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Predicting the Effect of Climate Change on the Potential Distribution of Crimean Juniper

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Abstract

Aim of study: The main purpose of the present study is to model present and future potential distribution areas of the Crimean juniper (*Juniperus excelsa* M. BIEB.) under climate change.

Area of study: The study was carried out in the Lakes District that covers Burdur, Isparta and Antalya provinces in the west of the Mediterranean region.

Material and methods: During the study, the inventory data of 40 productive juniper stands in the region were collected. The future projections for the study area were made for the year 2070 with all Representative Concentration Pathways (RCPs) scenarios and 19 bioclimatic predictors from HadGEM2-ES. Modeling process was performed by using the Maximum Entropy (MaxEnt) method.

Main results: The AUC value of the model was determined as 0.966 ± 0.028. The model identified that Precipitation of Driest Month, Temperature Seasonality, Precipitation of Coldest Quarter, Max Temperature of Warmest Month, Mean Diurnal Range were the major variables influencing the current and future distributions of the species. According to the models, there will be a dramatic decrease in the potential distribution of the Crimean juniper. Consequently, the results from all these studies will be able to create an effective base for the biodiversity and ecosystem planning studies to be realized according to the climate change scenarios.

Highlights: Understanding how climate change will affect the distribution of plant species in the future is an important topic in ecological researches. Climate change scenarios are the most preferred parameters to remove this uncertainty. It is predicted that the Crimean juniper will be affected by climate change and its distribution will decrease dramatically.

Keywords: Climate Change, Crimean Juniper, Maximum Entropy, Representative Concentration Pathways (RCPs)

İklim Değişikliğinin Boylu Ardıç Türünün Potansiyel Dağılımı Üzerindeki Etkisinin Kestirimi

Öz

Çalışmanın amacı: Bu çalışmanın amacı Boylu ardıç (*Juniperus excelsa* M. BIEB.) türünün günümüz ve gelecek için potansiyel dağılımlarının iklim değişimine göre modellenmesidir.

Çalışma alanı: Çalışma Batı Akdeniz Bölgesi'nde bulunan Burdur, Isparta ve Antalya illerini kapsayan Göller Bölgesi içerisinde gerçekleştirilmiştir.

Materyal ve yöntem: çalışmada herhangi bir hastalık belirtisi olmayan, kozalak verimi ve boy gelişimi iyi olan, saf ve doğal 40 farklı boylu ardıç meşçeresi kayıt altına alınmıştır. Geleceğe yönelik kestirimler 2070 yılına ait olarak, Temsili Konsantrasyon Rotaları senaryoları için HadGEM2-ES projeksiyonundan temin edilen 19 biyoklima verisine göre gerçekleştirilmiştir. Modelleme işlemi için Maksimum Entropi (MaxEnt) yöntemi kullanılmıştır.

Temel sonuçlar: Modele ait AUC değeri 0.966 ± 0.028 olarak tespit edilmiştir. En Kurak Ayın Yağış Miktarı, Mevsimsel Sıcaklık, En Soğuk Üç Ayın Yağış Miktarı, En Sıcak Ayın Maksimum Sıcaklığı, Gündüz Sınıf Ortalaması değişkenleri modele katkı yapan değişkenlerdir. Modele göre Boylu ardıç türünün dağılımında ciddi bir azalma görülmektedir. Sonuç olarak, çalışmadan elde edilen bulgular iklim değişikliği senaryolarına göre gerçekleştirilecek biyolojik çeşitlilik ve ekosistem planlama çalışmaları için etkili bir altlık oluşturabilecektir.

Araştırma vurguları: İklim değişikliğinin gelecekte bitki türlerinin dağılımını nasıl etkileyeceğini anlamak ekolojik araştırmalar açısından önem arz etmektedir. İklim değişikliği senaryoları bu belirsizliği ortadan kaldırmak için en çok tercih edilen parametrelerdir. Boylu ardıç türünün de iklim değişikliğinden etkileneceği ve dağılımının önemli ölçüde azalacağı öngörülmektedir.

Anahtar Kelimeler: İklim Değişikliği, Boylu Ardıç, Maksimum Entropi, Temsili Konsantrasyon Rotaları (TKR)

Introduction

Climate change is indicated by researchers as one of the most important global threats of the last century (Carle, 2015; Poushter & Huang, 2019). Although some changes are expected to occur due to the natural process of the climate, the gradual increase in anthropogenic effects in recent years has distanced the mentioned change from its natural process (John et al., 2003). Therefore, scientists studying on ecology have started to research on the estimation of the possible consequences of climate change. These studies are generally focused on the ecological properties of plant and animal species (Hsiung & Sunstein, 2006; Kelly & Goulden, 2008).

