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Synecology of Semi-Steppe Vegetation in Relation to Some Ecological Factors in Polour Rangelands of Mazandaran Province, Iran

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ABSTRACT This research investigates the vegetation of 4600 ha of Polour semi-steppe rangelands in relation to edaphic and physiographical parameters in Mazandaran Province. For this purpose, 23 land units were selected from overlaying slope, aspect and elevation maps using geographic information system (GIS). Within each unit, 3 parallel transects with 100 m length, each containing 10 quadrates (according to vegetation variation) were established. Sampling method was random systematic. Measured soil properties included texture, organic matter, pH, electrical conductivity, nitrogen, phosphorus, and litter. Soil and plant data were analyzed with redundancy analysis (RDA) and SHAZAM 10 package. RDA analysis suggesting that there was a relatively high correspondence between vegetation and environmental factors that explained 93% of the total variance in data set. RDA results showed that soil slope, aspect, soil texture, acidity, phosphorus, and litter were the major environmental factors responsible for variations in vegetation patterns. Furthermore, results also showed that for *F. ovina* and *P. bulbosa*, acidity and nitrogen, for *A. gossypinus*, organic matter and salinity and for *D. glomerata*, nitrogen had the most important role in plant presence and absence probability.

Key words: *Environmental factors, Presence and absence probability, Soil factors, Polour rangelands*

1 INTRODUCTION

The species-environment relationship has always been a central issue in ecology (Guisan and Zimmermann 2000), especially when the purpose of ecology is to inform rangeland management (Zhang *et al.*, 2013). For over a century, ecologists have attempted to determine the factors that control plant species distribution and variations (Motzkin *et al.,* 2002). Both biotic and abiotic factors are considered to be effective on distribution of plant communities (Zhang *et al.*, 2005). However, topography, climate and soil are three important environmental abiotic factors controlling vegetation composition in rangelands (Jafari, *et al.*, 2004). Understanding how environmental factors influence the distribution of vegetation allows environmental managers to plan for issues such as climate change, ecological restoration and intensified land use (Ashcroft, 2006).

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Although relationships between plant and both soil properties and environmental factors have been well developed for some plants, comparable understanding of how a variety of plant species in native rangelands respond to soil properties and environmental factors is poorly developed (Rezaei, 2003). On the other hand, scarcity of performed studies in this area, has led the researcher to identify the patterns for the relations between plant populations and key environmental factors using quantitative methods such as taxonomy and ordination. Such studies will soon gain importance in ecological researches (Hong and Jianhui, 1994). Thus the main purpose of this research was to detect relationships between vegetation patterns and environmental factors to find the answer to this question: what edaphic and topographic factors are important in affecting vegetation distribution in Polour rangelands. In doing so, key factors that drive vegetation development and other ecological parameters of the region were identified.

2 MATERIALS AND METHODS

2.1 Site Description

Polour rangelands are located in the Central Alborz mountainous region of Mazandaran Province, north of Iran (between 35° 50' to 35° 55' N and 51° 33' to 52° 04' E). The area is approximately 4600 ha, with elevation ranging from 2200 m to 3870 meter (Figure 1).

Estimated annual precipitation of the study area for a 15 years ranges from 550 mm. Minimum temperature is recorded in December (-25˚C), while the highest temperature reaches + 35˚C in June. This rangeland's topography is complex, thus it produces a diverse array of distinctive vegetation communities. Most of precipitation falls during winter and spring seasons (March-April). The soils of study area based on U. S. D. A Soil Taxonomy method are classified into Aridisoils and four subgroups of Typic calciorthids, Calcic Gypsiorthids, Typic Gypsiorthids and Typic Natargids.

