10.31195/ejejfs.435962

Eurasian Journal of Forest Science
2018 6(3): 69-82

http://dergipark.gov.tr/ejejfs

Climate change impacts on the potential distribution of *Taxus baccata* L. in the Eastern Mediterranean and the Bolkar Mountains (Turkey) from last glacial maximum to the future

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Abstract

The Pleistocene is an important period for assessing the effects of climate change on biological diversity. In the beginning of this period, many tree species disappeared in the flora of Europe, with ongoing, but smaller losses later, and many tree species exhibiting repeated strong range shifts mostly at the end of the period. It is thought that some areas will be more affected from possible climate change. The Mediterranean Basin is the most important among the mentioned sensitive areas. Species with scattered, relict populations in the region would be more affected by future climate change. One such species is *Taxus baccata*. *Taxus baccata*, which is distributed throughout the temperate zones of Northern hemisphere, is the only species of *Taxus* to be naturally distributed in Turkey. Apart from its general dispersal area in the north of Turkey, *Taxus baccata* is seen in small groups in protected local areas in southern Anatolia.

The aim of this study is to determine the potential effects of past and future climate change on the distribution of *Taxus baccata* in Bolkar Mountains, using species distribution modelling. We studied how the potential distribution has been affected by the Last Glacial Maximum (LGM) climate and the subsequent climate shift to the present, and it can be expected to be affected by future climate change, as represented by a range of future climate change scenarios. For this purpose, Maxent is used for determining the distribution of *Taxus baccata*. Our Maxent model results show that the AUC values are calculated as 0,85 and 0,80 in sequence.

Our results show that the *Taxus baccata* would have found suitable conditions in the Bolkar Mountains area even during the LGM, pointing to this as an important refuge area. With also find that the potential distribution in Kadincik Valley (on the southern slope of Bolkar Mountains) of *Taxus baccata* has been reduced with the shift to a Holocene climate, and the distribution in Taurus Mountains is likely diminish even further under future climate change.

Our results show that *Taxus baccata* is a cool-climate relict in southern Turkey and that its distribution is likely to come under further pressure from future climate change. This situation is likely shared with many other temperate plant species persisting with small populations in mountain areas in the region.

Key words: Climate change, Species Distribution Model, *Taxus baccata***,** Bolkar Mountains, Central Taurus Mountains, Turkey

Introduction

The distribution of plant species is sensitive to climate change. Paleobotanical and genetic studies show that there is a close relationship between climate change and changes in the physiological, genetic, spatial properties of plant populations and the species composition of plant communities (Medail and Diadema, 2009). When the climate conditions change, plants either migrate or adapt to the changing conditions, or, else, go extinct (Aitken et al., 2008; Ackerly et al., 2010; EEA, 2004). Mediterranean basin, our research area, is also included among these hotspots. Mediterranean basin is one of the significant centers in terms of plant diversity and endemism. This area is one of the refuges in Pleistocene for the pre-Quaternary flora of Europe (Biltekin et. al., 2017; Hewitt, 1996; Magri et al., 2017; Medail and Diadema, 2009; Martinetto et al., 2017). Therefore, these refuges will be most affected from possible climate changes in the future.

It can be stated that the ongoing climate changes have an effect on today's vegetation distribution. Glacial and interglacial periods in Pleistocene led to significant changes in the distribution of plant communities (Avcı, 2014). Glacial period in Pleistocene caused the extinction of the species that were intolerant to low temperatures (Eiserhardt et al., 2015; Svenning, 2003). Most of these extinctions happened in the beginning of Pleistocene (Biltekin et.al, 2015; Magri et. al, 2013; Martinetto, 2017). Some species in European tree flora migrated in the last period of Pleistocene (Mayol et al., 2015; Svenning et al., 2008). In this period, many nemoral tree species (*Fagus, Carpinus,* some *Quercus* species, *Tilia* and *Taxus baccata* etc.) which required relatively higher temperature was affected by the climate changes and they survived in refuges on the mountainsides stretching out east-west direction on The Pyrenees, The Alps, Iberian Peninsula and in Caucasus, Turkey, Italy (Svenning, et al., 2008; Hewitt, 1999). This condition was also been supported by the phylogeographic studies (i.e. genetic differentiation of population of nemoral species around Mediterranean and different genetic variability of the communities in the refuges of Last Glacial Maximum (LGM) within Mediterranean Basin). It became a refuge for plants in the areas of middle height in Mediterranean, which needed warmth in the Last Glacial Maximum (Svenning, et al., 2008). With temperature rise and retreat of glaciers with the transition to the Holocene, plant and animal species extended their areas to the north (Hewitt, 1999). In this period, some species which came out of refuges either hybridized or differentiated genetically (Avcı, 2011; Parker and Markwith, 2007).

The climate changes in the Quaternary led to significant changes in the sea levels, glaciers, fluvial systems in Turkey (Doğan, 2012; Kayan, 2012; Sarıkaya, 2012). All these changes also affected the dispersal area of some plants. They extended the dispersal areas of some plants while they narrowed the areas of some others. With the topographical conditions, the higher parts of the mountains, glacial valleys and depressions in Anatolia acted as a refuge for the species which were affected by the climate changes in the Pleistocene (Avcı, 2005-2011-2014). Glaciers in the Eastern Black Sea, the Central and Southeastern Taurus stretched out to a larger area especially during the Last Glacial Maximum (Turoğlu, 2011). The glaciers in the Bolkar Mountains reached their maximum size at 18.9 ± 3.3 ka. In this situation the length of the glaciers from the cirque is estimated to have reached 5.5 km. (Sarıkaya and Çiner, 2015).In this period, forest line levelled down more than today's forest line. Refuging on mountains, inner parts of valleys or around lakes, the species survived in isolated areas by varying during Last Glacial Maximum. The plants in the protected areas in Turkey which were on the migration corridor in Pleistocene constitute the significant amount of relict plants in Anatolia. The dispersal area of plant communities has changed with the changes in the climate after Last Glacial Maximum. In Holocene, the shrinking glaciers maintained its existence in the higher sections of the Bolkar Mountain. In the research area, current glaciers are gradually shrunk and covered with debris. (Sarıkaya and Çiner, 2015). While snowline was 2650 meters in Last Glacial Maximum, present snowline is 3450-3700 meters in Bolkar Mountains **(**Çiner and Sarıkaya, 2015). With the retreat of glaciers, forest line levelled up and plant communities extended their dispersal areas vertically (Avcı, 2005-2011-2014).

