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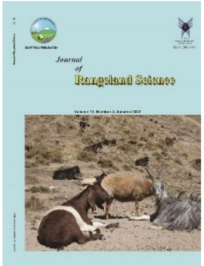

Research and Full Length Article:

Determination of Effective Factors on Distribution of Medicinal Species of *Vaccinium arctostaphylos* L. Using MaxEnt Model (Case Study: Namin Rangelands, Ardabil, Iran)

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Abstract. This research aimed to determine the potential habitats of *Vaccinium arctostaphylos* as a rare species using the MaxEnt method. For this purpose, sampling was performed from the areas of *V. arctostaphylos* at eight habitats in Namin rangelands, Ardabil, Iran in 2020. Also, latitude and longitude as well as physiographic factors were recorded using GPS. Soil samples were collected from depth of 0-30 cm. Then, some physicochemical properties of soil such as pH, electrical conductivity, soil texture, lime, soluble potassium, magnesium, soluble sodium, particulate organic matter, absorbable phosphorus, soluble bicarbonate and clay, silt and sand percentage were measured in the laboratory. The MaxEnt model was used to determine the relationship between environmental factors and the distribution of *V. arctostaphylos*. The map of environmental factors affecting the distribution of the species was prepared using IDW geostatistical method in Arc-GIS$_{ver.10.8}$ software. Kappa index was used to evaluate the conformity of the forecast map with the actual map. Results of the Jackknife efficiency index showed the variables of elevation, rainfall and temperature were the most important variables in the distribution of *V. arctostaphylos*, respectively. Results of response curves showed this species is likely to be present in the altitude range of 1500-1900 m. Also, the precipitation range in the presence habitats of species is 350-450 mm and the average annual temperature range is about 7-10 °C. Results showed that the accuracy of maximum entropy modeling with a Kappa index of 0.64 is acceptable and this model has good accuracy in predicting the presence of species with main habitat. Generally, results showed MaxEnt model could be used as a prediction tool to determine the distribution area of *V. arctostaphylos*. Moreover, the prepared forecast map can be used for better conservation of species and rangelands management and improvement of the regions and similar areas.

Key words: Modeling, Habitat distribution, MaxEnt, *Vaccinium arctostaphylos* L.

Introduction

Nowadays, along with the development of statistical methods and GIS in plant ecology, mapping to predict the distribution of plant species or vegetation types has become essential. Modeling of plant species distribution was defined as predicting the potential distribution of a plant species based on the relationship between plant species presence points and influential environmental variables. Habitat prediction models help natural resource managers to identify threatening factors for plant population's sustainability, determine essential factors in conservation planning, and study low cost and low time climate change scenarios. Also, they can determine optimal habitat of plant species, present new hypotheses in creating patterns of biodiversity, predict changes in future scenarios (including land-use change, management, etc.), and plan biological control for erosion and areas of conservation importance (Bagheri *et al*., 2017). Since the presence of any plant is affected by environmental factors and inter-species relations, one or more environmental factors have the most significant effect in the presence of a particular plant species if environmental factors affecting the distribution of any plant can be determined. Regarding environmental variables, species distribution prediction models can be obtained (Zare Chahouki, 2007; Robinson and Fordyce, 2017). Potential habitat prediction models can play an important role in proposing species adapted to different ecological conditions for the restoration and sustainable development of rangeland and forest ecosystems.

So far, a wide range of statistical models based on machine learning have been introduced (Bedia *et al*., 2011). An essential aspect of the model is choosing the appropriate modeling method because a low-utility choice will lead to poor performance forecasting (Gaston and Garcia-Vinas, 2011). Most of the available information is related to the presence of species, and the absence data are less available; even if these data are available, their values are questionable (Anderson *et al*., 2003); Therefore, modeling methods that use only presence data are suitable tools to overcome this problem (Graham *et al*., 2004; Zare Chahouki *et al*., 2018; Esfanjani *et al*., 2021; Esfanjani *et al*., 2019). The MaxEnt model is a multi-purpose method for predicting or inferring incomplete data and is considered as the only present method for modeling species distribution. Also, this model is more efficient than other types of models when the number of presence points is small (Phillips *et al*., 2006). Due to the features such as the use of only presence data and high predictability and machine learning, this model was used to study the environmental factors affecting the distribution of rare species of *V. arctostaphylos*. Globally, relatively much research was done to model the distribution of species using the entropy method. In this regard, Zhang *et al*. (2019) in a suitable habitat study predicted *Cinnamomum camphora* L. using the MaxEnt model under maximum climate change in China and by examining eight environmental variables, they concluded that the MaxEnt model is reliable for the prediction of the eventual habitat of the species (AUC: 0.01) and global warming causes expanding the potentially suitable habitats of the species. Palashi *et al*. (2019) determined the potential habitat of different plant species, and using the MaxEnt method in rangelands of Jiroft -Kerman Province, they prepared the habitat map of *Salsola rigida*, which showed a high correlation between actual and predicted maps. Their results showed that the accuracy of the classification of the model for lime percentage and soil electrical conductivity is acceptable, and soil variables including organic matter, moisture, and texture had the most excellent effect on the distribution of habitats of the plant species. Esfanjani *et al*. (2019) compared maximum entropy and logistic regression in order to determine the potential habitats of *Prangos pabularia*

Lindl. in southern rangelands of Ardabil province, Iran and related the MaxEnt method indicated that factors such as phosphorus (P), rainfall, and elevation were the most influential factors on the distribution of the habitat of *P. pabularia*. Also, Ghafari *et al*. (2019) in the determination of the practical factors in the distribution of *Festuca ovina* using MaxEnt method in Moghan-Sabalan rangelands located in Ardabil province stated that variables of elevation, slope, patch size coefficient, potassium depth 15-30, and lime of depth 0-15 were the most critical factors affecting the distribution of *F. ovina*. Esfanjani *et al*. (2020) in a study aimed at developing the best prediction model for the distribution of *Prangos uloptera* DC. Using two methods of logistic regression and MaxEnt in the southern rangelands of Ardabil province showed that in the MaxEnt method, the amount of sand, nitrogen, silt, and potassium had the most significant effect on the distribution of this plant.

