Vegetation diversity of ecological plant groups in relation to environmental factors on the southern slopes of Karkas Mountain (Natanz, Iran)

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Received: September 19, 2015 ▷ Accepted: May 23, 2016

Abstract. This study is aimed at identification of the ecological groups and at demonstration of relations between the soil chemical characteristics and plant diversity on the southern slopes of Karkas Mountain. Sampling of soil and vegetation was made using a randomized-systematic method. Percentage of the vegetation cover was recorded by abundance-cover scale in each sample plot. Within each sample plot, physical and chemical characteristics of the soil were determined. In order to investigate the variation of ecological groups, a cluster analysis was applied. Diversity indices, such as richness, dominance and evenness, were calculated by SDR and Ecological Methodology software for analysis of the relationship between diversity and environmental variables. ANOVA test was applied for showing the significant differences between habitats and groups. Eight vegetation groups were identified. The results indicated that there were significant differences between the groups in terms of biodiversity indices and environmental factors.

Key words: cluster analysis, diversity, ecological groups

Introduction

Investigation of biodiversity by using different diversity indices for description of the ecological status in the management of natural resources is essential (Maguran 1996). General interest in biodiversity has grown rapidly in recent decades, in parallel with the growing concern about environmental conservation in the main, largely as a consequence of the accelerating loss of natural habitats, habitat fragmentation and degradation, and the resulting extinctions of species (Zhang 2003, 2005). Decreased biodiversity reduces the plant community stability and degrades the ecosystem functions and processes (Tilman & al. 1997). The existing measurement methods of functional diversity are correlated with the species richness, and theoretically are thought to have obvious shortcomings (De Bello & al. 2006). Ecological species groups are useful for identifying the species sharing similar environmental affinities and typically occupying similar sites across the landscape, and for indicating the environmental complexes of habitats based on the abundance of different species groups (Rowe 1956; Simpson & al. 1990; Goebel & al. 2001). Application of ecological species groups helps discerning the species-environment relationships and plays an important role in biological society's classification, determination of changes in vegetation, distribution of vegetation and environmental factors and plant communities, as well as assessing the habitat quality (Barnes & al. 1982; Pourbabaei & al. 2006). Among the more modern analyses, some techniques of classification such as cluster analysis are often used (McInnes & Pugh 1998; Barnes & Griffiths 2008). This method uses hierarchical cluster analysis, an objective technique that has long been applied to a wide variety of ecological scenarios (Williams & al. 1966; Stocker & al. 1977; Baeur 1989; Yom-Tov & Radmon 1998; Hupalo & al. 2000; Miserere & al. 2003). Peng & al. 2012 identified the species diversity of evergreen-deciduous broadleaf forest in southwest China and classified the plant species by employing cluster analysis. Cluster analysis was also applied in other studies such as the review of biodiversity of tree and shrub communities in desert regions of Iran, and in the ecological studies in the western region of Abu Dhabi (United Arab Emirates), respectively, by Kashki & Amirabadizadeh (2012) and Sakkir & al. (2012). Diversity of plant groups is related to many ecological factors and this pattern has been frequently tested along the altitude line in the mountains (Kessler 2001; Lomolino 2001; Zhang & Chen 2004). Hoang & al (2011) studied human and environmental influences on plant diversity and composition in Ben En National Park. They have concluded that soil types and human disturbance had a small but significant effect on forest composition and ecosystem restoration in forests and shrublands should be given immediate serious attention by the management board. Kouhgardi & al. (2011) worked on ecological groups and their diversity to assess the effects of soil characteristics and physiographic factors (slope, aspect and elevation) on vegetation distribution in mountain forests south of Iran. Their results showed that the vegetation distribution pattern was primarily related to soil characteristics and elevation. Xie & al. (2013), in a study of species diversity using richness, evenness and diversity indices in the central part of the Heihe River Basin, have concluded that species diversity reduces along with decreasing soil water content, and that the order of species diversity was interdune lowland, flat slope, fixed dune, semifixed dune, and mobile dune. In a study of soil pH and species diversity in coastal dunes, Isermann (2005) showed that the species richness and diversity were highest in the gray dunes, where soil pH was at intermediate levels; both variables were lower in yellow and brown dunes and variability in pH increased with the increasing species diversity and also with scale. Generally, soil pH variability decreases with the increasing of vegetation cover. In a study of the effect of some environmental factors on plant species diversity in the mountainous grasslands of Hamedan, Fattahi & Ildoromi (2011) showed that soil characteristics and aspects had significant effects on diversity in the north, east and west aspects. Khalik & al. (2013), in a study of floristic diversity and vegetation analysis of Wadi Al-Noman (Mecca, Saudi Arabia), showed that species diversity (richness and evenness) is positively correlated with the increasing cover and pH. Until identification of the plant community in the Karkas Hunting-Prohibited Region by Khajeddinn & Yeganeh (2008), there have been no studies into diversity indices of the plant groups associated with the main ecological factors on the southern slopes of Karkas Mountain. The vegetation of Karkas Mountain is under high livestock grazing pressure of late.

