Maxent modeling for predicting the potential distribution of *Arbutus andrachne* L. belonging to climate change in Turkey.

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Abstract

Arbutus andrachne L., the strawberry tree, is an evergreen shrub or small tree in the Turkish flora and has broad uses. The wood is used for decorative purposes, packaging, and manufacturing furniture. The fruits are edible and used in treating many kinds of diseases. However, global warming might affect the abundance of this symbolic plant's distribution, especially at higher latitudes. This study was conducted to determine the expected effects of climate change on *A. andrachne.* For this purpose, Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 were used to expect climate change scenarios for 2050 and 2070, and potential distribution areas of *A. andrachne* were presented. The results indicated that the distribution of *A. andrachne* would decrease in the southern regions of Turkey. However, the spread of the species could be expanded in the western and northern areas. It is also expected that there would be potential habitat losses, which would affect the distribution of *A. andrachne.*

Keywords: *Arbutus andrachne*; distribution; Maxent; RCP 4.5; RCP 8.5; Turkey.

1. Introduction

All living organisms in nature (animals, plants, and microorganisms) are living in a delicate balance. Animals and plants are used to meet human needs (Gezgin, 2006). The demand for forest resources, considered one of the most important natural resources, has changed qualitatively and quantitatively due to rapid population growth during the second half of the twentieth century. Other factors such as technological developments, increased income, and individuals' education levels are other factors that led to the over-exploitation of natural resources (Ozkan & Akbulut, 2014). In recent years, the demand for non-wood forest products has increased significantly; therefore, forest resources have drawn new awareness (Bektas, 2014). Today, with the evaluation of plants in each country's flora, it is becoming increasingly important to cultivate new fruit species, expand their production and use areas, and use new plant species in landscape studies (Onursal & Gozlekci 2007; Nuh, 2015).

There are 12 species in the genus *Arbutus,* which belong to the Ericaeae family and are found in the Mediterranean, North West, and Central America. *Arbutus* taxa are evergreen, woody plants that take the form of tall shrubs. *Arbutus unedo* and *A. andrachne* are growing naturally in Turkey (Ansin & Ozkan, 1993). These two species are of great importance in Turkish forestry. This importance comes from the fact that these species' wood is used in packaging, chair and furniture construction, decorative, and biofuel. Also, the fruits are commonly consumed by humans and animals because they are rich in sugar and vitamin C (Sumbul *et al*., 2005; Aslan, 2011).

Arbutus andrachne has a wide distribution of up to 800 m elevations in southern Albania, Greece, Turkey, the Black Sea to Crimea to Lebanon and northern Iraq (Kayacik, 1982). It spreads in maquis stands, pine forests in the arid cliffs of coastal regions in Turkey. *A. andrachne* is a slow-growing species that develops well in nitrogenous, well-drained, and fertile soils but can also grow on stony, rocky slopes, calcareous and volcanic rock (Gungor *et al*., 2002).

Arbutus andrachne is an evergreen, thickly branched shrub or small tree that can reach up to 5-6 m in height. Young shoots are feathered. The leaves are broad, oval with a straight edge. The leaves are geared only in young plants. Their upper faces are dark, but the lower sides are light green and lint-free. The greenish-cream-colored flowers form in perforated compound clusters and bloom from March to April. The fruits, which ripen in autumn, are 1.0-1.5 cm in diameter and orange-yellow to light red (Kayacik, 1982).

Arbutus, one of the symbolic plants of Mediterranean vegetation with its attractive color, large leaves, and striking fruits in autumn, is also used as handicraft material due to the hardness of its wood texture. Its fruits contain plenty of tannins. Young shoots and leaves are used in the manufacture of different types of medicines. As the other parts of the plant contain high tannin levels, they are used in herbal medicine to relieve stomach and bowel laziness, reduce high blood pressure, relieve liver bloating, and have antipyretic properties. The plant is also useful in the spill of gallstones (Dingil, 1990). Oil derived from its wood is widely used in the perfume industry and medicine (Gultekin, 2004). Its evergreen leaves with long and persistent red berries make it a suitable ornamental plant for landscaping. In recent years, tourist goods have been produced from the green shoots in the Isparta and Antalya provinces of Turkey. These ornaments are exported to several countries. The wood of the plant is also used as firewood in bakeries. *A. andrachne* is an essential species in afforestation and erosion control studies because it is an arid species with kinky nature and desirable soil demand.

Expected climate change and global warming could lead to changes in species' natural distribution and the effects of harmful factors (Bellard *et al.,* 2012; Arslan, 2019). As a result, global climate change scenarios have gained importance in recent years to understand how the earth will react to climate change in the future (Remya *et al*., 2015; Moss *et al*., 2010; Hunt *et al*., 2007; El-Keblawy, 2014, Zare Chahouki *et al*., 2012; Zare Chahouki & Piri Sahragard, 2016).

Analyzing climate change effects on plant species in Turkey has vital importance for planning these species' future use. The potential future distribution of species in different scenarios can be demonstrated by the Maxent (Maximum Entropy Modeling) program using point field records, and layers created using digital bioclimate data.

