Contents available at ISC and SID

Journal homepage: www.rangeland.ir

Research and Full Length Article:

Investigation of the Relationship between Altitude and Aspect with Plant Diversity: A Case Study from Nawa Mountain Ecosystem in Zagros, Iran

Saeed Mahmoudi[A], Mahmud Khoramivafa [B]*, Moslem Hadidi[C]

[A]M.Sc Student of Agro-ecology, Department of Agronomy and Plant Breeding, Razi University, Kermanshah, Iran

[B]Assistant professor, Department of Agronomy and Plant Breeding, Razi University, Kermanshah, Iran, *(Corresponding author), Email: khoramivafa@razi.ac.ir

[C]Academic Center for Education, Cultural and Research, Kermanshah, Iran

Received on: 26/04/2017

Accepted on: 28/06/2017

Abstract. Mountain ranges cover around one-half of Iran, and Zagros ecosystem is considered as one of an important biological site in Iran. Physiographic factors such as altitude and aspect have an important role in plant species distribution. This study was conducted in the Nawa mountain ecosystem in the western side of Zagros ranges, located in the western zone of Iran in 2016. The experiment aim was to reveal the influences of altitude and aspect on features of plant biodiversity. Hence in the each main aspect regarding to gradient, transect-lines were established with distance 100 m into another and perpendicular to gradient from the elevation of 1200-2400 m a.s.l. Four plots (1 m^2) were randomly located along each transect; generally, 208 plots were drown. The Shannon–Wiener index for α-diversity was calculated, and field data were analyzed using two-way ANOVA. There were 158 identified plant species belonging to 104 genus and 27 families based on the results. Altitude and aspect had a significant effect on the plant diversity and species richness ($p<0.01$). The highest values of the Shannon–Wiener index and species richness (2.58 and 1033 respectively) were seen in lower elevations (from 1200-1400 m a.s.l.). Results also showed that the highest and lowest values of the plant diversity and species richness for the southern aspect were 2.51 and 8.9 and for eastern aspect 1.20 and 3.63, respectively. Interaction effects of environmental variables were only significant on the species richness. There was a negative correlation between the plant diversity and species richness with altitude in all main aspects, too. Along the altitudinal belts, the highest species diversity and richness belonged to low and mid-elevational zones of the Nawa mountain.

Key words: Plant biodiversity, Bio-indices, Physiographic factors, Richness, Zagros

Introduction

Biodiversity decline and climate changes have been emphasized as two major environmental problems during recent years (Heydari and Mahdavi, 2009). Nowadays, numerous sustainable development plans are programmed to minimize the damages associated with biodiversity. Thus, a balance between production and utilization can be achieved by studies on ecological resources and environment. The UN Convention on Biological Diversity (CBD) was established to counteract the increasing loss of biodiversity due to human activities at the global scale (Pimm *et al*., 2014). However, biodiversity is not evenly distributed, and there are regions that are naturally rich of species while others are naturally poor of species (Joppa *et al*., 2013). Also, greenhouse gas emissions, nitrogen deposition, land management, trade and mobility are considerably affecting on biodiversity at regional and local scales (IPCC-WGII, 2014). Therefore, national strategies for conservation and sustainable use of biological diversity were initiated. Plant diversity is considered very important at vegetation studies and environmental evaluations because it is one of important index to determine ecosystem status which can scan management of a role-playing (Goodman, 1975), plant diversity studies are an instrument to survey plant community dynamism for by species distribution status (Hayek *et al*., 2007) and the results of studies of the plant cover can be used to abate environmental problems in biological conservation in natural resources management and to previse ecosystem pollutions (Daubenmire, 1976). At the community level, some recent studies underpinned that the plant diversity has an important role in soil aggregate stability (Martin *et al*., 2010; Pérès *et al*., 2013; Pohl *et al*., 2009; Pohl *et al*., 2011).

Iran has a total area of 1.6 million km^2; one-half of this area is mountain areas. Alborz and Zagros are the largest mountain ranges in Iran. Zagros range stretches along the western parts of Iran and extends about 1700 km^2 from northwest to southeast (Noroozi *et al*., 2016). The physiographic factors are sustainable ecological factors with effects on the plant diversity and their distribution (Barnes *et al*., 1998). Many studies surveyed the effect of the physiographic factors on the plant diversity such as elevation from sea level (Fisher and Fulé, 2004; Grytnes and Vetaas, 2002), aspect (Badano *et al*., 2005; Bale *et al*., 1998; Mirzaei and Karami, 2015) and slope (Guerrero-Campo *et al*., 1999). Although there are some studies on the relationship between the plant diversity and environmental factors in Zagros ranges (Bazyar *et al*., 2013a; Heydari and Mahdavi, 2009; Mirzaei and Karami, 2015; Salehi *et al*., 2013), there is little information about biodiversity in this area and substantial gap in knowledge prevail.

In Southwest Asia in general and in Iran in particular, mountains have the majority of endemic vascular plant species (Noroozi *et al*., 2008; Noroozi *et al*., 2016; Noroozi *et al*., 2014). This endemic species richness is the result of the complex origin and histories of mountains, being shaped by tectonic uplift, geographic isolation, climate changes, glaciation and strong microhabitat differentiation (Dirnböck *et al*., 2011; Sandel *et al*., 2011). Hence, the current study attempts to find out the real interpretation of biodiversity of Nawa Mountain in western Zagros in Iran and to determine a relationship between the physiographic factors (altitude and aspect) and the plant diversity.

Materials and Methods

Study area

The study was carried out in an area of approximately 180 hectares in ranges of Nawa Mountain ecosystem in Zagros, Kermanshah province, western zone of Iran in 2016. Nawa ecosystem is located between 34°17' N to 34°20' N and 46°01' E to 46°06´ (Fig. 1). It is the highest mountain in the area, and it nucleated of the calcite and porphyry stones with the chalky sandstone. The altitude range is from 1178 to 2428 meters above sea level (m a.s.l). The area has a semiarid climate, and the rainy season (monsoon) lasts from mid-November to mid-May with the average annual rainfall of 467 mm. The average minimum and maximum temperature in this area were 11.7 C° and 27.6 C°, respectively. This area as rangeland is utilized by the local people for grazing of livestock; the local people also use many of the wild edible plants collected from Nawa Mountain.

