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Relationship between broadleaved mixed forest understory species groups with soil and elevation in a semi-arid Persian oak (*Quercus brantii* L.) ecosystem

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ABSTRACT

This research aimed to investigate the relationship between plant composition of Dinarkooh Protected Area (DPA), west of Iran (called Zagros forests) with elevation and soil properties. A total of 100 random sampling plots (25 × 25 m) at different elevations were sampled for their soil and collection of plant specimens and vegetation data based on Braun-Blanquet covered-abundance scale. Data were analyzed using TWINSPAN and multivariate statistical analysis packages. We recognized 142 plant species present in the study area identified under 105 genera and 29 families. Asteraceae, Papilionaceae and Poaceae were the most frequently encountered families. *Bromus* and *Astragalus* were also the largest genera in the study area. The plant species were grouped into three ecological groups based on elevation and soil properties: Group 1 with 20 species including *Scorzonera* sp. and *Cerastium inflatum* L. at lower elevation (1300-1500 m a.s.l.) and with clay-loam soil; Group 2 with 96 species, including *Onosma trachytrichum* Boiss., *Eryngium noeanum* Boiss. and *Acer monspessulanum* L. occurred at middle elevations with alkaline loam-clay soil; and Group 3 with 26 species, including *Bromus sterilis* L., *Minuartia meyeri*, *Minuartia meyeri* (Boiss.) Bornm., *Lithospermum* sp., *Scariola orientalis* (Boiss.) Sojak and *Trifolium tomentosum* L. at higher elevation with sandy-loam soil. Prevalent tree species included Oak (*Quercus brantii* Lindl. var. *persica* (Jaub. & Spach)) in Group 2 and *Acer monspessulanum* L. in Group 3. Low homogeneity of plant compositions at different elevations reflects the differences in habitat properties. Results showed that the elevation and soil properties played primary and complementary roles in vegetation spatial composition. Furthermore, diversity and richness of plant species was higher at middle elevations. More detailed investigation into biotic variables at the root level would complement current data to analyze this ecosystem.

Key words: Zagros forests, Dinarkooh, Ecological species group, Environmental factors, Multivariate analysis.

INTRODUCTION

A wide variety of natural forests from Mediterranean, Euro-Siberia and Irano-Turanian phytogeographic regions exist west of Iran over the Zagros Mountain Ranges (ZMRs) (Sagheb-Talebi *et al.* 2014). Biodiversity of ZMR includes many vegetation type and cover ranges in specific microclimates and elevations (Arekhi *et al*. 2011; Sagheb-Talebi *et al.* 2014). These forests have declined in the past 40 years more rapidly because of overexploitation, natural pests and diseases, fire and desiccation. For example, Dinarkooh protected area (DPA) experienced its hottest days in 2017 as reported by Islamic Republic of Iran Meteorological Organization (IRIMO). Incidents of forest fires frequented more often compared to previous years, hence population of oak trees declined and dried as much as 10% between 2009-2012 (Khansari *et al*. 2016). The study of species diversity and community plant composition provide information on the dynamics and workings of vegetation distribution.

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Also, the concept of ecological species group (ESG) provides valuable information about overall vegetation distribution, common soil characteristics and other variables that are difficult to measure. Zhang & Dong 2010, Adel *et al*. 2013, 2014 and Mirzaei *et al*. 2017 used ESG for describing the relationship between vegetation diversity (Goebel *et al.* 2001; Heydari *et al*. 2017 a) and environmental factors in large geographical scales, such as elevation, temperature and rainfall, as well as in small habitats such as soil factors.
Soil structure and physical properties accommodate water penetration and potential for plant seeds to grow into living and competing components of plant communities (Mc Cune 2006). Soil chemical properties including nutrients, salts and minerals, determine the rate of continuous growth and development of plants. Soil properties also determine the pattern of the rate at which plants can take form (develop their architecture) and function (compete). Furthermore, the chemical property of soil is the result of the kind of vegetation prospering on it (Binkley & Fisher 2012). This dynamic interaction of soil and plant reflects itself in type and extent of vegetation distribution in time (succession) and space (geography) as shown by Nadaf *et al*. 2017 and composition (diversity). For example, hemicriptophytes and cryptophytes replace annual herb species when nitrogen and other soil nutrients are less available (Heydari 2013 a). Soil physical and chemical properties affect plant diversity and evenness diversity indices of vegetation in a semi-arid forest of Zagros region (Salehi *et al*. 2013; Mirzaei & Moradi 2017). Physiography also affects overall biodiversity.
Although, Pourbabaei & Haghgooy 2012 introduced slope as the most important factor affecting diversity and richness of plants, there is no general agreement, however, among researchers on the effects of physiographical features, such as topography and slope (gradient) on plant biodiversity. For example, Razavi *et al.* 2009 reported that elevation had a negative effect on all diversity indices. Conversely, Taleshi & Akbarinia 2011 reported significantly positive correlation between slope, elevation and woody plant richness and diversity indices in the Hyrcanian forests. Hoesseinzade *et al.* 2016 in their study on the relationship of topography and plant biodiversity reported that slope did not affect diversity indices significantly, but elevation classes affected the richness and diversity indices significantly without influencing evenness index.
In recent decades, because of the importance of the Zagros Mountain forests, many aspects of ZMR vegetation, though limited in scale and scope, such as plant biodiversity in terms of soil and climate (Hatami *et al*. 2010; Aghaii *et al.* 2012); physiography (Hosseinzadeh *et al*. 2016); population dynamics and diversity (Shabanian *et al*. 2013; Mirzaei *et al.* 2017), competition, natural history and human impacts (Heydari *et al.* 2017 a, b) have been studied. The common persuasion of all research on ZMR plant biodiversity pointed out the immediate need for biodiversity conservation measures in ZMR forests. Consequently, the Ilam Department of Environment (DOE) designated two new protected areas (including DPA) in the past decade throughout Ilam Province, southwest of Iran. However, regardless of the constant need for collecting and analyzing ecological data in order to be able to establish a correct, coherent and comprehensive opinion on the future of DPA forests, no investigation was funded by DOE. Because of recent increased incidences of forest fires and past overexploitation in the ZMR forests and since, plants, as principal producers of forest ecosystems, are the first organisms to suffer from environmental changes (Dirnbock *et al.* 2002), we investigated the relationship between structural composition, presence features and ecology of the broadleaved mixed forest understory vegetation of a protected region of ZMR forests to provide basic analytical information for vegetation presence both for the present and other similar areas.

