

EFFECTS OF SOME ECOLOGICAL FACTORS ON DISTRIBUTION OF *PRANGOS ULOPTERA* AND *PRANGOS PABULARIA* IN RANGELANDS OF ARDABIL PROVINCE, IRAN

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Abstract. The aim of this study is to assess the effects of some environmental factors on the distribution of *Prangos uloptera* DC. and *Prangos pabularia* Lindl. in the rangelands of Ardabil province, in the north-west of Iran. Six sites with the distribution of the genus *Prangos* (presence) and six sites without *Prangos* (absence) were identified. Three 100m transects were established. On each transect, ten 4m² plots were located, and the total canopy cover and density of plants were recorded. Soil samples were collected from a depth of 0–30cm on each transect. Elevation, slope and aspect were extracted from the Digital Elevation Model (DEM), and rainfall, temperature were also extracted from the derived gradient equation and DEM for each plot. Soil parameters such as organic matter (OM), nitrogen (N), phosphate (P), potassium (K), pH, electric conductivity (EC) and texture were determined at the Soil Lab. Normality of data was tested. To compare the related parameters for the sites with the presence and absence of species, the one-way ANOVA was conducted. Cluster analysis was used to classify the collected samples. To determine the variables that were significant in the distinction of each groups and mean comparison, ANOVA and Tukey tests were conducted. To determine the importance of ecological factors for the presence and absence of the selected species, discriminant analysis was conducted. The results of the analysis of variance between presence and absence of *P. uloptera* and *P. pabularia* in habitats demonstrated significant differences for the parameters of elevation, slope, aspect, temperature, EC, pH, OM, nitrogen, phosphorus, clay, silt and sand and total canopy cover, $P < 0.01$. The result of grouping sampling plots using cluster analysis showed that plots in three groups were separated by significant differences ($P < 0.05$) in the multivariate analysis of variance. The results showed that *P. uloptera* was adapted in habitats with OM of 1.402%, N 0.126%, P 2.627_{ppm}, K 258_{ppm}, 1992m a.s.l., with average slope of 83.40%, clay 10.90%, silt 37.90%, sand 51.20%, and average precipitation of 353mm. However, *P. pabularia* was adapted in habitats with OM of 0.915%, N 0.088%, P 2.339_{ppm}, K 236_{ppm}, 1672m a.s.l., and with average slope of 84.80%, clay 13.60%, silt 29.70%, sand 56.70% and average precipitation of 370mm. With regard to the results from discriminant analysis, the percentages of slope, clay, sand, silt, OM, P and pH, aspect, precipitation and temperature play an effective role in the separation and distribution of the species studied. These results can be used to suggest suitable species in management and restoration of rangelands with the same ecological characteristics.

Keywords: *ecological factors, species dispersion, cluster analysis, discriminant analysis*

Introduction

Environmental factors affect the establishment and distribution of plant species (Ashcroft et al., 2011). Identification of factors that affect the distributions of species is an important unresolved issue in ecology (Araújo and Guisan, 2006). Often, there are many combinations of predictors that can explain distributions equally well, especially when environmental factors are correlated, and this introduces uncertainty into the effect of each factor (Platts et al., 2008; Murray and Conner, 2009). Therefore, the first step in rangeland management is to determine the habitats of plants and the effective factors affecting their distribution. Autecological field or laboratory studies have long

been relied upon to reveal environmental variables that impede a plant's migration into surrounding territory (Arundel, 2005). These variables—or limiters—shape various spatial aspects of individual plant species' distributions. Knowing specific influences on plants is important in many fields, but particularly for climate reconstruction based on fossil plant remains (Arundel, 2002). The presence and distribution of plant species in rangeland ecosystems are not random, but such factors as climate, soil, topography, anthropological and others play major roles in their development (Akbarlou and Nodehi, 2016). Determination of the factors that control the presence and distribution of rangeland species is one of the main objectives in the rangeland ecosystems studies.