The purpose of this study was to determine the relationship between diversity indices and environmental factors in the plant groups of the region.

Material and methods

Study area

The study area is a pastoral region located at 33°17' to 33°24' N and 51°39' to 51°49' E, with a mean altitude of 2750 m on the southern slopes of the Karkas Mountain (Natanz) in Central Iran.

Sampling method

Data were collected from 133 sample plots for this area using the systematic-random sampling method. Within each sample plot, plants and their estimated cover values were recorded. Sampling was done March to April in 2010. The size of plots was determined in 1.5 × 2 m by the minimal area method (Cain 1938).

Data analysis

Soil samples were collected from 0–15 depth in each sample plot and analyzed for soil characteristics, such as pH, EC, salinity and moisture (McKeague 1978).

The cover estimates of 78 plant species in 133 sample plots were subjected to Cluster Analysis. For the Cluster Analysis, PC-ORD software (Mc Cune 1997) was applied. Group names were considered on the basis of dominant species in each group.

In order to evaluate diversity of the ecological species groups, the data were transferred to SDR software and Ecological Methodology software and various indices were calculated for richness, dominance and evenness.

Statistical analysis

Statistical analyses were performed with SPSS Program (Inso Corporation 1999). ANOVA test was applied to show the significant differences of environmental factors and diversity indices between the ecological groups of the region. Also, a Pearson correlation table was drawn to show which parameter affects the diversity indices.

Results

Cluster Analysis

Clustering analysis of 133 sample plots after Ward`s method and a threshold value of 50 percent was carried out and summarized in a dendrogram on Fig. 1. The results indicated eight ecological groups shown in Table 1.

Table 1. Ecological groups in the studied region resulting from the Cluster Analysis.

Ecological groups	Dominant species	Participant species	Properties
1	*Artemisia aucheri* Boiss. – *Astragalus verus* Olivier *Artemisia aucheri* Boiss. – *Hordeum glaucu*m Steud.	*Acanthophyllum microcephallum* Boiss. *Acantholimon scorpius* Boiss. *Bromus tomentellus* Boiss.	Altitude: 2475-2749 m EC: 46-115 μs/cm^2 Sal: 23/8-62 mg/l pH: 7/5-8/7 Moisture: 0/4-9/93
2	*Artemisia aucheri* Boiss. – *Bromus tomentellus* Boiss. *Artemisia auchari* Boiss. – *Boissiera squarrosa* (Sol.) Nevski	*Alyssum bracteatum* Boiss. & Buhse *Sliene commelinifolia* Boiss. *Lappula microcarpa* Gurke	Altitude: 2675-2729 m EC: 44/7-141 μs/cm^2 Sal: 24/5-76/8mg/l pH: 7/4-8/32 Moisture: 4-8
3	*Boissiera Squarrosa* (Sol.) Nevski *Bromus tectorum* L.	*Astragalus gossypinus* Fisch. *Scariola orientalis* (Boiss.) Sojak *Andrachnea thelephioides* L.	Altitude: 2064-2740 m EC: 46-131 μs/cm^2 Sal: 25/2-70mg/l pH: 7/8-8/3 Moisture: 1/91-5
4	*Bromus tectorum* L. *Bromus tomentellus* Boiss. *Stachys inflata* Benth	*Poa bulbosa* L. *Tragopogon caricifolius* Boiss. *Eurotia ceratoides* C.A.Mey	Altitude: 2048-2729 m EC: 33/4-105 μs/cm^2 Sal: 18/2-57mg/l pH: 7/9-8/5 Moisture: 3-12
5	*Bromus tectorum* L. – *Bromus danthoniae* Trin. *Scariola orientalis* (Boiss.) Sojak	*Papaver commutatum* Fisch., C.A.Mey. & Trautv. *Polygonum paronychioides* C.A.Mey. *Senecio vernalis* Waldst. & Kit.	Altitude: 2147-2330 m EC: 53/4-110 μs/cm^2 Sal: 29/5-60mg/l pH: 7-8/4 Moisture: 3-12
6	*Acanthophyllum microcephalum* Boiss.	*Astragalus verus* Olivier *Hordeum glaucum* Steud.	Altitude: 2176-2721 m EC: 55/7-88/8 μs/cm^2 Sal: 29/5-48/5mg/l pH: 7/6-8/4 Moisture: 1/3-29/9
7	*Taeniaterum crinitum* (Schreb.) Nevski	*Alyssum bracteatum* Boiss. & Buhse *Boissiera squarrosa* (Sol.) Nevski *Stipa barbata* Desf.	Altitude: 2092-2688 m EC: 40/3-157μs/cm^2 Sal: 23/7-80mg/l pH: 7/9-8/4 Moisture: 0/2-7/2
8	*Artemisia sieberi* Besser	*Scariola orientals* (Boiss.) Sojak *Acanthophyllum bracteatu* Boiss. *Alhagi persarum* Boiss. & Buhse	Altitude: 2095-2312 m EC: 69/2-96/3μs/cm^2 Sal: 34/1-50/3mg/l pH: 7/7-8/2 Moisture: 1-14/2