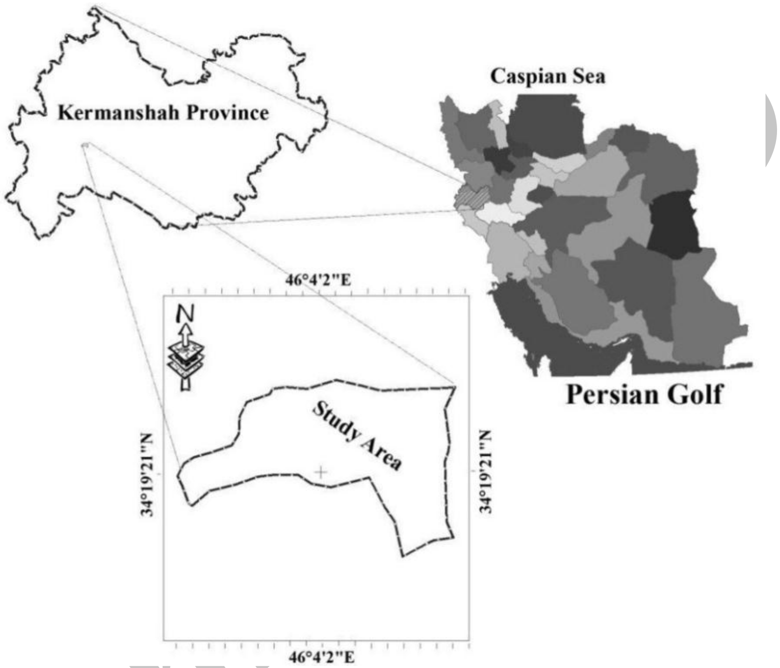

Fig. 1. The location of the study area, Zagros, Nawa Mountain

Sampling and research methods

Sampling was accorded with site topography. We used a systematic-randomized design (Barbour *et al*., 1999), and the sample number was also estimated by below formula (Krebs, 1998):

$$N = \left(\frac{t_{\alpha} CV}{D}\right)^2 \quad (1)$$

Where

N: number of sample,

CV: coefficient of variation,

t: amount of t-student (*P<0.05*) and

D: error.

With 30 initial samples and the error <0.02, we estimated the sample optimal number as 192; according to the aims of the study, the sample number of 208 was considered. Therefore, in the each main aspect (north, east, south, and west) regarding gradient, transect-lines were established with distance of 100 m into another from the elevation of 1200 to 2400 m a.s.l., and four plots of 1 m² were randomly located along each transect. In this study, elevation was categorized on four classes (1200-1400, 1500-1700, 1800-2000, and above 2000 m a.s.l.).

Scientific name of all herbaceous species was recorded within each plot, and the canopy cover percent was measured and recorded. For unknown species, herbaceous specimens were collected and taken to the Herbarium of Agricultural and Natural-resources Research Center of Kermanshah province for identification of the plants that were not identified in the field.

The bio-indices included the Shannon–Wiener index for α-diversity, species richness, and evenness calculated as follows (Magurran, 1988):

Shannon–Wiener index (H´)

It is very important to compare the diversity among samples and habitats to use an index that is more sensitive to richness. Value of the Shannon–Wiener index is usually found to fall between 1.5 and 3.5 and rarely exceeds 4.5 (Tebkew *et al*., 2014). The Shannon–Wiener index was estimated as follows:

$$H = \sum_{i=1} - (P_i \ln P_i) \quad (2)$$

Where

H': the Shannon–Wiener diversity index calculated with natural logarithms,

Pi: the proportion of individuals found in the i^{th} species stated by the ratio of total species,

Ln: natural logarithm of fond 2, and

S: the number of species in the total of sample (Fahimipoor *et al*., 2010).

Species richness (R)

It is defined as the number of species per plot, area or community (Magurran, 1988). Several indices masterminded to determine the species richness, but this index is noted index (Kent and Coker, 1992).

$$R=S \quad (3)$$

Where

R: the Menhink's richness index,

S: Number of plant species (Fahimipoor *et al*., 2010).

Data analysis

Survey of normality data distribution was done by Kolmogorov–Smirnov test, and Leven's test was applied to determine homogeneity of variances. Differences of the bio-indices between the altitudinal classes or different aspects and also their interactional effects were analyzed using two-way ANOVA, and means comparisons were done by DMRT method. The Pearson correlation analyses were performed to quantify the relationship between the bio-indices with altitude and aspect variables. The statistical analyses were done by SPSS 22 statistical software package. Calculating the bio-indices was done by Ecological Methodology 7.2 software (Kenny and Krebs, 2001).

Results

In general, 158 plant species belonging to 104 genus and 27 families were identified in the study area (Table 1). Results showed that Poaceae family had the highest frequencies (Fig. 2), and the species *Bromus tectorum*, *Poa bulbosa*, *Hordeum bulbosum*, *Bromus danthoniae*, and *Hordeum spontaneum* formed the most abundant plant species, respectively (Fig. 3).

Table 1. List of all herbaceous species encountered in the mountain ecosystem of Nawa, Western zone in Iran

