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Modeling habitat distribution of *Festuca ovina-Astragalus gossypinus* by using maximum entropy method in the Chaharbagh rangelands of Iran

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Abstract
The study was aimed to estimate the geographic distribution of *Festuca ovina-Astragalus gossypinus* in the Chaharbagh rangeland in Golestan province by using Maximum Entropy (MaxEnt) modeling technique. Sampling of vegetation was carried out following systematic random sampling approach. Soil properties (texture, organic carbon, pH, EC and N) were determined by standard methods. Geostatistical methods were used for mapping soil properties. Environmental variable maps were prepared. The agreement of predictive map with the actual map was checked by calculating Kappa coefficient value. Accuracy of predictive models was evaluated using the area under curve (AUC). Study revealed that Jackknife method and response curve were most important methods for environmental predictor variables. Correspondence of actual map with the predictive one was at satisfactory level (Kappa coefficient=0.65). The habitat requirements of *Festuca ovina-Astragalus gossypinus* indicated that the highest probability of presence occurred in the soils with N (0.14-0.18%), sand (35-38%), clay (20-24%) contents and low lime (11-13%) content.

Keywords: Chaharbagh rangeland, Environmental factors**,** Jackknife method, MaxEnt, Modeling

Introduction

In rangeland and pastureland plantings, *Festuca ovina* is a competitive understory grass suitable for stabilization of disturbed soils because of its dense root system. It provides excellent cover and erosion control in areas between tree rows of shelterbelts, windbreaks and tree farms. Drought tolerance and adaptations to a variety of soils make this species ideal for reclamation in areas receiving 12 to 24 inches of annual precipitation. This grass can also be used in areas where irrigation water is limited to provide ground cover (Ogle *et al.,* 2009). Hence, *Astragalus gossypinus* has valuable place in natural resources (Yazdanshenas *et al.,* 2014). Modeling spatial distribution of habitats plant species and identifying the most important environmental factors affecting them are very important. Species distribution modeling on the ecological characteristics of potential habitat is done to protect the species (Zare Chahouki *et al*., 2012). A variety of species distributions modeling methods are available to predict potential suitable habitat for a species (Guisan *et al*., 2007). Maximum Entropy is based on the unknown estimate of probability distribution of species (Philips *et al*., 2006) and this method has preference over other methods that are based on the presence of species (Baldwin, 2009). Smith *et al.* (2012) predicted potential distributions of large trees for conservation planning using area under curve (AUC) values for test of modelling prediction and showed that AUC values were of high accuracy for trees. Zare Chahouki and Piri Sahragard (2016) investigated MaxEnt method for habitat distribution modeling of three plant species in Garizat rangelands of Iran. They observed that vegetation distribution pattern was mainly related to soil characteristics such as EC, available moisture, lime, organic matter and elevation. Correspondence of actual map with predictive map was assessed at very satisfactory level. Piri Sahragard *et al.* (2016) investigated predictive distribution models for determination of optimal threshold of plant species in central Iran. Plant species distribution modelings are used for environmental problems. Many of these methods, create a continuous appropriate predictions and MaxEnt model has high degree of confidence (Liu *et al*., 2013). This study was attempted to predict plant species distribution of *Festuca ovina–Astragalus gossypinus* in Chaharbagh rangelands of Golestan province.

Materials and Methods

***Study area*:** The study area (Fig 1) was located on the eastern side of Qazal Road to Chaharbagh village (36° 43' 30" to 36° 30' 00" N, 54° 19' 30" to 54° 40'

30" E; 2208 to 2327 m) in southeast of Gorgan city. This forms a part of the Golestan province. The average rainfall and annual temperature is 348.5 mm and 6.5 °C, respectively. The rainfall is more than snowfall in the winter season. The region's climate falls under category of cold and Mediterranean.

