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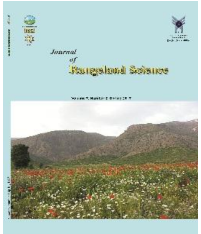

Research and Full Length Article:

Change of Species Diversity in Vascular Plants Across Ecological Species Groups

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Abstract. Biodiversity plays a crucial role in stability and productivity of natural ecosystem. The main goal of this research was to classify ecological groups in steppe rangeland and investigate their relationships with plant diversity indices. Therefore, fifty different Land Unit Tracts (LUT) were identified in Khod-Neuk basin, Yazd province, Iran, in 2010. Vegetation and soil samples were taken in the LUT's representative stands. Two way indicator species analysis (TWINSPAN) method were used to identify ecological groups on the basis of presence-absence and canopy cover of plant species. The diversity indices including species richness, Shannon-Wiener evenness index, Simpsons' dominance index, Shannon-Wiener diversity index and Simpsons' diversity index were analyzed in vascular plants based on species canopy cover data. Then the relationship between land unit distribution and diversity indices was assessed using Canonical Correspondence Analysis (CCA). Results showed that ecological groups were quite different in terms of species composition and plant diversity indices. So that, ecological group 2 had the lowest dominance index and the highest scores of other indices and ecological groups 1 and 5 had the lowest richness and along with ecological group 3 had the lowest species evenness values. Ecological group 5 had the lowest and the highest scores of Shannon-Weiner diversity index and Simpsons' dominance index respectively. The second group located in the mid altitudes with high saturation percentage and low Na, lime and Sodium Adsorption Ratio (SAR) had the highest diversity indices. Therefore, these groups are enough to delineate rangeland into ecological units which could be used for management purposes.

Key words: Vegetation, Richness, Evenness, TWINSPAN, CCA, Rangelands

Introduction

The relationships between species and their environment are among the most important data needed to understand and mange vegetation in rangeland ecosystems (Arekhi *et al.,* 2010; Nodehi *et al.,* 2015). An approach to deal with these relationships is developing ecological species groups (Kashian *et al.,* 2003; Eshaghi Rad and Banj Shafiei, 2010; Adel *et al.,* 2014). Ecological species groups are made up of species that co-occur frequently in the areas with the same environmental condition and exhibit similar environmental association and affinities (Grabherr *et al.,* 2003; Abella and Shelburne, 2004). Ecological species groups' concept is based on this theory that evolutionary and clonality processes such as competition limit species to those environmental combinations that have the best adaptation (Kashian *et al.,* 2003). When ecological species groups of an area were identified, their distribution can be used to understand soil characteristics and other variables that are often more difficult to measure directly (Meilleur *et al.,* 1992). As all species of a group are present on a site together, presence of one species show that the site can provide requirements of all species in the group (Kashian *et al.,* 2003). Plant ecological groups may consider as the parts of a region that identical ecological condition caused the same species composition to establish (Zahedi Amiri and Lust, 1999). In other word, parts of a region composed of the same ecological species groups, are forming the ecological groups. Therefore, classification of a vegetation area to ecological species groups will include soil and physiographic and other ecological conditions (Jangman *et al.,* 1987).

Ecological species groups of different ecosystems have been developed including upland rangelands of Iran (Jafarian *et al.,* 2011), Oak forest of western Iran (Arekhi *et al.,* 2010), hornbeam and beech forests of northern Iran (Jalilvand et al., 2007; Pourbabaei and Haghgooy, 2012; Eshaghi Rad and Banj Shafiei 2010; Adel *et al.,* 2014), Jack pine in northern Lower Michigan (Kashian *et al.,* 2003), southern Appalachian ground-flora and tree strata (Abella and Shelburne, 2004), forested wetlands (Zogg and Barnes, 1995), and disturbed hardwood forests of southwestern Quebec (Meilleur, *et al.,* 1992). Different environmental factors were reported as main variables in distribution of ecological species groups in different vegetation, for example combination of environment variables and aspect (Pourbabaei and Haghgooy, 2012), elevation and land form (Bergmeier, 2002), rainfall, temperature and altitude (Wang, *et al.,* 2002), physiographic factors, landscape position, and soil and vegetation (Smith, 1995).

Ecological species groups can be used as a unit of rangeland classification that are based on categorizing vegetation according to site potential. In other word, ecological species groups can be considered as the range sites. Range sites act as the primary organizational element to manage rangelands and obtain inventory and monitoring information during sampling. The vegetation represented by a range site must be sufficiently uniform for the valid interpretation and extrapolation of data for management applications, yet incorporate the inherent variability expected in rangeland landscapes (Weixelman *et al.,* 1997). These criteria are met in ecological species groups' concept. Therefore, ecological species groups can be considered as a unit for describing vegetation changes in natural ecosystems such as rangelands. Identifying areas of high ecological diversity and potential followed by scientific understanding of the factors that could affect these potentials are the main prerequisites for conservatory priorities, appropriate and reasonable management and utilization of vegetation in each region. To minimize reduction of species diversity and potential reduction of ecosystem resilience, ecological species groups can be a useful unit to evaluate changes in these managerial systems.