MATERIALS AND METHODS

Study area

Dinarkooh protected area (DPA) is a mountainous region located in the coordinates of 32° 54'58" north latitude and 47°17'22" east longitude near Abdanan, Ilam Province, Iran (Fig. 1). Altitude of the study area ranges from 1300 to 1900 m above sea level (asl). Climate of the region is cold in winter and arid in summer according to Emberger's classification. Based on the data from Ilam Meterological Office (2017), the average annual precipitation of the region is 292.2 mm, about 50% in January and February and more as rain. The average annual temperature is 25.6 °C, with an average of 39.1 °C. August is the warmest month, while January, with an average of 12.6 °C, is the coldest one. The average relative humidity in the area is 38.8% with the highest in December, 66.5 %, and lowest in August, 19.5%. The average annual evaporation is 3654.6 mm. Forests of this region are a mixed broadleaf forest type. The dominant canopy species in these forests is Persian oak (*Quercus brantii* Lindl.), also known as Brant’s oak, which is widely distributed across western Asia and the Middle East (Turkey, Iraq,

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Syria and Lebanon) (Heydari *et al.* 2017 b). Average diameter at breadth height (DBH), height and density per ha of oaks are consecutively 60 cm and 8 m for 115 individuals.

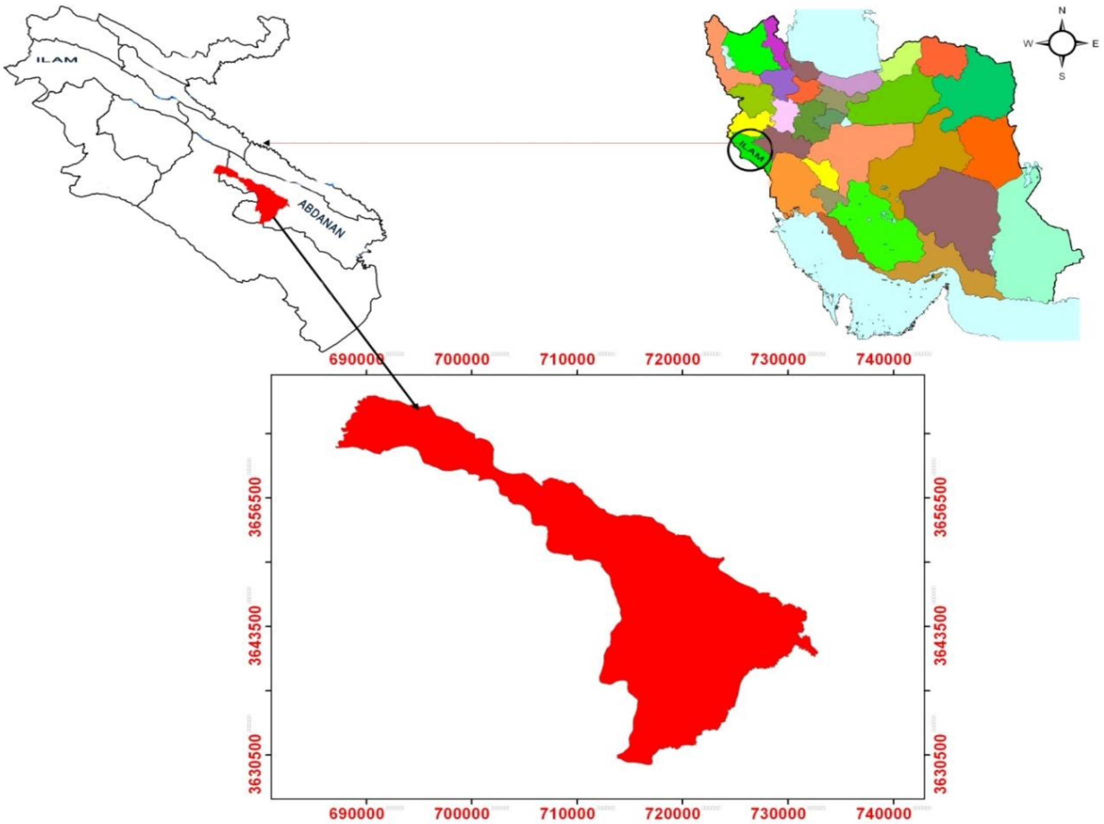

Fig. 1. Study area map: Dinarkooh protected area (Red), Abdanan City, Ilam Province, Iran.

Data collection

At first, we determined homogeneous units (150 × 100 m grid) according to the aspect, slope and elevation, then sampled a total of 100 random sampling plots (25 × 25 m) for soil and plant specimens accordingly. The samples were used for collecting ecological data of vegetation at northern aspect of three different altitudinal sites above sea level with respective gradients as follows: 1300-1500 m (low elevation), 1500-1700 m (middle elevation) and 1700-1900 m (high elevation). Four random sub-plots of 1×1 m within each plot were used to record data of herbaceous species by Braun-Blanquet covered-abundance scale. Three soil samples were taken around the center of each plot and under the layer of leaf litter to a depth of 20 cm. A combined sub-sample was prepared as a representative of the soil of that plot (Maranon *et al*. 1999), transferred to the laboratory, dried exposing to open air and sieved through a 2 mm diameter mesh screen after removing roots, stones and other impurities. The chemical and physical properties of soil were determined by the accredited Shimiyar Soil Laboratory, Tehran, Iran as follows: Soil texture was measured by hydrometric method (Bouyoucos 1962); soil moisture content using weight method (Famiglietti *et al*. 1998). Acidity and soil salinity were also determined using pH meter and electrical conductivity (EC) meter (Kalra & Maynard 1991) respectively. The cation exchange capacity was measured by obtaining soil extract with ammonium chloride solution, washed with ethanol using ICP-AES (Kalra & Maynard 1991). Available phosphorus was measured using Bray and Kurtz (1945) method; total nitrogen by Kjeldahl method (Bremmer & Mulvaney 1982); soluble potassium and magnesium via acetate ammonium extraction method of 1μ with acidity of 7 (Thomas1982); and calcium by titration method. The plant life form was determined for each species found in the study area according to the Raunkiaer (1934) classification scheme.

