BIODIVERSITAS
Volume 15, Number 1, April 2014
Pages: 31-38

ISSN: 1412-033X
E-ISSN: 2085-4722
10.13057/biodiv/d150105

How plant diversity features change across ecological species groups? A case study of a temperate deciduous forest in northern Iran

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Manuscript received: 24 December 2013. Revision accepted: 7 February 2014.

ABSTRACT

Bazdid Vahdati F, Saeidi Mehrvarz Sh, Naqinezhad A, Gholizadeh H. 2014. How plant diversity features change across ecological species groups? A case study of a temperate deciduous forest in northern Iran. Biodiversitas 15: 31-38. Species diversity is one of the most important indices for evaluating the stability and productivity of forest ecosystems. The aim of this research was to recognize ecological species groups and to determine the relationship between environmental variables and the distribution of ecological species groups. For this purpose, 25 400-m^2 relevés were sampled using the Braun-Blanquet method. Vegetation was classified using modified Two-Way Indicator Species Analysis (TWINSPAN) and resulted in three ecological species groups. Different species diversity indices were applied to quantify diversity of these species groups. ANOVA and Duncan's tests indicated that all species and environmental variables except altitude changed significantly across the species groups. The results also showed that the group located in the northern aspect and on low slopes had the highest diversity indices compared with groups located in dry aspects and on high slopes. In reality, abundant precipitation (northern aspect) and soil enrichment (low slopes) are principal factors that provide suitable conditions for plant growth and species diversity. Thus, the study of diversity changes in ecological species groups can result in an ecologically precise perspective for managing forest ecosystems.

Key words: Ata-Kuh, ecological species groups, Hyrcanian forests, Iran, plant diversity

INTRODUCTION

The assessment of forest biodiversity has become an important issue for studying ecosystems and their conservation (Aubert et al. 2003). Biodiversity preservation is considered to be a key management objective which is essential for the stability of forest ecosystems (Torras and Saura 2008). Forest biodiversity is considered at different levels, including genetic variation within species (genetic diversity), the variety of species in a community or area (species diversity), and the variety of habitat types within a landscape (ecosystem diversity) (Zhang et al. 2012). Complex interactions can occur within and amongst these levels. This complexity allows organisms to adapt to continually changing environmental conditions and to maintain ecosystem functions. Applying the ecological species group and indicator species in each group, through measures such as presence and absence or relative coverage of each group, will help identify species-environment relationships (Barnes et al. 1982). Moreover, the data of ecological species groups can be used to evaluate site conditions and vegetation classification.

The humid conditions on the northern slopes of the Alborz Mountains result in a Hyrcanian deciduous closed forest along the southern shores of the Caspian Sea (Zohary 1973). Because of their diverse topographic conditions, Hyrcanian forests can be considered hot spots of plant biodiversity (Eshaghi Rad and Banj Shafiei 2010). Generally, these forests are characterized by three elevational belts, lowland (50-500 m), submountain (501-1000 m), and mountain (1001-2200 m) (Zohary 1973; Naqinezhad et al. 2008; Hamzeh'ee et al. 2008; Siadati et al. 2010). The transition zone (i.e. submountain forests) in the eastern parts of the Hyrcanian forests are dominated by stands of *Quercus castaneifolia* and *Carpinus betulus* (Akhani et al. 2010). Despite changes in land use and the exploitation of natural resources, the lowland/submountain zones still contains few intact patches.

To date, some studies of plant species diversity and ecological species groups have been carried out in the Hyrcanian forests (e.g. Nazarian et al. 2004; Pourbabaei et al. 2006; Esmailzadeh and Hosseini 2007; Hamzeh'ee et al. 2008; Naqinezhad et al. 2008, 2012, 2013; Eshaghi Rad et al. 2009; Abedi and Pourbabaei 2010; Eshaghii Rad and Banj Shafiei 2010; Hashemi 2010; Kialashaki and Shabani 2010; Pourbabaei and Haghgooy 2012; Naqinezhad and Zarehzadeh 2013; Pourbabaei and Abedi 2013). However, no research has been carried out in the lowland/ submountain Ata-Kuh forest to identify ecological species groups and to find their relationships with environmental variables and biodiversity indices. It is obvious that effective conservation of the remaining Hyrcanian forests requires an understanding of the ecosystem processes

controlling species composition and biodiversity (Naqinezhad et al. 2013).

The objectives of this study were: (i) delimiting the main ecological species groups based on TWINSPAN classification, (ii) evaluating species diversity indices among the ecological species groups, and (iii) finding the relationship between topographic factors (altitude, slope and aspect) and ecological species groups in order to determine the main factors affecting the separation of ecological species groups and diversity indices.

