ISSN: 2538-2152; ECOPERSIA 2022;10(4):285-295.

Tarbiat Modares University

Effects of topographic variables on plant species diversity in rangelands of Hir County, Ardabil Province, Iran

ARTICLEINFO

Article Type
Original Research

Author
Ardavan Ghorbani, *Ph.D.*[1*]
Nooshin Porghorban, *M.Sc. Student*[2]
Mehdi Moamerin, *Ph.D.*[3]
Sahar Ghafarin, *Ph.D. Student*[4]
Mahmood Bidarlordn, *Ph.D.*[5]
MirMilad Taheri Niarin, *Ph.D. Student*[6]

How to cite this article
Ghorbani A., Porghorban N., Moamerin M., Ghafarin S, Bidarlordn M, Taheri Niarin MM. Effects of topographic variables on plant species diversity in rangelands of Hir County, Ardabil Province, Iran. ECOPERSIA 2022;10(4): 285-295

DOR:
20.1001.1.23222700.2022.10.4.3.2

[1] Professor, Department of Range and Watershed Management, Water Management Research Center, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran
[2] Former M.Sc. Student in Range Management, Department of Range and Watershed Management, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran.
[3] Associate Professor, Department of Plant Sciences and Medicinal Plants, Faculty of Meshginshar Agriculture, University of Mohaghegh Ardabili, Ardabil, Iran.
[4] Former Ph.D. Student in Rangeland Science and Engineering, Department of Range and Watershed Management, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran.
[5] Ph.D. at the Forests and Rangelands Research Department, Guilan Agricultural and Natural Resources Research and Education Center, Agricultural Research, Education and Extension Organization (AREEO), Rasht, Iran.
6 Former Ph.D. Student in Rangeland Sciences, Department of Range and Watershed Management, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran.

**** Correspondence***
Address: Department of Range and Watershed Management, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran.
Postal Code: 56199 13131
Tel: +98 (45) 33510136
Fax Number: +98 (45) 33510136
Email: a_ghorbani@uma.ac.ir

Article History
Received: May 10, 2022
Accepted: October 25, 2022
Published: November 15, 2022

ABSTRACT

Aims: This study was conducted to investigate the association between plant species diversity indices with topographic variables in the rangelands of Hir county, Ardabil Province, Iran.

Materials & Methods: Random-systematic sampling was performed in three elevation profiles at 11 sites. The elevation was divided into five classes, the slope into three classes, and the aspect into four classes. Indices of plant species richness, Margalef's, Menhinick's, Hill evenness, density, and dominance were calculated. Indices in different classes of topographic variables were analyzed using a one-way analysis of variance (ANOVA) and Duncan's mean comparison.

Findings: Results showed that the highest value of the Shannon-Wiener indices was observed in the elevation class of 1800-2000 meters above sea level (masl). The highest values of plant species evenness, richness, and diversity of Simpson's and Shannon-Wiener were related to the slope of 0-20%. The values of species richness indices and dominance in the southwest direction, and Menhinick's richness in the northwest direction, were higher than in the other directions. At the level of Plant Functional Types (PFTs), the highest amount of evenness is at the grasses PFT and elevation classes of 1800-2000 and 2400-2600 masl. The maximum amount of Hill evenness at the shrub PFT and slope of 40-60%. The highest amount of Margalef's richness and Shannon-Wiener plant diversity was in the forbs PFT and the southwest direction.

Conclusion: According to the results, elevation, and slope have the greatest effect and the aspects of the slope have the least effect on the diversity of plant species in the region.

Keywords: Elevation gradient; Physiographic factors: Plant functional types; Richness, Uniformity..