Though relationships between plant and both soil properties and other environmental factors have been well developed for some plants, comparable understanding of how a variety of plant species in native rangelands responds to soil properties and other environmental factors is poorly developed (Chuangye et al., 2015; Ghorbani et al., 2015; Sahragard and Zare Chahouki, 2015). Xu et al. (2008a) have studied the relationships between vegetation, soil and topography in the dry valley of China. Their results confirmed that plant diversity was mainly correlated with soil water content, and soil water content was mainly determined by soil texture, especially clay content. Yibing (2008), by conducting the Principal Component Analysis (PCA) and Canonical Correlation Analysis in China, showed that physical and chemical features of the soil, including humidity, salinity and acidity affected homogeneity of plant communities on the regional scale. Zhang and Dong (2010), in the study of relationships between environmental factors and vegetation diversity in Lesi plateau of China, reported that elevation, soil type, slope and aspect were important factors in Lesi zones' recovery, and had determinant roles in vegetation distribution. Zare et al. (2011), in a study on the relationship between environmental factors and plant distribution in arid and semiarid areas, reported that soil texture, salinity, effective soil depth, available N, K, OM, lime and soil moisture, were the major soil factors responsible for variations in the pattern of vegetation. Ghorbani and Asghari (2014), in the study of ecological factors affecting the distribution of *Festuca ovina* in the southeastern rangelands of Sabalan, reported that *F. ovina* is more compatible with higher altitudes and lower temperatures and does not tolerate soil salinity, and is more compatible with a pH of 7.1 to 7.3. OM, P and K provide better conditions for its growth.

To improve the management of rangelands and to offer a baseline for restoration attempts, an understanding of the factors that determine the rangelands vegetation distribution and composition is required. For this purpose, this study was conducted to identify the roles of topography, climate and soil components, in the distribution of *Prangos uloptera* and *P. pabularia*, in the rangelands of Ardabil province in north-western Iran. Identification of these parameters in a given ecosystem helps one apply appropriate management for restoration and development in the present and in similar rangelands.

Materials and Methods

Study area

The study area was selected in the rangelands of Ardabil province, Iran (37° 12' to 38° 07' N and 47° 51' to 48° 48' E) (Figure 1). Six habitats were selected with the genus *Prangos* distribution. *P. uloptera* were distributed in four habitats and *P. pabularia* were in two habitats. According to meteorological stations in the region (with a 10-year

period—2006 to 2015), the mean precipitation is 360mm/year. Also, maximum and minimum precipitations respectively occur in February and July. The mean of annual temperature is 9°C, the average annual minimum temperature is 3.2°C and the average annual maximum temperature is 14.8°C.

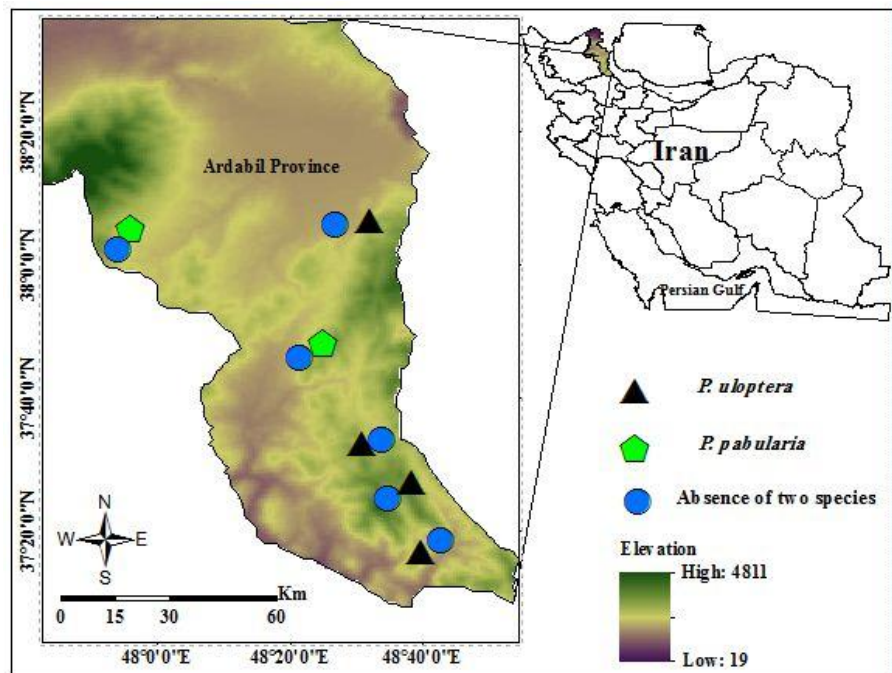


Figure 1. Location of the study area and sampling locations for presence and absence of the selected species in Ardabil province and Iran