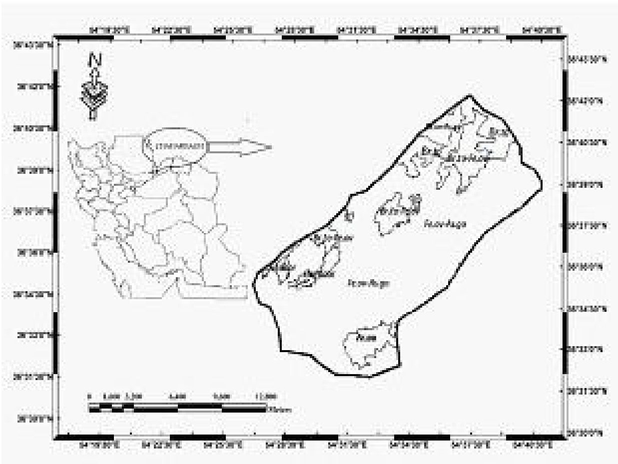

Fig 1. Geographical location of study area

***Sampling of vegetation and soil*:** Sampling of vegetation was carried out following systematic random sampling approach. A square meter of plot was used for sampling of vegetation (Zare Chahouki and Esfanjani, 2015) and each site had three transects (50 m). Along each transect 10 plots ($1m^2$) were placed. The distance between the plots was 5 m and the total plots were 120. The vegetation density was determined in each plot. Being a mountainous terrain, the soil samples were taken at 0-30 cm depth. Soil properties (texture, organic carbon, pH, EC, lime and N) were determined by standard methods.

***Mapping prediction models*:** Topographic data (elevation, slope, and aspect) was obtained from DEM with accuracy of 10 m. To map soil characteristics, geoestatistical method was used including variogram analysis and Kriging interpolation by GS+ Ver. 5.1.1, a software that is based on obtained predictive models for *Festuca ovina-Astragalus gossypinus* (Zare Chahouki and Esfanjani, 2015). Modeling was performed after preparing the environmental variable maps and their entry in the maximum entropy software (Zare Chahouki and Piri Sahragard, 2016). The area under the curve (AUC) of receiver operating characteristic function was used for the evaluation of discrimination ability (Fielding and Bell, 1997). The AUC ranges from 0.5 for an uninformative model to 1 for perfect discrimination. Jackknife analysis was also used to determine the importance of variables. MaxEnt 3.1 software was used (http: //www.cs.princeton. edu/~schapire/maxent/) to estimates the probability of species presence and absence ranging from 0 to 1 in which 0 and 1 stand for the lowest and highest probability rates, respectively. Because of continuous output of MaxEnt, optimal threshold value was determined for presence or absence of the target species (Phillips *et al*., 2006; Negga, 2007). After determining the optimal threshold using equal sensitivity and specificity method, species presence or absence maps were generated and their coincidence with the actual maps were investigated through calculating the kappa coefficient in the IDRISI Selva 17 software (Zare Chahouki and Pirisahragard, 2016).

Results and Discussion

***MaxEnt method*:** The results of methods based on presence of data were better than the methods based on presence and absence of data, because of low cost (Hirzel *et al*., 2002; 2006). Hence, MaxEnt method based on the presence of species was used. Assessment of accuracy level of model output showed that MaxEnt can successfully predict the occurrence of *Festuca ovina-Astragalus gossypinus* (AUC=0.57). The model indicated that habitat distribution of *Festuca ovina-Astragalus gossypinus* was mainly related to soil characteristics and the prediction was good (Fig 2). The probability distribution maps produced by MaxEnt indicated distinct differences in the spatial distribution of *Festuca ovina-Astragalus gossypinus* (Fig 2). The output of the MaxEnt model was between 0 and 1, and it was obtained with high sensitivity and specificity (Fig 3). *F. ovina-A. gossypinus* habitat was checked with the actual maps by measuring the Kappa coefficient using IDRISI Selva 17. Based on the obtained Kappa coefficients, it was considered that predictive maps of *F. ovina-A. gossypinus* habitat had a good agreement (Kappa index=0.65) (Monserud and Leemans, 1992).

