Original Research

Distribution of Vegetation Type according to Edaphic Properties and Topography in Iran

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Abstract

The current research was carried out to find the most effective environmental factors in plant species distribution. For this purpose, a study was conducted in the Taleghan rangelands of Tehran province. Based on a vegetation map and field surveys, indicator vegetation types were identified. Within each type, 3 parallel transects with 150 m length, each containing 15 quadrates (according to vegetation variations) were established. The sampling method was randomized systematic. Quadrat size was determined for each vegetation type using the minimal area method. The floristic list and canopy cover percentage were determined in each quadrat. The topographic conditions (elevation from sea, aspect, and slope) were recorded in quadrat locations. Soil samples were taken from 0-30 cm in starting and ending points of each transect. Measured soil properties included depth, texture, organic matter, lime, pH, electrical conductivity, nitrogen, and potassium. To determine the most environmentally effective factors on plant distribution, multivariate techniques, including the principal component analysis (PCA) and canonical correspondence analysis (CCA) methods were applied. The results indicated that edaphically factors such as texture, potassium, and organic matter play a main role in the distribution of plant species.

Keywords: plant-environment relationship, edaphic and topography factors, plant species distribution, Taleghan rangelands

Introduction

The relationships between plants and environment are an important factor in community ecology [1, 2]. Since the 1980s, great progress has been made in quantitative research on the relationship of plants and their environments at a regional landscape level. Study on the plant community pattern has become one of the focuses of plant ecology research. In a broader sense, the plant community distribution pattern is influenced by many environmental factors such as climate, soil, and topographic features. Quantitative separation was studied by previous scholars to investigate the contribution of environmental factors to the whole or different layers of plant community distribution pattern [3].

Effects of environmental factors on plant communities have been the subject of many ecological studies in recent years [4-9]. Range managers usually hypothesize that percentage cover is a function of landform and soil characteristics, and that vegetation cover is a complex object, but it is possible to make a correlation between vegetation type, landform and soil type [10]. For example, Naqinezhad et al. [11], in a study of vegetation-environment relationships in the Alderwoods communities of Caspian lowlands of Northern Iran (toward an ecological classification), found that the main environmental variables controlling the separation of vegetation groups are ground water level and acidity. In another study on the effects of soil and physio-

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Table 1. Surface of each type, canopy cover, frequency, density, and diversity indices of plant-dominant species in the study sites.

Vegetation type	Surface (ha)	Canopy cover (%)	Frequency (%)	Density (number of plants in plot 1*1m^2)	Diversity indices (Shannon)
Astragalus gossypinus	9.50	6.06	73.33	116.00	3.60
Hypericum persicum	2.67	2.50	50.00	0.05	1.20
Psathyrostachys fragile	2.85	12.51	76.66	145.00	3.21
Agropyron trichophorum	4.25	19.56	90.00	259.00	2.09
Phlomis orientalis	2.30	8.50	45.20	0.25	1.30
Stipa barbata	6.50	22.29	85.00	3.50	2.193
Bromus tomentellus	8.50	22.88	92.50	2.20	2.282
Agropyron tauri	7.68	32.46	95.00	3.30	2.15

graphic factors on ecological plant groups in the eastern Alborz Mountains rangeland of Iran indicated that plant species have different responses to edaphically and topographical parameters [12]. Topography is another factor that explains the variation in soil properties and composition among different stretches of land, and their provocation of modifications in the genetic processes of the soil [13], in its hydrological features, and the distribution of plants.

Oldeland et al. [14] used Redundancy Analysis (RDA) for studying combined vegetation indices, constrained ordination, and fuzzy classification for mapping semi-natural vegetation units from hyper spectral imagery. Tsiripidis et al. [15] have studied geographical and ecological differentiation in Greek Fagus forest vegetation with Detrended Correspondence Analysis (DCA). Baruch [16] investigated vegetation-environment relationships and classification of the seasonal savannas in Venezuela, using a classification by clustering and TWINSPAN. Floristic and environmental data were ordered with the canonical correspondence analysis (CCA). He found that floristic and structure of the savannas responds directly or indirectly to elevation, water and nutrient availability. Makarenkov and Legendre [17] investigated the effects of water content and reflection of soil radiation on the vegetation cover percentage of *Calmagrostis epigejos* and *Corynephrous canscens* using multivariate analysis (CCA, RDA) and non-linear regression. They found that *Ca. epigejos* is the indicator of wet sites, while *Co. canscens* indicates dry sites.