Many plant and animal species will be unable to adapt locally or move fast enough to track suitable climates. With the effect of climate change or other stress factors, many species will face the extinction in the future or during climate change (IPCC, 2014).
Some species *(e.g. Cedrus libani, Juniperus drupacea)* have limited, scattered distribution areas in Mediterranean Basin, one of the most sensitive areas in terms of possible climate change. Climate change causes changes in the frequency, intensity, area distribution and timing of extreme weather and climate events. The frequency of heavy precipitation events has increased over most areas. From 1900 to 2005, precipitation increased significantly in the Mediterranean (IPCC,2007).
The Bolkar Mountains in the Mediterranean Basin are rich in plant diversity and reflect the changing processes well. The investigative site, biodiversity conservation area, is an important part of the habitats of endangered species. The forests that are distributed outside the local climatic zones, which emerged as a result of topography in the Bolkar Mountains, are all dry forests. But the changes in the climate conditions between the northern and southern parts of the Bolkar Mountains have caused some changes in the main species in the dry forest areas. Inside the valley there are relatively more species of hygrophilous such as *Taxus baccata*.
Based on the mentioned reasons, by taking the different climate change scenarios into consideration, we have studied the state of temperate, relatively moisture-demanding European yew (*Taxus baccata),* which survives in the protected places on the Bolkar Mountains, in the Last Glacial Maximum and its future distribution area in our research. In this context, we tried find answers to these following questions:
- How was the potential distribution of *Taxus baccata* on the Bolkar Mountains in the Last Glacial Maximum? Did this area have potential to act as a glacial refuge for the species?
- How is the potential distribution of *Taxus baccata* today? Can the species already today be considered a climate relict species in the region?
- How will be the distribution of *Taxus baccata* in the future? Notably, will the species come under future climate stress?

Study area

The southern slopes of Bolkar Mountains, stretching roughly in the line of NE-SW, are under the effect of Mediterranean climate. Precipitation and temperature properties change as the altitude changes on the mountains. In Mersin station in 7 m altitude, the mean annual temperature is 28.0 °C, mean annual precipitation is 589.1 mm while in 2000 m altitude, temperature is 18.0 °C, and precipitation is around 1627.5 mm. In Tarsus meteorology station in 12 m altitude, the temperature is 27.1 °C and precipitation is 610.8 mm. As the altitude increases, temperature lowers to around 17.0 °C in 2000 m, precipitation levels up to around 1675.5 mm. Northern slopes on Bolkar Mountains is different from southern slopes. Since these areas are open to the north, they are more under the effect of continental climate. The temperature and rainfall properties on Bolkar Mountains change within short distances.

The vegetation on Bolkar Mountains consists of 3 groups: forest, shrub and alpine formations. Dried forests constitute the forest formation in the research area. Dried forests in the southern part of the area generally consist of tree species like *Pinus brutia*, *P. nigra*, *Abies cilicica* subsp. *cilicica*, *Juniperus drupacea* and *Cedrus libani*, in the northern part they consist of *P. nigra, J. excelsa*, *Quercus pubescens* and *Q. ithaburensis* subsp. *macrolepis*. Shrub formation arising from forest destruction is usually represented by maquis. Alpine plants start approximately from 2100 m and they are also very rich in plant species such as *Astragalus sp., Acantholimon sp., Ononis sp., Marrubium sp., Onasma sp*., *Eryngium sp*..

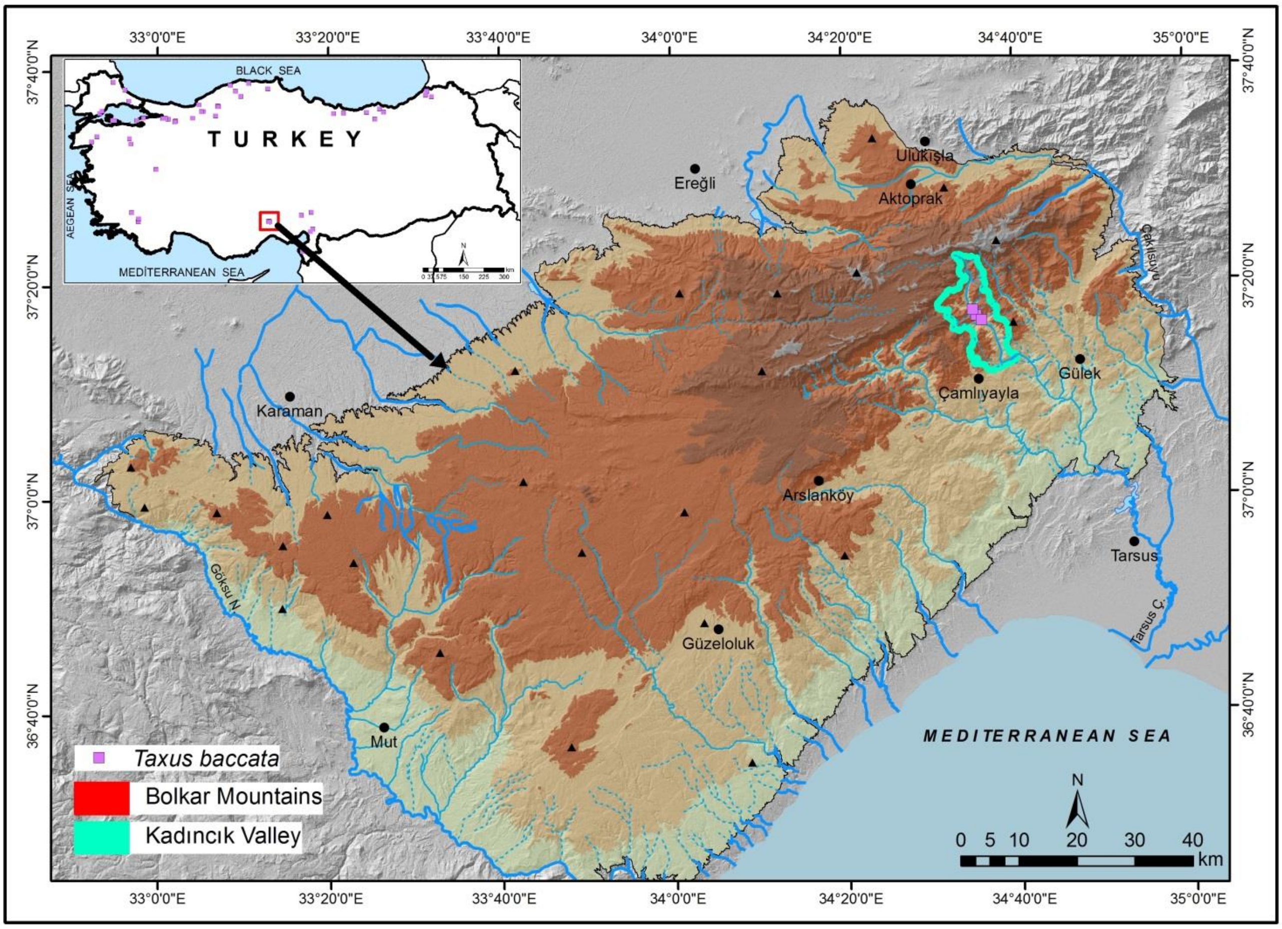

Figure 1. Location map of Bolkar Mountains

Apart from the general distribution, deep valleys in Bolkar Mountains are also rich in terms of flora and they are in contradiction with its environment. The existence of *Taxus baccata* in the deep Kadincik Valley on the southern slope of Bolkar Mountains is quite remarkable. Developing in a protected area because of topographic conditions, *Taxus baccata* which is a nemoral tree species due to the local climatic conditions had the opportunity to thrive. In this area, other main hygrophilous species that accompany *Taxus baccata* are *Carpinus orientalis, Salix alba, Salix caprea, Ostrya carpinifolia, Fraxinus ornus* subsp. *cilicica, Alnus glutinosa, Ulmus glabra* subsp. *montana* and *Juglans regia.*

