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Predicting impacts of future climate change on the distribution and ecological dimension of *Amygdalus scoparia* Spach

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Abstract. This study aimed to predict the potential distribution of *Amygdalus scoparia* and the changes in its ecological dimension under climate change scenarios using MaxEnt model in Iran. Species presence data, current climate data and different scenarios of CCM4 in 2050 and 2070 were used. Fars Province boundary and whole area of Iran were considered as the modeling boundary and projection boundary, respectively. The predictive power of the model was within acceptable levels (AUC = 0.88). The Bio3, Bio15 and Bio4 variables had the greatest impact on predicting the potential distribution of *A. scoparia*. The highest percentage of potential niche of *A. scoparia* will occur in 2070 under RCP4.5 scenario (24.62%) in Fars Province. In Iran, however, the highest (22.57%) and lowest (16.77%) potential niche of *A. scoparia* belong to current and RCP8.5 scenarios in 2050. *Amygdalus scoparia* lacks specialization in Fars Province, but the breadth of its ecological niche will be decreased in future and its distribution will be limited in main mountain ranges, i.e., the Alborz in northern and the Zagros in western Iran.

Keywords. Climate Change, Potential Distribution, *Amygdalus scoparia*, MaxEnt, Ecological Niche.

1. INTRODUCTION

Wild almond (*Amygdalus scoparia*) is a distinct and well-known xerophyte species in mountainous areas of Irano-Turanian floristic region. Large areas of its stands are distributed over dry and hot mountains of central, eastern and western Iran, Turkey, Afghanistan, Turkmenistan, and western Pakistan (Mozaffarian, 2004). It is an upright broom-like shrub up to 3-4 m tall with non-angled branches. The trunks of well developed individuals can be as thick as an arm. In some localities, *A. scoparia* is the dominant element in the arid forest ecosystems. It occurs most commonly above 1200 m altitude. The most elevated stands reach 2700 m (Browicz and Zohary, 1996). *A. scoparia* as a lithophyte plant grows on loose conglomerates and limestone cliffs, loose volcanic rocks, crevices in rock slopes and in clay and sandy soils in arid and semi-arid mountainous regions where soils are very poorly developed. It is highly drought tolerant and play valuable role in soil conservation, slopes stabilization and surface runoff reduction in arid mountainous areas (Tavakoli Neko *et al*., 2012; Abbasi, 2017). Furthermore, it is a pioneer species that colonizes sites lacking developed soil and provide favorable conditions for establishment of other species through providing microclimate and coping with unfavorable conditions in rock debris and stony slopes (Morshedi and Koravand, 2016).

A. scoparia plays pivotal role in the livelihood of local communities in arid mountainous regions of Iran. Local people and rural villagers use its fruits, gum and also bark and root for medicinal purposes. Furthermore, twigs are used for making traditional homewares and handicrafts. Wooden beams are used to build house and support roof. Branches and boughs are cut for wood fuel usage. Charcoal production is a major utilization of wild almond by locals (Browicz and Zohary, 1996).

Degradation of habitats by anthropogenic and natural factors such as overutilization, grafting of cultivated almond on the wild almond, insects and diseases outbreak, climate change, drought and fire are endangering factors in *A. scoparia* habitats (Golestaneh et al., 2012). Despite the tremendous importance of this species for the livelihood and survival of local communities and arid mountain forests health and production, overuse during last decades was serious threats to survival and regeneration of *A. scoparia* and has imposed intolerable pressure on habitats (Haidarian Aghakhani *et al*., 2017). Moreover, outbreak of pathogenic agents such as *Wilsonomyces carpophilus* and *Biscogniauxia mediterranea* have brought about various diseases such as dieback and decline, shot hole, canker and etc. on wild almond (Mirabdollahi *et al*., 2019). Therefore, with regard to the outstanding ecological and economic attributes of this species in arid forests, it is necessary to provide favorable conditions for sustainable exploitation of current habitats and planning to expand its distribution in areas that are potentially suitable for establishment. This can be achieved through the study of the effects of destructive human and natural causes such as climate change on it to conserve and improve the economic, social and ecological values of *A. scoparia* forests.

Climate change is one of the main drivers of plant ecosystems distribution. Changes in plant species distribution within a specific ecosystem is also affected by climate change (Pacific *et al*., 2015). Climate change can greatly impact biodiversity in ecosystems (Sintayehu, 2018). However, the effects of climate change on arid and semi-arid ecosystems are more severe than humid and semi-humid ecosystems (Grime *et al*., 2008). Since displacement or alteration of species geographical distribution is one of the ways for resistance to climate change, understanding the impact of climate change on species potential distribution and mitigating its deleterious effects on biodiversity is necessary for management decisions (Pressey *et al*., 2007). Plant species respond to climate change in a variety of ways such as adaptation, displacement in various directions and movement to higher elevation and latitude to find suitable climates. Local, regional, or global extinction is another response of plants to climate change (Parmesan and Hanley, 2015). Factors such as the genetic diversity of plant species, the ability to adapt to the magnitude of climate change, and the availability of space for species movement to other micro-climates can influence plant species responses to climate change (Loarie *et al*., 2009). Because of these differences, plant species are not equally susceptible to climate change (Walther, 2010).

Recent conditions of climate change have taken the plants, particularly the rare ones, to the brink of extinction (Deb *et al*., 2017). There is increasing evidence that species are changing their distribution as a result of environmental warming, particularly in montane ecosystems and that organisms living at high altitudes are particularly at risk because of their restricted climatic niches and specific adaptations (Bennett *et al*., 2019). It has been reported that average air temperature will rise between 1.69 and 6.88 °C in Iran by 2100 and climate is getting warm across the country especially in spring and summer (Zarenistanak *et al*., 2014). The effect of rising temperature on reducing current and potential distribution range of species has been reported in several studies (Vessella and Schirone, 2013; Al-Qaddi *et al*., 2016; Tarkesh and Jetschke, 2016). For example, climate change has been reported as a major factor in the decline of desirable habitat of *Ferula xylorhachis* in northeastern Iran (Mazangi *et al*., 2016). In a study by Sangoony *et al.* (2016) the optimal habitat size of *Bromus tomentellus* decreased by more than 51% in scenario 2080. Haidarian Aghakhani *et al.* (2017) reported a decrease of 43% and 59% in the area of *A. scoparia* habitat in Central Zagros Mountain, in Chaharmahal-e Bakhtiari Province, western Iran under RCP4.5 and RCP8.5 scenarios by 2050. Moreover, among the studies conducted from 2014 to 2018 on 37 species in Iran, about 81% of the studies indicated a decrease in the habitat size and distribution area of species due to climate change that reptiles followed by plants has shown highest declining rate (Yousefi *et al*., 2019). Therefore, understanding the potential impacts of climate change on species distribution to ameliorate its destructive effects on biodiversity is essential (Pressey *et al*., 2007). Consequently, predicting the potential distributions of endangered species in future climates can provide useful insights into their responses to climate change.

