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[Research]

Vegetation-Environmental Relationships and Ecological Species Groups of the Ilam Oak Forest Landscape, Iran

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ABSTRACT

The study was carried out in the Ilam Oak forest that is located in the west part of Iran. The objective of this research was to determine the plant ecological groups and site classification in this region. Data were collected from 117 sample plots using the systematic-random sampling method. The size of sampling plots was 20 m×20 m for the tree and shrub species and 1.5 m ×1.5 m for herbaceous species. Whittaker's nested plot method was used in order to record the herbaceous species. Soil samples were collected and analyzed to study soil properties. Multivariate analysis methods were used to classify and determine the relationship between species composition and environmental factors and to recognize ecological species groups. PC-ORD and SPSS software were used for data analyzing. Five ecological groups were specified in the study area. *Cerasus microcarpa* was the indicator species in the first group, which showed high correlation with carbon and nitrogen. *Quercus brantii* showed the strongest correlation with $CaCO_3$. The third group was *Acer monspessulanum*. Elevation and clay were the most important factors that separated this group. *Amygdalus orientalis* showed high correlation with elevation. These two above mentioned groups were located in higher altitude. *Astragalus liyciodes* was the indicator species in another distinct group in the study region with high level of stoniness percentage. *Astragalus* group was observed where soil stoniness was high. Results also showed that groups at higher elevation showed lower richness.

Keywords: *Ecological species groups, Environmental factors, Ilam Province, Multivariate analysis, PC-ORD, Site classification.*

INTRODUCTION

Species-environment relationships are among the most important data needed to understand vegetation patterns on forest landscapes (Whittaker 1956; Host & Pregitzer 1992; Hix & Pearcy 1997). Developing ecological species groups, comprised of co-occurring species exhibiting similar environmental affinities, is one method to discern species-environment relationships (Muller-Dombois & Ellenberg 1974; Host & Pregitzer 1991; Kashian *et al.* 2003). Ecological species groups are useful to identify species sharing similar environmental affinities and typically occupying similar sites across the landscape, and to indicate environmental complexes of forest sites based on the abundance of different species groups (Rowe 1956; Simpson *et al.* 1990; Goebel *et al.* 2001). Ecological species groups differ from individual indicator species, in that once vegetation-environment relationships are established the abundance of multiple species of a group may strongly indicate environmental site conditions than the abundance of individual species (Bergeron & Bouchard 1984; Spies & Barnes 1985). Including several species in a group for indicating environmental conditions may compensate for absences of individual species resulting from reasons unrelated to environmental site factors (Barnes *et al.* 1998). This has been perceived as an advantage of using species groups, rather than individual species, for indicating environmental conditions (Spies & Barnes 1985).The ecological species groups help to distinguish and map landscape ecosystems in the field by their presence or absence and by the relative coverage of plants in each group. They are never used alone, but always with attributes of physiographic, soil, microclimate, and the composition and vigor of over-story trees (Barnes *et al.* 1998).The data of ecological species groups are often used for vegetation classification (Brown et al. 1996; Konollova & Chytry 2004) as a source of information on the spatial distribution of vegetation (Moustafa & Zaghloul 1996; Regato-Pajares & Elena-Rossello 1995).

Species groups have typically been constructed using combinations of field observations, inspections of tabular species×site matrices, and multiple-variant analyses such as cluster analysis (Spies & Barnes 1985; Godart 1989; Kashian *et al.* 2003).The size of groups varies within and among studies, ranging from lesser than three to greater than eight species (Bergeron & Bonchard 1984; Godart 1989; Host & Pregitzer, 1991). As in many multivariate studies in plant ecology, species groups are hypotheses about species distributions and their relationships to environmental factors. These hypotheses have practical value for estimating site condition, and are tractable for refinement through experimental research developing causal relationships about species distributions (Pabst & Spies, 1998).

