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Vegetation-environment relationship in the birch (*Betula pendula* Roth.) site in the mountainous riparian forests of Marmisho valley

Javad Eshaghi Rad[1*], Ahmad Alijanpour[2] and Rouhollah Rostami[3]

[1] Prof., Dept. of Forestry, Faculty of Natural Resources, Urmia University, Urmia,I. R. Iran
[2]Associate Prof., Dept. of Forestry, Faculty of Natural Resources, Urmia University, Urmia,I. R. Iran
[3] Ph.D. Student of Forestry, Dept. of Forestry, Faculty of Natural Resources, Urmia University, Urmia,I. R. Iran

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Abstract
Marmisho valley, located in the north-western Iran, encompasses high species diversity and a unique habitat for birch stands (*Betula pendula* Roth.). This study was carried out to investigate the vegetation-environment relationship in this area and also to determine the most important environmental factors affecting species distribution with emphasis on the birch species distribution. 30 sample plots were implemented using a random sampling method with a grid size of 200 × 100 m. At each sampling point, 400 m^2 and 100 m^2 were set up respectively for recording the cover-abundance of woody species and herbaceous species. Also at the center, a soil sample was taken from 0-30 cm depth of mineral soil. As a result, 251 taxa were observed in Marmisho valley. The results of cluster analysis illustrated that sampling plots were respectively divided into three and five ecological groups based on woody and herbaceous species composition, in which significant differences between different ecological groups were approved by MRPP analysis. In addition, DCA indicated that soil texture and soil pH had the most influence on the distribution of ecological groups in the region. Marmisho valley encompasses high level of plant diversity. Therefore, we need urgent forest management strategies such as protective plan to conserve the region.

Keywords: Ecological group, Forest ecosystem, Plant composition, Soil, Iran.

1. Introduction
By studying the vegetation and its relationships with environmental factors such as physiography, soil and climate, it is possible to understand the stability of plant communities. One of the most important factors in determining and evaluating the status of vegetation in a forest ecosystem is its soil properties which is a crucial part of forest ecosystems and thus enhances the quality of biodiversity (Kooch et al., 2010). Also, physiographic factors play an important role in the distribution of plant species and their diversity by affecting soil moisture and soil chemical components (Enright et al., 2005). Generally, there is a strong relationship between soil and vegetation (Kepfer-Rojas et al., 2019) and this is an important and practical issue in terms of development and rehabilitation of forest communities (Rikhari et al., 1991). Species with a limited ecological range are known as representative for having the ability to predict environmental conditions, especially in local conditions with local scale (Small et al., 2005; Saberi et al., 2021). Furthermore, plant species that form an ecological group, which is defined as co-occurring species exhibiting similar environmental affinities, should exhibit similar relationships to environmental factors which lead to the identification of environmental gradients affecting species distribution (Abella & Covington, 2006). Ecological groups are comprised of plants that occur together under certain combinations of site factors. They are species that are perceived to have similar

∗Corresponding author Tel: +984432770489 Email: j.eshagh@urmia.ac.ir

ecological requirements and tolerances (Gabor et al., 2019).

In this regard, vegetation classification for recognition of ecological group is done to separate heterogeneous vegetation data into more homogeneous groups to make the study of vegetation easier (Eshaghi Rad et al., 2008).In this context, numerous studies have been carried out on the flora of different regions to classify the vegetation and its relationships with environmental variables. In coniferous forests, Abella & Shelburne (2006) classified plant communities of *Pinus ponderosa* (Dougl.) Lawson in Arizona and recognized 18 ecological groups in the region. Also, Souza et al. (2014) conducted a study to classify vegetation in subtropical mixed forests of southern Braziln and seven ecological groups were proposed according to altitude gradient. Abdel Khalik et al. (2013) studied the plant composition in the Al-Noman region in Saudi Arabia, resulted in identification of four ecological groups.

Recently, Liang & Wei (2020) examined the relationships between forest structure, plant diversity, and soil properties at three different soil depths in the mountainous region of northern China. They stated that the diversity of plant species decreased with decreasing soil depth.

Many researches have been carried out on the flora of different regions of Iran to classify the vegetation and its relationships with environmental variables. Arekhi et al. (2010) studied the relationship between environmental variables and oak associations in the Zagros forests (Ilam province) and as a result, five ecological groups were separated and the distribution of vegetation types in this region strongly correlated with altitude and some soil properties such as organic carbon, nitrogen soil. Also, Adel et al. (2014) investigated the relationship between environmental factors and plant species of beech forests (Guilan province) in northern Iran. The most effective environmental variables associated on the distribution of six ecological groups in this region were altitude, slope, aspect, pH, C, N, P, and C/N ratio. Furthermore, Bazdid Vahdati et al. (2017) found similar effective environmental variables, explaining the distribution of three ecological groups in this region.