CITATION LINKS

[1] Maguran A. E. Measuring biological... [2] Samadi S., Ghorbani A., Moameri M., Abbasi M., Bidarlord M. The impact of ... [3] Chawla A., Rajkumar S., Singh K.N., Brij Lal R.D.S., Thukral A.K. Plant ... [4] Mesdaghi M. Plant Ecology. Publication of Jahade ... [5] Motamedi J., Afradi J., Sheidai Karkaj E., Alijanpour A., Emadodin I., Banej Shafiei Sh., Zandi Esfahan E. Environmental ... [6] FAO. Global Forest Resources Assessment Main Report. Food and Agriculture Organization, Rome - Italy. 2020. ... [7] Karatassiou M., Parissi ZM., Panajiotidis S., Stergiou A. Impact of grazing on diversity... [8] Jiang Y., Kang M., Zhu Y., Ku G. Plant ... [9] Zhang J. Population characteristics of endangered. ... [10] Wang B., Zhang G., Duan J. Relationship between ... [11] Thammanu S., Marod D., Han H., Bhusal N., Asanok L., Ketdee P., Gaewsingha N., Lee S., Chung J. The influence of ... [12] Abbasi Kesbi M., Tataian M.R., Tamartash R., Fattahi B. Species diversity in relation to ... [13] Ghafari S., Ghorbani A., Moameri M., Mostafazadeh R., Bidarlord M. Composition and ... [14] Ghorbani A., Taheri Niari M.M., Moameri M., Bidar Lord M., Ghafari S. The study of ... [15] Moghaddam M.R. Ecology of Terrestrial ... [16] Taheri Niari M.M., Ghorbani A., Bidar Lord M., Ghafari S. Structural analysis of ... [17] Ghorbani A., Dadjoo F., Moameri M., Bidar Lord M. Study the relationship of net primary production ... [18] Mirzaei Mossivand A., Ghorbani A., Zare Chahoki M.A., Keivan Behjou F., Sefidi K. Study of flora, life form, chrotype, diversity ... [19] Samadi Khangah S., Ghorbani A., Moameri M. Relationship between ... [20] Raunkiaer C. The Life Form of Plant and ... [21] Margalef's R. Diversity, stability, and maturity in natural ... [22] Krebs C.J. Ecology, The experimental analysis of ... [23] Ghorbani A., Porghorban N., Ghafari S. ... [24] Santos B.A., Barbosa D.C.A., Tabarelli M. Directional changes in plant assemblages along an altitudinal ... [25] Fisher M.A., Fuel P.Z. Changes in forest vegetation and arbuscular mycorrhizae along a steep ... [26] Ming C., Chen W.L., Tina Z.Q., Xie Z.Q. Altitudinal pattern of ... [27] Jahedi Pour S., Koocheki A., Nassiri Mahallati M., Rezvani Moghaddam P. The effect ... [28] Mohammadzadeh A., Basiry R., Torahi A.A., Dadashian R., Elahian M. Evaluation of diversity of plant species in Arasbaran area ... [29] Vaseghi P., Ejtehadi H., Zokaei M., Jouharchi M.R. Floristic studies, life form and chorology of plants ... [30] Armesto J.J., Martinez J.A. Relation ... [31] Badano E.I., Cavieres L.A., ... [32] Hua Y. Distribution of plant species richness ... [33] Ghorbani A., Abbasi Khalki M., Asghari A., Zare Hesari B. ... [34] Marsh W.M. Landscape ...

Introduction

Diversity is a key issue in sustainable management and nature protection. Nature protection aims to maintain the largest possible number of native species in an area, and this goal can be achieved by recognizing the diversity and ways to measure it [1]. Therefore, the study of diversity by providing basic information about the distribution, and abundance of species, recognizing and maximizing the characteristics of plant society, helps effective management, sustainable use, and protection of diversity[2]. Since the base of the ecological pyramid is based on vegetation, the greater the diversity in this bed, the greater the correlation of the species to adverse environmental conditions [3]. Plant diversity has been widely used in vegetation studies and environmental assessments as one of the important indicators in determining the managerial role and assessing the status of ecosystems [4,5]. Plant diversity changes the functioning of ecosystems and services that are essential to human well-being as well as endangered species [6]. However, they can be intensely affected by the high severity of climate change, soil attributes, nutrient depletion, fires as well as human activities [7].