Taleghan rangelands are located in the Central Alborz mountainous region of Alborz province north of Iran (50º19´30″ E, 36º5´20″ N to 51º11´6″E, 36º23´36″ N). The climate varies from Semi-arid to semi-humidity. Average annual precipitation of the study area ranges from 500-600 mm. Minimum temperature is recorded in December (-25ºC), while the highest temperature touches +35ºC in June. This rangeland's topography is complex, thus producing a diverse array of distinctive vegetation communities.

Environmental factors affect range plant growth and need to be understood and considered by rangeland managers. Plant growth and development are controlled by internal regulators, which are modified according to environmental conditions. Thus the main purpose of this research was to detect relationships among vegetation patterns and related environmental factors to find the answer to this question: What edaphic and topographic factors are most important in affecting vegetation distribution in Taleghan rangelands. In doing so, key factors that drive vegetation development and other ecological parameters of the region were identified.

Experimental Procedures

Data Collection

Based on field surveys, vegetation types were identified. The plant dominant species in the studied sites (8 types) include: *Stipa barbata*, *Bromus tomentellus*, *Astragalus gossypinus*, *Psathyrostachys fragile*, *Agropyron tauri*, *Agropyron trichophorum*, *Hypericum persicum*, and *Phlomis orientalis*. The surface of each type, canopy cover, frequency, density, and diversity were determined in each type (Table 1).

Sampling method was randomized systematic. Regarding the type, distribution pattern, and density of plant vegetation, quadrat size was determined for each vegetation type using the minimal area method. Within each type, 3 parallel transects with 150 m length, each containing 15 quadrats (according to vegetation variations), were established.

Soil samples were taken from 0-30 cm layer in initiating and ending points of each transect. Measured soil factors included texture (determined by Bouyoucos hydromerter), organic carbon (determined using Walkely and Black rapid titration, [18]), pH was measured in soil extract (soil water ratio=1:5) (determined by pH meter), electrical conductivity (EC) (determined by conductivity meter), lime (determined using 1 N HCl, [19], and nitrogen (determined using the Kjeldahl method) [20]. In quadrat locations, elevation (using GPS), aspect (using a compass), altitude (using an altimeter), slope (using a clinometer), and

Table 2. Comparison of edaphic and topographic properties in vegetation types.

Vegetation type	pH	EC (ds/m)	OM (%)	Lime (%)	K (ppm)	Depth (cm)	Gravel (%)	N (%)	Silt (%)	Clay (%)	Sand (%)	Altitude (m)	Slope (%)	Aspect
Astragalus gossypinus	7.69^{d}	0.22^{a}	0.88^{ab}	2.46^{ab}	8.89^{a}	25	15	0.12^{de}	31.20^{c}	32.33^{d}	35.73^{b}	2047.88^{c}	30	N
Hypericum persicum	7.70^{d}	0.24^{a}	0.76^{ab}	2.56^{ab}	7.66^{a}	50	9	0.12^{d}	34.35^{c}	37.30^{e}	27.913^{a}	2026.88^{b}	10	N
Psathyrostachys fragile	7.11^{d}	0.27^{ab}	0.35^{a}	0.37^{a}	152.0^{b}	8	47	0.03^{a}	10.13^{a}	5.63^{a}	84.24^{e}	2240^{f}	48	N
Agropyron trichophorum	7.35^{b}	0.36^{c}	3.12^{c}	6.23^{bc}	563.338^{e}	50	10.5	0.12^{de}	45.40^{e}	24.23^{c}	30.37^{ab}	1810^{a}	40	N
Phlomis orientalis	7.51^{c}	0.32^{bc}	0.81^{ab}	7.79^{c}	246.25^{cd}	50	45.73	0.06^{bc}	15.50^{b}	12.65^{b}	71.85^{d}	1810^{a}	15	S
Stipa barbata	7.17^{a}	0.27^{ab}	1.09^{b}	2.28^{ab}	242.92^{cd}	50	37.08	0.07^{c}	15.45^{b}	10.67^{ab}	72.95^{d}	2100d	10	S
Bromus tomentellus	7.08^{a}	0.24^{a}	0.66^{ab}	0.36^{a}	205.0^{bc}	25	33.94	0.04^{ab}	19.30^{b}	9.10^{ab}	71.60^{d}	2150^{e}	45	S
Agropyron tauri	7.38^{b}	0.38^{c}	3.24^{c}	28.34^{d}	295.83^{d}	15	43.86	0.14^{e}	41.06^{d}	10.13^{ab}	48.23^{c}	2347.58^{g}	35	N
F (in ANOVA table)	35.910**	8.998**	36.250**	75.080**	68.517**			42.737**	121.417**	44.934**	93.113**	5.642**		