Marmisho valley, located in the north-western Iran, encompasses high species diversity and a unique habitat for birch species (*Betula pendula* Roth.) (Eshaghi Rad et al., 2019). The birch family, Betulaceae, contains trees and shrubs that are an ecologically and economically important component of temperate and boreal forests of the northern Hemisphere (Schenk et al., 2008). Relationships between vegetation and environment in birch site in the mountainous riparian forests have not been studied so far. Therefore, the purpose of this study was to classify the vegetation of this high diverse area to identify ecological groups and to determine the most important environmental factors (physiographic and soil) affecting the distribution of species.

2. Materials and methods:

2.1 Study area

Marmisho riparian forests with an area of 60 ha, located in the northwestern of Iran (Figure 1). (Longitude: 34º 37′ 29″- 37º 36′ 88″ N; Latitude: 44º 36′ 80″- 44º 42′ 12″ E). The average annual rainfall is 367 mm. The highest average annual temperature is 33.1 °C, the lowest average temperature is -15.5 °C, and the average frost days are 119 days in a year. The elevation ranged from 1600 to 1800 m a.s.l. with a slope percentage of 30-60%.

Figure 1. A photo of studied forests.

2.2. Vegetation and soil sampling

30 sample plots were taken using systematic random sampling method with 200 m × 100 m grid. At each point, 400 m^2 (20×20m) sample

plots was considered for woody species in overstory stratum. Also, in the center of each main plot, a 100 m^2 (10 ×10 m) subplot was set up to sample all vascular herbaceous species (and also seedling and sapling < 0.5 m in height).

In each plot, the abundance and cover of species was estimated by Van der Maarel scale (Van der Maarel, 1979). Plant species were identified using the color flora of Iran (Ghahraman, 1979-2008), flora of Iran (Assadi, 1998-2021) and Flora Iranica (Rechinger, 1963-2012). Soil samples were taken from a depth of 0–30 cm from the mineral soil at each sampling point (Molder et al., 2014). Some physico-chemical soil properties were measured including: soil pH by pH meter, soil texture by hydrometer method, available phosphorus (mg/kg) by Olsen method, exchangeable potassium (mg/kg) by flame photometric method, total nitrogen (N) using the Kjeldahl method and organic carbon content (C) was measured using Walkley and Black method (Neatraur et al., 2005).

2.3. Data analysis

Before data analysis, species with less than 5% frequency were excluded from the species matrix and the matrix of soil physical and chemical variables was standardized to mean 0 and variance 1 prior to ordination. Cluster analysis was used to recognize the ecological groups based on woody and herbaceous data using Sorensen distance measurement and flexible-β linkage method (β = -0.25). In addition, Multi-response Permutation Procedure (MRPP) was used to test the significance difference in species composition between recognized ecological groups in the species space (McCune & Mefford, 1999). Furthermore, we conducted the indicator species analysis as well as Monte Carlo test considering all sampling plots to identify the indicator species for both woody and herbaceous ecological groups which were previously determined by cluster analysis. For ordination of sampling plots, Detrended Correspondence Analysis (DCA) was applied to assess the rate and direction of changes on the species composition in the region. For an ecological interpretation of the ordination result, Pearson correlation coefficients were computed between sampling point scores on the first two axes and soil properties. The computer program PC-ORD for Windows version 4.0 was used for the floristic data analysis (McCune & Mefford, 1999).

3. Results

251 taxa (Tree, shrub, bush, and herbaceous species) were identified in the area. Figure 2 and 3 show the result of cluster analysis. The sample plots of the study area were divided into three ecological groups based on the abundance and coverage of tree and shrub species. Also, the results of MRPP analysis showed that there were significant differences between the three groups (Table 1).

As depicted in Figure 2, the sample plots of the study area were classified into five groups based on herbaceous species composition. The result of MRPP analysis also illustrated that there were statistically significant differences among the five ecological groups (Table 2).

Indicator species for different woody ecological groups separated in the cluster analysis are listed in Table 3. These species had significant indicator values (tested by Monte Carlo analysis).

Indicator species for distinct herbaceous ecological groups which were divided in the cluster analysis are listed in Table 4. Indicator values of these species were significant that were tested by Monte Carlo analysis.

The means of soil characteristics in different ecological groups based on woody species composition are presented in Table 5. Soil clay percentage and pH are significantly lower in group 2 than the other groups. Other soil variables were not statistically different amongst the woody ecological groups.

The DCA ordination diagram of woody species separated samples in three ecological groups based on speciescomposition (Fig4.). Clay content and soil pH had the greatest impact on the distribution of three ecological groups which were divided in the study area. Since these variables were significantly correlated with sampling point scores on the first axis (Table 6).

