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Predicting potential distribution of plant species by modeling techniques in southern rangelands of Golestan, Iran

Mohammad Ali Zarechahouki*[1] and Javad Esfanjani[2]
[1]Department of Rehabilitation of Arid and Mountainous Regions, University of Tehran, Iran
[2]Natural Resources Faculty, Goonbad Kavoos University, Iran
* Corresponding author e-mail: mazare@ut.ac.ir
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Abstract
This paper investigates the use of ôEcological niche factor analysisô(ENFA) method for modeling plant species, geographic distributions with presence-only data and ôLogistic Regressionô(LR) methods for the investigation of plant species distribution with presence-absence data in south of Golestan. Plant density and cover, soil texture, pH, electrical conductivity (EC), gypsum contents, organic matter, lime and topography (elevation, slope and aspect) are the sample variables using the randomized systematic method. Within each vegetation type, the samples were collected using 10 quadrates placed at an interval of 5 m along three 50m transects. To map soil characteristics, the geostatistical method was used. According to the results in the ENFA method, variable amounts of clay and slope impact on *Artemisia aucheri* type, Elevation and sand content had the greatest impact on the *Festuca ovina- Astragalus gossypinus* type, because elevation gradients create varied climates, along with the resultant soil differentiation; promoting the diversification of plant species, and the effect of environmental factors were important amount of sand and aspect on the *Bromus tomentellus* type and amount of sand, elevation, and rate of organic carbon had the greatest impact on *Bromus tomentellus-Festuca ovina* type. Butin LR method, slope factor had the most impact on the distribution of *Artemisia aucheri* type .The most important factors affecting the *Artemisia aucheri* habitat are the degree of slope ,Sand and elevation effect of the *Festuca ovina- Astragalus gossypinus* type. This aspect affected the *Bromus tomentellus* type and Elevation affected the *Bromus tomentellus- Festuca ovina* type. The accuracy of the logistic regression results regarding the Kappa Index was more than ENFA method.

Keywords: ENFA**,** Environmental factor, Golestan, LR, Modeling

Introduction
Distribution of plant communities due to various factors such as climate, physical and chemical properties of soil, physiographic factors such as elevation, slope and aspect and human factors are not random in rangeland ecosystems (Neeti *et al*., 2007). Predictive models of species distribution range limits the prediction of species distribution and their habitats, so they could be used as a tool for conservation and management purposes. In order to map the species distribution, spatial correlation method is used in species distribution models, the main part of the research topics in the field of plant ecology and geography (Boyce, 2006; Hirzel, 2002). Different types of modeling techniques are used to ût different types of biological information recorded ateach sample site:(1) presence-only: occurrences of the target species Are recorded; (2) presence/absence: each sample site is carefully monitored to assert with sufûcient certainty, whether the species is present or absent. With plants, for instance, it is commonly done byexhaustively listing all species present in each sample site. The liability of absences depends on the species ôcharacteristics (e.g. biology, behaviour, history) (Hirzel *et al*., 2001), their local abundance and the ease of detection (K´ery, 2002), and the survey design (Mackenzie and Royle, 2005). ZareChahouki and ZareChahouki (2010) have predicted distribution plant species using logistic regression in Poshtkouh rangelands of Yazd. The results show that the vegetation distribution is mainly related to soil characteristics such as texture, gravel, EC, gypsum, lime and OM. The presence of *Artemisia sieberi-Zygophyllum eurypterum*is related to gravel, lime, available water and pH. *Ephedra strobilaceae-Zygophyllum eurypterum*is positively related to gypsum. *Rheum ribes-Artemisia sieberi* has relations with clay and organic matter (OM). *Cornulaca monacantha* is also related to elevation above sea, gravel and gypsum. The presence of *Seidlitzia rosmarinus*is related to lime. Electrical conductivity is the