The use of species distribution models (SDMs) to predict the impact of climate change on species distribution and ecological dimension has become common and an important tool for assessing the potential impacts of climate change on plant communities (Sinclair et al., 2010). The SDMs correlate the climatic conditions associated with the species habitat to the observed presence areas of each species, which is consistent with Hutchinson's (1957) definition of species' environmental niche (Bellard et al., 2016). In other words, ecological niche models try to simulate the climatic nesting of a species using environmental variables and mathematical algorithms and present it geographically on a map (Mckenney *et al*., 2007). The predictions made by these models provide the basis for conservation planning decisions, so these models are useful for important decisions in ecological issues (Guisan and Zimmermann, 2000; Upson *et al*., 2016). In addition, General Circulation Models (GCM) have been developed as reliable and powerful tools to enhance understanding of climate change impacts and improve the ability to predict future climate patterns (Potta, 2004). The RCPs (Representative Concentration Pathways) are climate change scenarios that have been developed based on various input variables such as the amount of greenhouse gas emissions due to population growth and the economy of different countries, the level of used technologies, land use changes and environmental policies to be used in GCM models. The RCPs reflect the trends of different concentrations of greenhouse gases including carbon dioxide, vapor, nitrogen oxides, methane and ozone (Pachauri *et al*., 2014).

Due to the value of *A. scoparia* forest in Iran, various studies have been carried out to recognize its ecological needs, to model its distribution and to predict the impact of climate change on its distribution in different parts of Iran (Salarian et al., 2008; Goodarzi et al., 2012; Tavakoli Neko et al., 2012; Piri Sahragard et al., 2017; Haidarian Aghakhani *et al*., 2017). However, there is little information on how the size and extent of *A. scoparia* forests vary in facing of climate change. Therefore, this study aimed to predict the current potential distribution and the changes of potential ecological niche of *A. scoparia* under the climate change scenarios using MaxEnt model in Iran. Based on the literature review, this study is the first of its kind that models current and future distribution of *A. scoparia* under different climate scenarios across Iran.

2. MATERIALS AND METHODS

2.1 Study and projection areas

In this study, Fars Province boundary and whole area of Iran were considered as the modeling boundary and projection boundary, respectively (Fig. 1). Fars Province is located in southern part of the Zagros Mountains and in Irano-Turanian floristic region. The climate of Fars Province is semi-arid with average annual temperature and rainfall of 18 °C and 307 mm, respectively (Arvin and Shojaeezadeh, 2014). The average air temperature in the southern and northern parts of Iran ranges from 25 to 40 and 10 to 20 °C, respectively. Although there is considerable variation in temperature and precipitation across the country, the average annual precipitation is about 240 mm (Alizadeh, 2010).

2.2 Recording presence points of *A. scoparia*

First, pure habitats of *A. scoparia* were identified in Fars Province. Then, geographical coordinates of 200 presence points of *A. scoparia* were recorded using the GPS in 2017-2019 period. The presence points were identified by locating quadrats along four sampling lines (sample lines were perpendicular to each other) (Fig. 1). The distance between sample lines was 1000 m according to habitat conditions and vegetation changes. In order to avoid spatial autocorrelation, the presence points were considered one kilometer apart. So that, only one presence point was recorded in each 1 Km^2 network (Shrestha *et al*., 2018). Quadrat size was determined 25 m^2 by the minimal area method according to species characteristics (Piri Sahragard et al., 2017).

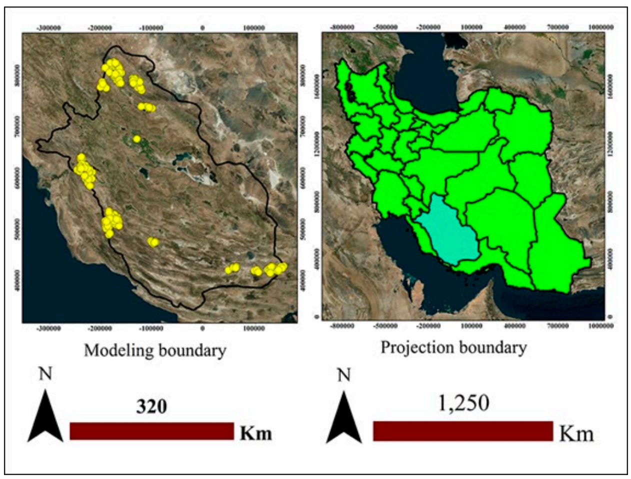

Fig. 1. Fars Province with the presence points of *Amygdalus scoparia* (left) and whole area of Iran (right).

2.3 Climate variables

The CCM4 model available in the Worldclim climate database was used for modeling of climate change (Hijmans *et al*., 2005). In this model, there are four climate change scenarios from optimistic to pessimistic for 2050 and 2070. These scenarios include RCP2.5, RCP4.5, RCP6 and RCP8.5. Current climate data were used to estimate the current distribution area of *A. scoparia*. This information was obtained from the interpolation of the geographical position of all meteorological stations in 1950-2000 period. Before entering the input variables into the model, the correlation between them was calculated and the variables with high correlation (higher than 0.85) were not entered into the model. Table 1 shows climate variables used in the study along with their range of changes and measurement units. Due to the necessity of the variables being identical in all modeling scenarios, the same scenarios were used to generalize the modeling results.

2.4 Modeling current and future potential distribution and analyzing the importance of variables

Modeling the potential distribution of *A. scoparia* under current conditions and climatic scenarios of RCP2.6; RCP4.5; RCP6 and RCP 8.5 was performed for 2050 and 2070 using the MaxEnt model (Phillips et al., 2006). In this study, 70% of the data were considered for training and 30% for test. The maximum iteration of the model run was assumed 1000 to achieve proper convergence. Model validation was performed using the area under the curve (AUC) of ROC function. The Jackknife test was used to determine the importance of environmental variables. This method has acceptable accuracy for assessing the importance of variables (Verbyla and Litvaitis, 1989).

Tab. 1. Variables, units and range of change in Fars Province.

Variable	Title	Range of change	Unit
Bio3	Isothermality (BIO2/BIO7)	32-43	Dimensionless
Bio4	Temperature Seasonality (Standard Deviation)	5784-9017	Degrees Celsius
Bio13	Precipitation of Wettest Month	27-86	Millimeters
Bio14	Precipitation of Driest Month	0-2	Millimeters
Bio15	Precipitation Seasonality (Coefficient of Variation)	79-126	Fraction
Bio17	Precipitation of Driest Quarter	0-17	Millimeters
Bio19	Precipitation of Coldest Quarter	66-201	Millimeters

2.5 Selecting the threshold limit of species presence

The TSS statistic was used to determine the optimum threshold for presence of the species and to identify the point of distinction based on sensitivity (SE) and specificity (SP) values in R 3.1.1 software; then prediction map of presence-absence of species was prepared. The TSS statistic is one of the appropriate statistic to determine the optimum threshold of presence. Independency of the model sensitivity to species prevalence is main reason for choosing this method (Allouche et al., 2006). For this purpose, 10,000 background absence points and presence points as well as the predicted value for these points were used. After applying the optimum threshold limit on species distribution map, calculations of changes in potential niche area of species were performed using ArcGIS 10.2 software. Assessment of threshold value for separation of presence and absence data including Correct classification, Misclassification, Sensitivity, Specificity, False positive rate and False negative rate was performed in SPSS 20 software.

2.6 Quantifying the dimensions of ecological niche

Statistical values of habitat overlap showing the extent of overlap between ecological niches as well as breadth of niches representing specialist and generalist were calculated in ENMtools 1.3 software. Overlap analysis of ecological niches was performed using two indices of Schoener's D (Schoener, 1968) and Hellinger's I (Warren *et al*., 2008). Habitat overlap indices range from 0 to 1 (Mirshamsi, 2013) whose high values mean complete overlap and low values mean less overlap of ecological niches. Breadth index of ecological niche was measured with Levin's B1 and B2 (uncertainty) indices (Levin, 1968). The values for these indices also fluctuate between 0 and 1, with values close to zero meaning specialist and values close to 1 meaning generalist (Vorsino et al., 2013).