2. Materials and Methods

2.1. Study species

Taxus L. is naturally represented by 10 species in the Eastern Asia, North Africa, Anatolia, Europe and North America. *Taxus baccata* is evergreen conifer species that is distributed in Central and Southern Europe, Northwestern Africa, Northern Iran and Southwest Asia. Distributed mostly in temperate zones of Northern hemisphere, *Taxus baccata* is the only species of *Taxus* to be naturally distributed in Turkey. Its largest distribution area in Turkey is Black Sea Region (Coode and Cullen, 1965; Farjon and Filer, 2013).

Older members of this species is usually found between 300-1500 m a.s.l of the forest areas in Northern Turkey. Found alone or in small groups in the mentioned areas, *Taxus baccata* is shade-adapted, sensitive to low temperatures and frost. Apart from its general distribution area in the North of Turkey, *Taxus baccata* is seen in small groups on the Sultan Mountains, Denizli Bozdağ, the Amanos Mountains and the Bolkar Mountains (Coode and Cullen, 1965). Distributing sporadically in different regions besides these areas, *Taxus baccata* is seen occasionally in the protected areas in the upper course of Kadincik Stream Valley on the research area, Bolkar Mountains.

2.2. Species Distribution Data

In addition to the survey of the distribution data of *Taxus baccata* in Europe, their distribution areas in Turkey, surveys and *Flora of Turkey and the East Aegean Islands* (Davis, 1965-1985; Davis et al., 1988; Güner et al., 2008; Özhatay and Kültür, 2006; Özhatay et al., 1999-2009-2011) and herbarium samples (34 registries) are supplied by scanning from the database (729 registries) of Atlas Florae Europaeae (AFE), Global Biodiversity Information Facility (GBIF). AFE 50x50 km grid system based on Universal Transverse Mercator (UTM) and the Military Grid Reference (MGRS) is used for absolute data for distribution projections of *Taxus baccata* (Luomus, 2017) (Figure 2)

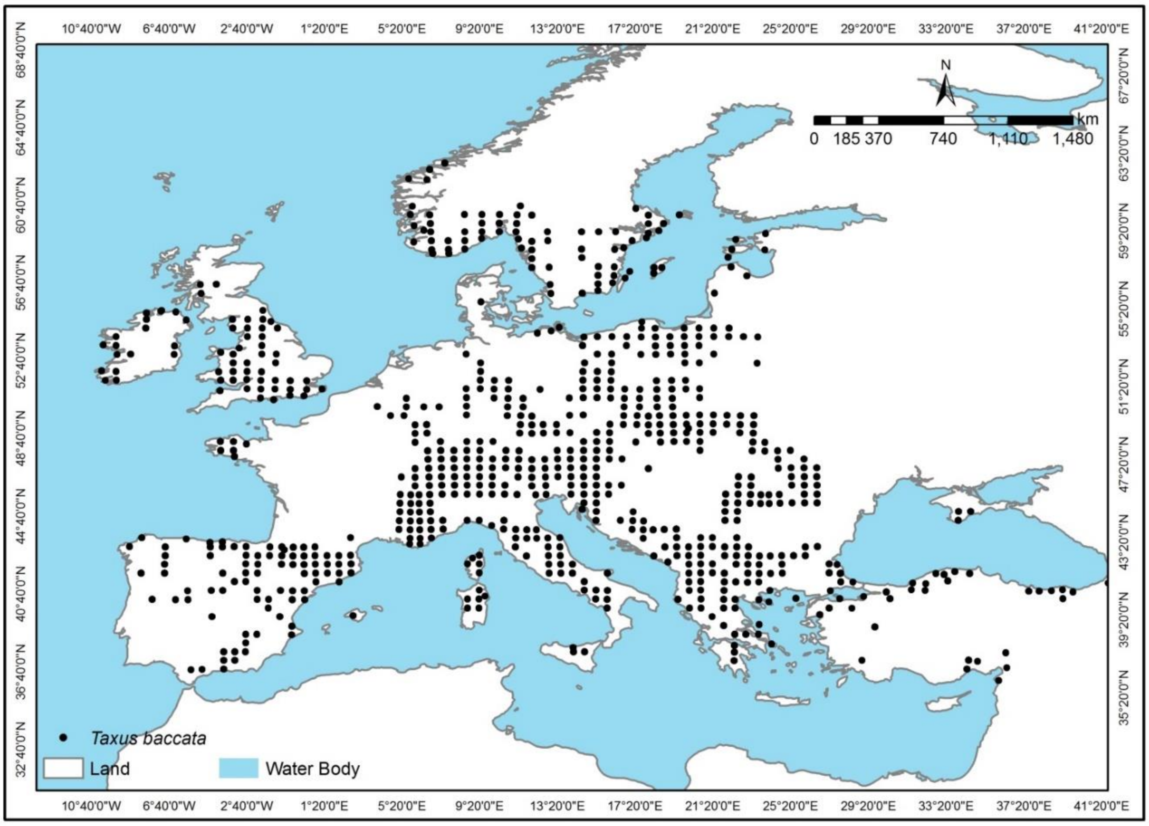

Figure 2. Occurrence data distribution map for *Taxus baccata*

In order to interpret the past and future distribution patterns of *Taxus baccata* in our research area, this species distribution around Bolkar Mountains in these periods should be examined. Therefore, smaller scaled distribution patterns that show Turkey and its surroundings are produced. However, only the distributions of it on Bolkar Mountains are crucial for this research.

2.3. Climate Data

CMIP5 is used for past and future climate data in the species distribution models. (MIROC ESM Model for Interdisciplinary Research on Climate) which has been produced for RCP (Representative

Concentration Pathways) 8,5 scenario, and CCSM4 (Community Climate System Model is used in the model. The data produced by CCSM4 and MIROC ESM are compared and it has been decided that the models produced by CSSM4 is appropriate for this study.
In order to put forth the present situation, the data produced by interpolating the data of weather stations in different parts of the world (Hijmans et al. 2005).

