number of benefits [4]. Archaeological findings give information for the aforementioned benefits. Previous research has showed that the species was used for food and medicine in ancient times and even cultivated. At present, capers are used by many people as an ornamental plant, cultivated for purposes such as erosion control and animal breeding, consumed as food and directly commercialized by generating income [5]. In addition, there are studies showing that it is used for disease treatment such as hypertension, atherosclerosis, and circulatory disorders [5]. Furthermore, Kart [6] found evidence that these species have analgesic, anti-inflammatory, antioxidant, antitumoral, diuretic, antidiarrheal, hypoglycemic, expectorant, antibacterial, antiallergic, antihypertensive, antifungal, and antihyperlipidemic properties

When the site factors of the *C. spinosa* are examined, it is seen that it is a species with production potential on the slopes outside the irrigation area or on the slopes where no species has been cultivated previously [5]. In this sense, determining the suitable ecological demands of the species and simulating its potential distribution areas form the basis of both sustainable and more effective utilization [7]. Species distribution modeling is pointed out as the most influential method that can serve this purpose [8]. Estimating the potential distribution areas of species using species distribution models has become an important component of conservation and planning studies on rare and endangered species [9;10], biodiversity studies [11], estimation of the effects of climate change on species distribution [12], and invasive species [13] issues in recent years. In this direction, various modeling techniques have been developed over time. These methods, which can be expressed as species distribution modeling, ecological niche modeling or habitat suitability modeling depending on the structure of dependent and independent variables. They provide practical and effective results by simulating the situations of species under various ecological and climatic conditions. For these reasons, the mentioned methods are becoming popular day by day. In the present study, the potential distribution areas of *C. spinosa* in Babadağ Region (Fethiye) were determined by using Maximum Entropy (MaxEnt), which is one of the most preferred modeling methods. Many species of non-wood forest products (NWFP), including *C. spinosa*, are distributed in Babadağ Region. It is important to determine the possible distribution areas of these species. In this direction, it is thought that the results acquired from present study will contribute to the determination of the NWFP potential of the region.

2. Material and method

2.1. *Study area and species occurrence data*

The study area is Babadağ Region, which is located within the borders of Fethiye district of Muğla province. The main tree species in the region are Red pine, Black pine, Crimean junipers, Taurus cedar, Mediterranean cypress [14]. The elevation range of the study area begins at 0 meters (m) above sea level and rises to 1938 m at the peak of Babadağ. The location map indicating the study area is given in Figure 1. In the present study, field studies were carried out in 200 sample areas and the presence data of *C. spinosa* were recorded at 18 locations.