Species diversity that defined as a combination of the species abundance and species evenness have been widely used in vegetation studies and environmental evaluations as one of the important characteristics for quick determination of the ecosystems status (Primack, 1993; Sharafatmandrad *et al.*, 2014; Nodehi *et al.*, 2015; Jouri *et al.*, 2015). If an ecosystem has higher species diversity then it will have a greater likelihood of stability because greater number of species at a region makes natural ecosystems structure more complex and as a result such ecosystems have more ability to respond to changes over time and are more stable (Nodehi *et al.*, 2015). Species diversity in vegetation community of an ecosystem provides an indicator for showing damage to ecosystems and ability of the ecosystem for biological conservation (Ali *et al.*, 2000; Primack, 1993). Rangeland species diversity and richness may be strongly influenced by grazing, range management practices, individual species responses, and abiotic factors such as soil characteristics and light availability (Sharafatmandrad *et al.*, 2014; Nodehi et al., 2015; Jouri *et al.*, 2015).

In sum, plant diversity is considered as an important indicator of ecological and management processes within the ecosystem and ecological species groups can regarded as range sites, the principal units of rangeland classification. Despite different studies on identifying ecological groups in rangelands, their species diversity and richness have been rarely assessed for rangelands of Iran. Therefore, our main objectives were to (1) developed ecological species groups for rangelands of Khodniuk basine, Pishkuh region, Yazd Province, Iran, and (2) employ them to assess changes of plants species diversity in relation to environment.

Material and Methods

The field research is Khodniuk basin, part of Ardakan-Yazd basin located in Yazd Province in center of Iran (31º45'-32º03' N, 53º28'-53º47' E) (Fig 1). This area covers more than 60,000 ha and its elevation ranges from 2000 to 3367 m above sea level. The landscape is mostly alluvial plain and begins moving up slope toward the mountains so that slopes over 60 degrees can be seen at the crest of the mountains. The study site receives about 124-227 mm of annual precipitation in accordance with the elevation gradient. The annual mean temperature ranges between 8.75ºC and 17.6ºC in the opposite of elevation gradient. The study was done in the spring 2010.

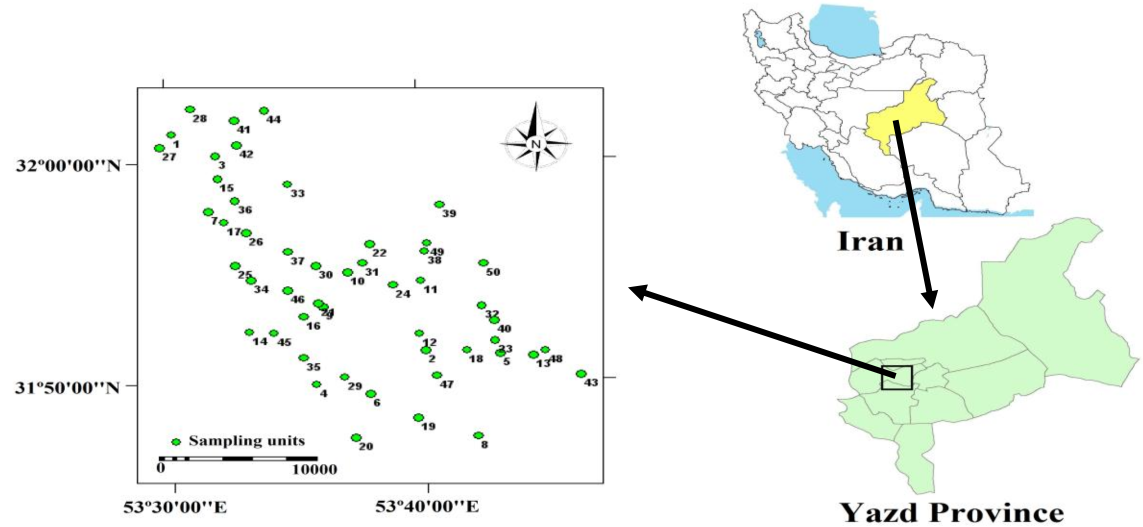

Fig. 1. Map of the study area in central Iran and location of sampling units (sampling units are showed in top left map).

Vegetation Sampling

The first step in the research was classifying study site that provides the possibility of detailed classification of the region to the Land Unit Tracts based on determined factors including land form characteristics (slope, height above sea level and slope aspect) and geological formations (Rezaei and Gilkes, 2005). Therefore, 50 Land Unit Tracts were extracted by overlaying elevation, slope, slope aspect and geology maps guidelines for surveying soil and land resources using ILWIS 3.1. Land Unit Tracts were then extracted and specified points were implemented on the ground Using Global position system (GPS).

Since diversity indices are sensitive to the plot size and number, optimum area of sampling unit for plant communities was identified using minimum area method and optimum number of required sampling units was calculated using statistical method by a pilot sampling and obtained vegetation variation and selected the desired accuracy of estimation. Finally sampling was taken using thirty 1×2 m plots along three 300 m transects in units dominated by subshrubs (mostly *Artemisia sieberi*) and forty 4×4 m plots along three 400 m transects in units dominated by shrubs and bushes (mostly *Zygophylum spp*). In each plot, plants were listed and their abundance (canopy cover) and density (frequency) were recorded. The mean of plots for the measured attributes were generalized to the sampling units.