The study of plant diversity and the relationship between richness, diversity, and physiographic factors has been a significant topic for researchers around the world. For example, Jiang *et al*. [8] in the study of topographic effects (elevation, slope, and aspect) on plant diversity in the east of Helan Mountain in China showed that with increasing elevation, species richness has increased. Chawla *et al*. [3] in the study of plant diversity of woody species along the elevation gradient in the Western Himalayas showed that the values of plant diversity indices with increasing elevation, first had an upward trend (at middle elevations), then a downward trend (at high elevations). In another study, Zhang [9] in investigating the relationship between environmental factors and plant diversity in the Shanxi, China loess plateau identified plant communities with different compositions, structures, and environments by cluster analysis. Their results showed that elevation, soil type, slope, and aspects were important factors in regenerating loess areas and played a decisive role in vegetation distribution. Wang *et al*. [10] in the study of the relationship between topographic factors and plant distribution in the forests of southern China, concluded that elevation and slope were the first and second important topographic factors in plant distribution, respectively. In another study, Thammanu *et al*. [11] investigated the effect of environmental factors on the composition and plant diversity of species in the forests of northern Thailand and reported that elevation was one of the most important factors in plant distribution.

Abbasi Kesbi *et al*. [12] in the study of plant diversity and richness of rangeland species in the Lashgerdar protected region, Malayer, Iran stated that there was a significant relationship between physiographic factors and species diversity of plants, however, there was no relationship between evenness indices and physiographic factors. Ghafari *et al*. [13] in the study of the composition and structure of species along the Moghan-Sabalan elevational gradient, in Iran, reported that elevation was the most important factor in species distribution. Ghorbani *et al*. [14] in the study of the effect of topographic factors on plant diversity indices in an elevational gradient of QezelOzan – Kosar, Ardabil Province, Iran, reported that changes in elevation, slope, and aspect have a significant effect on plant diversity, richness, evenness, and dominance indices.

The plant diversity in the rangeland ecosystems is directly affected by the vegetative characteristics and diversity of its species, which in addition to the main food chain as a protective shield, always ensures the sustainability of this ecosystem [4, 14]. Principled protection and exploitation of rangeland ecosystems depend on management based on quantitative development and maintenance of the highest number of native species in this ecosystem [15, 16]. Therefore, one of the ways to identify and evaluate rangelands is to recognize the species diversity of plants and measure and estimate it [1, 14].

Hir-Neour regions are one of the significant rangeland ecosystems in Ardabil Province, which are exploited by rural and nomadic pastoralists. Limited studies have been conducted in the field of plant diversity, therefore, to support, protect and exploit this ecosystem, it is necessary to have a proper understanding of the plant diversity status of this ecosystem. Therefore, the purpose of this study was to investigate and evaluate the plant diversity of this ecosystem concerning changes in elevation, slope, and aspect factors.

Materials & Methods

Study Area

The study area (Hir-Neour rangelands) is located 48 km southeast of Ardabil capital city (Figure 1). Elevation varies from 1400 to 3200 masl. Based on the rainfall gradient extracted from 25 years of data from meteorological stations around the study area, the average annual rainfall is 338 to 390 mm. The soil texture is loamy-clayey and fertile rangelands and the vegetation physiognomy of the region is forbs, shrubs, and grasses [17].

Sampling Method

With the initial survey of the study area using topographic maps and field visits, three elevation profiles were selected according to the road accessibility and in each profile, three, five, and three (11 in total) sampling sites were selected, respectively (Figure 1). At each site, three transects with a distance of 50 meters from each other were selected. The location of the first transect was randomly selected. Subsequent transects were systematically selected in the direction perpendicular to the slope. In each transect, 10 plots of one m^2 (30 plots in each site) were sampled at intervals of 10 meters (330 plots)