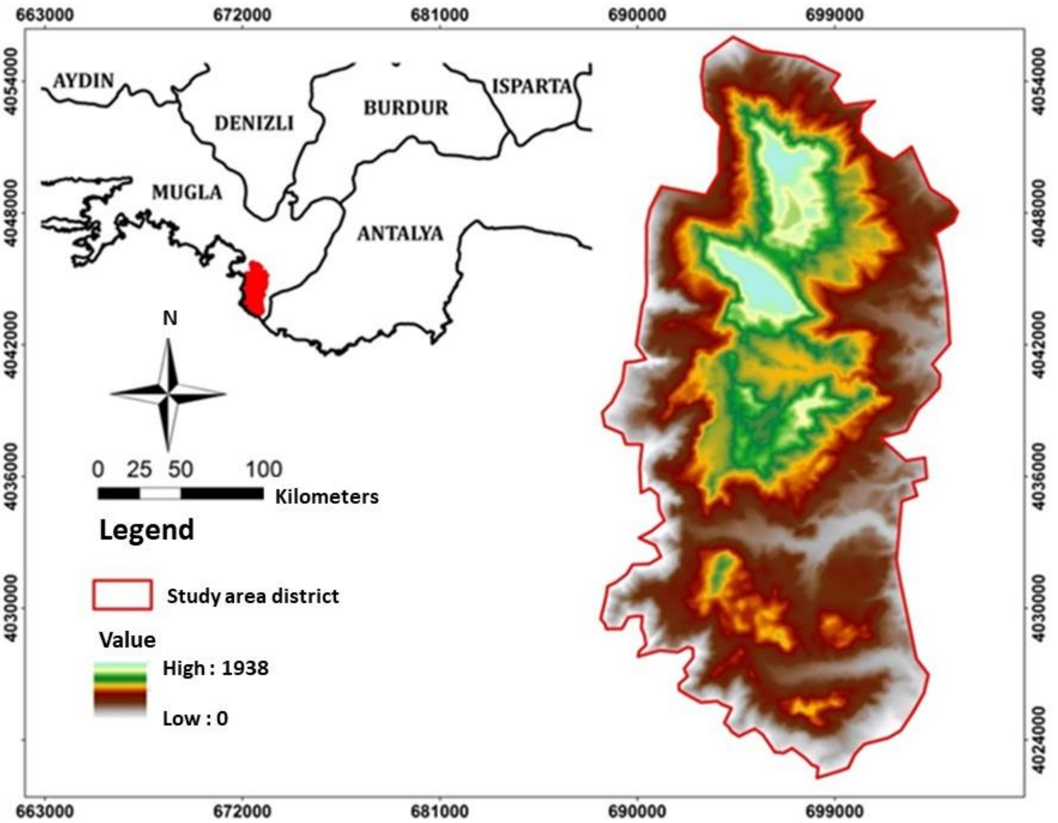

Figure 1**.** Location map of the Babadağ Region

2.2. Environmental variables

The bioclimatic variables were downloaded from WorldClim (www. worldclim.org/data/worldclim21.html) version 2.1 with 30 arc seconds spatial resolutions (~1 km). As a topographic variable, the elevation variable was first downloaded from the USGS database (www.earthexplorer.usgs.gov). Then, slope, aspect, roughness, roughness, shadowing, topographic position index bases were created by using the elevation pad in ArcMap software. Then, the layers for the aspect suitability index, heat index, and radiation index were created with the formulas in the literature. Finally, a total of 31 variables were determined by obtaining the bedrock map from the General Directorate of Mineral Research and Exploration (https://www.mta.gov.tr/en/) and the canopy shading map from the forest management data of Turkey General Directorate of Forestry.

2.3. Variable selection and statistical analysis

To reduce the multicollinearity issues, Pearson's correlation analysis was performed on environmental variables. Among the variables that were determined to be highly correlated (Pearson's R $\geq$ 0.80) with each other, they were eliminated based on expertise. In other words, the variable known to be effective in the distribution of the species (according to the literature) was selected from two highly correlated variables [11].

Maximum Entropy (MaxEnt) method was employed to model the *C. spinosa* species. MaxEnt is one of the most preferred methods in modeling studies in recent years. The fact that the MaxEnt method, which only works with presence data, reveals more descriptive results with less data, is shown as one of the main reasons for the frequent use of the method. In the study, bootstrap option with 10 test percentages and 10 replicates were preferred as modeling parameters [15]. The bootstrap method was used because it gives better results with less data. As a result of the analyses, a potential distribution map and values ranging from 0-1 were obtained. Within the scope of the study, areas with values above 0.5 were accepted as potential areas. In this context, the final map was created by accepting the value of 0.5 as the threshold value.

Factor Analysis of Mixed Data (FAMD) method was used to reveal the potential effects of variables not included in the formation of the Maxent model. As a result of the analysis, the component with the highest explanation for *C. spinosa* was determined, and the variable with the highest correlation with that axis was associated with the distribution of the species.

3. Results

Previous literature has highlighted those environmental variables affect the distribution of species [16;17]. Therefore, the environmental variables to be employed in this study were determined based on the findings of these studies. Then, correlation analysis was performed between these variables to eliminate the multicollinearity problem. Pearson's Correlation analysis results are given in Figure 2.