Soil Sampling and Analysis

Composite soil samples were collected from three points of each transect at 0-30 cm and 0-50 deep based on the rooting depth in the bush lands and shrub lands respectively and analyzed to evaluate the soil properties that might have been influenced the ecological groups. These properties included soil texture, gravel content, pH, electrical conductivity (EC), $CaCO_3$, Na^+, Ca^{2+}, Mg^{2+}. Soil texture (clay, silt and sand) were determined by the hydrometer method (Gee and Bauder, 1986). Gravel percentage was calculated as the difference between soil weight before and after sieving divided to soil weight before sieving. The EC (ds/m) was measured by saturated loose soil extraction method and EC meter (Bower and Wilcox, 1965). The pH was measured by electrode using a 1:1 ratio of saturated paste

(Thomas, 1965). The calcium carbonate of the soil (measured as $CaCO_3$ equivalent) (%) was determined by the Calcimeter method (Dreimanis, 1962). Calcium, Magnesium and Sodium were determined by atomic absorption spectrophotometer (AAS).

Diversity indices

Species richness

Species richness expresses different species presence and can be obtained through counting number of species in sampling units or a specific region. Species richness can be measured in many ways, and little consensus exists as to which measure is most appropriate. Here, plant species richness was calculated as the number of plant species for each sampling unit.

$R=S$

(Equation 1)

Where:

R= species richness

S =number of species sampled per sampling unit

Evenness index

This index shows the individuals' distribution among the different species. As individuals are distributed more evenly, sustainability and stability will be more and biodiversity will be higher consequently. Here, Shannon−Wiener Evenness Index was calculated as fallow (Shannon and Weaver, 1949; Pielou, 1975):

$$E_H = \frac{H'}{H'_{Max}} = \frac{-\sum_{i=1}^{s} p_i \ln(p_i)}{\ln(S)}$$

(Equation 2)

Where:

E_H= Evenness Index,

H'= Shannon diversity index,

P_i = proportion of points along each sampling unit at which species i was recorded,

S =number of species sampled per sampling unit.

Dominance index

Dominance index expresses frequency of population of some species in comparison to others that is used as a measure of diversity. Here, Simpson's Index was calculated as fallow (Simpson, 1949):

$$D_D = \sum_{i=1}^{s} (P_i)^2$$

(Equation 3)

Where:

D= Dominance index

P_i = Proportion of points along each sampling unit at which species i was recorded,

S =number of species sampled per sampling unit.

Species diversity index

Diversity index takes into account species richness and evenness simultaneously and incorporates both of them into a single value. Here, Shannon−Wiener Index and Simpson's Index was calculated as fallow (Shannon and Weaver, 1949; Pielou, 1975):

$$H' = -\sum_{i=1}^{s} p_i \ln(p_i)$$

(Equation 4)

$$1-D = 1-\sum_{i=1}^{s} (P_i)^2$$

(Equation 5)

Where:

H'= Shannon diversity index,

1-D=Simpson's index of diversity,

P_i = proportion of points along each sampling unit at which species i was recorded,

S =number of species sampled per sampling unit.

Data Analyses

The TWINSPAN technique was used to classify vegetation into ecological groups.

In this analysis, the sampling sites were classified using divisive hierarchical classification and species are then classified based on the sites classification (Gauch and Whittaker, 1981). The output of this analysis is a two-way ordered Table summarizing the relationship between samples and species. Due to the low number of species in most of units, TWINSPAN classification (Jangman *et al.*, 1987) was stopped at level 3 so that floristic structure of units in each group can be indicator of an interpretable ecological concept. Groups were named based on the two species with the highest percentage of canopy cover (Abd El-Ghani 1998). The identified ecological groups were then compared in terms of environmental factors. After extracting ecological groups, biodiversity indices were calculated for each ecological group. Here, biodiversity indices served as environmental variables. Before performing ordination technique, biodiversity indices data were tested for normality. In general, five variables including species richness, Simpson and Shannon-Wiener diversity indices, Simpson's dominance index and Shannon-Wiener evenness index were considered in the final analysis.

A direct gradient analysis was used to show and explain the relationship between ecological groups and biodiversity indices. To select the best ordination technique, it was necessary to determine assemblage variation (gradient length) (Jangman *et al.* 1987). So detrended correspondence analysis (DCA) was performed. If the gradient length is less than about 2.5 SD (standard deviation), the assemblage variation is within a relatively narrow range, and the linear approach of PCA is appropriate. If the gradient length is 3 or more SD, the assemblage variation is over a larger range, and the unimodal-based approach of CA is appropriate (Ter Braak and Prentice, 1985). Low weight was given to rare species and vegetation cover data were log-transformed before analysis. The significance of the first and second axes was determined using Monte-Carlo permutation test to check if the structure of the data set has not arisen by chance. Intra-set correlations were then used to assess the importance of biodiversity indices (PC-ORD, version 4.14. MjM Software, Gleneden Beach, Oregon, USA.). CANOCO (version 4.5, Centre for Biometry Wageningen (NL) and Microcomputer Power, Ithaca NY, USA) was used to perform TWINSPAN and CCA. One way ANOVA was used to determine whether the biodiversity indices means of ecological groups differ and Duncan's test was then used for multiple comparisons. The chi-square test used to compare ecological groups richness values. In order to compare ecological groups in aspect environmental variables One-way ANOVA and Duncan's test were used (Mesdaghi, 2012).