3. RESULTS

3.1 Evaluating accuracy of the prediction models

As noted, the AUC was used to evaluate the accuracy of the prediction models. The AUC which is derived from the ROC diagram is a quantitative indicator for showing the performance and predictive power of the model. Vertical axis indicates the sensitivity (true positive) and the horizontal axis shows the specificity (false positive) in the

AUC curve. According to Swets (1988) classification (Appendix 1), the AUC values indicated acceptable accuracy of prediction models in training and test phases in this study (AUC = 0.88).

3.2 Analyzing the significance of climatic variables and response curves

Investigating the importance of variables using the Jackknife test showed that Bio3, Bio15 and Bio4 variables had the most effects on habitat distribution of *A. scoparia* (Fig. 2). The Bio19 had the least effect on the prediction model of species distribution. Interpretation of the response curves of *A. scoparia* to each of these variables showed that by increasing the value of Bio3 variable the suitability of the habitat is decreased and consequently the probability of species presence decrease. Accordingly, the highest rate of habitat suitability and thus the highest probability of occurrence for this species is in areas with isothermal value between 31 and 34. On the other hand, by increasing the Bio15 variable (seasonal precipitation coefficient) up to 85, the habitat suitability can increase and thus the probability of species presence increase. However, by increasing the value of this variable to over 85, habitat suitability and species probability decrease (Appendix 2). Investigating of the species response curve to change in Bio4 variable (seasonal temperature variations) also indicates that by increasing the value of this variable up to 6500 will increase habitat suitability and increase the probability of species presence. But a further increase in this value can reduce habitat suitability and thus reduce the likelihood of species presence probability.

3.3 Prediction map of potential and current distribution of species in Fars Province and Iran

Prediction map for potential distribution of *A. scoparia* in current scenario is presented in Fig. 3. On this map blue color states high probability and brown color

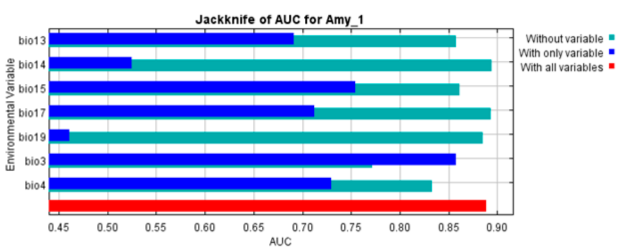

Fig. 2. Jackknife test results to determine the importance of environmental variables in *Amygdalus scoparia* habitats.

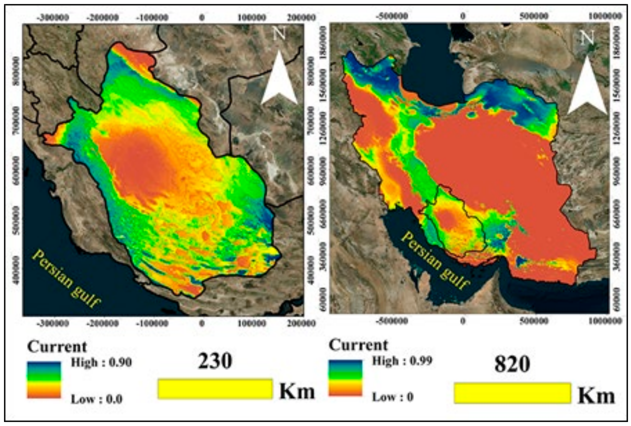

Fig. 3. Prediction map for potential distribution of *Amygdalus scoparia* in current scenario in Fars Province and Iran.

presents low probability. Accordingly, the most favorable areas for species presence in Fars Province are in the western, southeastern, and northern regions of the province (left map). Studying the potential distribution range of *A. scoparia* in Iran showed that the species has the ability to grow in northwest, north, northeast and along the Zagros Mountains to the north of Bandar Abbas City in southern Iran. In general, the northern parts of the country are more favorable for the establishment of the species, and the potential distribution of the species in this area is higher than in other parts of the country.

Examination of potential distribution changes of *A. scoparia* under climate scenarios of 2050 and 2070 showed that in central parts of Fars Province which are not suitable for the species at current scenario will have the potential for species presence in 2050 under RCP4.5 and RCP8.5 scenarios. In the case of RCP 8.5 scenario occurrence, parts of south-east, south and south-west of Fars Province that have high potential for species presence in RCP2.6 and RCP4.5 scenarios will face a decline in suitability and thus a decrease in potential for the species distribution. The 2070 map shows that under the RCP2.6, RCP6 and RCP8.5 scenarios, the central area of Fars Province is still unsuitable for species distribution. In the RCP4.5 scenario, large portions of the province will have potential for species presence, which is similar to the results for the RCP4.5 scenario in 2050 (Fig. 4). Modeling the potential distribution range of the species in Iran also showed that in 2050 under the RCP4.5 and RCP6 scenarios some parts of the south and south of the country will have potential for species presence. As temperatures rise in 2050 and move toward a pessimistic scenario, the range of species distribution will be reduced and the potential distribution of species will be limited to the western and northwestern parts of the country. In 2070, by moving from an

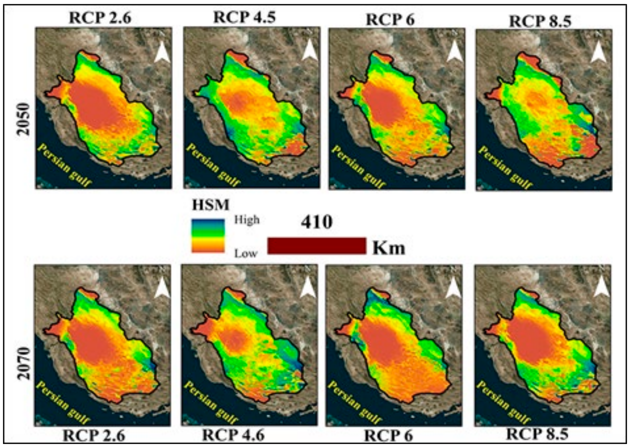

Fig. 4. Potential distribution of *Amygdalus scoparia* in different scenarios of 2050 and 2070 in Fars Province.

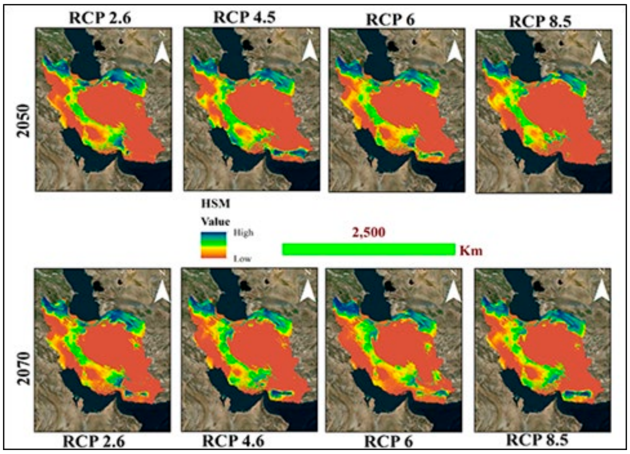

Fig. 5. Potential distribution of *Amygdalus scoparia* in different scenarios of 2050 and 2070 in Iran.

optimistic scenario to a pessimistic scenario the potential distribution range of the species will extend to eastern and southeastern regions of the country in addition to the western and northern parts (Fig. 5).