The data related to the applied models are 2,5 arc-minute/~5 km resolution for Last Glacial Maximum, 30 arc-second/~1 km resolution for future. Data that involves today's conditions are 30 arc-second/~1 km resolution.
19 climate variables supplied from the WorldClim database are used for species distribution models (Table 1). Modeling is done for all the areas where *Taxus baccata* shows and clips our study area from inside. For this reason, we think it would be appropriate to use 19 variables. Relevant climate variables represent the climate conditions of today (between 1950-2000), Last Glacial Maximum (~22,000 year ago) and future (between ~2061-2080).

Table 1. Bioclimatic variables and their explanations

Bioclimatic Variable	Explanation
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3	Isothermality (BIO2/BIO7) (* 100)
BIO4	Temperature Seasonality (standard deviation *100)
BIO5	Max Temperature of Warmest Month
BIO6	Min Temperature of Coldest Month
BIO7	Temperature Annual Range (BIO5-BIO6)
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

Species Distribution Modelling

Maxent 3,3,3 Maximum Entropy Modelling of Species has been used in order to predict how *Taxus baccata* distributed in the areas in the past and how it will be distributed in the future. Maxent has been designed to make predictions on incomplete data (Phillips et. al, 2006). The model was run more than once for species with its "replicate" feature and "cross-validation" is used in the produced species distribution model. It is stated that this cross validation method shows correct results in small data sets since it is used for data verification (Beton, 2011). Therefore, 15 replicates are used in this research, 500 iterations has been done for each replicate. In the study, the potential dispersal areas of *Taxus baccata* in the past, future and at present are estimated and projected by Maxent model, using today's climate data.

The performance of the produced species distribution model was tested by ROC (Receiver Operating Characteristic) analyses, using the AUC (Area Under the ROC Curve) metric to describe the model's discriminatory capacity (Phillips et al., 2006). The closer AUC test value is to 1, the better the distinction is, model is sensitive and descriptive (Oliveria et al., 2010). The models with AUC test value between 0.75-1.00 can considered to have high predictive power. Values about 0.5 show that the model is not sensitive and it is not sufficient in descriptiveness better than a random draw (Elith, 2002; Phillips and Dudik, 2008).

One of the methods we use while investigating the contributions of variables in the model output is jack-knife. According to this method, each variable included in the model is left out in each repetition and remaining ones are evaluated. After that all variables are included in the analysis and the model is run and evaluations are carried out (Pearson et al., 2007). Therefore, the contribution of each variable to the model is defined. In other words, the lower the total gets when one variable is left out, the more significant the left-out variable is.

Results

Climatic forcing in the Species Distribution Model

Maxent models with adequate predictive power were applied to past, present, and future climate data to assess the potential distribution of *Taxus baccata* in these periods.

Predicted possible distribution map of the species distribution model which are carried out with Maxent for *Taxus baccata*, showed better results than random prediction. ROC curve charts show us that compatible models are produced (Figure 3).

ROC is formed to test the model and accordingly, for model test and training data, AUC values are calculated as 0,85 and 0,80 in sequence and standard deviation is calculated as 0.014. That AUC test values are close to 1 and standard deviation is low shows that both models are successful

The percentage contribution to dispersal pattern obtained from the model result of used 19 bioclimatic parameters is included in the model output. Accordingly, BIO4 has contributed %53,8, BIO 7 %13,9 BIO6 %7,7.

Among the contributions of 19 variables to the model, it is seen that BIO4, one of the most effective variables in the model output according to the jackknife analysis of the Maxent model, has contributed to the model the most when the variables evaluated relatively. When the jackknife analysis is evaluated alone, the contribution of the other variables (BIO7, BIO11, BIO6) that contribute to the model increase along with BIO4 (Figure 4).