Sampling method

Initially, in order to recognize the distribution of the genus *Prangos*, an overall study was conducted by literature review (Rechinger, 1987; Mozaffarian, 2007; Azimi et al., 2011; Teimoorzadeh et al., 2015; Ghorbani et al., 2015). Moreover, fieldworks were conducted in Ardabil province to select the habitat of the genus *Prangos*. Finally, six habitats were identified with *P. uloptera* and *P. pabularia* distributions. In each habitat, initially one site with genus *Prangos* distribution was selected as the presence of the selected species. Near to each of the selected sites, another site with the absence of genus *Prangos* were selected in the same habitat (overall, for the presence and absences of genus *Prangos*, 12 sites were selected). A Digital Elevation Model (DEM) map was derived using 1:25000 topographic maps of the National Cartographic Center of Iran, with 10 m horizontal and vertical accuracy. Slope and aspect maps were derived from the DEM for the selected habitats and sites. By considering the studies conducted on the rangelands of Ardabil province (i.e. Ghorbani and Asghari, 2014; Ghorbani et al., 2015), in each site three 100 m transects were established. The first one was selected randomly, and the second one as parallel with 500 m distance, and the third one perpendicular to both. By considering the abovementioned literature and using minimal area method (Kent and Coker, 1996), the size of plots was determined as 4m². The number of plots was also determined by considering the literature (i.e. Ghorbani and Asghari, 2014; Ghorbani et al., 2015), and the pre-samples taken were calculated

(Kerbs, 1999) as about 10 samples. Overall, ten 4m² plots were selected for each transect, wherein the distance between the plots (from the centre of each one) was 10m, for the 12 selected sites, for the presence and absence of species. Within each plot (presence and absence of the species), total canopy cover, percentage and density of plants, including the selected species, were recorded. In each site, nine soil samples were collected from the depth of (0–30 cm) (Northup et al., 1996). The soil properties—such as N, OM, EC, pH, P, K and texture—were measured via laboratory analysis at the Soil Lab of Ardabil University.

Data analysis

Kolmogorov-Smirnov test was used to assess the normality of data. To analyse significant difference between the effects of environmental factors on the presence or absence of two selected species, the one-way ANOVA was used. For grouping the collected samples on the basis of the recorded ecological factors, cluster analysis was used. To determine the variables that assume significance in the distinction of identified groups and to compare these, ANOVA and Tukey test were used. The importance of each measured variable in the distribution of selected species was analysed using discriminant analysis. The ArcGIS10 was used to extract the base map and SPSS18 software was used for data analysis.

Results

The results of the analysis of variance between presence and absence of *P. uloptera* and *P. pabularia* in habitats demonstrated significant difference for the parameters of elevation, slope, aspect, temperature, EC, pH, OM, nitrogen, phosphorus, clay, silt and sand and total canopy cover, $P < 0.01$ (Table 1). The clustering of sampling plots, using cluster analysis, indicated that the plots are divided into three groups ($P < 0.01$) in the multivariate analysis of variance (Figure 2). The discrimination based on the plots revealed that Group 1 is related to the absence of the two species in the habitats, Group 2 shows the habitat of *P. uloptera*, and Group 3 indicates the habitat of *P. pabularia*. The results of multivariate analysis of variance among the groups proved that the resultant groups had significant differences in all the variables, except for the precipitation level and potassium, $P < 0.01$ (Table 2). The elevation, organic matter and silt in the habitat of *P. uloptera* (Group 2) were higher than the habitat of *P. pabularia* and the habitats without the study species, which had significant difference, $P < 0.01$ (Table 2). In the habitat of *P. pabularia* (Group 3), the percentage of sand and temperature were higher than other habitats, which had significant difference ($P < 0.01$), as well as the habitats without the study species had the highest electrical conductivity, clay and phosphorus compared to other habitats ($P < 0.01$). The slope in the habitats of *P. uloptera* and *P. pabularia* had the highest percentage (over 83%) and the habitats without the study species had lower percentage (mean slope of 66%). The results showed that *P. uloptera* was adapted in habitats with average OM of 1.402%, N 0.126%, P 2.627_{ppm}, K 258_{ppm}, 1992m elevation a.s.l., slope 83.40%, clay 10.90%, silt 37.90%, sand 51.20%, and also average precipitation of 353mm. However, *P. pabularia* was adapted in habitats with average OM 0.915%, N 0.088%, P 2.339_{ppm}, K 236_{ppm}, 1672m elevation a.s.l., average slope 84.80%, clay 13.60%, silt 29.70%, sand 56.70%, and also average precipitation of 370 mm.