Data analysis

We analyzed data by TWINSPAN analysis based on the presence of plant species in plots and compared statistically significant differences between plant compositions of groups by multi-response permutation analysis (MRPP) (McCune & Grace 2002). This procedure calculates a T-statistic, a p value, and an A-statistic. Separation

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between groups is described by the T-statistic. The likelihood of reaching the observed difference (T) is evaluated using the p value. The A-statistic estimates within-group homogeneity compared to what is expected by chance, with A = 1 in completely identical plots and A = 0 in those communities equal to chance expectation. The Sørenson (Bray–Curtis) dissimilarity index was used during these tests (McCune & Mefford 1999). We used PAST software for calculating biodiversity indices of each group (Hammer 2001) and performed Spearman's correlation coefficients test between explanatory variables using SPSS (Version 24). We analyzed relationships between species and environmental factors using Canonical Correspondence Analysis (CCA) (McGarigal *et al*. 2000) and also One-Way Analysis of Variance to test the differences between the values of physiographic and soil characteristics among the groups at 95% probability level as well as Duncan's multi-range test to compare the means. Further data analysis was performed via SPSS (version 24) and PC-ORD software (McCune 2006).

RESULTS

Plant species

One hundred and forty two plant species belonging to 105 genera and 29 families were identified in the study area (Table 1). Asteraceae, Papilionaceae, Poaceae and Lamiaceae exhibited greater richness, respectively and comprised 50% of the total species number. Astragalus and Bromus were present with 7 and 5 species followed by Centaurea and Trifolium, each with 4 species, respectively. These plant species differed in their occurrence pattern along the elevation. Oaks displayed signs of declining climax state in only one disturbed and altered station due to soil erosion at 1800 m above sea level. They were uniformly distanced and almost equal in size and dimensions, healthy with an average height of about 8 m tall as well as DBH of 60 cm and had no sprouts or seedlings. Soil was washed off under canopy and there was not any understory vegetation. TWINSPAN analysis of all plant species yielded three final ecological species groups (Fig. 2). Group 1 with 20 species including *Scorzonera* sp. and *Cerastium inflatum* as indicator species occurring in 50% of the sampling plots; Group 2 with 96 species, including *Onosma trachytrichum* Boiss, *Eryngium noeanum* Boiss and *Acer monspessulanum* occurring as indicator species in 30% of the sampling plots; and Group 3 with 26 species, including *Bromus strilis, Minuartia meyeri*, *Lithospermum* sp., *Scariola orientalis* and *Trifolium tomentosum* as indicator species in this group in 20% of sampling plots (Fig. 2). Results indicated that few species, such as *Adonis* sp., *Bromus sericeus* Drobov, *Chaerophyllum* sp., *Eremopoa persica* (Trin) Roshev var. *persica*, and *Holosteum umbellatum* L. were observed exclusively in higher elevation ranges (1700-1900 m asl). Many species including, *Ornithogalum persicum* Hausskn. ex Bornm, *Taeniatherum crinitum* (Schreb.) Nevski and *Ferula behbodiana* exhibited sparse dispersion along slopes and other species such as *Trifolium resupinatum* L., *Poa bulbusa* L., *Bromus fasciculatus* Preslvar., occurred along the slope 1300 -1900 m. Results also indicated that the number of species in each group varied altogether: the number of species were 96, 20 and 26 for Groups 2, 1 and 3 respectively (Table 1). TWINSPAN analysis on 100 sample plots in the study area showed 2 subgroups each with different numbers of species (Fig. 2).

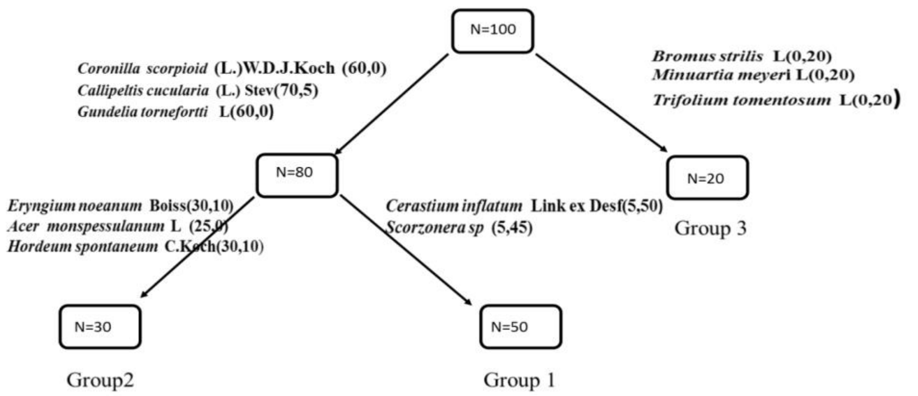

Fig. 2. Diagram of TWINSPAN analysis on 100 sample plots in the study area (Numbers into the parenthesis show the presence of each species in the left and right subgroups).

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Table 1. List of plant species in ecological groups of DPA.