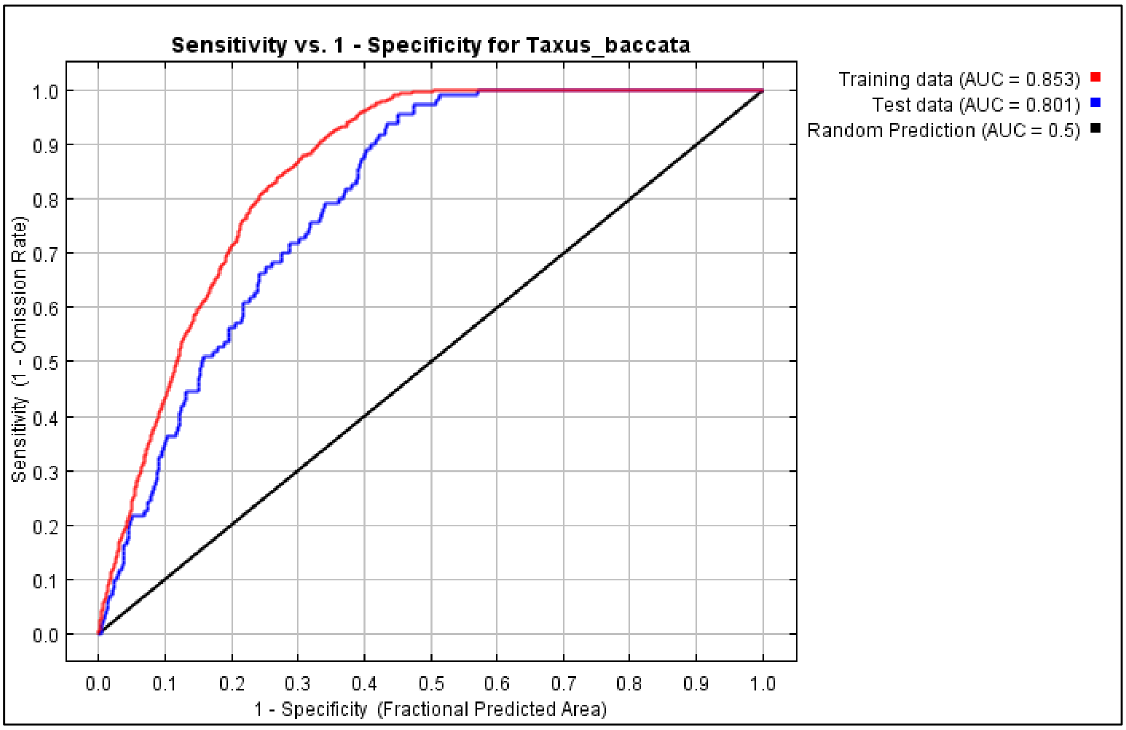

Figure 3. ROC curve and AUC values for Maxent model

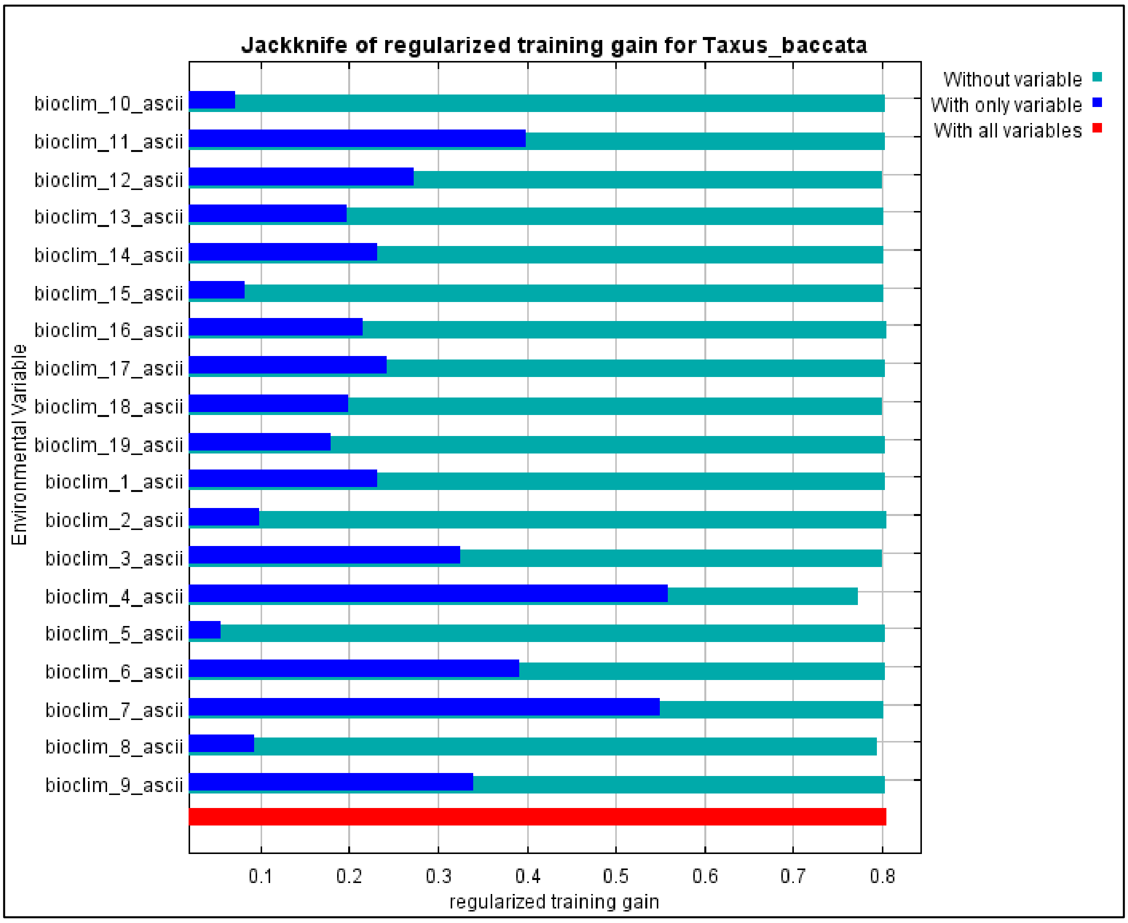

Figure 4. Jackknife test of variable importance of *Taxus baccata*

3.2 Potential Taxus baccata Distributions during the Last Glacial Maximum*, Current and Future*

Considering the potential distribution of *Taxus baccata* during the Last Glacial Maximum, especially the northern Anatolian coasts had the suitable conditions for *Taxus baccata* (Figure 5). These suitable areas stretch out to the east of Colchic area, and encircle the Marmara Sea from the coasts of Black Sea to the west. They further extend from the southern coasts of the Marmara Sea to the Kaz Mountains in the west. *Taxus baccata* range to the Taurus Mountains by the mountainside corridor in the inner parts of Anatolia. Inner parts of the protected valleys of the mountain areas in southern Anatolia also had suitable conditions for *Taxus baccata* during Last Glacial Maximum, including the Bolkar and Amanos Mountains (Figure 5), which hence may have functioned as glacial refuge regions.

Compared to the Last Glacial Maximum potential distribution in the area, the current potential distribution is increased in northern and western Turkey, but reduced in the south-eastern part (Figure 5), suggesting that populations here can be considered climatic relicts. However, current suitability in the Bolkar Mountains is much larger than during the LGM (Figure 6).

Under future climate change, as represented by the CCSM scenario, *Taxus baccata* will lose major part of its suitable distribution area in the south of Anatolia (Figure 5) as well as in the Bolkar Mountains specifically (Figure 6).

Discussion and Conclusions

The Quaternary is the period in which are of suitable climatic conditions for temperate vegetation was limited in Turkey and significant floristic changes happened vegetation zones moved down vertically a few hundred meters in glacial periods, it moved up a few hundreds in interglacial period. The last one of the mentioned climate changes happened in Last Glacial Maximum. Glaciers which cover larger areas in Last Glacial Maximum on the higher parts of Bolkar Mountains and permanent snowline which was lower than today's lowered the forest line. Changing conditions after this period caused changes in the dispersal area of plant communities. Vegetation zones moved up vertically due to the withdrawal of glaciers and the rise of permanent snowline. In sum, the species that need warmer temperatures can move away from any area or totally disappear in the cold climate following a warmer one after the possible climate change. Instead, plants that are more tolerant to cold climates take place. If the area is mountainous, heat-tolerant plants take shelter in inner parts of valleys and to the southern slopes.

Although dry forests are dominant in our research area, the species which needs respectively more humidity such as *Taxus baccata, Ostrya carpinifolia, Carpinus orientalis, Corylus avellena, Cornus sanguinea* are seen in the inner parts of Kadincik Valley which is a protected area. Both climate and morphological features of the land are quite effective on plant diversity on the area.

The questions need to be answered in our research are: What are the changes in the dispersal area of *Taxus baccata* in Last Glacial Maximum, today and in the future?

Applied ENM (Ecological Niche Modelling) Assessment: While assessing the obtained results of Maxent, it must not be ignored that the modelling is based on the prediction and it is not accurate. The statistical validity of results obtained by Maxent method is carried out by tests along with model analysis. Within the scope of statistical try-outs, modellings have given meaningful results.