N	Scientific name	Family name	N	Scientific name	Family name
1	*Achillea vermicularis*	Asteraceae	80	*Iris imbricate*	Iridaceae
2	*Aegilops ovata L.*	Poaceae	81	*Isatis cappadocica*	Brassicaceae
3	*Aegilops triaristata Willd.*	Poaceae	82	*Ixiolirion tataricum*	Amaryllidaceae
4	*Aegilops triuncialis L.*	Poaceae	83	*Lagoecia cumonoides*	Apiaceae
5	*Aethionema grandiflorum*	Brassicaceae	84	*Lappula barbata*	Boraginaceae
6	*Aethionema spp.*	Brassicaceae	85	*Lathyrus inconspicuus*	Papilionaceae
7	*Agropyron trichophorum*	Poaceae	86	*Lens culinaris*	Papilionaceae
8	*Alcea sulphurea*	Malvaceae	87	*Leontice leontopetalum*	Podophyllaceae
9	*Alliaria petiolata*	Brassicaceae	88	*Linaria spp.*	Scrophulariaceae
10	*Allium dictyoprasum*	Liliaceae	89	*Linum mucronatum*	Linaceae
11	*Allium iranicum*	Liliaceae	90	*Lolium rigidum*	Poaceae
12	*Alyssum meniocoides*	Brassicaceae	91	*Lolium temulentum*	Poaceae
13	*Anthemis hyalina*	Asteraceae	92	*Malabaila secacul*	Apiaceae
14	*Arabis caucasica*	Brassicaceae	93	*Marrubium crassidens. var. br.*	Labiatae
15	*Arenaria serpyllifolia*	Caryophyllaceae	94	*Marrubium crassidens. var. cr.*	Labiatae
16	*Artedia squamata*	Apiaceae	95	*Matthiola longipetala Vent.*	Cruciferae
17	*Astragalus membranaceus*	Papilionaceae	96	*Medicago orbicularis L.*	Papilionaceae
18	*Astragalus iranicus*	Papilionaceae	97	*Medicago polymorpha L.*	Papilionaceae
19	*Astragalus jesseni*	Papilionaceae	98	*Medicago radiata*	Papilionaceae
20	*Astragalus ovinus*	Papilionaceae	99	*Onobrychis crista-galli*	Papilionaceae
21	*Astragalus parrovianus*	Papilionaceae	100	*Onosma latifolium*	Boraginaceae
22	*Avena aterilis*	Poaceae	101	*Orobanche alba Steph.*	Orobanchaceae
23	*Bellevalia longipes*	Liliaceae	102	*Papaver macrostomum*	Papaveraceae
24	*Biebersteinia multifida*	Caryophyllaceae	103	*Phleum boissieri*	Poaceae
25	*Boissiera squarosa*	Poaceae	104	*Phlomis herba-venti*	Labiatae
26	*Bongardia chrysogonum L.*	Podophyllaceae	105	*Phlomis lanceolata*	Labiatae
27	*Bromus danthoniae*	Poaceae	106	*Phlomis persica Boiss.*	Labiatae
28	*Bromus sterilis L.*	Poaceae	107	*Picnomon acarna L. Cass*	Asteraceae
29	*Bromus tectorum L. var. hir.*	Poaceae	108	*Pisum sativum*	Papilionaceae
30	*Bromus tectorum L. var. tec.*	Poaceae	109	*Poa bulbosa*	Poaceae
31	*Bunium paucifolium*	Apiaceae	110	*Prangos ferulacea L.*	Apiaceae
32	*Carduus pycnocycla*	Apiaceae	111	*Prangos pabularia Lindl.*	Apiaceae
33	*Catabrosa aquatica*	Poaceae	112	*Ranunculus arvensis*	Ranunculaceae
34	*Caucalis platycarpus*	Apiaceae	113	*Roemeria hybrida*	Papaveraceae
35	*Caucalis spp.*	Apiaceae	114	*Rumex vesicarius*	Polygonaceae
36	*Cephalaria spp.*	Dipsacaceae	115	*Salvia multicaulis*	Labiatae
37	*Cephalaria syriaca*	Dipsacaceae	116	*Sameraria stylophora*	Crassulaceae
38	*Cerastium inflatum*	Caryophyllaceae	117	*Scandix stellata*	Apiaceae
39	*Chaerophyllum macropodum*	Apiaceae	118	*Scorzonera hispanica*	Asteraceae
40	*Chardinia orientalis*	Asteraceae	119	*Scorzonera phaeopappa*	Asteraceae
41	*Cichorium intybus*	Compositae	120	*Senecio vernalis*	Asteraceae
42	*Clypeola lappacea*	Brassicaceae	121	*Senecio vulgaris L.*	Asteraceae
43	*Coronilla scorpioides*	Papilionaceae	122	*Silene aucheriana*	Caryophyllaceae
44	*Cousinia phyllocephala*	Asteraceae	123	*Silene montbretiana*	Caryophyllaceae

45	*Crepis sancta*	Asteraceae	124	*Smyrniopsis aucheri Boiss.*	Apiaceae
46	*Cruciata coronata*	Rubiaceae	125	*Smyrnium aucheri*	Apiaceae
47	*Crupina crupinastrum*	Asteraceae	126	*Stachys benthamiana Boiss.*	Labiatae
48	*Dianthus crinitus Sm.*	Caryophyllaceae	127	*Stachys lavandulifolia Vahl.*	Labiatae
49	*Dianthus orientalis*	Caryophyllaceae	128	*Stroganowia persica Busch*	Cruciferae
50	*Echinaria capitata*	Poaceae	129	*Taeniatherum crinitum*	Poaceae
51	*Echium italicum*	Boraginaceae	130	*Tanacetum polycephalum*	Asteraceae
52	*Eremopoa persica*	Poaceae	131	*Torilis leptophylla L.*	Apiaceae
53	*Eremostachys laevigata*	Labiatae	132	*Torilis radiate Moench*	Apiaceae
54	*Eremurus inderiensis*	Liliaceae	133	*Tragopogon longirostris*	Asteraceae
55	*Erodium cicutarium*	Geraniaceae	134	*Trifolium arvense*	Papilionaceae
56	*Eryngium billardieri*	Apiaceae	135	*Trifolium echinatum*	Papilionaceae
57	*Euphorbia condylocarpa*	Euphorbiaceae	136	*Trifolium arvense*	Papilionaceae
58	*Euphorbia densa Schrenk*	Euphorbiaceae	137	*Trifolium campestre*	Papilionaceae
59	*Euphorbia denticulata*	Euphorbiaceae	138	*Trifolium grandiflorum*	Papilionaceae
60	*Ferula caspica*	Apiaceae	139	*Trifolium hirtum*	Papilionaceae
61	*Festuca ovina Brot.*	Poaceae	140	*Trifolium purpureum*	Papilionaceae
62	*Fibigia macrocarpa*	Brassicaceae	141	*Trifolium scabrum*	Papilionaceae
63	*Fritillaria imperialis*	Liliaceae	142	*Trifolium stellatum*	Papilionaceae
64	*Fritillaria straussii*	Liliaceae	143	*Trifolium tomentosum*	Papilionaceae
65	*Galium aparine L.*	Rubiaceae	144	*Trigonella aurantiaca Boiss.*	Papilionaceae
66	*Galium aucheri Boiss.*	Rubiaceae	145	*Trigonosciadium brachytaenium*	Apiaceae
67	*Galium tricornutum Dandy.*	Rubiaceae	146	*Tulip chrysantha*	Liliaceae
68	*Garhadiolus angulosus*	Asteraceae	147	*Tulipa systole*	Liliaceae
69	*Gentiana olivieri*	Gentianaceae	148	*Valerianella actinophylla*	Valerianaceae
70	*Geranium rotundifolium*	Geraniaceae	149	*Valerianella vesicaria*	Valerianaceae
71	*Gundelia tournefortii*	Asteraceae	150	*Verbascum spp.*	Scrophulariaceae
72	*Helianthemum ledifolium*	Cistaceae	151	*Veronica cymbalaria*	Scrophulariaceae
73	*Heteranthelium piliferum*	Poaceae	152	*Vicia ervilia*	Papilionaceae
74	*Hippocrepis bisiliqua*	Papilionaceae	153	*Vicia variabilis*	Papilionaceae
75	*Hordeum bulbosum L.*	Poaceae	154	*Vicia michauxii*	Papilionaceae
76	*Hordeum distichon L.*	Poaceae	155	*Vulpia myuros*	Poaceae
77	*Hordeum glaucum*	Poaceae	156	*Ziziphora capitata*	Lamiaceae
78	*Hordeum spontaneum*	Poaceae	157	*Ziziphora tenuior*	Lamiaceae
79	*Hypericum scabrum*	Hypericaceae	158	*Zosima absinthifolia*	Apiaceae