Namin rangelands are one of the most important rangelands in Iran that are important from ecological aspects such as high forage quality, genetic and economic resources, forage production, livestock breeding and beekeeping. *Vaccinium arctostaphylos* L. from the Ericaceae family, which is commonly grown in the understory of Fagus trees in the forests of the north of Iran and the ecotone of these forests and grasslands, is one of the rare and valuable plants in terms of medicinal properties. It is a shrub plant or semi-shrubs up to 3 m tall with dark purple or spherical round fruits, and they are full of seeds. *Vaccinium* plant has one species in Iran and grows mainly in the heights of Gilan (ecotone ecosystems of forests and grasslands between Ardabil and Gilan), which are endangered due to the impossibility of reproduction in nature through seeds (Nikavar, 2004; Emad *et al*., 2012; Hasanlou *et al*., 2019). Therefore, due to the existing research gap, insufficient knowledge about the ecological factors affecting the distribution of this rare and endangered species, this study aimed to determine the most critical environmental variables affecting the distribution of *V. arctostaphylos* using climate, soil, and topography factors and evaluation of habitat prediction ability using MaxEnt method in Namin region, Ardabil province, Iran. Understanding the environmental factors affecting the distribution of plants can be helpful in familiarity with the adaptation of native species, the preferential orientation of the species, and their use in rangeland improvement programs.

Materials and Methods

Study area

The study area is located in the geographical range of 38˚10´30˝ to 48˚34´00˝ E longitude and 38˚27´30˝ to 48˚42´00˝ N latitude in Namin region of Ardabil province in 2020 (Fig. 1). The average rainfall of the region using the information of the nearest station (Namin station with an altitude of 1345 m above sea level) is 378 mm, and the average temperature of the region is 8.9°C (average minimum 3.03 and average maximum 14.7°C) (Teimourzadeh *et al*., 2015; Azimi Motem *et al*., 2011). The existence of different topographic conditions and high altitude differences and proximity to the Caspian Sea had provided suitable vegetation conditions for different species and for establishing different plant communities in this area of ecotone (Teimourzadeh *et al*., 2015; Dadjou *et al*., 2018).

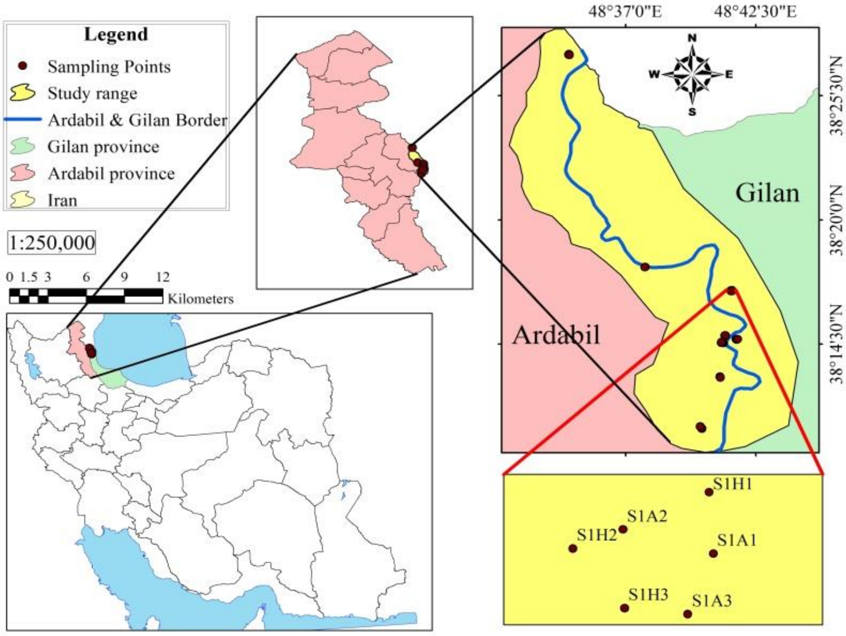

Fig. 1. Location of the study area in Namin region, Ardabil province of Iran

Sampling Method

In this study, after a field visit to the study area, eight habitats were selected according to the diverse topography of the area and the purpose of the study. Then, sampling was performed inside each habitat from the presence areas of the species (Fig. 2). Since this plant is a rare species, the location of the species was determined in each habitat, and in the next step, longitude and latitude information and physiographic factors were recorded using GPS, and soil samples from the presence areas of species were collected from a depth of 0-30 cm (active rooting depth) (Ghorbani *et al*., 2015). In the soil science laboratory of the University of Mohaghegh Ardabili, some physical and chemical properties of soil such as pH, electrical conductivity, soil texture, lime, soluble potassium, magnesium, soluble sodium, particulate organic matter, absorbable phosphorus, soluble bicarbonate, and the percentage of clay, silt and sand were measured using physical and chemical analysis methods (Table 1) (Jafari Haghighi, 2003).

Fig. 2. Pictures of *V. arctostaphylos* in the study area

Table 1. Topographic, climatic, plant and soil factors of *V. arctostaphylos* species distribution sites

No.	Location name	Elevation (masl)	Slope (%)	Aspect	Temp. (°C)	Rainfall (mm/Y)	Density (No./ha)	pH	EC µS/cm)	Texture (%)	Lime (%)
1	Sooha	1733	23.17	-0.056	9.07	409.21	26	5.3	0.44	Sandy loam	4.39
2	Aladizge	1394	10.49	0.68	10.74	341.63	2	5.4	0.34	Loam	4.24
3	Sagezchi1	1795	27.29	-0.065	8.82	419.32	5	5.3	0.42	Sandy loam	5.02
4	Sagezchi2	1725	31.85	0.41	9.08	408.92	45	5.5	0.45	Sandy loam	5.23
5	Sagezchi3	1675	19.90	-0.045	9.34	398.55	13	5.5	0.38	Sandy loam	4.80
6	Shoghaldare	1601	18.87	0.17	9.59	388.15	4	6.1	0.66	Sandy loam	4.97
7	Hor	1627	26.48	0.24	9.45	394.10	3	6.8	0.91	Loamy sand	7.56
8	Tifiye	1840	20.21	-0.09	8.39	436.84	2	6.5	0.66	Sandy loam	7.88

In order to develop the model of spatial distribution of the species, a digital elevation model (DEM) map with a scale of 1:25000 and maps related to soil characteristics was prepared using geostatistical methods and interpolation techniques in Arc $GIS_{ver.10.8}$ software. In order to evaluate the interpolation methods, among geostatistical methods, Inverse Distance Weighting (IDW) method was selected, and two statistical parameters of mean absolute error (MAE) and root mean square error (RMSE) were used. Finally, by overlying the point maps of the sampling points and the maps of topographic, climatic, and soil factors, the environmental data were obtained using spatial statistics methods (Ghorbani *et al.*, 2018).