Table 7 shows the mean soil characteristics in different ecological groups based on herbaceous composition. Soil clay percentage and pH are significantly lower in group 2 than the other groups. Other soil variables were not statistically different amongst herbaceous ecological groups.

Figure 5 shows DCA ordination of sampling points based on herbaceous species composition in the study area.As Clay content and soil pH were significantly correlated with sampling point scores on the first axis (Table 8),these variables had the greatest effect on the distribution of five ecological groups which were recognized in the area.

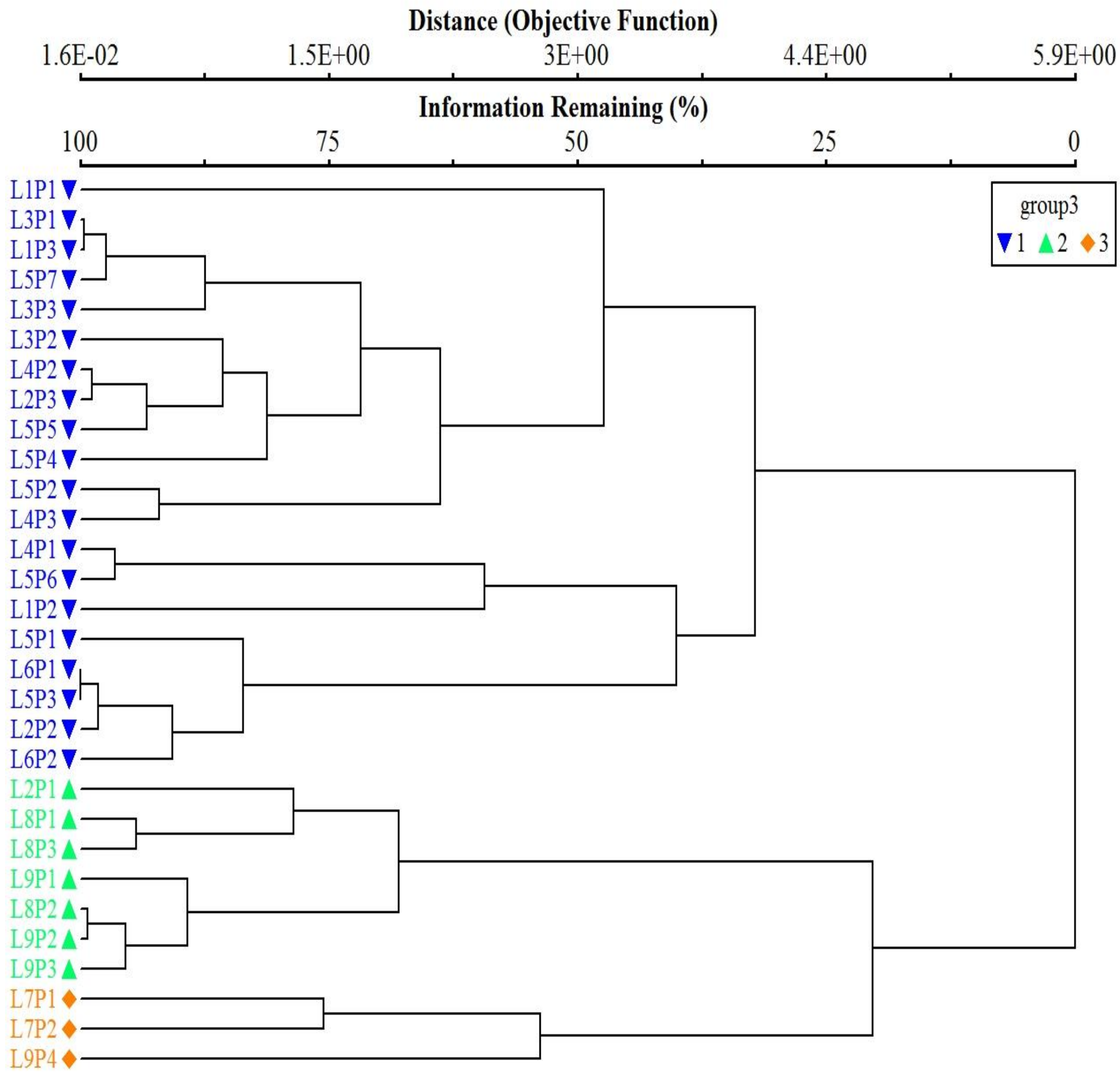

Figure 2. Classification diagram of sampling plots by cluster analysis for woody species (L: Line, P: Plot).

Table 1. MRPP test results for woody ecological groups in the study area.

