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Effects of physiographic factors and soil properties on distribution of *Ferula gummosa* Boiss: case study of Karaj Kalarud Region

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Abstract

Ferula gummosa Boiss, belonging to Umbelliferae family, is widely distributed in mountainous regions of Iran, especially Zagros and Alborz Mountains. This species is of great economic importance due to industrial, pharmaceutical, food and forage uses. In the present study, the effect of some ecological factors associated with *Ferula gummosa* Boiss was investigated in one of the natural habitats of this species in Kalarood summer rangeland of Alborz province. The sample size was determined by minimal area method. A random-systematic sampling method was used where the frequency of *Ferula gummosa* Boiss was maximum. Vegetation parameters including frequency, density and canopy cover as well as some physiographic characteristics of the habitat, such as altitude (a.s.l), slope percentage, aspect, and Landform Index (LI) were measured. In addition, soil samples were taken from a depth of 0-30 cm in the center of each quadrate to measure pH, percentage of organic carbon (OC), nitrogen (N), phosphorus (P), and potassium (K) in soil laboratory. According to the obtained results of ordination (RDA), frequency, canopy cover, density, and species relative importance showed a direct relationship with slope percentage and an inverse relationship with sand percentage.

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Introduction

Biosphere, or the world we are living in, is composed of ecosystems with their components and relationships (Mesdaghi, 2005, Mohtashamnia *et al.*, 2007). The presence of species and distribution of plant communities in these ecosystems are not random but climate, soil, topography and environmental factors play a major role in their distribution. These areas are formed as a result of interaction effect of environmental factors including climate, physiography and organism (Ghorbani and Asghari, 2014) and are managed as a natural ecosystem.

Among different components of ecosystem, physiography is of utmost importance, because it is the most stable component of an ecosystem and is least affected by natural and human short-and long-term degradation. In addition, ecosystem function is affected by physiography through controlling both regional climate and soil development.

Soil properties are the resultant of other effects of environmental factors over time. Strong correlation and close relationship between vegetation and soil is so that the change in the status of each factor affects other ecosystem functions severely (Hajabbasi, 1999). Physico-chemical properties of soil in relation to vegetation cause a broad geographic distribution of plant species (Leonard, 1998). The features of physiography including altitude, slope and aspect are the factors that affect water availability and other environmental conditions such as light, temperature, etc (Vetaas and Gerytnes, 2002).

Qualitative and quantitative study and recognition of existing vegetation as well as environmental conditions such as altitude, slope, aspect, soil and climate are required in the detection of vegetation changes trend. In addition, obtained information would be useful in the preservation of vegetation and optimal management plan with the goal of sustainable development. Also, in order to prevent the growing trend of rangeland degradation, grazing management and range improvement programs are essential. On the other hand, by identifying the behaviors and actions of plant species and their ecological relationships with environmental factors, it will be possible to avoid wasting cost and time. Therefore, given the important role of plant species in ecosystem balance and different uses of ecosystems being used by human directly or indirectly, the necessity of recognizing the relationships between plants and environmental factors to achieve ecosystem stability and sustainability is inevitable (Rahimdokht, 2012).

Due to the widespread distribution of *Ferula gummosa* Boiss in Alborz rangelands and growing pharmaceutical and industrial uses of this species, this research was aimed to understand the relationship between habitat (environmental) factors and the distribution of this species, so that relevant basic information could be provided for the beneficiaries as well as providing the continuing production of this species in addition to harvesting the crop.

Materials and methods

Study area

The study area is a part of the Kalarood summer rangeland with an area of 2942 hectares, located between longitudes of 51° 21′ 01" E and 51° 22′ 41" E and latitudes of 36° 00′ 10" N and 36° 02′ 38" N (Fig. 1). Minimum and maximum altitudes of the study area are 2320 and 3680 m a.s.l, respectively, and the average altitude is 3000 meters. The physical appearance of the study area is mountainous with an average slope of 59%. The average annual rainfall is 602 mm and the mean annual temperature is 7.9° C. According to the Demarton classification, the study area has a very humid climate. Geologically, the study area belongs to the Barut Formation, consisting of colorful micaceous siltstone and shale rocks along with the chert-bearing dolomite layers (Vahdati daneshmand, 2000).

Research method

The habitats of *Ferula gummosa* Boiss were identified using the vegetation map of the Alborz province, earlier prepared in the research project entitled "Ecological zones of the country" (Yousefkalafi *et al.*, 2011). Then, one of the vegetative regions, located at 59 km from the city of Karaj, on the road of Karaj – Chalus, was selected.