Results

Classification

Fifty sampling units were classified to 5 ecological group using TWINSPAN (Fig 2). The description of identified ecological groups is summarized in Table 1.

Group 1 (*Ferula ovina- Artemisia aucheri*) includes five sampling units that were located in high altitude and sloppy areas. Tragacanth species i.e. *Acantholimon scorpius*, *Astragalus gossypinus*, *Astragalus strictifolius*, and *Acanthophyllum sordium* were frequently observed in these sampling units. *Stipa barbata* is the main grass species in this group. The main annual species were *Astragalus mollis*, *Senecio vernalis*, and *Bromus tectorum*. The highest amount of calcium carbonate and the lowest amount of pH were related to the soils of this group.

Group 2 (*Astragalus glaucacanthus - Artemisia sieberi*) includes seven sampling units that were generally located in the middle altitude areas and with low slopes. *Scariola orientalis*, *Cousinia piptocephala*, *Stachys inflata*, and *Noaea mucronata* can be noted as important shrub species. *Stachys inflata* was specific to this group. *Iris songarica* and *Stipa barbata* were the only forb and grass species in this group respectively.

Group 3 (*Artemisia sieberi - Stipa barbata*) sampling units were located in areas with higher altitude and slopes than Group 2 sampling units. In terms of species composition, this group was the same as group 2 but *Stachys inflata* was completely omitted. *Euphorbia sp*, *Acantholimon scorpius*, *Poa cinaica* and *Stipa arabica* were added to this group. The highest and lowest percentages of sand and silt belonged to soils of this group.

Group 4 (*Artemisia sieberi - Noaea mucronata*) contains seven sampling units that were generally located in the low altitude areas and flat plains. *Salsola arbuscula* and *Zygophyllum eurypterum* were the main bushy species. *Bromus tectorum* can be noted as the most important annual species in the group.

Group 5 (*Artemisia sieberi - Salsola arbusculiformis*) consists of sixteen sampling plots that were located in the low altitude areas and flat plains. *Boissiera squarrosa*, *Bromus tectorum* (annual species) and *Stipa barbata* (the only perennial species) were the main grasses in this group.

Table 1. Summary of identified ecological species groups.

Group name	Main environmental characteristics	Main species
Group 1 (*Ferula ovina-Artemisia aucheri*)	High altitude and sloppy areas, the highest amount of calcium carbonate and the lowest amount of ph	*Ferula ovina*, *Artemisia aucheri*, *Acantholimon scorpius*, *Asteragalus gossipinus*, *Astragalus strictifolius*, *Acanthophyllum sordium Stipa barbata Astragalus mollis*, *Senecio vernalis*, *Bromus tectorum*.
Group 2 (*As.glaucacanthus-Artemisia sieberi*)	Middle altitude areas with low slopes.	*Astragalus glaucacanthus*, *Artemisia sieberi*, *Scariola orientalis*, *Cousinia piptocephala*, *Stachys inflata*, *Noaea mucronata*, *Stachys inflate*, *Iris songarica*, *Stipa barbata*
Group 3 (*Artemisia sieberi - Stipa barbata*)	Middle altitude areas with low slopes, the highest percentages of sand	*Astragalus glaucacanthus*, *Artemisia sieberi*, *Scariola orientalis*, *Cousinia piptocephala*, *Stachys inflata*, *Noaea mucronata*, *Iris songarica*, *Stipa barbata*, *Euphorbia sp*, *Acantholimon scorpius*, *Poa cinaica* and *Stipa arabica*
Group 4 (*Artemisia sieberi-Noaea mucronata*)	Low altitude areas and flat plains.	*Artemisia sieberi*, *Noaea mucronata*, *Salsola arbuscula*, *Zygophyllum eurypterum*, *Bromus tectorum*
Group 5 (*Artemisia sieberi - Salsola arbusculiformis*)	Low altitude areas and flat plains	*Artemisia sieberi*, *Salsola arbusculiformis*, *Stipa barbata*, *Boissiera squarrosa*, *Bromus tectorum*