After completing the information, the MaxEnt method was used to model the potential habitat of the *V. arctostaphylos* species. Preparation of input layers for the MaxEnt model algorithm evaluates the probability of distribution of maximum values affected by constraints caused by environmental variables affecting the spatial distributions of the species. In this model, the probability of unknown distribution $\hat{\pi}$ was calculated using species presence points (x_1 to x_n) and limited geographical space (set of pixels in the study area) (Phillips *et al.*, 2006). The entropy $\hat{\pi}$ was calculated as follows (Equation 1).

$$H(\hat{\pi})=\sum_{x\in X}\hat{\pi}(X)\ln\hat{\pi}(x) \quad \text{Equation (1)}$$

Where:
Ln: natural logarithm,
X: the set of region pixels,
x: species presence points

To implement the MaxEnt method, we are faced with several input and output parameters. Inputs are information on the presence of species and environmental layers in ASCI format. The presence points of the studied species were prepared in Excel files in CSV format; then, the data of species present, and environmental layers were entered into $MAXENT_{3.3.4}$ software. Therefore, for modeling using the MaxEnt model, all input maps of the model must be prepared in one frame and have the same reference ground and coordinate system. Also, to implement this method, 70% of the presence points were used randomly for educational data and the remaining 30% to evaluate the model results. Moreover, two options were used to construct response curves for environmental characteristics, and the Jackknife test was used to determine the influential variables (Phillips *et al.*, 2006). To determine the influential variables and the option related to the area under the curve, (AUC) was selected to evaluate the accuracy of the prediction model. Because model's output is a continuous probabilistic map, the optimal presence threshold must be determined to determine the presence of the species in question (Phillips *et al*., 2004; Negga *et al*., 2007). The Jackknife test was also used to evaluate the significance of each variable in the model preparation. Receiver Operating Characteristics (ROC) provides all possible threshold limits. The ROC curve describes the relationship between correctly predicted attendances (sensitivity) and the ratio of absences that are incorrectly predicted (1-specificity). After determining the optimal threshold by the method of equal sensitivity and specificity, the continuous prediction map becomes the presence and absence maps of the species. The area under the curve between 0.7 and 0.8 indicates a good model; between 0.8 and 0.9, it is a great model and more than 0.9, it indicates an excellent model prediction (Giovanelli *et al*., 2010).

Eventually, the model output was the species habitat prediction map. The validation of the prediction map was done by comparing the plant ground map with the Kappa index. Kappa index was also used to assess the accommodation of the forecast map with the actual distribution map. The kappa index shows the degree of agreement between the values of observations and the values of predictions, and the error matrix is used to calculate it (Zare Chahouki *et al*., 2013). The kappa index equation is in relation (2) (Latimer *et al*., 2006):

$$K=\frac{(a+b)-[(a+c)(a+b)+(b+d)(c+d)]/n}{n-[(a+c)(a+b)+(b+d)(c+d)]/n} \quad \text{Equation (2)}$$

Where:

(a) represents the values that exist both in reality and in the model, and the model records it as a presence,
(b) values that are only seen in the model but not seen in the real world,
(c) values that exist in reality, but it is not seen in the model,
(d) values that do not exist in the model or in reality and the model records it as an absence.

Results

The accuracy of interpolation methods was investigated for all environmental variables using the intersection method. The results showed that the actual values and predicted values for most soil variables were more consistent with the inverse distance weighting (IDW) method. When the Mean Absolute Error (MAE) and Mean Bias Error low or close to zero, it means that a suitable method has been used to show the reality (Khosravi and Abbasi, 2014). Table 2 shows the best interpolation method (IDW).

Table 2. Cross-validation results for interpolation of soil properties entered into the MaxEnt model

Soil properties	Simple kriging		Ordinary kriging		IDW	
	MAE	**RMSE**	**MAE**	**RMSE**	**MAE**	**RMSE**
pH	0.066	0.31	0.00006	0.23	-0.000036	0.24
EC	-0.008	0.23	0.0031	0.26	0.000097	0.31
Lime (%)	0.0058	1.43	-0.017	1.38	0.00064	1.72
Mg (ppm)	-1.136	16.61	-0.886	19.65	-0.0066	23.99
K (mg/kg)	-3.404	129.06	-3.338	102.28	-0.046	143.97
Na (ppm)	-0.0157	9.46	0.132	12.55	0.0175	13.82
P (mg/kg)	-0.096	3.21	-0.089	3.59	-0.00032	4.28
OC (%)	0.60	7.18	-0.13	7.97	0.00076	9.24
Hco_3- (meq/1)	-0.016	5.22	-0.029	6.22	0.0021	7.83
Soil Texture (%)	0.79-	41.55	0.94	38.74	0.021	40.47
Clay	0.21-	4.56	-0.07	4.24	-0.0039	4.52
Silt	3.29	10.69	-0.82	12.52	-0.0022	18.72
Sand	0.19	12.88	-0.083	14.49	0.0061	18.35

The sensitivity of the MaxEnt model has been shown in Fig. 3, using the ROC curve in the study area. The area under the curve is equal to the probability of distinguishing between the presence and absence points, which varies from 0.5 to 1; values above 0.5 are significant. The MaxEnt method produces two ROC curves based on learning and test data. As shown in the figure, the area under the curve (AUC) for learning data is about 0.987 and for test data, it is about 0.981 in the study area. According to the area classification under the curve of Sweet (1988), the model indicates a good prediction against the area under the curve with a value of 0.5, which means that the prediction is random.