Table 1. Analysis of variance of environmental factors and their effects on the presence or absence of *P. uloptera* and *P. pabularia*

		Sum of Squares	df	F
Elevation (m)	Between Groups	36923549.214	2	19.033**
	Within Groups	39461.356	33	
Slope%	Between Groups	64745.081	2	125.221**
	Within Groups	2881.912	33	
Aspect	Between Groups	500.211	2	9.949**
	Within Groups	27.389	33	
Precipitation (mm)	Between Groups	1370579.678	2	1.384 ^{ns}
	Within Groups	4879.101	33	
Temperature (C°)	Between Groups	403.843	2	12.331**
	Within Groups	27.899	33	
EC (Ds/m)	Between Groups	1.336	2	31.840**
	Within Groups	0.242	33	
pH	Between Groups	8.403	2	34.046**
	Within Groups	1.603	33	
OM%	Between Groups	99.024	2	17.665**
	Within Groups	9.800	33	
N%	Between Groups	0.864	2	11.705**
	Within Groups	0.057	33	
P (ppm)	Between Groups	370.154	2	6.722**
	Within Groups	13.940	33	
K (ppm)	Between Groups	1770318.244	2	1.976 ^{ns}
	Within Groups	19596.654	33	
Clay%	Between Groups	10490.046	2	83.939**
	Within Groups	421.744	33	
Silt%	Between Groups	29395.534	2	17.834**
	Within Groups	279.344	33	
Sand%	Between Groups	21747.143	2	34.008**
	Within Groups	1668.023	33	
Density <i>P. uloptera</i>	Between Groups	35.600	2	197.225**
	Within Groups	3.220	33	
Density <i>P. pabularia</i>	Between Groups	2.722	2	277.272**
	Within Groups	0.752	33	
Total Canopy Cover	Between Groups	6430.225	2	101.987**
	Within Groups	245.368	33	

** , ^{ns}: Respectively significant at 1% and non-significant

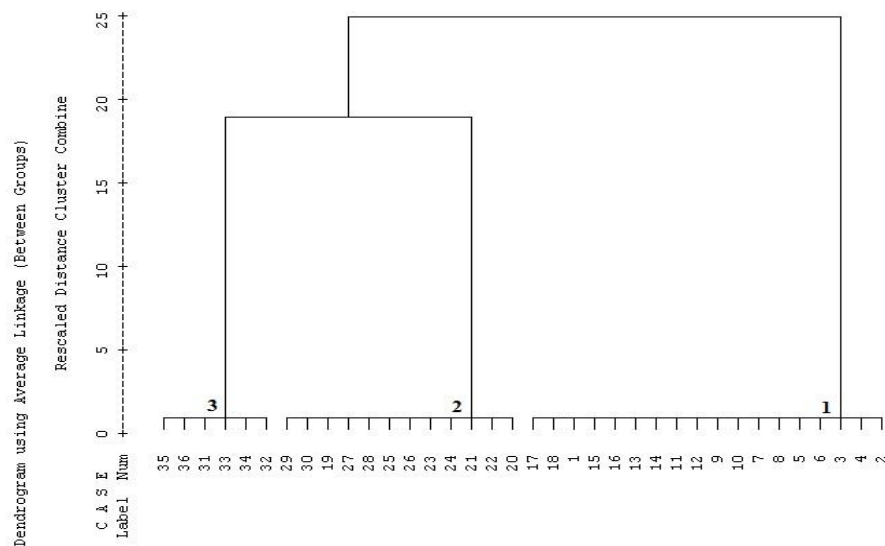


Figure 2. Cluster analysis of ecological factors and density of *P. uloptera* and *P. pabularia* using cluster analysis method

Table 2. Comparison of measured characteristics in the conditions of the presence and absence of species