most effective factor on the presence of *Tamarix ramosissima*. ZareChahouki *et al.* (2010) used multivariate statistical methods as a tool for model based prediction of vegetation types. Vegetation modeling results with CCA shows that predictive map of vegetation corresponds with the actual map (with high accuracy). Predictive maps of *Cornulaca monachantha*, *Ephedra strobilacea Zygophyllum eurypterum*, *Seidlitzia rosmarinus, and Tamarix ramosissima,* which have narrow amplitude, have high accordance with the actual vegetation map prepared for the study area. Among species of the study area, predictive model of *Artemisia sieberi*is impossible, due to its ability to grow in most parts of Poshtkouh rangelands with relatively different habitat conditions. Comparing CCA and LR methods showed that each technique has its advantages and drawbacks. In general, LR will provide better specific model, but CCA will provide a broader overview of multiple species. In their research, ZareChahouki and Ahvazi (2012), in order to predicting potential distributions of *Zygophyllum eurypterum* by three modeling techniques (ENFA, ANN and logistic) in North East of Semnan, Iran, the results of ENFA method show that 25200 hectares or 34 percent of study site is a potential habitat of *Z. eurypterum*. The results also revealed that maps generated using the LR and ANN models for *Z. eurypterum* species have a high accordance with their corresponding actual maps of the study area. This species is distributed in rangeland with alkali-saline soil, high in lime percent, silty-sandy texture and in 1000-2000 meters elevation. Trethowan *et al*. (2011) investigated using ecological niche models of species habitat *Campuloclinium macrocephalum*. Wolmarans *et al*. (2010) predicted the distribution of invasive species range ecological niche models using only the data presence. The main purpose of this research was to investigate the relationship between soil and physiographic characteristics with plant species to determine the most important factors affecting the separation of this plant species and then preparing the prediction map of two models including ENFA and logistic in predicting plant species distribution. Given the importance of plant species (medicinal, nutritional and protective), we decided to model habitat of the species in south of Golestan, Iran.

Materials and Methods

Geographic study area in south of Golestan: It is located in 40 degrees North and 28 degrees 04 minutes east, 60 minutes and 40 degrees 50 minutes north and 27 degrees 45 minutes east, maximum altitude of 2327 m and a minimum altitude of 2208 m. Geologically, the bedrock formations are blessed with dark-colored limestone lithology of Cretaceous to Quaternary. Ambrezhe based on regional climate, high altitude and cold climate, mean annual temperature -5.6°C and mean annual precipitation of 305 mm, which is more precipitative in the winter and the snow (Behmanesh *et al*. 2008). Five vegetation types were identified in the study area *i.e. Artimisia auchri, Festuca ovina-Asteragalus gossypinus, Bromus tomentalus, Bromus tomentalus-Festuca ovina* (Fig. 1).