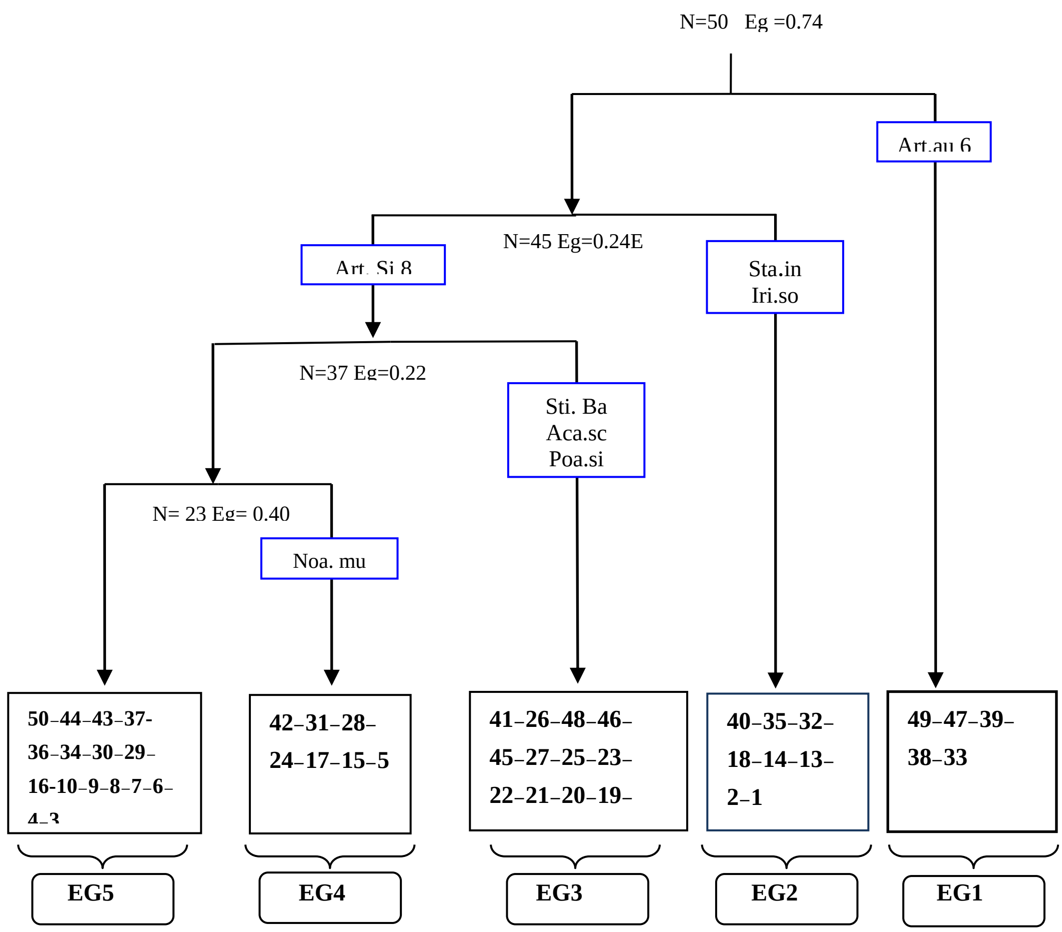

Fig. 2. Dendrogram resulted from TWINSPAN and character species differentiating each group (N=number of sampling units; Eg=eigenvalue)

Comparisons of Ecological Groups in terms of environmental factors

There were significant differences between ecological groups in terms of slope, elevation, lime, saturated water content, gravel, Na, and SAR ($p<0.01$) (Table 2). Ecological group 1 had the highest elevation, slope, gravel and Caco3. Ecological group 5 had the highest Na and SAR. Ecological groups 2 and 3 were located on low slopes of middle altitudes and had the lowest Na and SAR and the highest saturated water content. Ecological group 4 was located in lowlands and had intermediate soil properties.

Table 2. Mean standard error and statistical comparison of environmental variables in ecological groups

Diversity Indices	Species Ecological Groups						
	Group 1	Group 2	Group 3	Group 4	Group 5	P	F
EC (ds/m)	1.28±0.30	2.15±2.3	2.60±1.69	0.94±0.14	2.90±1.47	0.17	0.95
PH	7.87±0.09	8.00±0.12	8.05±0.04	8.08±0.08	8.09±0.04	1.4	0.24
Na (mg/l)	48.00±23.63^{ab}	25.71±5.82^{b}	33.57±6.21^{b}	49.57±5.09^{ab}	92.81±19.16^{a}	3.74	0.01
Ca+Mg (mg/l)	50.4±7.63	50.57±2.7	55.71±3.51	57.86±4.61	65.31±4.43	1.85	0.13
SAR (%)	10.02±5.22^{ab}	5.13±1.18^{c}	6.19±1.07^{c}	9.25±0.87^{ab}	15.27±2.68^{a}	3.47	0.01
Lime (%)	38.75±5.68^{a}	25.07±4.17^{c}	28.37±2.89^{ab}	30.75±4^{ab}	24.89±2.15^{c}	2.99	0.01
Sand(%)	78.9±2.07	69.29±3.58	60.86±4.67	71.11±6.51	68.31±3.77	1.39	0.25
Silt(%)	14.48±2.11	23.11±2.62	26.54±3.49	19.53±5.23	20.8±2.28	1.43	0.24
Clay(%)	7.00±0.72	7.99±0.92	9.03±0.62	9.36±1.44	8.01±0.39	1.16	0.34
Elevation (masl)	2568±48^{a}	2354±37^{b}	2439±40^{ab}	2184±28^{c}	2160±40^{c}	14.15	0.000
Slope(%)	35.5±4.64^{a}	4.54±0.67^{ab}	6.57±2.88^{ab}	2.5±0.42^{ab}	7.53±2.08^{ab}	11.3	0.000
Saturation (%)	13.4±1.03^{c}	29.16±3.61^{a}	24.05±1.84^{ab}	26.87±1.46^{ab}	20.29±2.55^{b}	5.47	0.001
Gravel (%)	35.52±5.71^{a}	20.45±2.76^{b}	25.35±2.33^{b}	27.64±3.95^{ab}	20.33±1.42^{b}	2.68	0.04

Means of rows with the same letter are not significantly different ($\rho<0.01$).