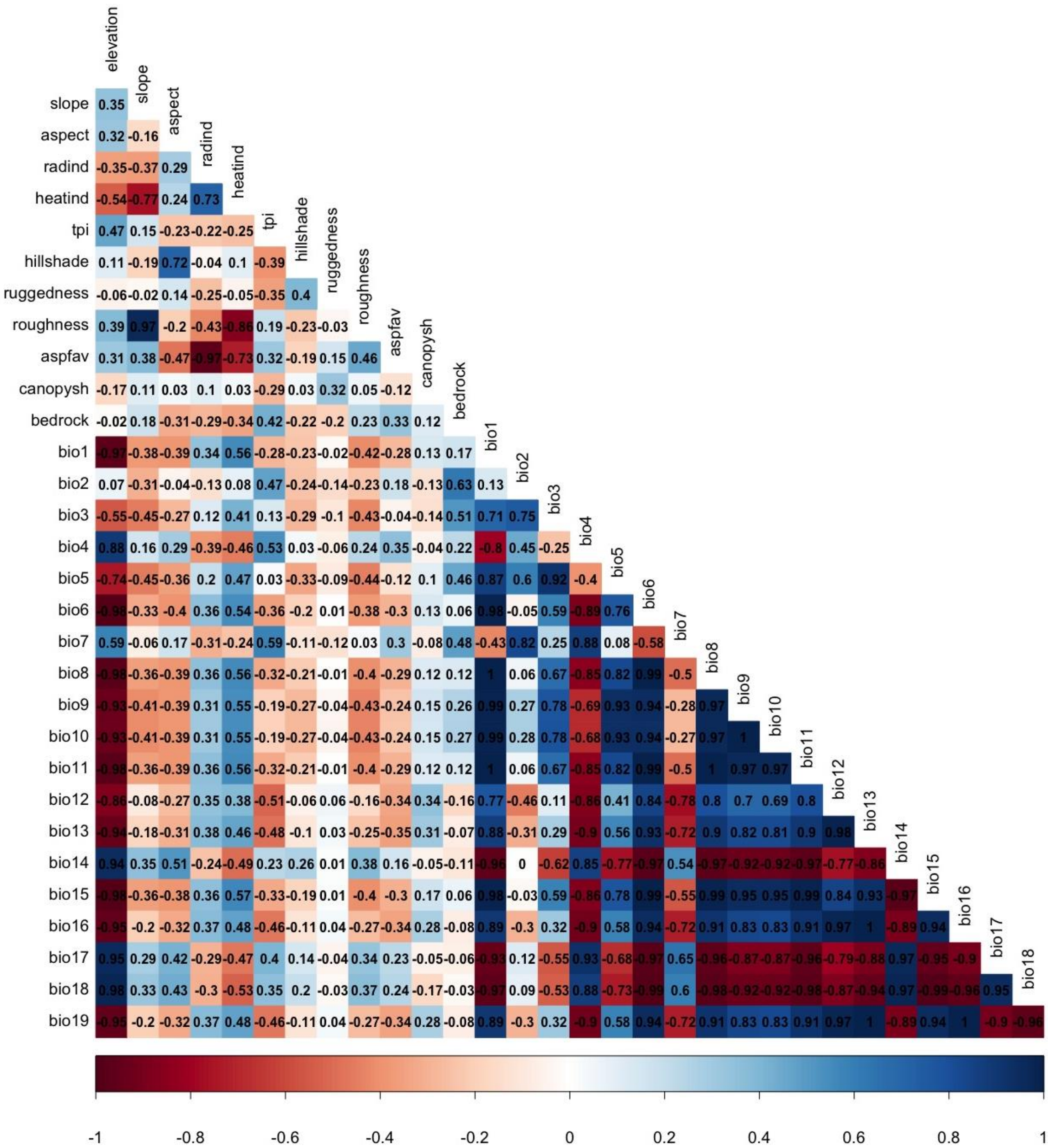

Figure 2. Results of the Pearson's Correlation analysis

As a result of this analysis, it was determined that 12 variables among the climatic and topographic variables could be used in the modeling. The variables that were included in the modeling are given in Table 1.

Table 1. Selected variables using Pearson's Correlation analysis

Variables	**Variables**
Elevation	Roughness
Slope	Topographic position index (tpi)
Heat index	Canopy shading (canopysh)
Radiation index (radind)	Bedrock
Hillshade	Mean diurnal range (bio2)
Ruggedness	Maximum temperature of warmest month (bio5)

In the present study, geographical distribution of *C. spinosa* that located in Babadağ Region, Fethiye, was assessed with Maximum Entropy method, considering environmental and climate variables. The Area Under Cover (AUC) value of the potential distribution model obtained as a result of the analysis was examined. The model performances were evaluated based on the AUC values (Training AUC: 0.909, Test AUC: 0.906).

The results showed that the most important variables affecting the distribution of the *C. spinosa* were bedrock 1 and 5 (alluvial and ophiolite), elevation, tpi, and hillshade, respectively. The marginal response curves of the variables indicated a negative relationship with elevation. The effects of the variables that create the model and the relationship between the target species and the response curves are examined. The responding curves of the variables contributing to the model are given in Figure 3.