**Level of significant is 1%

EC – Electrical conductivity, O.M. – Organic matter, K – Potassium, N – Nitrogen

depth of soil were also recorded. All sampling sites were located in a steady slope.

Data Analysis Methods

Data matrix of environmental factors and vegetation type was made. Windows (Ver. 3.0) of PC-ORD [21] was used for ordination of vegetation types in gradient of edaphic and topography (aspect, slope, and altitude) factors. Data were analyzed by multivariate techniques, i.e. principal component analysis (PCA) and canonical correspondence analysis (CCA).

To apply PCA, data standardization is necessary if we are analyzing variables that are measured in different units. Also, species with high variance, often the abundant ones, therefore dominate the PCA solution, whereas species with low variance, often the rare ones, have only minor influence on the solution. These may be reasons for applying the standardized PCA, in which all species receive equal weight [22]. Therefore, data was centred and standardized by standard deviation. Eigenvalues for each principal component was compared to a broken-stick eigenvalue to determine if the captured variance summarized more information than expected by chance. Broken-stick eigenvalues have been shown to be a robust method for selection of non-trivial components in PCA [19, 23]. Principal components are considered useful, or non-trivial, if their eigenvalue exceeds that of their broken-stick counterpart [24].

For direct gradient ordination we used CCA [23, 25] to examine the relationships between the measured variables and the distribution of plant communities, which produces indicator values for each species in each group, which are tested for statistical differences using a Monte Carlo technique (Table 5) [26]. In addition, the data were analyzed using detrended correspondence analysis (DCA). This ordination method relies on a unimodal response model, and is less sensitive to distortions caused by high turnover of species than PCA-ordination, which was used by Kadamon and Danin [27].

Also, ANOVA and the Duncan test with SPSS (Ver. 16.0) were used to assess the effect of the various environmental data in each type. This *post hoc* test (or multiple comparison tests) was used to determine the significant differences between group means in an analysis of variance setting. Duncan's test is based on the range statistic.

Results

One-way ANOVA was made to compare soil properties of different vegetation types. Table 2 gives the mean and standard deviation values of edaphic and topographic variables in eight vegetation types. Data analysis indicates that soils of different types are significantly different.

The results of the PCA ordination are presented in Table 3 and Fig. 1. Broken-stick eigenvalues for the data set indicate that the first three principal components (PC1, PC2, and PC3) resolutely captured more variance than expected by chance. The first three principal components together

Table 3. Results of principal component analysis applied to the correlation matrix of the vegetation-environmental factors.