Comparisons of Ecological Groups in terms of environmental factors

The results of one way ANOVA and chi-square showed that there were significant differences between ecological groups in terms of biodiversity indices (p<0.01) (Table 3). Based on Duncan's multiple range and chi-squire tests, ecological group 2 had the lowest dominance index and the highest scores of other indices. Ecological groups 1 and 5 had the lowest richness and along with ecological group 3 had the lowest species evenness values. Ecological group 5 had the lowest Shannon-Weiner diversity and the highest Simpsons' dominance indices.

Table 3. Mean standard error and statistical comparison of biodiversity indices in ecological groups

Diversity Indices	Species Ecological Groups						
	Group 1	Group 2	Group 3	Group 4	Group 5	χ^2	P
Species richness	5.0±2.0[c]	12.0±2.0[a]	10.0±3.0[ab]	8.0±2.0[b]	6.0±3.0[c]	31.54	0.000
Simpson's Dominance	0.68±0.06[b]	0.51±0.04[c]	0.71±0.03[b]	0.73±0.04[b]	0.87±0.04[a]	9.23	0.000
Shannon-Wiener diversity	0.54±0.1[bc]	1.21±0.09[a]	0.75±0.06[b]	0.65±0.10[b]	0.30±0.07[c]	15.58	0.000
Simpson diversity	0.32±0.06[b]	0.49±0.04[a]	0.29±0.03[b]	0.27±0.04[b]	0.14±0.04[c]	9.22	0.000
Shannon Evenness	0.58±0.05[a]	0.60±0.04[a]	0.40±0.03[b]	0.45±0.05[ab]	0.28±0.06[b]	5.56	0.000

Means of rows with the same letter are not significantly different (ρ<0.01).

Canonical Correspondence Analysis (CCA)

The performed DCA in order to select the best ordination technique showed that the gradient length is higher than 3 SD (Table 4). So canonical correspondence analysis (CCA) approved to be an appropriate ordination for testing the vegetation and environmental variables relationships. This was a direct gradient analysis that relates vegetation variations to environmental variables in addition to providing a basis to statistically test significant relationships between environmental variables and vegetation groups' distribution. Analyzing vegetation data and biodiversity indices using CCA clearly revealed the relationships between biodiversity indices variations and the ecological groups' distribution as well as representing a graphical interpretation. The first and the second axes of CCA had the highest eigenvalues (Table 5). These two axes had the highest environment-species correlations and explained 28.3% of the total variation. These results indicate strong relationships between vegetation and considered environmental variables in CCA. Monte Carlo test (99 permutations without restriction) showed that the eigenvalue of the first and the second axes were quite significant. So this suggests that the patterns found are not chance patterns.

Correlation coefficients between biodiversity indices and ordination axes are presented in Table 5. these results indicate that the first axis of CCA were positively correlated with richness and negatively correlated with evenness indices. The second axis were positively correlated with Simpson's Dominance Index and negatively correlated with Shannon and Simpson diversity indices. CCA biplot (Fig. 3) indicates the simultaneous results of TWINSPAN and CCA that clearly confirm five ecological groups resulted from TWINSPAN and showed that ecological groups were completely separated in relation to biodiversity and differences in species composition. Biplot shows spatial distribution and grouping of sampling units in the space of the first and the second axes of ordination. In general, the closer the sampling units, the more similar the species compositions and the further the sampling units, the more different the species composition. Given the importance of the first axis of CCA and the high species composition variation along the first axis (the length of gradient > 4 S.D), it can be concluded that the basic progression in species composition occurs along the first axis, so that along the first axis, from medium to high elevations, ecological group 3 with dominant species *Artemisia sieberi*, high species richness and low species evenness gradually replaces by ecological group 1 with dominant species *Artemisia aucheri*, low species richness and high species evenness. Ecological groups 5 and 2 were located in different sides of the second axis and the dominance index and two diversity indices were respectively reached the highest scores in them besides having fewer differences in species composition. Group 4 was located in the center of the diagram and between the other groups in terms of species composition and biodiversity indices.

Table 4. The results of CCA and the length of the gradients studied using DCA.

Ordination Method	Statistics	Axis 1	Axis 2	Axis 3
DCA	Gradient length	4.34	2.8	1.4
CCA	Eigen values	0.50	0.16	0.13
	Explained variance	19.7	6.50	5.30
	Correlation (environment-species)	0.83	0.88	0.79

Table 5. Correlation coefficients between diversity indices and CCA axes

Diversity indices	Axis 1	Axis 2	Axis 3
Richness	0.55**	-0.67**	0.45**
Simpson's Dominance	0.016	0.87**	-0.24
Shannon-Wiener diversity	-0.05	-0.93**	0.25
Simpson diversity	-0.16	-0.87**	0.24
Shannon Evenness	-0.48**	-0.74**	0.42**