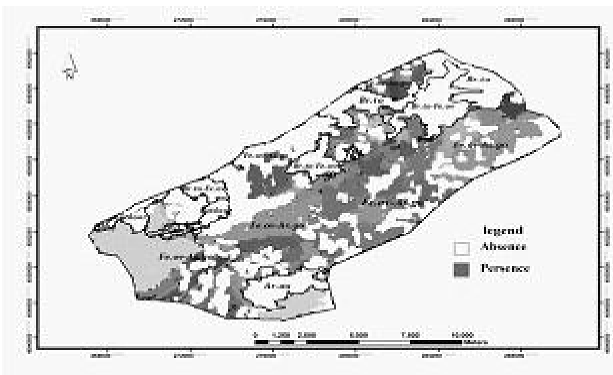

Fig 2. The predicted distribution for *F. ovna-A. gossypinus* from the MaxEnt model

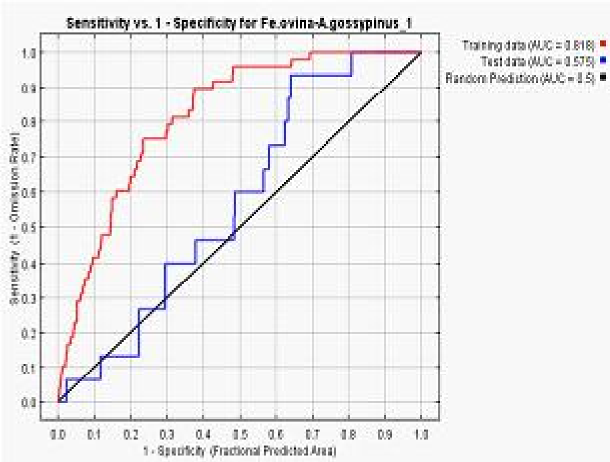

Fig 3. ROC curves of sensitivity vs. specificity for *F. ovina-A. gossypinus*

***Jackknife method*:** This method was used for identifying the most important variables. Based on Jackknife method (Fig 4) N, sand, clay and lime were identified as the most important variables in the *F. ovina-A. gossypinus* habitat. The results indicated that when other variables (e.g. physiographic factors) were individually used in *F. ovina-A. gossypinus* habitat, they were likely to have little importance in the model. This indicated that these variables were not useful for estimating the distribution of species individually. The Jackknife test of variable importance showed that clay was the most important predictor of *F. ovina-A. gossypinus* habitat distribution. These variables presented higher rates (that contained the maximum information) than other variables. The habitat requirements of *F. ovina-A. gossypinus* indicated that the highest probability of presence occurred in the soils with N (0.14-0.18%), sand (35-38%) and clay (20-24%) contents and low lime (11-13%) content. Soil characteristics affect the distribution and duration of water stored in the soil, and these, in turn, affect plant distribution and vegetation structure. Under given climatic and vegetation conditions the above soil-texture-dependent physical properties, through their influence on soil water movement and the energy state of the water in the soil column, determine the soil wetness values which in turn establish the water condition of the plant (Fernandez-Illescas *et al*., 2001). Therefore, *F. ovina-A. gossypinus* was affected by the soil texture (Zare Chahouki and Esfanjani, 2015) and grown in the loam soil. Also check out species by MaxEnt model indicated that lime creates soil building unsuitable for the *F. ovina-A. gossypinus.*, but when the lime was reduced, the root zone of the plant created the conditions for allowing the presence of *F. ovina-A. gossypinus* species.