	Absence of two species (1)		<i>P. uloptera</i> (2)		<i>P. pabularia</i> (3)	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Elevation (m)	1861 ^b	28.000	1992 ^a	26.000	1672 ^c	22.000
Slope%	66.300 ^b	0.919	83.400 ^a	0.765	84.800 ^a	1.084
Aspect	0.012 ^b	0.001	0.013 ^b	0.001	0.012 ^b	0.001
Precipitation (mm)	359 ^a	4.620	353 ^a	6.843	370 ^a	1.539
Temperature (C°)	8.943 ^b	0.081	8.665 ^b	0.061	9.499 ^a	0.196
EC (Ds/m)	0.537 ^a	0.005	0.487 ^b	0.004	0.480 ^b	0.008
pH	7.679 ^a	0.011	7.535 ^b	0.014	7.666 ^a	0.021
OM%	1.181 ^b	0.037	1.402 ^a	0.055	0.915 ^c	0.058
N%	0.113 ^a	0.004	0.126 ^a	0.005	0.088 ^b	0.006
P (ppm)	2.875 ^a	0.086	2.628 ^{ab}	0.092	2.339 ^b	0.051
K (ppm)	250 ^a	3.188	258 ^a	9.810	236 ^a	4.403
Clay%	17.800 ^a	2.387	10.900 ^c	1.399	13.600 ^b	2.305
Silt%	34.600 ^b	2.560	37.900 ^a	2.737	29.700 ^c	2.606
Sand%	47.600 ^c	3.439	51.200 ^b	3.675	56.700 ^a	3.400
Density of <i>P. uloptera</i>	0.000 ^b	0.000	0.667 ^a	0.017	0.000 ^b	0.000
Density of <i>P. pabularia</i>	0.000 ^b	0.000	0.000 ^b	0.000	0.240 ^a	0.022
Total Canopy Cover%	46.150 ^c	0.389	56.200 ^a	0.957	52.450 ^b	0.657

Same letters in a row indicate no significant difference.

By using the discriminant analysis of habitats based on environmental factors and the results obtained, the two functions justified respectively 69.8% and 32% and a total of 100% of the variance of total data. Moreover, the canonical correlation coefficient showed that the Functions 1 and 2 were able to discriminate well between the groups (Table 3). Table 4 indicates the values of Wilks' lambda for functions, which increase from the Function 1 through the Function 2. The index closer to zero shows more appropriate estimated function in discrimination of groups, so Functions 1 and 2 had proper estimation in discrimination of groups. Considering the significance of chi-square values at the level of <0.01, the mean groups are different. In each of the Functions 1 and 2, the study parameters had different coefficients, so that the factors influencing the grouping of habitats as well as the distribution of the species studied can be determined, thanks to these coefficients (Table 5). Accordingly, the slope, clay, sand, silt, pH, organic matter, temperature, aspect, potassium and precipitation are effective in discrimination of habitats and the distribution of the species studied. Clay and temperature, having the highest standardized coefficients, as well as potassium and organic matter, having the lowest standardized coefficients, respectively had the maximum and minimum impacts on the first detection function. The average annual precipitation has the greatest effect on Function 2. Owing to structural coefficients (Table 5), slope, clay, EC, potassium and sand in the first function, as well as pH, silt, organic matter, elevation, temperature, nitrogen, aspect, potassium and precipitation in the second function, show the most correlation with functions formed. According to stepwise discriminant analysis, the functional equation can be set as Function 1 using canonical discriminant function coefficients, where factors involving pH, organic matter, potassium, slope, aspect, clay, silt, sand, phosphorus, and average temperature have been included into the equation.

$$Y_1 = -1.437 \text{ pH} - 0.365 \text{ OM} - 0.002 \text{ K} + 0.041 \text{ Slope} - 0.010 \text{ Aspect} - 0.320 \text{ Clay} - 0.068 \text{ Silt} + 0.121 \text{ Sand} + 0.016 P_{(mm)} + 1.184 T_{(C^{\circ})} - 4.988 \quad (\text{Eq.1})$$

The results of the classification of habitats studied by discriminant analysis are shown in Table 6. The percentages presented in this table show the matching level of observed and predicted cases. If the two species are in sites without Function 1 function properly, they determine membership of the Group 1 in 100 per cent of cases. If the data of absence of two species are in the first function, the function will properly determine membership of the Group 1 in 100 per cent of cases. If the data of *P. uloptera* are in the Function 1, the function will properly determine membership of the Group 2 in 99.20 per cent of cases. If the data of *P. pabularia* are in Function 1, the function will properly determine membership of Group 3 in 98.30 per cent of cases. Overall, 99.40% of the main grouped cases have been properly classified. Accordingly, the results of this investigation indicated the effects of environmental factors on discrimination of habitats of studied species and the sites without the two species (Figure 2). In this figure, Group 1 represents the sites without the two species, Group 2 reflects the habitats of *P. uloptera*, and Group 3 shows the habitats of *P. pabularia*.