MATERIALS AND METHODS

Study site

Ata-Kuh forest with an area of 700 ha is situated 10 km southeastern of Lahijan (Guilan Province), between 37º 09′ 28.4″ and 37º 09′ 23.4″ N and between 50º 05′ 06.9″ and 50º 06′ 04.1″ E (Figure 1). The altitude ranges between 250 and 680 m. The study area is located on the northern slope of the Alborz Mountains. In this area, the major geological formations are composed of Cretaceous basaltic rocks, Triassic granite rocks, and Carboniferous metamorphic phyllitic and schistic rocks (Darvishzadeh 1991). The most important soil types in Ata-Kuh forest are brownish and loamy.

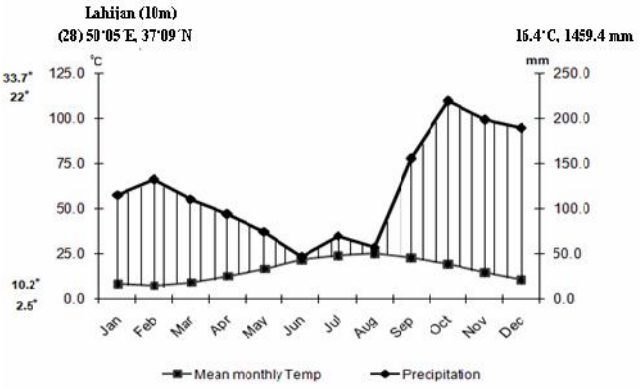

Figure 2. Climatological diagram from Lahijan station (1982-2010).

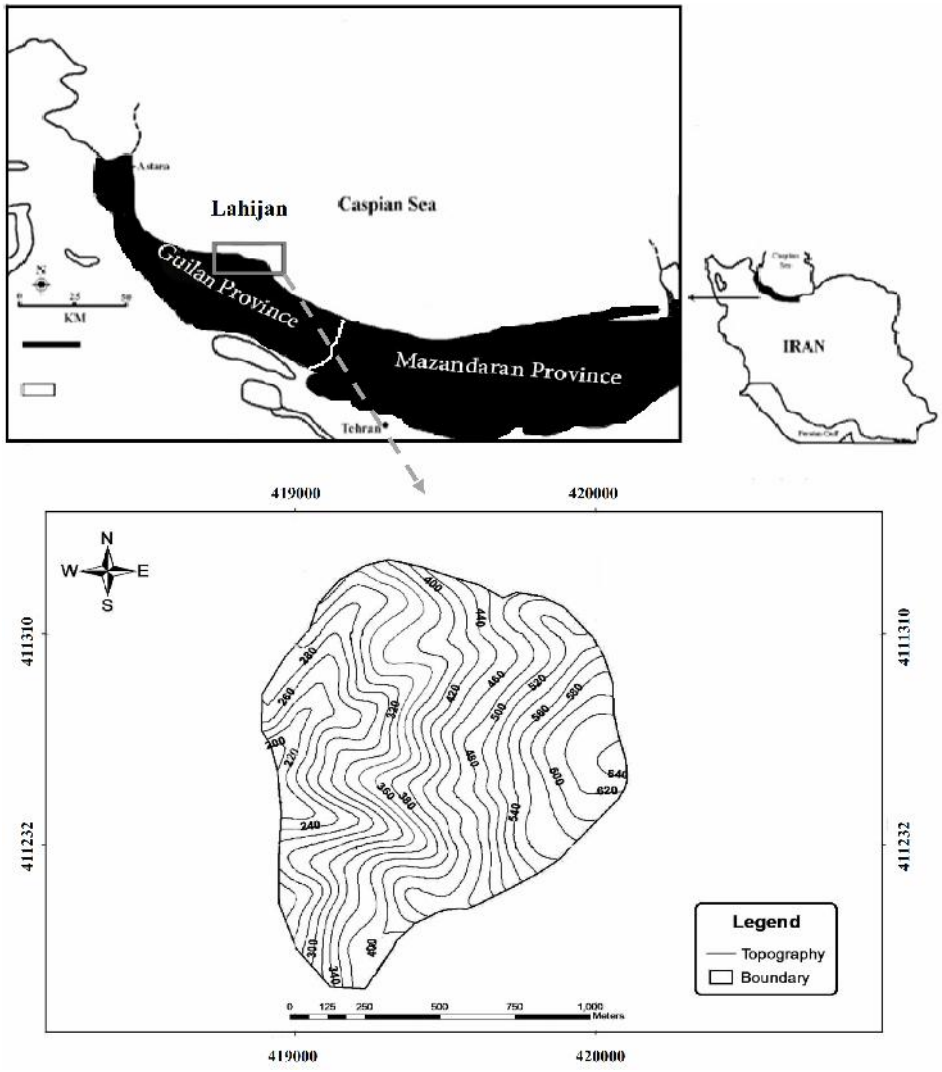

Figure 1. The topographic map of Ata-Kuh forest showing position of the area in Iran