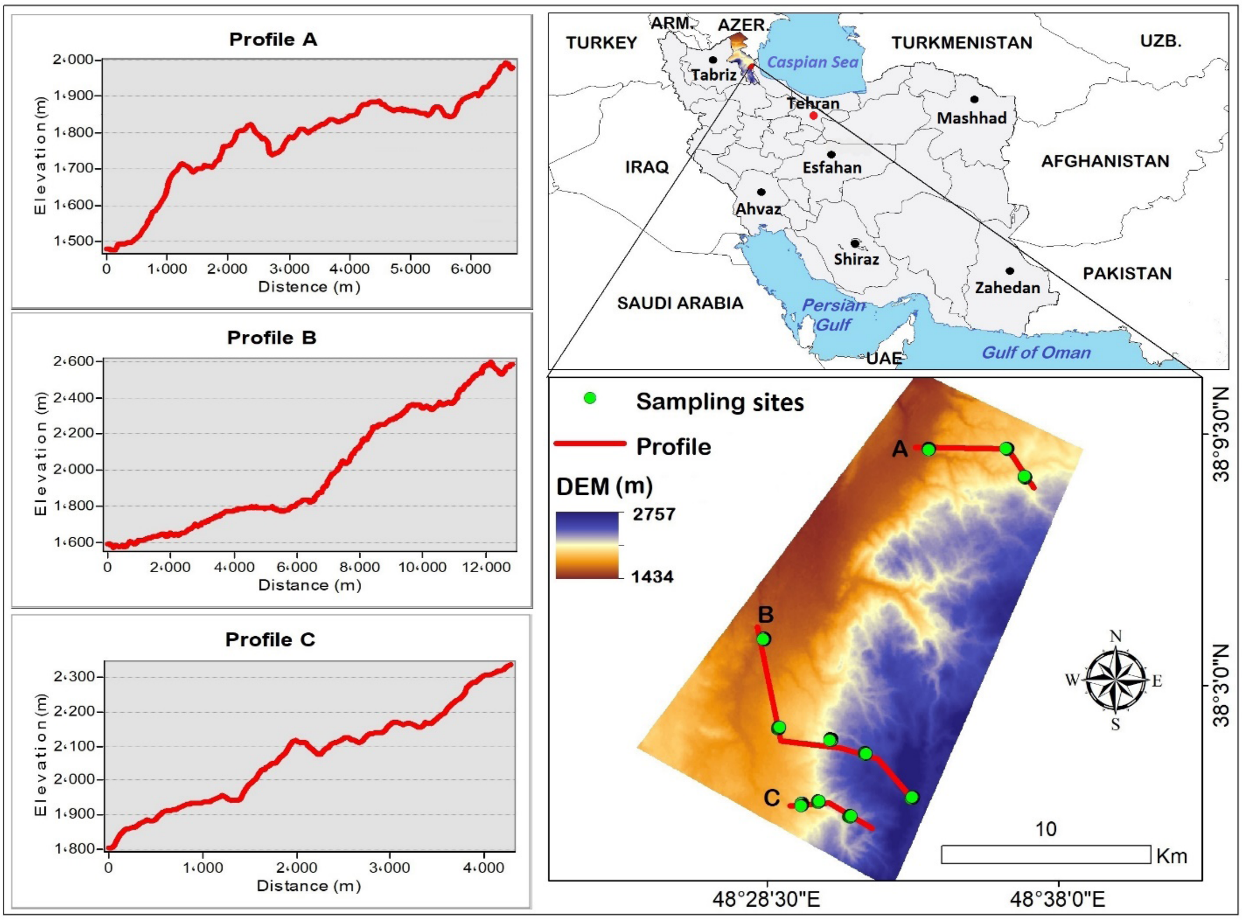

Figure 1) Location of the study area in Ardabil Province and Iran, three selected profiles (elevation variations and distance), and sampling sites.

[DOR: 20.1001.1.23222700.2022.10.4.3.2]

Table 1) Characteristics of topographic factors.