Table 3. Eigenvalues and the percentage of variance explained by the two first functions

Function	Eigenvalue	Variance (%)	Cumulative (%)	Canonical correlation
1	7.062 ^a	69.8	69.8	0.936
2	3.048 ^a	30.2	100.0	0.868

a. First 2 canonical discriminant functions were used in the analysis.

Table 4. Wilks' lambda values in discriminant analysis

Test of function(s)	Wilks' lambda	Chi-square	df	Sig.
1 through 2	0.031	1225.138	24	0.000
2	0.247	491.507	11	0.000

Table 5. Standardized canonical discriminant function coefficients and structure matrix in the sites studied

	Standardized canonical discriminant function coefficients		Structure matrix	
	Function		Function	
	1	2	1	2
Slope%	0.428	.0510	0.315*	-0.027
EC (Ds/m)	-	-	-0.259*	0.060
Clay%	-1.458	0.129	-0.237*	0.154
P (ppm)	-	-	-0.148*	-0.022
Sand%	0.895	0.060	0.143*	0.124
pH	-0.221	0.182	-0.111	0.184*
Silt%	-0.595	-0.205	0.001	-0.181*
OM%	-0.192	-0.380	0.008	-0.180*
Elevation (m)	-	-	0.005	-0.171*
Temperature (C ^o)	1.259	0.209	0.011	0.150*
N%	-	-	0.037	-0.149*
Aspect	-0.789	-0.109	0.057	-0.103*
K (ppm)	-0.174	0.310	-0.002	-0.060*
Precipitation (mm)	0.980	0.521	0.004	0.050*

Table 6. The results of classification using discriminant analysis

Classification results ^a					
	site	Predicted group membership			Total
		Absence of two species	<i>P. uloptera</i>	<i>P. pabularia</i>	
Original %	Absence of two species	100.0	0.0	0.0	100.0
	<i>P. uloptera</i>	0.8	99.2	0.0	100.0
	<i>P. pabularia</i>	0.0	1.7	98.3	100.0

a.99.4% of original grouped cases correctly classified.

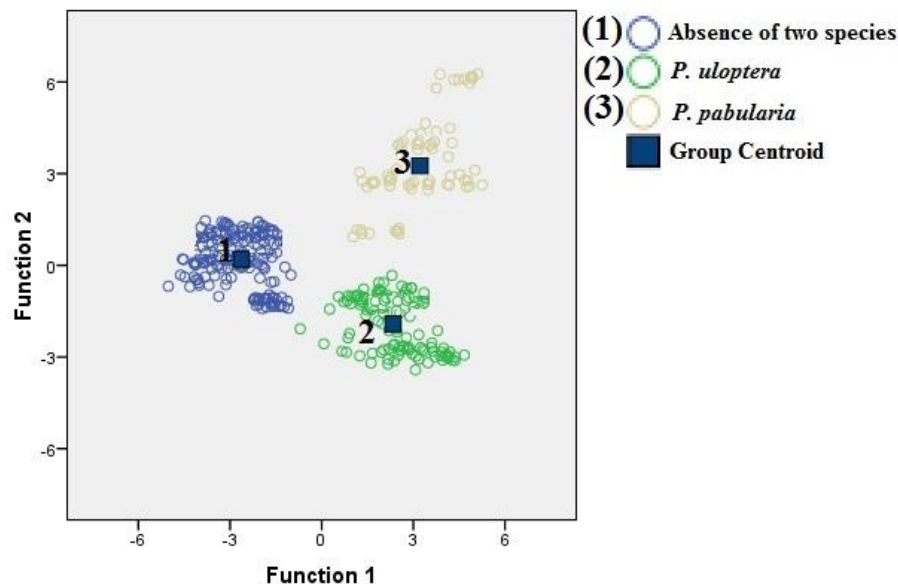


Figure 3. Canonical discriminant functions in the conditions of presence and absence of species