Axis	Eigenvalue	% of Variance	Cum. % of Var.	Broken-stick Eigenvalue*		
1	5.708	40.773	40.773	3.252		
2	3.868	27.528	68.401	2.242		
3	2.349	16.778	85.179	1.752		
4	0.364	9.498	94.677	1.418		
5	0.242	3.311	97.988	1.168		
6	0.041	1.719	99.707	0.968		
7	0.000	0.293	100.000	0.802		
Factor	Eigenvector					
	1	2	3	4	5	6
Altitude	-0.1445	0.2012	-0.4645	-0.2367	**-0.5302**	-0.2175
Aspect	-0.2507	-0.1068	0.3998	-0.1705	-0.3737	**0.7006**
Slope	-0.1041	0.269	-0.2733	**0.5642**	0.187	0.4201
Depth	0.1598	-0.2177	**0.5197**	-0.0502	-0.1771	-0.2414
gravel	-0.3282	0.218	0.0356	**-0.3486**	0.282	-0.0077
Clay	**0.3419**	-0.2805	-0.0982	0.0632	0.0244	0.0064
Sand	**-0.4091**	0.0502	0.0808	-0.0803	0.1144	-0.1051
Silt	**0.382**	0.1759	-0.0431	0.097	-0.1913	0.1968
pH	0.3149	-0.2125	-0.0775	-0.3023	**0.4793**	0.2635
Ec	0.1079	0.3021	0.2582	-0.0979	**0.4281**	-0.192
OM	0.2426	**0.396**	0.1235	0.0296	-0.1789	-0.0001
Lime	0.1326	0.3954	-0.0358	**-0.4535**	0.0502	0.2433
K	0.053	0.3414	**0.4046**	0.329	-0.0248	-0.1014
N	**0.3898**	0.1025	-0.0865	-0.1922	-0.164	0.0373

*Nontrivial principal component as based on broken-stick eigenvalue

accounted for 88.70% of the total variance in data set. The first three axes of the PCA ordination of soil samples accounted for 40.77%, 27.52%, and 16.78 of the total variability, respectively (Table 3). This means that the first principal component is by far the most important for representing the variation of the eight vegetation types. Considering the correlations between plants types and soil characters, the first principal component includes edaphic and topographic factors such as nitrogen, silt, sand, and clay. The second axis was positively correlated with organic matter. The third axis was positively correlated with depth and potassium of soil. Therefore, among all edaphic and topographic factors, soil characteristics such as nitrogen and texture are the most effective factors in the distribution of grass species. Figs. 1 and 2 show the eight vegetation types against their values for axes 1 and 2, also axes 1 and 3. Considering the relationship between vegetation types and soil characteristics, we can suggest that the changes of plant patterns (in different types) are related to the soil properties.

Agropyron tricophorum type is normally found in places with higher silt, nitrogen, and lower sand, while *Ag. tauri* prefers those sites with higher organic matter and potassium. *As. gossypinus* and *Hy. persicum* types show similar behavior to occur on soils with low clay, silt, nitrogen, and organic matter. Although *Br. tomentellus* and *Ps. fragilis* types represent a strong direct relationship with increase of sand and reduction of potassium, *Br. tomentellus* shows a different behavior in comparison to *Ps. fragilis* in sites with high organic matter. *S. barbata* and *Ph. orientalis* types have a direct relation with high sand, potassium, plus low silt, clay and nitrogen, while *As. gossypinus* and *Hy. persicum* show an inverse relation with mentioned factors.

Where length of gradient in DCA analysis was ≥4.5, then DCA was used for further analyses. In this study, length of gradient in DCA analysis is ≤4.5, therefore in this case, results of principal component analysis (PCA) is more useful for investigation of effective environmental factors in the distribution of vegetation types (Table 4).

Table 4. Results of detrended correspondence analysis (DCA).

Axes	1	2	3
Eigenvalues	0.025	0.00042	0.00049
Lengths of gradient	0.43	0.126	0.09

The results of CCA ordination are presented in Table 5 and Fig. 2. Four groups were determined in relation to the edaphic and topographic variables and site points jointly represent the dominant patterns in community composition in so far as these can be explained by these variables.

The species points and the vectors of the edaphic and topographic variables jointly reflect the species distributions along each of the environmental variables. The length of the vectors indicates the relative importance of the variables in determining the axis, and the angle between an arrow and an axis is an inverse measure of their correlation.

Each edaphic and topographic factor is an indicator of the specific habitat. In view point of the species reaction to the different factors based on their position in the landscape, the results showed that:

Astragalus gossypinus and *Hy. persicum* type has non-linear relation with clay and elevation in the first layer. The above-mentioned types are normally found in place with a heavy texture, nitrogen, organic matter, and lower Ec and with higher elevation.