Maximum entropy models offer a clean approach to joining various logical confirmation pieces, keeping in mind the end goal to gauge the likelihood of a specific phonetic class happening with one particular semantic setting. Maximum entropy is a supervised probabilistic machine learning model used for sequential data classification (Khan, 2016).

The RCPs (Representative Concentration Pathway) is consistent with a wide range of possible future anthropogenic changes, Greenhouse Gas Emissions and aim to represent their atmospheric concentrations (Collins & Knutti, 2014). RCP 2.6 assumes that global annual Greenhouse Gas emissions (measured in CO2-equivalents) peak between 2010–2020, with emissions declining substantially after that. Emissions in RCP 4.5 peak around 2040 and then lower. In RCP 6, emissions peak around 2080, then lower. In RCP 8.5, emissions continue to rise throughout the 21st century (Meinshausen *et al.*, 2011). The IPCC studies the carbon cycle separately, predicting higher ocean uptake of carbon corresponding to higher concentration pathways. Still, land carbon uptake is much more uncertain due to the combined effect of climate change and land-use changes (IPCC, 2014).

In this study, we aim to determine potential distribution areas of *A. andrachne* under various climate change scenarios and estimate how the spread of the species will be affected by climate change. In addition to the current situation, RCP 4.5 and RCP 8.5 climate change scenarios are presented for *A. andrachne*.

2. Material and Method

The data about the spatial distribution of *Arbutus andrachne* are obtained from our observations and previous literature records (OGM 2019; Davis 1965; 1978). Also, data obtained from the WorldClim (URL-1) database for about 1 km^2 (30 arc seconds) were used as the bioclim layers' base. Sampling sites and field data on *A. andrachne* are presented in Figure 1 and Table 1. The test data used in modeling are given in Table 2.

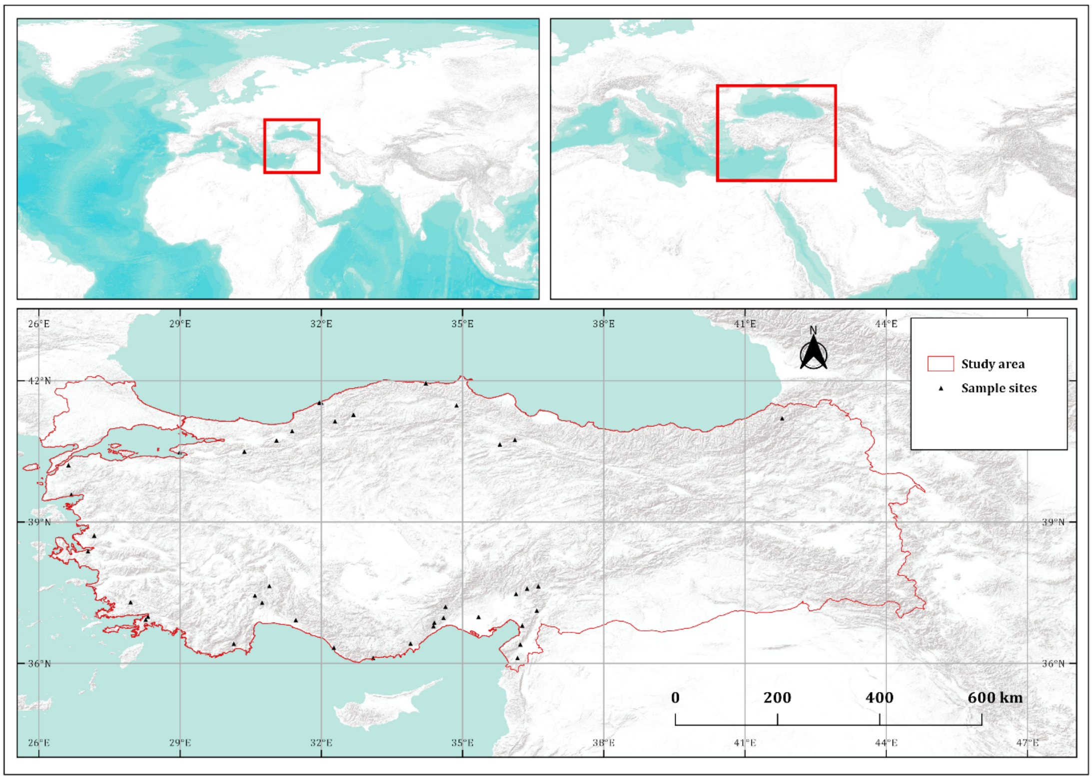

Fig. 1. Examined sample sites for *Arbutus andrachne* from Turkey as a study area.

Table 1. Distribution and climatic data of sites used in the present study.

