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Short communication

Ecological species group—Environmental factors relationships in unharvested beech forests in the north of Iran

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ABSTRACT

Beech forests are the richest forest community in Iran because they are both economically and environmentally valuable. The greatest forest volume occurs in Iran's beech forests. Forests dominated by oriental beech (*Fagus orientalis* Lipskey) cover about 565,000 ha and represent the total area of indigenous forests in Guilan Province. A system for classifying beech forests over such a large area is needed to aid its management. The aim of this study was to investigate the relationship between environmental factors with ecological species groups in unharvested beech forests in Guilan province in northern Iran using multivariate techniques of DCA and CCA. For this purpose, a random systematic 150 m × 200 m gird sampling plan was used to establish 60 1000 m^2 circular plots. In each plot, environmental factors (topographic and soil variables) and percent cover of each herbaceous species were recorded. The result of TWINSPAN analysis showed that six groups were distinct. Multivariate analysis was performed through CANOCO 4.5 to explore the relationship between the environmental factors and the plant community. The most important environmental factors associated with plant composition in beech communities were elevation, slope, slope aspect, N, P, K, pH, C, C/N ratio, organic matter, leaf litter, soil texture (clay, sand, silt) and EC. The use of natural vegetation as an indicator for site quality provides good results, due to the close relationship it has with abiotic site characteristics.

1. Introduction

Extant forests of northern Iran consist mostly of broadleaf deciduous species, but some areas are locally covered by a Mediterranean-type vegetation. Moreover, the distribution of forest types in northern Iran is heterogeneous, with forest productivity following a decreasing west-east gradient. Caspian forests appear to be very similar to broadleaf forests typical of central Europe, northern Turkey and the Caucasus (Marvie Mohadjer, 2006). Forests of the Guilan Province are located in the western part of the Hyrcanian forest region. The dominant species in the northern forests of Iran is beech (*Fagus orientalis* Lipsky), which covers about 565,000 ha and represents the total area of indigenous forests in Guilan Province. Beech forests are the richest, most productive forest communities in Iran because of their economical and environmental value. These forests represent a major carbon pool in the region and are important for their economic value, ability to protect soil, and provide recreation resources (Adel et al., 2012). The greatest forest volume occurs in Iran's beech forests (Adel et al., 2013).

The importance of the herb layer as containing indicator species has a long history in ecology to classify site type, natural community, or productivity class (Abella and Shelburne, 2004). Because they are responsive to changes in site conditions, certain understory plants act as phytometers that integrate many environmental factors that are difficult to measure directly (e.g., macroclimate, microclimate, physiography, soil and light conditions) (Barnes et al., 1998). Ecological species groups are comprised of plants that repeatedly occur together when certain combinations of site factors occur; they are species that are perceived to have similar ecological requirements or tolerances to environmental stresses and limitations (Host and Pregitzer, 1991). Ecological species groups are distinguished by their species composition and abundance patterns among sampling plots. Identifying ecological species groups involves recognizing species that share similar environmental affinities and typically occupy the same sites across the landscape in predictable relative proportions. They can be used to indicate environmental complexes of forest sites based on the presence

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and abundance of these different indicator species that form associations with fidelity to site (Goebel et al., 2001). 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 physiography, soil, microclimate, and overstory tree composition and vigor (Barnes et al., 1998). Soil types with different structure and nutrients are important for plant growth and community development. Soil conditions are different in different forest areas and are also related to the restoration process (Zhang and Dong, 2010). The interactions of environmental factors are important in the restoration process and must be considered in the management of the areas (Gattie et al., 2003).