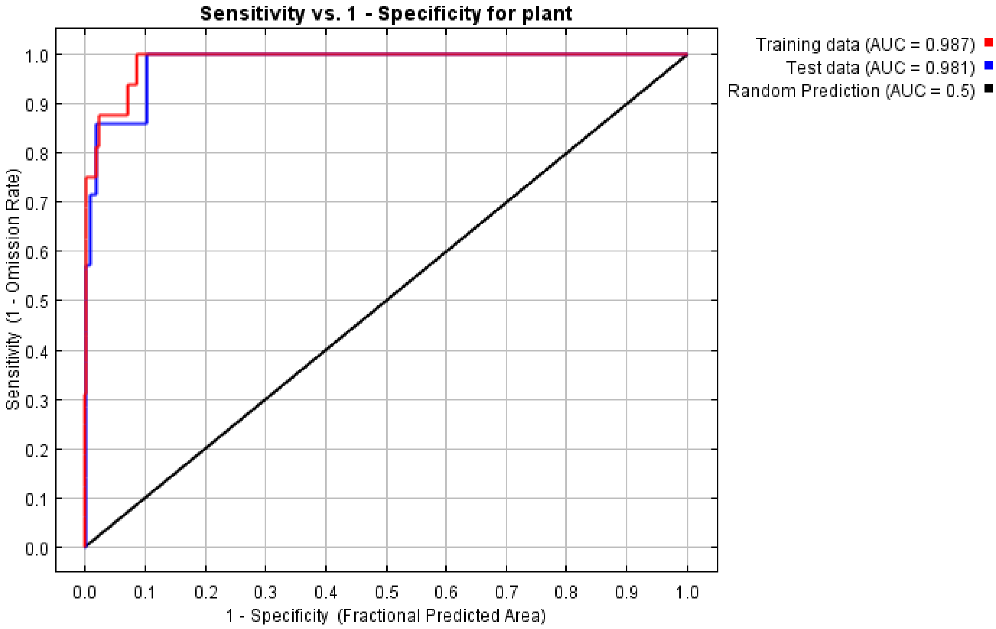

Fig. 3. Sensitivity analysis of the MaxEnt model using the area under the curve in the study area

Locations of presence and absence of *V. arctostaphylos* were predicted using the distributional pattern of affective environmental variables. Fig. 4 shows the habitat prediction map for the species in the study area using the MaxEnt model. The output of the entropy model is a continuous probable map in which an optimal presence threshold value must be set to confirm the presence or absence of target species. After determining the optimal threshold using the test of sensitivity and specificity, the continuous prediction map became the presence and absence of map (0 and 1); so that points larger than the threshold are considered as presence and areas lower than it are the absence.

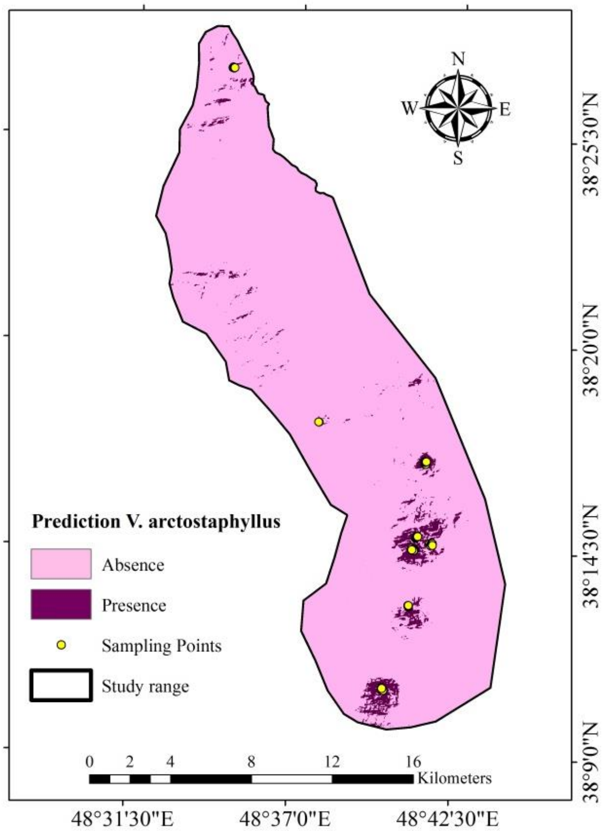

Fig. 4. The predicted distribution for *V. arctostaphylos habitat from the* MaxEnt model

In the Jackknife method, an environmental variable is removed from the model, and the model continues using other variables; also, the model is executed separately with the excluded variable. In this way, the contribution of each environmental variable in the whole model (including all variables) is calculated (Hosseini *et al.*, 2013). The results of the Jackknife method to determine the importance of variables in the geographical distribution of *V. arctostaphylos* showed that the variables of elevation, rainfall, and temperature had the most excellent effect on the distribution of the species, respectively. Among the soil properties, the effects of the variables of clay percentage, organic matter percentage, sodium, magnesium, geographical aspect, pH, phosphorus, and slope are in the following priorities. Therefore, the mentioned variables have the most helpful information, and other environmental variables have more negligible effect when they are executed separately in Jackknife operation. In Fig. 5, the vertical axis of the environmental variables and the horizontal axis show the effect and importance of the variables in three modes (no variable, only with the variable and with all variables) in obtaining the prediction model. Response curves represent the relationships between environmental variables and the distribution of suitable habitats for plants and can provide helpful information about the environmental thresholds required for the distribution of the plants.