The use of ecological species groups for forest ecosystem classification and mapping was implemented first in the southwestern German state of Baden-Wurttemberg (Barnes *et al.* 1998). The approach also has been applied in distinguishing and mapping landscape ecosystem types in old growth forest in Michigan and in highly disturbed Oak-hardwood forests of southern Michigan and Wisconsin. Meanwhile, ecological species groups have been used to identify different ecosystems in southern Belgium woodlands (Godart 1989), forested wetlands (Zogg & Barnes 1995), Neka's forests, north of Iran (Zahedi & Limayee 2002), Michigan oak forests (Vandvik & John 2002), Marivan Ghamishleh's forests (west of Iran)(Basiri *et al.* 2004), Poshtkouh's rangelands of Yazad province, Iran (Jafari *et al.* 2004), Kelarabad's plain forest, north of Iran (Mahmoodi *et al.* 2005) and Kheirood kenar's forests, north of Iran (Salehi *et al.* 2005), Arizona Pinus Ponderosa Landscape(Scott *et al.* 2006) ,Hornbeam forest ecosystems in Southern Caspian (Jalilvan *et al.* 2007) and Moist Savana site (Munhoz *et al.* 2008).

Ecological species groups have not been developed in the Ilam Oak forests and the objectives of this study were first of all to develop ecological species groups for Oak forests of western Iran and then to quantify the relationship between environmental factors with ecological species groups in order to determine the main factors which affect the separation of vegetation types.

MATERIALS AND METHODS

Description of Study area

This study was carried out in the Ilam Oak Forest in north of Ilam city (Fig. 1). Altitude ranges from 1400 to 2200 m, and slope ranges from 5% to 75%. Average annual precipitation and temperature are 590.37 mm and 17.12°C, respectively. The minimum recorded temperature was 4.62°C in December and the maximum recorded temperature was 29.93°C that occurred in July. The lowest rainfall occurs in the month of July (0.05 mm) and the highest occurs in February.

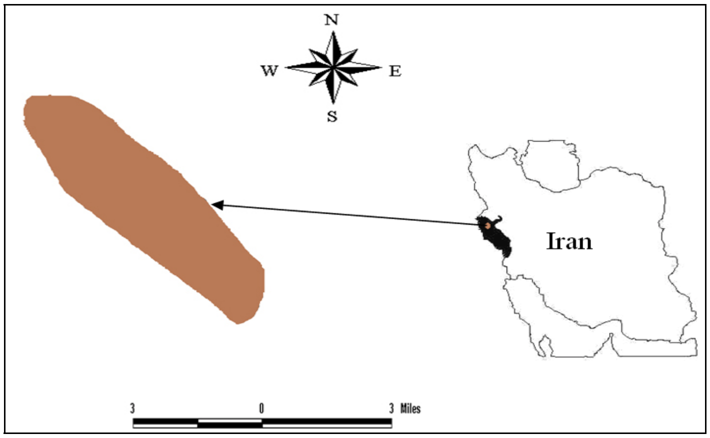

Fig 1. Location of study area

2.2. DATA COLLECTION

2.2.1. Vegetation sampling procedures

A quantitative survey of the vegetation was carried out in 2007 and 117 sample plots were taken from 30000 ha. The study sites were selected some distance away from roads to eliminate the effect of disturbance caused by traffic. Systematic-random sampling method was used to gather data from 117 sample plots. The sample plot size was 20 m×20 m for tree and shrub species and it was 1.5 m×1.5 m for herbaceous species (Fig. 2). The sampling plot areas were determined using nested plot sampling. First of all, characteristics of each sampling plot (i.e., altitude, aspect and slope) were recorded using GPS. Then, types of species were identified and abundance-dominance for each species was estimated on the basis of Braun-Blanquet scale (Muller-Dombois & Ellenberg 1974; Bredenkamp *et al*. 1986; Kooij *et al*. 1990; Fuls *et al*. 1993).

Soil sampling procedures

Soil samples were collected from the center of all plots at the depth of 0-20cm. Soil samples were air dried and sieved through a 2-mm sieve to remove larger size. Bouyoucos hydrometer method was used to determine the soil texture. Organic carbon (C), total nitrogen (N) and soluble potassium (K) were determined based on Walkely and Black rapid titration (Black 1979), Kjeldah and flame photometry methods, respectively. Finally, pH and electrical conductivity (EC) of the soil samples were determined by means of digital pH meter and Conductivity Bridge.