Well-defined species–environment relationships are important to understand vegetation patterns on forest landscapes (Hix & Pearcy, 1997). Ecological species groups act to integrate site attributes and can simplify the process of mapping ecological land units (Host and Pregitzer, 1991). Ecological species groups are often used for vegetation classification (Konollova & Chytry, 2004) and as a source of information on the spatial distribution of vegetation (Regato-Pajares and Elenna-Rosselo, 1995). Vegetation can function as a useful classifier of habitats because plants are a conspicuous and stationary habitat element, making them relatively easy to survey and track over time. Vegetation can also be highly sensitive to extrinsic biotic, environmental, or geomorphic factors, expressing localized changes through patterns in survival, growth and propagation (Bowers and Boutin, 2008). Therefore, phytosociology's major applications are in ecological assessment; vegetation mapping, monitoring environmental changes and nature conservation inventory (Dengler et al., 2008). Vegetation classification can be used for ecological studies and practical monitoring of vegetation cover (Woldewahid et al., 2007). Successful long-term monitoring of habitats is best achieved when using quantitative analysis for precise determination of change in vegetation over time (Benhouhou et al., 2003).

Species group research identifies environmental gradients correlated with species distributions, classifies species assemblages occupying similar environmental complexes, and relates species distributions to management-oriented variables such as tree growth. Once species groups are developed for an area, their distribution can be used for inferring soil properties and other variables relatively difficult to measure (Abella and Covington, 2006). 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 conditions, and are tractable for refinement through experimental research developing causal relationships about species distributions (Pabst and Spies, 1998). Determining of vegetation types has been the subject of numerous studies in a wide range of environments (Morgenthal et al., 2006). Mataji et al. (2009) observed that nitrogen, carbon, phosphorus, silt, moisture and acidity were factors in the occurrence of beech populations in northern Iran. Eshaghi Rad and Banj Shafiei (2010) identified aspect, clay, nitrogen, carbon, C/N, organic material and phosphorus as the main factors that affect the distribution of beech communities in northern Iran. Naqinezhad et al. (2008) found three major types of Acer glutinosa ssp. barbata habitats in Hyrcanian lowlands are distinguished mainly based on groundwater regime, soils factors and geomorphology. Naqinezhad et al. (2013) stated that the polythetic divisive classification method is an attractive preliminary tool for identifying associations between plant species and continuous and discrete environmental factors. Abella and Covington identified that fifteen ecological species group principles chiefly developed in temperate regions, and suggest that vegetation–environment research has great potential for enhancing our understanding of forests areas. Dvorsky et al. (2011) stated the most important environmental factors influencing the species composition were altitude, soil moisture and salinity in East Ladakh, India. The aim of this study was to investigate the relationship between environmental factors with ecological species groups in unharvested beech forests in Guilan province in northern Iran using multivariate techniques of DCA and CCA. Numerical classification has been reported as a powerful tool in detecting fine patterns of floristic variation and is confirmed in the present study.

2. Materials and methods

2.1. Study area

The study area is located in Zilaki, near Roudbar City, which is in the southern part of Guilan Province, northern Iran (36°54′30″–36°56′06″ N, 49°46′24″–49°51′17″ E) (Fig. 1). Elevation within the study area ranges from 1010 to 1560 m a.s.l., with 30–40% slopes that generally face northward. Common forest soils are deep and brown and have a heavy texture and weak acidic pH. Parent materials include lime silt, sandstone, siltstone and shill. The climate, based on the Emberger classification (Dagett, 1977), is very humid with mean annual precipitation of 1560 mm at the nearest meteorological station (Rasht City). The annual mean maximum temperature has been recorded in August (29.3 °C) and average minimum temperature in February (2.7 °C). The usual harvest method employed in the Hyrcanian forest is a single-tree selection system, but logging has never occurred in the study area. Consequently, the forest is uneven-aged and is composed of mixed deciduous broadleaf stands dominated by *Fagus orientalis*.