Site code	Latitude	Longitude	City	District	Altitude (m)	Total annual Precipitation (mm)	Temperature (°C)
1	36° 59' 28"	35° 20' 20"	Adana	Yüreğir	28	58.25	18.98
2	37° 28' 35"	36° 8' 9"	Osmaniye	Kadirli	277	65.92	17.51
3	40° 38' 55"	35° 47' 30"	Amasya	Merkez	500	37.17	11.41
4	40° 44' 44"	36° 6' 41"	Amasya	Merkez	321	42.08	12.39
5	36° 20' 7"	32° 16' 0"	Antalya	Alanya	297	70.75	17.70
6	36° 55' 22"	31° 27' 27"	Antalya	Manavgat	429	74.25	16.63
7	41° 12' 8"	41° 47' 14"	Artvin	Merkez	538	94.17	12.12
8	40° 44' 3"	31° 2' 51"	Düzce	Gölyaka	447	58.50	11.35
9	40° 55' 54"	31° 22' 45"	Düzce	Yığılca	526	58.83	11.05
10	40° 29' 1"	28° 59' 33"	Yalova	Armutlu	484	54.67	12.42
11	37° 26' 27"	30° 35' 21"	Burdur	Bucak	868	43.50	12.65
12	37° 17' 25"	30° 44' 30"	Burdur	Bucak	601	50.67	14.78
13	37° 38' 44"	30° 53' 45"	Isparta	Eğirdir	1080	46.75	11.65
14	38° 22' 54"	27° 2' 38"	Izmir	Balçova	339	57.92	16.18
15	37° 35' 27"	36° 22' 8"	K. Maras	Andırın	1123	58.33	11.05
16	36° 24' 10"	36° 13' 35"	Hatay	Merkez	253	76.08	18.58
17	36° 24' 10"	36° 13' 35"	Hatay	Merkez	253	76.08	18.58
18	36° 7' 6"	36° 9' 58"	Hatay	Merkez	454	80.67	16.92
19	36° 48' 19"	36° 16' 0"	Hatay	Dörtyo	433	74.00	16.09
20	37° 38' 21"	36° 36' 31"	K. Maras	Merkez	511	58.83	15.00
21	41° 56' 51"	34° 13' 11"	Kastamonu	Çatalzeytin	254	77.00	12.85
22	36° 47' 33"	34° 22' 54"	Mersin	Merkez	395	59.58	16.43
23	36° 58' 8"	34° 35' 44"	Mersin	Merkez	404	61.42	16.26
24	37° 12' 9"	34° 38' 13"	Mersin	Tarsus	794	56.25	13.24
25	36° 55' 52"	28° 16' 12"	Mugla	Marmaris	199	84.42	17.62
26	40° 29' 54"	30° 21' 55"	Sakarya	Geyve	181	53.33	12.74
27	41° 16' 49"	32° 40' 58"	Karabük	Safranbolu	584	56.42	10.89
28	41° 8' 18"	32° 17' 28"	Karabük	Yenice	296	56.50	11.78

Table 2. Attribute information for data tested in the modeling.

Site code	Latitude	Longitude	City	District	Altitude (m)	Total annual Precipitation (mm)	Temperature (°C)
1	36° 6' 57"	33° 6' 2"	Mersin	Bozyazı	16	53.17	18.58
2	36° 52' 4"	34° 23' 60"	Mersin	Merkez	817	57.92	14.05
3	37° 7' 21"	36° 34' 34"	Gaziantep	Islahiye	944	63.25	12.96
4	36° 25' 19"	33° 53' 40"	Mersin	Silifke	180	54.50	17.98
5	36° 25' 10"	30° 8' 26"	Antalya	Finike	256	65.42	17.39
6	37° 18' 7"	27° 56' 55"	Muğla	Yatağan	691	70.83	14.78
7	36° 59' 50"	28° 19' 5"	Muğla	Ula	94	87.25	18.13
8	38° 42' 49"	27° 10' 34"	Izmir	Menemen	381	60.00	14.82
9	40° 12' 31"	26° 37' 46"	Çanakkale	Lapseki	183	54.75	14.08
10	39° 35' 6"	26° 41' 24"	Balikesir	Edremit	150	57.17	14.25
11	41° 28' 29"	34° 52' 18"	Sinop	Boyabat	380	52.25	11.88
12	41° 32' 23"	31° 59' 57"	Zonguldak	Çaycuma	160	85.83	13.23

Various types of Species Distribution Models (SDM) such as CLIMEX, Doup, Genetic Algorithm (GARP), and Maximum Entropy (Maxent) are used to evaluate ecological requirements, ecological responses, and spreading areas (Elith & Leathwick 2009; Brito *et.al.*, 2009; Wei *et.al.*, 2018). These modeling approaches include using both asset data and continuous and categorical data as input variables, testing for accuracy of estimation, always stable and reliable, even with missing data, small sample sizes, and gaps. Maxent stands out due to its advantages, such as producing a spatially open habitat conformity map directly and evaluating the significance levels of individual environmental variables using the built-in jackknife test (Tsoar *et.al.*, 2007; Phillips & Dudik 2008; Pearson *et.al.*, 2007).