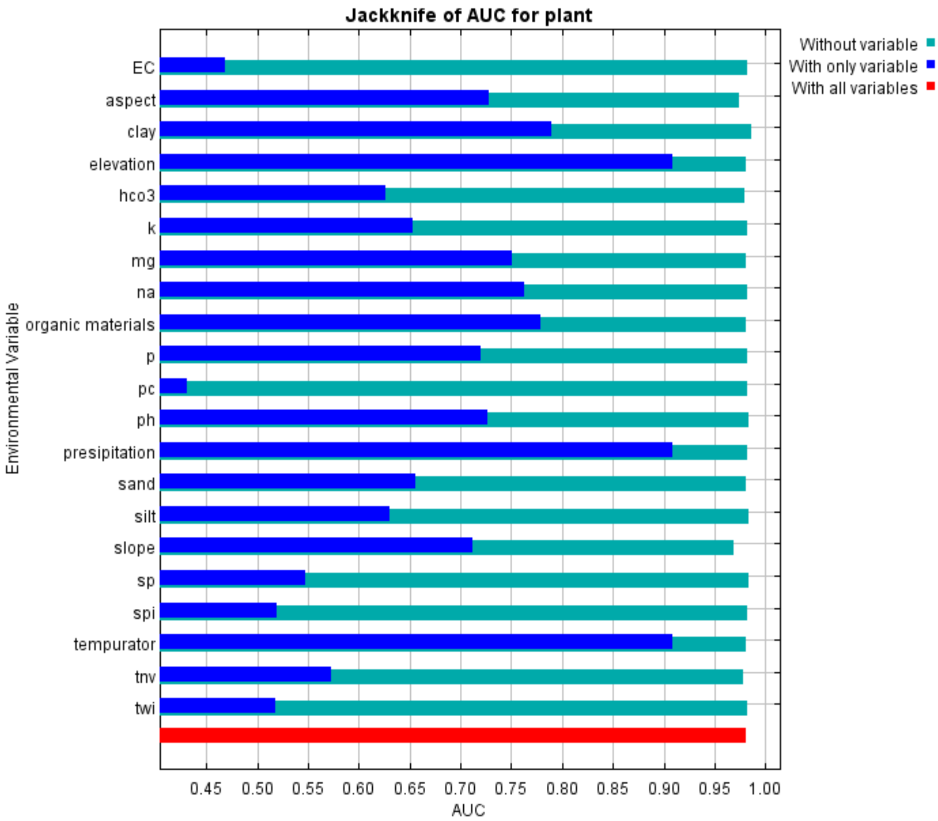

Fig. 5. Jackknife results of the importance of environmental variables for *V. arctostaphylos*

The response curve shows the relationship between environmental variables and the suitable habitat of *V. arctostaphylos*. In this study, using the MaxEnt model, the response curve was prepared for the most critical environmental variables (determined in the Jackknife method). Fig. 6 shows the most essential response curves of *V. arctostaphylos* to environmental variables in the study area. The results of response curves show that the probability of the presence of *V. arctostaphylos* increases in the elevation range of 1500-1900 meters above sea level. In addition, the probability of the presence of *V. arctostaphylos* enhances in 350-450 mm of the precipitation range and about 7-10°C of annual temperature in the studied habitats. Based on the response curves of soil variables including the percentage of clay, the percentage of organic matter, and sodium, we find that the model distinguishes irregularities in environmental variables.

Given that equilibrium and stability in the plant community mean maximum entropy, low accuracy in the input data can be very effective in separating communities by the MaxEnt method. The accuracy of the MaxEnt model and the degree of accommodation between the forecast map and the actual species distribution map was calculated using the cross-validation method. In the study area, the kappa index value was 0.64, which is a good accuracy for the forecasting model.