Sal: Salinity.

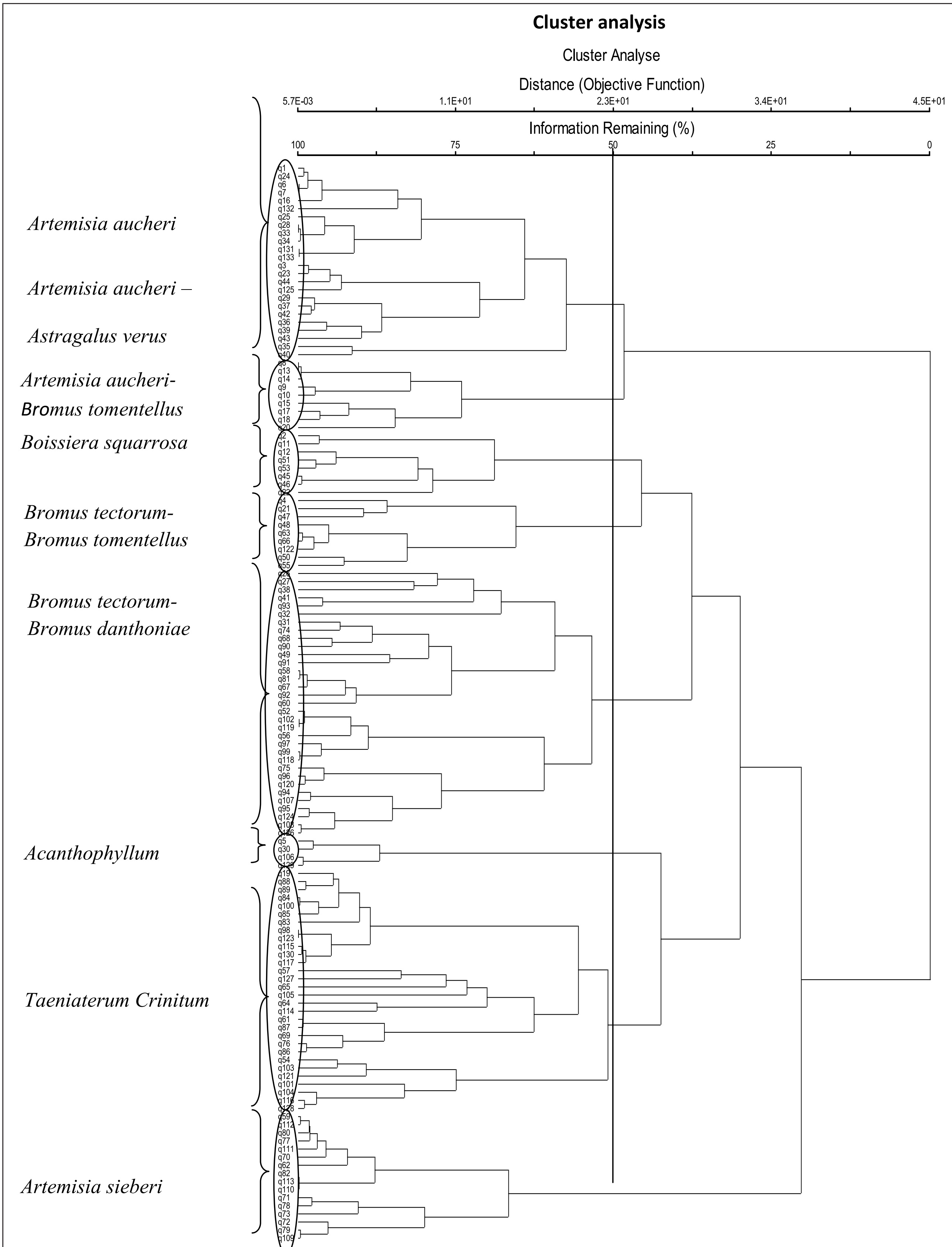

Fig. 1. The dendrogram resulted from a cluster analysis of 133 quadrates using Sorensen distance measure and Ward's method. A vertical dashed line represents reference point for delimiting 8 ecological groups.

Species diversity of the habitats and their ecological groups are indicated in Table 2 and 3. Table 2 shows that Margalef has the highest and Menhinick has the lowest richness index for the habitats. Simpson D is high among the dominance indices. Simpson (Evenness) and Simpson1/D is low. Mean diversity indices in the ecological groups are indicated in Table 3. It shows that the species richness in Group 8 is the highest. Groups 5, 4 and 3 have the highest evenness, Shannon diversity and Simpson diversity indices, respectively.

Table 2. Diversity indices for the habitats.

			Index	Value
Richness		1	Margalef	7.68
		2	Menhinick	.67
Diversity (heterogeneity)		1	Shannon	2.99
		2	Brillouin	2.98
	Dominance	3	Simpson1/D	.08
		4	Simpson D	12.27
		5	McIntosh	.72
		6	Berger-parker	.15
Evenness		1	Simpson	.17
		2	Camargo	.83
		3	Smith & Wilson1/D	.93
		4	Pielou	.7

Table 3. Mean diversity indices in the ecological groups.

	S	E	H	D
Ecological group 1	7.2	.53	1.04	.51
Ecological group 2	7	.73	1.39	.69
Ecological group 3	7.2	.74	1.43	.7
Ecological group 4	7.5	.73	1.44	.69
Ecological group 5	7	.76	1.43	.68
Ecological group 6	7.55	.64	1.3	.62
Ecological group 7	7.53	.67	1.32	.62