Group code	T	A	P*
1 vs. 2	-16.25	0.16	0.0002
1 vs. 3	-4.70	0.08	0.0014
2 vs. 3	-11.48	0.21	0.0000006

*: Significance at the level of 1%

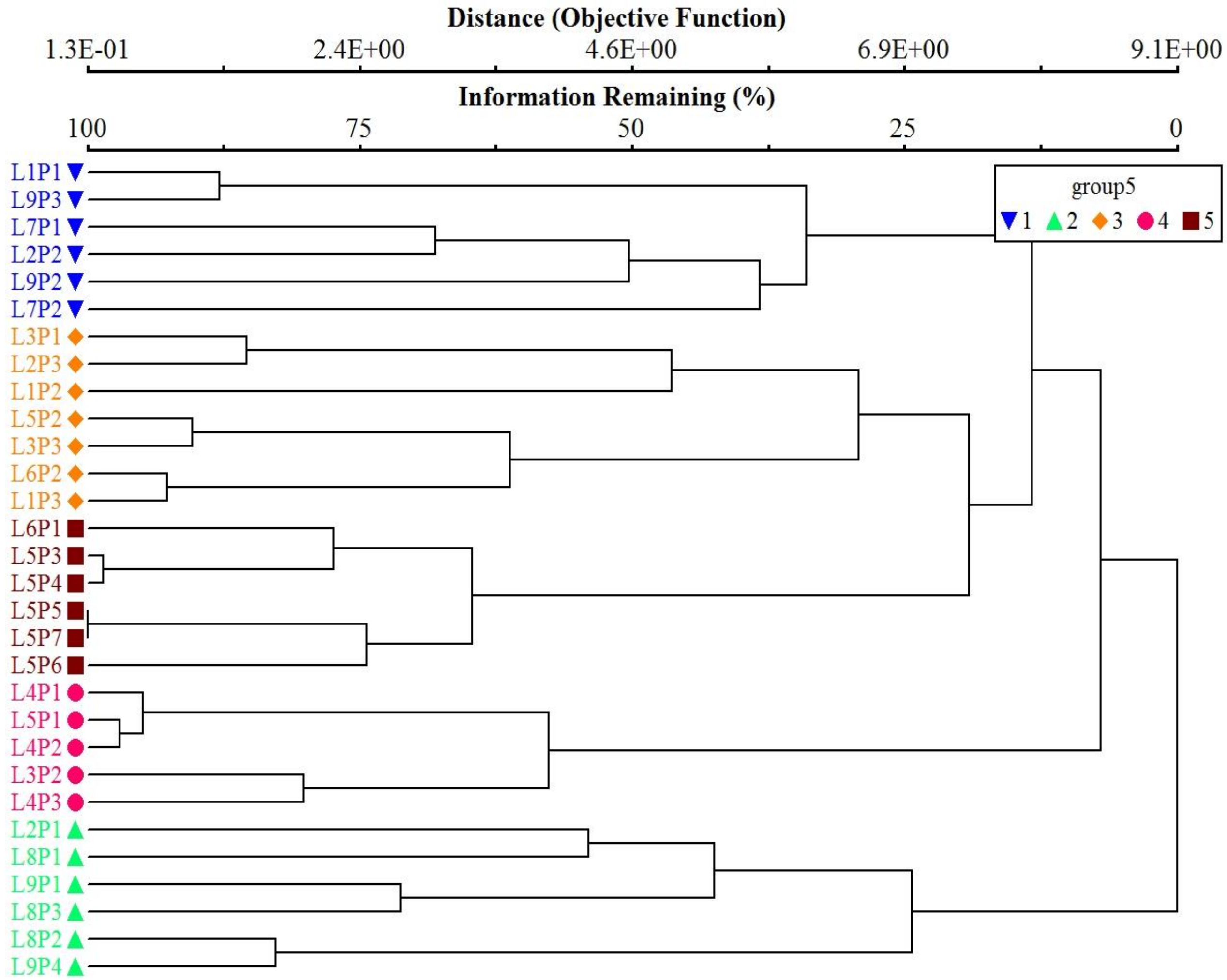

Figure 3. Classification diagram of sampling plots by cluster analysis for herbaceous species composition (L: Line, P: Plot).

Table 2. MRPP test results for herbaceous ecological groups.

Group code	T	A	P*
1 vs. 2	-5.05	0.04	0.0002
1 vs. 3	-6.50	0.05	0.00002
1 vs. 4	-3.29	0.03	0.004
1 vs. 5	-3.82	0.05	0.002
2 vs. 3	-4.49	0.03	0.0003
2 vs. 4	-4.03	0.06	0.002
2 vs. 5	-2.72	0.03	0.006
3 vs. 4	-4.50	0.05	0.0004
3 vs. 5	-4.10	0.04	0.0008
4 vs. 5	-2.75	0.07	0.01

*: Significance at the level of 1%

Table 3. Indicator species of woody ecological groups in the study area.