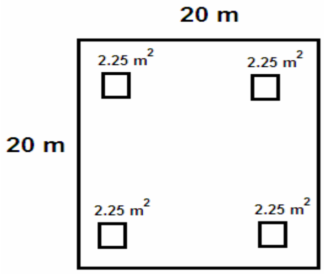

Fig 2. Size and location of sample plots

Data analysis methods

Vegetation data from the Ilam Oak forest of Zagros mountainous were analyzed using PC-ORD software (McCune & Mefford 1999).The data were entered into a Microsoft Excel and then transferred to the PC-ORD program. The resulting samples by species data matrix consisted of 222 species and 117 sample plots. A second samples-by environmental variables data matrix was also constructed for subsequent analyses and 117 sample plots. Classification and ordination methods were used to analyze these data. Classification was performed using TWINSPAN. Two gradient analyses were also performed using the Principal component analysis (PCA) and Canonical correspondence analysis (CCA) ordination methods.

After classification of the vegetation, relationships between environmental factors (topography and soil) and vegetation were studied using PCA and CCA methods.

CCA is a form of direct gradient analysis which was used in order to examine the relationships of the floristic composition with environmental variables. Canonical ordination is easier to apply and requires less data than regression. Significance of species-environment correlation was tested by distribution free Monte Carlo test (1000 permutations).

RESULTS AND DISCUSSION

TWINSPAN

TWINSPAN was performed for vegetation analysis in 117 sample plots using ordinal scale of Van-der-Marrel (Van-der-Marrel 1979). The results of TWINSPAN classification are presented in Fig. 3.

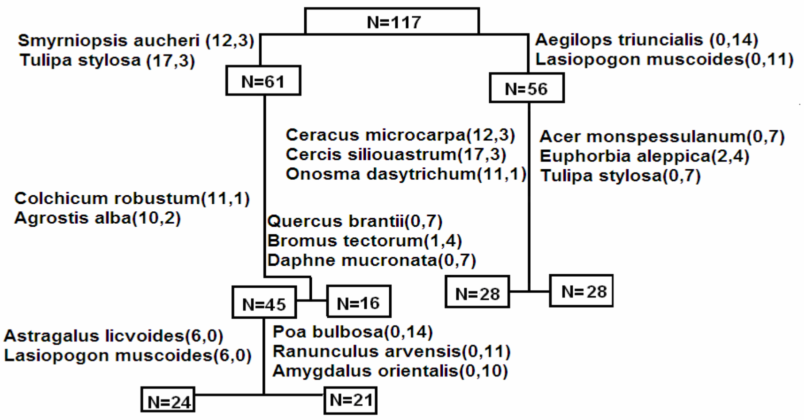

Fig 3. Dendrogram of TWINSPAN for vegetation in the study area

According to eigen value of each division, vegetation of the study area was classified into five ecological group types. Each type differs from the other in terms of its environmental needs. These ecological groups are as follows:

Group 1: *Cerasus microcapa*
Group 2*: Quercus brantii*
Group 3: *Acer monspessulanum*
Group 4: *Amygdalus orientalis*
Group 5: *Astragalus licyoides*

According to the results of vegetation classification, plots were classified into different groups. Analysis of tree, shrub and herb layers (together) was carried out in five steps (Fig. 3). The indicator species of the first division on the left side of the Figure 3 include: *Smyrniopsis aucheri* and *Tulipa stylosa*, and on the right side contain *Aegilops triuncialis* and *Lasiopogon muscoides*. In the second division, the indicator species are *Colchicum robustum* and *Agrostis alba* on the left side, *and Quercus brantii, Bromus* and *Daphne mucronata* are located on the right side. The indicator species of the third division are as follows: *Ceracus microcarpa, Cercis siliquastrum ,Onosma dasytrichum* and *Vicia ervilia* on the left side. In the same division, the indicator species *Acer monspessulanum, Euphobia aleppica* and *Tulipa stylosa* are present on the right side. In the fourth division, the indicator species are *Astragalus licyoides, Hetrocaryum macrocarpum* and *Lasiopogon muscoides* on the left side, while *Poa bulbosa, Ranunculus arvensis* and *Amygdalus orientalis* are three indicators species on the right side.

PCA

To determine most effective variables on the separation of vegetation types, PCA was performed on 9 factors in 117 sample plots (Fig. 4).

Broken-stick Eigen values for data set indicate that the first two principal components (PC1 and PC2) resolutely captured more variance. The first two principles components together accounted for 66% of the total variance in data set. Therefore, 42.748% and 21.173% variance were accounted for by the first and second principal components, respectively. This means that the first and second principal components are by far the most important for representing the variation of the five vegetation types (Table 1).