Distribution of Taxus baccata: As the distribution pattern of Last Glacial Maximum is examined, it is necessary to mention the past possible distribution of *Taxus baccata*. When LGM model is analyzed; it is observed that there are suitable conditions for this species to disperse on Bolkar Mountains in this period. According to the species distribution models carried out for *Taxus baccata*, a tree species belonging to Europe-Siberia flora region, likely shifted to Mediterranean in Last Glacial Maximum and after with the temperature rise, it shifted to the northern latitudes. Also some modeling studies

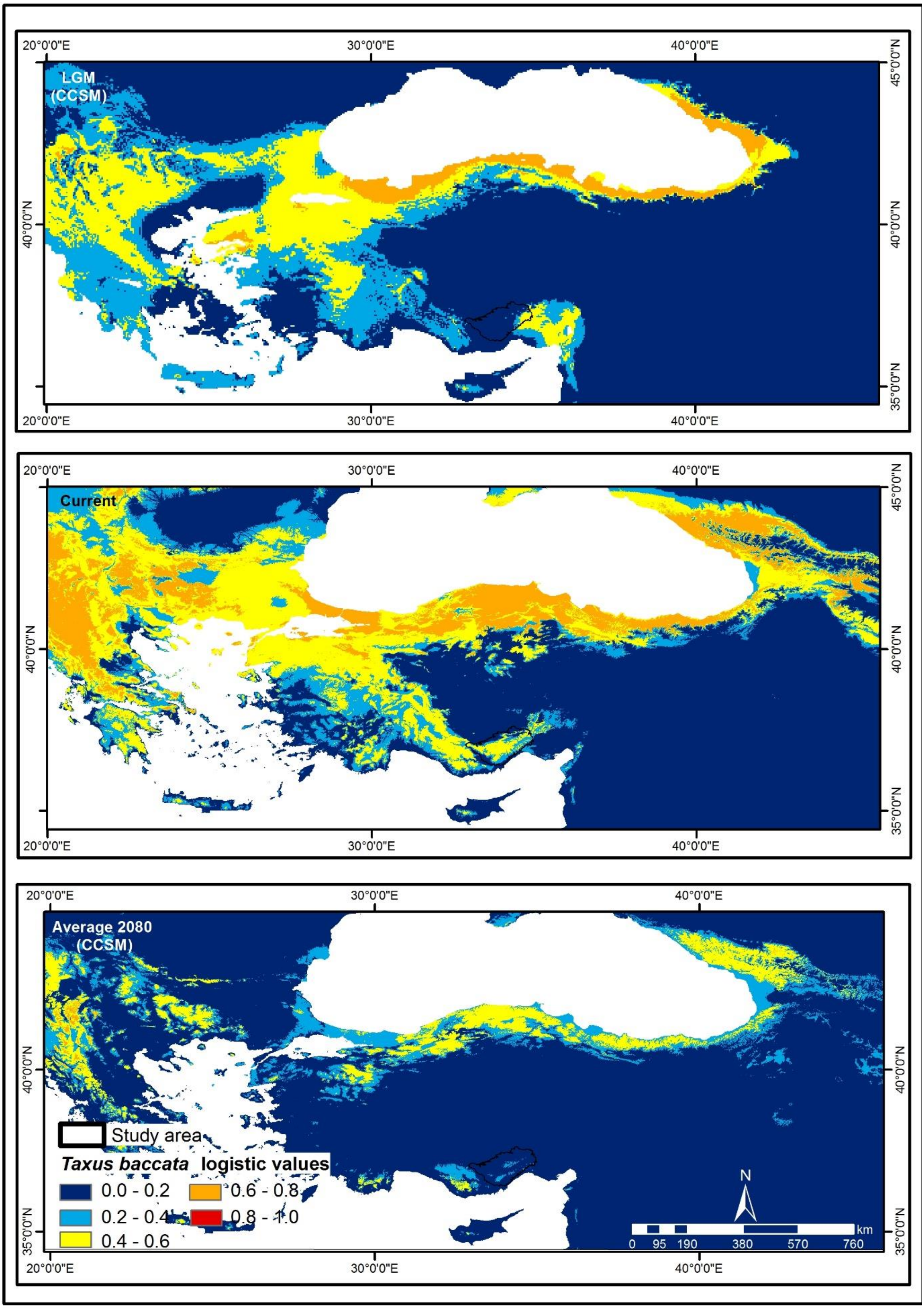

Figure 5. The Last Glacial Maximum, today and approximately 2080 distribution of *Taxus baccata* around Turkey and surroundings