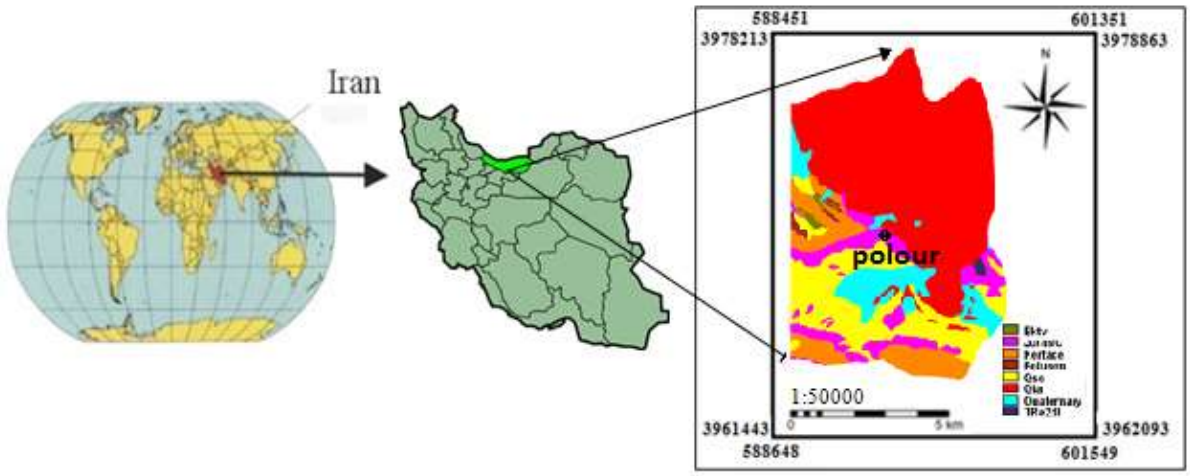

Figure 1 Geographical situation of the study area

2.2 Methods

Initially, in order to generalize reorganization of the study area and the investigation of plant vegetation, a field survey was done. Then using ArcGIS 9.2 package, 23 land units were selected from overlaying slope, aspect and elevation maps and sampling was done within each unit with random systematic method. According to species and distribution of plant communities, the proper area of sampling plot was determined by minimal area method and the number of plot after the primary sampling was determined by statistical method. Sampling in each unit was done along three 100 meter transects. Ten plots (1 m^2) were established along each transect in 10 meter distances. The type and the total of existing species and the percentage of vegetation cover were determined in each plot. The dominant plant species in the studied sites were *Dactylis glomerata, Festuca ovina, Medicago sativa, Poa bulbosa, Thymus kotschyanus, Achillea biebersteinii, Agropyron trichophorum, Asperula setosa, Astragalus depressus, Bromus tomentellus*.

In each land unit, three profiles were dug and soil samples were taken. A total number of 69 soil samples were taken from 0-30 cm depth at the starting, mean and ending point of each quadrate.

2.3 Laboratory Study

The soil samples were air dried at room temperature and passed through a 2 mm sieve. The weight of fine fraction (< 2 mm) in each soil sample was determined and was kept for laboratory analyses. Soil texture was determined by hydrometer method (Bouyoucos, 1951), pH and EC in a saturation extract by pH meter (McLean, 1982) and EC meter (Rhoades, 1982); organic matter by the Walkley and Black's method (Nelson and Sommers, 1982); phosphorus by Olsen method (Olsen and Sommers, 1982); and Total Nitrogen (N) by Kjeldahl method (Bremner and Mulvaney, 1982).

2.4 Statistical Analyses

In the first step, redundancy analysis (RDA) was conducted on vegetation and plant type-environmental variable matrix using the CANOCO program (Ter Braak and Smilauer, 2002). Canonical analyses such as redundancy analysis (RDA; Rao 1964), canonical correspondence analysis (CCA; Ter Braak, 1986), and distance-based redundancy analysis (db-RDA; Legendre and Anderson, 1999) provided the means for conducting direct explanatory analyses in which the association among species could be studied with respect to their common and unique relationships with environmental variables or any other set of predictors of interest.

Then SHAZAM 10.0 package was applied to find the logical relationship between each plant species and environmental variables. The statistical pattern was evaluated qualitatively using logic function was evaluated. With appropriate pattern estimation, the efficiency of each variable was determined. Thereby, elasticity at mean and marginal effect was estimated. This analysis was performed for four species, separately. Whereby, two classes of presence and absence and environmental variables were imported into analysis as independent and dependent variables, respectively. Finally, a model with the most percentage of right prediction was selected for each species. The effective variable or variables in presence and absence probability of each species with their quota were also estimated.

3 RESULTS

3.1 Results of RDA ordination

The effect of 12 environmental factors on distribution of plant species was studied using RDA method. Table 1 and Figure 2 demonstrate the results of RDA analysis. As it shown in Table 1, consecutive decreasing of Eigen value indicated that plant species and environmental factors were properly organized.