**= significant at 1% probability level

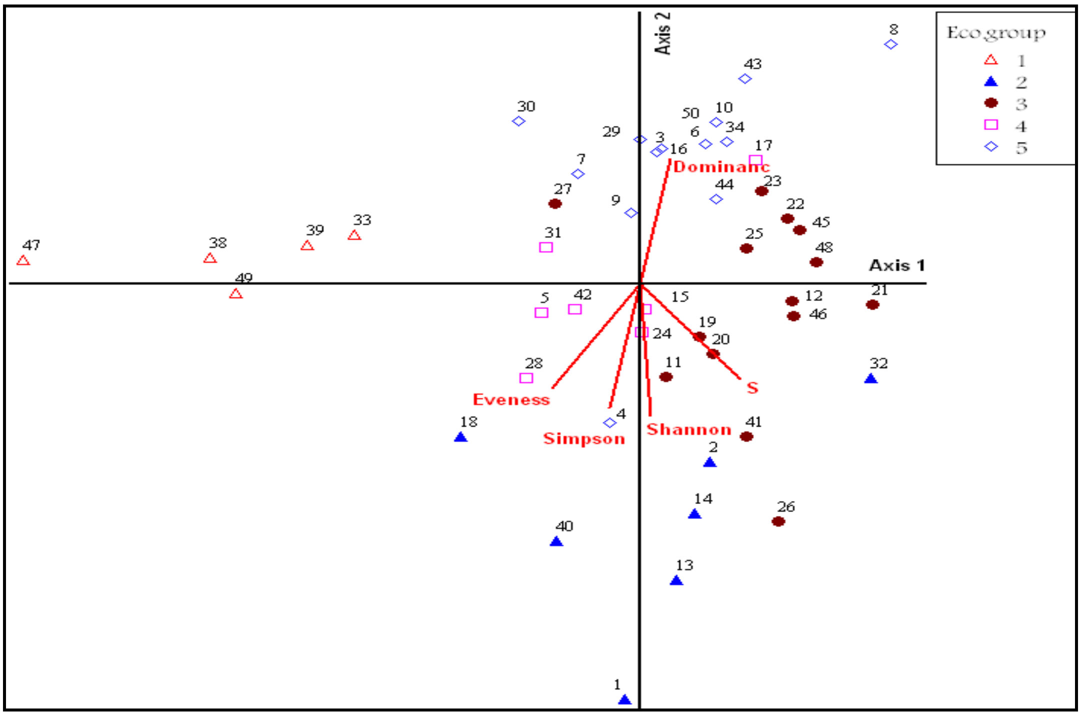

Fig 3. Biplot of CCA and five ecological groups (Biodiversity indices were used instead of environmental variables).

Discussions and Conclusion

Results of ordination along with one-way ANOVA and chi-square test showed there were significant differences between ecological groups in terms of species composition (Fig 3), environmental factors and biodiversity (Tables 2 and 3). Sample units with similar environmental variables, species composition and diversity form distinct ecological groups that each group is distinct from other groups in terms of floristic characteristics, topography, soil and biodiversity.

By moving along the first axis from the region's central highlands where the ecological group3 is located toward the high and steep mountains where ecological group 1 is present, besides basic changes in the species composition, species richness was decreased but evenness was increased. These changes can be explained through rainfall and soil moisture increase and temperature decrease along the altitudinal gradient in the region. As the winter precipitation falls predominantly as snow in highlands areas, *Artemisia sieberi* and most of its associated species that have the largest development in the central highlands and in ecological Group 3, due to the sensitivity to low temperatures (Yaghmaie *et al.,* 2008) have been removed and replaced with cold tolerant species such as *Artemisia aucheri, Ferula ovina* and tragacanth species such as *Acanthophyllum sordium* and *Asteragalus gossipinus* in Ecological Group 1. In the species replacements, overall changes happened in species composition and basic progression occurred in the region vegetation. Central highlands as a transition zone have suitable temperature and moisture conditions and there was an overlap in the downstream and upstream plants. Therefore these areas in most cases had higher species richness than other areas (Hegazy *et al.,* 1998). If the lower temperature and soil limitations resulting from slope increase at elevations may be the main reason for the richness decline in ecological Group 5. Species diversity and richness decrease with increasing elevation, slope, and consequently more difficult living conditions (Esmaeelzade and Hosseini, 2007). Low-temperature tolerant plants that could have grown on shallow soils and unstable bed material, in mountain proper moisture conditions are well developed and their uniform distribution is increased species evenness. Ecological Group 2 was located in the central highlands as ecological Group 3 and had the same species composition and richness. However increase in species evenness and richness had increased Shannon-Wiener and Simpson diversity indices and decreased Simpson's Dominance Index in this group. The increase can be attributed to the suitable soil conditions in addition to the desired temperature and moisture in middle latitudes. The least amount of lime, sodium and sodium adsorption ratio and highest soil moisture saturation were observed in this group. Some studies reported high levels of $Caco_3$ as the main reason for the low species diversity and richness (Abd El-Ghani, 1998). In contrast, other studies introduced $Caco_3$ soils as one of the positive factors affecting species diversity (Zare Chahoki *et al.,* 2009). So this factor in some cases has a direct relationship with vegetation parameters and in other cases is inversely related to vegetation parameters. This dual role can be related to the soil lime ad moisture conditions, so that the proper moisture and lime is effective in developing soil structure and pH adjustment, followed by the nutrients absorption. However, soil moisture decrease and lime increase will cause a problem for plants due to formation of hardpan, increase of pH and salts in the roots zone (Zare Chahoki, 2001). Grasses removal of calcareous deposits can be mostly related to the inability of these plants to overcome the osmotic potential of the soil caused by calcium carbonate (Buxbaum and Vanderbilt, 2007). High amount of lime reduces the availability of micronutrients such as zinc and manganese to plants (Mahmoodi and Hakimian, 2007) and changes ecological groups through changing the soil texture from sandy to loamy (Kororey and Khoshnevis, 2000). High saturated water content causes soil to store more moisture during a rainfall event and improve plant growth as well as increase in soil water storage. In contrast to Group 2, the highest dominance index and the lowest species diversity were observed in ecological group 5. Located at low elevations and consequently reduced precipitation and increased evapotranspiration on the one hand (Huston 1994) and soil limitations including high levels of salts and sodium absorption ratio and low saturated water content on the other hand, may be the main reasons for the decline in the diversity indices of this group. Excessive concentrations of cautions such as sodium, magnesium and calcium increase osmotic pressure and lead to physiological drought. Consequently water absorption by plants is disrupted and plant growth stops. Only the halophytes with high resistance to salts will be able to continue to grow and survive in such soils. However, high concentrations of salts in the soil itself alone are not harmful to plants, but the adverse effects are more related to their solubility (Mirdavoodi and Zahedi Pour, 2005) and relative contribution to the soil (Wang and Redmann, 1996). Excessive increase in soil sodium and its proportion in comparison to calcium and magnesium (increasing SAR) leads to aggregates dispersion, soil structure degradation, plant respiration disruption and consequently reduction of plant growth parameters (Ghorbanian and Jafari, 2007). Group 4 had intermediate environmental conditions and was placed in the center of the diagram in terms of species composition and diversity indices. In this study, we tried to reduce some of deficiencies of biodiversity functions with little change in their computation, so that they can be used in rangeland sites assessment and classification in a more suitable way.