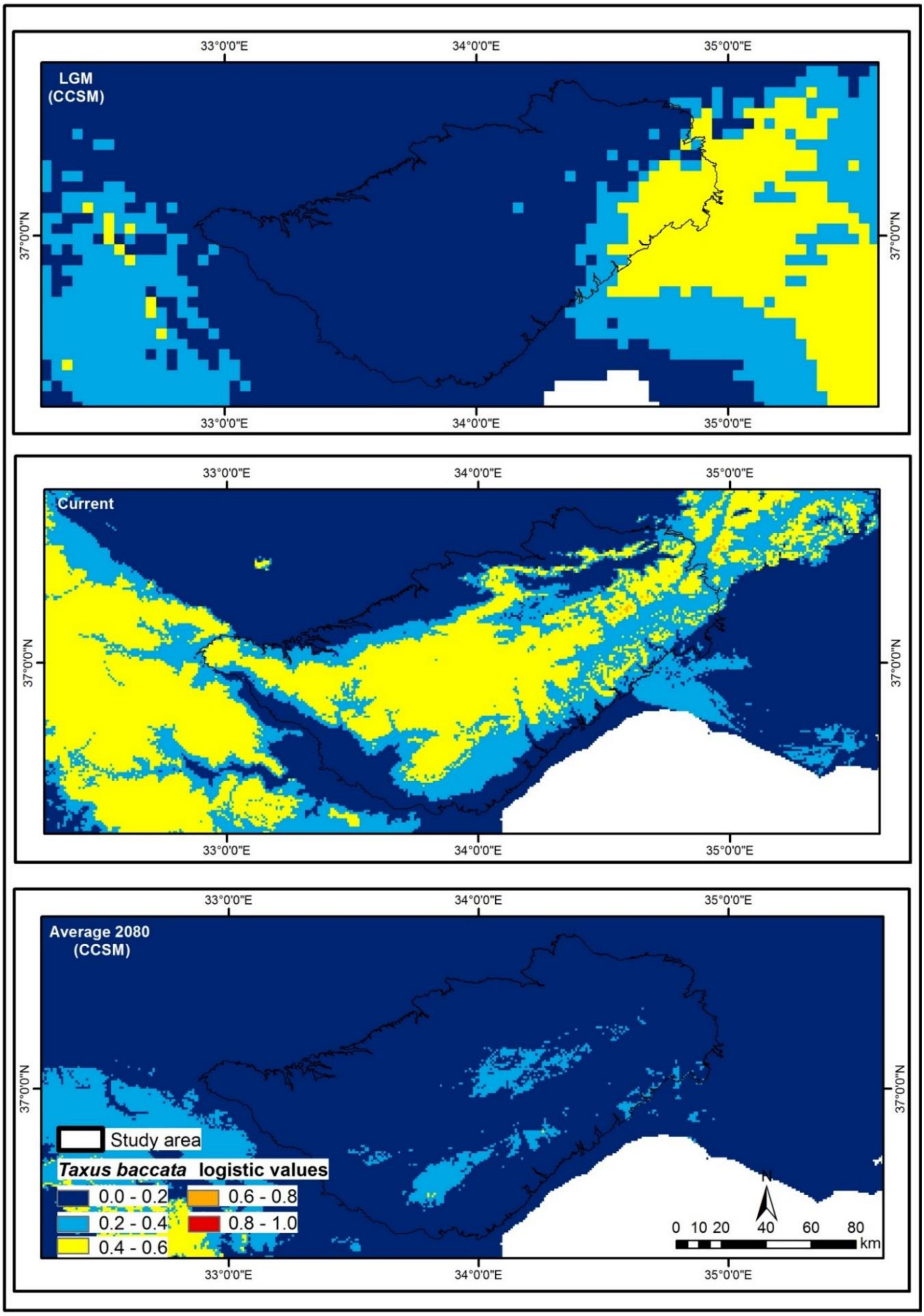

Figure 6. The Last Glacial Maximum, today and approximately 2080 distribution of *Taxus baccata* around Bolkar Mountains.

about hygrophilous species show similar results with *Taxus baccata* in Anatolia (Dyderski et al., 2017). Paleoecological research based on plant macrofossils and pollen fossils revealed the distribution of *Taxus baccata* in the Mediterranean basin with the rise in the rainfall in the Paleogene (Sadori et al., 2004; Drescher-Schneider et al., 2007) Paleogeographic studies support the idea that there were more refuge in the Mediterranean and Black sea regions for nemoral tree species in Last Glacial Maximum (Leroy & Arpe 2007). In the pollen analysis carried out in the marsh lands of Akgöl (in Ereğli-in the north of Bolkar Mountains), younger Dryas climate has been observed. In pollen diagrams, some sporadic species that are sensitive to relatively low temperatures like *Betula* has been seen today around the research area. In Late Quaternary, high pollen count pertaining to broad leaved tree species like *Fraxinus ornus* and *Quercus* are seen clearly in another pollen study done around Beyşehir Lake (in North West of Bolkar Mountains) close to our research area (Bottema & Woldring, 1984; van Zeist et al., 1975; Bottema & Woldring, 2001-2002). Considering today's distribution of *Taxus baccata* on Bolkar Mountains, it is thought that the distribution of this species is possible during LGM.

In our research area, *Taxus baccata* survives in microclimate areas that will constitute a refuge in the area. Taking the above mentioned conditions into consideration, it is considered that today's distribution of the species has taken its shape with the effect of last glacial period (Figure 5). As a conclusion, migration corridor in LGM is not constituted by the Anatolian Diagonal between Central and Eastern Anatolia for *Taxus baccata* dispersing on the mountainsides in the south of Anatolia. In other words, "migration corridor" for *Taxus baccata* in Anatolia is composed by the mountainsides in the inner parts of west Anatolia. Relatively high mountains on this corridor (such as Murat Mountain , Yirce Mountain, the Sultan Mountains and the mountainsides of lakes region) could make step stones in the migration of *Taxus baccata* to the south. Ranging to Taşeli Plateau, *Taxus baccata* could have found the opportunity to disperse to the Bolkars and Amanos Mountains in the east. The microclimatic factor of Kadıncık Valley and its topographical structure have affected the distribution of the species.

Under the climate changes expected, our results suggest that the Bolkar Mounatins will no longer be a suitable area for the distribution of *Taxus baccata*. *Taxus baccata* has already limited distribution in the research area and in the protected areas inside the valleys that can be a refuge for them. Hence, there is a high risk that they will become extinct in the region, although it is important to note that remnant populations or individuals may be able to survive for a long time, for example in microclimatically less stressful microsites. To limit this risk, it is important to ensure that current occurrences in the region are adequately protected and not subject to land use pressures, as well as to include the species in reforestation plans for sites locally or elsewhere in Turkey that are estimated to remain suitable under the expected future climate change.

Acknowledgements: This research was supported by the Scientific Research Projects Unit of Istanbul University (Project Number: 32478) and is part of the PhD thesis of Derya Evrim KOC.

JCS considers this work a contribution to his VILLUM Investigator project funded by VILLUM FONDEN (grant 16549) and also to his TREECHANGE project funded by from the Danish Council for Independent Research | Natural Sciences (grant 6108-00078B).

References

Ackerly, D.D., Loarie S.R., Cornwell W.K., Kraft H.J., Weiss S.B., Hamilton H. & Branciforte R. (2010). The geographyof climate change: implications for conservation biogeography. Diversity and Distributions 16: 476–487.

Aitken, S., Yeaman, S., Holliday, J., Wang, T. & Curtis, McLane S. (2008). Adaptation, migration or extirpation: climate change outcomes for tree populations. Evolutionary Applications 1(1): 91-111.

Avcı, M. (2005). Çeşitlilik ve endemizm açısından Türkiye'nin bitki örtüsü. İstanbul Üniversitesi Edebiyat Fakültesi Coğrafya Bölümü Coğrafya Dergisi 13:27-55.

Avcı, M. (2011). Moleküler Biyocoğrafya: Gelişimi, kapsamı, paleobiyocoğrafya ve biyolojik çeşitlilik açısından bir değerlendirme: Fiziki Coğrafya Araştırmaları (ed. by D. Ekinci) Türk Coğrafya Kurumu, İstanbul, pp.241-266.

Avcı, M. (2014). Paleocoğrafya: Resimli türkiye florası I (ed. by A. Güner & T. Ekim) Ali Nihat Gökyiğit Vakfı, Flora Araştırmaları Derneği ve Türkiye İş Bankası Kültür Yayınları Yayını, İstanbul, pp. 49-75.

Baldwin, R. (2009). Use of maximum entropy modeling in wildlife research. Entropy11: 854-866.

Bennett, K., Tzedakis, P. & Willis, K. (1991). Quaternary refugia of north european trees. Journal of Biogeography 18:103-115.

Beton, D. (2011). Effects of climate change on biodiversity: a case study on four plant species using distribution models. Ortadoğu Teknik Üniversitesi Fen Bilimleri Enstitüsü, Doktora Tezi, Ankara.

Biltekin, D., Speranta-Maria, P., Suc, J-P., Qu´ezel, P., Jim´enez-Moreno, G., Yavuz, N. & Çağatay, M. (2015). Anatolia: a long-time plant refuge area documented by pollen records over the last 23 million years. Review of Palaeobotany and Palynology (215):1-22.