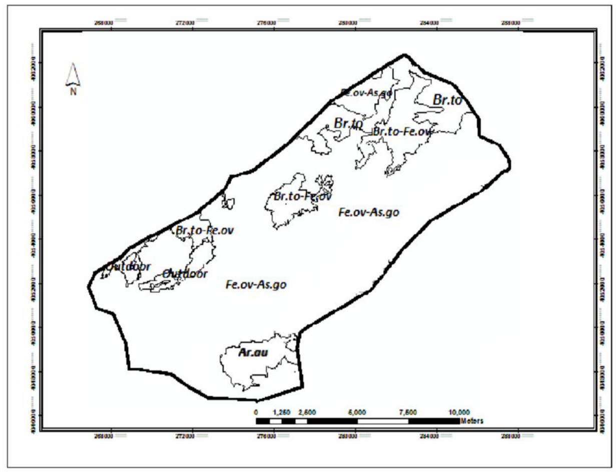

Fig 1. Geographical location and vegetation types in the study area

According to a key area of each vegetation type random-systematic sampling was done. For sampling of vegetation a square meter plots (Behmanesh *et al*. 2008) was used, so that at each site, three 50 m transects were considered. Along each transect were placed 10 plots of one square meter, at a distance of 5 m. A total of 150 plots were cast types, then each plot was determined by the number and canopy cover. Soil samples were taken between 0ï 30 cm (sampling of the soil due to the mountainous terrain and deep rooted plants depths were determined 30-0 cm layer). Measured soil factors included texture (determined by Bouyoucos hydromerter), Organic carbon (determined using Walkely and Black rapid titration, Black, 1979), pH in saturation extract (determined by pH meter), electrical conductivity (ECe) (determined by conductivity meter), lime (determined using 1N HCl, Jackson, 1967), N were determined by Kjeldahl apparatus and titration method.

Mapping prediction models: To plant predictive mapping, it is necessary to prepare the maps of all affective factors of models. Topographic data (elevation, slope, and aspect) were derived 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 each species (through ENFA method and LR method) related to predictive maps prepared in GIS (Fig. 2 and 3). The maps of environmental variables by Biomapper software used the ENFA method. The major part of the environmental impact of the independent variables is examined and a comparison of the species and the environmental characteristics of the study area based on factors such as marginality and specialization is made that led to the creation of habitat suitability maps. Kappa (ê) statistics were used to objectively assess the model performance and model agreement.

Results and Discussion

The results of the ENFA method: According to Boyce index and the suitable standard deviation algorithm was determined. The harmonic algorithm for the species *Artemisia aucheri* and *Bromus tomentellus-Festuca ovina*, and for the species *Festuca ovina- Astragalus gossypinus, Bromus tomentellus* are determined the middle algorithm (Table 1).

According to the analysis, the advantage matrix table resulting in the analysis of the correlation matrix, and the eigenvalues of the covariance matrix are shown in Table 2.

With regarding the marginality, zero means that there is no difference between habitats and species suitable habitats. The greater number that zero and close to number 1 means that species lives in a particular habitat and very different niche than the parameter of the total study area and specialization, high levels (close to number 1) indicate a species expert. According to the above table the most important environmental factors affecting plant species were studied, *Artemisia aucheri* type: amount of clay and slope and EC, *Festuca ovina-Astragalus gossypinus* type amount of sand and elevation, *Bromus tomentellus* type: sand and the aspect (Fig. 2) and *Bromus tomentellus- Festuca ovina* type amount of sand, altitude and soil organic carbon. The compliance rates in other plant types are as follows in Table 3.

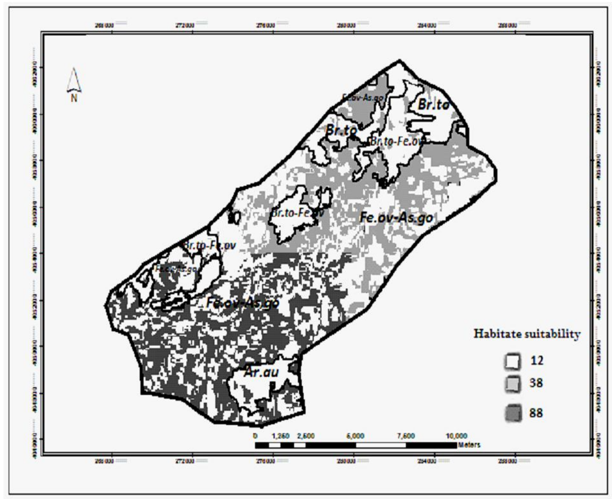

Fig 2. Suitability habitat classification map *Festuca ovina-Astragalus gossypinus* with actual vegetation map with ENFA method

Table 1. Boyce index and the standard deviation of the different algorithms

Type Algorithm	*A. aucheri*	*F. ovina-A. gossypinus*	*B. tomentellus*	*B. tomentellus-F. ovina*
Middle	0.17±0.22	0.34±0.40	0.40±0.21	0.11±0.48
Geometric mean	0.08±0.38	0.31±0.34	0.09±0.52	0.11±0.43
Harmonic	0.38±0.24	0.21±0.69	0.07±0.68	0.16±0.44
Minimum distance	0.77±0	0.77±0	0.77±0	0.77±0