Table 1. Broken-stick Eigen values, % of Variance and Cum.% of Var for data set of PCA

AXIS	Eigen value	% of Variance	Cum.% of Var.	Broken-stick Eigen value
1	5.412	42.748	42.748	3.318
2	4.176	21.173	65.922	2.318
3	1.697	11.316	75.237	1.818
4	1.120	7.465	82.702	1.485
5	0.803	5.353	88.055	1.235
6	0.441	2.943	90.998	1.035
7	0.405	2.700	93.697	0.868
8	0.332	2.211	95.908	0.725
9	0.226	1.505	97.413	0.600
10	0.151	1.009	98.422	0.489

Considering the correlations between variables and components, the first principal component includes environmental factors such as organic carbon, total nitrogen, clay and altitude. Axis 1 seems to represent the essentially organic carbon, total nitrogen, clay and elevation gradient, while axis 2 is reflecting a gradient of lime and stoniness. As mentioned above, PC1 accounted for 42.748% of the total variance, which is mostly related to soil properties. Therefore, among all environmental factors, soil characteristics such as carbon, total nitrogen, lime, texture and stoniness are the most effective factors in the distribution of ecological species groups.

The first ordination axis showed a positive correlation with altitude and clay and a negative correlation with carbon, nitrogen, stoniness and richness. The second ordination axis was positively correlated with carbon, clay, stoniness and negatively correlated with altitude, lime, biodiversity and richness (Table 2).

Fig. 4 shows a plot of the five ecological groups against their values for axes 1 and 2. For the interpretation of the diagram and vegetation types' spatial distribution, in addition to the soil characteristics (Table 2) the following points should also be taken into consideration:

a) In the diagram, the distance between the indicator points of the vegetation types (groups) shows the degree of similarity and dissimilarity in the environmental factors.

b) Those plant sites that are located in the positive direction of axis 1 have positive correlation with factors of this direction. This area of axis has inverse relationship with PC1 factors in the negative direction of axis 1. The same relationship holds for the second axis.

c) The distance between the indicator points of the vegetation types from axes is representative of the relationship power in the explanation of variations. Whenever the length of vector loading (as indicator of the vegetation in types) is bigger, the angle between vectors and axes is smaller; therefore the correlation between vegetation types with axes and relation power is more.

Regarding axis 1, the highest correlation belongs to the first, third and fourth groups. This shows axis 1 properties. The first group shows the highest correlation with the negative direction of axis 1 and third and fourth groups show the highest correlation with the positive direction of axis 1. In addition, in the third and fourth group, environmental characteristics are approximately similar in axes 1 and 2. The first group showed negative correlation with the third and fourth group, in other words least correlation existed between the first group and third and fourth group. In axis 2, the highest correlation belonged to the second and fifth group. This shows axis 2 properties. The second group showed the strongest correlation with the negative direction of axis 2, and the fifth group showed the strongest correlation with the positive direction of axis 2. In the study area, environmental conditions in each group differ from each other.

Table 2. PCA applied to the correlation matrix of the environment factors in the study area

Environmental factors	AXIS 1	AXIS 2
Caco3	0.135 ^{ns}-	0.43 **-
C	0.4 **-	0.22 *
Ph	-0.0 2 ^{ns}	0.1 ^{ns}-
EC	0.04 ^{ns}-	0.03 ^{ns}-
N	0.39 **-	0.18 ^{ns}-
C/N	0.19 ^{ns}	0.056 ^{ns}
K	0.17 ^{ns}	0.085 ^{ns}
Clay %	0.49 **	0.28 *
Silt %	0.09 ^{ns}	0.15 ^{ns}
Sand %	0.02 ^{ns}-	0.13 ^{ns}-
Slop	0.02 ^{ns}-	0.1 ^{ns}
Elevation	0.57 **	0.22 *
Aspect	0.13 ^{ns}-	0.06 ^{ns}-
Stoniness	0. 2 *-	0.5 **
Over-story canopy	0.17 ^{ns}	0.12 ^{ns}-
Biodiversity	0.04 ^{ns}-	0.31**-
Evenness	0.14 ^{ns}-	0.01 ^{ns}-
Richness	0.38**-	0.27 **-

ns: No significant, * Significant (α = 5%),** Significant (α =1%)

With regard to its position in the second quarter of the diagram, the first group has higher correlation with negative direction of axis 1. Therefore, this type showed the strongest relation with variables of this direction of axis 1 (organic carbon and nitrogen). Because of the greater distance between the first group and the second axis, this type showed lower correlation with the factors of second axis. The fifth group had weak correlation with variables of richness and lime in the positive direction of axis 2 and the maximum correlation with stoniness. On the contrary, the second group which is in the negative direction of axis 2, showed the strongest relation with variables of richness and lime. Indicator environmental factors of third and fourth groups were approximately similar in axis 1 and 2. These two groups showed high correlation with positive direction of axis 1 and low correlation with axis 2. Meanwhile, they comforted in the first and fourth quarter of the coordinate axes and had a direct relation with elevation and clay.