Table 3. Climatic variables (www.wordclim.org)

bio_01 = Annual Mean Temperature
bio_02 = Mean Diurnal Range (Mean of monthly) (max temp. - min temp.))
bio_03 = Isothermality (BIO2/BIO7) (*100)
bio_04 = Temperature Seasonality (standard deviation *100)
bio_05 = Max Temperature of Warmest Month
bio_06 = Min Temperature of Coldest Month
bio_07 = Temperature Annual Range (BIO5-BIO6)
bio_08 = Mean Temperature of Wettest Quarter
bio_09 = Mean Temperature of Driest Quarter
bio_10 = Mean Temperature of Warmest Quarter
bio_11 = Mean Temperature of Coldest Quarter
bio_12 = Annual Precipitation
bio_13 = Precipitation of Wettest Month
bio_14 = Precipitation of Driest Month
bio_15 = Precipitation Seasonality (Coefficient of Variation)
bio_16 = Precipitation of Wettest Quarter
bio_17 = Precipitation of Driest Quarter
bio_18 = Precipitation of Warmest Quarter
bio_19 = Precipitation of Coldest Quarter

Climate data were composed of parameters from 1950-1990, and 19 climatic variables were used (Hijmans *et.al*., 2005) (Table 3). The Maximum Entropy algorithm processed these data, and the potential distribution area of the species was determined for nowadays conditions. Also, the possible distribution range of the species between 2050 and 2070 years was modeled according to the climate change scenario of the Hadley Global Environment Model 2 - Earth System (HadGEM2-ES).

The AUC (Area Under the Curve) value was used to determine the Maxent modeling performance. AUC is a value between 0 and 1, and if this value is more significant than 0.5, the modeling performs better than a random estimate (Suel, 2014; Mert & Kirac, 2017; Oruc *et.al*., 2017; Dulgeroglu & Aksoy, 2018). To show how the estimation is based on a particular variable, response curves were created. MESS (multivariate environmental similarity surface) analysis was performed to show the location of the new bioclimatic conditions encountered during the process. The jackknife test was applied to determine the contribution of environmental variables used in modeling.

3. Results and Discussion

The potential distribution modeling of *Arbutus andrachne* in current climatic conditions was better than a random estimate (Figure 2). Figure 3 shows the neglect rate and the projected area as a function of the cumulative threshold. The neglect rate is calculated both in educational records and in test records (if test data are used). The neglect rate should be close to the projected omissions due to the definition of the cumulative threshold. AUC was calculated as 0.919 for training data and 0.871 for test data (Figure 4).