According to the available data from the nearest climatological station (Lahijan station), for a period of 28 years from 1982 to 2010, the average annual temperature was 16.5˚ C. Mean maximum temperature in the hottest months (July and August) and mean lowest temperature in the coldest months (January and February) were 22˚C and 10.2˚C, respectively. The average total annual precipitation and average annual temperature are 1459.4 mm and 16.47˚ C, respectively (Figure 2). The climate of the area is estimated to be temperate oceanic climate (sub-Mediterranean variant), according to the recent bioclimatic classification of Iran (Djamali et al. 2011).

Vegetation sampling

The vegetation was collected phytosociologically during growing seasons from March 2010 to March 2011 according to Braun-Blanquet approach (Braun-Blanquet 1964; Mueller-Dombois and Ellenberg 1974) and using the seven-degree scale (r, +, 1…5). Only floristically and

environmentally homogeneous areas were selected. According to the Braun-Blanquet method, a homogenous area is subjectively chosen and is necessary for relevés sampling. A total of 25 relevés with an area of 400 m^2 were sampled. Topographic variables (altitude, slope, and aspect) were measured using GPS (Garmin, model Geko), Suunto clinometers and Suunto compass in each relevé, respectively. Slope of the area was divided into three floors: low sloping (0-15 %), moderate sloping (15-30 %) and high sloping (more than 30 %) and geographical aspect quantitated by using Cos (45-Aspect) +1. Its value varies between zero to 2 (Beers et al. 1966).

Nomenclature for vascular plants was based on (Rechinger 1963-2010; Assadi et al. 1988-2011). Moreover, the ferns were identified using Khoshravesh et al. (2009).

Data analysis

The phytosociological data were analyzed using the modified TWINSPAN method (Hill 1979; Roleček et al. 2009) embedded in the JUICE 7.0 program (Tichý 2002). TWINSPAN analysis is one of the most popular classification methods used in plant community ecology (Lepš and Šmilauer 1999). In this method, relevés are compared based on presence or absence of species. Pseudospecies cut levels were set to seven and the values of cut levels to 1, 2, 3, 4, 5, 6, 7. Tow relevés were selected as a minimum group size for division. The fidelity of species to clusters and diagnostic species for vegetation units was determined using the phi-coefficient, based on presence/absence data (Chytrý et al. 2002; Tichý and Chytrý 2006). Also, threshold value of *phi* = 0.25 was selected (Illyés et al. 2007).

In order to evaluate plant species diversity, various indices may be used. In this study, we applied the Shannon Wiener (H′) and Simpson (1-D) diversity indices, Smith and Wilson evenness index, and species richness. Shannon-Wiener diversity index, which takes into account both species abundance and species richness, was used because of increased sensitivity to rare species and because it is the most commonly used index (Kent and Coker 1992). In addition, the Simpson index (1-D) was used due to more sensitivity to the most frequent plant species (Krebs 1999). These indices were calculated after transformation of the Braun-Blanquet scale values to percentage cover: r= 0.1%; 1= 2.5%; 2=15.0%; 3=37.5%; 4=62.5%; 5=87.5% (Pyšek et al. 2004).

Shannon-Wiener H':

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

Simpson 1-D:

$$1\text{-}D = 1 - \sum_{i=1}^{s} (P)_i^2$$

Where:

p_i: the relative cover of ith species

S: the total number of species in the sampling relevés.

The evenness index expresses how individuals are distributed among the different species. The Smith and Wilson evenness index (E_{var}) was used, because it is independent of species richness and is sensitive to both rare and common species in the community (Krebs 1999).

$$E_{var} = \frac{2}{p \arctan\left\{\sum_{i=1}^{s}\left[\log_e(ni) - \sum_{j=1}^{s}\log_e(nj)/s\right]^2 / S\right\}}$$

Where:

arctangent: measured as an angle in radians,

n_i: the percentage cover of the i_{th} species,

n_j: the percentage cover of the j_{th} species,

S: the total number of species in the sampling relevés.

Numbers of species per relevé was taken as a measure of species richness (S) (Timilsina et al. 2007). Normality of the obtained data was checked using the Kolmogorov-Smirnov test. A one-way ANOVA was used to evaluate differences among groups identified by TWINSPAN, and Duncan's test was used for comparing mean. All diversity indices and statistical analyses were calculated using Ecological Methodology ver. 6.0 (Krebs 1999) and SPSS 16.0 for windows, respectively.