2.2. Data collection

This study included 170 ha of beech forests. We used a random systematic 150 m × 200 m grid sampling plan to establish 60 1000-m^2 circular plots in July, 2012. In each plot, we recorded slope percentage, geographical aspect, elevation, crown canopy percentage and percent cover of each herbaceous species. In addition, litter depth was measured at five locations within each plot. Because the 1000-m^2 plots were too large for detailed measurements of herbaceous species, we used a sub-sampling method according to the Whittaker nested plot sampling protocol and minimal areas method (Cain, 1938). Hence, sub-plots of 32 m^2 (center of each plot) were used for herbaceous species measurements, which consisted of percent cover of each species based on the Domin criterion. After leaf litter had been removed, soil samples were collected at these 60 sampling plots in the study area. At each sampling plot, soil samples were collected from 0 to 30 cm (Eshaghi Rad and Banj Shafiei, 2010) depth for physical and chemical properties. In each plot, we collected a composite sample, mixing five sub-samples, four in the corners of each plot and one in the center (Fig. 2). Soil samples were prepared for analysis by air-drying and sieving using a 2 mm screen. Sand, silt and clay percentages were determined by the hydrometric method (Bouyoucos, 1962). Soil pH and electrical conductivity (EC) were determined using appropriate meters. Total N was analyzed by the Kjeldahl method (Bremner, 1996). Available P was determined by colorimetry according to the Bray-II method (Bray and Kurtz, 1945). Organic carbon and organic matter were determined by the Walkley and Black (1934) method. C/N ratio and base saturation were calculated. Total K was analyzed by flame atomic absorption spectrophotometer (MAPA, 1994).

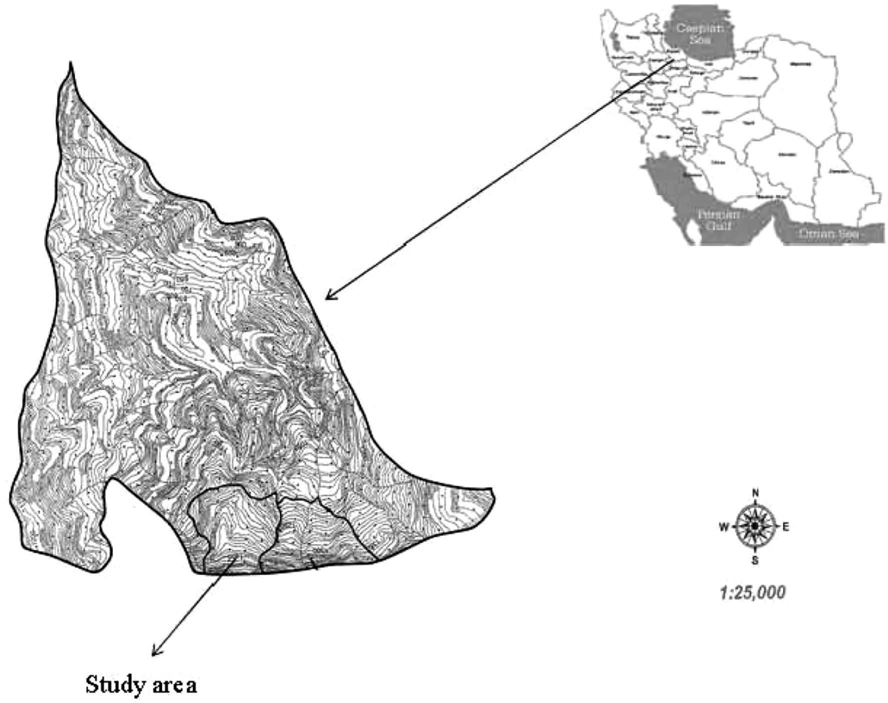

Fig. 1. Study area map: Zilaki Forest, Roudbar city, Northern Iran.

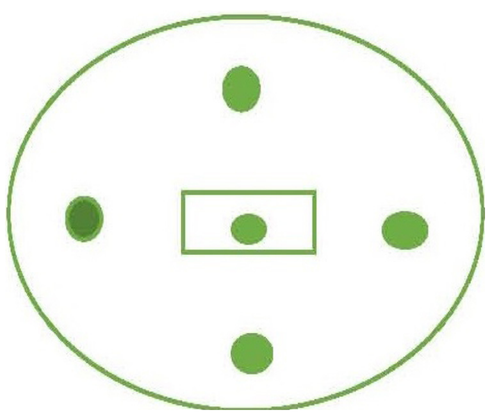

Fig. 2. Fill points are soil sample location and rectangular is herbaceous layer sample location.