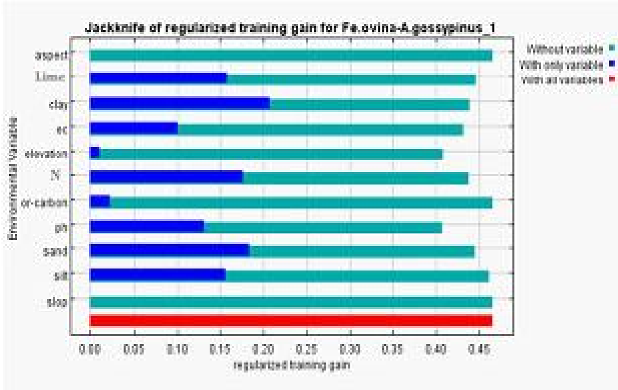

Fig 4. Jackknife results of variable importance

The response curves (Fig 5) showed relationships of environmental variables and suitable habitat distribution of plant species. Theses curve can provide useful information about the required environmental threshold for optimal growth of plant species. Response curves analysis of the most important variables of *F. ovina-A. gossypinus* showed that was increase in clay in surface soil depth, sand, N and lime amount (Fig 5).

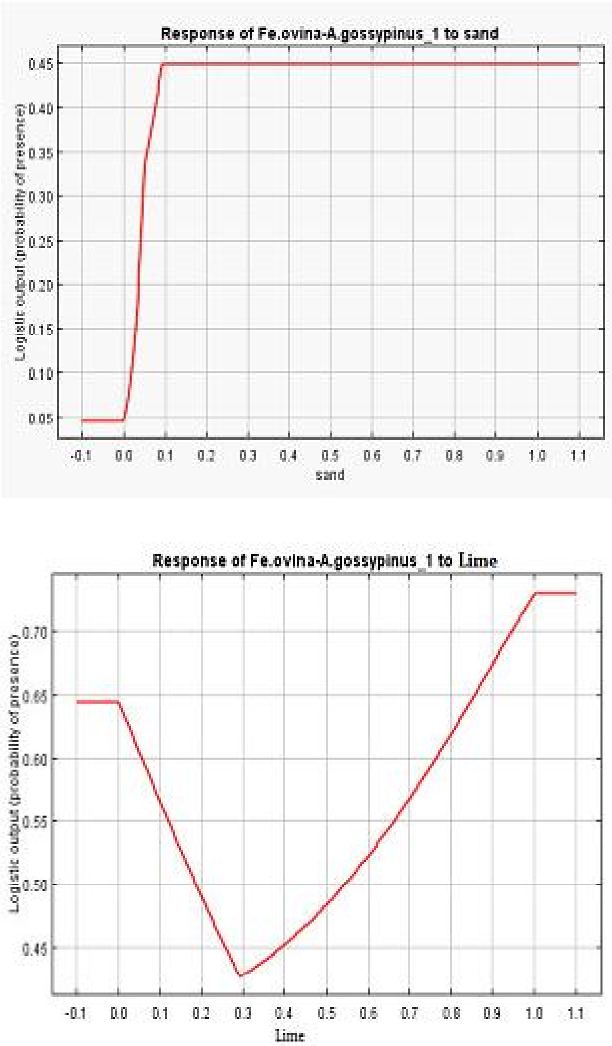

Fig 5. Response curves of the most influential predictors for *F.ovina-A.gossypinus*

Conclusion

This study revealed that the habitat distribution pattern of *F. ovina-A. gossypinus* can be modelled with low number of occurrence data and environmental variables using MaxEnt. The MaxEnt model predicted the potential habitat for *F. ovina-A. gossypinus* with good success rates (Kappa=0.65). Method such as Maximum Entropy was effective in indication of species distribution. It revealed the most important environmental factors affecting the habitats of important species of plants such as *F. ovina-A. gossypinus* and can be used for correct management in rangelands. Besides that the species can be used for preventing of soil erosion and ecological imbalances of the region. Thus, the ability to set thresholds in natural systems can help us to understand and manage the tradeoffs between biodiversity and production.

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