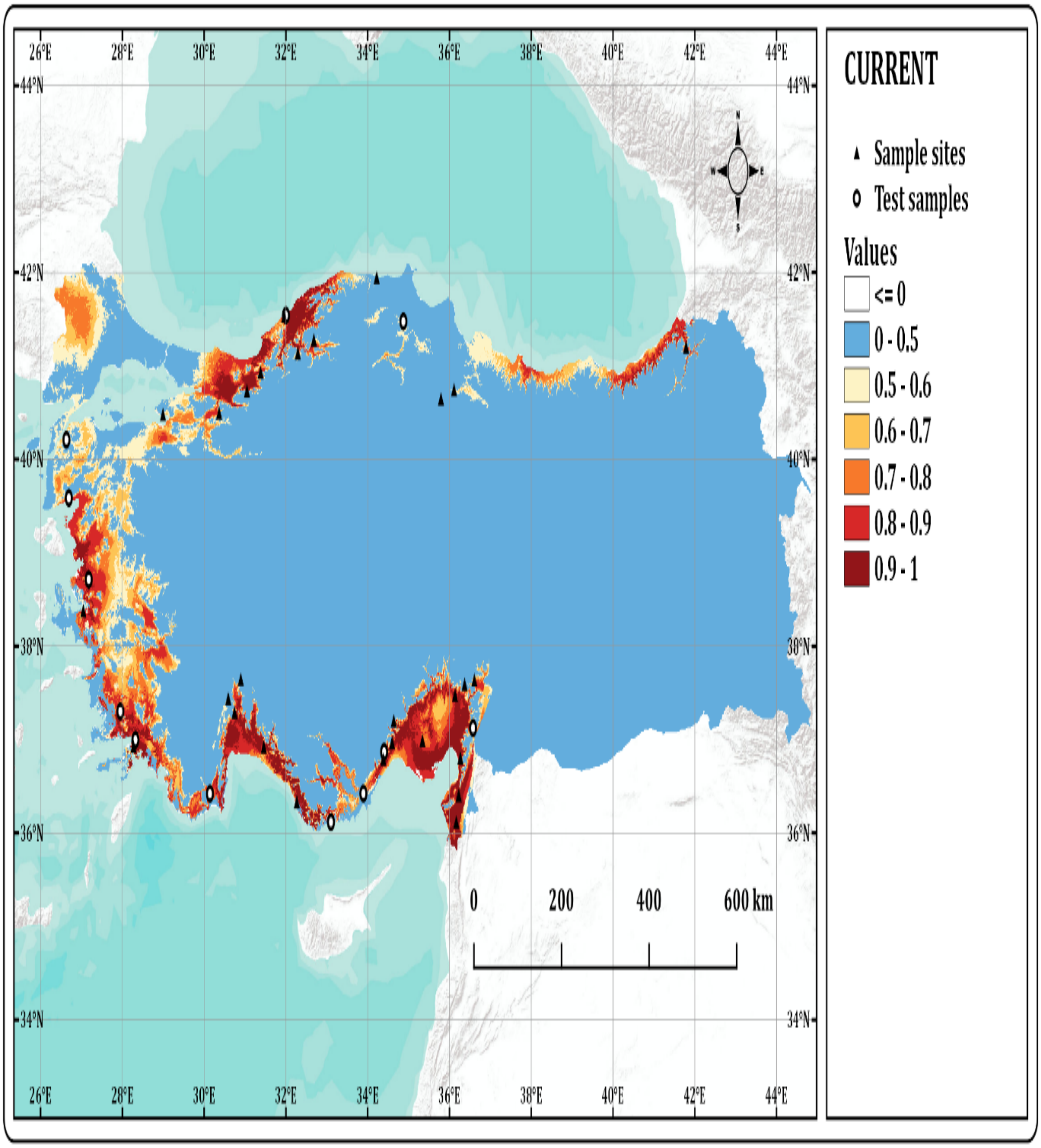

Fig. 2. The potential current *distribution* of *Arbutus andrachne.*

The current distribution map is a representation of the Maxent model for *A. andrachne*. As the values approach 1, the warm colors indicate areas with better-prescribed conditions. Black triangles show the position of the assets used for training, and circles show the test positions. The established ecological niche model shows the areas where the species exist and areas with no suitable species but with climatic conditions ideal for survival (Pearson, 2007).

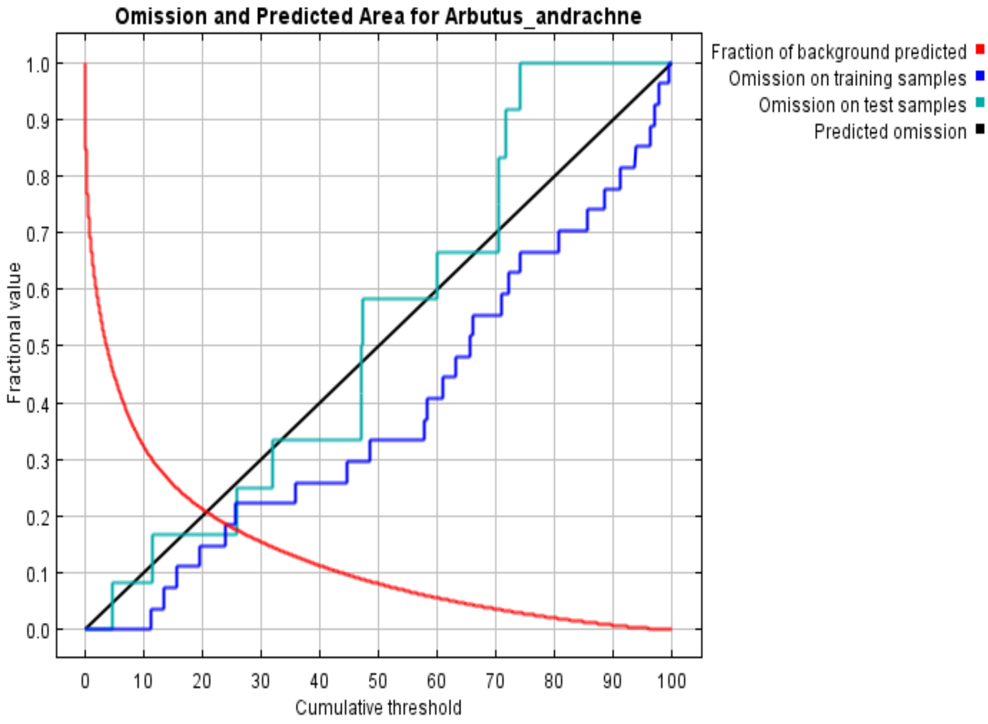

Fig. 3. The neglect rate and the projected area as a function of the cumulative threshold.