Ecological groups	Species
Group 1	*Amygdalus kotschyi* Boiss.
Group 2	*Salix alba* L., *Salix aegyptiaca* L., *Betula pendula, Rubus caesius* L. *Tamarix ramossisima* Ledeb
Group 3	*Acer monspessulanum* L., *Pistacia atlantica* Desf., *Cerasus microcarpa* subsp. *microcarpa* C.A.Mey.)

Table 4. Indicator species of herbaceous ecological groups in the study area.

Ecological groups	Species
Group 1	*Hordeum bulbosum* L.
Group 2	*Plantago lagopus* L., *Plantago lanceolata* L., *Plantago major* L.
Group 3	*Chaerophyllum macropodun* Boiss., *Crucianella gilanica* Trin., *Galium verum* L.
Group 4	*Inula britannica* L., *Inula viscidula* Boiss&Kotschy., *Medicago sativa* L., *Vicia variabilis* Freyn & Sint.
Group5	*Papaver bracteatum* Lindl., *Prangos ferulacea* (L.) Lindl.

Table 5. Mean ± standard deviation of soil characteristics in different ecological groups based on woody species composition.

Variables	Group 1	Group 2	Group 3
pH	7.1 ±0.29[a]	6.5 ±0.11[b]	7.2 ±0.26[a]
Organic matter (%)	2.92 ±0.46[a]	2.12 ±0.37[a]	2.40 ±0.31[a]
Total nitrogen (%)	0.29 ±0.08[a]	0.21 ±0.09[a]	0.24 ±0.09[a]
C/N	9.98 ±3.46[a]	9.99 ±3.06[a]	9.27 ±3.75[a]
Clay (%)	15.2 ±2.78[ab]	12.8 ±1.78[b]	16.4 ±2.16[a]
Silt (%)	21.8 ±6.15[a]	19.2 ±8.33[a]	21.6 ±7.69[a]
Sand (%)	62.8 ±21.5[a]	67.8 ±28.3[a]	62 ±24.89 [a]
Soil moisture (%)	48.5 ±12.57[a]	41.1 ±13.08[a]	42.8 ±14.12[a]
EC (ds/m)	0.57 ±0.18[ab]	0.95 ±0.19[a]	0.51±0.12[b]
Phosphorus (mg/kg)	11.95 ±3.59[a]	10.23 ±2.67[a]	8.01±2.88[a]
Potassium (mg/kg)	244.46 ±115.31[a]	228.37 ±100.28[a]	184.4 ±98.45[a]

**Significant at the p = 0.01 level showed with different letter

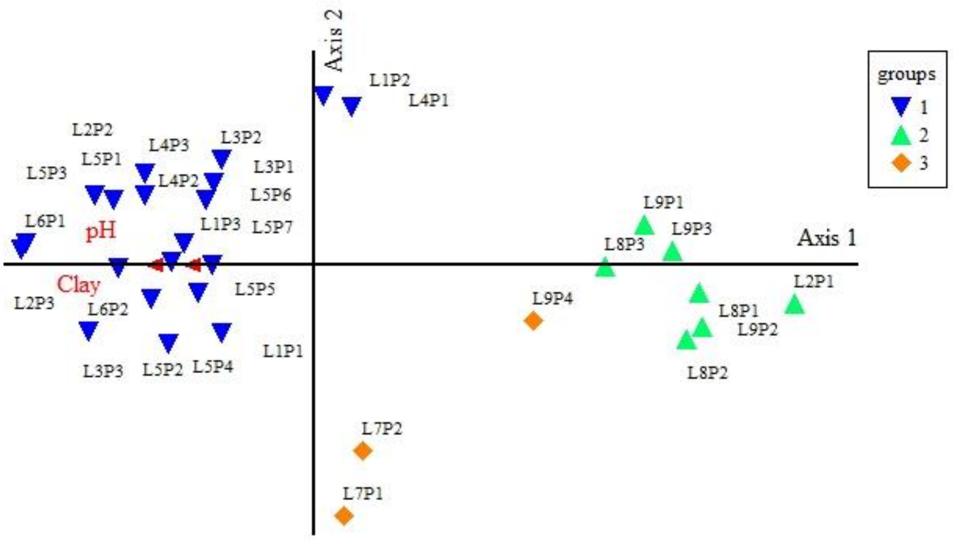

Figure 4. DCA ordination of sampling points based on woody species composition (Arrows represent correlations between sampling point scores on the first two axes and soil properties).

Table 6. Pearson correlation coefficients between the DCA ordination axes (based on wood species composition) and soil attributes.