Turkey has an important place in terms of its biodiversity (Kaya & Raynal, 2001). In particular, many of them consist of endemic, rare and relict plant species. As a result, many studies focus on the plant species in Turkey. Among these studies, it is seen that what is carried out in forestry is generally related to the main forest tree species that are using for production, the species that require special protection or various plant species of commercial importance. The ones within the scope of ecology mostly deal with issues such as species distribution or productivity (Özkan et al., 2010b; Gülsoy et al., 2014b). Considering the increasing needs of timbers and their contribution to the global carbon budget in recent years, there is a significant increase in the number of ecological researches, especially for main forest tree species.

Junipers distribute to wide areas in Turkey and have various taxon with high-quality wood features. Additionally, juniper species come to the forefront with their antioxidant and antimicrobial effects in addition to their essential oil and phenolic content in parts such as conifers, leaves, bark and roots (Zheljazkov et al., 2018; Gülsoy et al., 2019). In other words, junipers have important medicinal and aromatic plant properties as well as wood properties. Sixty of the 70 species of Junipers that distribute around the world are found in the northern hemisphere and seven of them (*Juniperus communis, Juniperus drupacea*, *Juniperus excelsa, Juniperus foetidissima, Juniperus oxycedrus*, *Juniperus phoenicia*, *Juniperus sabina*) distribute in Turkey (Fakir, 2014). Among the existing juniper species, *Juniperus excelsa* (Crimean juniper), *Juniperus oxycedrus* (Prickly juniper) and *Juniperus foetidissima* (Foetid juniper) are the most widespread juniper species in our country, and these species have a widespread distribution especially in the appropriate Mediterranean habitats of our country (Coode & Cullen, 1966; Eliçin, 1977; Özkan et al., 2010a; Gülsoy & Çıvğa, 2016).

The Crimean juniper is the most widely distributed juniper species in Turkey. And so, the sustainability of this species in natural areas has great importance. However, in the Mediterranean region, the forests have been constantly destroyed or narrowed due to wood production, grazing, wildfires and conversion of forests to agricultural areas (Fontaine et al., 2007; Karavani et al., 2018). Throughout history, one of the species affected by this process in the Mediterranean region has been the Crimean juniper. From this point of view, especially in the Mediterranean region, important information has been revealed that will contribute to the sustainability of the Crimean juniper in the natural distribution areas by paying attention to issues such as site factors (Özkan, 2010 and Özkan et al., 2010a) and potential distributions (Özkan et al., 2015). On the other hand, the climate change process, which has been increasingly felt in recent years, has started to affect the Crimean juniper species as well as many other living and tree species in the Mediterranean region. Such that, in the previous studies, it is also stated that ecosystems in the Mediterranean region can be the most susceptible areas to the climate change process in the future. As an indicator of this situation, in the Mediterranean region, it is predicted that the number and severity of forest fires will increase with climate change, invasive species may increase, and ecosystems may be increasingly sensitive to pathogens and pests (Koç et al., 2018). When the subject is considered in this respect, the issue of how the distribution areas of this species will be affected in the future has become important. In this study, it is aimed to model the potential distribution areas of the Crimean juniper under future climate change scenarios by determining the locations of pure and natural juniper stands (healthy and productive) in the Mediterranean region. As a result of the present study, according to the climate change process, the ecology of the Crimean juniper in the Mediterranean region has been revealed. Also, it has been aimed to contribute to the issues such as measures to be taken and correct management planning to ensure the continuity of the species.

Material and Methods

Material

This study was carried out in the Lakes District (Isparta, Antalya and Burdur provinces), which are within the Mediterranean region. In the present study, data were collected from 40 pure and natural Crimean juniper stands that are good growth and without disease symptoms. The study area and the sample plots are given in Figure 1.

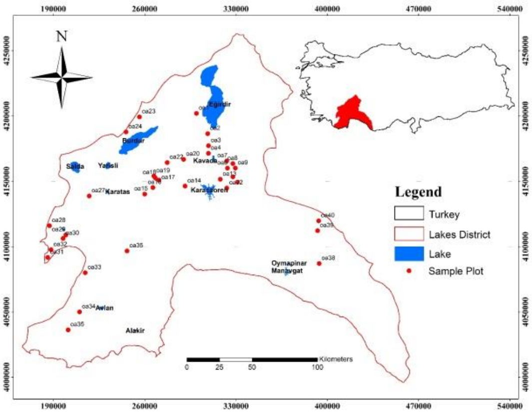

Figure 1. Study area and sample plots.