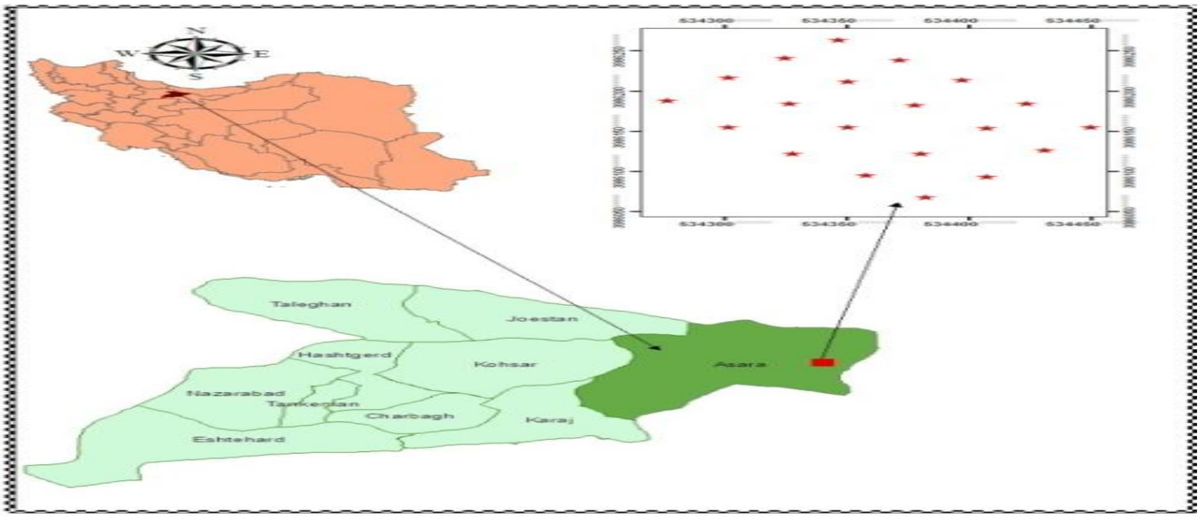

Fig. 1. Location of the study area in Iran.

The sample size was determined using Cochran's formula (equation 1) and minimal area method was used to determine the quadrate size.

$$N = \frac{t^2 s^2}{(k\bar{x})^2} \qquad \text{(eq. 1)}$$

In each plot, the frequency, canopy cover and density of *Ferula gummosa* and other species were measured. A random-systematic sampling was used and according to the field observations, a grid of 20m*20m was selected and implemented. Then, at the intersection of the sides of the grid, sample plots with dimensions of 1×1 was selected and in each plot, characteristics of the habitat including elevation, land form, slope, aspect and LI index were measured with the help of GPS and inclinometer. For each species, the vegetation characteristics such as frequency, density and canopy cover were recorded. In order to calculate relative Importance Value (I.V) for each species, the collected data were transferred into the Excel software and by using the equation 2 (eq. 2), the mentioned parameter was calculated.

$$I.V = (R.F + R.D + R.CC)/3 \qquad \text{(eq. 2)}$$

Where in above equation, R.F, is the relative frequency, R.D, is the relative density and R.CC, is the relative canopy cover.

LI Index was used in order to quantify the landform and to estimate it the average slope of the land in eight cardinal directions was calculated. The reason for choosing grid is to encompass all landforms because in transect method the probability for the presence of all landforms is less (Rubino and McCarthy, 2003).

In addition, in each plot, soil samples were taken from 0-30 depth considering the mountainous region and the rooting depth of plant species. In the laboratory, soil samples were passed through a 2-mm sieve. Soil physico-chemical parameters including soil texture, pH, organic carbon, lime, nitrogen, available phosphorous, and potassium were measured by the hydrometer method, pH meter, Walkley and Black method, calcimeter method, Kjeldahl and titration method, Olson method, and flame photometry, respectively (Jafari haghighi, 2003).

All data obtained from field sampling as well as the results of soil analysis were analyzed by Ecological software of Canoco 4.5.

Results and discussion

Detrended Correspondence Analysis (DCA) on the IV parameter of *Ferula gummosa* Boiss indicates that the data follow a linear distribution (the longest gradient length of the vegetation data matrix was calculated to be 0.387 that it is less than three). As a result, direct gradient analysis of Redundancy Analysis (RDA) was used to determine the relationship between vegetation parameters of *Ferula gummosa* Boiss and environmental variables. Since the data of environmental factors have different units, these data were standardized by dividing the values of data by standard deviation and then converted using the logarithmic relationship as follows (eq. 3).

$$A' = \log(A+1) \qquad \text{(eq.3)}$$

The results of RDA, using 12 environmental factors, are presented in Tables 1 and 2.

As can be observed in Table 1, 55.1% of total variance (58.9%) is explained by the first axis. In addition, those variables that the VIF value is greater than 10, consequently it is likely to be collinearity (inflation) among environmental factors (Bihamta, M. R. and Zare Chahouki, M. A., 2011). Considering the interaction effects (collinearity) among environmental variables, to determine their significance (or not), the variance of the studied parameters need be evaluated when other variables are in the model. The conditional effects of the studied variables are presented in table 3.

Table 1. Results of RDA ordination using 12 environmental factors.

Ordination axes	1	2	3	4	Total variance
Eigenvalues	0.551	0.023	0.014	0.00	1
Species – environment correlations	0.772	0.774	0.636	0.472	
Cumulative percentage variance of species data	55.1	57.5	58.9	58.9	
Cumulative percentage variance of species – Environment relation	93.6	97.6	99.9	100	
Sum of all canonical eigenvalues					0.589

Table 2. Weighted mean, standard deviation, and VIF of the studied parameters.