Bromus tomentellus and *Ps. fragilis* types have non-linear relation with gravel and sand. Relation power depends on the relative distance between indicator points of environmental characteristics and vegetation types. The above-mentioned types represent soils with light texture and low salinity, organic matter, nitrogen, and lime. *St. barbata*, *Ag. tauri,* and *Ph. orientalis* types are influenced by the slope, pH, lime, and gravel. Soils with moderate texture, high depth and low acidity and elevation indicate *Ag. tricophorum* habitat. *Ag. tauri* has the strongest non-linear relationship with high salinity. That is, high salinity is the indicator of habitat of *Ag. tauri*.

Discussion

In the present study, the combination of PCA and CCA results showed that in the study area, among different edaphic (include pH, nitrogen, potassium, lime, texture, gravel, organic matter, electrical conductivity, soil depths) and topographic factors (aspect, slope, and altitude) the occurrence and distribution of vegetation types was most strongly correlated with altitude and some soil characteristics such as texture, organic matter, nitrogen, and potassium.

Soil is one of the most important components influencing vegetation. Vegetation and soil are both influenced by topography. Topographic characteristics can also regulate moisture distribution patterns. Most studies that have been conducted to date have focused on the relationships between two components [7, 28], but few have investigated the relationships between vegetation, soil, and topography [23].

The plant species reaction to environmental factors in CCA analyses showed that each species has reacted to one or several edaphic or topographic factors, considering the fact that the length of gradient in DCA analysis was ≤4.5 and the above-mentioned types had weak nonlinear relationships with environmental factors. Therefore, in this study, results of principal component analysis (PCA) are better than DCA and CCA for investigating effective environmental factors in the distribution of vegetation types. In addition, the results of ANOVA analysis indicate that soils of different types are significantly different and the Duncan test showed that there were significant differences among types.

Based on the results of PCA, the first axis represented a landscape gradient; it was correlated to soil texture and soil nitrogen. Soil depth and texture are important in view of their effect on availability of moisture for plants. Texture plays a significant role in regulating vegetation patterns, including vegetation composition, functional group,

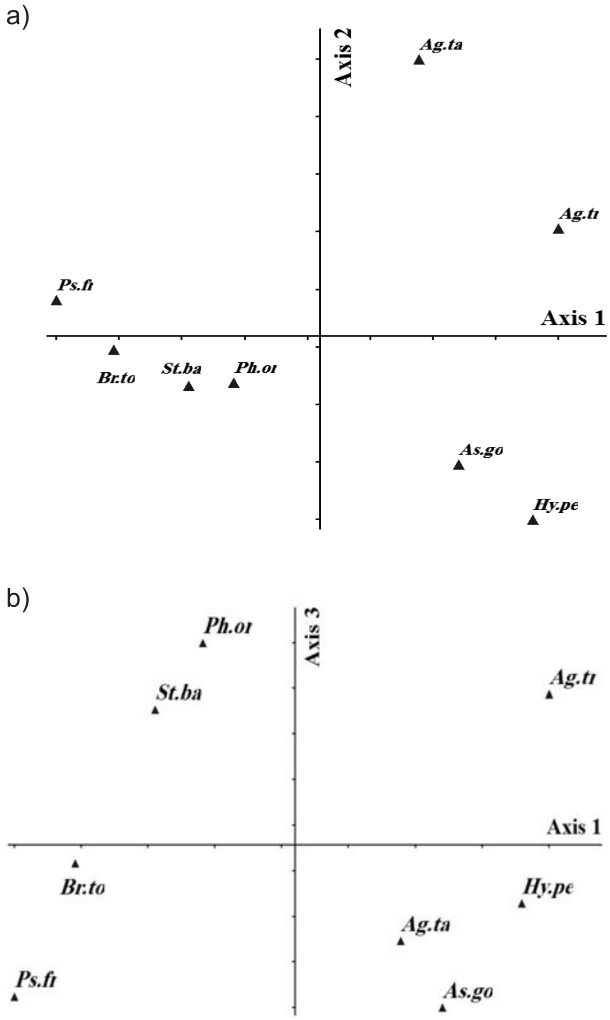

Fig. 1. PCA – ordination diagram of the vegetation types related to the environmental factors in the study area: a) shows the eight vegetation types against their values for axes 1 and 2, b) shows the eight vegetation types against their values for axes 1 and 3. (*Br. to.– Bromus tomentellus, Ps. fr.– Psathyrostachys fragilis, Ag. ta.– Agropyron tauri, Ag. tr.– Agropyron tricophorum, St. ba.– Stipa barbata, Ph. or.– Phlomis orientalis, As. go.– Astragalus gossypinus, Hy.pe.– Hypericum persicum*)