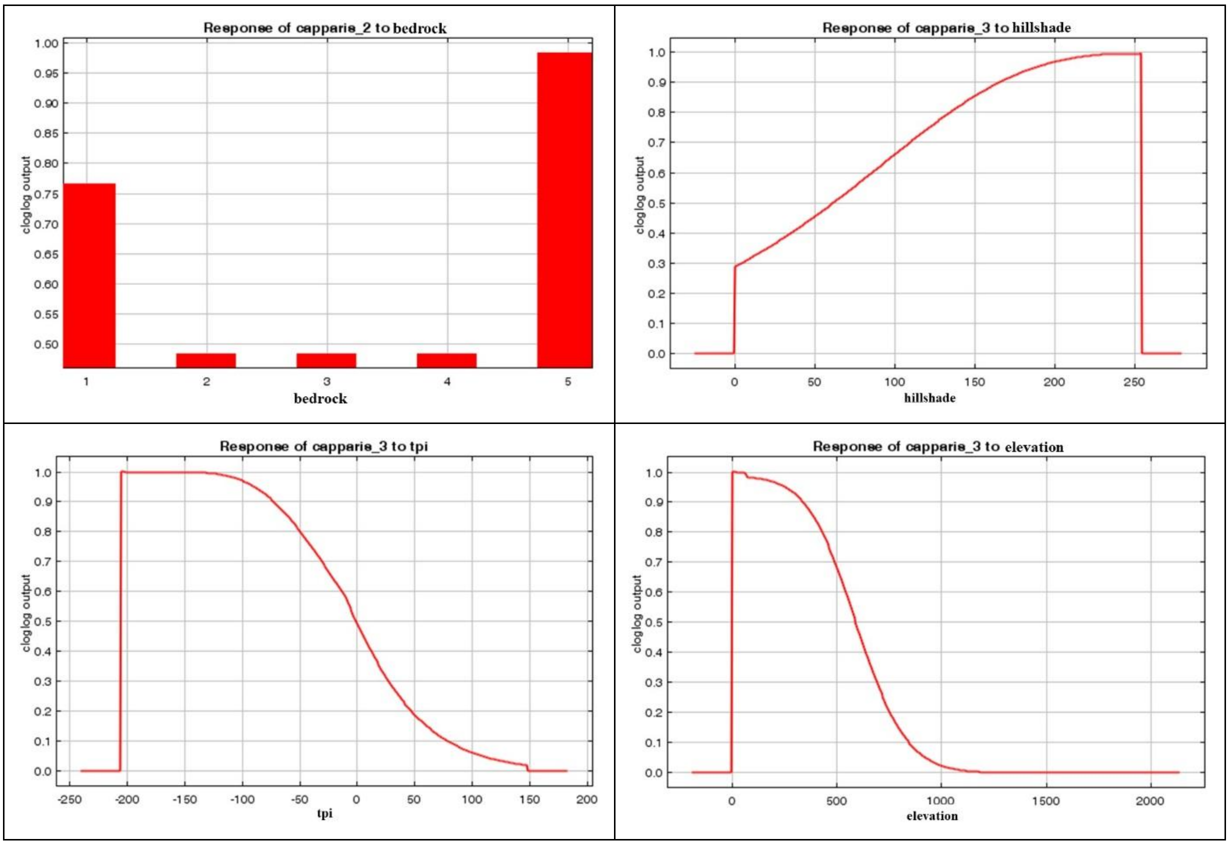

Figure 3. Marginal response curves of the variables contributing to the model

The prediction map provided by the MaxEnt program was arranged using ArcGIS software. The resulting map shows the potential distribution and suitable areas of the species *C. spinosa* (Figure 4a). In addition, the potential distribution map was classified according to 0.5 threshold value in terms of predictive values, and then a suitability map was created (Figure 4b).