Topographic Factors	Class Code	Observations/ Selected Sites	Number of Sampling Plots in Each Class
Elevation (masl)	1	1600-1800	63
	2	1800-2000	146
	3	2000-2200	61
	4	2200-2400	30
	5	2400-2600	30
Slope (%)	1	0-20	146
	2	20-40	152
	3	40-60	32
Aspect	1	North	84
	2	Northwest	71
	3	West	102
	4	Southwest	73

in May 2016. Dimensions and number of plots were determined according to the structure of vegetation and the number of samples required and according to various literature related to the surrounding areas [16, 18, 19].
The location of sampling plots was recorded using a GPS device and, in each plot, the number of species was recorded, and unknown species were collected and transferred to the herbarium of the University of Mohaghegh Ardabili. The collected species were identified using literature such as Flora Iranica, and Iranian Flora. The biogeographical distribution of plant species and Plant Functional Types (PFTs) were determined. Raunkiaer classification was used to determine the PFTs of the species [20].
To investigate the relationship between species diversity of plants with topographic factors and to investigate their differences based on selected sampling sites and taking into account the number of samples, elevation was classified into five; slope into three, and aspects into four classes (Table 1).

Data Analysis

Using data on plant species density, the normality of the data was first examined using the Kolmogorov-Smirnov test. By the equations in Table 2, the indices of plant species diversity, richness, evenness, and dominance for the selected sites were calculated using $PAST_{ver.5}$ software. After calculating these indices, a one-way analysis of variance (ANOVA) was used to investigate the differences between sites with different elevation, slope, and aspect classes. Duncan's comparison test in $SPSS_{ver.22}$ software was used to compare the means.

Findings

Flora at the study area

The results showed that 110 species from 28 families are distributed at the selected sites. The most important plant families are included: Asteraceae with 21 species and Fabaceae with 13 species. Hemicryptophytes with 55 species and therophytes with 35 species are the most prominent PFTs by Raunkiaer's method. In terms of general PFTs, 81% of the plants are forbs, 11% are shrubs, and 8% of grasses. In terms of biogeographical distribution, Iran-Turonian species with 51% were the dominant group.

[DOR: 20.1001.1.23222700.2022.10.4.3.2]

Table 2) Indices of diversity, richness, evenness, and dominance of plant species.

Indices	Equations	Definition of Units
Shannon- Wiener Diversity		where H is the Shannon- Wiener diversity indices, *Pi* is the ratio of individuals of species *i* to the total sample, *S* is the number of species, and Ln *P* is the logarithm of *P*. The value of these indices varies from zero to 4.5 [23].
Simpson's Diversity		Where 1-*D*: Simpson's diversity indices, *N*: total number of samples, and n: number of individuals in each species. The value of these indices varies from zero to one [23].
Menhinick's Richness		Where *S* is the plot area, *N* is the number of plant species, and N is N squared. The value of these indices varies from zero to infinity [23].
Margalef's Richness		Where *S*: plot area, *N*: number of plant species, and Ln (*N*): N logarithm. The value of these indices varies from zero to one [23].
Hill Evenness		Where δ is the Simpson's indices and *H* is the Shannon- Wiener indices. When the abundance of all species in a sample is equal, the evenness indices will be maximized. The value of these indices varies from zero to one [23].
Species Dominance		Where *D* is Simpson's indices, *N* is the total number of samples and *ni* is the number of individuals in each species. The numerical value obtained from numerical indices is between zero and one, and the closer the numerical indices obtained is to zero, the lower the dominance of the species, and vice versa, the closer the numerical indices are to one, the greater the dominance of the species [24].

Table 3) Effects of elevation classes on plant density and selected indices.