Axis 1 describes 71.4% of changes and Axis 2 describes 16.3% of changes.

The correlation between environmental factors in 3 Axes of RDA was high, this result showed that there was a strong correlation between plant species and environmental factors. The first axis was positively correlated with slope, aspect, sand and pH and negatively correlated with silt. The second axis was positively correlated with litter and negatively with phosphorus. The third axis was positively correlated with clay, organic matter and nitrogen while negatively correlated with altitude.

Figure 2 presents a scheme of 10 plant species against their values for axis 1 and 2. From this diagram, the distance between the indicators points of plant species showed the degree of connection between environmental factors. In another word, this distance was the power of relationship in the explanation of variation. Whenever the length of vector loading (as indicator of the plant species) was bigger, the angle between vectors and axis was smaller. Thus, there was a more powerful correlation between plant species and axis (Zare Chahouki *et al.*, 2002). With regard to RD1, almost all coefficients of the environmental factors were positive. Therefore, those plant sites lying in the negative direction of axis 1 had opposite relationship with RD1 factors. In the second axis of RDA (RD2), coefficient for phosphorus was negative, while for percentage of litter was positive (Fig 2). As mentioned above, relationship power depended on the length of vector loading and the angles between vectors and axes. Therefore, it could be explained that Thy. Ko species was more related to RD2 rather than RD1, while Br.to, and Ach.bi are more related to RD1 rather than RD2. Furthermore, in connection with As.de, the influence of environmental variables were rather similar in axes 1 and 2 (Figure 2).

Table 1 RDA applied to the correlation matrix of the vegetation-environmental factors in the study area

Axes	**Eigenvalue**	**Correlation**	**Cum. % of Var.**	
1	0.516	0.93	71.4	
2	0.118	0.84	16.3	
3	0.044	0.74	6.0	
4	0.026	0.72	3.6	
Factors	**Eigenvector**			
	1	**2**	**3**	**4**
Slope	0.4254	-0.2129	-0.3469	0.2700
Aspect	0.4293	-0.0007	-0.1818	-0.2837
Altitude	-0.0850	0.1761	-0.2941	0.1063
Clay	-0.3777	-0.2112	0.3887	0.1647
Sand	0.4613	0.0739	-0.3869	-0.0493
Silt	-0.4293	0.0265	0.3149	-0.0325
OM	0.0857	-0.1015	0.3426	0.1269
N	-0.1635	0.0576	0.4031	0.2097
P	0.1091	-0.3184	0.0221	0.1564
EC	-0.1413	0.1902	0.0941	-0.2441
pH	0.2849	0.0064	0.1320	-0.1768
Litter	-0.0694	0.6384	0.0033	0.2272