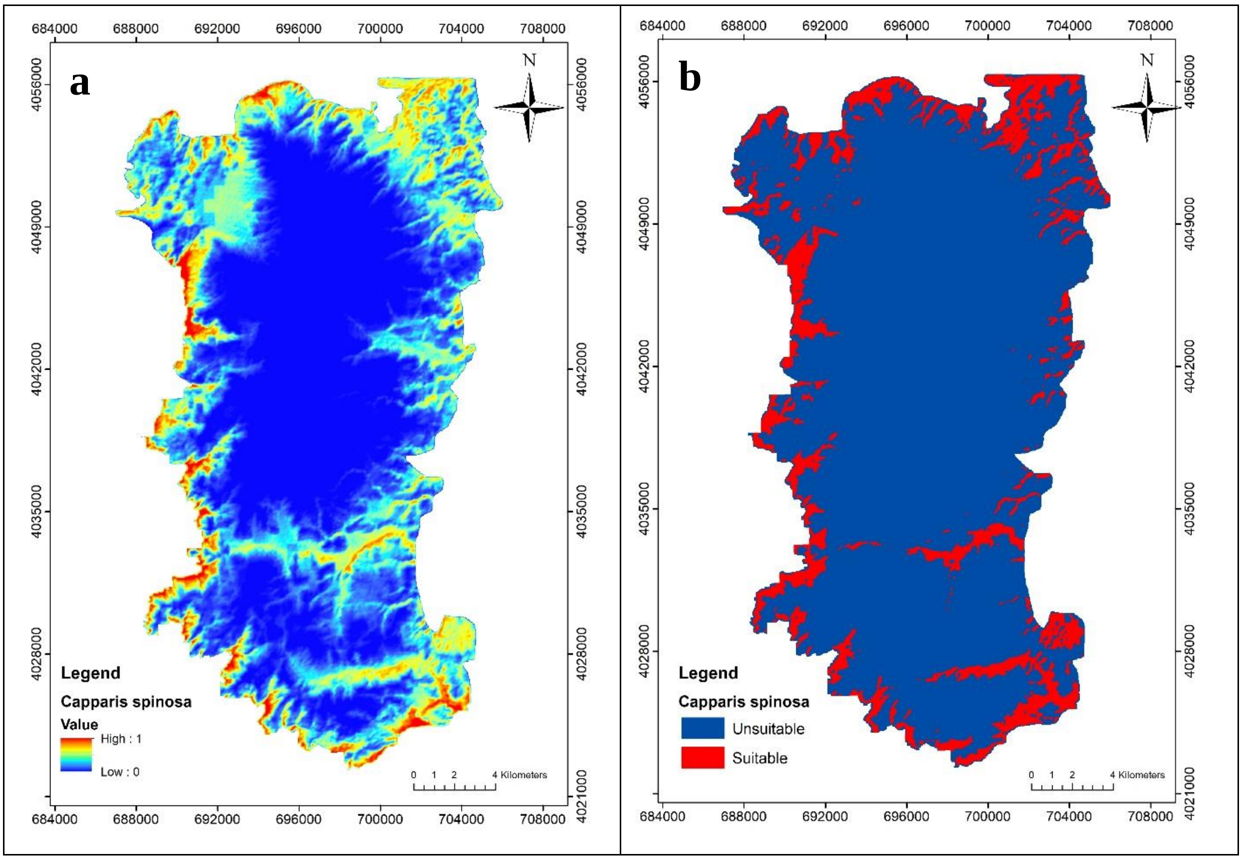

Figure 4. Potential distribution (a) and suitable areas (b) maps (0.5 threshold) of *C. spinosa*

On the figure 2b, the potential areas where the *C. spinosa* species is most likely to exist are displayed in red while the unsuitable areas for the species are blue.

Only 4 of the variables included in the modeling process (bedrock, hillshade, tpi and elevation) were included in the model obtained by the MaxEnt method. However, other variables are also likely to have an effect on the distribution of the species directly or indirectly. In modeling studies, evaluations are generally made on the variables that create the model. However, this does not mean that other variables have no effect. It is obvious that the predictive maps obtained with the variables that create the model offer practical application opportunities in practice. It is one of the best examples that can be given to the aforementioned applications, especially since it is an excellent base for breeding studies to be carried out in the natural areas of the species. However, this should not cause other variables to be ignored. Therefore, FAMD was applied in order to determine the effects of the variables not included in the MaxEnt model. The reason for using FAMD is that there are both continuous and categorical variables in the data. Principal component analysis (PCA) is preferred if all of the data are continuous, and multiple correspondence analysis (MCA) is preferred if all of the data are categorical. However, FAMD can work with both data types and is expressed as a version of PCA that can work with both categorical and continuous data [18].

The predictive values in the model map obtained by the MaxEnt method were also included in the MAFD as a variable (*C. spinosa*) to determine the effect of the variables on the species distribution. The eigenvalues and variance explanation rates obtained for the components as a result of MAFD are presented in Table 2.

Table 2. Eigenvalues and variance explanation ratios of components

Components	Eigenvalue	Percentage of variance	Cumulative percentage of variance
Component 1	3.932377	35.748886	35.74889
Component 2	2.035578	18.505253	54.25414
Component 3	1.438370	13.076094	67.33023
Component 4	1.062831	9.662096	76.99233
Component 5	0.774047	7.036791	84.02912

While commenting on the components, it is expected that the eigenvalue should be greater than 1% and the variance explanation rate greater than 10% [19]. Component 1 component 2 and component 3 meet these conditions.

That’s why, evaluations were made on these three variables. Square Cosine values ($\cos^2$) were used to evaluate the relations of the variables with the components (Table 3).

Square Cosine is a measure obtained as a result of PCA. When PCA transforms the dataset into a set of interconnected components, it obtains weight vectors that represent the relationship of each component with the original dataset. Sometimes, "cosine similarity" is used to measure the similarities between these weight vectors. Cosine similarity represents the angle between two vectors and expresses the similarity between vectors as an angle.

Square Cosine is calculated by taking the square of the cosine similarity value. It is a measure that assesses the similarity of each component with other components and is used in interpreting PCA results. If the square cosine value is close to 1, it indicates that two components are highly similar. If the value approaches 0, it means that two components are completely opposite to each other. These values are used to understand the relationships between variables in the dataset and to evaluate the accuracy of PCA results.