Parameter	Weighted Mean	Standard deviation	Variance Inflation Factor (VIF)
Height	4.42	0.01	1.94
Slope	1.78	0.17	1.85
LI	0.37	0.18	3.89
Clay	1.02	0.35	7.86
Silt	1.61	0.18	11.6
Sand	2.11	0.11	7.16
K	1.03	0.31	6.75
P	1.01	0.25	2.73
N	0.49	0.12	18.80
OC	0.39	0.13	16.51
Ph	1.82	0.00	4.31
$Caco_3$	0.25	0.19	3.39

According to the obtained results, among 12 environmental factors, the percentage of slope and sand showed significant difference at the 0.05% significance level. So that 44% of total explained variance by 12 environmental variables (74.4%) is assigned to these two variables. Therefore, in order to prevent model complexity, the variables having no significant difference with vegetation variables were removed and a biplot was drawn using the variables of slope and sand (Figure 2).

Our results clearly indicatedthat the percentage of slope and sand had a direct and inverse relationship to the density, canopy cover, frequency and importance value of *Ferula gommosa* Boiss respectively.

Table 3. The conditional effects of the environmental variables.

Variable	Var.N	Lambda A	P-value	F-ratio
Slope	2	0.2	0.038*	4.55
Sand	6	0.22	0.014*	6.52
Caco3	12	0.05	$0.21^{n.s}$	1.55
Height	1	0.03	$0.42^{n.s}$	0.68
Li	3	0.04	$0.29^{n.s}$	1.31
OC	10	0.02	$0.532^{n.s}$	0.48
N	9	0	$0.712^{n.s}$	0.23
Clay	4	0.01	$0.758^{n.s}$	0.18
K	7	0.01	$0.804^{n.s}$	0.11
PH	11	0	$0.834^{n.s}$	0.12
Silt	5	0.01	$0.778^{n.s}$	0.13
P	8	0	$0.986^{n.s}$	0.01

***:**Significant in confidence level of 95%

n.s: not Significant in confidence level of 95%.

According to the obtained results, the 12-environmental variables could explain 58.9% of total variance in the vegetation variables of *Ferula gummosa* Boiss In addition, it can be concluded that the environmental factors of nitrogen, organic carbon, silt, clay, sand and potassium had the highest Variance Inflation Factor (VIF). As a result, regardless of the collinearity of environmental variables, *Ferula gummosa* Boiss is more affected by soil fertility and soil texture as compared to other variables.

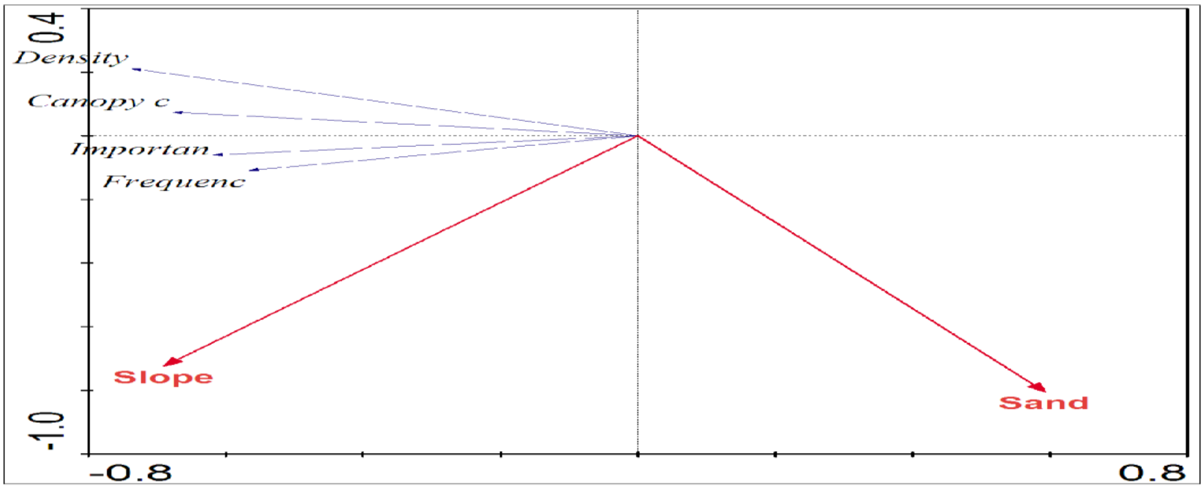

Fig. 2. The biplot of RDA constrained ordination on the first and second axes.

As stated in results of biplot obtained from RDA, the percentage of slope and sand had a direct and inverse relationship to the density, canopy cover, frequency, and importance value of *Ferula gummosa* Boiss, respectively. However, according to the Shelford's Law of Tolerance, the mentioned direct or inverse relationships are quite relative and can be true in the ecological tolerance of *Ferula gummosa* Boiss.

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