Bottema, S. & Woldring, H. (1984). Late Quaternary vegetation and climate of Southwest Turkey II. Palaeohistoria 26:123-149.

Coode, M. & Cullen, J. (1965). *Taxus* L.: Flora of Turkey and the east aegean islands (Vol.I) (ed. by P. Davis, M. Coode & J. Cullen) Edinburgh University Press, Edinburgh, pp. 75-76.

Davis, P.H. (1965-1985). Flora of Turkey and the east aegean islands (Vol1-9) Edinburgh University Press, Edinburgh.

Davis, P.H., Mill, R. & Tan, K. (1988). Flora of Turkey and the East Aegean islands (Vol 10) Edinburgh University Press, Edinburgh..

Doğan, U., (2012). Akarsu Süreçleri: Kuvaterner Bilimi (ed. by N Kazancı & A Gürbüz) Ankara Üniversitesi Yayınları, Ankara, pp.281-306:

Donatella, M., Rita, D., Aranabarri, J., Filetcher, W. & Gonzalez Samperiz, P. (2017). Quaternary disappearance of tree taxa from southern europe: timing and trends. Quaternary Science Reviews 163: 23-55.

Drescher-Schneider, R., de Beaulieu, J.L., Magny, M., Walter-Simonnet, A.V., Bossuet, G., Millet, L., . . . Drescher, A. (2007). Vegetation history, climate and human impact over the last 15.000 years at Lago dell'Accesa (Tuscany, Central Italy). Vegetation History and Archaeobotany 16:279-299.

Eastwood, W. (2004). East Mediterranean vegetation and climate change: Balkan Biodiversity: Pattern and Process in the European Hotspot (ed. by H. Griffiths, B. Kryštufek & J. Reed) Springer Science Business Media, Holland, pp.25-48.

EEA (2004). Impacts of Europe's changing climate(an indicator-based assesment) European Environment Agency, Denmark.

Elith, J. (2002). Quantitative methods for modeling species habitat: comperative performance and an aplication to australian plants (ed. by S Ferson & M Burgman) Quantitative Methods for Conservation Biology Springer New York, pp. 39-58.

Farjon, A. & Filer, D. (2013). An atlas of the world's an analysis of their distribution. Biogeography, Diversity and Conservation Status Boston, Brill.

Güner, A., Özhatay, N., Ekim, T. & Başer, K. (2008). Flora of Turkey and East Agean Islands (Vol 11). Edinburg, Edinburg University Press.

Hewitt, G. (1996). Some genetic consequences of ice ages, and their role in divergence and speciation. Biological Journal of the Linnean Society 58: 247–276.

Hewitt, G. (1999). Post-glacial re-colonization of European biota. Biological Journal of the Linnean Society 68:87-112.

Hijmans. R, Cameron S, Parra J, Jones P & Jarvis A (2005) Very hight resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.

Intergovernmental Panel on Climate Change (2007). The physical science basis. contribution of working group to the fourth assessment. Cambridge, Cambridge University Press.

Intergovernmental Panel on Climate Change (2014). Climate change 2014 synthesis report, contribution of working groups i, ii and iii to the fifth assessment report of the intergovernmental panel on climate change (ed. by Core Writing Team, R Pachauri & L Meyer) Switzerland, Geneva.

Kayhan, İ. (2012). Kuvaterner'de deniz seviyeleri değişmeleri: Kuvaterner Bilimi (ed. by N. Kazancı & A. Gürbüz) Ankara Üniversitesi Yayınları, Ankara, pp.59-78.

Martinetto, E., Momohara, A., Bizzarri, R., Baldanza, A., Delfino, M., Esu, D. & Sardella. R. (2017). Late persistence and deterministic extinction of "humid thermophilous plant taxa of East Asian affinity" (HUTEA) in Southern Europe. Palaeogeography, Palaeoclimatology, Palaeoecology (467): 211-231.

Mayol, M., Riba, M., González-Martínez, S.C., Bagnoli, F., de Beaulieu, J.L., Berganzo, E., Burgarella, C., Dubreuil, M., Krajmerová, D., Paule, L., Romšáková, I., Vettori, C., Vincenot, L., Vendramin, G.G. (2015). Adapting through glacial cycles: insights from a long-lived tree (*Taxus baccata).* New Phytologist (208)3: 973-986.

Medail, F. & Diadema, K. (2009). Glacial refugia influence plant diversity patterns in the Mediterranean Basin. Journal of Biogeography 36: 1333-1345.

Oliveira, M., Hamilton, S., Calheiros, D., Jacobi, C. & Latini, R. (2010). Modeling the potential distribution of the invasive Golden Mussel Limnoperna Fortunei in the Paraguay river system using limnological variables. Brazilian Journal of Biology 70(3): 831-840.

Parker, K. & Markwith, S. (2007). Expanding biogeographic horizons with genetic approaches. Geography Compass 1(3): 246-274.

Pearson, R., Christopher, J.R., Nakamura, M. & Peterson, A. (2007). Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in madagascar. Journal of Biogeography 34:102-117.

Phillips, S. & Dudik, M. (2008). Modelling of species distribution with maxent: new extensions and a comprehensive evalution. Ecography 31(2): 161-175.

Phillips, S., Robert, P., Anderso, C. & Robert, E. (2006). Maximum entropy modeling of species geographic distribution. Ecological Modeling 190(3-4): 231-259.

Sadori, L., Giraudi, C., Petitti, P., & Ramrath, A. (2004). Human impact at Lago di Mezzano (Central Italy) during the bronze age: a multidisciplinary approach. Quaternary International 113(1): 5-17.

Sarıkaya, M. (2012). Kuvaterner buzullaşmaları; yayılımı ve zamanlası: Kuvaterner Bilimi (ed. by N. Kazancı & A. Gürbüz), Ankara Üniversitesi Yayınları, Ankara, pp. 41-58.

Svenning, J.C., Normand, S. & Kageyama, M. (2008). Glacial refugia of temperate trees in Europe: insights from species distribution modelling. Journal of Ecolog 96(6): 1117-1127

Turoğlu, H. (2011). Buzullar ve Buzul Jeomorfolojisi. Çantay Kitapevi, İstanbul.

van Zeist, W., Woldring, H. & Stapert, D. (1975). Late Quaternary vegetation and climate of southwestern Turkey. *Palaeohistoria* 17: 53-143.

Woldring, H. & Bottema, S. (2001-2002). The vegetation history of East-Central Anatolia in relation to archaeology: the Eski Acigol pollen evidence compared with the near eastern environment. P*alaeohistoria* 43/44: 1-34.

Submitted:23.06.2018
Accepted: 26.10.2018