Ecological group 8	8.02	.57	1.19	.46

S: Species richness, **E**: Evenness index, **H**: Shannon diversity index, **D**: Simpson diversity index.

Statistical analysis

ANOVA and Duncan's tests showed that there were significant differences between the groups in terms of diversity indices (*P*<0.05) (Table 4).

Table 4. ANOVA results for diversity indices.

		Sum of squares	df	Mean square	F	Sig.
S	Between groups	16676.448	7	2382.350	577.133	.000
E	Between groups	1779.429	7	254.204	14930.912	.000
H	Between groups	6259.209	7	894.173	8561.545	.000
D	Between groups	1408.732	7	201.247	11305.246	.000

Fig. 2 shows the changes in species richness. There were not any significant differences between the Groups 2 and 5 and between the Groups 6 and 7. The maximum of species richness was reached in Group 8. The lowest was in Groups 2 and 5. Fig. 3 shows the changes in evenness. There were not any significant differences between the Groups 2 and 4. The maximum evenness was reached in Group 5 and Group 1 showed the minimum evenness. Fig. 4 shows the changes in the Shannon index. Group 4 indicated the maximum and Group 1 the minimum of it. There were not any significant differences between the Groups 3 and 5 in the Shannon index. Fig. 5 shows the changes in the Simpson index. There were not any significant differences between the Groups 2 and 4 in it. The maximum of the Simpson index was reached in Group 3 and the minimum in Group 8.