Variables	Axis 1	Axis 2
Sand	0.13	0.15
Silt	0.12	0.19
Clay	-0.53**	0.01
Phosphorus	0.18	0.09
Potassium	-0.01	0.22
Organic carbon	-0.21	0.03
Total Nitrogen	0.15	0.11
Soil moisture	0.08	-0.07
pH	-0.44**	0.01
EC	-0.27	0.18
C/N	-0.11	0.05

**Correlation is significant at the p = 0.01 level with a 2-tailed test

Table 7. Mean ± standard deviation of soil characteristics in different ecological groups based on herbaceous composition.

Variables	Group 1	Group 2	Group 3	Group 4	Group 5
pH	7.1±0.41[a]	6.4±0.31[b]	7.2 ±0.43[a]	7.2 ±0.38[a]	7.0 ±0.30[ab]
Organic matter (%)	2.3 ±0.52[a]	1.1 ±0.43[a]	2.4 ±0.29[a]	3.2 ±0.37[a]	2.6 ±0.28[a]
Total nitrogen (%)	0.23 ±0.09[a]	0.19 ±0.08[a]	0.24 ±0.10[a]	0.33 ±0.12[a]	0.27 ±0.14[a]
C/N	9.9 ±4.25[a]	9.9 ±3.99[a]	8.7 ±3.64[a]	9.9 ±4.22[a]	9.9 ±4.46[a]
Clay (%)	16.4 ±6.23[a]	11.3 ±4.56[b]	16.2 ±6.51[a]	15.2 ±6.12[a]	14.3 ±5.51[a]
Silt (%)	21.7 ±8.76)	17.5 ±7.69[a]	22.0 ±9.65[a]	22.5 ±10.09[a]	21.3 ±9.82[a]
Sand(%)	61.77 ±22.39[a]	70.16 ±32.81 [a]	61.75 ±28.76 [a]	62.25 ±27.63 [a]	64.33 ±24.37[a]
Soil moisture (%)	40.4 ±12.57[a]	39.1 ±11.21[a]	47.5 ±18.36[a]	48.2 ±15.89[a]	46.6 ±18.76[a]
EC (ds/m)	0.44 ±0.21[a]	0.27 ±0.09[a]	0.40 ±0.19[a]	0.46 ±0.13[a]	0.48 ±0.22[a]
Phosphorus (mg/kg)	7.84 ±3.88[a]	9.01 ±4.23[a]	9.87 ±4.51[a]	8.75 ±3.99[a]	7.70 ±3.28[a]
Potassium (mg/kg)	259.5 ±122.1[a]	215.5 ±103.8[a]	259.5 ±111.2[a]	275.5 ±118.9[a]	234.6 ±101.6[a]

**Significant at the p = 0.01 level showed with different letter

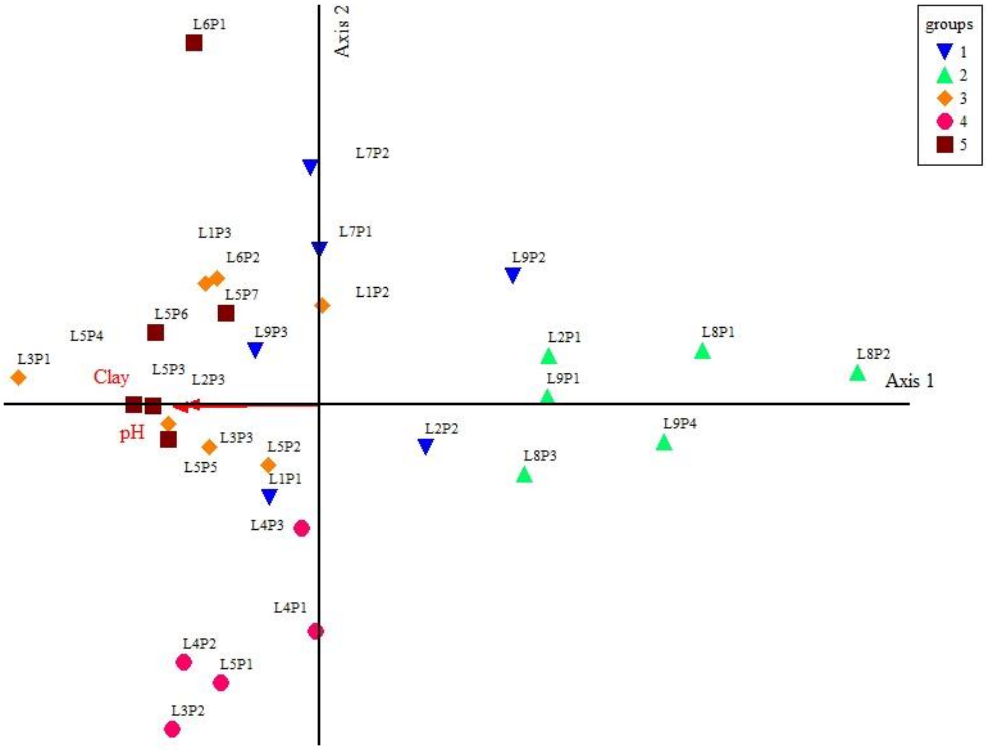

Figure 5. DCA ordination of sampling points based on herbaceous species composition (Arrows represent correlations between sampling point scores on the first two axes and soil properties).