Group 1: *Astragalus* (*caprini*) *adulterinus* Podlech, *Astragalus* sp., *Bromus fasciculatus* Presl var. *alexandrines*, *Bromus tectorum* L., *Cerastium inflatum* Link ex Desf, *Cirsium* sp., *Echinaria capitata* (L.) Desf, *Ephorbia macroclada* Boiss, *Ferula behbodiana* (Rech. f. & Esfand.), *Helianthemum salicifolium* (L.) Miller, *Heteranthelium piliferum* (Banks & Solands) Hochst, *Hordeum bulbosa* L., *Hypericum helianthemoides* (Spach) Boiss, *Pimpinella* sp., *Scabiosa palaestina* L., *Scorzonera* sp., *Scrophularia striata* Boiss, *Siebera nana* (DC) Bornm, *Tragopogon* sp., *Zoegea leptaurea* L.

Group 2: *Achillea wilhelmsii* C.Koch, *Acinus graveolens* (M.B.) Link, *Aegilops umbellulata* Zhuk, *Allium* sp., *Anagalis arvensis* L, *Arenaria* sp., *Asperula glomerata* (M.B.) Griseb, *Astragalus fasicolifolius* Boiss, *Astragalus* (*campylanthus*) *ecbatanus* Bunge, *Astragalus* (*caprini*) *ovinus* Boiss, *Astragalus* (*caprini*) *bicinus* Boiss & Hausskn, *Astragalus* (*incani*) sp., *Bromus danthoniae* Trin, *Bunium luristanicum* Rech. f., *Bunium microcarpum* (Boiss.) Freyn & Bornm, *Callipeltis cucularia* (L.)Stev, *Cardaria draba* (L.)Desv, *Carthamus oxyacantha* M.B, *Centaurea bruguieriana* (DC.)Hand.-Mzt, *Centaurea depressa* M.B, *Centaurea elymaitica* Mozaff. sp. nov., *Centaurea virgata* Lam, *Cephalaria syriaca* (L.) Schrad, *Ceratocephalus falcate* (L.) Pers., *Chardinia orientalis* (L.) O. Kuntze, *Colchicum speciosum* steven, *Coronilla scorpioides* (L.) W.D.J. Koch, *Corydalis verticillaris* DC, *Cotoneaster lurstanicus* Klotz, *Cousinia cylindracea* Boiss, *Cousinia jacobsii* Rech.f., *Crataegus asarulus* L, *Crupina crupinastrum* (Moris)Vis, , *Echinops quercetorum* Mozaff. sp. nov, *Echinops kermanshahanicus* Mozaffarian, *Echinops* sp., *Eryngium noeanum* Boiss, *Euphorbia denticulate* Lam, *Euphorbia* sp., *Fritillaria zogrica* Staf, *Galium* sp., *Geranium tuberosum* L, *Gladiolus atroviolaceus* Boiss, *Gundelia tournefortii* L., *Haplophyllum buxbaumii* Boiss, *Lactuca* sp., *Lagoecia cuminoides* L, *Lamium amplexicaule* L., *Lappula sessiliflora* (Boiss.) Gurke, *Lens orientalis* (Boiss.) Hand. Mzt., *Linum mucronatum* Bertol. Subsp. *mucronatum*, *Lophchloa phleoides* (Vill.) Reichenb, *Malabaila porphyrodiscus* Stapf & Wettst, *Marrubium cuneatum* Russel, *Medicago radiate* L., *Onosma* sp., *Onosma* Boiss, *Ornithogalum persicum* Hausskn. ex. Bornm, *Outreya carduiformis* Jaub. & Spach, *Papaver dubium* L., *trachytrichum*, *Parentucellia latifolia* (L.) Caruel, *Phlomis* sp., *Picnomon acarna* (L.) Cass, *Poa bulbosa* L., *Quercus brantii* Lindl. var. *persica* (Jaub. & Spach), *Reseda lutea* L., *Roemeria refracta* DC, *Scandix stellata* Banks & Soland, *Scleanthus orientalis* Rossler, *Scorpiurus muricatus* L, *Scorzonera calyculata* Boiss, *Scrophularia* sp., *Senecio glaucus* L., *Silene conoidea* L., *Silene* sp., *Solenathus circinnatus* Ledeb, *Taeniatherum crinitum* (Schreb.) Nevski, *Teucrium oliverianum* Gingins, *Teucrium polium* L., *Torilis leptophylla* (L.) Reichenb, *Tragopogon longisostris* Bisch, *Trifolium resupinatum* L., *Hordeum spontaneum* C. Koch *Trigonella spruneriana* Boiss, *Tulipa cystola* L, *Valerianella oxyrrhyncha* Fisch. & C.A. Mey, *Valerianella vesicaria* (L.), Moench, *Vicia sativa* L., *Viola modesta* Feenzl, *Vulpia myurus* (L.) C.C. Gmelin, *Ziziphora capitata* L., *Lathyrus macropus* Hook & Arn, *Onoberchis caputgali* (L.) Lam, *Trigonella monantha* C.A. Mey, *Medicago orbicularis* (L.)

Group 3: *Acer monspessulanum* L., *Adonis* sp., *Anthemis hussknechtii* Boiss & Reut, *Anthemis* sp., *Bromus sericeus* Drobov, *Bromus strilis* L., *Ceracus microcarpa* (C.A. Mey.) Vis, *Chaerophyllum* sp., *Crepis sancta* (L.) Babocok, *Cymbolaena griffithii* (A. Gray) Wagenitz, *Eremopoa persica* (Trin.) Roshev. var. *persica*, *Erysimum* sp., *Ficaria kochii* (Ledeb.) Iranshahr & Rech.f., *Gladiolus* sp., *Holosteum umbellatum* L., *Hypericum* sp., *Lithospermum arvense* L., *Lithospermum* sp., *Minuartia meyeri* L., *Scariola orientalis* (Boiss.) Gurke, *Stachys benthamiana* Boiss, *Trifolium campestre* Schreb, *Trifolium purpureum* Loisel. var. *purpureum*, *Trifolium tomentosum* L., *Turgenia latifolia* (L.) Hoffin, *Vaccaria grandiflora* (Fisch. & DC.) Jaub. & Spach.