RESULTS AND DISCUSSION

Results

Three distinct groups of species were identified using modified TWINSPAN analysis for the 25 relevés at the first level of analysis (Figure 3, Table 1). Ecological species group I was altitudinally ranged from 250 m to 360 m asl. and located on south-facing slopes. There are 104 species in this ecological species group. The most important diagnostic species of this group was *Parrotia persica* C.A. Mey., a thermophilous Arcto-Tertiary relict species (Akhani et al. 2010). Other herbal diagnostic species were *Solanum nigrum* L., *Ophioglossum vulgatum* L. and *Viola sintenisii* W. Becker. This group has been under degradation owing to agricultural activities and livestock grazing.

Group II was altitudinally ranged from 500 m to 680 m asl. and found on high slopes (more than 30 %) with a southeast aspect. Also, 147 species were recorded in this ecological species group. This ecological species group was characterized with *Fagus orientalis* Lipsky and *Rubus*

hirtus Waldst. & Kit. as its dominant species. Other important species were *Crataegus pseudomelanocarpa* Popov ex Lincz., *Primula heterochroma* Stapf, *Viola odorata* L., *Bromus japonicus* Thunb. ex Murray, *Oplismenus undulatifolius* (Ard.) P. Beauv. and *Solanum kieseritzkii* C.A. Mey.

Table 1. Combined synoptic table of percentage frequency (constancy) and fidelity (phi coefficient × 100, upper indices). Only species with phi coefficient ≥0.25 (frequency and fidelity in bold) were considered as diagnostic species for specific vegetation groups.