3.4 Dimensions of ecological niche of species

The results of investigating of niche breadth index in different scenarios showed that the highest niche breadth in Fars Province was at RCP4.5 scenario. This increase in niche width is line with the increase in the potential distribution of species (Fig. 6). The lowest niche breadth in Fars Province was related to the RCP6 scenario in 2070 (Table 2). In this scenario, large areas in the center of the province lack the potential for species presence, which has reduced the ecological niche breadth of the species. The

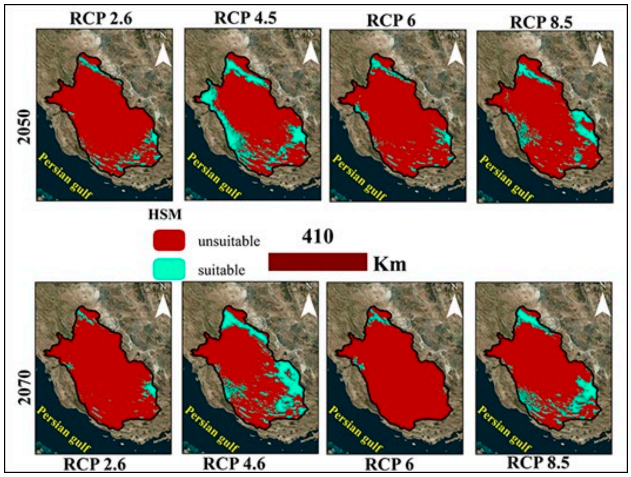

Fig. 6. Prediction binary map of potential climatic niche of *Amygdalus scoparia* under different scenarios in Fars Province.

Tab. 2. Breadth changes of *Amygdalus scoparia* niche based on relevant metrics used in climatic scenarios.

Scenario, Year	Fars Province		Iran	
	B1	B2	B1	B2
Rcp2.6, 2050	0.57	0.96	0.32	0.93
Rcp2.6, 2070	0.55	0.96	0.34	0.93
Rcp4.5, 2050	0.75	0.98	0.37	0.94
Rcp4.5, 2070	0.74	0.98	0.35	0.93
Rcp6, 2050	0.61	0.97	0.35	0.93
Rcp6, 2070	0.54	0.96	0.35	0.94
Rcp8.5, 2050	0.70	0.98	0.31	0.92
Rcp8.5, 2070	0.60	0.96	0.36	0.93
Current	0.71	0.98	0.35	0.93

results of the potential distribution range of the species in Iran showed that the highest and lowest extent of niches belong to the RCP4.5 and RCP8.5 scenarios, respectively, in 2050. This is in consistent with the potential distribution maps of the species in 2050.

The overlap rates of *A. scoparia* ecological niche based on I and D indices in Fars Province and Iran are presented in Tables 3-6. In Fars Province, the highest rate of niche overlap was 0.86 which calculated between RCP6, 2050 and RCP2.6, 2070 scenarios. The overlap value for the mentioned scenarios was 0.98 based on I index. The lowest value of niche overlap in Fars Province was calculated 0.63 for the scenarios of RCP8.5, 2050 and RCP2.6, 2050 (Appendix 3). The overlap value of these two scenarios was 0.84 based on I index (Appendix 4).

In Iran, over 50% overlap among all the scenarios was observed. The highest overlap of niches currently was with the RCP2.6 scenarios for 2050 and 2070. The lowest

Tab. 3. Overlap of ecological niches of *Amygdalus scoparia* based on D index in Iran.

Species	2.62050	2.62070	4.52050	4.52070	6.2050	6.2070	8.52050	8.52070	Current
2.62050	1	0.85	0.77	0.75	0.84	0.72	0.71	0.78	0.86
2.62070	x	1	0.80	0.79	0.87	0.78	0.75	0.81	0.85
4.52050	x	x	1	0.78	0.82	0.72	0.74	0.81	0.85
4.52070	x	x	x	1	0.82	0.77	0.76	0.84	0.77
6.2050	x	x	x	x	1	0.77	0.77	0.83	0.85
6.2070	x	x	x	x	x	1	0.72	0.77	0.72
8.52050	x	x	x	x	x	x	1	0.74	0.74
8.52070	x	x	x	x	x	x	x	1	0.77
Current	x	x	x	x	x	x	x	x	1

Tab. 4. Overlap of ecological niches of *Amygdalus scoparia* based on I index in Iran.

Species	2.62050	2.62070	4.52050	4.52070	6.2050	6.2070	8.52050	8.52070	Current
2.62050	1	0.95	0.91	0.89	0.94	0.87	0.87	0.91	0.96
2.62070	x	1	0.93	0.93	0.96	0.91	0.90	0.94	0.95
4.52050	x	x	1	0.91	0.94	0.87	0.90	0.92	0.96
4.52070	x	x	x	1	0.94	0.91	0.91	0.95	0.90
6.2050	x	x	x	x	1	0.90	0.91	0.95	0.95
6.2070	x	x	x	x	x	1	0.86	0.92	0.87
8.52050	x	x	x	x	x	x	1	0.89	0.90
8.52070	x	x	x	x	x	x	x	1	0.91
Current	x	x	x	x	x	x	x	x	1

overlap with an index value of 0.71 was found between the RCP2.6, 2050 and RCP8.5, 2050 scenarios (Tables 3 and 4). According to the results of I index, the highest overlap of ecological nests was 0.96 which related to the RCP2.62070, RCP6 2050, RCP4.52050 and current scenarios. According to this index, the lowest value of overlap between the different scenarios was 0.87 (Appendix 5).

3.5 Selecting the optimal threshold and evaluating the accuracy of prediction models

The appropriate threshold value was calculated 0.51 based on TSS statistic. Then, the accuracy of the classification of presence and absence data was evaluated with regard to threshold value by the statistic presented in Tab. 5. This indicates that resulting threshold had suitable discriminatory ability to distinguish presence and absence of species in the classification of species presence and absence. Because by considering optimum threshold of 0.51, the model's ability to detect species presence and absence was greater than 0.80. In other words, the prediction model was able to correctly predict 85% of species presence (Sensitivity = 0.85). Species absence was predicted with an accuracy of 0.83 (Specificity = 0.83). In total, 83% of the used points were classified correctly. Misclassification of the presence and absence points was 16%.

Tab. 5. Statistic of evaluating the accuracy of prediction model after applying threshold value.

Statistic	Value	Lower bound (95%)	Upper bound (95%)
Correct classification	0.83	0.82	0.83
Misclassification	0.16	0.16	0.17
Sensitivity	0.85	0.79	0.89
Specificity	0.83	0.82	0.83
False positive rate	0.17	0.16	0.17
False negative rate	0.15	0.10	0.19

3.6 Final maps of species potential distribution in different climatic scenarios

In Fars Province, large portions of the province were identified unsuitable by applying threshold limit derived from the RCP2.6 scenario in 2050. In this scenario, a lim-

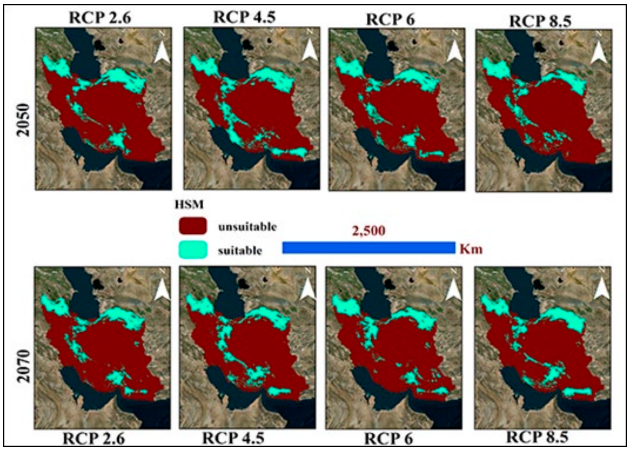

Fig. 7. Prediction binary map of potential climatic niche of Amygdalus scoparia under different scenarios in Iran.