All plant life forms (cryptophytes or geophytes, 14 species, hemicryptophytes, 48 species, chaemophytes, 11 species, therophytes, 64 species and phanerophytes, 5 species) occurred in the study area. Percentages of therophytes and hemicryptophytes were the highest in all groups (79% combined), while phanerophytes and geophytes (combined 10-11%) exhibited the lowest percentage (number) of species (Fig. 3).

Comparison of the plant composition of TWINSPAN groups by MRPP

Based on MRPP, all TWINSPAN groups (Fig. 2) have significant differences in their plant composition and therefore, cannot be integrated. In addition, based on T statistic, between-group plant composition differences were in the following order: Groups 1 and 3 > Groups 1 and 2 > Groups 2 and 3. Furthermore, small values of statistics A indicated low homogeneity among groups (Table 2).

Table 2. Result of MRPP based on vegetation composition.

Groups	Statistics T A	Observed Δ	Expected Δ	Statistics A	P
3,1	-4.91	36.49	49.46	0.262	0.001
3, 2	-2.86	38.28	50.98	0.249	0.011
1, 2	-3.07	52.08	60.27	0.135	0.011

Statistic T describes the differences between Groups, Statistic A describes within- group homogeneity.

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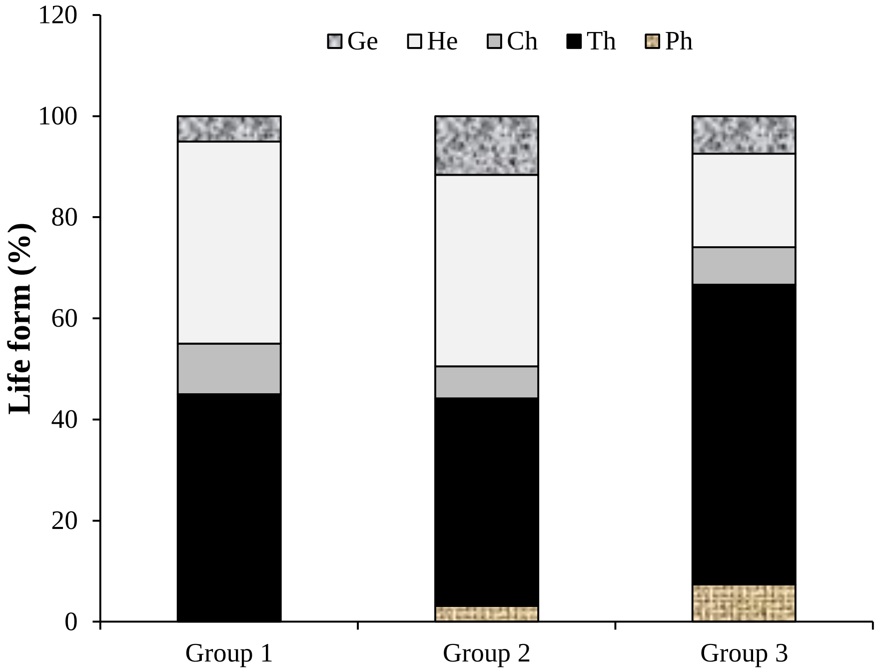

Fig. 3. Stacked within group percentages of life forms of vegetation at DPA in 2017. Abbreviation of life forms: Ge: Geophyte, He: Hemicryptophyte, Ch: Chamophyte, Th: Therophyte, Ph: Phanerophyte.

ANOVA analysis

The results of One-Way Analysis of Variance (ANOVA) showed a significant difference between the three ecological groups in the study area for soil sand, calcium and phosphorus contents, soil salinity as well as wetness and elevation (Table 3). Soil texture was almost similar for their contents of silt and clay at different elevations, but differed in the content of sand. Soil type for lower elevation was clay-loam, for middle was loam –clay and for upper was sandy- clay-loam (Table 3).

Generally, there were not significant differences in the nutrient contents of N, P, K, Ca and Mg in lower to mid-elevations, while differences became relatively significant at the upper elevation. N, K, Ca and Mg contents of soil demonstrated similar trends against elevation (Table 3). Results also indicated that ecological indices of richness, diversity and evenness were increasingly greater at mid-elevation, while declined in upper elevation.

Relationships between plant compositions and topographic and soil properties

Results of CCA correlation between topography and soil properties and also vegetation groups are shown in Table 4. The first and second axes showed the greatest eigenvalues (0.58 and 0.46, respectively). Based on these results, Group 1 exhibits a positive correlation with axis 1 while a negative correlation with axis 2 in terms of soil moisture content. Soil clay and cation exchange capacity are the determining factors for this group which occurred mostly in slopes. Group 2 displays a positive correlation with both axes 1 and 2 and soil pH. Group 3 reveals a positive correlation with axis 1 (soil P and silt contents) and axis 2 in terms of elevation above the sea level (Fig. 4).

Results of Spearman's correlation between diversity indices and environmental factors

Correlations between environmental factors and richness, evenness and Shannon diversity indices are shown in Table 5. Richness was positively correlated with EC and P, while negatively with elevation. In addition, Spearman's correlation analysis exhibited strong positive correlations between Shannon diversity and elevation as well as EC. Evenness was positively correlated with EC and pH while negatively with slope.

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Table 3. The environmental variables and diversity indices between ecological species groups in the study area (Data are mean ± SE).