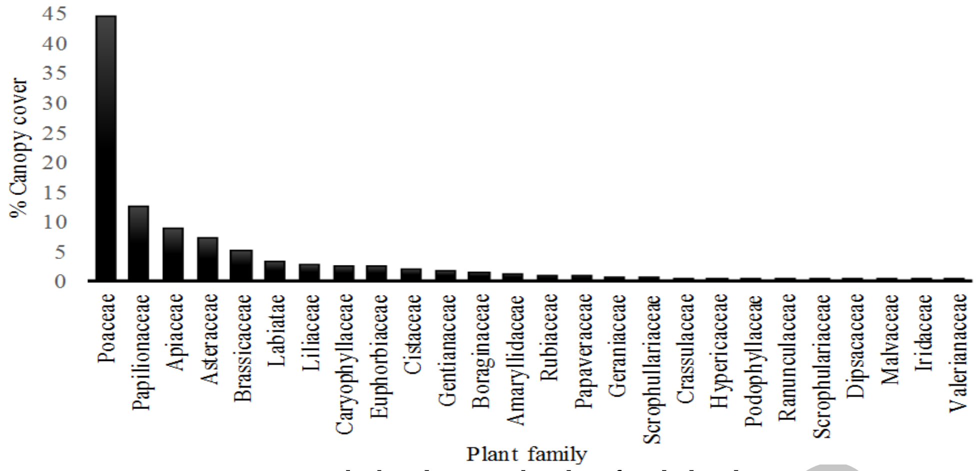

Fig. 2. Rank abundance in the plant family level

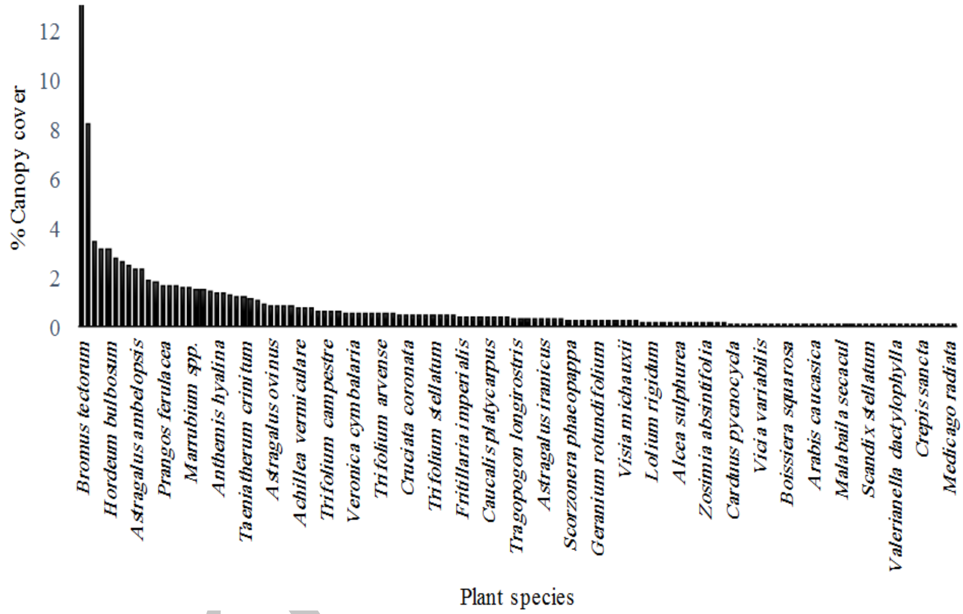

Fig. 3. Rank abundance in the plant species level

Our analysis of the data obtained from 208 plots revealed that the mean ± SD of the bio-indices including Shannon–Wiener (*H´*), species richness (*R*), and Evenness (*E*) was 1.86±0.87, 6.11±3.78, and 0.57±0.24, respectively (Table 2). The results of this study revealed that altitude had a significant effect on the plant diversity and species richness ($p<0.01$), but it had no significant effect on the evenness ($p<0.05$), (Table 3). The results obtained from multivariate Duncan's test showed that the highest value of the Shannon–Wiener index was seen in the altitudinal class 1200-1400 m a.s.l. (with the mean of 2.58) and the lowest value of the Shannon–Wiener index was seen in the altitudinal class above 2000 m a.s.l. (with the mean of 1.29). The highest values of the species richness belonged to altitudinal range from 1200-1400 m a.s.l. (with the mean of 10.33), and the lowest values of the species richness belonged to altitudinal range above 2000 m a.s.l. (with the mean of 3.50) (Table 4).

Table 2. Minimum rate, maximum rate, mean, and standard deviation of biodiversity indices in study area

Bio-indices	Minimum	Maximum	Mean	S. Deviation
Biodiversity (H´)	0.000	3.765	1.860	0.877
Richness (R)	1.000	21.000	6.110	3.789
Evenness (E)	0.000	0.998	0.575	0.249

The results of this study showed that the aspect had a significant effect on the plant diversity and species richness (p<0.01), but the aspect had no significant effect on the evenness (p<0.05). According to the results obtained from multivariate Duncan's test, the highest and lowest values of the Shannon–Wiener index and species richness were given for the southern and eastern aspects, respectively, (Table 4). Interactional effects of the environmental variables were exclusively significant on the species richness (p<0.01) (Table 3). Fig. 4 shows a trend of the bio- indices changes regarding the altitudinal classes in each main aspect.