Table 3. Square Cosine values of the components

	Component 1	Component 2	Component 3
slope	0.795412	0.000000	0.000005
radind	0.000203	0.246500	**0.148542**
heatind	0.597991	0.003228	0.003429
ruggedness	0.161884	0.035264	0.002769
roughness	0.751617	0.000100	0.000927
bio2	0.003275	0.333213	0.002923
bio5	0.097201	0.067752	0.001705
canopysh	0.001135	0.068868	0.002406
C. spinosa	0.061751	0.001242	**0.261998**

As seen in Table 3, *C. spinosa*, the variable belonging to the predictive values, showed the highest $\cos^2$ value with component 3. Therefore, the relationship of *C. spinosa* with other variables was interpreted only through component 3. In addition, it was seen that the variable with the highest $\cos^2$ value with component 3 was radind. It was determined that the values of other variables were quite low. Therefore, only radind could be associated with *C. spinosa*.

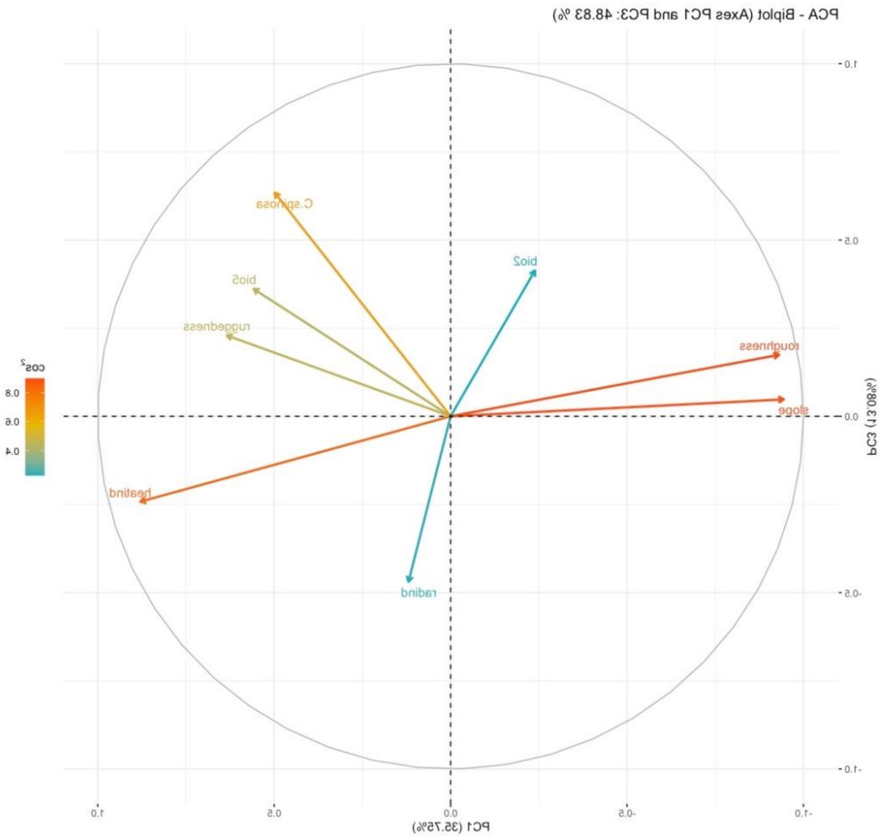

Figure 5. MAFD graph

According to component 3, there exists a negative relationship between C. spinosa and radial variables as illustrated in Figure 5. This relationship is determined through the utilization of aspect values that range from 0 to 1. As the value approaches 1, it signifies southern aspects characterized by greater insolation, whereas lower values correspond to northern aspects characterized by comparatively lower temperatures.

4. Conclusions and discussion

C. spinosa is a species that exhibits a widespread distribution across a considerable geographic range, while also holding economic significance [20;21]. Studies conducted on the species in different regions have revealed that factors influencing the species' distribution can vary depending on regional disparities [22]. Therefore, determining the habitat requirements of C. spinosa in different regions is of paramount importance for sustainable utilization. In this context, the MaxEnt method was employed in the study to identify the factors affecting the distribution of C. spinosa. Subsequently, the Factor Analysis of Mixed Data (FAMD) method was utilized to assess the extent to which non-included variables affect the species' distribution. According to MaxEnt results, it has been determined that the model performance and predictive power are excellent [23]. Swets [24] categorized AUC values as excellent (AUC>0,90), good (0.90>AUC>0.81), fair (0.80>AUC>0.71), poor (0.70>AUC>0.61) and fail (AUC<0.60). The marginal response curves of the variables indicated a negative relationship with elevation. The effects of the variables that create the model and the relationship between the target species and the response curves are examined. The responding curves of the variables contributing to the model are given in Figure 3. When the marginal response curves were examined, it was determined that the species preferred alluvial, and ophiolitic types as bedrock preference. The hillshade index also indicate that potential distribution areas of *C. spinosa* decreased in shading conditions with higher 200 values. In other words, the hillshade index showed that the species prefers shaded areas in all other aspects, except for the northern aspects. Topographic position index, which is another variable that contributes to the model, it is seen that the areas where *C. spinosa* species are widely distributed are plain and concave areas. A negative relationship was observed between elevation, which is the last variable contributing to the model, and potential suitable areas. In terms of studies, there are findings stating that the *C. spinosa* prefers low elevations, that it is a species that makes tap roots and can take its roots deep [5]. Therefore, the determination of elevation as an important variable for the present study might be due to the negative relationship between elevation and soil depth. On the other hand, Ashraf et al. [20] identified bio12 as one of the most important variables affecting the distribution of *C. spinosa*. In this study, it was determined that elevation showed a very high correlation with bio12 (Figure 2), and in this respect, it was aligned with the mentioned study. It has been concluded that there is a negative, but relatively more curvilinear relationship with the hillshade and tpi variables contributing to the model, similar to elevation. In terms of bedrock variable, it has been determined that there are 5 (alluvial, carbonate, limestone, detrial and ophiolitic) different bedrock types in the study area, of which alluvial, limestone and ophiolitic type rocks represent potential suitable areas. The areas with alluvial, limestone, and ophiolitic rock structures below 1000 meters in Babadağ Region are potential suitable areas for *C. spinosa*. In addition, it prefers plain and concave areas and shady areas on slope positions except for the northern. As can be understood from the evaluations of the model obtained from the MaxEnt method, the results coincide with the findings of the researchers regarding the *C. spinosa* [19;21].