Table 2. Rates and environmental matrix table and marginality independent variables of types

Type	Variable	1	2	3	Marginality	Specialization
A. aucheri	Clay	0.77	-0.64	*	0.77	1.52
	Slope	0.64	0.77	*	0.63	1.27
F. ovina-A. gossypinus	Sand	0.80	0.80	*	0.79	4.35
	Elevation	0.60	-0.60	*	0.60	3.28
B. tomentellus	Sand	0.90	-0.44	*	0.89	37.7
	Aspect	0.44	0.90	*	0.44	18.23
B. tomentellus-F. ovina	Sand	0.68	0.72	0.03	0.68	30.69
	Elevation	0.54	-0.36	0.66	0.53	24.14
	Organic carbon	0.50	-0.59	-0.75	0.49	22.26

Table 3. Kappa index and the degree of match model maps with actual maps

Type name	Kappa index	Compliance rates
Artemisia aucheri	0.57	good
Festuca ovina- Astragalus gossypinus	0.70	good
Bromus tomentellus	0.58	good
Bromus tomentellus- Festuca ovina	0.50	good

The results of the Logistic regression method: To provide prediction habitat map, you must first determine the environmental factors affecting each of the types using logistic regression. According to the results of the logistic regression, the most important environmental factors are as given in Table 4.

Table 4. Most important environmental factors on plant species using logistic regression method

Type name	Environmental factors
Artemisia aucheri	Slope
Festuca ovina-Astragalus gossypinus	Amount of sand and elevation
Bromus tomentellus	Aspect
Bromus tomentellus–Festuca ovina	Elevation

The predicted occurrence probability of types are expressed via the equations (1, 2, 3, 4) Regarding equation (1), the occurrence of *Artemisia aucheri* is dependent on the slope and, regarding equation (2) the occurrence of *Festuca ovina- Astragalus gossypinus* is dependent on the amount of sand and elevation. Regarding equation (3) the occurrence of *Bromus tomentellus* is dependent on the aspect. According the equation (4) the occurrence of *Bromus tomentellus-Festuca ovina* is dependent on the elevation. Based on the predictive model obtained using the LR method, predictive vegetation maps were generated in the GIS environment. Fig. 3 shows the predicted map of *B. tomentellus* the logistic regression model.

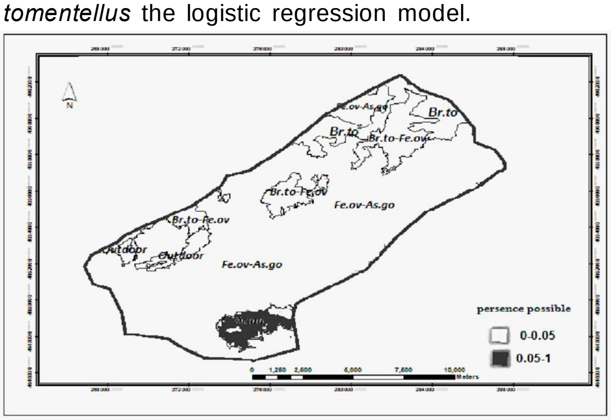

Fig 3. Distribution of predicted habitat maps *Artemisia aucheri* type whit LR method

Logistic equation:

$$1.\ P(A.\ \mathit{aucheri}1) = \frac{Exp\ (./740Slop - 26/037)}{1 + Exp\ (./740Slop - 26/037)}$$

$$2.\ P(F.\ \mathit{ovina} - A.\ \mathit{gossypinus}) = \frac{Exp\ (-./316Sand + 11/608)}{1 + Exp\ (-./316Sand + 11/608)} + \frac{Exp\ (-./86Elevation + 20273/67)}{1 + Exp\ (-./386Elevation + 20273/67)}$$

$$3.\ P(B.\ \mathit{tomentellus}) = \frac{Exp\ (-./414Aspect - 110/942)}{1 + Exp\ (-./414Aspect - 110/942)}$$

$$4.\ P(B.\ \mathit{tomentellus} - F.\ \mathit{ovina}) = \frac{Exp\ (-./092Elevation - 215/556)}{1 + Exp\ (-./092Elevation - 215/556)}$$

According to the maps, models and comparing them with the actual maps in other vegetative types, the compliance rates in other plant types are as given in Table 5.