Table 8. Pearson correlation coefficients between the DCA ordination axes (based on herbaceous composition) and soil attributes

Variables	Axis 1	Axis 2
Sand	0.19	0.11
Silt	0.11	0.23
Clay	-0.50**	0.01
Phosphorus	0.15	0.05
Potassium	-0.002	0.16
Organic carbon	-0.25	0.08
Total Nitrogen	0.19	0.21
Soil moisture	0.05	-0.05
pH	-0.46**	0.02
EC	-0.29	0.19
C/N	-0.17	0.02

**Correlation is significant at the p = 0.01 level with a 2-tailed test

4. Discussion

Knowledge of species–environment relationships is important in understanding vegetation patterns in forested areas. For this reason, numerous studies have been conducted in different terrestrial ecosystems of Iran (Eshaghi Rad & Banj shafeie, 2010). However, little is known about ecological groups and the inter-specific associations of mountainous riparian ecosystems in Iran. Riparian ecosystems are very important from an ecological point of view because they constitute ecotones between terrestrial and aquatic systems and therefore represent areas where many physical, abiotic and biotic processes are continuously changing. 251 recorded species in Marmisho valley indicated that this region includes high species diversity (Eshaghi rad et al., 2019). Several environmental factors account for a high number of species in the riparian zone, including high productivity (Araujo Calçada et al., 2015), level of groundwater table and flow-facilitated dispersal of propagules (Nilsson et al., 2010). Also, cluster analysis showed that the sampling plot of the study was divided into three ecological groups based on the abundance and cover of woody species and five ecological groups regarding to herbaceous composition which reflected riparian complexity and dynamics. Based on DCA results, soil texture and pH played major roles in the distribution of these ecological groups. These results were consistent with Janisova (2005), Taghipour et al. (2008) and Zolfaghari et al. (2010).

Amygdalus kotschyi Boiss as indicator species of the first group and *Cerasus microcarpa* subsp. *microcarpa* C.A.Mey; *Acer monspessulanum* L.; *Pistacia atlantica* Desf., as indicator species of the third group, observed on the hillslopes with higher clay and pH values compared to other ecological groups. In this context, Ravanbakhsh & Moshki (2016) stated that *Pistacia atlantica-Amygdalus* spp. communities belonged to the lowlands along with less rainfall and soils with higher pH values. In general, the soil of the studied area was light (sand content ranged 62-68%) which was favorable especially for almond species (Javidfar, 2017). Indicator species of second group, which extended on the riverbank and inside the valley, such as *Betula pendula*, *Salix aegyptiaca*, *Salix alba* and *Tamarix ramossisima* which are moisture demanding species indicated high soil moisture of the area. Birch species was present in all sample plots of this group. Also, the soil clay of this group was lower than that of other groups. The reason for lower clay in this group might be due to more leaching in the area near the river (Araujo Calçada et al., 2015). Generally, soil texture is important to plants for a variety of reasons, including permeability and moisture retention (Sperry et al., 2002) and might impact on soil water holding capacity, the cycle of nutrients, aeration, and depth of roots resulting in variation in plant distribution (Abd El-Ghani & Amer, 2003). No data on the vegetation-environment relationships in the mountainous riparian forests exists that makes direct comparison somewhat difficult. The results of the research conducted by Jafari et al. (2004) in Yazd province and Jafari et al. (2008) in Qom province also showed that soil texture was amongst the factors having the most crucial role in plant establishment and development. Furthermore, Davies et al. (2007) and Abbadi & El Sheikh (2002) also illustrated that soil texture is one of the important factors in separation of ecological groups. Due to shoet elevation gradient in Marmisho forests (1600 to 1800 a.s.l), our results also indicated that altitude had no effect on the determination of herbaceous and woody ecological groups due to the low elevation changes in the study area. Although altitude has a great effect on species diversity and soil by affecting the various factors which was confirmed in many studies (Vetaas & Grytness, 2002; Fisher et al., 2004; Kooch & Tavakoli Feizabadi, 2018; Bayranvand et al., 2019). Also, Bazdid Vahdati (2017) stated that the diversity of the ecological species groups decreased with elevation in beech forests in northern Iran.