Group number	**1**	**2**	**3**
Number of relevés	**5**	**9**	**11**
Parrotia persica		**87** $^{68.0}$	. 8
Solanum nigrum		**67** $^{75.6}$	. .
Ophioglossum vulgatum		**61** $^{54.2}$	. 17
Viola sintenisii		**57** $^{50.4}$	30 42
Fagus orientalis		30	**87** $^{87.8}$ 33
Rubus hirtus		33	**81** $^{62.1}$ 42
Oplismenus undulatifolius		.	**80** $^{58.9}$ 31
Primula heterochroma		.	**60** $^{55.8}$ 17
Viola odorata		.	**50** $^{54.6}$ 8
Crataegus pseudomelanocarpa		.	**40** $^{55.5}$.
Carpinus betulus		.	33 **80** $^{77.7}$
Thelypteris palustris		.	. **71** $^{75.6}$
Crataegus microphylla var. *dolichoocarpa*		.	20 **67** $^{61.9}$
Rhynchocorys maxima		.	10 **58** $^{58.1}$
Stellaria media		.	10 **54** $^{53.0}$
Calystegia sylvestris		33	. **51** $^{53.0}$
Rumex sanguineus		.	. **52** $^{56.8}$
Veronica crista-galli		.	. **44** $^{56.8}$
Diospyros lotus		33	10 **42** $^{50.1}$
Smilax excelsa		33	30 **41** $^{39.6}$
Mespilus germanica		33	30 **38** $^{35.2}$
Viola caspia subsp. *caspia*		.	10 42
Asplenium scolopendrium		33	40 17
Geum urbanum		.	30 42
Bromus japonicus		33	30 42
Fragaria vesca		33	60 33
Poa annua		33	10 50
Hypericum androsaemum		100	20 42
Epimedium pinnatum		67	50 8
Ruscus hyrcanus		.	60 50
Hypericum perforatum		67	. 25
Cystopteris fragilis var. *fragilis*		.	60 50
Salvia glutinosa		.	50 75
Athyrium filix-femina		.	40 42
Pteris cretica		100	70 50
Oxalis corniculata		33	10 33
Willemetia tuberosa		.	. **33** $^{50.0}$
Geum iranicum		33	20 33
Lamium album subsp. *album*		.	. 25
Poa nemoralis		.	. 25
Scilla hohenackeri		.	20 25
Potentilla reptans		.	. 25
Thelypteris limbosperma		33	. 25
Cerastium glomeratum		.	. 25
Veronica persica		.	. 25
Gleditsia caspica		.	. 25
Rubus sanctus×hirtus		.	10 17
Juncus acutus		.	. 17
Carex grioletii		.	10 17
Polystichum woronowii		33	20 17
Parietaria officinalis		33	20 17
Euphorbia stricta		.	30 17
Fragaria viridis		67	20 25
Carex divulsa subsp. *divulsa*		.	10 17
Urtica dioica subsp. *dioica*		.	. 17
Pterocarya fraxinifolia		.	. 17
Pimpinella affinis		.	. 17
Luzula forsteri		.	. 17
Sambucus ebulus		.	20 17
Ranunculus arvensis		.	. 17
Dryopteris pallida		.	10 17
Polystichum lonchitis		.	20 17
Rumex pulcher subsp. *pulcher*		.	10 17
Pteridium aquilinum		33	. 17
Asplenium trichomanes		.	. 17
Campanula latifolia		33	10 17
Arum maculatum		.	. 8
Albizia julibrissin		.	. 8
Thlaspi umbellatum		.	. 8
Carex digitata		33	. 8
Chelidonium majus		.	. 8
Acer campestre		.	. 8
Carex diluta		.	. 8
Campanula rapunculus subsp. *lambertiana*		.	. 8
Teucrium hyrcanicum		.	. 8
Crocus caspius		.	. 8
Polystichum braunii		33	. 8
Aira elegans		.	. 8
Geranium purpureum		.	. 8
Pyrus communis		.	. 8
Sedum stolonifer		.	. 8
Clinopodium cf. *vulgare*		.	. 8
Poa trivialis		.	. 8
Ilex spinigera		.	. 8
Polygonum lapathifolium subsp. *brittingeri*		33	. 8
Phytolacca americana		33	. 8
Prunella vulgaris		.	. 8
Carex remota subsp. *remota*		33	8 .
Torilis leptophylla		.	. 8
Cyperus rotundus		.	. 8
Rubus discolor		33	. 8
Rubus caesius		33	30 8
Dryopteris filix-mas		.	20 8
Rubus sanctus×dolichocarpus		.	20 8
Rubus saxatilis		.	20 8
Amaranthus chlorostachys		33	10 8
Conyza canadensis		.	10 8
Circaea lutetiana		.	20 8
Dioscorea communis		.	10 8
Mercurialis perennis		.	10 8
Dryopteris affinis		.	10 8
Milium pedicellare		.	10 8
Potentilla adscharica		.	. 8
Nonnea lutea		.	. 8
Lolium persicum		.	. 8
Ornithogalum sintenisii		.	. 8
Agrimonia eupatoria		.	. 8
Lophochloa phleoides		.	. 8
Silene apetala		.	. 8
Prunus divaricata		.	. 8
Taraxacum sp.		33	10 8
Viola caspia subsp *sylvestroides*		33	10 8
Matteuccia struthiopteris		.	. 8
Thlaspi hastulatum		33	. .
Capsella bursa-pastoris		.	10 .
Rubus sanctus×hyrcanus		33	10 .
Solanum kiseritzckii		30	. .
Rubus persicus		.	10 .
Euphorbia squamosa		.	10 .
Scutellaria tournefortii		33	10 .
Ficus carica		33	. .
Sida rhombifolia		33	. .
Mentha aquatica		33	. .
Cyclamen coum var. *caucasicum*		.	10 .

Hedera pastuchovii	33	.	.	*Cardamine impetiens* var. *pectinata*	.	10	.
Euphorbia amygdaloides	33	.	.	*Polypodium vulgare*	.	10	.
Setaria glauca	33	.	.	*Cardamine hirsuta*	.	10	.
Lepidium draba	.	10	.				