A typical Mediterranean climate is observed in the part of the region where the study is carried, covering the Antalya. Towards the inner parts of the provinces of Isparta and Burdur, the transition climate between the Mediterranean climate and the continental climate is observed. The mentioned climatic difference causes a very high species diversity in the region. Besides, landform varies within the study area. The

These methods run with different algorithms and can produce different results. For instance, DA, LRA, CART, GAM and RF methods, which are classified within grouping techniques, only run with both

Crimean juniper mostly distributes in stony and rocky areas with shallow soils.

Climate data

In this study, bioclimatic data downloaded from the WorldClim (www.worldclim.org) website for the projection of HADGEM-ES at a resolution of 30 arc seconds (~ 1 km) was used. Climate data was downloaded both for today and for 2070. Climate data was provided for 4 different scenarios (RCP 2.6, 4.5, 6.0, 8.5) presented in the IPCC 5th Assessment report. Climate data was cut according to the scale of the study area after downloaded all over the world. Before the modeling process, Pearson correlation analysis was applied by predicted that there may be a multicollinearity problem between bioclimatic variables. ArcMap 10.2 software (ESRI, 2011) was used to edited climate variables and Rstudio software (R Studio Team, 2020) was used for correlation analysis.

Predictive modeling

Several modeling methods are used more frequently in studies to determine potential distribution areas of species. Among these methods, discriminant analysis (DA), logistic regression analysis (LRA), generalized additive model (GAM), classification and regression tree technique (CART) and random forest (RF) method, analysis of genetics algorithm for rule-set production (GARP) and maximum entropy approach (MAXENT) are the most preferred. The main reason why different methods are tried for potential distribution models is the popular idea of making the best estimation to determine the potential areas of the target species by considering the different site factors of ecosystems (Grossman et al., 2010; Evans et al., 2011; Hijmans & Elith, 2017; Özdemir, 2018). In the process, the fact that this popular idea prevailed in studies has integrated different approaches to quantitative studies in the field of ecology and the methods expressed have emerged. presence and absence data. However, MAXENT and GARP, which are classified within profile techniques, only run with presence data. This study has been carried out in productive Crimean juniper stands that have 50 % density and good growth in the Mediterranean region. As a method, MAXENT, which is suitable for the presence data, was preferred. Thus, the current and future potential distribution areas of the Crimean juniper have been determined (Leathwick et al., 2006; Ward et al., 2009; Mert & Kıraç, 2017; Oruç et al., 2017; Qin et al., 2017). In summary, the potential distribution areas for four different scenarios were modeled and their maps were created. MaxEnt 3.3.3k software was used for modeling. Test data set and iteration numbers were selected as 10% and 10 respectively. The validation of the models was carried out using the AUC values of the training and test data sets of the models acquired.

Results and Discussion

Model Evaluation and Validation

MaxEnt method was used to model bioclimate variables for today and future. At this stage, first of all, the potential distribution areas of the Crimean juniper were predicted with the help of the presence data using climatic variables. However, to determine the variables to be used in modeling, correlation coefficients between each other were used. As a result of the correlation analysis, eliminations were carried out among the variables with a value higher than 0.80 in terms of the correlation coefficient between them. According to this elimination, the modeling process was continued with 5 variables (bio2, bio4, bio5, bio14 and bio19), which were determined to have no multiple connection problems among bioclimatic variables (Table 1).

Table 1. Correlation matrix between climatic predictors.