CCA

CCA was used to analyze the relationship between species distribution and environmental variables. CCA is a technique that shows non-linear relationships between species with environmental factors and chooses the best weights for environmental variables. According to Tables 3 and 4, first axis (eigen value=0.488) accounted for 56.3% variation in environmental factors data. Correlation between the first axis and species-environmental variables was 0.96 and Monte Carlo permutation test for the first axis was highly significant (*P* = 0.01). The second axis (eigen value = 0.163) explained 19.5% variation. In addition, the Monte Carlo test for the second axis was highly significant (*P* = 0.01).

Table 3. Cannical correspondence analysis for environmental data

	Axis 1	Axis 2	Axis 3
Eigen value	0.488	0.163	0.018
% of variance explained	56.3	19.5	2.0
% Cumulative explained	56.3	75.8	77.8

Table 4. Monte Carlo test for species-environment correlations

Axis	Species-environment correlation	Mean	Minimum	Maximum	P
1	0.958	0.753	0.425	0.935	0.01
2	0.980	0.485	0.138	0.917	0.01
3	0.867	0.387	0.015	0.754	0.01

The results of CCA ordination are presented in Table 5 and Fig. 5. Five groups were determined in relation to the environmental factors. Each environmental factor is an indicator of the specific site. Group 1 has non-linear relation with carbon, nitrogen and stoniness. In other words, organic carbon, nitrogen and stoniness are the indicators of sites of this type. The second group has a non-linear relation with lime and richness. Relation power depends on the relative distance between indicator points of soil characteristics and vegetation types. The above mentioned type represents soils with light texture. The fourth group has a non-linear relationship with elevation and located in high site. The third and fourth groups have non-linear relation with clay and occur in soils with heavy texture. Soils with heavy texture indicate third and fourth group sites. Fifth group was located in positive direction of axis 2 and showed high correlation with stoniness and low correlation with lime and richness.

Fig 6. shows spatial distribution of plots in each ecological group, resulting from TWINSPAN classification.

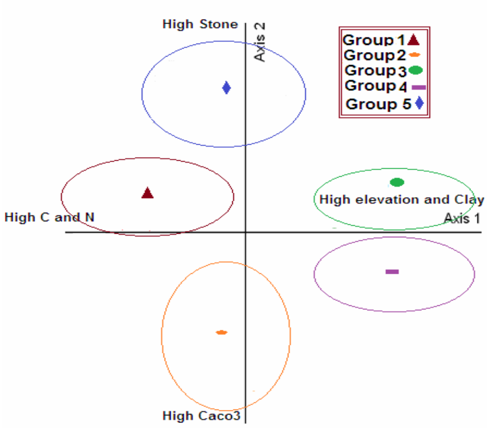

Fig 4. PCA-ordination diagram of the vegetation types related to the environmental Factors in the study area

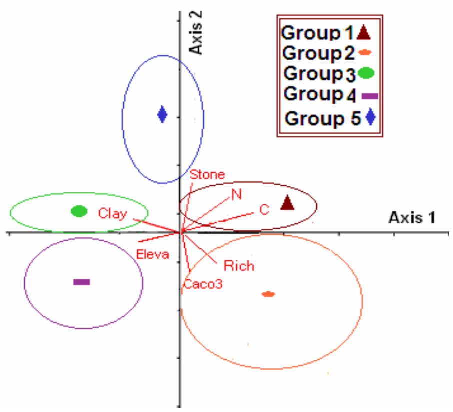

Fig 5. CCA-ordination diagram of the environmental data

Table 5. CCA applied to the correlation matrix of the environmental factors in the study area