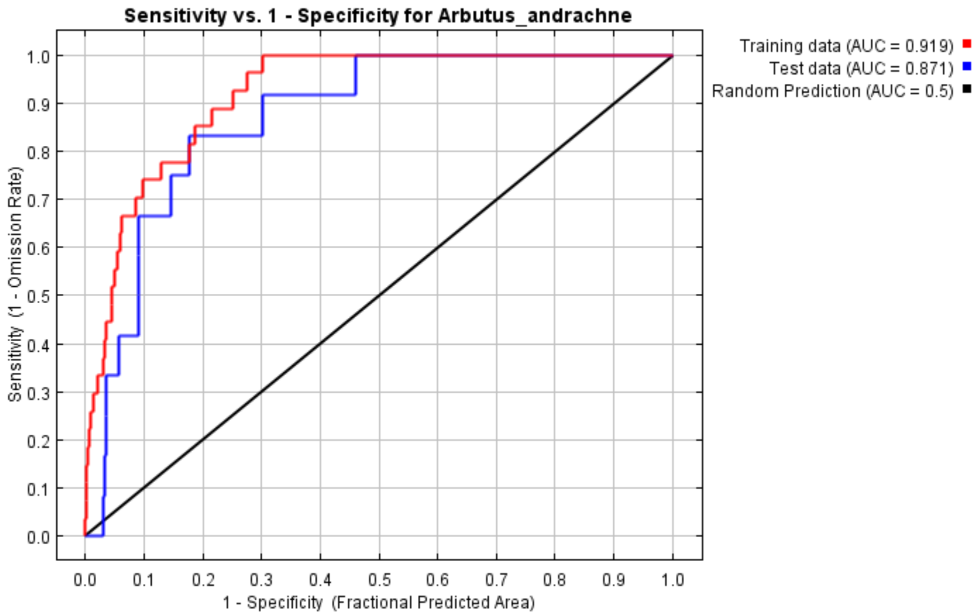

Fig. 4. AUC (Area Under the Curve) and Test data rates.

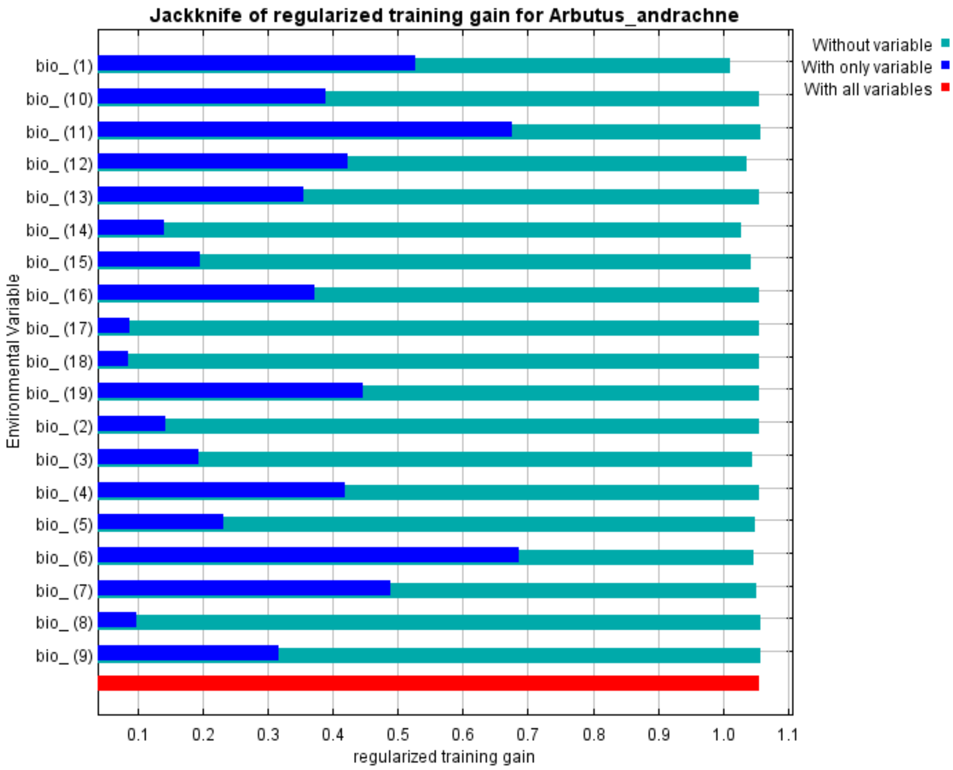

Fig. 5. According to Jackknife test results, environmental variables' relative importance values determine Arbutus andrachne's distribution.

According to the jackknife test results, the environmental variable with the highest gain is the Minimum Temperature of Coldest Month (bio_6). Therefore, it seems to have the most useful information on its own. The environmental variable that reduces the gain most when ignored is Annual Mean Temperature (bio_1), so it seems to have the most information not available in other variables (Figure 5).

The possible distribution models of *Arbutus andrachne* in 2050 and 2070 were better than a random estimate. The potential distributions of *A. andrachne* under RCP 4.5 and RCP 8.5 climate change scenarios for 2050 and 2070 are given in more detail in Figures 5 and 6. The potential distribution of *A. andrachne* under bioclimatic conditions in 2050 and 2070 decreases in RCP 4.5 and RCP 8.5 scenarios. According to the model results, climate change allows the species to extend its distribution area to the west and north while narrowing its distribution area in the southern regions (Figure 6 and Figure 7). In the current habitat, the current climatic conditions are not considered very suitable, especially in the south of the country to live in 2070.

On the other hand, the spread in Marmara and Western Black Sea regions is increasing. As a result, these estimates show that the geographical distribution of *A. andrachne* will be reduced in the future. That habitat will lead to significant loss according to the climate change scenario.