Parameter/ Indices	Elevation (masl)					F
	1600-1800	1800-2000	2000-2200	2200-2400	2400-2600	
Density	293.44 ± 26.87^{a}	201.23 ± 8.72^{b}	146.75 ± 13.00^{c}	86.13 ± 9.85^{d}	75.50 ± 5.51^{d}	23.93**
Shannon-Wiener diversity	1.65 ± 0.05^{a}	1.67 ± 0.03^{a}	1.36 ± 0.05^{b}	1.66 ± 0.08^{a}	1.53 ± 0.07^{a}	7.24**
Simpson's Diversity	0.69 ± 0.01^{a}	0.71 ± 0.01^{a}	0.62 ± 0.02^{b}	0.72 ± 0.02^{a}	0.68 ± 0.03^{a}	4.60**
Menhinick's Richness	0.89 ± 0.05^{ab}	0.91 ± 0.02^{ab}	0.79 ± 0.04^{a}	1.06 ± 0.07^{c}	1.00 ± 0.05^{bc}	3.81**
Margalef's Richness	2.14 ± 0.09^{a}	2.12 ± 0.05^{ab}	1.61 ± 0.09^{c}	1.86 ± 0.11^{cb}	1.72 ± 0.09^{c}	8.56**
Hill Evenness	0.46 ± 0.01^{a}	0.49 ± 0.01^{a}	0.46 ± 0.01^{a}	0.64 ± 0.02^{b}	0.59 ± 0.02^{b}	11.73**
Species Dominance	0.30 ± 0.01^{a}	0.28 ± 0.01^{a}	0.37 ± 0.02^{b}	0.27 ± 0.02^{a}	0.31 ± 0.03^{a}	4.60**

**Significant effect at the level of 1%; Similar letters had no significant difference at different elevation classes ($p \leq 0.05$)

[DOR: 20.1001.1.23222700.2022.10.4.3.2]

Table 4) Effects of slope classes on plant density and selected indices.

Parameter/ Indices	Slope (%)			F
	0-20	20-40	40-60	
Density	218.34 ± 13.87a	160.43 ± 9.31b	168.88 ± 18.88b	6.64**
Shannon-Wiener diversity	1.71 ± 0.02a	1.51 ± 0.03b	1.49 ± 0.10b	9.70**
Simpson's diversity	0.73 ± 0.00a	0.66 ± 0.01b	0.63 ± 0.03b	10.98**
Menhinick's richness	0.89 ± 0.02a	0.90 ± 0.02a	0.99 ± 0.08a	1.24ns
Margalef's richness	2.02 ± 0.04a	1.89 ± 0.05a	2.10 ± 0.17a	2.02ns
Hill evenness	0.52 ± 0.01a	0.50 ± 0.01a	0.47 ± 0.03a	1.31ns
Species dominance	0.26 ± 0.00a	0.33 ± 0.01b	0.36 ± 0.03b	10.98**

**Significant effect at the level of 1%; *Significance effect at the level of 5%; ns no significance. Similar letters had no significant difference at different slope classes (p≤0.05)

Table 5) Effects of aspects classes on plant density and selected indices.

Parameter/ Indices	Aspects				F
	North	Northwest	West	Southwest	
Density	234.32 ± 20.63a	154.18 ± 16.29bc	175.54 ± 10.26ab	192.50 ± 15.21ab	4.63**
Shannon-Wiener diversity	1.67 ± 0.03a	1.52 ± 0.04a	1.64 ± 0.04a	1.51 ± 0.06a	2.10ns
Simpson's diversity	0.72 ± 0.01a	0.66 ± 0.01a	0.69 ± 0.01a	0.65 ± 0.02a	2.53*
Menhinick's richness	0.83 ± 0.03a	0.96 ± 0.04a	0.94 ± 0.03a	0.90 ± 0.04a	1.71ns
Margalef's richness	1.91 ± 0.05a	1.88 ± 0.07ab	2.08 ± 0.07a	2.04 ± 0.09a	2.26ns
Hill evenness	0.53 ± 0.01a	0.52 ± 0.01a	0.49 ± 0.01a	0.47 ± 0.02a	3.89**
Species dominance	0.27 ± 0.01a	0.33 ± 0.01a	0.30 ± 0.01a	0.34 ± 0.02a	2.53*

**Significant effect at the level of 1%; *Significance effect at the level of 5%; ns no significance. Similar letters had no significant difference in different aspects (p≤0.05)

The effect of topographic variables on plant diversity indices at the level of total species

Based on the results obtained from the ANOVA table in different elevation classes with density and the indices of diversity, richness, evenness, and dominance of plants were significant (p<0.01) (Table 3).