Environmental factors	AXIS 1	AXIS 2
Caco3	0.1 5 ^{ns}	0.5 **-
C	0.45 **	0.25 *
Ph	0.01 ^{ns}-	0.1 ^{ns}
EC	0.18 ^{ns}-	0.12 ^{ns}-
N	0.3 **	0.39 **
C/N	0.15 ^{ns} -	0.11 ^{ns}
K	0.11 ^{ns}-	0.18 ^{ns}
Clay %	0.52 **-	0.2 *
Silt %	0.05 ^{ns}-	0.12 ^{ns}-
Sand %	0.03 ^{ns}-	0.02 ^{ns}-
Slop	0.12 ^{ns}	0.03 ^{ns} -
Elevation	0.59 **-	0.11 ^{ns}-
Aspect	0.16 ^{ns}	0.12 ^{ns}-
Stoniness	0.25 *	0.42 **
Over story canopy	0.17 ^{ns}-	0.0 7 ^{ns}
Biodiversity	0.31 **	0.13 ^{ns}
Evenness	0.03 ^{ns}	0.02 ^{ns}-
Richness	0.35 **	0.37 **-

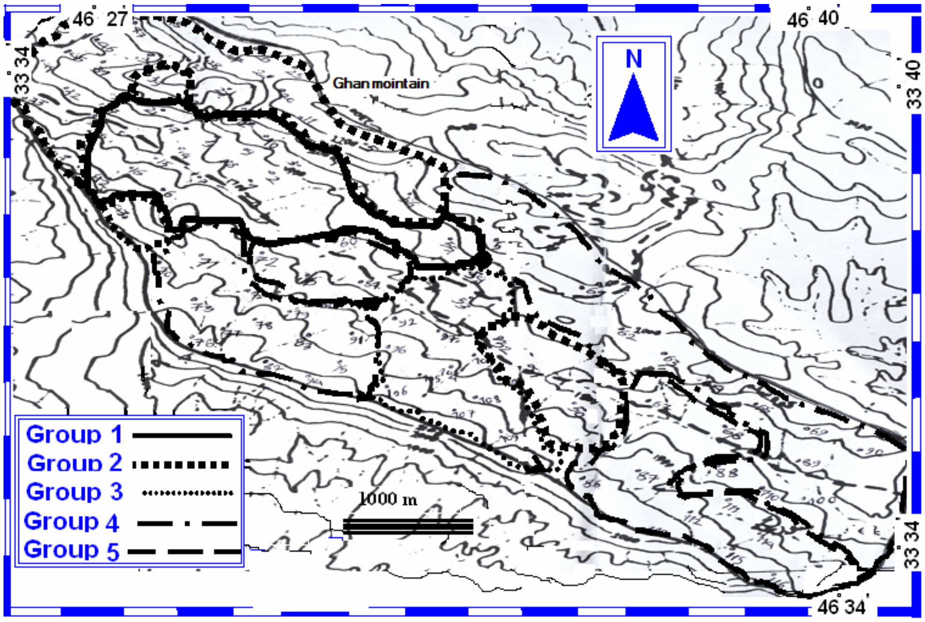

Fig 6. CCA-ordination of quadrates in each ecological groups resulting from TWINSPAN classification on Map

CONCLUSIONS

Species groups classified under the present study are initially multivariate hypotheses about the species which often grow together and have similar environmental requirements. Site conditions can be reasonably estimated on this landscape by observing plant species distributions. It is believed that studies of communities and individual species combined with classifications of ecological species groups provide a stronger understanding of vegetation-environment relationships than studies on one species. For example in the present study, analysis of *Cerasus microcarpa* distribution showed that it dominated plots containing the highest soil nitrogen and carbon. Also, *Acer* and *Astragalus* groups dominated in high soil clay plots. Several forms of vegetation-environment research are useful for furthering our understanding of species distributions on environmentally diverse oak forest landscapes.