The predictive map obtained for C. spinosa has been thresholded at a value of 0.5, categorizing areas into suitable and unsuitable categories. As a result of this classification, a predictive map consisting of two distinct colors has been generated. It is evident from this map that the species shows a preference for areas within the study area characterized by noticeably lower elevations. These areas also correspond to regions with relatively higher soil depth. These findings provide valuable insights into the distribution of the species within the study area.

The natural regeneration of *C. spinosa* primarily occurs through seed dispersal, although it is relatively weak. The species' seeds can remain dormant in the soil for extended periods and sprout after a few years. Therefore, it is crucial to investigate the seed germination biology, primary agricultural techniques for plant breeding, and the species' habitat requirements. The root system of *C. spinosa* reaches deep underground moisture sources, typically at depths of 10-18 meters or more [21]. Furthermore, its extensive root system and ground cover effectively prevent soil erosion. The plant stores moisture in its leaves, making it resilient against drought and summer heat, eliminating the need for irrigation. Additionally, *C. spinosa* is fire-resistant, making it suitable for planting in fire breaks to combat wildfires. The species also has significant economic value for food and medicinal purposes. Therefore, conserving and cultivating *C. spinosa* in appropriate natural areas is crucial for sustainable utilization. Modeling studies are valuable tools for understanding the ecological needs of the species. However, the study's findings suggest that relying solely on modeling methods may not sufficiently characterize the species' distribution. Consequently, incorporating different statistical approaches would be beneficial, and the results obtained using FAMD in this study serve as a notable example in addressing the aforementioned issue.

Acknowledgements

This study was presented at the 6th International Conference on Computational Mathematics and Engineering Sciences (CMES 2022) and published in the abstract book.

References

[1] CFE. (2021). Non-Wood Forest Products Assesment Report of Turkey. The Chamber of Forest Engineers of Turkey, Ankara.

[2] Giritlioğlu, N., Yildiz, E., & Gürbüz, O. (2020). Effect of Caper Buds (*Capparis* spp.) on Phenolics, Antioxidant Capacity, and Bioaccessibility on Kombucha Tea Production. *Academic Food Journal*, 18(4): 390-401. https://doi.org/10.24323/akademik-gida.850909

[3] Yeğenoğlu, S., & Ayşe, U.Z. (2011). Caper: Its importance from historical and medical perspective. *Lokman Hekim Journal*, 35-36.

[4] Kolanci, B.Y. (2020). Antik Dönemde Kapari Bitkisi (Capparis spp.). A life dedicated to Anatolian prehistory: Festschrift for jak yakar, Editors: Barış Gür, Semra Dalkılıç, 263-272, Ankara.

[5] Şat, İ.G., & Çil, Y.M. (2006). Yeni bir Tarımsal Ürün: Kapari (*Capparis* spp.). Türkiye, 9, 24-26.