The results obtained from the ANOVA table in different slope classes showed that density and the indices of plant diversity and dominance were significant (p<0.01). However, the indices of richness and evenness were not significant (Table 4). The results obtained from the ANOVA table in different aspect classes showed that density (p<0.01), and the indices of Simpson's diversity (p<0.05), evenness

[DOR: 20.1001.1.23222700.2022.10.4.3.2]

Table 6) Effects of elevation classes on the selected indices.

PFTs	Indices	Elevation (masl)					F
		1600-1800	1800-2000	2000-2200	2200-2400	2400-2600	
Forbs	Shannon-Wiener diversity	1.24 ± 0.06ᵃ	1.55 ± 0.06ᵇ	1.17 ± 0.07ᵃ	1.10 ± 0.07ᵃᶜ	0.92 ± 0.08ᶜ	9.48**
	Margalef's richness	1.24 ± 0.06ᵃ	1.66 ± 0.11ᵇ	1.16 ± 0.10ᵃ	1.06 ± 0.08ᵃᶜ	0.83 ± 0.08ᶜ	10.56**
	Hill evenness	0.48 ± 0.03ᵃ	0.58 ± 0.02ᵇ	0.63 ± 0.03ᵇ	0.74 ± 0.03ᶜ	0.73 ± 0.03ᶜ	11.58**
Grasses	Shannon-Wiener diversity	0.58 ± 0.05ᵃ	0.37 ± 0.06ᵇ	0.46 ± 0.05ᵃᵇ	0.52 ± 0.06ᵃᵇ	0.45 ± 0.07ᵃᵇ	1.54ⁿˢ
	Margalef's richness	0.38 ± 0.02ᵃ	0.25 ± 0.04ᵃ	0.35 ± 0.05ᵃ	0.33 ± 0.04ᵃ	0.28 ± 0.04ᵃ	1.46ⁿˢ
	Hill evenness	0.67 ± 0.02ᵃ	0.88 ± 0.02ᵇ	0.77 ± 0.03ᶜ	0.87 ± 0.02ᵇ	0.88 ± 0.02ᵇ	11.76**
Shrubs	Shannon-Wiener diversity	0.44 ± 0.08ᵃ	0.58 ± 0.09ᵃᵇ	0.67 ± 0.08ᵃᵇ	0.60 ± 0.07ᵃᵇ	0.78 ± 0.05ᵇ	2.62**
	Margalef's richness	0.50 ± 0.09ᵃ	0.62 ± 0.10ᵃ	0.97 ± 0.12ᵇ	0.70 ± 0.07ᵃᵇ	0.97 ± 0.07ᵇ	4.86**
	Hill evenness	0.90 ± 0.02ᵃᵇ	0.83 ± 0.02ᵃ	0.93 ± 0.01ᵇ	0.86 ± 0.03ᵃᵇ	0.89 ± 0.01ᵃᵇ	2.53**

**Significant effect at the level of 1%; *Significance effect at the level of 5%; ns no significance. Similar letters had no significant difference in different aspects (p≤0.05)

Table 7) Effects of slope classes on the selected indices.