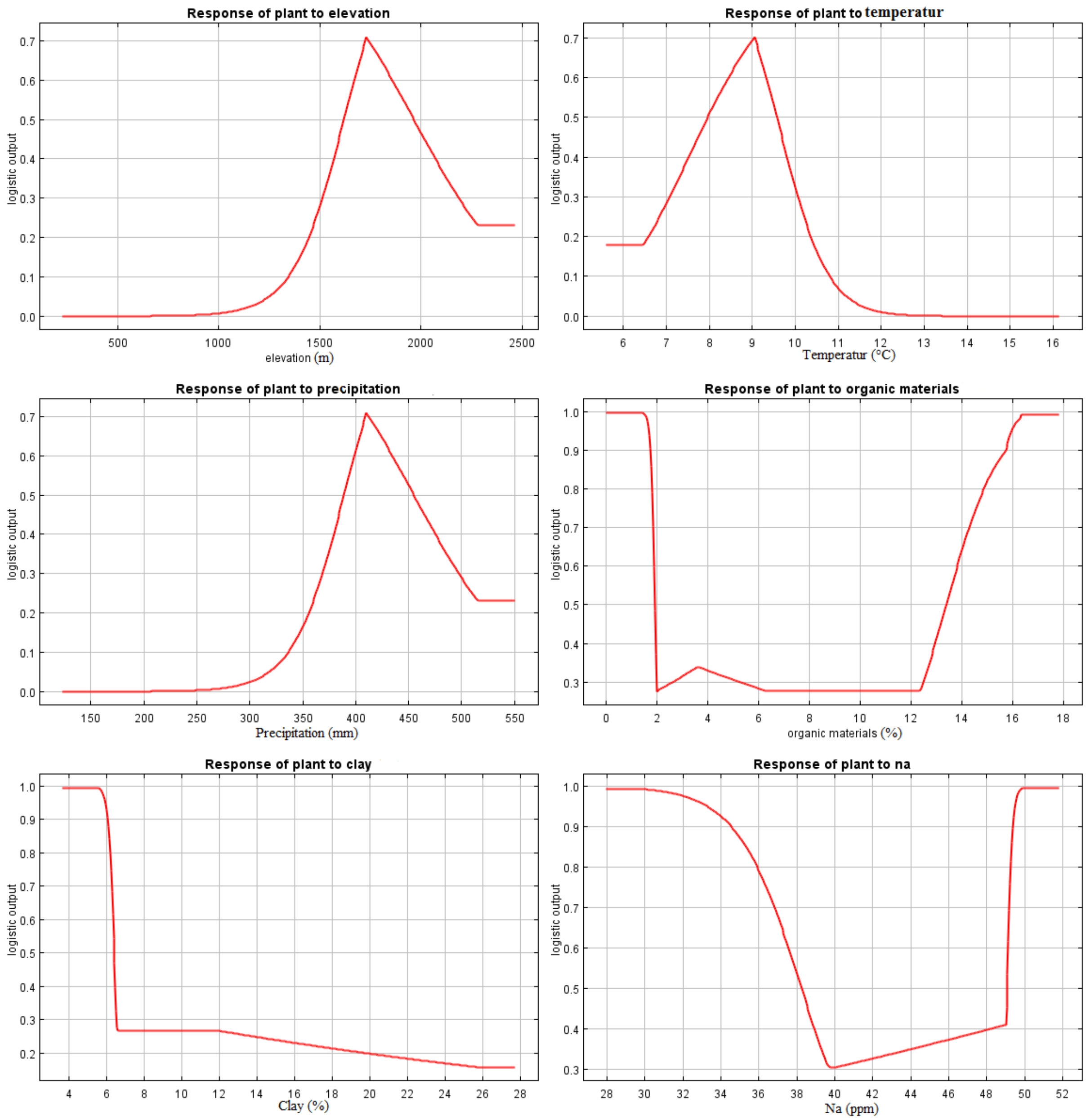

Fig. 6. Response curves of the most effective predictors for *V. arctostaphylos*

Discussion

Each plant correlates with some climatic, topographic, and soil characteristics according to the properties of the habitat, ecological needs, and environmental stress tolerance range. Therefore, identifying the main factors affecting the presence and absence of plant species and study of each species in plant communities can avoid spending much expense. In this study, the factors affecting the presence of *V. arctostaphylos* were studied. The results on sensitivity of the MaxEnt model in the study area showed that the area under the curve (AUC) for learning data was 0.987 and for the test data, it was 0.982, which according to Hoffman *et al.* (2008) theory, is a good predictor of the model against the area under the curve with a value of 0.5. It means that prediction is random. Based on the jackknife operation results, the variables of elevation, rainfall, and temperature had the most significant effect on the distribution of the studied species, which is consistent with the results of studies of Hasanlou *et al*. (2019) on the genus *Vaccinium*. Moreover, among the soil properties, the effect of variables of clay percent, organic matter percentage, sodium, magnesium, geographical aspect, pH, phosphorus, and slope were ranked in the following priorities. According to the study of Zarabi *et al*. (2017) in modeling the suitability of wild pistacia (*Pistacia vera*) habitat in Sarakhs forests region of Khorasan Razavi, Iran, climatic factors (temperature and rainfall) and elevation are the most important factors affecting the habitat distribution. Ma and Sun (2018) used the MaxEnt model to predict the distribution of *Stipa purpurea* on the Tibetan Plateau, which performs well to understand the environmental relationships of species, and after examining 11 environmental variables, they concluded that rainfall, elevation, and temperature are important factors for growth and distribution this plant. In their study, it was found that temperature is an important climatic factor for plant growth in arid and semi-arid regions. Ghaffari *et al*. (2016) in determining the factors affecting the distribution of *Festuca ovina* by the MaxEnt method in Moghan-Sabalan rangelands of Ardabil province reported that the elevation is one of the most important factors affecting the presence of the *F. ovina*. In addition, Esfanjani *et al*. (2019) stated that the variables of elevation, rainfall, and soil phosphorus were the most important factors affecting the distribution of the *Prangos pabularia* in the southern rangelands of Ardabil province.

According to the results of the present study, *V. arctostaphylos* prefers acidic soils with medium to heavy texture and the percentage of clay and silt particles in the soil was effective in the distribution of *V. arctostaphylos* species. According to various studies, the genus *Vaccinium* is acidophilic plant and is found in soils rich in organic matter, and an acidic pH (Hasanlou *et al*., 2019; Ostrolucka *et al*., 2004). Soil particle size distribution affects the process of erosion, temperature, porosity, and other soil properties and therefore plays a vital role in plant growth (Diaz-Zorita & Groveand, 2007). Molaei *et al*. (2015) in their studies reported a significant relationship between *Artemisia aucheri*, organic matter, and soil pH. Khalasi Ahvazi *et al*. (2015) expressed that results of the MaxEnt modeling showing the variables of clay, gravel, first depth available moisture and first and second depth lime were the most important factors affecting the distribution of *A. aucheri* species. In addition, Zare Chahouki *et al*. (2018) related the most important influential variables in the habitat preference of *Stipa barbata* which were elevation, phosphorus, silt, potassium, organic matter and slope, respectively; the results of the present study are consistent with their results.

Based on the results of the response curve, *V. arctostaphylos* is likely to be present in the elevation range of 1500-1900 m above sea level. Also, the precipitation range in the presence of *V. arctostaphylos* species is

350-450 mm, and the average annual temperature range is about 7-10°C. The main reason for these irregular changes is in the low accuracy of the soil maps because the distances between the samples and the intermediation of the soil maps have not been observed. According to the study of Hasanlou *et al*. (2019), *V. arctostaphylos* grows in cold climates of mountainous areas with an elevation range of 1100 to 1900 m above sea level. The validation of the prediction map was done by comparing the plant ground map with the Kappa index. Based on the accuracy of the MaxEnt model, it was calculated using the cross-validation method, which in the study area was 0.64, and it indicates a good agreement of the predictive model. Based on the Kappa coefficient, we can say that this model was a success for *V. arctostaphylos* habitat, and locations of distribution of this species were predicted with reasonable accuracy. According to Ma and Sun (2018), Promnikorn *et al*. (2019), Esfanjani *et al*. (2019), and Borna *et al*. (2020), MaxEnt modeling can reasonably predict the distribution of the studied species. Models such as MaxEnt, ENFA, and other models based on sampling process to estimate the probability of presence should be considered as important options for some species distribution models in rangelands (Khalasi Ahwazi *et al*., 2015).

In general, this study showed that the MaxEnt method could provide a good prediction model for the habitat of the *V. arctostaphylos* species, which has unique habitat conditions. Understanding the environmental characteristics of the habitat of each plant species has an influential role in suggesting species adaptable with environmental conditions in similar areas. Therefore, by focusing on these characteristics in future research and using the MaxEnt method, the success of utilization projects and vegetation sustainable protection can be increased and save cost and time. So, the results of this study can be used to improve and restore the habitat of *V. arctostaphylos* and areas with similar conditions, especially the Namin rangelands, for management and planning purposes in order to protect the habitat of the rare species. In general, the results showed that MaxEnt model could be used as a prediction tool to determine the location of *V. arctostaphylos* species. In addition, the prepared forecast map can be used for better conservation of this species and rangelands management and improvement of the regions and areas with similar conditions.

References

Anderson, R.P., Lew, D. and Peterson, A.T., 2003. Evaluating predictive models of species distributions: criteria for selecting optimal models. Journal of Ecological Modelling, 162: 211–232.

Azimi Motem, F., Talai, R., Asiabizadeh, F. and Houshyar, M., 2011. A survey on flora, life forms and geographical distribution of plant species in the protected forests of Fandoghlu (Ardabil province). Iranian journal of Taxonomy and Biosystematics, 9: 75-88. (In Persian).

Bagheri, H., Ghorbani, A., Zare Chahouki, M.A., Jafari, A.A. and Sefidi, K., 2017. Halophyte species distribution modeling with MaxEnt model in the surrounding rangelands of Meighan playa, Iran. Applied Ecology and Environmental Research, 30(2): 15-29. (In Persian).

Bedia, J., Busque, J. and Gutierrez, J. M., 2011. Predicting plant species distribution across an alpine rangeland in northern Spain. A comparison of probabilistic methods. Journal of Applied Vegetation Science, 14: 415-432.