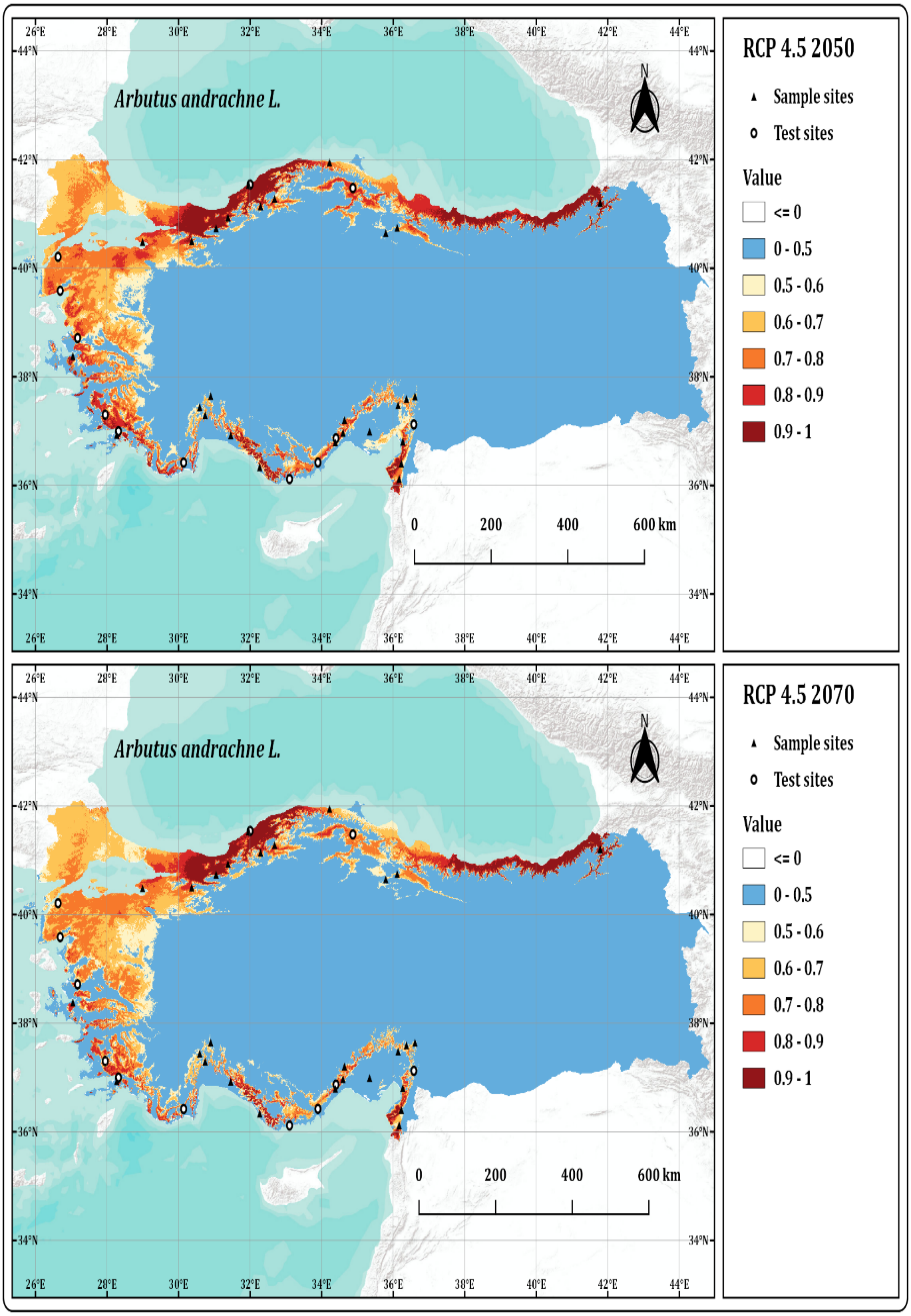

Fig. 6. Future potential distribution of *Arbutus andrachne* L. in Turkey according to RCP4.5.