Tab. 6. Changes in the area of desirable habitats of *Amygdalus scoparia* under different scenarios in Fars Province and Iran.

Scenario	Area in Fars Province (Km^2)	% of occupation	Area in Iran (Km^2)	% of occupation
2.62050	10374.50	8.44	297702.01	18.34
2.62070	5423.58	4.41	298744.30	18.44
4.52050	28652.21	23.33	365594.15	22.57
4.52070	30234.71	24.62	323839.93	19.99
62050	10138.52	8.25	302383.39	18.67
62070	2986.27	2.43	300007.54	18.52
8.52050	18756.17	15.27	271112.44	16.73
8.52070	21316.22	17.36	331563.08	20.47
Current	21266.31	17.32	365303.01	22.55

ited portion (4.41%) of the province will have the potential to accept the species (4.41%). The highest area (23.33%) of the province that have the potential to accept the species in 2050 belongs to the RCP4.5 scenario. The results of the applying scenarios in 2070 also largely coincided with 2050. The largest area of the species potential habitat in 2070 will be under the RCP4.5 scenario (24.62%) in the province (Fig. 6). In whole country of Iran, the highest extent (22.57%) of habitat occupation will occur in 2050 under the RCP4.5 scenario. In 2050, in addition to northern parts of Iran, the south and southwestern parts of the country around Khuzestan Province will potentially have a species presence. But in later scenarios, the potential distribution of the species will be reduced. The lowest extent of potential distribution in 2050 will occur under the RCP8.5 scenario (16.77%) (Fig. 7).

Table 6 shows the changes in the area of desirable habitats under species occupation in different scenarios along with the occupancy rate. In the scale of Iran, the largest area that can be potentially occupied by species is related to the current scenario (22.5%). The lowest potential occupation will occur in the RCP8.5 scenario in 2050 in Iran.

4. DISCUSSION

Climatic variables are the most important controller of species distribution (Guisan and Zimmermann, 2000) in terrestrial ecosystems. They have a direct influence on the behavior and physiology of plants. Temperature is the most important driver among the climatic factors in species distribution, in particular. They can largely affect the plants, as they cannot evade adverse climatic conditions by sheltering or migrating (Hirzel and Le Lay, 2008). In other words, the spatial distribution of each plant species depends on its range of tolerance to climatic factors, ecological niche, and its biological interactions (Pearman et al., 2008). A decrease in the area of a species habitat due to climate change is one of the factors that can affect species survival in ecosystem (Lavergne et al., 2006; Becerra-López *et al*., 2017). In fact, due to the species' need for moisture and temperature, climate change can affect the geographical range of species distribution. In this study, the potential impacts of climate change on the potential distribution of *A. scoparia* and its ecological dimensions in Fars Province and Iran were investigated using the MaxEnt model for the first time.

Model accuracy evaluation with the AUC statistic indicated acceptable performance of the prediction model (AUC = 0.88). It has been reported that the value of AUC statistic in the MaxEnt model is mostly affected by the extent of ecological niche of plant species. The prediction performance of the MaxEnt model is excellent for species with small ecological niches (Zare Chahouki and Piri Sahragard, 2016). As discussed before, *A. scoparia* has tiny ecological niche. Numerous studies have reported that the MaxEnt is a suitable method for modeling plant species distribution due to its special features such as high prediction performance with low sample size (Pearson, 2007), lack of over-fitting (when wrong prediction of absence is zero and there are no in overestimation error or error in presence prediction) (Williams, 1995; Tibshirani, 1996), being generative and productive and ease of use by experts and users (Phillips et al., 2006). Because of these capabilities, the successful application of this method in modeling species geographical distribution, tolerance of species to environmental variables, conservation of species niche, identifying areas for conservation priority and logical estimation of species niche even with low sample size have been reported (Suárez-Mota et al., 2016; Antúnez et al., 2018).

The largest potential habitats of *A. scoparia* are located in the eastern, southeastern, western and northern parts in Fars Province at the present time. Large parts of Iran including northwest, north and north-east are potentially capable to support the species. It has the ability to settle in these areas provided other conditions to be favorable. Overall, the northern parts of Iran are more favorable for the establishment of the species especially in terms of climatic conditions. This part of the country is more likely to be occupied by *A. scoparia* than other parts. Currently, total area of *A. scoparia* habitats in Fars Province and Iran is 21266.31 km^2 (17.32% of the province total area) and 365303.01 km^2 (22.55% of the country total area), respectively.

Analysis of relative importance of *A. scoparia* habitat's variables showed that the Bio3, Bio4 and Bio15 variables had the most influence on species distribution and habitat suitability determination. These variables can provide useful information on the habitat distribution of this species; whereas the Bio19 variable had the least effect in this respect. Therefore, model run only with this variable is not useful for estimating the distribution of the species under study. The most suitable habitat and thus high probability of species presence are in areas where the Bio3 variable (isothermal) is about 31 to 34 ^{0}C, Bio15 variable (seasonal rainfall) with coefficient of variation between 80 and 90; and the Bio4 variable (seasonal temperature) with standard deviation between 6000 and 7000. Any increase in the values of these variables to higher amount will result in lower habitat suitability and thus lower probability of species presence in these areas. Annual temperature and rainfall have been reported as important variables affecting the occurrence of *A. scoparia*. This species is more likely to occur in areas with temperatures of 24 to 26 °C and annual rainfall of 400 to 600 mm (Haiydariyan Aghakhani *et al*., 2017). In total, isothermal, seasonal rainfall and seasonal temperature variables accounted for a significant percentage of changes in species distribution, and have the highest contribution in determining habitat suitability for *A. scoparia*.

The use of overlap and ecological niche breadth indices provides complete insight into the status of plant species (Wan et al., 2017). In the modeling process, the use of niche measurement indices enables researchers to judge about the ecological niche of a species based on the input variables to the model (Suárez-Mota et al., 2015). If the species ecological niche is large, it can be considered equivalent to the suitable conditions based on the variables used. The value represented by the metrics used indicates the degree of overlap that has been happened with regard to the variables used in modeling. Considering the climatic variables used in Fars Province based on niche breadth criteria, the highest niche breadth was in the RCP4.5 scenario in 2050, which is consistent with the findings from the distribution area. The highest niche size of the species was in the RCP4.5 scenario of 2070, which is justified by findings for distribution area. The highest niche overlap of species was observed between RCP2.6 in 2070 and RCP6 in 2050 according to D and I indices in Fars Province. Because 86% of habitats in these period are considered as common. In Fars Province, ecological niches overlap was greater than 50% in most of the studied scenarios. This indicates that with the change in temperature in different scenarios, the occupation of the new area will be accompanied by including of the old areas. On the scale of Iran, results indicated the same situation. Consequently, most climate nests of *A. scoparia* will be located in areas that has been previously occupied by other scenarios in future climate change scenarios.