Borna, F., Tamartash, R., Tatian, M.R. and Gholami, V., 2020. Habitat suitability modeling of Onobrychis cornuta using Ecological Niche Factor Analysis in Rangeland of Baladeh, Nour. Plant Research, 27(1): 98-111. (In Persian).

Dadjou, F., Ghorbani, A., Moameri, M. and Bidarlord, M., 2018. Effects of temperature and rainfall on the aboveground net primary production of Hir and Neur rangelands in Ardabil province. Iranian journal of Range and Desert Research, 25(3): 577-593.

Diaz-Zorita, M., J. H. and Groveand, E., 2007. Sieving duration and sieve loading impacts on dry soil fragment size distributions. Soil and Tillage Research, 94(1): 15-20.

Emad, M., Gheibi, F., Rasouli, S.M., Khanjanzadeh, R. and Mohammadi Jozani, S., 2012. Book of Ghareghat industrial medicinal plant. Pooneh Publication, Tehran, Iran. 40p. (In Persian).

Esfanjani, J., Ghorbani, A. Moameri, M., ZareChahouki, M. A., Esmali Ouri, A. and Mirzaei Mossivand, A., 2020. Prediction of distribution of *Prangos uloptera* DC. Using Two Modeling techniques in southern rangelands of Ardabil province, Iran. Journal of Rangeland Science, 10(2): 137-148.

Esfanjani, J., Ghorbani, A., Moameri, M., Chahouki, M.A. and EsmaliOuri, A., 2021. Application of modeling techniques for the identification the relationship between environmental factors and plant species in rangelands of Iran. Ecological Informatics, 61: 101229.

Esfanjani, J., Ghorbani, A., Moameri, M., Zare Chahouki, M.A., Esmaili Ouri, A. and Mirzaei Mossivand, A., 2019. Comparison of maximum entropy and logistic regression for distribution modeling of *Prangos pabularia* lindl. in southern rangelands of Ardabil province, Iran. Range Management & Agroforestry, 40(2): 202-206.

Gaston, A. and Garcia-Vinas, J. I., 2011. Modeling species distributions with penalised logistic regressions: A comparison with maximum entropy models. Journal of Ecological Modelling, 222: 2037-2041.

Ghafari, S., Ghorbani, A., Moameri, M., Mostafazadeh, R., Bidarlord, M. and Kakehmami, A., 2019. Determining the effective factors in *Festuca ovina* species distribution using maximum entropy method (Case study: Altitude gradient of Moghan-Sabalanestan rangelands of Ardabil). Iranian journal of Range and Desert Research, 27(3): 433-462. (In Persian).

Ghorbani, A., Abbasi Khalaki, M., Asghari, A., Omidi A. and Zare Hesari, B., 2015. Comparing environmental factors on distribution of *Artemisia fragrans* and *Artemisia austriaca* in southeastern rangelands of Sabalan. Rangeland, 9(2): 129-141.

Giovanelli, J.G.R.., Siqueira, M.F.D., Haddad, C.F.B. and Alexandrina, J., 2010. Modeling a spatially restricted distribution in the Neotropics: how the size of calibration area affects the performance of five presence-only methods. Ecological Modeling; 221: 215-224.

Graham, C.H., Ferrier, S., Huettman, F., Moritz C. and Peterson, A.T., 2004. New developments in museum based informatics and applications in biodiversity analysis. Journal of Trends in Ecology and Evolution, 19(9): 497–503.

Hasanlou, T., Jafarkhani Kermani, M., Dalvand, Y. and Rezazadeh, SH., 2019. A complete review on genus *Vaccinium* and Iranian Ghareghat. Iranian journal of Medicinal Plants, 18(72): 46-65. (In Persian).

Hoffman, D.J., Narumalani, S., Mishra, D.R., Merani, P. and Wilson, R.J., 2008. Predicting potential occurrence and spread of invasive plant species along the North Platte River, Nebraska. Invasive Plant Science and Management, 1: 359-367.

Hosseini. S.Z., Kappas, M., Zare Chahouki, M.A., Gerold, G., Erasni D. and Rafiei Emem, A., 2013. Modeling potential habitats for *Artemisia sieberi* and *Artemisia aucheri* in Poshtkouh area, central Iran using the maximum entropy model and Geostatistics. Journal of Ecological Informatics, 18: 61-68.

Jafari Haghighi, M., 2003. Soil analysis Methods: sampling and important physical and chemical analyses. Publisher Nedaye Zoha, Iran. 240p. (In Persian).

Khalasi Ahwazi, L., Zare Chahouki, M.A. and Hosseini, S.Z., 2015. Modeling geographic distribution of *Artemisia sieberi* and *A. aucheri* using presence-only modeling methods (Maxent & ENFA). Iranian journal of Renewable Natural Resources Research, 6(1): 57-73. (In Persian).

Khosravi, Y. and Abbasi, E., 2014. Spatial Analysis of environmental data using geostatistical. Publisher Zanjan Azarkolk, Iran 282p. (In Persian).

Latimer, A.M., Wu, S.S., Gelfand, A.E. and Silander, J.A., 2006. Building statistical models to analyze species distributions. Ecological Applications, 16: 33-50.

Ma, B. and Sun, J., 2018. Predicting the distribution of *Stipa purpurea* across the Tibetan Plateau via the MaxEnt model. BMC Ecology, 18(10): 61-68.

Molaei, M., 2015. Investigation of the effect of some ecological factors on spatial changes of *Artemisia aucheri* and *A. melanolepis* species in the southeastern slopes of Sabalan. MSc Thesis in Rangeland Management, Mohaghegh Ardabili University, Ardabil, Iran. 130 p. (In Persian).

Negga, H., 2007. Predictive modeling of amphibian distribution using ecological survey data: a case study of central Portugal. M.Sc. Thesis. ITC, the Netherlands. 74p.

Nikavar, B. and Amin, Gh.R., 2004. Anthocyanins from *Vaccinium arctostaphylos* Berries. Pharmaceutical Biology, 42(4-5): 289–291. (In Persian).

Ostrolucka, M.G., Libiakova, G. and Ondruskova, E.G., 2004. In vitro propagation of vaccinium species. Acta Universitatis, Biology, 676: 207-212.

Palashi, F., Piri sahragard, H. and Ajorlo, M., 2019. Determination of potential habitat of range plant species using maximum entropy method. Journal of Rangeland Science, 10(1): 16-27.

Phillips, S.J., Anderson, R.P. and Schapire, R.E., 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling, 190: 231–259.