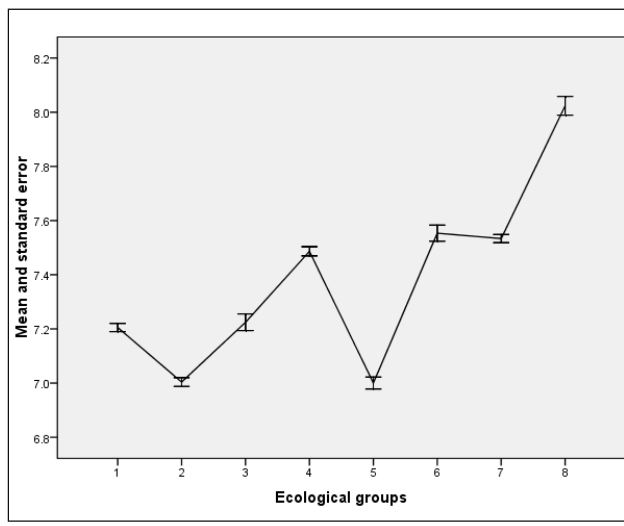

Fig. 2. Changes in species richness.

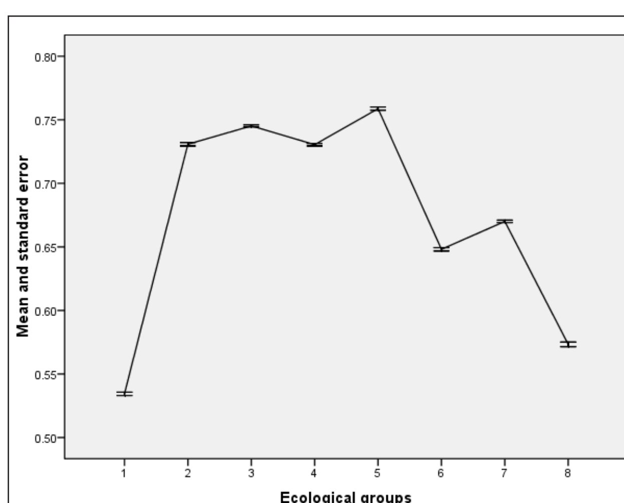

Fig. 3. Changes in evenness.

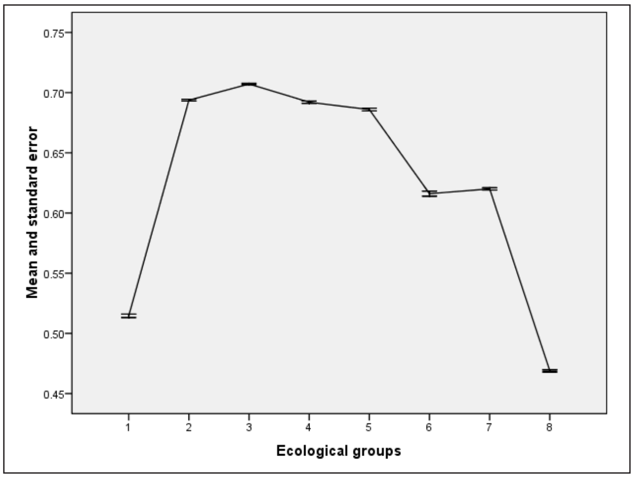

Fig. 4. Changes in the Shannon index.

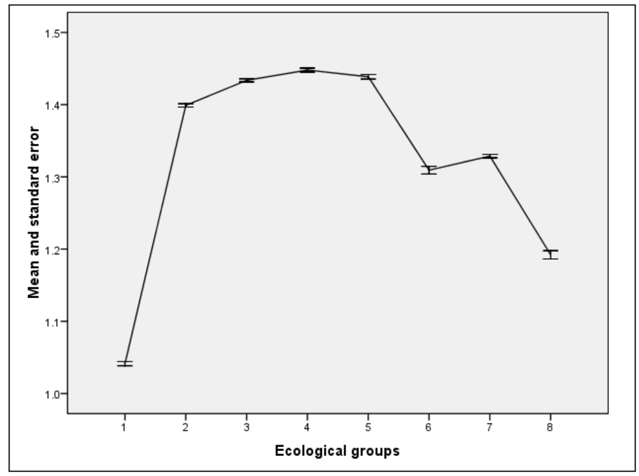

Fig. 5. Changes in the Simpson index.