Modeling of current and future potential distribution of *A. scoparia* showed that some parts at the center of Fars Province that do not currently occupied by the species will have potential suitability under the RCP4.5 and RCP8.5 scenarios in 2050. By 2070, a large proportion of the province will have a potential for species presence (24.62%) in the RCP4.5 scenario in 2050. Due to the limited range of climatic factors affecting the habitat suitability of the species resulting narrow niches of *A. scoparia*, high fluctuations of the effective climatic variables can lead to loss of potential habitat suitablility. It has been reported that failure to adapt to the prevailing environmental conditions in an area and thus having limited habitat can ultimately lead to species extinction (Pressey, 2007). It should be noted that fluctuations in climate variables can even affect the suitability of habitats where species are currently available.

Although the generation of binary maps from continuous probabilistic maps has been criticized due to some limitations in evaluating the accuracy of probabilities predicted by the model (Vaughan and Ormerod, 2005; Freeman and Moisen, 2008), these maps can be used to evaluate the predictive validity of the model as well as in practical projects (Jimenez-Valverde and Lobo, 2007). According to the binary maps of suitability, the highest habitat area for occupation of species will be occurred under the RCP4.5 scenario in 2050 and 2070 in Fars Province (23.33 and 24.62% of the province total area), respectively. In the scale of Iran, the highest and lowest areas that potentially can be occupied by species was allocated to the current and the RCP8.5 scenarios, in 2050, respectively. In other words, the species have the largest potential habitats in current climatic conditions. The current potential distribution range of the species is limited to the northeast, northwest and western regions (around the Zagros Mountains) in Iran. Results of species distribution changes in 2050 showed that under the RCP2.6 scenario the extent of habitat of the species will expand to the south of the country due to favorable climatic conditions, and species distribution range will decrease by moving to pessimistic scenarios. With the use of pessimistic climate scenarios, the areas in the southeastern part of the country will have high potential for species distribution due to favorable climatic conditions by 2070. Our results revealed that the trend of potential niche changes in *A. scoparia* will not be linear with the change in scenarios of temperature rise. Consistent with the findings of this study, the expansion of potential areas for species establishment under the influence of RCP and RCP8.5 climate scenarios in the western Himalayas has been reported by Thapa *et al.* (2018). In fact, with increasing temperature and stress to plants, their ability to survive in drier, warmer and minimum conditions of its favorable distribution range will decrease (Allen and Breshears, 1998). Therefore, organizing strategies for the conservation and restoration of forest ecosystems under short and long terms niether guarantee species survival nor distribution (Antúnez et al., 2018). Given the adverse ecosystem conditions in arid forests of the Fars Province and the unique habitat conditions of *A. scoparia*, these issues should be considered by planners and authorities in the conservation, exploitation, and development programs.

In general, it seems that the central regions of Fars Province are not suitable for the presence of species due to lower altitude and consequently higher temperatures even under different climatic scenarios. In eastern, southeastern, western and northern parts of Fars Province suitable climatic conditions and other environmental factors such as elevation, physiographic and soil characteristics meet the ecological needs of the species, thus have more potential for species establishment. It has been reported that climate change can affect the spatial distribution of species through expansion of suitable potential habitats toward highlands (Thuiller, 2007; Bellard *et al.*, 2013). In addition to climate change, other factors such as infrastructure development, human intervention and land use change can also lead to species migration to higher altitudes (Shrestha *et al.*, 2018). In the case of *A. scoparia*, the results of previous studies indicate that in addition to climatic factors, altitude, physiographic characteristics, soil physical characteristics such as sand percentage and type of geological formation are the most important factors in limiting the presence of *A. scoparia* (Salarian et al., 2008; Tavakoli Neko et al., 2012). For example, the highest probability of *A. scoparia* presence in different parts of Iran is at an altitude of 1500 to 2150 m above msl and the presence of species outside this elevation range is severely restricted (Tavakoli Neko et al., 2012).

5. CONCLUSIONS

Local authorities have started a rehabilitation and conservation program to recover degraded habitats and relicts of *A. scoparia* stands in Fars Province, Iran. They aim to extent the area of current habitats to larger size. Understanding potential impact of climate change on current and potential distribution areas of *A. scoparia* is major requirements to implement rehabilitation and conservation practices in the habitats. The findings of this research provide significant implications for the understanding of how and to what extent the spatial distribution of *A. scoparia* affected by the variations of environmental and climatic variables.

Our study showed that most of the potential habitats of *A. scoparia* in Fars Province and Iran belong to current scenario. However, in some areas potential habitat expansion or contraction will occur in future climate scenarios in both Fars Province and Iran. The relationship between temperature rise in climate scenarios and the spread of species ecological niches is not linear. Clearly, an increase in the area of potential habitats with favorable climatic conditions will expand habitats of this species in the future. Following the expansion of *A. scoparia* habitats in Fars Province and Iran in future, sustainable forest ecosystems in these areas will be provided in addition to reduction in soil erosion and land degradation. However, it should be noted that the presence of a plant species in an area is resultant of numerous environmental variables including soil, geological formations, land use, ecological demands of the species and etc. Therefore, these variables along with climatic variables must be considered in identification of potential desirable areas for the establishment of the species.

Various actions must be undertaken by the local authorities to promote the conservation of *A. scoparia* in Fars Province as well as Iran. Enhancing the position of local communities and utilizer groups in conservation of habitats, creating alternative livelihoods for utilizer groups to provide sustainable income for them and reduce their forest dependency, development of ecotourism in wild almond forest in order to introduce the importance of such species to the people, introducing modern utilization methods to the utilizer groups, manual seeding of wild almond seeds in degraded habitats to enhance its natural regeneration, and finally prohibit of grafting domestic almond on the rootstocks and twigs of wild almonds by farmers and utilizers are some actions that we recommend to be implemented by the local authorities.

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REFERENCES

Abbasi S., 2017. Persian gum: a novel natural hydrocolloid. Nutrition and Food Sciences Research, 4, 1–2.

Alizadeh A., 2010. Principals of applied hydrology. 29th edition, University of Imam Reza Press, Iran, 912p.

Allen C.D., Breshears D.D., 1998. Drought-induced shift of a forest-woodland ecotone: rapid landscape response to climate variation. Proceedings of the National Academy of Sciences of the United States of America, 95, 14839–14842.

Allouche O., Tsoar A., Kadmon R., 2006. Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). Journal of Applied Ecology, 43, 1223–1232.

Al-Qaddi N., Vessella F., Stephan J., Al-Eisawi D., Schirone B., 2016. Current and future suitability areas of kermes oak (*Quercus coccifera* L.) in the Levant under climate change. Regional Environmental Change, 17, 143–156.

Antúnez P., Suárez-Mota M.E., Valenzuela-Encinas, C., Ruiz-Aquino F., 2018. The potential distribution of tree species in three periods of time under a climate change scenario. Forests, 9, 628.

Arvin A., Shojaeezadeh K., 2014. Assessment of climate tourism in Shiraz city using physiologic equivalence temperature and predicted mean vote indexes. Journal of Physical Geography, 7, 87–98.

Becerra-López J.L., Bautista A. R., Méndez U.R., Pavón N.P., Rojas G.S., 2017.Effect of climate change on halophytic grasslands loss and its impact in the viability of Gopherus flavomarginatu, Nature Conservation, 21, 39–55.

Bellard C., Cassey P., Blackburn T.M., 2016. Alien species as a driver of recent extinctions. Biology Letters, 12, 20150623.