Other soil properties were not amongst the factors affecting the separation of the ecological group in the study area. However, Ahmadi et al. (2007) identified soil salinity as one of the effective factors in separation of vegetation types. Also, Toranj Zar et al. (2011) and Rudy et al. (2012) observed that electrical conductivity plays an important role in the determination of ecological species. Jafari et al. (2009) observed that there was a special relationship between potassium, electrical conductivity, and soil texture and distribution of plant species. Eshaghi Rad & Banj shafeie (2010) stated that the distribution of the four ecological groups in beech communities in Hyrcanian forests were better associated with total nitrogen, organic matter, phosphorus and exchangeable bases than with elevation, slope, C/N ratio and pH in the study area. The results of other study conducted in the temperate deciduous forests in the Western Carpathian Mountains (Gabor et al., 2019), was partly similar with the previous one, indicated that altitude, pH, organic matter, potassium and magnesium were selected as the significant environmental drivers responsible for the ecological group variability. Our results in the birch site in the mountainous riparian forests of Marmisho valley were mainly different from the results of other studies in well-studied forests such as Hyrcanian forests and Zagros forests because vegetation types, human activities and climatic zones could affect vegetation-environment relationships (Araujo Calçada et al., 2015).

5. Conclusion

In general, Marmisho valley supports high plant species diversity. Three woody ecological groups and five herbaceous ecological groups in the study area shows crucial variation in the vegetation which are affected by soil texture and soil pH as major factors in the distribution of ecological groups in the region.

These forests are very important in terms of conservation of biological reserves, prevention of soil erosion and ecotourism services. Therefore, we need urgent forest management strategies such as protective plan to conserve the high plant species diversity in the region.

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ارتباط پوشش گیاهی- محیط در رویشگاه توس (*Betula pendula* Roth.) جنگل‌های کرانرودی کوهستانی دره مارمیشو

جواد اسحاقی‌راد[1*]، احمد علیجانپور[2] و روح‌الله رستمی[3]

[1] استاد، گروه جنگل‌داری، دانشکده منابع طبیعی، دانشگاه ارومیه، ارومیه
[2] دانشیار، گروه جنگل‌داری، دانشکده منابع طبیعی، دانشگاه ارومیه، ارومیه
[3] دانشجوی دکتری جنگلداری، گروه جنگل‌داری، دانشکده منابع طبیعی، دانشگاه ارومیه، ارومیه

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چکیده

دره مارمیشو واقع در شمال غرب ایران، تنوع گونه‌ای بالای داشته و یک زیستگاه منحصربفرد برای توده‌های توس (*Betula pendula* Roth.) به‌شمار می‌رود. این پژوهش برای بررسی ارتباط پوشش گیاهی- محیط در این منطقه و همچنین برای تعیین مهمترین عوامل موثر بر پراکنش گونه‌ها با تاکید بر پراکنش گونه توس انجام شد. ۳۰ قطعه نمونه با استفاده از روش منظم- تصادفی با ابعاد شبکه ۲۰۰×۱۰۰ متر برداشت شد. در هر نقطه نمونه‌برداری، قطعات نمونه ۴۰۰ و ۱۰۰ مترمربعی به ترتیب برای ثبت فراوانی-پوشش گونه‌های چوبی و گونه‌های علفی پیاده شد. همچنین در مرکز هر قطعه نمونه، یک نمونه خاک از عمق ۰-۳۰ سانتی‌متر خاک معدنی برداشت شد. بعنوان نتیجه، ۲۵۱ تاکسون گیاهی در دره مارمیشو مشاهده شد. نتایج آنالیز خوشه‌ای نشان داد که قطعات نمونه بر اساس ترکیب گونه‌های علفی و چوبی به ترتیب به سه و پنج گروه بوم‌شناختی تفکیک شدند، که تفاوت معنی‌دار بین گروه‌های بوم‌شناختی مختلف با استفاده از تجزیه و تحلیل MRPP مورد تایید قرار گرفت. بعلاوه، تجزیه و تحلیل DCA نشان داد که بافت خاک و اسیدیته خاک مهمترین تاثیر را بر پراکنش گروه‌های بوم‌شناختی منطقه داشتند. دره مارمیشو سطح بالایی از تنوع گونه‌ای را دربر دارد. بنابراین ما به راهبردهای فوری مدیریت جنگل ازجمله طرح حفاظتی برای حفاظت از منطقه نیاز داریم.

واژه‌های کلیدی: گروه‌های بوم‌شناختی، اکوسیستم جنگل، ترکیب گونه‌ای، خاک، ایران.

[*] نویسندهٔ مسئول   شمارهٔ تماس: ۴۴۳۲۷۷۰۴۸۹   ایمیل: j.eshagh@urmia.ac.ir