2.3. Data analysis

A two-way indicator species analysis (TWINSPAN) was used to classify the 60 sampling plots into groups with similar species abundance patterns. The cut-off level of 'pseudo-species' followed the software's default. We then used the indicator species analysis (ISA) to extract those significantly associated with each group. TWINSPAN and ISA were performed by PC-ORD 5.10 (McCune and Mefford, 2006). Multivariate analysis was performed through CANOCO 4.5 to explore the relationship between the environmental factors (topographic and soil variables) and the plant community in unharvested beech forests of North Iran. To determine whether to use linear or unimodal based numerical methods, detrended correspondence analysis (DCA) with detrending by segments was first conducted to analyze the vegetation data to evaluate the gradient length of the first axis. A Monte Carlo permutation test based on 499 random permutations was conducted to test the significance of the eigenvalues of the first canonical axis. Inter-set correlations from the ordination analysis were used to assess the importance of the environmental variables (Liu et al., 2012). Environmental variables were included in this analysis such as elevation, slope, slope aspect, N, P, K, pH, C, C/N ratio, organic matter, leaf litter, soil texture (clay, sand, silt) and EC. Aspect data were transformed using the equation $A = \cos(45 - A) + 1$ (Beers et al., 1996). Kolmogorov–Smirnov tests were used to test normality of all parameters. The significance of difference between environmental variable means among groups was analyzed by the one-way ANOVA, followed by the Duncan test at the 95% level. All statistical analyses were performed in SPSS (version 18.0).

3. Results

3.1. TWINSPAN results

The results of TWINSPAN showed six distinct groups: the first group, as indicated by *Primola heterichroma*, was included in thirteen samples (Fig. 3). The second group consisted of eleven samples in which *Asperula odorata* was the indicator species. *Polystichum woronomii* was the indicator species of the third group that was represented by ten samples. The fourth group consisted of eight samples in which *Euphorbia amygdaloides* was the indicator species. *Bromus benekenii* was the indicator species in the fifth group represented by twelve samples. The Sixth group was comprised of six samples in which *Sedum stoloniferum* was the indicator species.

3.2. CCA ordination results

The CCA ordination was used because the length of the gradient was calculated (3.24) to be greater than 3. The first (0.424) and second (0.327) axes had the largest Eigenvalues, which accounted for 75.2% of the change and variation. The results of CCA indicated that clay, aspect and EC were the most important factors in the first group (Fig. 4). Phosphorus, nitrogen, carbon, organic material,