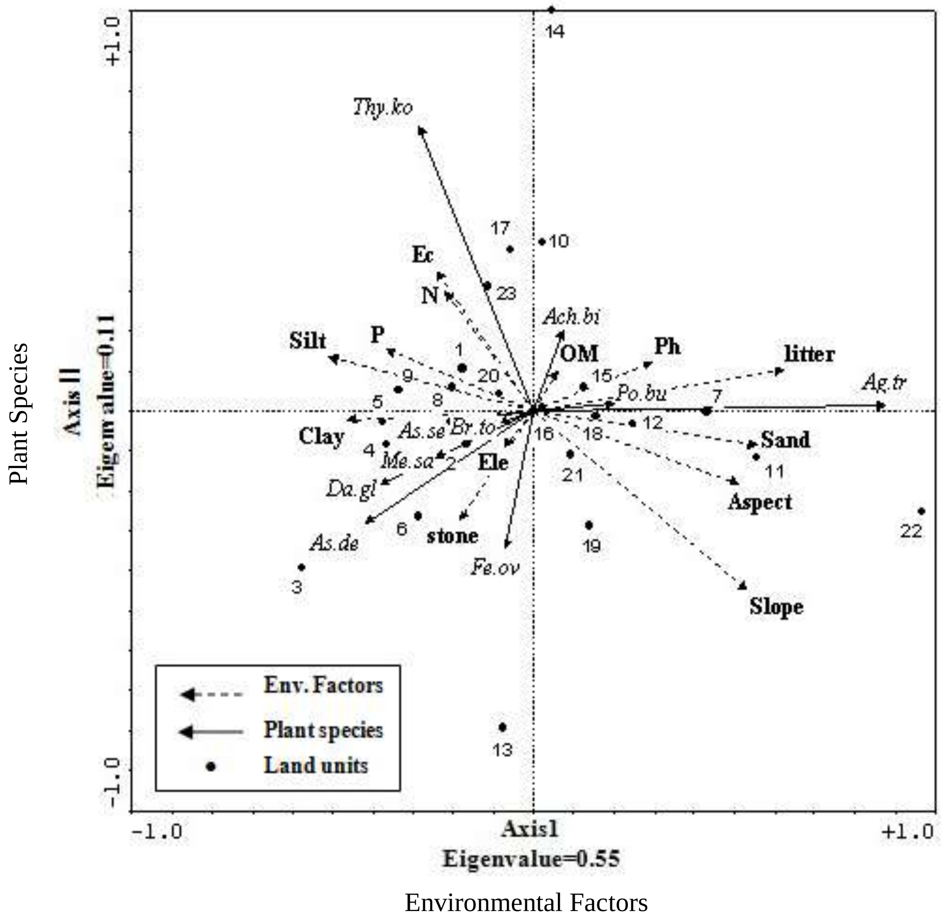

Figure 2 RDA diagram of the plant species in connection with the environmental factors in the study area

3.2 Results of SHAZAM Analysis for study species

The Logical Relationship between some plant species and environmental variables results obtained of SHAZAM Analysis have been given in the following:

- *Festuca ovina*

The following model could performed well for *F. ovina.*

$$P\ (Fe.ovina) = \frac{1}{1 + e^{-(0.0345Asp + 0.0089Ele + 5.28OM - 41.63N - 3.28pH + 0.3138EC - 0.1595St - 22.704)}} \quad (1)$$

As depicted by the model, the most important factors that affect the distribution of this species were aspect, elevation, organic matter, nitrogen, acidity, EC and silt. The presence probability of this species increased by increasing in OM, EC and altitude, while the presence probability of this species decreased by increasing in N, pH and stone. With one percent increasing in elevation, organic matter and acidity, presence probability will increase as much as 13.46, 5.07 and 11.37 percent, respectively. Also, with one unit increasing in those variables, the presence probability will increase as much as 0.0021, 1.289 and 0.076

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units respectively (Table 2). Results showed that the most Elasticity at Mean emanate of acidity and the most Marginal Effect emanate of nitrogen, so these variables had special importance in presence probability of *F. ovina*. Table 2 showed that the Likelihood Ratio test (LR) in this estimation was found significant at P<0.05 level. Mcfadden, Maddala and Estrella indicated that the explanatory variables of model could properly describe the changes of dependent variables. From the model also, percentage of Right Prediction was 81.81%, meaning that the presence or absence probability of plant species were correctly predicted by 81.81% of the variables.

Table 2 Most important factors affecting the presence probability of *F. ovina*

Variable	Mean of variable	Estimated Coefficient	Standard Error	t-ratio	Elasticity at Means	Marginal Effect
Aspect	-	0.0345	0.0186	1.854	3.266	0.0084
Elevation	2611.4	0.0089	0.0042	2.124	13.467	0.0021
OM	1.665	5.284	2.921	1.809	5.077	1.289
N	0.172	-41.636	20.670	-2.014	-4.150	-10.162
pH	7.266	-3.288	1.746	-1.882	-13.789	-0.802
EC	62.773	0.313	0.124	2.527	11.370	0.076
Stone	20.718	-0.159	0.095	-1.674	-1.908	-0.038

Statistical coefficients

Statisti.	Log-Liklihood	Liklihood Ratio Test	t-ratio	Estrella	Maddala	CraggUhler	Mcfadden
Coeffi.	-15.158	16.718	0.0460	0.668	0.532	0.711	0.551

According to model, the most important factors affecting distribution of this species were organic matter, phosphorus and EC. The presence probability of this species increased with increasing in these variables. With one percent increasing in organic matter, phosphorus and EC, the presence probability will increase as much as 10.44, 6.52 and 10.74 percent, respectively. Also with one unit increasing in these variables, the presence probability will increase as much as 2.49, 0.222 and 0.695 units, respectively (Table 3). Results showed that the most Elasticity at Mean and the most Marginal Effect emanate of organic matter, so it had special importance in presence probability of *A. gossypinus*. As Table 3 shows, the Likelihood Ratio test (LR) in this estimation was found significant at P<0.05 level. Mcfadden, Maddala and Estrella indicated that the explanatory variables of model could properly describe the changes of dependent variables. Also according to model, percentage of Right Prediction was 100%, so the presence or absence probability of plant species were correctly predicted by all of the variables.