Table 3. Two-way ANOVA results on the bio-indices in different altitudinal classes and different aspects

Sources of variation	df	MS	F-values
Altitude			
Shannon–Wiener index	3	18.89	44.66**
Species richness	3	482.63	145.23**
Evenness	3	0.08	1.30ns
Aspect			
Shannon–Wiener index	3	279.30	84.06**
Species richness	3	17.46	71.78**
Evenness	3	0.06	0.96ns
Altitude*Aspect			
Shannon–Wiener index	9	0.24	1.01ns
Species richness	9	9.26	2.79**
Evenness	9	0.04	0.69ns

ns: no significant, and **: significant (*p<0.01*)

Table 4. The results of Duncan's test on the plant diversity, richness, and evenness amongst the altitudinal classes and different aspects (p<0.05)

Physiographic variables	Shannon–Wiener index	Species richness	Evenness
Elevation classes			
1200-1400 m a.s.l.	2.58[a]	10.33[a]	0.51[a]
1500-1700 m a.s.l.	2.21[b]	6.96[b]	0.57[a]
1800-2000 m a.s.l.	1.53[c]	4.52[c]	0.57[a]
Above 2000 m a.s.l.	1.29[d]	3.50[d]	0.61[a]
Aspect classes			
South	2.51[a]	8.90[a]	0.58[a]
West	2.15[b]	6.81[b]	0.62[a]
North	1.56[c]	5.10[c]	0.54[a]
East	1.20[d]	3.63[d]	0.55[a]

Relationships between altitude and the plant diversity

Correlation analysis among the altitude and bio-indices was done separately in different aspects. The results showed that there was a negative strong correlation between herbaceous diversity and altitude (r= -0.69, p<0.01) and also between the species richness and altitude (r= -0.75, p<0.01) in the northern aspect. In the eastern aspect, diversity and richness of herbaceous species had a negative strong correlation with altitude (r= -0.75 and r= -0.83, respectively, p<0.01). In the southern aspect, there was a negative strong correlation between the herbaceous diversity and altitude (r= -0.79, p<0.01) and also between the species richness and altitude (r= -0.84, p<0.01). In this study, the plant diversity and species richness had a negative strong correlation with altitude (r= -0.69 and r= -0.81, respectively, p<0.01) in the western aspect. There was a positive correlation between evenness and altitude (r= 0.28, p<0.05) in the western aspect, exclusively.

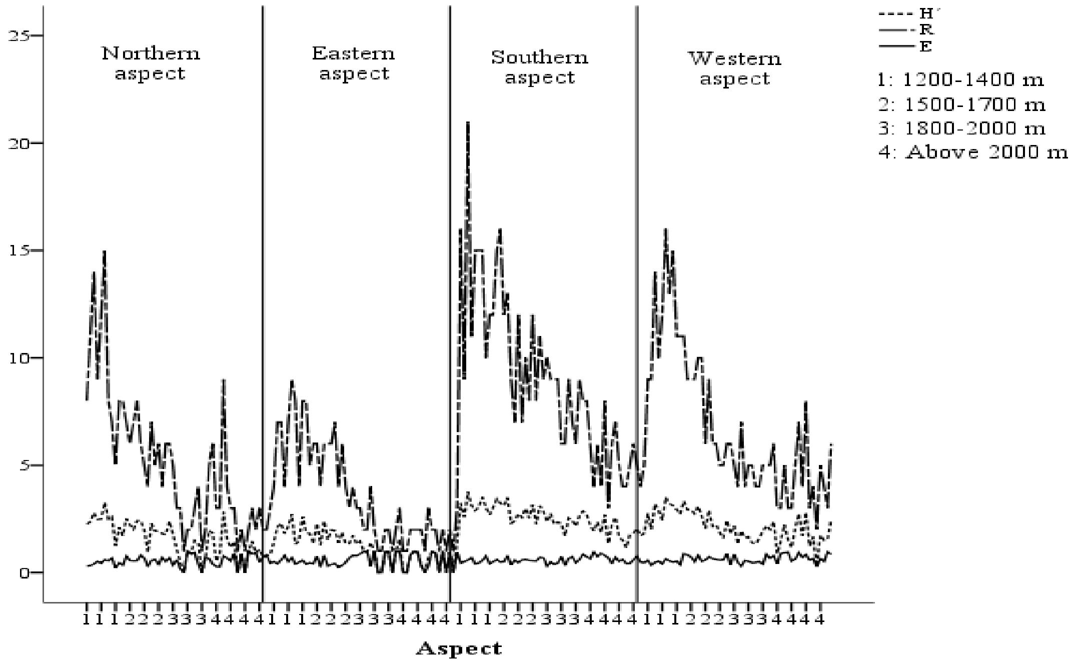

Fig. 4. A trend of the bio- indices changes regarding to the altitudinal classes in each main aspect

Discussion

The results of data analysis revealed that there are 158 plant species belonging to 104 genus and 27 families in the study area and the highest frequencies belonged to Poaceae family, *Bromus* genus, especially *Bromus tectorum* species which is consistent with the results of studies conducted in Zagros range in the west of Iran (Heydari and Mahdavi, 2009; Mirzaei and Karami, 2015).

According to the results of this study, the minimum value of the bio-indices H´ and E was zero; a reason of this occurrence was only one species appearance in some plots inasmuch as the study area was mountain and some plots were randomly falling in gravelly and rocky spots, and these samples are very important since habitat affiliation of 252 species of alpine endemics of Iran is known and screes and rocks are copacetic habitats (for 44% of them) (Noroozi *et al*., 2016). The study area has a good status of the plant species diversity and richness. A good status of the plant species diversity and richness are very valuable in the study area as it has consequences on higher trophic levels (Moreira *et al*., 2016); in this special case, the consequences of plant intra-specific and inter-specific diversity on the associated faunas have been the focus of much research over the last decade (Abdala-Roberts *et al*., 2015; Castagneyrol *et al*., 2013; Cook-Patton *et al*., 2011; Haddad *et al*., 2011; Johnson *et al*., 2006; Moreira and Mooney, 2013).