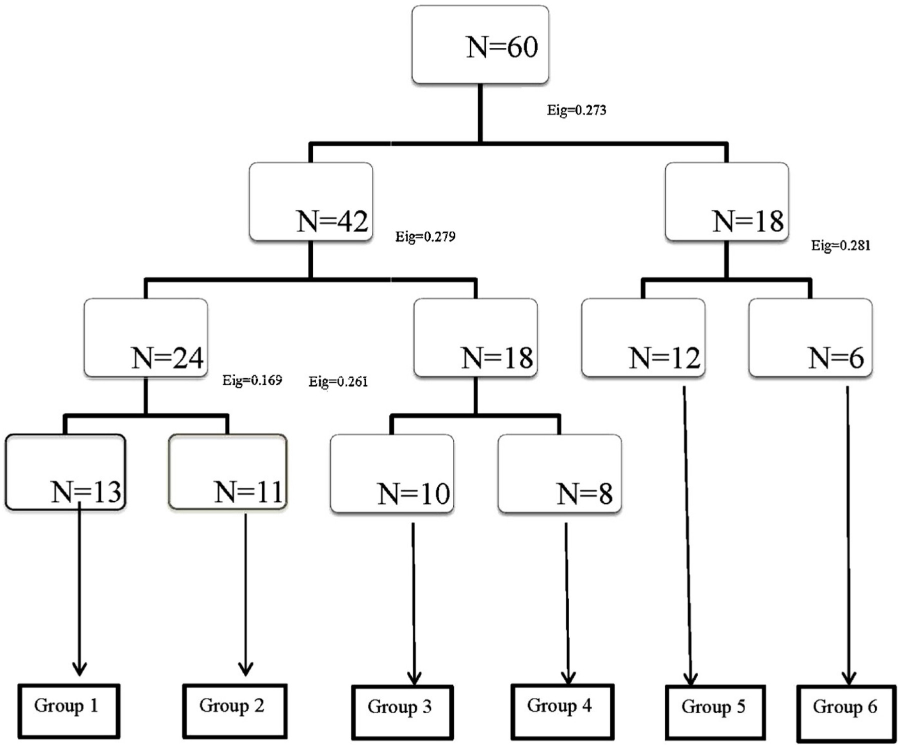

Fig. 3. Diagram of TWINSPAN analyses on 60 sample plots in study area.

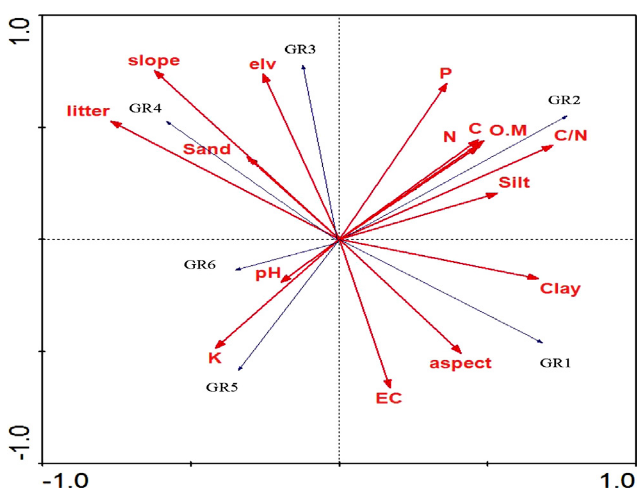

Fig. 4. Ordination diagram showing the result of CCA analysis of vegetation and environment variables in the study area. Abbreviations of vegetation and environment variables: GR = Group, elv = Elevation.

carbon to nitrogen ratio and silt were the most important factors in the second group. Altitude was the separation factor in the third group, and sand, litter and slope were separation factors in group four. The breakdown factor in group five was potassium, whereas pH was the separation factor in the sixth group.

3.3. ANOVA results

The six ecological groups were significantly different in their associations with soil and physiographic factors (Table 1). The highest content of clay, aspect and EC were associated with the first group. The maximum amount of phosphorus, nitrogen, carbon, organic material, silt and ratio of carbon to nitrogen occurred in the second group. Elevation was the greatest in the third group. Sand, litter and slope were maximum in the fourth group. Maximum potassium content was related to the fifth group. The highest level of pH occurred in the sixth group. In contrast, litter was least in the first group, as was the amount of potassium and slope. The lowest level of salinity, pH and sand content was related to the second group. The minimum transformation of geo graphical aspect occurred in the fourth group, where silt and organic matter content were also at their minimums. Nitrogen and clay contents were lowest in the fifth group. In the sixth group, elevation was lowest and phosphorus, carbon and carbon:nitrogen were minimal.

4. Discussion

One of the effective variables in the separation of the first group was EC. Similarly, Monier et al. (2006), who categorized 25 plant populations using soil properties, found that EC was one of the most important factors. Shaltout et al. (2002) concluded that salinity was key to community separation. The first ecological group tends to occur on clay soils and on north aspects that are moister. The geographical distribution of plants is influenced by the amount of available water and light, and, soil temperature. Aspect is influential because it indirectly affects these key resources in an integral way through the amount of solar radiation received by the site, which in turn affects temperature, soil moisture, humidity, vapor pressure deficits, transpiration, and other factors that limit the survival, growth and distribution of plants (Sebastia, 2004; Small and McCarthy, 2005). Mataji et al. (2009) analyzed the soil characteristics in the *Rusco-Fagetum* ecological group in Iran and showed that clay content is important in the spread of beech communities. Clay soils influences the formation of plant communities (Badano et al., 2005; Small and McCarthy, 2005).