- A. gossypinus

The following model could performed well for *A. gossypinus.*

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$$P\ (As.gossypinus) = \frac{1}{1+e^{-(10.36OM+0.92P+0.28EC-38.826)}} \tag{2}$$

Table 3 Important factors affecting the presence probability of *A. gossypinus*

Variable	Mean of variable	Estimated Coefficient	Standard Error	t-ratio	Elasticity at Means	Marginal Effect	
OM	1.685	10.364	3.987	2.599	10.440	2.492	
P	11.784	0.926	0.403	2.295	6.528	0.222	
EC	62.174	0.289	0.144	2.006	10.749	0.695	
Statistical coefficients							
Statisti.	**Log-Liklihood**	**Liklihood Ratio Test**	**t-ratio**	**Estrella**	**Maddala**	**CraggUhler**	**Mcfadden**
Coeffi.	-15.746	21.430	0.0291	0.790	0.606	0.812	0.680

- *P. bulbosa*

The following model could performed well for *P. bulbosa.*

$$P\ (Po.bulbosa) = \frac{1}{1+e^{-(0.2008Sl+33.86N+0.82P+3.70pH-0.21St-58.995)}} \tag{3}$$

According to model, the most important factors affecting distribution of this species are slope, nitrogen, phosphorus, acidity and stone. The presence probability of this species increases by increasing in slope, nitrogen, phosphorus and acidity while this probability will be decreased by increasing in stone. With one percent increasing in slope, N, P and pH, the presence probability will increase as much as 3.54, 3.31, 5.48 and 15.26 percent, respectively. Also with one unit increasing in these variables, the presence probability will increase as much as 0.049, 8.31, 0.202 and 0.909 units, respectively (Table 4). Results showed that the most Elasticity at Mean and the most Marginal Effect emanate of nitrogen, so this variable has special importance in presence probability of *P. bulbosa*. As Table 4 shows, Likelihood Ratio test (LR) in this estimation was found significant at $P<0.05$ level. Mcfadden, Maddala and Estrella indicated that the explanatory variables of model could properly describe the changes of dependent variables. Also according to model, percentage of Right Prediction was 86.36%., meaning that the presence or absence probability of plant species were correctly predicted by 86.36%. of the variables.

According to model, the most important factors affecting the distribution of this species are aspect, altitude, silt, organic matter, nitrogen and phosphorus. The presence probability of this species increases by increasing in altitude and organic matter, while this probability will be decreased by increasing in silt, nitrogen and phosphorus. With one percent increasing in altitude and organic matter, the presence probability will increase as much as 26.32 and 17.72 percent, respectively. Also with one unit increasing in these variables, the presence probability will increase as much as 0.00045 and 0.484 units, respectively (Table 5). Results showed that the most Elasticity at Mean emanate of altitude and the most Marginal Effect emanate of nitrogen, so these variables have special importance in presence probability of *D. glomerata*. As Table 5 shows, Likelihood Ratio test (LR) in this estimation was found significant at $P< 0.05$ level. Mcfadden, Maddala and Estrella indicated that the explanatory variable of model could properly describe the changes of dependent variables. Also according to model, percentage of Right Prediction is 100%, so the presence or absence probability of plant species were correctly predicted by all of the variables.