Bellard C., Thuiller W., Leroy B., Genovesi P., Bakkenes M., Courchamp F., (2013). Will climate change promote future invasions? Global Change Biology, 19, 3740–3748.

Bennett M., Marquet P.A., Sillero-Zubiri C., Marino J., 2019. Shifts in habitat suitability and the conservation status of the Endangered Andean cat *Leopardus jacobita* under climate change scenarios. Oryx, 53(2), 356-367.

Browicz K., Zohary D., 1996. The genus Amygdalus L. (Rosaceae): Species relationships, distribution and evolution under domestication. Genetic Resources and Crop Evolution, 43, 229-247.

Deb C.R., Jamir N.S., Kikon Z.P., 2017. Distribution prediction model of a rare Orchid species (*Vanda bicolor Griff.*) using small sample size. American. Journal of Plant Sciences, 8 (06), 1388.

Freeman E.A., Moisen G.G., 2008. A comparison of the performance of threshold criteria for binary classification in terms of predicted prevalence and kappa. Ecological Modelling, 217, 48–58.

Golestaneh S.R., Karampour F., Farrar N., 2012. Introduction of the destructive agents affecting wild almond Amygdalus scoparia forests in Koh-Siah Dashti area in Bushehr Province. Forest and Range Protection Research, 10, 153–164.

Goodarzi Gh.R., Sagheb-Talebi Kh., Ahmadloo F., 2012. The study of effective factors on Almond (Amygdalus scoparia Spach.) distribution in Markazi Province. Iranian Journal of Forest, 4, 209–220.

Grime J.P., Fridley J.D., Askew A.P., Thompson K., Hodgson J.G., Bennett R., 2008. Long-term resistance to simulated climate change in an infertile grassland. Proceedings of the National Academy of Sciences, 105, 10028–10032.

Guisan A., Zimmermann N.E., 2000. Predictive habitat distribution models in ecology. Ecological Modelling, 135, 147–186.

Haidarian Aghakhani M., Tamartash R., Jafarian Z., Tarkesh Esfahani M., Tatian M.R., 2017. Forecasts of climate change effects on Amygdalus scoparia potential distribution by using ensemble modeling in Central Zagros. Jourornal RS & GIS for Natural Resources, 8, 1–14. (In Persian).

Hijmans R.J., Cameron S. E., Parra J.L., Jones P.G., Jarvis A., 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology, 25, 1965–1978.

Hirzel A.H., Le Lay G., 2008. Habitat suitability modelling and niche theory. Journal of Applied Ecology, 45, 1372–1381.

Hutchinson G.E., 1957. Population studies – animal ecology and demography – concluding remarks. Cold Spring Harbor Symposia on Quantitative Biology, 22, 415–427.

Jimenez-Valverde A., Lobo J.M., 2007. Threshold criteria for conversion of probability of species presence to either–or presence–absence. Acta Oecologica, 31, 361–369.

Lavergne S., Molina J., Debussche M., 2006. Fingerprints of environmental change on the rare Mediterranean flora: a 115-year study. Global Change Biology, 12, 1466–1478.

Levin R., 1968. Evolution in Changing Environments: Some Theoretical Explorations, Monographs in Population Biology. Princeton University Press, USA, 120 pp.

Loarie S.R., Duffy P.B., Hamilton H., Asner G.P., Field C.B., Ackerly D.D., 2009. The velocity of climate change. Nature, 462 (7276), 1052±5.

McKenney D.W., Pedlar J.H., Lawrence K., Campbell K., Hutchinson M.F., 2007. Potential impacts of climate change on the distribution of North American trees. BioScience, 57, 939–948.

Mazangi A., Ejtehadi H., Mirshamsi O., Ghassemzade, F., Hosseinian yousefkhani S.S., 2016. Effects of climate change on the distribution of endemic *Ferula xylorhachis* Rech.f. (Apiaceae: Scandiceae) in Iran: predictions from ecological niche models, Russ. Journal of Ecology, 47(4), 349–354.

Mirabdollahi Shamsi M., Akbarinia M., Mirabolfathy M., Manzari Sh., Ahmadikhah A., 2019. Dieback and decline of wild almond (Amygdalus scoparia Spach) in the Harat protected forest of Yazd Province, Iran. Forest Pathology, DOI: 10.1111/efp.12538

Mirshamsi O., 2013. Ecological niche modeling of two scorpion species Mesobuthus eupeus (C. L. Koch, 1839) and M. Phillipsii (Pocock, 1889) from the Iranian Plateau and Zagros region (Arachnida: Scorpiones). Euscorpius, 15, 1–10.

Morshedi J., Koravand E., 2016. Site selection for *Amygdalus scoparia* implant using GIS techniques and AHP methods In Mordghafar Watershed, Izeh Township. *Wetland Ecobiology*, 7 (4), 69-86.

Mozaffarian V., 2004. Trees and shrubs of Iran. Contemporary culture publications, Iran, 671 pp.

Pachauri R.K., Allen M.R., Barros V., Broome J., Cramer W., Christ R., Church J., Clarke L., Dahe Q., Dasgupta P., 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, IPCC, 153 pp.

Parmesan C., Hanley M.E., 2015. Plants and climate change: complexities and surprises. Annals of Botany. 116, 849±64.

Pearman P.B., Guisan A., Broennimann O., Randin C.F., 2008. Niche dynamics in space and time. Trends in Ecology and Evolution, 23, 149–158.

Phillips S., Robert P., Anderso C., Robert E., 2006. Maximum entropy modeling of species geographic distribution. Ecological Modeling, 190, 231–259.

Piri Sahragard H., Zare Chahouki M. A., Ajorlo M., Nohtani M., 2017. Predictive habitat distribution modeling of Amygdalus scoparia Spach in Moshakieh rangelands of Qom Province. Journal of Forestry and Wood Products, 69, 725–734.

Potta S., 2004. Application of Stochastic Downscaling Techniques to Global Climate Model Data for Regional Climate Prediction, MSc Thesis, Louisiana State University, 153 pp.

Pressey R.L., Cabeza M., Watts M.E., Cowling R.M., Wilson K.A., 2007. Conservation planning in a changing world. Trends in Ecology and Evolution, 22, 583–592.

Sangoony H., Vahabi M., Tarkesh M., Soltani S., 2016. Range shift of *Bromus tomentellus* Boiss as a reaction to climate change in Central Zagros, Iran. Applied Ecology and Environment Research, 14, 85-100.

Salarian A., Mataji A., Iranmanesh Y., 2008. Study of habitat requirement of Amygdalous scoparia species in Zagros forests. (Case study: Kareh bas habitat of Chahar Mahal and Bakhtiari Province. Iranian Journal of Forest and Poplar Research, 4, 528–542.

Schoener T.W., 1968. Anolis lizards of Bimini: resource partitioning in a complex fauna. Ecology, 49,704–726.

Shrestha U.B., Sharma K.P., Devkota A., Siwakoti M., Shrestha B.B., 2018. Potential impact of climate change on the distribution of six invasive alien plants in Nepal. Ecological Indicators, 95, 99–107.

Sinclair S., White M., Newell G., 2010. How useful are species distribution models for managing biodiversity under future climates? Ecology and Society, 15, 8 [online].

Sintayehu D.W., 2018. Impact of climate change on biodiversity and associated key ecosystem services in Africa: a systematic review. Ecosystem Health and Sustainability, 4, 225–239.