Phosphorus was one of the important soil factors in the separation of the second ecological group. Other factors characteristic of this ecological group included nitrogen, organic matter, organic

Table 1
Mean of the environmental variables between species groups in the study area.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	P
Slope (%)	17.33	28.75	40.37	42.8	30.83	28.41	0.005**
Elevation (m)	1225	1285	1341	1338	1284	1257	0.000**
Aspect	1.41	1.05	1.09	0.802	1.32	0.803	0.044**
Litter (cm)	2.89	3.77	4.42	5	3.1	3.25	0.014**
K (ppm)	311	327	324	337	342	329	0.030**
N (%)	0.265	0.3	0.06	0.17	0.05	0.09	0.002**
O.M. (%)	2.59	1.27	3.14	0.59	0.34	0.37	0.000**
EC	53.42	48.75	49.56	49.31	50.9	52.38	0.000**
pH	5.35	4.9	5.3	5.4	5.3	5.6	0.000**
P (ppm)	46.44	49.31	47.66	48.27	44.5	43.89	0.000**
C (%)	2.52	3.04	0.34	1.31	0.54	0.3	0.000**
C/N	6.18	10.47	10.13	7.7	6	5	0.000**
Sand (%)	11	10	14	17	13	8	0.000**
Silt (%)	28.5	37	50	50	32	25	0.000**
Clay (%)	65	60.5	55	51	37	36	0.000**

** Significant difference between means at the $\alpha = 0.05$ level.

carbon and C/N ratio. Nitrogen and phosphorus play a fundamental role in plant nutrition, and their concentration and availability determine to a large extent soil fertility and site productivity as these elements are required in relatively large amounts by plants. Biggelow and Canham (2002) observed that there is a direct correlation between the distribution of plant species and phosphorus in northeastern America. Amorin and Batalha (2007) reported that phosphorus was the main factor that defined plant communities in Brazil, and nutrients in general played a major role in the classification of ecological groups.

Nitrogen is a key nutrient in many biological processes and it is the main factor in plant growth. It also has a major influence on soil fauna and flora that can either make nutrients more available to plants or bind them in biological processes and growth causing short-term deficiencies in plants. Nitrogen is also subject to leaching, especially in well-drained soils. Abella and Covington (2006) established the role of nutrient elements in the distribution and constancy of plants. Nitrogen (N) and phosphorus (P) are important nutrients in plant metabolic processes: N is an important component of protein; P is a key element in cellular energy transfer and a structural element in nucleic acids. N and P are also the primary nutrients that restrict plant growth in many natural environments (Jiang et al., 2012).

Organic materials may be rich in nitrogen and characteristically have a high adsorption capability, which increases the soil's exchange capacity and therefore its fertility levels (Su et al., 2002; Zhenghu et al., 2004). Fu et al. (2004) pointed out that organic matter and nitrogen content determined the distribution of plants in Beijing, China. Spencera et al. (2004) also emphasized the role of organic compounds in plant growth. Christine and McCarthy (2005) observed that the ratio of C/N was the main determinant in the establishment of herbaceous plants. High C/N ratios result in reduced nitrogen availability to plants as it is tied up by soil microbes.

Second ecological group had the lowest acidity (pH) of all groups recognized in this study. Low soil acidity results in decreased concentration of nutrient elements. Ecological group two is located on silty soils that have favorable moisture conditions. Bajtala (1999) noted the role of soil moisture in the distribution of plant species in the National Park, Alberta-Canada. Mataji et al. (2009) stated that silt soils are effective in developing communities of *Carpineto-Fagetum*. They observed that nitrogen, carbon, phosphorus, silt, moisture and acidity were factors in the occurrence of beech populations in northern Iran. Eshaghi Rad and Banj Shafiei (2010) identified aspect, clay, nitrogen, carbon, C/N, organic material and phosphorus as the main factors that affect the distribution of beech communities in northern Iran.