Table 5. Kappa index and the degree of match model maps with actual maps

Type name	Kappa index	Compliance rates
Artemisia aucheri	0.80	good
Festuca ovina-Astragalus gossypinus	0.98	very good
Bromus tomentellus	0.61	good
Bromus tomentellus -Festuca ovina	0.57	good

According to the modeling maps and comparing them with the actual maps in all vegetative types, both ENFA and logistic regression methods had good accuracy.

The Comparison of two modeling techniques (ENFA and logistic): The accuracy of the logistic regression results regarding the Kappa Index was more than ENFA method. Because in logistic regression analysis, the variable presence or absence of species is a qualitative variable (ZareChahouki, 2010) but Ecological niche method is a factor analysis that is used to determine the most influential variables in the large number of variables and the relationships between them is unknown (Pearson, 1901). So it can be deduced that the number of additional environmental data, the accuracy of the productive map will be more in ENFA method. According to the results, the *Artemisia aucheri* type, preference variables amounts of clay, slope in the ENFA but in logistic regression method, slope factor has the most effect on the distribution of *Artemisia aucheri* type, so that the effect of slope appears on soil depth so as to increase or decrease the slope gradient and soil depth, resulting in effect on the root establishment. Elevation and sand content had the greatest impact on the use of ENFA method in the *Festuca ovina- Astragalus gossypinus* type. Elevation gradients create varied climates, along with resultant soil differentiation; they promote the diversification of plant species (Brown, 2001; Lomolino, 2001). Many studies have investigated species distribution along withthe elevation gradient across habits and taxa (Rahbek, 1997; Austrheim, 2002), as part of efforts to understand ecosystem effects on distribution of vegetation (Tilman and Downing, 1994). Also ZareChahouki *et al*. (2012) showed the effect of Elevation on grassland plant communities of North East province of Iran, Semnan. But in logistic regression method, sand and elevation impacted the *Festuca ovina-Astragalus gossypinus* type. Sand and aspect were important environmental factors affecting use of ENFA method in the *Bromus tomentellus* type. But in the logistic regression method, the *Bromus tomentellus* type was affected by aspect. The amount of sand, elevation, and rate of organic carbon had the greatest impact on the *Bromus tomentellus-Festuca ovina* type, (ENFA method). But In logistic regression method, the *Bromus tomentellus- Festuca ovina* type was affected by elevation. One of the most important factors was soil texture in determining habitat suitability of plant species. Due to the effect of soil, water content and plant available nutrients and ventilation is important on vegetation distribution (Rangel *et al*., 2006). Other researchers demonstrated the relationship between vegetation and soil characteristics (Fairchild and Brother Son, 1980; Jensen, 1990.

Since it is time-consuming and costly to collect field data for ecological studies, using this modeling approach is suitable for breeding and development of rangeland. Therefore, in order to revive and develop pastures, different method of modeling is done on pastures and the best practice shall be provided for management purposes in the study area and similar areas.

References

Austrheim, G. 2002. Plant diversity patterns in semi-natural grasslands along an elevational gradient in Southern Norway. *Plant Ecology Journal* 161:193-205.

Behmanesh, B., G. A. Heshmati and M. Baghani. 2008. Assessment medical plant diversity of ChaharBagh mountainous rangelands in Golestan province. *Iranian Journal of Rangeland* 2: 141-150.