[6] Kart, A. (2019). Bioactive, pharmacological effects of caper plant and its use in neurodegenerative diseases. *Veterinary Journal of Mehmet Akif Ersoy University*, 4(2), 101-107. https://doi.org/10.24880/maeuvfd.615592

[7] Naudiyal, N., & Schmerbeck, J. (2021). Potential distribution of oak forests in the central Himalayas and implications for future ecosystem services supply to rural communities. *Ecosystem Services*, *50*, 101310. https://doi.org/10.1016/j.ecoser.2021.101310

[8] Lissovsky, A.A., & Dudov, S.V. (2021). Species-Distribution Modeling: Advantages and limitations of its application. 2. MaxEnt. *Biology Bulletin Reviews*, 11(3), 265-275. https://doi.org/10.1134/S2079086421030087

[9] Zhang, P., Grenouillet, G., Dong, X., Zheng, Y., Lek, S., & Chang, J. (2021). Capturing response differences of species distribution to climate and human pressures by incorporating local adaptation: Implications for the conservation of a critically endangered species. *Journal of Environmental Management*, 284, 111998. https://doi.org/10.1016/j.jenvman.2021.111998

[10] Oğuzoğlu, Ş., & Özkan, K. (2008). Productivity distribution modelling of Anatolian Black Pine Pinus nigra subsp. pallasiana var. pallasiana in the Türkmen Mountain, Eskişehir. Biyolojik Çeşitlilik ve Koruma, 8(2), 134-140.

[11] Hosseini, N., Mehrabian, A., & Mostafavi, H. (2022). Modeling climate change effects on spatial distribution of wild Aegilops L. (Poaceae) toward food security management and biodiversity conservation in Iran. *Integrated Environmental Assessment and Management*, 18(3), 697-708. https://doi.org/10.1002/ieam.4531

[12] Özdemir, S., Gülsoy, S., & Mert, O.P. (2020). Redicting the effect of climate change on the potential distribution of *Crimean Juniper*. *Kastamonu University Journal of Forestry Faculty*, 20(2), 133-142.

[13] Zhang H, Song J, Zhao H, Li M, & Han W. (2021). Predicting the distribution of the invasive species *Leptocybe invasa*: Combining MaxEnt and Geodetector Models. *Insects*, 12(2), 92. https://doi.org/10.3390/insects12020092

[14] Güngör, H., Solak, M.H., Alli, H., Işiloğlu, M., & Kalmiş, E. (2016). Contributions to the macrofungal diversity of Muğla province (Turkey). Mycotaxon, Link, 131(1): 255-256.

[15] Mert, A., & Kıraç, A. (2017). Habitat Suitability Mapping of *Anatololacerta danfordi* (Günter, 1876) in Isparta-Sütçüler District. Bilge International Journal of Science and Technology Research, 1(1), 16-22.

[16] Mert, A., Özkan, K., Şentürk, Ö., & Negiz, M.G. (2016). Changing the potential distribution of Turkey Oak (*Quercus cerris* L.) under climate change in Turkey. *Polish Journal of Environmental Studies*, 25(4), 1633-1638. https://doi.org/10.15244/pjoes/62230

[17] Evcin, Ö., & Kalleci, B. (2020). *Glis glis* (Nehring, 1903) (Rodentia: Gliridae) Türünün Kastamonu İlindeki Yayılış Gösterdiği Alanların ve Potansiyel Dağılımının Tespit Edilmesi. *Bilge International Journal of Science and Technology Research*, 4(2), 73-77. https://doi.org/10.30516/bilgesci.779010

[18] Chavent, M., Kuentz-Simonet, V., Labenne, A., & Saracco, J. (2014). Multivariate analysis of mixed data: The R package PCAmixdata. *arXiv preprint arXiv*, 1411.4911.

[19] Özdemir, S., & Çınar, T. (2023). Determining indicator plant species of *Pinus brutia* Ten. Site index classes using interspecific correlation analysis in Antalya (Turkey). *CERNE*, 29, e-103188.

[20] Ashraf, U., Chaudhry, M.N., Ahmad, S.R., Ashraf, I., Arslan, M., Noor, H., & Jabbar, M. (2018). Impacts of climate change on *Capparis spinosa* L. based on ecological niche modeling. *PeerJ*, 6, e5792. https://doi.org/10.7717/peerj.5792

[21] Fici, S. (2014). A taxonomic revision of the *Capparis spinosa* group (*Capparaceae*) from the Mediterranean to Central Asia. *Phytotaxa*, 174(1), 1-24. http://dx.doi.org/10.11646/phytotaxa.174.1.1

[22] Rakhimova, T., Vaisova, G. B., Rakhimova, N. K., & Matkarimova, A. (2021). Phytocoenotic distribution of *Capparis spinosa* L. (*Capparaceae*) under different ecological conditions in Uzbekistan. *Annals of the Romanian Society for Cell Biology*, 25(6), 7882-7895.

[23] Gassó, N., Thuiller, W., Pino, J., & Vilà, M. (2012). Potential distribution range of invasive plant species in Spain. *NeoBiota*, 12, 25. https://doi.org/10.3897/neobiota.12.2341

[24] Swets, K.A. (1988). Measuring the accuracy of diagnostic systems. *Science*, 240, 1285–1293.