The ecological species groups were defined for the oak forests of Ilam. It was the first attempt to develop such species groups in this part of region. The ecological profiles typically showed that each species of a group had similar responses over the range of ecosystems. This confirms the usefulness of the species-group approach where the ecologist may rely on more than one species to help determine site quality or identify ecosystem types in the field. Therefore, errors due to site characteristics are less likely to occur. The results showed that in the study area, among different environmental factors (edaphically and topographic variables), the distribution of vegetation types were most strongly controlled with some soil characteristics such as organic carbon, total nitrogen, clay and elevation. Results of PCA showed that the first two principal components together, accounted for 66% of the total variance. Therefore, 42.748% and 21.173% variances were accounted for the first and second principal components, respectively. Results also showed that the first axis showed the strongest correlation with productivity factors and the second axis with topographic factors. This result has been reported by many investigations (Zahedi 1998; Zahedi & Limayee 2002; Hasseanzad *et al.* 2004; Salehi *et al.* 2005; Mahmoodi *et al.* 2005). Also soil texture controls distribution of plant species by affecting moisture availability, aeration and distribution of plant roots. Soil texture is the most fundamental physical property controlling water, nutrient and oxygen exchange and uptake (Schoenholtz *et al*. 2000) and influences the growth and distribution of vegetation (Fisher & Binkley 2000). Organic carbon and nitrogen are the effective factors in the differentiation of vegetation types (Zahedi & Limayee 2000; Salehi *et al*. 2005).By and large, each plant species has a particular relation with environmental variables. These relations are due to site condition and plant ecological needs. In plain and lowland forests, changes of vegetation were mainly related to soil properties. On the high lands, changes of vegetation does not just relate to soil properties. Other factors such as altitude, aspect and slope were effective during the presence of plant ecological species (Salehi *et al*. 2005; Zarrinkafsh & Kalantary 2006). 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. Since, these methods have high accuracy and different abilities, they could be used to analyze sites and to determine effective ecological factors. Analyzing ecological data using ordination methods makes simple understanding of the complex relationship between plants and environmental gradients. In addition, these methods prevent presence of ineffective factors and data complexity from affecting ecological models. Various disturbances are serious limiting factors to the use of vegetation in species groups for land classification. This is especially true in western oak forests of Iran, where logging, agriculture, fire and grazing have altered the existing vegetation. Therefore, soil and physiographic factors must be emphasized in any attempt to classify local ecosystems or evaluate site quality. Multivariate analysis has showed considerable variations of soil properties in the study site. There is a close relationship between variation in soil characteristics and plant populations in plain forest areas. In the mountainous forest areas, factors such as elevation, slope, aspect and terrain are complementary to the variations in soil characteristics to determine the changes of ecological systems.

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روابط بین رستنی‌ها- عوامل محیطی و گروه گونه‌های اکولوژیکی در جنگل‌های بلوط ایلام، ایران

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چکیده

این مطالعه در جنگلهای بلوط ایلام واقع در غرب کشور انجام گردید. هدف این مطالعه تعیین گروه گونه های اکولوژیک و طبقه بندی رویشگاه بود. در این مطالعه، داده ها با استفاده از ۱۱۷ پلات جمع آوری و روش نمونه گیری اتخاذ شده، طبقه بندی- تصادفی بود. اندازه پلاتهای نمونه برداری برای گونه های درختی و درختچه ای ۲۰*۲۰ متر و برای گونه های علفی ۱,۵*۱,۵ متر بود. برای ثبت گونه های علفی، روش پلات لانه ای ویتاکر مورد استفاده واقع شد. نمونه های خاک برای مطالعه خصوصیات خاک جمع آوری شدند. روش های تجزیه چند متغیره برای طبقه بندی و تعیین رابطه بین ترکیب گونه ای و فاکتور های محیطی و برای تشخیص گروه گونه های اکولوژیک استفاده گردیدند. نرم افزارهای PC-ORD و SPSS برای تجزیه و تحلیل داده ها استفاده شدند. پنج گروه گونه اکولوژیک در منطقه تشخیص داده شدند. *Cerasus microcarpa* گونه شاخص در گروه اول بود. این گروه همبستگی بالایی با کربن و نیتروژن داشت. *Quercus brantii* بالاترین همبستگی را با کربنات کلسیم داشت. گروه سوم *Acer monspessulanum* بود. مهمترین فاکتور برای تفکیک این گروه ارتفاع و رس بود. گروه *Amygdalus orientalis* همبستگی بالایی با ارتفاع داشت. این دو گروه اشاره شده در بالا در ارتفاع بالاتر واقع بودند. *Astragalus liyciodes* گونه شاخص درگروه مشخص دیگر در منطقه مورد مطالعه در سطح بالایی از در صد سنگ حضور داشت. گروه گونه *Astragalus* جائیکه میزان سنگ خاک زیاد بود، مشاهده گردید. نتایج این مطالعه همچنین نشان داد که گروه گونه های در ارتفاعات بالاتر از غنای کمتری برخودار بودند.