	bio_1	bio_2	bio_3	bio_4	bio_5	bio_6	bio_7	bio_8	bio_9	bio_10	bio_11	bio_12	bio_13	bio_14	bio_15	bio_16	bio_17	bio_18	bio_19
bio_1	1	0.011	0.363	-0.783	0.915	0.983	-0.484	0.996	0.995	0.994	0.996	0.314	0.431	-0.845	0.528	0.422	-0.807	-0.876	0.422
bio_2	0.011	1	0.89	0.181	0.398	-0.118	0.797	0	0.056	0.068	0	-0.812	-0.707	0.38	-0.548	-0.718	0.376	0.273	-0.718
bio_3	0.363	0.89	1	-0.271	0.65	0.271	0.444	0.375	0.381	0.388	0.375	-0.586	-0.464	0.114	-0.3	-0.469	0.119	-0.022	-0.469
bio_4	-0.783	0.181	-0.271	1	-0.593	-0.864	0.731	-0.835	-0.726	-0.716	-0.835	-0.476	-0.519	0.563	-0.541	-0.53	0.55	0.633	-0.53
bio_5	0.915	0.398	0.65	-0.593	1	0.842	-0.099	0.898	0.934	0.939	0.898	-0.042	0.107	-0.645	0.258	0.091	-0.605	-0.695	0.091
bio_6	0.983	-0.118	0.271	-0.864	0.842	1	-0.62	0.991	0.964	0.96	0.991	0.43	0.525	-0.846	0.591	0.52	-0.804	-0.87	0.52
bio_7	-0.484	0.797	0.444	0.731	-0.099	-0.62	1	-0.522	-0.421	-0.405	-0.522	-0.855	-0.814	0.623	-0.716	-0.827	0.603	0.593	-0.827
bio_8	0.996	0	0.375	-0.835	0.898	0.991	-0.522	1	0.984	0.981	10	0.337	0.451	-0.821	0.545	0.445	-0.789	-0.865	0.445
bio_9	0.995	0.056	0.381	-0.726	0.934	0.964	-0.421	0.984	1	0.998	0.984	0.278	0.409	-0.845	0.521	0.398	-0.81	-0.884	0.398
bio_10	0.994	0.068	0.388	-0.716	0.939	0.96	-0.405	0.981	0.998	1	0.981	0.248	0.375	-0.846	0.485	0.363	-0.81	-0.871	0.363
bio_11	0.996	0	0.375	-0.835	0.898	0.991	-0.522	10	0.984	0.981	1	0.337	0.451	-0.821	0.545	0.445	-0.789	-0.865	0.445
bio_12	0.314	-0.812	-0.586	-0.476	-0.042	0.43	-0.855	0.337	0.278	0.248	0.337	1	0.97	-0.535	0.872	0.978	-0.519	-0.567	0.978
bio_13	0.431	-0.707	-0.464	-0.519	0.107	0.525	-0.814	0.451	0.409	0.375	0.451	0.97	1	-0.609	0.961	0.998	-0.619	-0.694	0.998
bio_14	-0.845	0.38	0.114	0.563	-0.645	-0.846	0.623	-0.821	-0.845	-0.846	-0.821	-0.535	-0.609	1	-0.649	-0.601	0.958	0.935	-0.601
bio_15	0.528	-0.548	-0.3	-0.541	0.258	0.591	-0.716	0.545	0.521	0.485	0.545	0.872	0.961	-0.649	1	0.953	-0.706	-0.791	0.953
bio_16	0.422	-0.718	-0.469	-0.53	0.091	0.52	-0.827	0.445	0.398	0.363	0.445	0.978	0.998	-0.601	0.953	1	-0.61	-0.684	10
bio_17	-0.807	0.376	0.119	0.55	-0.605	-0.804	0.603	-0.789	-0.81	-0.81	-0.789	-0.519	-0.619	0.958	-0.706	-0.61	1	0.952	-0.61
bio_17	-0.876	0.273	-0.022	0.633	-0.695	-0.87	0.593	-0.865	-0.884	-0.871	-0.865	-0.567	-0.694	0.935	-0.791	-0.684	0.952	1	-0.684
bio_19	0.422	-0.718	-0.469	-0.53	0.091	0.52	-0.827	0.445	0.398	0.363	0.445	0.978	0.998	-0.601	0.953	10	-0.61	-0.684	1

Following the determination of the variables, the average AUC value of the model for actual distribution obtained as a result of the modeling process performed with the MaxEnt method was 0.966 (standard error: ± 0.038), and the AUC values of the training and test data set were 0.974 and 0.968, respectively (Figure 2).