Variable	Group 1 1300-1500	Group 2 1500-1700	Group 3 1700-1900	Significance
Ca (Meq l^{-1})	21.81 ± 1.95[a]	18.49 ± 4.76[a]	2.06 ± 0.00[b]	0.009**
Mg (Meq l^{-1})	2.95 ± 0.307[a]	3.07 ± 0.365[a]	2.41± 0.00[b]	0.459
K (Meq l^{-1})	1.79 ± 0.158[b]	1.65 ± 0.146[b]	2.31 ± 0.00[a]	0.044**
P (Meq l^{-1})	6.57 ± 1.02[a]	5.94 ± 0.033[b]	6.70 ± 0.00[a]	0.731
N (Meq l^{-1})	0.076 ±0.015[b]	0.090 ± 0.046[b]	0.300 ± 0.00[a]	0.14
Ec (d.s m^{-1})	282 ± 6.92[a]	189 ± 10.25 [b]	163 ± 0.00[b]	0.000**
pH	7.18 ± 0.029[a]	7.22 ± 0.163[a]	7.10 ± 0.00[b]	0.140
% Soil moisture	0.158 ± 0.007[b]	0.150 ± 0.002[b]	0.190 ± 0.00[a]	0.001**
Slope%	21.25 ± 6.59[a]	19.37 ±4.85[b]	17.50 ± 6.29[c]	0.924
Sand%	18.26 ± 0.652[c]	22.5 ± 1.32[b]	34 ± 0.00[a]	0.000**
Silt%	40.62 ±1.33[a]	40.12 ± 3.22[a]	34 ± 0.00[b]	0.224
Clay%	40.12 ± 1.27[a]	37.12 ± 1.87[a]	33 ± 0.00[b]	0.036**
Shannon diversity index	0.426 ± 0.001[b]	0.77 ± 0.001[a]	0.680 ± 0.001[b]	0.02**
Species richness R=S	2.21 ± 0.30[c]	4.38 ± 0.30[a]	3.10 ± 0.30[b]	0.001**
Evenness e^H/S	0.0817 ± 0.006[b]	0.217 ± 0.006[a]	0.084 ± 0.006[b]	0.02**

Within rows, means with the same letters do not significantly differ ($P < 0.05$), based on Duncan test; ** Significant difference between means at the $\alpha = 0.05$ level.

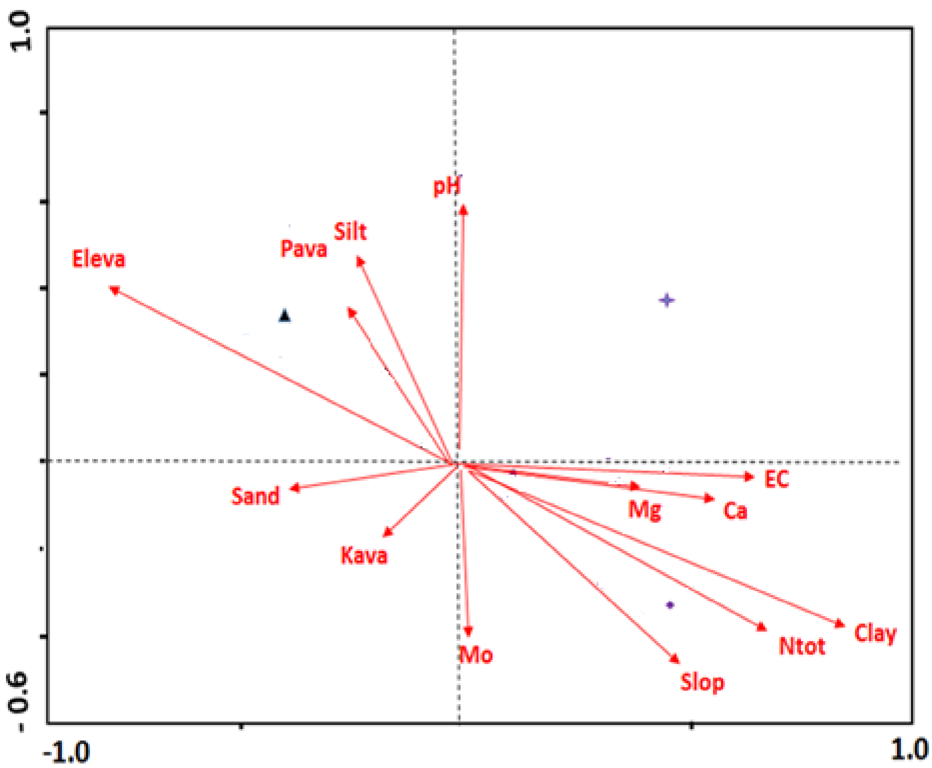

Fig .4. Ordination diagram showing the result of CCA analysis of vegetation and topographic and soil properties in the study area. Abbreviation of vegetation and environment variables: Eleva = Elevation, Pava = Phosphorus available, Kava = Potassium available, MO = moisture, Ntot = Total nitrogen, ◆ = Gorup 1, ✦ = Group 2, ▲ = Group 3.

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Table 4. CCA correlation matrix of the environmental factors in the study area.

Environmental factors	AXIS 1	AXIS 2
Ca (Meq L^{-1})	0.38*	-0.24^{ns}
Mg (Meq L^{-1})	0.33*	-0.36*
K (Meq L^{-1})	-0.35*	-0.37*
P (Meq L^{-1})	0.30*	0.51**
N (Meq L^{-1})	0.32*	-0.37*
Ec (ds m^{-1})	0.72**	-0.25^{ns}
pH	*0.88***	0.05^{ns}
Moisture	0.05^{ns}	-0.89**
Clay (%)	0.54**	-0.46**
Sand (%)	-0.67**	-0.07^{ns}
Silt (%)	0.35	0.64
Elevation	0.56**	0.47**
Slope (%)	0.5^{ns}	0.4^{ns}
Eigenvalue	*0.58*	0.46
Rate of variance explained (%)	30.40	27.60
Rate of cumulative explained (%)	30.40	58.00

Table 5. Spearman's correlation between environmental variables and ecological indices at DPA, 2017.