Table 4 Important factors affecting the presence probability of *P. bulbosa*

Variable	Mean of variable	Estimated Coefficient	Standard Error	t-ratio	Elasticity at Means	Marginal Effect
Slope	31.091	0.2008	0.0810	2.477	3.540	0.0493
N	0.172	33.860	19.085	1.774	3.315	8.313
P	11.735	0.824	0.345	2.388	5.487	0.202
pH	7.266	3.705	1.784	2.076	15.264	0.909
Stone	20.718	-0.2153	0.124	-1.732	-2.529	-0.052

Statistical coefficients

Statisti.	Log-Liklihood	Liklihood Ratio Test	t-ratio	Estrella	Maddala	CraggUhler	Mcfadden
Coeffi.	-15.158	16.574	0.0393	0.663	0.529	0.707	0.546

- D. glomerata:

The following model could performed well for *D. glomerate.*

$$P\ (Da.\ glomerata) = \frac{1}{1 + e^{-(-0.06Asp+0.01Ele-0.30Silt+11.15OM-33.98N-1.142P-1.6953)}} \qquad (4)$$

Table 5 Important factors affecting the presence probability of *D. glomerata*

Variable	Mean of variable	Estimated Coefficient	Standard Error	t-ratio	Elasticity at Means	Marginal Effect
Aspect	-	-0.065	0.023	-2.745	-10.270	-0.0028
Elevation	2611.4	0.010	0.0058	1.798	26.328	0.0004
Silt	32.606	-0.307	0.176	-1.745	-9.583	-0.013
OM	1.665	11.154	5.810	1.919	17.726	0.484
N	0.172	-33.981	28.627	-1.187	-5.602	-1.476
P	11.735	-1.142	0.441	-2.589	-12.798	-0.049

Statistical coefficients

Statisti.	Log-Liklihood	Liklihood Ratio Test	t-ratio	Estrella	Maddala	CraggUhler	Mcfadden
Coeffi.	-12.891	21.248	0.0308	0.869	0.619	0.897	0.824

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4 DISCUSSION

The present study examined the relationship between environmental variables and plant distribution in a part of mountainous ecosystem of Polour rangelands in Mazandaran Province, Iran. In our study area, the differences of climate features were relatively small, so plant distribution might be potentially influenced by edaphic (acidity, nitrogen, potassium, gravel, organic matter, electrical conductivity, soil texture) and topographical properties (aspect, slope and altitude). Analysis with RDA confirms that there was a relatively high correlation between vegetation and environmental factors that explain 93% of the total variance in data set. The RDA results showed that slope, aspect, soil texture, acidity, phosphorus and litter were the most important factors for the distribution of the vegetation pattern (Table 1, Figure 2).

Results of SHAZAM analysis showed that the acidity and nitrogen are the most effective factors in the distribution of *F. ovina* and *P. bulbosa* species and the most significant variables in the distribution of *A. gossypinus* are organic matter and salinity also distribution of *D. glomerata* was controlled by nitrogen. Based on RDA results, between various environmental variables, some agents such as soil texture, soil acidity, phosphorus and also slope and aspect were the most effective factors controlling vegetation distribution in Polour region. In fact, soil texture controls distribution of plant species by affecting moisture availability, ventilation and distribution of plant roots (Jafari, *et al.*, 2004). It also controled the dynamics of soil organic matter in many simulation models or organic matter decomposition and formation (Rastetter *et al.*, 1991). The effect of soil salinity and acidity on vegetation distribution was well documented (Zegeye *et al.*, 2006; Youssef and Al-Fredan, 2008). In relation to the role of phosphorus on plant distribution, it was well established that the phosphorus and nitrogen content of soil were important determinants for the reconstruction or conservation of species-rich rangelands (Marini *et al.*, 2007; Cristofoli *et al.*, 2010). Similarly, Fahimipour (2010), stated that phosphorus and the distribution of plant species were strongly correlated with each other.

Based on SHAZAM results, organic matter was one of the effective factors in the distribution of *A. gossypinus*, while, distribution of *F. ovina*, *P. bulbosa* and *D. glomerata* species seems to be more influenced by nitrogen. soil organic matter within the rangeland system provide more nutrients for plant growth, which resulted in a positive feedback as more plant biomass was likely to produce more soil organic matter (Rezaei, 2003). Organic matter and nitrogen were vital for plant feeding. In addition, soil organic matter is an important determinant of soil fertility because of its impact on ion exchange capacities and its near-stoichiometric relationship to nitrogen (Tavili *et al.*, 2008). Sperry and Hack (2002) suggested that nitrogen is the most important limiting factor, after water, to plant growth and production. It has been demonstrated that floristic differences were controlled by soil nitrogen (Abella and Covington, 2006; Eshaghi and Shafiei, 2010). Also, He (2007) showed that silt and clay content, organic matter and total nitrogen were mainly related to vegetation distribution.