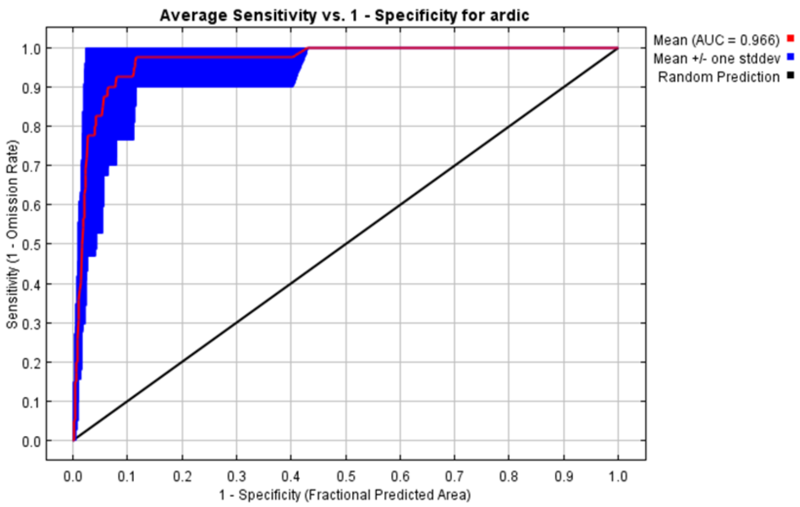

Figure 2. The ROC curve of *Juniperus excelsa.*

The variable that made the highest contribution to the model was bio-4 with 34.8%. The order of variables in terms of contribution rates to the model is bio-14 (33.6%), bio-19 (17.9%), bio-5 (10.2%) and bio-2 (3.4%). Jackknife test results showing the significance levels of the variables are given in Figure 3.

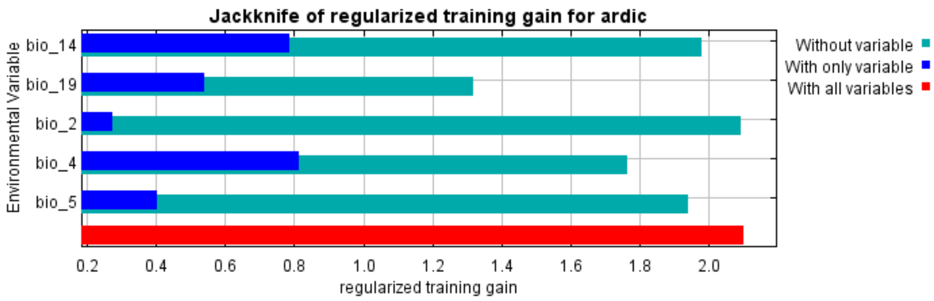

Figure 3. The Jackknife test results for indicating the relative contribution of climatic variables.

Visualization of the model created for the study area, potential distribution maps of the Crimean juniper have been acquired for the present and future (Figure 4). As a result, potential distribution maps created for the Lakes District for the present and 2070 have formed a tool that can be interpreted simultaneously.