The results of the present study revealed that the altitude had a significant effect on the plant diversity and species richness (p<0.01). According to the results, the plant diversity and species richness were decreased to increase altitude as the most values of bio-indices H´ and R belonged to altitudinal class 1200-1400 m a.s.l. Appearance of fewer plant species in high elevations can emanate temperature dwindling and thermal fluctuations to increase elevation in mountain areas. Reduction of air temperature with increasing altitude means the reduction of available energy for plants (Miyajima and Takahashi, 2007). Also, soil erosion by the rainwater in high elevations can cause to decrease soil depth and soil aggregate stability, so plant species normotopic can confront limitations to decrease soil fertilization and soil nucleated in long-term. Physic-chemical properties and physiographic characteristics of soil are the main effective factors in the existence of plant species (Enright *et al*., 2005). The soil fertility is the main environmental factor in vegetation establishment (Sebastiá, 2004). Several important effects of altitude (e.g., on temperature, rainfall and soil properties, and various species types in different levels) have been described by the others (Ediriweera *et al*., 2008; Garcia-Aguirre *et al*., 2007). These results are consistent with several studies accomplished in Zagros ranges (Bazyar *et al*., 2013b; Heidari *et al*., 2010; Heydari and Mahdavi, 2009) and in other areas (Chawla *et al*., 2008; Fisher and Fulé, 2004; Fu *et al*., 2004; Grytnes and Vetaas, 2002).

In this study, there were significant differences in numeric mean bio-indices including the Shannon–Wiener index and species richness between the aspects classes ($p<0.01$). Across the study site, the southern aspect had the highest value of plant diversity and richness, and after the southern aspect, the second grade of the plant diversity and richness belonged to the western aspect. These results support the results given in previous studies in western Zagros in Iran (Heydari and Mahdavi, 2009; Mirzaei and Karami, 2015), but our this finding were not consistent with the findings of Bazyar et al. (2013 b) reporting that the mean of herbaceous diversity and richness was higher in the northern and eastern aspects than southern and western aspects in a study in northern Zagros of Iran (Bazyar *et al*., 2013b).

One reason for higher herbaceous diversity and richness in southern and western aspects can be the fact that those aspects have lower tree cover density leading to increase the herbaceous cover level in the forest floor. Furthermore, effects of the geographical aspects on the solar energy acceding onto ground cause deficit of moisture content in northern aspect as compared to the southern aspect. High diversity and richness of species in southern aspects have been attributed to higher temperature and aridity of those aspects as compared to the others (Badano *et al*., 2005).

The plant diversity and species richness have been described in this paper by the Shannon-Wiener index and the total number of species in each sampling plot for comparing α-diversity level of different altitudinal classes in each geographical aspect. Along the altitudinal gradient, the highest species diversity and richness occurred in the low and mid-elevational zones of Nawa Mountain, which is consistent with other researches elsewhere (Austrheim, 2002; Huang *et al*., 2003; Jiang *et al*., 2007; Sklenar and Ramsay, 2001; Wang *et al*., 2004).

The results showed that there was a negative correlation between the plant diversity and species richness with altitude in all main aspects, which is consistent with the results of a study conducted by Mirzaei and Karami (2015) in Zagros ecosystems in the west of Iran (Mirzaei and Karami, 2015).

Conclusion

As a conclusion, the current study can briefly indicate that Nawa Mountain possesses a good herbaceous diversity and species richness. Geographical factors (altitude and aspect) have a significant effect on the plant diversity and species richness. The plant diversity and species richness decrease to increase the elevation from sea level, and the southern aspect has the highest value of the plant diversity and species richness among four main aspects. Along the altitudinal belts, the highest species diversity and richness belonged to low and mid-elevational zones of the mountain range from 1200 to 1400 m a.s.l. Grazing livestock and immethodical utilization of wild edible plants by the local people threat the plant diversity in Nawa Mountain; therefore, conservation of this biodiversity is essential in Nawa Mountain.

Acknowledgment

The research is supported by Razi University of Kermanshah, Iran. The authors thank Alireza Bagheri and Nastaran Jalilian to help in identification of plant species and also Maryam Ahmadi to statistical counseling.

References

Abdala-Roberts, L., Mooney, K.A., Quijano-Medina. T., Campos-Navarrete, M.J., González-Moreno, A. and Parra-Tabla, V., 2015. Comparison of tree genotypic diversity and species diversity effects on different guilds of insect herbivores. Oikos, 124(11): 1527-1535.

Austrheim, G., 2002. Plant diversity patterns in semi-natural grasslands along an elevational gradient in southern Norway. Plant Ecology, 161(2): 193-205.

Badano, E.I., Cavieres, L.A., Molina-Montenegro, M.A. and Quiroz, C., 2005. Slope aspect influences plant association patterns in the Mediterranean matorral of central Chile. Journal of Arid Environments, 62(1): 93-108.

Bale, C., Williams, J. and Charley, J., 1998. The impact of aspect on forest structure and floristics in some Eastern Australian sites. Forest Ecology and Management, 110(1): 363-377.

Barbour, M., Burk, J., Pitts, W., Gilliam, F. and Schwartz, M., 1999. Methods of sampling the plant community. Terrestrial Plant Ecology, 3rd Edition. Wesley Longman, Inc., Don Mills, ON.

Barnes, B., Zak, D., Denton, S. and Spurr, S., 1998. Forest Ecology, 4'"ed. John Wiley & Sons, Inc. New York, NY.

Bazyar, M., Bonyad, A. and Babaie Kafaki, S., 2013a. Study of most element of forest destruction by used the IRS-1C and LANDSAT image in the southern zagros forest (Case study: Kohkeloeye and Boveirahmad province). International journal of Advanced Biological and Biomedical Research, 1(1): 35-44.

Bazyar, M., Haidari, M., Shabanian, N. and Haidari, R.H., 2013b. Impact of physiographical factors on the plant species diversity in the Northern Zagros Forest (Case study, Kurdistan Province, Marivan region). Annals of Biological Research, 4(1): 317-324.

Castagneyrol, B., Giffard, B., Péré, C. and Jactel, H., 2013. Plant apparency, an overlooked driver of associational resistance to insect herbivory. Journal of Ecology, 101(2): 418-429.

Chawla, A., Rajkumar, S., Singh, K., Lal, B., Singh, R. and Thukral, A**.,** 2008. Plant species diversity along an altitudinal gradient of Bhabha Valley in western Himalaya. Journal of Mountain Science, 5(2): 157-177.

Cook-Patton, S.C., McArt, S.H., Parachnowitsch, A.L., Thaler, J.S. and Agrawal, A.A., 2011. A direct comparison of the consequences of plant genotypic and species diversity on communities and ecosystem function. Ecology, 92(4): 915-923.

Daubenmire, R., 1976. The use of vegetation in assessing the productivity of forest lands. The botanical review, 42(2): 115-143.