Table 5. Monte Carlo test for species–environment correlations.

Axis	Spp–envt Corr	Mean	Minimum	Maximum	P
1	0.997	0.945	0.609	0.998	0.0600
2	0.998	0.878	0.565	0.989	0.0100
3	0.924	0.792	0.400	0.964	0.0800

P – Proportion of randomized runs with species-environment correlation greater than or equal to the observed species-environment correlation; i.e., P – (1+no. permutations×oobserved)/(1+no. permutation).

and structure. Soil texture controls the dynamics of soil organic matter in many simulation models or organic matter decomposition and formation [29]. It also influences infiltration, moisture retention, and the availability of water and nutrients to plants [30]. This is due to the role and function of mentioned factors on the growth and nutrition of plants. Carevic et al. [31], in a study on the effects of soil water holding capacity and effective soil texture on soil and plant water status, found that climatic conditions and soil water availability have a strong influence on plant water status. Also, Sperry and Hacke [30] suggested that nitrogen is the most important limiting factor, after water, to plant growth and production. It has been demonstrated that floristic differences were affected by soil nitrogen [28, 32]. Organic matter and nitrogen are 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 [4]. The second axis represented mainly soil organic matter. Organic matter improves soil structure, moisture content, and fertility. This is in agreement with the results of many other studies that organic matter as an important factor in the distribution of the ground flora [28, 33, 34]. The third axis represents potassium, in the study area; potassium is one of the effective factors in the distribution of vegetation types.

The aspect and elevation influenced the distribution of *Br. tomentellus* and *Ps. fragilis* types in the investigated communities, most probably through its influence on temperature and moisture (not measured in the present study, but inferred). This is in agreement with many studies that have evidenced aspect and elevation as an important factor in the distribution of ground flora [16, 32]. The distribution of the different ecological groups such as *Ag. tricophorum* and *Ag. tauri* was affected by soil texture, organic matter, potassium, and nitrogen content.

Totally, in arid environments soil salinity is important to vegetation distribution [23], while this research showed that in humid and semi-humid regions soil fertilizer factors are vital for plant growth. The lack of strong correlations among environmental factors and vegetation characteristics are potentially related to several factors. First, various combinations of environmental factors can produce relatively equivalent environments for plant growth [35, 36]. Second, many plant species common to the Artemisia steppe possess wide ecological amplitudes and large ecotype variation [8, 31]. Third, interactions between plant species or functional groups can mask the relationships among environmental factors and vegetation characteristics.

Conclusions

In total, 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 analyses (PCA and CCA) can be useful for describing species variation and understanding the relationships between ecological variables, and distribution of plant communities can provide guidance to sustainable management, reclamation, and development of this and similar regions. The results will also provide a theoretical base for the restoration of degenerated vegetation in this area. 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.