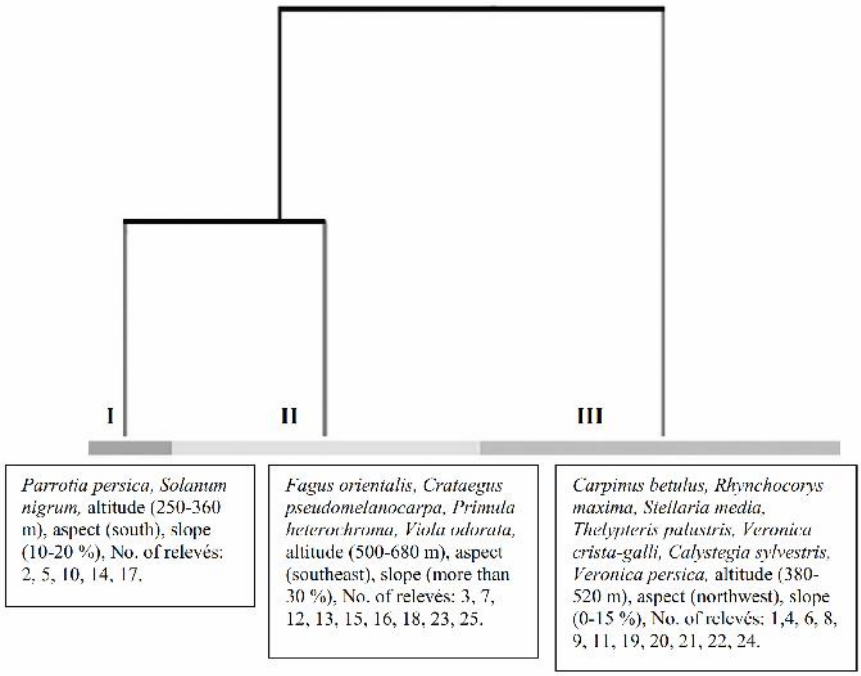

Figure 3. TWINSPAN classification dendrogram for Ata-Kuh forest indicating diagnostic species, ecological factor (altitude, aspect and slope) and number of relevés for each ecological species group in the boxes.

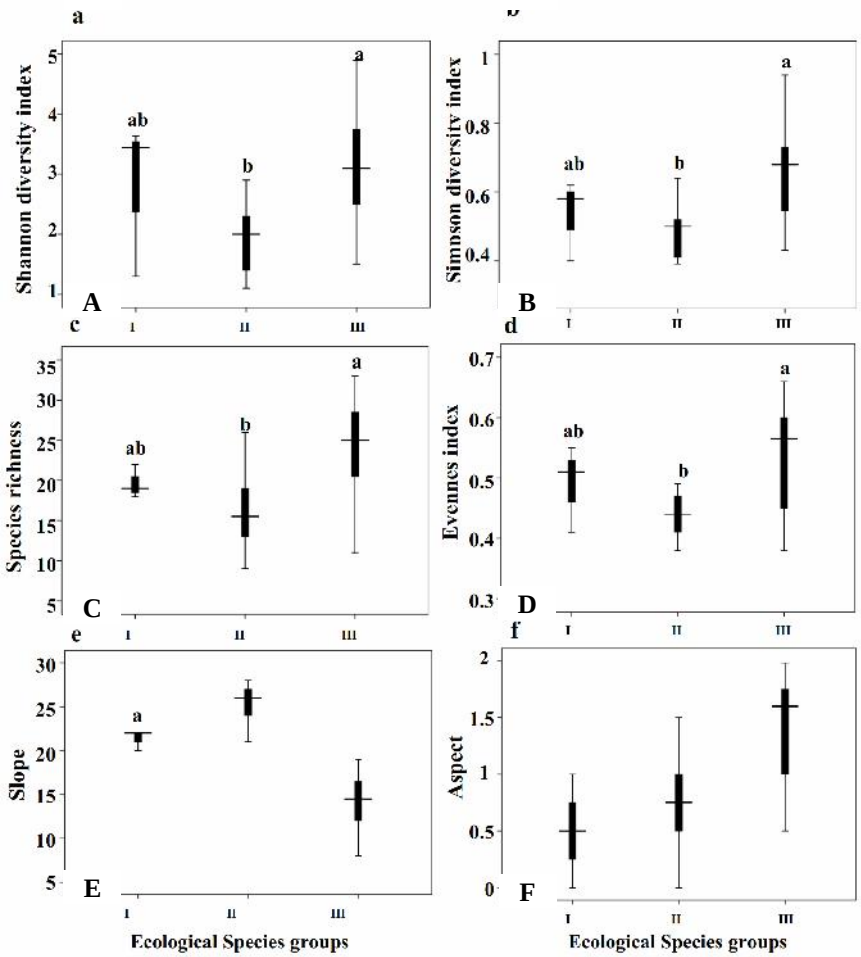

Figure 4. The relationship between ecological species group and (A) Shannon diversity index, (B) Simpson diversity index, (C) Species richness, (D) Evenness index, (E) Slope and (F) Aspect in Ata-Kuh forest.

Ecological group III was observed in the middle elevations (380-520 m asl.), and the habitat was more or less flat (0-15 %) and relatively humid (northwest aspects). 260 species were recorded in this ecological species group. The most important diagnostic woody and liana species were *Carpinus betulus* L., *Diospyros lotus* L., *Crataegus microphylla* K. Koch., *Mespilus germanica* L. and *Smilax excelsa* L. In this group, dominant and diagnostic understorey species were *Rhynchocorys maxima* Richter, *Stellaria media* (L.) Cirillo, *Thelypteris palustris* Schott, *Veronica crista-galli* Steven, *Calystegia sylvestris* Roem. & Schult. and *Veronica persica* Poir.

The one-way ANOVA test indicated that there were significant differences between groups in terms of diversity indices and topographic factors in the studied areas ($P < 0.05$) while there were no significant differences between groups in terms of altitude (Table 2). Duncan's test indicated that the highest value of all diversity indices was found in group III, and the lowest values of these indices were in group II.