	Environmental variable				
Indices	Elevation	Slope	EC (d.s/m)	pH	P
Richness	-0.587**	ns	0.582**	ns	0.482*
Evenness	ns	-0.495*	0.457*	0.597**	ns
Shannon diversity	0.474*	ns	0.556*	ns	ns

*: p ≤ 0.05, **: p ≤ 0.01, ns: no significance.

DISCUSSION

Results of vegetation data of 142 plant species in DPA woodland showed the inherently dynamic interaction of plant species with elevation and soil factors as different between ecological groups with different species compositions and different environmental properties. In this study, elevation affected plant biodiversity as three separate plant groups were identified as follows: Group 1 with 20 species which occurs in lower elevations, Group 2 with 96 species in the middle and Group 3 with 26 species in the upper ones. Spearman's correlation confirmed the moderate effects of soil texture and EC as well as elevation on plant composition. Soil texture, soil cation exchange capacity and EC proportionally played a greater role in plant occurrence. Furthermore, slope exhibited greater correlation with the occurrence of plant species. Other authors (Mirzaei *et al*. 2008; Kouva *et al.* 2014) reported similar findings and indicated that suitable habitat conditions, such as soil in mid-elevations contribute to widespread species occurrence and richness in woodland areas. In the present study, CCA analysis of data revealed that the elevation is the most determining environmental factor in the separation of species belonged to Group 3 from those of other ecological plant groups, a finding reported by other authors as well (Pinke *et al*. 2010; Esmailzade *et al*. 2011; Adel *et al*. 2014). Greater presence of phanerophytes in the middle and upper elevations (Groups 2 and 3), while less frequent in the lower elevations (Group 1). As well as greater occurrence of therophytes and hemichryptophytes indicate their adaptation for living under harsh climatic conditions, such as greater differences in seasonal temperature extremes and fluctuations in precipitation (winter time) as well as

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evaporation rates (summer time). Prevalence of therophytes at DPA is in agreement with findings of Fallah *et al*. (2012) who reported short- term growth season, low precipitation and high evaporation (cause of local droughts) during recent years in ZMR forests. Therophytes are usually found in dry and semiarid regions such as DPA and also disturbed areas, primarily because of their shorter life cycle, low tolerance threshold against heat coinciding with seasonal temperature rise (Heydari *et al*. 2013 b) along with adaptations for absorbing water at depth (Erfanzadeh *et al*. 2010; Esmailzadeh *et al*. 2011). Lower homogeneity and greater heterogeneity of plant compositions show the differences in habitat properties. Lower species richness and sprouting of exclusive broadleaf tree species in the stations may be due to global warming favoring annuals and habitat degradation, such as soil erosion and increased human activity impacting tree species negatively (Barbero *et al.* 1990; García-Valdés *et al*. 2015). Comparing richness of chamaeophytes and phanerophytes within each group indicates that these life forms, commonly adapted for cold mountain climate, are most likely to become vulnerable to warmer climate change. Majority of plant species in Group 3 grow in lower banks of the hillsides and less steep grounds with greater sand content. Sandy soil is appropriate habitat for its well-oxygenated property (Arekhi *et al*. 2011). Commonly, higher elevation soils contain more sand, whereas silt and clay are deposited in ditches or washed off downhill to lower ground. Our results exhibit that soil in study area contains more sand in higher elevations, while silt and clay occur more frequently in middle and lower elevations, respectively (Table 3).

In addition, our results indicated that the chemical properties, such as pH and EC of soil also affect plant composition and distribution as indicated by Spearman's correlation analysis. Species in Group 1, however, occupied clay soils with greater EC and cation exchange capacity while those of Group 2 revealed positive correlation with axis 2 in terms of pH in CCA analysis. The soil pH significantly influences the nutrition availability to the point that it can isolate plant groups and alter nutrients balance (Mataji *et al.* 2007). Although, in our study, P contents of soils showed some difference. It seems that the moisture, clay and silt contents in the rhizosphere might have played a greater role in root aeration and nutrient availability (Tables 3 and 4). Aghaii *et al*. 2012 and Pourbabaii *et al*. 2014 illustrated the role of phosphorus in the dispersion of plant species. In the present study, however, plant distribution correlated weak-moderate with P content in soil. Although plants in Group 3 exhibited greater preference (affinity) for this element (Table 3). Lower quantity of P in middle elevations (Table 3) indicates greater within- and between- species competition for P in Group 2 with 96 species among all vegetation forms. Phosphorus plays an important role in plants nutrition. So that, its concentration and availability is essential for plants (Zare-maivan 2013, Adel 2014). Usually, in wooded habitats and forests, plants develop mycorrhizal associations to compensate their needs to this element. Greater number of species in Group 2 reveals greater need for P, and thus greater need for mycorrhizal symbiosis (Zare-Maivan 2013), a finding supported by the study of Mirzaei & Moradi 2017 on the relationships between flora biodiversity, soil physicochemical properties and mycorrhizal fungi. Although, competitor cations in soil, Mg and Ca are both needed for proper functioning of plants, any change in Mg/Ca ratio in soil would affect soil solute potential and cation exchange capacity rendering stressed leaves an impact on the functioning of plant roots, though at different rates on each plant species (Pourbabaei *et al.* 2015). CCA analysis, which analyzes the direct correlation (regression) of vegetation (groups) with all environmental factors, displayed the moderately positive correlation (preference) of plant species in Group 1 for N, Ca and Mg, and Group 3 for P, while Group 2 exhibited negative correlation with K (Fig. 3). K is a cation that exacerbates the action of carbonates in the bedrock and the amount of which is reduced under dry conditions. Therefore, it affects plant transpiration rate negatively and increases its resistance to drought (Mataji *et al*. 2010). It also influences soil texture and soil matrix as well as solute potentials, including a change in salinity and EC particularly in soils with greater clay content. In addition, potential for cation and anion accumulations is increased (Jayawickreme *et al.* 2011) which, in turn, renders nutrient absorption more selective for plant roots. Results indicate that plants in Groups 1 and 2 were more responsive to EC than plants in Group 3 which occupied a higher elevation with eroded soil downhill. However, species of *Quercus brantii* Lindl. var. *persica* (Jaub & Spach), though present in all elevations, prevailed at mid-elevation, while *Acer monspessulanum* L at higher ones. The canopy of trees, such as oak and maple increase the forest litter (Pourbabaei *et al.* 2011), creates greater soil porosity and a continuous flow of the nutrients cycling, enriches soil fertility (Heydari *et al.* 2013 b) and also accommodates further activity of microorganisms and mycorrhizal fungi. These are evident in Group 2 (mid-elevation) in which greater vegetation composition and species richness occurred (Table 5). ANOVA analysis revealed significant differences between vegetation groups in terms of diversity indices. Richness, evenness, and diversity index were significantly higher in the middle-elevation (group 2) than other elevations (groups).