Discussion and conclusion

Establishment of plant communities occurs under the terms of climate and environmental conditions of the habitat; the plants are not randomly distributed across the globe. It is possible distribution of any plant in specific geographic limitation because any plant has specific environmental requirements that, if have in a certain area of growth and reproduction, these requirements must be provided. Comparison of the selected ecological factors in the habitats with the presence or absence of species demonstrated that most of the variables had significant differences. According to the field studies, no *P. pabularia* was found in sites with elevations >1,700 metres and *P. uloptera* had greater density in the higher elevations. Thus, the ecological requirements of these species appear to be different, and environmental characteristics of the distribution ranges of these species will have different effects. According to Ghorbani et al. (2015), the most important factors in the separation of plant species were reported to be elevation, slope percentage, soil texture, and depth in the southeastern rangelands of Sabalan. Moreover, Zhang and Dong (2010), in their study of the relationships between environmental factors and vegetation diversity, observed that elevation, soil type, slope and aspect were important factors in Lesi zones' recovery and played determinant roles in vegetation distribution. The precipitation and temperature were the study factors which, in turn, are affected by the elevation, and had significant differences among habitats in the study—so that *P. pabularia* in sites with higher precipitation and temperature and *P. uloptera* in sites with lower precipitation and temperature are more compatible. Ghorbani and Asghari (2014) also emphasized that precipitation and temperature can affect the distribution of *Festuca ovina* in southeastern rangelands of Sabalan, Ardabil, Iran. The organic matter content was the factor that had a significant impact on the distribution of the species studied. The organic matter content in the habitats of *P. uloptera* was more than in the habitats of *P. pabularia*. The density and total canopy cover were higher in the habitats of *P. uloptera* than the habitats of *P. pabularia*, probably due to the large amount of litter in these habitats. Soil organic matter within the rangeland system provides more nutrients for plant growth, which

results in a positive feedback, as more plant biomass is likely to produce more soil organic matter (Ryals et al., 2014). Additionally, organic matter affects soil chemicals, physical and biological properties, and this has been suggested as the single most important indicator of soil quality (Xu et al., 2008b; Ryals et al., 2014; Mirzaei Mossivand and Bahrami, 2015).

The results of many studies showed that OM was one of the soil characteristics affecting the distribution of vegetation that was in agreement with the results of Salama et al. (2013), Zare et al. (2011), He et al. (2007) and Abd El-Ghani and Amer (2003). Kooch et al. (2007), in their study of ecological distribution of indicator species and effective soil factors in Mazandaran province, showed that the distribution of vegetation was correlated with soil properties such as soil texture, P, OM, N and pH. According to the results, both *P. uloptera* and *P. pabularia* species prefer often soils with sandy-loam textures, and this means that they are more compatible with lighter textured soils. The soil texture affects the penetration and retention of water, and the availability of water and nutrients in plants (Sperry and Hacke, 2002). Soil texture controls dynamics of soil organic matter in many simulation models or organic matter decomposition and formation (Raich et al., 1991), and influences infiltration and moisture retention and the availability of water and nutrients by plants (Sperry and Hacke, 2002). Some studies, such as of Xu et al. (2008a) and Zarei et al. (2010), proved that the soil texture (clay, silt and sand) is one of the most important factors affecting plant type distribution. Results of Abadi and El Sheikh (2002) and Davies et al. (2006) showed that soil texture is the most important factor in the separation of ecological groups. The results of discriminant analysis showed that slope, clay, sand, silt, pH, organic matter, temperature, aspect, potassium and precipitation contribute to the discrimination of the habitats and the distribution of the species studied. Ghorbani et al. (2015) and Jafarian et al. (2010) also stated that the use of discriminant analysis in the relationship between environmental factors and distribution of vegetation has been beneficial. As the findings were presented, if the eigenvalues and canonical correlation coefficient are higher, the function obtained will be stronger, and the accuracy of classification will be greater. Discrimination variables that entered into the functions belonged to all the climatic, soil and topographic factors, representing the right choice of the parameters. In general, it can be stated that the functions resulting from discriminant analysis could be applied to the same species in other sites, using the findings of the present study, and identifying factors influencing the presence and absence of the species studied in the rangelands of Ardabil, thereby saving time required for similar studies. Details of this study can be useful in the optimal management of the rangelands. In addition, according to the survey results and discrimination of the habitats related to the species studied and the effects of ecological factors on their distribution, these findings could be used in the improvement and restoration of the same rangelands.

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