Shannon-Wiener (H′) and Simpson (1-D) diversity indices were relatively high in the group III compared to other ecological groups (Figure 4.A-B). The lowest and highest values of the species richness index (S) were shown in groups II and III, respectively (Figure 4.C). Moreover, group II had the lowest value of Smith and Wilson's evenness index (E_{var}). In contrast, this index was considerably higher in group III (Figure 4.D).

The value for slope in group III was significantly lower than in the other groups. Groups I and II were located in dry aspects, and there were no significant differences between these two groups in terms of slope and aspect. On the other hand, group III was located in more humid aspects and showed a statistically significant

difference with other groups (Figure 4.E-F).

Table 2. Summary statistics (Means ± standard error) and *P*-value from ANOVA of different biodiversity indices and topographic variables in the studied ecological species groups in Ata-Kuh forest. Abbreviation: H′ = Shannon-Wiener diversity index, 1-D = Simpson diversity index, E_{var} = Smith and Wilson evenness index, S = species richness.

Indices and variables	Group I Means (± SE)	Group II Means (± SE)	Group III Means (± SE)	*P*-value
H′	$2.79^{ab} \pm 0.74$	$1.92^{b} \pm 0.17$	$3.11^{a} \pm 0.26$	0.01*
1-D	$0.53^{ab} \pm 0.06$	$0.49^{b} \pm 0.27$	$0.66^{a} \pm 0.04$	0.01*
E_{var}	$0.49^{ab} \pm 0.04$	$0.43^{b} \pm 0.01$	$0.53^{a} \pm 0.02$	0.01*
S	$19.66^{ab} \pm 1.20$	$16.20^{b} \pm 1.54$	$23.91^{a} \pm 1.86$	0.01*
Alt. (m asl.)	551.33±44.87	538.90±21.06	505.83 ± 41.00	0.71ns
Slope (%)	$21.33^{a} \pm 0.66$	$25.30^{a} \pm 0.66$	$14.91^{b} \pm 1.38$	0.00*
Aspect (º)	$0.50^{b} \pm 0.28$	$0.75^{b} \pm 0.13$	$1.43^{a} \pm 0.13$	0.00*

Note: Significant differences showed by different letters (a, b, $P < 0.05$); * significant at 0.05 level, n.s.= no significant.

Discussion

The study of ecological species groups is one method of discerning vegetation-environment relationships. Diversity measures are very effective ways to evaluate both the ecological status and conservation management. Species diversity is also regarded as one of the most central criteria in decisions regarding forest management priorities and posses vital importance for the conservation of natural communities which are increasingly threatened by industrial and urban expansion and forest clearing (Naveh and Whittaker 1980).

Topographic factors were introduced as an important factor of vegetation distribution (Mark et al. 2000). Altitudes, geographical aspect, and slope have also been mentioned as factors affecting diversity (Vujnovic et al. 2002). In the present study, aspect and slope had significant effects on the diversity and distribution of ecological groups, but no direct relationship between the distribution of ecological groups and elevation was observed. This may be due to the rather limited altitudinal distribution of studied relevés in the area. Similar results were achieved in other studies related to the Hyrcanian forest (Esmailzadeh et al. 2012; Pourbabaei et al. 2006). The studied area is part of the Hyrcanian lowland/submountain forests (Frey and Probst 1986). The occurrence of significant roles of slope inclination and aspect on distribution of ecological species groups of the forests were observed in several investigations (e.g. Pourbabaei et al. 2006; Eshaghii Rad and Banj Shafiei 2010; Kialashaki and Shabani 2010; Pourbabaei and Haghgooy 2012).

Ecological species group II, with an indicator woody species of *Fagus orientalis*, located densely in areas with steep slope (more than 30%) and dry aspects, exhibited the lowest amount of diversity indices which is consistent with the study results of Moore and Vankat (1986), Eshaghi Rad et al. (2009) and Kialashaki and Shabani (2010). Pourbabaei and Haghgooy (2012) expressed that *Fagus orientalis* stands were often found on 38.5% slope and with less moisture. Likewise, Mataji and Babaei (2006) and Atalay (2006) stated that this species is common on drier slopes (southwest-and south-facing slopes).

Barbier et al. (2008) stated that light is a major limiting factor of forest vegetation cover and species richness. In the group II, the dense cover of *Fagus orientalis* with its close canopy resulted in a high level of shade on the forest floor. As we thought, low ground-layer vegetation can be affected by high shade. These findings were consistent with the findings of other researchers (Hill 1979; Schoonmaker and Mckee 1988; Fahy and Gormally 1998).