Phillips, S.J., Dudık, M. and Schapire, R.E., 2004. A maximum entropy approach to species distribution modeling. In: Proceedings of the 21st International Conference on Machine Learning, ACM Press, New York. 655–662.

Promnikorn, K., Jutamanee, K. and Kraichak, E., 2019. MaxEnt model for predicting potential distribution of *Vitex glabrata* R.Br. in Thailand. Agriculture and Natural Resources, 53: 44-48.

Robinson, L. and Fordyce, J.A., 2017. Species-free species distribution models describe macro ecological properties of protected area networks. Plus One, 12: 1-19.

Sweet, J.A., 1988. Measuring the accuracy of diagnostic systems. Science, 240: 1285-1293.

Teimourzadeh, A., Gorbani, A. and Kavianpour, A.H., 2015. Study on the flora, life forms and chorology of south eastern of Namin forests (Asi-Gheran, Fandoghloo, Hasani and Bobini), Ardabil Province. Plant research (Iranian Journal of Biology), 28(2): 264-275. (In Persian).

Zarabi, M., Haghdadi, R. and Yousefi, H., 2017. Habitat utility modeling of organic (wild) pistachios (*Pistacia Vera*) using maximum entropy method (MaxEnt) in Sarakhs Forest Area (Gonbadli in khorasan Province). Ecohydrology, 4(3): 817-824. (In Persian).

Zare Chahooki, M.A., Piri Sahragard, H. and Azanivand, H., 2013. Habitat distribution modeling of some halophyte plant species using maximum entropy method (Maxent) in Hoze Soltan rangelands of Qum Province. Journal of Rangeland Science, 7(3): 212-221. (In Persian).

Zare Chahooki, M.A., Jafari, M., Azanivand, H., Moghadam, M.R., Farahpour, M. and Shafizadeh Nasrabadi, M., 2007. Application of logistic regression to study the relationship between presence of plant species and environmental factors. Watershed Management Resources (Journal of Pajouhesh va Sazandegi), 3(20): 136-143. (In Persian).

Zare Chahouki, M.A., Abbasi, M. and Azarnivand, H., 2018. Prediction of potential habitat for *Stipa barbata* species using maximum entropy model (Case Study: Taleghan Miany rangelands). Journal of Rangeland Science, 12(1): 35-47. (In Persian).

Zhang, L., Jing, Z., Li, Z., Liu, Y. and Fang, S., 2019. Predictive modeling of suitable habitats for *Cinnamomum camphora* L. presl using MaxEnt model under climate change in China. International Environmental Research and Public Health, 16(17): 31-85.

تعیین عوامل تأثیرگذار در انتشار گونه دارویی قره‌قات (*Vaccinium arctostaphylos* L.) با روش آنتروپی حداکثر (مطالعه موردی: مراتع شهرستان نمین- اردبیل)

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چکیده. این مطالعه با هدف مدل‌سازی پیش‌بینی رویشگاه بالقوه گونه نادر قره‌قات (*Vaccinium arctostaphylos* L.) با استفاده از روش آنتروپی حداکثر و تعیین آشیان اکولوژیک پتانسیل گونه مورد مطالعه انجام شد. برای این منظور در مراتع نمین اردبیل در سال ۱۳۹۹، نمونه‌برداری از مناطق حضور گونه قره‌قات در ۸ رویشگاه در فصل رویش انجام شد. هم‌چنین، اطلاعات طول و عرض جغرافیایی و عوامل فیزیوگرافی گونه مورد نظر در هر رویشگاه از مراتع منطقه نمین با استفاده از GPS ثبت شد و نمونه‌های خاک از عمق ۰-۳۰ سانتی‌متری جمع‌آوری شدند. سپس برخی از خصوصیات فیزیکی و شیمیایی خاک از قبیل pH، قابلیت هدایت الکتریکی، بافت خاک، آهک، پتاسیم محلول، منیزیم، سدیم محلول، ماده آلی ذره‌ای، فسفر قابل‌جذب، بی‌کربنات محلول و درصد رس، سیلت و شن در آزمایشگاه اندازه‌گیری شدند. در گام بعد برای تعیین ارتباط بین عوامل محیطی و پراکنش گونه قره‌قات از مدل آنتروپی حداکثر استفاده شد. نقشه عوامل محیطی مؤثر بر پراکنش گونه مورد نظر با استفاده از روش آمار مکانی IDW در محیط نرم‌افزار $\text{Arc GIS}_{\text{ver10.8}}$ تهیه شد. نقش عوامل محیطی مؤثر بر پراکنش گونه با استفاده از روش جک‌نایف و منحنی‌های پاسخ بررسی گردید. نتایج حاصل از شاخص کارائی جک‌نایف نشان داد که به‌ترتیب متغیرهای ارتفاع، بارندگی و درجه حرارت مهم‌ترین متغیرهای موثر در توزیع قره‌قات معرفی شدند. نتایج منحنی‌های پاسخ در منطقه نشان داد که این گونه در دامنه ارتفاعی ۱۹۰۰-۱۵۰۰ متر از سطح دریا احتمال حضور دارد. همچنین، دامنه بارندگی حضور گونه قره‌قات ۴۵۰-۳۵۰ میلی‌متر و دامنه دمای متوسط سالانه در حدود ۱۰-۷ درجه سانتی‌گراد در رویشگاه‌های مورد مطالعه است. برای ارزیابی میزان تطابق نقشه پیش‌بینی با نقشه واقعی از شاخص کاپا استفاده شد. بر این اساس صحت مربوط به مدل‌سازی آنتروپی حداکثر با مقدار شاخص کاپای ۰/۶۴، قابل قبول بوده و این مدل، دارای دقت خوب در پیش‌بینی حضور گونه با رویشگاه واقعی می‌باشد. به‌طور کلی نتایج نشان داد که مدل آنتروپی حداکثر می‌تواند به‌عنوان یک ابزار پیش‌بینی برای تعیین موقعیت گونه قره‌قات استفاده شود. همچنین، نقشه پیش‌بینی تهیه‌شده برای حفاظت بهتر و مدیریت و اصلاح مراتع منطقه و مناطق دارای شرایط مشابه قابل استفاده است.

واژه‌های کلیدی: مدل‌سازی، پراکنش رویشگاه، آنتروپی حداکثر، گونه قره‌قات