Third ecological group occurred at high elevations, where only certain species are able to grow in the characteristically harsh climates including decrease air pressure and its dilution, increase in ultraviolet rays, reduced temperatures, changes in the type and amount of precipitation. Elevation is usually an important factor for vegetation development and distribution in mountains, and therefore, it is significant in vegetation restoration in such areas (Zhang and Dong, 2010). Other researchers have also noted the role of elevation in the distribution pattern of plant communities (Grytnes and Vetaas, 2002; Alessandro and Marcello, 2003; Kabrick et al., 2004; Lososova et al., 2004; Fisher and Fuel, 2004).

Ecological group three had a lower salinity than most other groups, which influences the occurrence and growth of species in this group. The amount of salinity can have negative effects on species that are related to increase environmental drought, increased osmotic pressure of the soil solution, and ion toxicity, which limit the water and nutrients that can be absorbed by plant roots (Khresat and Qudah, 2006).

The fourth ecological group was on steeper slopes with sandier soils and more litter. Abbadi and El-Sheikh (2002) and Grongroft et al. (2003) discussed the importance of slopes in the distribution of plant species. Badano et al. (2005) and Boll et al., 2005 also emphasized the role of slope in the pattern of plant distribution across the landscape. Slope influences on plant distribution in mountainous terrain are related to a number of factors that affect plants such as decreased soil depth and increased water drainage. Plant establishment becomes increasingly difficult with increasing slope steepness due to reduced soil depth, lack of nutrients and moisture and also difficulty of constancy of seed (Campo et al., 1999). This unit had the highest percentage of sand, giving it the lightest texture among the groups. Ismaelzade et al. (2011) associated the amount of sand to the development of different types of beech forests. This ecological group had more litter and probably slower decomposition due to limited water and nutrient holding capacity typical of sandy soils that inhibit micro-organism activity. Thus, it appears that soil texture is the main driver in this ecological group in determining the plant community. Vetaas (2000) demonstrated the role of litter thickness on the distribution of plants.

Potassium is important in defining the fifth ecological group of species. Potassium plays a role in regulating photosynthesis, carbohydrate transport, protein synthesis, and other important physiological processes. In addition, existence of potassium in the soil makes easy to transform the water and nutrients in the soil, then potassium can be taken into account as a fertile material of the soil. Zare Chahoki et al. (2007) and Enright et al. (2005) have reported on the role of potassium in the distribution of plant species.

In ecological group six, pH is the most important factor affecting the plant community. Soil pH is an important determinant of the productive capability of a site (Jobbagy and Jackson, 2003). Soil acidity has a strong influence on nutrient availability (Farley and Kelly, 2004). Kashina et al. (2003), Gough et al. (2000) and Brofske et al. (2001) have shown the important role of pH in the separation of plant groups.

5. Conclusion

We assessed the impacts of environmental factors on forests dominated by *Fagus orientalis* in north of Iran. We found that topographic and soil variables were useful in separating six ecological species groups. The temperate forests in north of Iran are some of the world's most productive forests. The differences of physiographic and soil characteristics in forest sites were associated with several plant communities in this region (Zahedi Amiri, 1998). Ecological species groups represent the relation between plant community and site environment. Variations in soil resources are foundational and important to the distribution and abundance of plants and the communities that they form on specific sites. Also in phytosociological studies, the concept of ecological species groups useful in classifying natural communities, determining changes in vegetation, understanding vegetation distribution and environmental factors, estimating species niches, calibrating indicator value for species, modeling potential distribution of species and plant communities and assessing habitat quality. Indicator species can be among the most sensitive species to environmental change or degradation in a region, acting as an early warning for monitoring. Also, they can be used to predict differences in site productivity, which can be used to assess site suitability for species and support decision making in forest restoration, management and planning (Fontaine et al., 2007). The use of natural vegetation as an indicator for site quality provides good results due to the close relationship it has with abiotic site characteristics (Waring et al., 2006).

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