Therefore, canopy cover percentage was used to introduce species diversity, evenness and dominance indices instead of species frequency. With this change, some of weaknesses of most biodiversity indices were eliminated. When considering frequency as species abundance, a seedling and a mature plant (despite their different effects on ecosystem) have the same effect in calculations of biodiversity indices and identification and count of individual plants that can be very time consuming and low accurate most of the time. So by considering canopy cover percentage as species abundance, the problems associated with frequency in calculations of biodiversity indices were solved.

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تغییر شاخص‌های تنوع گونه‌ای گیاهان آوندی در گروه‌های اکولوژیک

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چکیده. تنوع زیستی نقش مهمی در پایداری و تولید کنندگی اکوسیستم‌های طبیعی دارد. هدف از این تحقیق طبقه بندی گروه‌های اکولوژیک در یک مرتع استپی و بررسی ارتباط آنها با شاخص های تنوع زیستی گیاهی بود. در این راستا، در سال۱۳۹۰، ۵۰ واحد همگن زمینی حوزه آبخیز خود- نیوک در استان یزد مشخص گردید. در توده گیاهی معرف هر واحد اقدام به نمونه‌برداری از پوشش گیاهی و خاک شد. برای تعیین گروه‌های اکولوژیک منطقه از روش طبقه‌بندی گونه‌های شاخص دوطرفه (TWINSPAN) استفاده شد. طبقه‌بندی پوشش گیاهی بر اساس داده‌های حضور غیاب و وفور گونه‌ها به تشخیص ۵ گروه اکولوژیک منتج شد. مطالعه شاخص‌های تنوع زیستی بر مبنای داده‌های وفور گونه‌ها و با استفاده از غنای گونه‌ای، شاخص یکنواختی شانون-وینر، شاخص غلبه سیمپسون، شاخص‌های تنوع شانون-وینر و سیمپسون انجام شد. بررسی روابط بین توزیع واحدهای نمونه‌برداری و شاخص‌های تنوع زیستی با استفاده از تجزیه CCA صورت گرفت. نتایج نشان داد که گروه‌های اکولوژیک از نظر پوشش گیاهی و شاخص‌های تنوع زیستی کاملاً از یکدیگر متمایزند. به طوری که گروه اکولوژیک ۲ دارای کمترین شاخص غلبه و بالاترین مقدار سایر شاخص‌ها بود و گروه‌های اکولوژیک ۱ و ۵ دارای کمترین غنای گونه¬ای بوده و به همراه گروه ۳ کمترین مقادیر یکنواختی را داشتند. گروه اکولوژیک ۵ دارای کمترین و بیشترین مقادیر به ترتیب شاخص تنوع شانون-وینر و شاخص غلبه سیمپسون بود. در ادامه مقایسات آماری نشان داد گروه ۲ گیاهی با واقع شدن در ارتفاعات میانی و برخورداری از خاکی با رطوبت اشباع بالا و حداقل آهک، سدیم و نسبت جذب سدیم از بالاترین شاخص‌های تنوع گیاهی در منطقه برخوردار است. بنابراین گروه‌ها جهت ارائه واحدهای اکولوژیکی مراتع کافی بوده و می‌توانند برای اهداف مرتع‌داری مورد استفاده قرار گیرند.

کلمات کلیدی: پوشش گیاهی، غنا، یکنواختی، آنالیز TWINSPAN، آنالیز CCA، مراتع