Dirnböck, T., Essl, F. and Rabitsch, W., 2011. Disproportional risk for habitat loss of high-altitude endemic species under climate change. Global Change Biology, 17(2): 990-996.

Ediriweera, S., Singhakumara, B. and Ashton, M.S., 2008. Variation in canopy structure, light and soil nutrition across elevation of a Sri Lankan tropical rain forest. Forest Ecology and Management, 256(6): 1339-1349.

Enright, N., Miller, B. and Akhter, R., 2005. Desert vegetation and vegetation-environment relationships in Kirthar National Park, Sindh, Pakistan. Journal of Arid Environments, 61(3): 397-418.

Fahimipoor, F., Chahouki, Z., Jafari, M., Goldansaz, M. and Mohhebi, Z., 2010. Investigation of Plant Diversity in Middle Rangelands of Taleghan by Using BIO-DAP. Journal of Rangeland Science, 1(1): 47-52.

Fisher, M.A. and Fulé, P.Z., 2004. Changes in forest vegetation and arbuscular mycorrhizae along a steep elevation gradient in Arizona. Forest Ecology and Management, 200(1): 293-311.

Fu, B., Liu, S., Ma, K. and Zhu, Y., 2004. Relationships between soil characteristics, topography and plant diversity in a heterogeneous deciduous broad-leaved forest near Beijing, China. Plant and soil, 261(1): 47-54.

Garcia-Aguirre, M.C., Ortiz, M.A., Zamorano, J.J. and Reyes, Y., 2007. Vegetation and landform relationships at Ajusco volcano Mexico, using a geographic information system (GIS). Forest Ecology and management, 239(1): 1-12.

Goodman, D., 1975. The theory of diversity-stability relationships in ecology. Quarterly Review of Biology: 237-266.

Grytnes, J.A. and Vetaas, O.R., 2002. Species richness and altitude: a comparison between null models and interpolated plant species richness along the Himalayan altitudinal gradient, Nepal. The American Naturalist, 159(3): 294-304.

Guerrero-Campo, J.n., Alberto, F., Maestro, M., Hodgson, J. and Montserrat-Martí, G., 1999. Plant community patterns in a gypsum area of NE Spain. II. Effects of ion washing on topographic distribution of vegetation. Journal of Arid Environments, 41(4): 411-419.

Haddad, N.M., Crutsinger, G.M., Gross, K., Haarstad, J. and Tilman, D., 2011. Plant diversity and the stability of foodwebs. Ecology letters, 14(1): 42-46.

Hayek, L.-A.C., Buzas, M.A. and Osterman, L.E., 2007. Community structure of foraminiferal communities within temporal biozones from the western Arctic Ocean. The Journal of Foraminiferal Research, 37(1): 33-40.

Heidari, M., ATTAR, R.S. and Hatami, K., 2010. The evaluation of herb Layer biodiversity in relation to physiographical factors in south of Zagros forest ecosystem (Case study: Dalab protected area). Renewable Natural Resources Research, 1(2): 28-42.

Heydari, M. and Mahdavi, A., 2009. Pattern of plant species diversity in related to physiographic factors in Melah Gavan protected area, Iran. Asian Journal of Biological Sciences, 2(1): 21-28.

Huang, X., Jiang, Y., Liu, Q., Huang, Q. and Dai, Q., 2003. The Spatial Pattern of Biodiversity in Subalpine Meadow on Mt. Xiaowutai [J]. Acta Geographica Sinica, 58: 186-192.

IPCC-WGII, 2014. Climate Change 2014– Impacts, Adaptation and Vulnerability: Regional Aspects. Cambridge University Press.

Jiang, Y., Kang, M., Zhu, Y. and Xu, G., 2007. Plant biodiversity patterns on Helan Mountain, China. Acta Oecologica, 32(2): 125-133.

Johnson, M.T., Lajeunesse, M.J. and Agrawal, A.A., 2006. Additive and interactive effects of plant genotypic diversity on arthropod communities and plant fitness. Ecology letters, 9(1): 24-34.

Joppa, L., Visconti, P., Jenkins, C. and Pimm, S., 2013. Achieving the convention on biological diversity's goals for plant conservation. science, 341(6150): 1100-1103.

Kenny, A. and Krebs, C., 2001. Ecological methodology program package, Version 6.0. University of British Columbia, Canada.

Kent, M. and Coker, P., 1992. Vegetation Description and Analysis–A Practical Approach Belhaven Press London Google Scholar. Belhaven Press, London.

Krebs, C., J, 1998; 620 pp. Ecological methodology. Addison Wesley Longman, Menlo Park California (USA).

Magurran, A., E, 1988. Ecological Diversity and its Measurement. Princeton Univ. Press, New Jersey.

Martin, C., Pohl, M., Alewell, C., Körner, C. and Rixen, C., 2010. Interrill erosion at disturbed alpine sites: effects of plant functional diversity and vegetation cover. Basic and Applied Ecology, 11(7): 619-626.

Mirzaei, J. and Karami, A., 2015. Plant Diversity and Richness in Relation to Environmental Gradient in Zagros Ecosystems, West of Iran. Journal of Rangeland Science, 5(4): 294-302.

Miyajima, Y. and Takahashi, K., 2007. Changes with altitude of the stand structure of temperate forests on Mount Norikura, central Japan. Journal of forest research, 12(3): 187-192.

Moreira, X., Abdala-Roberts, L., Rasmann, S., Castagneyrol, B. and Mooney, K.A., 2016. Plant diversity effects on insect herbivores and their natural enemies: current thinking, recent findings, and future directions. Current Opinion in Insect Science, 14: 1-7.

Moreira, X. and Mooney, K.A., 2013. Influence of plant genetic diversity on interactions between higher trophic levels. Biology Letters, 9(3): 1-4.

Noroozi, J., Akhani, H. and Breckle, S.-W., 2008. Biodiversity and phytogeography of the alpine flora of Iran. Biodiversity and Conservation, 17(3): 493-521.

Noroozi, J., Moser, D. and Essl, F., 2016. Diversity, distribution, ecology and description rates of alpine endemic plant species from Iranian mountains. Alpine botany, 126(1): 1-9.

Noroozi, J., Willner, W., Pauli, H. and Grabherr, G., 2014. Phytosociology and ecology of the high-alpine to subnival scree vegetation of N and NW Iran (Alborz and Azerbaijan Mts.). Applied Vegetation Science, 17(1): 142-161.