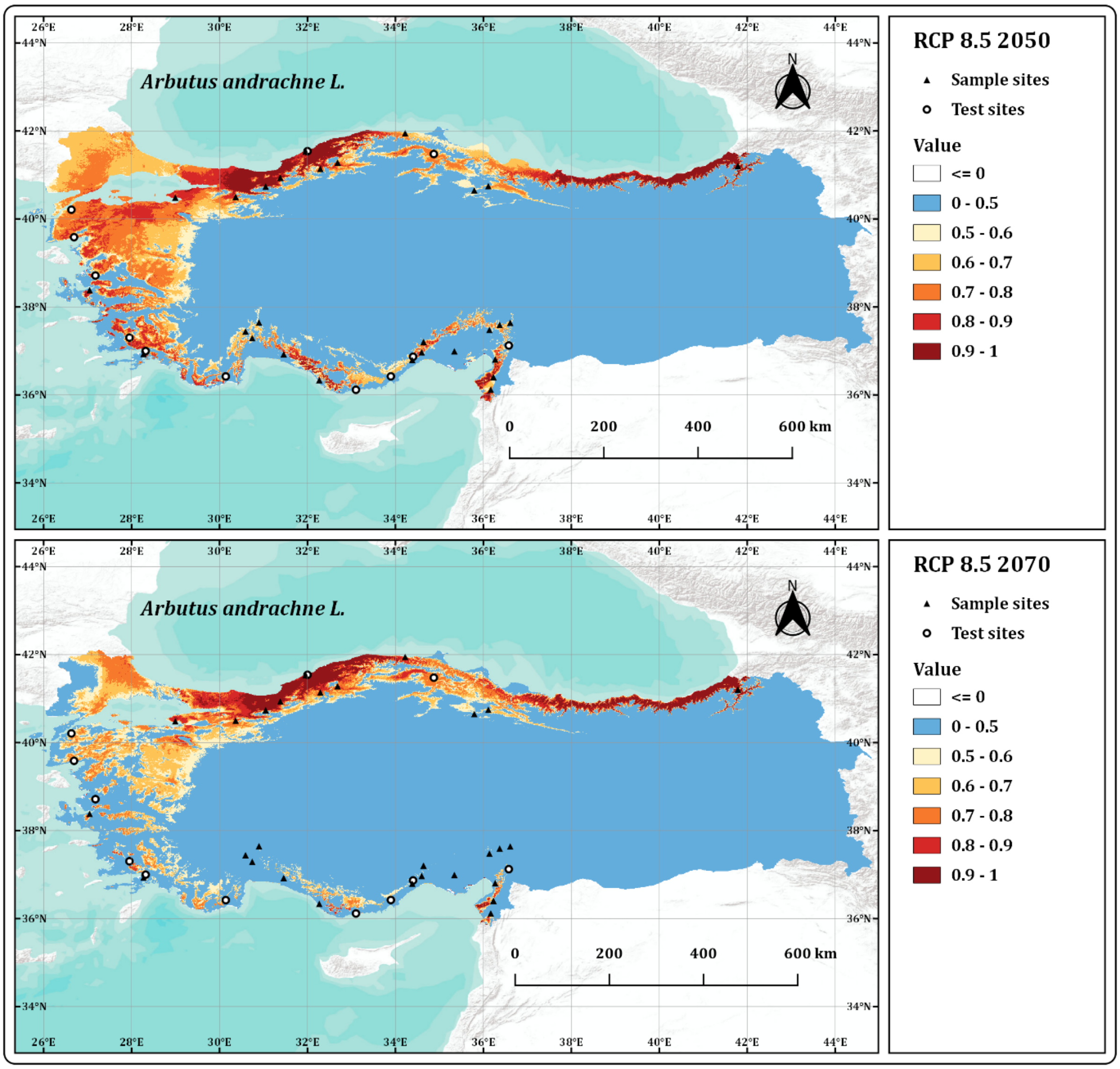

Fig. 7. Future potential distribution of *Arbutus andrachne* L. in Turkey according to RCP8.5.

Many studies on climate change state that plant distribution will change (Akyol & Orucu, 2019; Arslan & Orucu, 2019; Sarikaya & Orucu, 2019). It has been reported that endemic species in the Mediterranean will be less affected by natural and anthropogenic factors because they are stress-tolerant and adapted to challenging habitats (Medail & Verlaque, 1997; Dulgeroglu & Aksoy, 2018).

In studies conducted on the effects of climate changes on plants, it is foreseen that the spread of some species will decrease. It has been reported that there are hazards of extinction, especially if plants spreading in the Mediterranean basin do not adapt to climate change (Moiseev & Shiyatov, 2003; IPCC, 2014; Khanum *et al*., 2013; Dülgeroğlu & Aksoy, 2018; Orucu & Akyol, 2019).Piri Sahragard *et.al*. (2018) stated that potential distribution maps of plant habitats prepared using Maxent modeling are of higher priority for conservation on the local scale in arid mountainous rangelands.

The study by Riberio *et al*. (2017) used the Maxent program on *Arbutus unedo* in Portugal. It indicated that species distribution would change towards the country's central and northern regions according to projections for 2050 and 2070. Our study supports this research.

4. Conclusions

Our study determined that Arbutus andrachne's distribution will increase in western and northern parts of Turkey according to 2050 and 2070 scenarios. However, possible habitat loss can reach serious rates. The emergence of invasive species due to harsh habitat conditions and climate changes indicates that suitable conservation measures should be taken, especially for species with limited spread.In this context, because *A. andrachne* is an intensive species in terms of land demand, it is of great importance to take into account potential expansion in the future and to take necessary measures for use in afforestation and erosion control works and the utilization of non-wood forest products. Climate change is not limited to habitat loss, and the ecosystem and ecology of the species will change. Therefore, more detailed and comprehensive studies on the interaction of climate change and *Arbutus* species are required.

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