According to Durak 2012, greater species richness and diversity occur in middle elevation and reduces as elevation increases. Results of T statistic of MRPP show the higher differences which occurred between Groups 1 and 3, 1 and 2, and also 2 and 3, respectively. Findings of the present study are in line with those of Rostamikia 2010 and Hatami 2010 who indicated the limiting impacts of elevation on the vegetation distribution and species diversity in Zagros forests up to 1800 m, while above this elevation, species diversity was reduced. Researchers used indices of richness and diversity to establish biodiversity patterns based on elevation (Fossa 2004) or other environmental variables (Naqinezhad *et al*. 2008; Aghaii *et al*. 2012; Adel *et al*. 2014; Mirzaei & Karami 2015; Khansari *et al*. 2016; Fattahi *et al.* 2017). Our study are also in line with the argument of Pang *et al*. 2011 and Durak 2012 who believe that study of communities and individuals provides a better understanding of the relationships between the vegetation and environment by classifying into ecological groups in comparison with the study of species individually. However, it is realized that other criteria, such as species turnover rate and sudden drastic shifts in environmental variables, both in magnitude and scope, must be incorporated in the further ecosystem management planning or simulation modeling activity. Our Results provided novel analytical data about vegetation component of DPA in relation to elevation and soil factors in specific and compliment overall information on Zagros forests of Iran to date.

CONCLUSION

Relationship between broadleaved mixed forest understory species groups of the semi-arid Mediterranean oak forest with soil and elevation were examined at Dinarkooh Protected Area for the first time. Results of this study provide novel analytical data about vegetation component of DPA in relation to elevation and soil factors in specific and compliment body of information on Zagros forests of Iran to date. Results showed that the elevation and soil properties played primary and complementary roles in vegetation spatial composition, respectively. Although, diversity and richness of plant species was higher at middle elevations. More detailed investigation into microhabitat at the root level, particularly for the effects of biotic variables, would yield broader information.

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رابطه بین گروه گونه‌های زیر اشکوب جنگل‌های پهن برگ آمیخته با خصوصیات خاک و ارتفاع از سطح دریا در اکوسیستم نیمه خشک بلوط ایرانی (*Quercus brantii* L.)

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چکیده

هدف این تحقیق بررسی ارتباط بین ترکیب گیاهی با خصوصیات خاک و ارتفاع از سطح دریا در منطقه حفاظت شده دینارکوه در غرب ایران (معروف به جنگل‌های زاگرس) است. در مجموع به صورت تصادفی صد قطعه نمونه (۲۵×۲۵ متر) در ارتفاعات مختلف برای برداشت نمونه‌های خاک و پوشش گیاهی بر مبنای معیار براون بلانکه پیاده شد. داده‌ها با استفاده از تحلیل دو طرفه گونه‌های شاخص (TWINSPAN) و آنالیز چند متغیره تجزیه و تحلیل شدند. در مجموع ۱۴۲ گونه در منطقه مورد مطالعه شناسایی شد که متعلق به ۱۰۵ جنس و ۲۹ خانواده بودند. بر این اساس Asteraceae، Papilionaceae و Poaceae خانواده‌های غالب این منطقه بودند. همچنین *Bromus* و *Astragalus* بزرگ‌ترین جنس‌ها در منطقه مورد مطالعه بودند. گونه‌های گیاهی در سه گروه بوم‌شناختی بر اساس ارتفاع و عوامل خاک قرار گرفتند: گروه اول با ۲۰ گونه از قبیل *Scorzonera* sp. و *Cerastium inflatum* L. در ارتفاع از سطح دریای پایین‌تر (۱۵۰۰-۱۳۰۰) و با خاک رسی-لومی، گروه ۲ با ۹۶ گونه شامل *Onosma trachytrichum* Boiss. *Eryngium noeanum* Boiss. و *Acer monspessulanum* L. در ارتفاع میانی در خاک قلیایی با بافت لومی-رسی و گروه ۳ با ۲۶ گونه شامل *Bromus sterilis L.*, *Minuartia meyeri*, *Minuartia meyeri* (Boiss.) Bornm. *Lithospermum* sp., *Scariola orientalis* (Boiss.) Sojak و *Trifolium tomentosum* L. در ارتفاع بالا با خاک شنی-لومی قرار داشتند. گونه‌های غالب درختی شامل بلوط ایرانی (*Quercus brantii* Lindl.) در گروه دوم و *Acer monspessulanum* L. در گروه سوم حضور داشتند. همگنی پایین ترکیب گیاهی در رویشگاه‌ها، منعکس کننده تفاوت در ویژگی‌های رویشگاهی است. نتایج نشان داد که ارتفاع از سطح دریا و خصوصیات خاک نقش اصلی و مکمل را در ترکیب پوشش گیاهی ایفا کرده‌اند. همچنین نتایج نشان داد که تنوع و غنای گونه‌های گیاهی در ارتفاع میانی بیشتر بود. تحقیقات تفصیلی با توجه به دیگر خصوصیات محیطی و زیست شناختی می‌تواند تحلیل بهتری از عملکرد این بوم سازگان ارائه دهد.

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