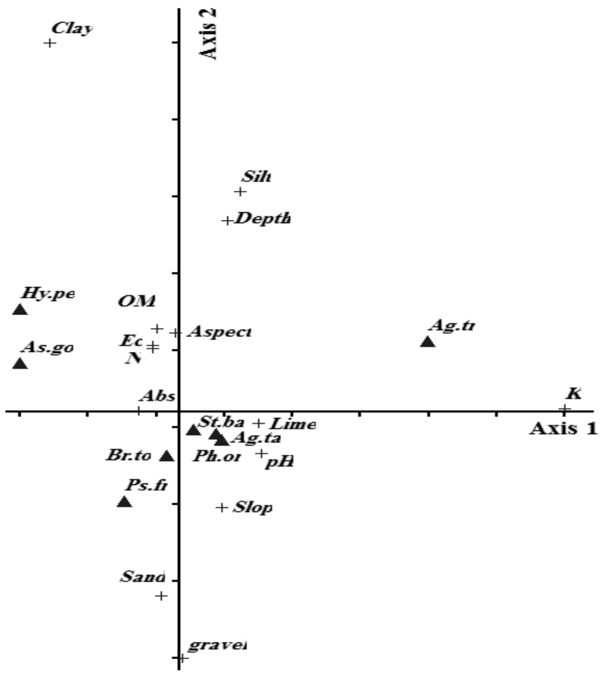

Fig. 2. CCA – ordination diagram of the environmental data. For vegetation types and variable abbreviations, see Fig. 1. (Δ) represents the vegetation types. (+) represents environmental factors.