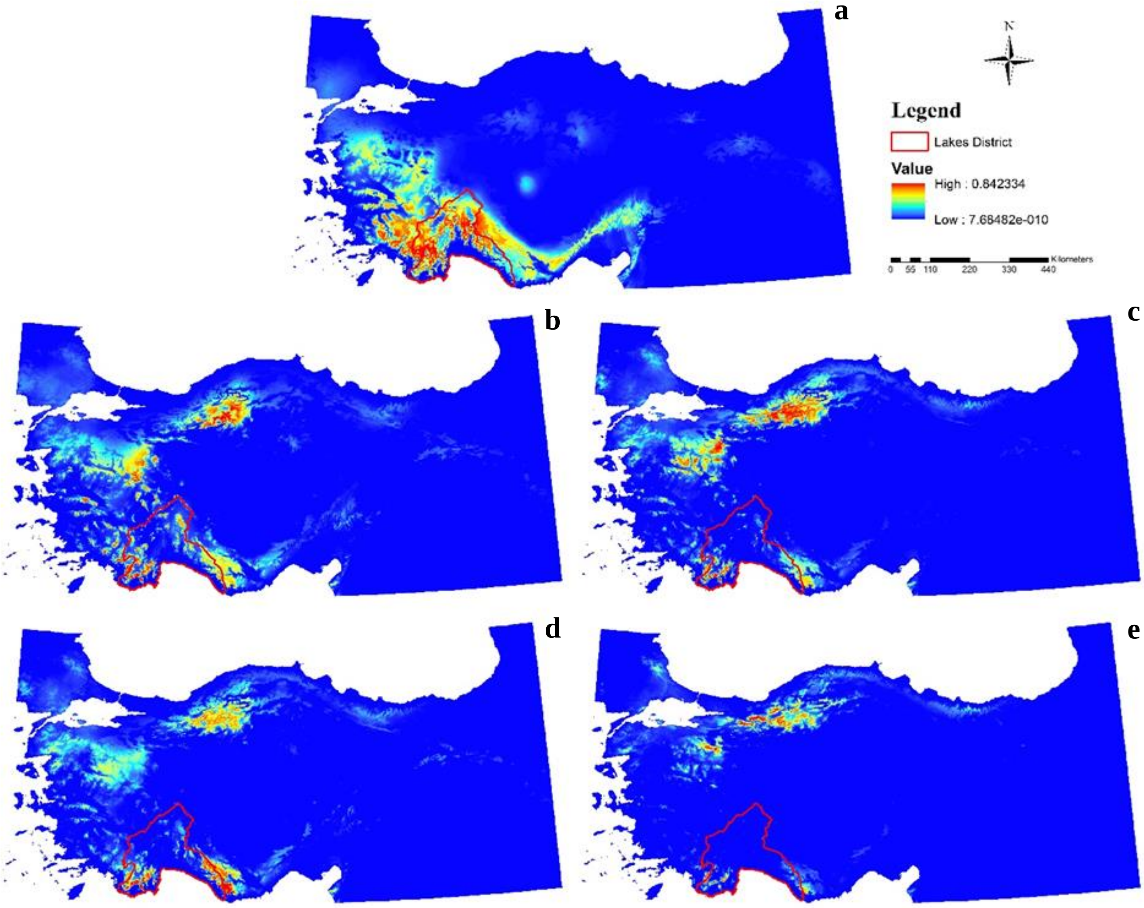

Figure 4. Predicted current (a) and future species distributions for *Juniperus excelsa* M. Bieb. (Future predictions are based on four representative concentration pathways (RCP2.6:b, RCP4.5:c, RCP6.0:d, RCP8.5:d) for 2070).

Discussion

In this study, the potential distribution modeling was carried out using the data obtained for the Crimean juniper located in the Lakes District. The predictions were visualized not only for the Lakes District but also across Turkey. Therefore, it would be more appropriate to present the findings determined for the distribution of the Crimean juniper on two different scales. Namely, considering the findings obtained, it is noteworthy that the distribution of Crimean juniper located in the Lakes District has decreased significantly in all scenarios.

As for considering the scale of Turkey shows that the distribution of Crimean juniper shifts to the western Black Sea and inner parts of western Anatolia. Besides, the significant decrease in the distribution for RCP6.0 and RCP8.5 scenarios is remarkable.

In the study, only bioclimatic variables were preferred as predictors. In this way, it is aimed to reveal possible changes in the distribution of the Crimean juniper that may occur under climate change. However, edaphic and biotic factors have an impact on the distribution of species as well as on climatic factors (Mert & Kıraç, 2017).

Although it is known that climate factors may have indirect correlation with other factors, it is also suggested that estimates can be made by including edaphic and biotic factors (Özkan et al., 2015; Mert et al., 2016; Kıraç & Mert, 2019). As it is mentioned before, modeling using bioclimate variables is often preferred to reveal the possible effects of climate change (Kurpis et al., 2019; Mohammadi et al., 2019; Atauchi et al., 2020).

The potential distribution areas obtained as a result of modeling is parallel with the distribution areas of Crimean juniper in the literature. It is stated that in literature, the Crimean juniper distributes local areas in the colder zones in the Taurus mountain range in the Mediterranean and 1000-1300m intervals in the Anatolian plateau (Özkan et al., 2015). It is also expressed that the Crimean juniper can tolerate dry and cold weather conditions. Based on this information, the actual potential distribution area of the Crimean juniper obtained is similar to the literature (Adams et al., 2013; Adams et al., 2014; Gülsoy et al., 2014a; Özkan et al., 2010a). Also, findings show that the future distributions coincide with the actual distribution of the Crimean juniper, however, there is a remarkable change and decrease in the distribution in terms of scenarios. Though, for mentioned changes to occur, other suitability parameters for the species must also be found. For instance, it is possible to have a predicted distribution with suitable bedrock corridors. Likewise, if conditions are not available, the species may have to adapt, otherwise, the continuity of the species in that locality may be endangered (Kıraç & Mert, 2019; Özdemir, 2018).

Determining the potential distribution areas of the species has great importance in terms of evaluating their ecological niches. It is thought that the findings obtained are important. Since Crimean juniper has a major role in protecting the associated flora and fauna, preventing slopes erosion and conserving the underground water (Douaihy et al., 2013).

The present and future findings acquired are thought to be a guide for decision-makers' ecosystem planning and biodiversity conservation strategies for both tall juniper species and other threatened plant species.

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