Suárez-Mota M.E., Ortiz E., Villaseñor J.L., Espinosa-Garcia F.J., 2016. Ecological niche modeling of invasive plant species according to invasion status and management needs: The case of Chromolaena odorata (Asteraceae) in South Africa. Polish Journal of Ecology, 64, 369–383.

Suárez-Mota M.E., Villaseñor J.L., López-Mata L., 2015. Ecological niche similarity between congeneric Mexican plant species. Plant Ecology and Evolution, 148, 318–328.

Swets J.A., 1988. Measuring the accuracy of diagnostic systems. Science, 240, 1285–1293.

Tarkesh M., Jetschke G., 2016. Investigation of current and future potential distribution of *Astragalus gossypinus* in Central Iran using species distribution modelling. Arabian Journal of Geosciences, 9(1), 1-11.

Tavakoli Neko H., Pourmeydani A., Adnani S.M., Sagheb-Talebi Kh., 2012. Impact of some important ecological factors on presence of mountain Almond (Amygdalus scoparia Spach.) in Qom Province, Iran. Iranian Journal of Forest and Poplar Research, 19, 523–542.

Thapa S., Chitale V., Joshi-Rijal S., Bisht N., Shrestha B.B., 2018. Understanding the dynamics in distribution of invasive alien plant species under predicted climate change in Western Himalaya. PLoS One, 13, e0195752.

Thuiller W., 2007. Biodiversity: climate change and the ecologist. Nature, 448, 550–552.

Upson R., Williams J.J, Wilkinson T.P, Clubbe C.P, Maclean I.M.D., McAdam J.H., Moat J.F., 2016. Potential impacts of climate change on native plant distributions in the Falkland islands. PLoS ONE, 11(11): e0167026.

Verbyla D.L., Litvaitis J.A., 1989. Resampling methods for evaluation of classification accuracy of wildlife habitat models. Environmental Management, 13, 783–787.

Vessella F., Schirone B., 2013 Predicting potential distribution of *Quercus suber* in Italy based on ecological niche models: Conservation insights and reforestation involvements. Forest Ecology and Management, 304, 150–161.

Vorsino A.E., King C.B., Haines W.P., Rubinoff D., 2013. Modeling the Habitat Retreat of the Rediscovered Endemic Hawaiian Moth Omiodes continuatalis Wallengren (Lepidoptera: Crambidae). PLoS ONE, 8, e51885.

Walther G.R., 2010. Community and ecosystem responses to recent climate change. Philosophical Transactions of the Royal Society B: Biological Sciences, 365, 2019–2024.

Wan J.Z., Wang C.J., Tan J.F., Yu F.H., 2017. Climatic niche divergence and habitat suitability of eight alien invasive weeds in China under climate change. Ecology and evolution, 7, 1541–1552.

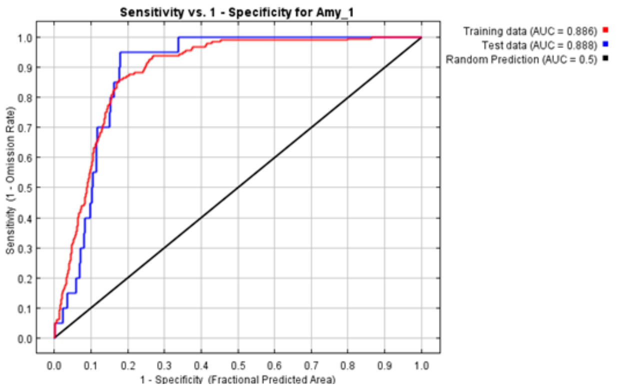
Yousefi M., Kafash A., Valizadegan N., Ilanloo S.S., Rajabizadeh M., Malekoutikhah S., Yousefkhani S.Sh., Ashrafi S., 2019. Climate Change is a Major Problem for Biodiversity Conservation: A Systematic Review of Recent Studies in Iran. Contemporary Problems of Ecology, 12(4), 394–403.

Zare Chahouki M.A., Piri Sahragard H., 2016. MaxEnt modelling for distribution of plant species habitats of rangelands (Iran). Polish Journal of Ecology, 64, 453–467.

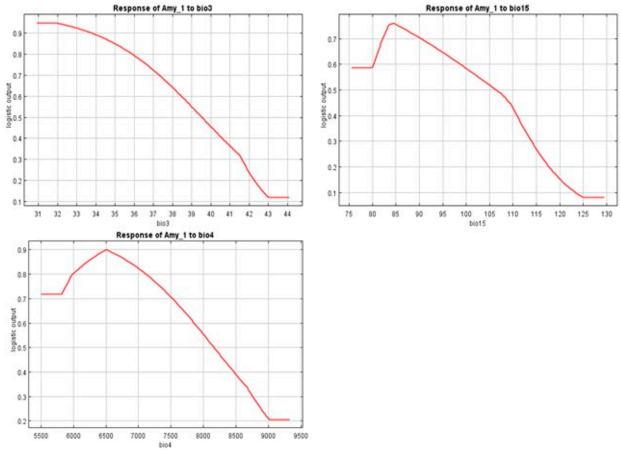
Zarenistanak M., Dhorde A. G., Kripalani R.H., 2014. Temperature analysis over southwest Iran: trends and projections. Theoretical and Applied Climatology, 116(1), 103-117.

Appendix 1. Classification of the Area under the Curve of the ROC curve (Swets, 1988)

Coefficient class	Range
Poor	0.50-0.70
Acceptable	0.70-0.90
Good	0.90-1.00



Appendix 2. The value of the AUC for the ROC curve for training and test data in maximum entropy prediction model.



Appendix 5. Response curves of ther most important variables in the habitat of *A. scoparia.*

Appendix 3. Overlap of ecological niches of *Amygdalus scoparia* based on D index in Fars Province.

Species	2.62050	2.62070	4.52050	4.52070	6.2050	6.2070	8.52050	8.52070	Current
2.62050	1	0.78	0.72	0.74	0.80	0.73	0.63	0.83	0.74
2.62070	x	1	0.72	0.75	0.86	0.82	0.69	0.77	0.74
4.52050	x	x	1	0.81	0.76	0.68	0.78	0.75	0.81
4.52070	x	x	x	1	0.79	0.70	0.79	0.77	0.77
6.2050	x	x	x	x	1	0.80	0.72	0.81	0.78
6.2070	x	x	x	x	x	1	0.65	0.71	0.72
8.52050	x	x	x	x	x	x	1	0.66	0.72
8.52070	x	x	x	x	x	x	x	1	0.74
Current	x	x	x	x	x	x	x	x	1

Appendix 4. Overlap of ecological niches of *Amygdalus scoparia* based on I index in Fars Province.

Species	2.62050	2.62070	4.52050	4.52070	6.2050	6.2070	8.52050	8.52070	Current
2.62050	1	0.96	0.90	0.92	0.96	0.94	0.84	0.97	0.93
2.62070	x	1.00	0.93	0.95	0.98	0.97	0.90	0.96	0.94
4.52050	x	x	1.00	0.95	0.94	0.91	0.95	0.92	0.96
4.52070	x	x	x	1.00	0.95	0.92	0.94	0.93	0.94
6.2050	x	x	x	x	1.00	0.96	0.90	0.97	0.95
6.2070	x	x	x	x	x	1.00	0.87	0.94	0.93
8.52050	x	x	x	x	x	x	1.00	0.86	0.91
8.52070	x	x	x	x	x	x	x	1.00	0.93
Current	x	x	x	x	x	x	x	x	1.00