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References

1. LENG W., HE H., LI X., YUANMAN H. Effects of different sampling modes on the results of vegetation ordination analysis. Ying Yong Sheng Tai Xue Bao, **17**, 1563, **2006**.
2. LEONARD S. G., MILES R. L., BURKHARTDT J. W. Comparison of soil properties associated with basin wildrye and black greasewood in the Great Basin region, **1984**.
3. LI G., XIAOAN W., HUA G., ZHIHONG Z. Effects of ecological factors on plant communities of Ziwuling Mountain, Shaanxi Province, China. Acta Ecol. Sinica, **28**, (6), 2463, **2008**.
4. TAVILI A., BINIAZ M., ZARECHAHUUKI M. A. Plant-site factors relationship in Zereshkin rangelands, Iran. J. Balkan Ecol., **11**, (1), 83, **2008**.
5. JAFARI M., ZARE CHAHOUKI M. A., TAVILI A., AZARNIVAND H. Soil-Vegetation Relationships in Hoze Soltan Region of Qom Province, Iran. Pakistan J. Nutr., **2**, (6), 329, **2003**.
6. DAVIES K.W., BATESA J.D., MILLER R.F. Environmental and vegetation relationships of the *Artemisia tridentata* spp. Wyomingensis alliance. J. Arid Environ., **70**, 478, **2007**.
7. TAMARTASH R., YOUSEFIAN M., TATIAN M. R., AHSANI M. Vegetation analysis in rangelands of Lasem, Iran. American-Eurasian J. Agric. & Environ. Sci., **7**, (4), 397, **2010**.
8. ZARE CHAHOUKI M. A., AZARNIVAND H., JAFARI M., TAVILI A. Multivariate Statistical Methods as a Tool for Model Based Prediction of Vegetation Types, Russian Journal of Ecology, **41**, (1), 84, **2009**.
9. WEST N. E. Plant synecology in the service of rangeland management. In: Tueller, P.T. (Ed.), Vegetation, **1988**.
10. ZHANG Y. M., CHEN Y. N. PAN B. R. Distribution and floristic of desert plant communities in the lower reaches of Tarim River, southern Xinjiang, People's Republic of China, J. Arid Environ., **63**, 772, **2005**.
11. NAQINEZHAD A., HAMZEH'EE B., AATTAR F. Vegetation-environment relationships in the alderwood communities of Caspian lowlands, N. Iran (toward an ecological classification), Funct Ecol. Plants, **203**, (7), 567, **2008**.
12. TATIAN M. R., ARZANI H., REIHAN M. K., BAHMANYAR M. A., JALILVAND H. Effect of soil and physiographic factors on ecological plant groups in the eastern Alborz mountain rangeland of Iran. Grassland Science, **56**, (2), 77, **2010**.
13. BRUBAKER S.C., JONES A.J., LEWISE D.T., FRANK K. Soil properties associated with landscape positions and management. Soil Sci. Soc. Am. J., **57**, 235, **1993**.
14. OLDELAND J., ADORIGO W., LIECKFELD L., LUCIEER A., JURGENS N. Combining vegetation indices, constrained ordination and fuzzy classification for mapping semi-natural vegetation units from hyper spectral imagery. Rem. Sens. Environ., **114**, (60), 1155, **2010**.
15. TSIRIPIDIS I., BERGMEIER E., DIMOPOULOS P. Geographical and ecological differentiation in Greek Fagus forest vegetation. J. Veg Sci., **18**, (5), 743, **2009**.
16. BARUCH Z. Vegetation-environment relationships and classification of the seasonal savannas in Venezuela. Flora, **200**, 49, **2005**.
17. MAKARENKOV V., LENGENDRE P. Nonlinear redundancy analysis and canonical correspondence analysis based on polynomial regression. J. Ecol., **83**, (4), 1146, **2002**.
18. BLACK C. A. Methods of soil analysis. American Society of Agronomy, **2**, 771, **1979**.
19. JACKSON D. A. Stopping rules in principal component analysis-a comparison of heuristic and statistical approaches. J. Ecol., **74**, (8), 2204, **1993**.
20. JACKSON M. L. Soil Chemical Analysis. Prentice-Hall of India, New Dehli, pp. 498, **1967**.
21. MCCUNE B., MEFFORD M. J. PC-ORD. Multivariate Analysis of Ecological Data Version 3.0. MjM Software Design. Gleneden Beach, OR. **1997**.
22. JONGMAN R. H. G., Ter Break C. J. F., VANTONGEREN O.F.R. Data Analysis in community and landscape ecology. Center Fire Agricultural Publishing and Documentation, Wageningen, **1987**.
23. ZARE CHAHOUKI M. A., KHALASI AHVAZI L., AZARNIVAND H. Environmental factors affecting distribution of vegetation communities in Iranian rangelands. Vegetos, 23, 1, **2010**.
24. LEGENDRE P., LEGENDRE L. Numerical ecology, Amsterdam: Elsevier Science BV, **1998**.
25. TER BRAAK C. J. F. Canonical correspondence analysis: a new eigenvector method for multivariate director gradient analysis. J. Ecol., **67**, 1167, **1986**.
26. DUFREˆNE M., LEGENDRA P. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol. Monogr., **67**, 345, **1997**.
27. KADAMON R., DANIN A. Floristic variation in Israel: a GIS analysis. Flora, **192**, 341, **1997**.
28. ABELLA S.R., COVINGTON W., Vegetation-environment relationships and ecological species groups of an Arizona *Pinus ponderosa* landscape. USA, **185**, (2), 255, **2006**.
29. RASTETTER E. B., RYAN M. G., SHAVER G. R., MELILLO J. M., NADELHOFFER K. J., HOBBIE J. E. ABER J. D. A general biochemistry model describing the responses of the C and N cycles in terrestrial ecosystems to changes in CO_2, climate and N deposition. Tree Physiol., **9**, 101, **1991**.
30. SPERRY J. S., HACKE U. G. Desert shrub water relations with respect to soil characteristics and plant functional type. Funct Ecol., **16**, 367, **2002**.
31. CAREVIC F.S., FERNANDEZ M., ALEJANO R., VAZQUEZ-PIQUE J., PAPIAS R., CORRAL E., DOMINGO J. Plant water relations and edaphic climatic conditions affecting acorn production in a holm oak (*Quercus ilex* L. ssp. ballota) open woodland. Agro Forest. Syst., **78**, (3), 299, **2010**.
32. ESHAGHI R. J., BANJ SHAFIEI A. The distribution of ecological species groups in Fagetum communities of Caspian forests: Determination of effective environmental factors. Flora, **205**, 721, **2010**.
33. BADEN J., BATSON T., STALTER J. Factors affecting the distribution of vegetation of abandoned rice fields, Georgetown Co., South Carolina. Castenea, **40**, 171, **2007**.
34. HE M.Z. ZHENG J.G., LI X.R., QIAN Y.L. Environmental factors affecting vegetation composition in the Alxa Plateau. China. J. Arid Environ., **69**, 473, **2007**.
35. DAUBENMIRE R. Plant Communities: A Textbook of Plant Synecology. Harper & Row, New York, pp. 300, **1968**.
36. JENSEN M. E. Interpretation of environmental gradients which influence sagebrush community distribution in Northeast Nevada. J. Range Manag., **43**, (2), 85, **1990**.