Aspect is considered an important factor in the distribution of ground flora (Olivero and Hix 1998). The aspect influences the distribution of ecological groups, probably through its influence on temperature and moisture (Eshaghii Rad and Banj Shafiei 2010). South-facing slopes receive more solar radiation and less precipitation; thus, these factors lead to higher soil temperatures and produce unsuitable conditions for plant growth. Small and McCarthy (2005) also mentioned that the diversity and species richness of south-facing slopes is less than that of northern slopes. Moreover, slope inclination is regarded as one of the most important abiotic factors controlling the pedogenic process on a local scale (McDaniel et al. 1992; Buol et al. 1997). Slope can control the movement of water and material on a hillside and contribute to the spatial differences of soil properties (Tsui et al. 2004). The negative effects of slope on species diversity in the current investigation were obvious, owing to soil erosion, water drainage, and unfavorable conditions for plant growth (Hall 1983). This was consistent with study results obtained in other parts of the Hyrcanian forest (e.g. Hashemi 2010; Esmailzadeh et al. 2012). Nevertheless, *Solanum kieseritzkii*, a shady species in forests, functioned as the dominant species in group II and, like in other studies (Mataji et al. 2010), tended to grow on high-sloped ground.

Ecological species group III, with an indicator woody species of *Carpinus betulus*, represented high species diversity and was located on low slopes with more moisture. Tanács et al. (2007) stated that oak-hornbeam forests were observed on northern slopes. Kavgaci et al. (2011) expressed that species richness is high in the *Carpinus betulus* dominated forest. They also found that this species appears densely on gently inclined slopes.

Barbier et al. (2008) believed that understory plant species have different optimal light requirements. Furthermore, in spaces between the trees and shrubs, light-demanding species and spiny shrubs such as *Crataegus microphylla* and *Mespilus germanica* have been located.

Many species of this group are light-demanding, and as they receive high amounts of light, the herb layer becomes more abundant. Naaf and Wulf (2007) stated that increases in species richness are mainly due to high light. Abrari Vajari et al. (2012) also found a positive correlation between light and species richness in the Hyrcanian forests. Eshaghi Rad et al. (2009), while studying plant species diversity in deciduous forests of Iran, determined that high levels of light at the forest floor in *Querco-Carpinetum*

communities resulted in high density and frequency of ground layer species. Instead, the presence of relatively dense tree species provides suitable habitat conditions for growing shade-demanding plants.

North aspect and low slope were topographic factors which had a positive effect on species diversity. Atalay (2006) also mentioned that biodiversity richness of the north-facing slopes is more than that of the southern slopes. This is in agreement with results obtained in other forest areas (e.g. Kooch et al. 2009; Abedi and Pourbabaei 2010; Hashemi 2010). We observed higher species diversity in lower slopes (group III) in comparison with higher slopes (groups I and II) (Abedi and Pourbabaei 2010). The high species diversity at lower slopes could also be attributed to soil conditions. As Salehi et al. (2007) stated, slope and aspect influence vegetation and soil conditions. Also, Tsui et al. (2004) found that soils accumulate soluble ions from the summit and deposit them on the footslope, where leaching is weaker and soil enrichment is stronger. MacArthur (1965) reported that an increase in productivity may cause a gradual increase in species richness. Nevertheless, soil properties produce favorable conditions for plant growth at this site.

One reason for the higher diversity in group III with *Carpinus betulus* as the dominant species could be due to the higher decomposition rate of *Carpinus betulus* compared to *Fagus orientalis* and thus nutrient availability, tree growth, and long-term site productivity (Cornelissen 1996; Toutain 1987; Prescott et al. 2000).

CONCLUSION

From the current investigation it can be concluded that in comparison with groups I and II, group III had higher diversity indices because of more suitable topographic conditions (i.e. north aspect and higher humidity and slopes less than 15%) in this group. It seems that other topographic, soil and physiographic factors such as land form, parent materials and soil physico-chemical properties also affect vegetation and diversity indices in this area; hence more attention should be paid to soil and anthropogenic factors in future studies. These results also suggest that diversity evaluation can be considered as a complement to the assessment of vegetation, if the main objective of forest managers is to maintain or even increase plant biodiversity in a forest ecosystem.

ACKNOWLEDGEMENTS

This research project was financially supported by the Faculty of Science, Guilan University and research grant of Alireza Naqinezhad in University of Mazandaran, Iran. The authors are indebted to Robabeh Shahi Shavvon for her invaluable assistance in the field studies. Sincere thanks are also due to Prof. John Edmondson from Liverpool Museums, England for his helpful suggestions.

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