Environmental factors between the groups

ANOVA and Duncan's tests showed that there were significant differences between the groups in terms of environmental factors ($P<0.05$) (Table 5). Pearson's correlations between the environmental factors and diversity indices are given in Table 6. There is a positive correlation between the species richness and the Shannon index with the environmental factors, except for altitude, as well as a positive correlation between evenness and Simpson's diversity with the environmental factors, except for pH.

Table 5. ANOVA and Duncan's tests differences between the groups in terms of environmental factors.

		Sum of squares	df	Mean square	F	Sig.
pH	Between groups	2418.137	7	345.448	6680.942	.000
EC	Between groups	3585136.673	7	512162.382	1297.015	.000
Sal	Between groups	964596.836	7	137799.548	1269.005	.000
Alt	Between groups	5165990464.331	7	737998637.762	32049.036	.000
Moisture	Between groups	522779.859	7	74682.837	6632.462	.000

Table 6. Pearson's correlations between the environmental factors and diversity indices.

		pH	EC	Sal	Alt	Moisture
S	Pearson correlation	.152**	.070**	.059**	-.116**	.065**
	Sig. (2-tailed)	.000	.000	.000	.000	.000
E	Pearson correlation	-.088**	.043**	.041**	.044**	.123**
	Sig. (2-tailed)	.000	.000	.000	.000	.000
H	Pearson correlation	.029**	.075**	.064**	-.017**	.145**
	Sig. (2-tailed)	.000	.000	.000	.000	.000
D	Pearson correlation	-.010**	.062**	.055**	.024**	.169**
	Sig. (2-tailed)	.000	.000	.000	.000	.000

** Correlation is significant at the 0.01 level (2-tailed).

Discussion

A cluster analysis of the 133 sample plots has indicated eight plant communities that differed in species composition and abundance. This study showed significant correlations between the soil moisture content, relative moisture, pH value and diversity, consistent with the findings of different researches (Kleijn & Muller 2006) who have shown that many environmental factors determine both species richness and biomass in the natural ecosystems (Maestre & al. 2006; Fornara & Tilman 2009; Ma & al. 2010; Pausas & Austin 2001). In this study consistent with the reports of different researches (Yukun & al. 2009; Zuo & al. 2012; Zhang & Zhang 2011), there are significant correlations between the soil moisture content, relative moisture, pH value and diversity. With regard to Shannon's index (H=2.99), this region is relatively away from stress and degradation. A high Simpson index (D=12.67) indicated the presence of some dominant species such as *Artemisia aucheri* Boiss., *Artemisia sieberi* Besser, *Bromus danthonia* DC., *Bromus tectorum* L.,*Taeniatrum crinitum* (Schreb) Nevski, with covering percentages of 1448, 1038, 1153, 1620, and 1708, respectively. Evenness (Simpson's index) with the increasing Simpson's dominance index is reduced. Thus diversity of the region (Simpson 1/d) is reduced (Table 2). This study consistent with the reports of most researches about the relationship between altitude and diversity (Pourbabaei & al. 2006; Meng & al. 2012) has confirmed that increasing altitude showed a decrease in richness and Shannon's index owing to the extreme conditions at high altitudes. Group 3 with the indicator species of *Boissiera squarrosa-Bromus tectorum* had a high pH, low EC, low salinity, low altitude, low moisture, low species richness, high evenness, the highest diversity and the highest dominance. Because of low altitude and low salinity, this Group has the highest diversity. Group 4 with the indicator species of *Bromus tectorum* had a high pH, high EC, high salinity, low altitude, high moisture, high species richness, high evenness, the highest diversity, and high dominance. Group 5 with the indicator species of *Scariola orientalis* had a high pH, high EC, high salinity, low altitude, lowest moisture, low species richness, the highest evenness, highest diversity, and high dominance. Also Group 7 with the indicator species of *Taeniaterum crinitum* had a high pH, high EC, high salinity, the lowest altitude, low humidity, high species richness, high evenness, high diversity, and high dominance. Because of low altitude, this Group similarly to Groups 3, 4 and 5 had the highest diversity. Group 1 with indicator species of *Artemisia aucheri-Astragalus verus* had the highest pH, high EC, high salinity, low altitude, low moisture, low species richness, low evenness, low Shannon diversity, and low dominance. Because of the high salinity, this Group had low diversity. Group 6 with the indicator species of *Acanthophyllum microcephalum* had a low pH, the lowest EC, lowest salinity, low altitude, highest moisture, high species richness, low evenness, low diversity, and low dominance. Garcia & al. 1993 in a study of the aboveground biomass and species richness in a Mediterranean salt marsh showed that salinity was negatively correlated with the species richness, because high salt concentrations in the soil lead to a decrease in water potential, which affects water availability (Hasegawa & al. 2000). Non-positive relationships between evenness and richness could arise due to the effects of migration rate or local species interactions (Wilsey & Gray Stirling 2007). Group 6 with low pH has the highest evenness, while Group 2 with indicator species of *Artemisia aucheri – Bromus tomentellus* had the lowest pH, highest EC, highest salinity, highest altitude, low moisture, lowest species richness, highest evenness, highest Shannon diversity and dominance. Shinohara & Iyobe (2004) have found that vegetation change at sites with low pH and high electrical conductivity was small. The lower amount of Shannon's index is related to the hard circumstances of the ecological group (Krebs 1998). Group 8 with the indicator species of *Artemisia sieberi Besser* had a high pH, high EC, high salinity, the lowest altitude, lowest humidity, high species richness, low evenness, low diversity, and low dominance. Because this group was located at the lowest altitude, livestock grazing pressure was higher than in the other groups. ANOVA and Duncan's tests showed that there were significant differences between the groups in terms of diversity indices (P < 0.05) (Table 4). ANOVA and Duncan's tests showed also that there were significant differences between the groups in terms of environmental factors (P < 0.05) (Table 5). Table 6 indicates the Pearson's correlation values obtained between some environmental factors (pH, EC, salinity, altitude, and moisture) and diversity indices. A variety of abiotic factors have been suggested as determinants of plant species diversity. In this study, strong correlations ($P < 0.01$) were found between the environmental factors and plant diversity. For example, there were positive correlations among the species richness and pH, EC, salinity, and moisture, and there were negative correlations between the species richness and altitude. Since altitude normally determines the microclimate and habitat in the mountain regions and is also a primary determinant of plant species diversity, many studies have found and supported a relation between plant diversity and altitudinal gradient such as vegetation-environmental relationships (Arekhi 2010).