Pérès, G., Cluzeau, D., Menasseri, S., Soussana, J-F., Bessler, H., Engels, C,, Habekost, M., Gleixner, G., Weigelt, A. and Weisser, W.W., 2013. Mechanisms linking plant community properties to soil aggregate stability in an experimental grassland plant diversity gradient. Plant and soil, 373(1-2): 285-299.

Pimm, S.L., Jenkins, C.N., Abell, R., Brooks, T.M., Gittleman, J.L., Joppa, L.N., Raven, P.H., Roberts, C.M. and Sexton, J.O., 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science, 344(6187): 987-997.

Pohl, M., Alig, D., Körner, C. and Rixen, C., 2009. Higher plant diversity enhances soil stability in disturbed alpine ecosystems. Plant and Soil, 324(1-2): 91-102.

Pohl, M., Stroude, R., Buttler, A. and Rixen, C., 2011. Functional traits and root morphology of alpine plants. Annals of Botany, 108(3): 537-545.

Salehi, A., Heydari, M., Poorbabaei, H., Rostami, T., Begim Faghir, M. and Ostad Hashmei, R**.,** 2013. Plant species in Oak (Quercus brantii Lindl.) understory and their relationship with physical and chemical properties of soil in different altitude classes in the Arghvan valley protected area, Iran. Caspian Journal of Environmental Sciences, 11(1): 97-110.

Sandel, B., Arge, L., Dalsgaard, B., Davies, R.G., Gaston, K.J., Sutherland, W.J. and Svenning, J-C., 2011. The influence of Late Quaternary climate-change velocity on species endemism. Science, 334(6056): 660-664.

Sebastiá, M.-T., 2004. Role of topography and soils in grassland structuring at the landscape and community scales. Basic and Applied Ecology, 5(4): 331-346.

Sklenar, P. and Ramsay, P.M., 2001. Diversity of zonal páramo plant communities in Ecuador. Diversity and Distributions, 7(3): 113-124.

Tebkew, M., Asfaw, Z. and Zewudie, S., 2014. Underutilized wild edible plants in the Chilga District, northwestern Ethiopia: focus on wild woody plants. Agriculture & Food Security, 3(1): 12.

Wang, Z., Chen, A., Piao, S. and Fang, J., 2004. Pattern of species richness along an altitudinal gradient on Gaoligong mountains, southwest China. Biodiversity science, 12(1): 82-88.

ارتباط بین ارتفاع و جهت شیب با تنوع گیاهی: مطالعه موردی اکوسیستم کوهستانی نوا واقع در زاگرس، ایران

سعید محمودی [الف]، محمود خرمی‌وفا [ب]*، مسلم حدیدی [ج]

[الف] دانشجوی کارشناسی ارشد اگرواکولوژی، دانشکده کشاورزی، دانشگاه رازی، کرمانشاه

[ب] استادیار گروه زراعت و اصلاح نباتات دانشکده علوم مهندسی کشاورزی، دانشگاه رازی، کرمانشاه، *(نگارنده مسئول)، پست الکترونیک: khoramivafa@razi.ac.ir

[ج] عضو هیأت علمی سازمان جهاد دانشگاهی کرمانشاه

تاریخ دریافت: ۱۳۹۶/۰۲/۰۶

تاریخ پذیرش: ۱۳۹۶/۰۴/۰۷

چکیده. رشته کوه‌ها نیمی از مساحت ایران را پوشش می‌دهند، که در این بین اکوسیستم زاگرس به عنوان یک مکان زیستی مهم در ایران مطرح است. عوامل فیزیوگرافیک مانند ارتفاع و جهت شیب نقش مهمی در توزیع گونه‌های گیاهی در اکوسیستم‌های کوهستانی دارند. این مطالعه در اکوسیستم کوهستانی نوا در رشته کوه زاگرس، واقع درسمت غربی رشته کوه زاگرس در غرب ایران در سال ۱۳۹۵ انجام شد. هدف از انجام این مطالعه، مشخص کردن اثرات ارتفاع و جهت شیب بر ویژگی‌های تنوع زیستی گیاهی بود. از این‌رو در هر جهت اصلی با توجه به جهت شیب، خطوط ترانسکت به فاصله ۱۰۰ متر از یکدیکر از ارتفاع ۱۲۰۰ تا ۲۴۰۰ متر از سطح دریا و عمود بر جهت شیب مستقر شدند. در امتداد هر خط ترانکست، به طور تصادفی چهار پلات یک متر مربعی در مجموع ۲۰۸ پلات) برداشت گردید. به منظور ارزیابی تنوع آلفا، شاخص شانون-وینر محاسبه شد. داده‌ای میدانی نیز با استفاده از تجزیه واریانس دوطرفه، تجزیه و تحلیل شدند. بر اساس نتایج بدست آمده، ۱۵۸ گونه علفی متعلق به ۱۰۴ جنس و ۲۷ خانواده در ناحیه مورد مطالعه شناسایی شدند. هر دو عامل ارتفاع از سطح دریا و جهت شیب، تأثیر معنی‌داری بر تنوع و غنای گونه‌ای در سطح احتمال ۹۹ درصد داشتند. بیشترین مقادیر شاخص تنوع شانون-وینر و غنای گونه‌ای (به ترتیب ۲/۵۸ و ۱۰/۳۳) در ارتفاعات پایین‌تر (۱۲۰۰ تا ۱۴۰۰ متر) مشاهده شد. نتایج همچنین نشان داد که بیشترین و کمترین مقادیر تنوع شانون-وینر و غنای گونه‌ای به ترتیب به جهت‌های جغرافیایی جنوبی (به ترتیب ۲/۵۱ و ۸/۹۰) و شرقی (به ترتیب ۱/۲۰ و ۳/۶۳) مربوط بودند. اثرات متقابل متغیرهای محیطی تنها بر غنای گونه‌ای معنی‌دار بودند. علاوه بر این بین تنوع گیاهی و غنای گونه‌ای با عامل ارتفاع از سطح دریا در تمام جهت‌های اصلی همبستگی منفی مشاهده شد و در طول کمربندهای ارتفاعی، بیشترین تنوع و غنای گونه‌ای به بخش‌های پایینی تا میانی اکوسیستم کوهستانی نوا تعلق داشت.

کلمات کلیدی: تنوع زیستی گیاهی، شاخص‌های زیستی، عوامل فیزیوگرافیک، غنا، زاگرس