Boyce, M. 2006. Scale for resource selection functions. *Diversity and Distributions* 12: 269-276.

Black, C. A. 1979. Methods of soil analysis. *American Society of Agronomy* 2: 771-1572.

Brown, J. 2001. Mammals on mountainsides: elevational patterns of diversity. *Global Ecology and Biogeography* 10: 101-109.

Fairchild, J. A. and J. D. Brother son. 1980. Micro habital relationship of six major shrub in Navajo National Monument, Arizonal. *Journal of Range Management* 33: 150-156.

Hirzel, A. H., J. Hausser., D. Chessel and N. Perrin. 2002. Ecological niche factor analysis: how to compute habitat -suitability maps without absence data? *Ecology Journal* 83: 2027ï 2036.

Hirzel, A. H., V. Helfer and F. M´etral. 2001. Assessing habitat-suitability models with a virtual species. *Ecology Model* 145: 111ï 121.

Jackson, M. L. 1967. *Soil Chemical Analysis*. Prentice-Hall of India, New Delhi.

Jensen, M. 1990. Interpretation of environmental gradients which influence Sage bush community distribution Nevada. *Journal of Range Management* 43: 161-166.

K´ery, M. 2002. Inferring the absence of a species: a case study of snakes. *Journal of Wildlife Management* 66: 330ï 338.

Lomolino, M. V. 2001. Elevation gradients of species density: historical and prospective views. *Global Ecology and Biogeography* 10: 3-13.

Mackenzie, D. I and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. *Journal of Applied Ecol*ogy 42: 1105-1114.

Neeti, N., T. Vaclavik and M. Niphadkar. 2007. Potential distribution of Japanese knot weed in Massachusets. *ESRI Annual user Conference*.

Pearson, K. 1901. On lines and planes of closest fit to a system of points in space. *Philosophical Journal* 2: 559-572.

Rangel, T. F. L. V. B., J. A. F. Diniz-Filho and L. M. Bini. 2006. Towards an integrated computational tool forspatial analysis in macroecology and biogeography. *Global Ecology and Biogeography* 15: 321-327.

Rahbek, C. 1997. The relationship among area, elevation and regional species richness in neotropical birds. *American Naturalist*. 149: 875-902.

Tilman, D. and J. A. Downing. 1994. Biodiversity and stability in grasslands. *Nature Journal* 367: 363-365.

Trethowan, P. D., M.P. Robertsonb and A. J McConnachiec. 2011. Ecological niche modelling of an invasive alien plant and its potential biological control agents. *South African Journal of Botany* 77: 137-146.

Wolmarans, R., M. P. Robertson and B. J. Van Rensburg. 2010. Predicting invasive alien plant distributions: how geographical bias in occurrence records influences model performance. *Journal of Biogeography* 37:1629-1834.

ZareChahouki, M. A. and A. ZareChahouki. 2010. Predicting the distribution of plant species using logistic regression (Case study: Garizat rangelands of Yazd province). *Desert Journal* 15: 151-158.

ZareChahouki, M. A., H. Azarnivand., M. Jafari and A. Tavili. 2010. Multivariate Statistical Methods as a Tool for Model Based Prediction of Vegetation Types. *Russian Journal of Ecology* 41: 84-94.

ZareChahouki, M. A., L. Khalasiahvazi and H. Azanivand. 2012. Comparison of three modeling approaches for predicting plant species distribution in mountainous scrub vegetation (Semnan rangelands, IRAN). *Polish Journal of Ecology* 60: 277-289.

ZareChahouki, M. A. 2010. *Data analysis in natural resource research with SPSS software.* Tehran University Pub. Iran.

ZareChahouki, M. A. and L. K. Ahvazi. 2012. Predicting potential distributions of *Zygophyllum eurypterum* by three modeling techniques (ENFA, ANN and logistic) in North East of Semnan, Iran. *Range Management and Agroforestry* 33: 123-128.