Increasing pH increases the Shannon index (Table 6). This means that an increasing pH makes environmental circumstances suitable for the presence of more species. In fact, with an increasing pH the presence of nonhalophytic species such as *Stipa barbata* and *Poa bulbosa* (Table 1) increases. The species richness index increases with pH increase. Also, with increasing pH, Simpson's (D) index decreases. This status reduces evenness of the region (Table 6). Many authors have also reported higher plant diversity at higher soil pH values. In Europe, plant diversity is strongly positively related to the soil pH (Grime 1979; Grubb 1987; Ewald 2003). In other studies, there has been shown a positive relationship between an increasing pH and diversity (Partel 2002; Partel & al. 1996, 2004; Rodriguez-Loinaz & al. 2008; Leniere & Houle 2006).

Water availability is important in affecting the plant species richness. A small difference in soil moisture may result in a significant difference in seed germination and, hence, in floristic diversity (Pausas & Austin 2001 & Wang & al. 2008). In this study, a conclusion was reached that there exists a strong positive correlation between soil moisture and species richness, species diversity and evenness (Table 6). Yukun & al. (2009) indicated in their study a significant positive correlation between the species richness and soil moisture content ($r = 0.743$) and relative moisture ($r = 0.705$) in nine sample plots.

A low Shannon's index is related to the hard circumstances of the ecological groups, thus the group with high evenness and richness indices has the highest species diversity (Krebs 1998). In this study, the low mean Shannon's diversity index between the groups (H=1. 3) (Table 3) was related to the high grazing pressure. The highest amount of evenness in Group 5 (Table 3) indicated high species diversity. The highest species richness was in Group 8, but the Group did not have the highest species diversity (Table 3). This Group had low moisture. Perring (1959) and Pourbabaei (2012) had similar findings.

In general, the present study highlighted the relationships between soil characteristics and species diversity in the Karkas Mountain, and revealed how these factors affected diversity. Also, it has illustrated that soil characteristics play a more important role in the species diversity and on the basis of these results range managers should give special consideration to soil changes or erosion.

Acknowledgements. The authors are grateful to the University of Isfahan for support of their research.

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