The aspect and elevation influenced the distribution of *D. gmerata* and *F .ovina* species and slope influenced the distribution of *P. bulbosa* in investigated area. Elevation, slope and aspects were three environmental factors affecting soil and climate. So, elevation was often used as an indirect predictor of temperature and evapo-transpiration. In mountainous terrains variations in slope, aspect, and radiation could significantly alter the relationship between elevation and temperature (Jafari *et al.*, 2004; Ashcroft, 2006), but most probably through its influence on temperature and moisture (not measured in the present study, but inferred). There was an agreement in many studies that aspect and elevation were the most important factors affecting the distribution of ground flora (Baruch, 2005; Eshaghi and Shafiei, 2010). The similar results were reported by Zare Chahouki (2012), during their investigations on vegetation of the mountainous region in north of Iran.

The present study addressed some aspects of relationships between environmental factors and plant distribution in native rangelands within mountainous areas of Iran. It was anticipated that this finding could be used as a tool for prediction of presence and absence probability of these plant species in rangeland within similar ecosystems.

5 CONCLUSION

Overally, each plant species has specific relations with environmental variables; these relations are because of habitat conditions, plant ecological needs and tolerance ranges. Understanding the indicator of environmental factors of a given site leads us to recommend adaptable species for reclamation and improvement of that site and similar sites. Therefore, the use of multivariate analysis (RDA) can be useful for describing species variation and understanding the relationships between ecological variables, and distribution of plant communities can provide guidance leading to sustainable management, reclamation, and development of rangelands with similar conditions.

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سین‌اکولوژی مراتع نیمه استپی در ارتباط با برخی عوامل اکولوژیکی در مراتع پلور مازندران

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چکیده این تحقیق به بررسی پوشش گیاهی در رابطه با برخی عوامل ادافیکی و فیزیوگرافی در بخشی از مراتع نیمه استپی پلور به مساحتی تقریبی ۴۶۰۰ هکتار در استان مازندران می‌پردازد. بدین منظور، ۲۳ واحد کاری از تلفیق نقشه‌های شیب، جهت شیب، ارتفاع و زمین‌شناسی، با استفاده از سامانه اطلاعات جغرافیایی تعیین گردید. سپس در هر واحد، نمونه‌برداری از پوشش گیاهی به روش سیستماتیک-تصادفی و از طریق پلات‌گذاری در امتداد ۳ ترانسکت ۱۰۰ متری انجام شد. در طول هر ترانسکت، ۱۰پلات با ابعاد یک متر مربع و به فاصله ۱۰ متر از هم قرار داده شد. هم‌چنین در ابتدا و انتها و وسط هر ترانسکت پروفیل حفر و از عمق ۳۰-۰ سانتی‌متری نمونه خاک برداشت شد. خصوصیات خاک از قبیل بافت خاک، اسیدیته، ماده آلی، EC و ازت اندازه‌گیری گردید. از نرم افزار CANOCO و روش آنالیز افزونگی (RDA) و از نرم‌افزار SHAZAM نسخه ۱۰ برای آزمون روابط بین گونه‌های گیاهی و عوامل محیطی استفاده شد. محور یک RDA همبستگی معنی‌داری با شیب، جهت، شن، سیلت، فسفر، اسیدیته و لاشبرگ نشان داد، در حالی که محور دوم تنها با عامل شوری همبستگی معنی‌دار داشت. این گرادیان‌ها همبستگی نزدیکی با دو محور اول RDA دارند و ۹۳ درصد از روابط گونه-عوامل محیطی در مراتع ییلاقی پلور را شامل می‌شوند. در این تحقیق به منظور بررسی گونه‌های گیاهی در ارتباط با عوامل محیطی و یافتن رابطه منطقی بین آن‌ها استفاده گردید. نتایج نشان داد که برای گونه‌های *F. ovina* و *P. bulbosa* دو متغیر اسیدیته و ازت، برای گونه *A. gossypinus* دو متغیر هدایت الکتریکی و ماده آلی و برای گونه *D. glomerata* دو متغیر ارتفاع و ازت، اهمیت خاصی در احتمال حضور یا عدم حضور دارند.

کلمات کلیدی: عوامل محیطی، احتمال حضور و عدم حضور، عوامل خاک، مراتع پلور

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