PFTs	Indices	Slope (%)			F
		0-20	20-40	40-60	
Forbs	Shannon-Wiener diversity	1.28 ± 0.05ᵃ	1.12 ± 0.06ᵃ	1.11 ± 0.07ᵃ	2.61ⁿˢ
	Margalef's richness	1.32 ± 0.07ᵃ	1.07 ± 0.06ᵃ	1.09 ± 0.11ᵃ	3.39*
	Hill evenness	0.59 ± 0.02ᵃ	0.66 ± 0.03ᵃ	0.66 ± 0.03ᵃ	2.16ⁿˢ
Grasses	Shannon-Wiener diversity	0.40 ± 0.04ᵃ	0.55 ± 0.04ᵇ	0.54 ± 0.07ᵃᵇ	3.74*
	Margalef's richness	0.27 ± 0.02ᵃ	0.39 ± 0.03ᵇ	0.31 ± 0.05ᵃᵇ	3.64*
	Hill evenness	0.82 ± 0.02ᵃ	0.75 ± 0.02ᵃ	0.91 ± 0.01ᵇ	8.00**
Shrubs	Shannon-Wiener diversity	0.61 ± 0.04ᵃ	0.64 ± 0.06ᵃ	0.57 ± 0.09ᵃ	0.20ⁿˢ
	Margalef's richness	0.74 ± 0.06ᵃ	0.75 ± 0.08ᵃ	0.79 ± 0.12ᵃ	0.07ⁿˢ
	Hill evenness	0.86 ± 0.01ᵃ	0.89 ± 0.01ᵃ	0.95 ± 0.01ᵇ	4.84**

**Significant effect at the level of 1%; *Significance effect at the level of 5%; ns no significance. Similar letters had no significant difference in different aspects (p≤0.05)

(p<0.01), and species dominance (p<0.05) were significant. However, the indices of Shannon-Wiener diversity and richness were not significant (Table 5).

The effect of topographic variables on plant diversity indices at the level of PFTs

The results of ANOVA of numerical indices of diversity, richness, and evenness with elevation classes for forbs and shrubs FTPs were significant (p<0.01). However, for grasses PFT only the evenness index was significant (p<0.01) (Table 6).

The results of ANOVA for forbs FTP, only richness index with slope classes was

[DOR: 20.1001.1.23222700.2022.10.4.3.2]

Table 8) Effects of aspects classes on the selected indices.

PFTs	Indices	Aspects				F
		North	Northwest	West	Southwest	
Forbs	Shannon-Wiener diversity	1.22 ± 0.06[a]	0.98 ± 0.06[a]	1.33 ± 0.05[a]	1.79 ± 0.16[b]	8.22[**]
	Margalef's richness	1.17 ± 0.16[a]	0.94 ± 0.06[a]	1.37 ± 0.08[a]	2.09 ± 0.02[b]	8.49[**]
	Hill evenness	0.64 ± 0.03[a]	0.65 ± 0.03[a]	0.60 ± 0.02[a]	0.54 ± 0.10[a]	0.77[ns]
Grasses	Shannon-Wiener diversity	0.52 ± 0.05[a]	0.51 ± 0.04[a]	0.41 ± 0.04[a]	0.45 ± 0.23[a]	1.09[ns]
	Margalef's richness	0.34 ± 0.03[a]	0.32 ± 0.03[a]	0.30 ± 0.03[a]	0.28 ± 0.14[a]	0.30[**]
	Hill evenness	0.78 ± 0.02[a]	0.83 ± 0.02[a]	0.82 ± 0.02[a]	0.88 ± 0.09[a]	0.80[ns]
Shrubs	Shannon-Wiener diversity	0.54 ± 0.06[a]	0.67 ± 0.05[a]	0.59 ± 0.06[a]	1.21 ± 0.28[b]	2.66[*]
	Margalef's richness	0.64 ± 0.07[a]	0.81 ± 0.07[ab]	0.75 ± 0.08[a]	1.27 ± 0.37[b]	1.64[ns]
	Hill evenness	0.89 ± 0.02[a]	0.88 ± 0.01[a]	0.88 ± 0.01[a]	0.81 ± 0.06[a]	0.33[ns]

**Significant effect at the level of 1%; *Significance effect at the level of 5%; [ns] no significance. Similar letters had no significant difference in different aspects (p≤0.05)

[DOR: 20.1001.1.23222700.2022.10.4.3.2]

significant ($p<0.05$). For grasses FTP, the indices of diversity ($p<0.05$), richness ($p<0.05$), and evenness ($p<0.01$) with slope classes were significant. For shrubs PFT, only the evenness index with slope classes was significant ($p<0.01$) (Table 7).

The results of ANOVA for forbs FTP, indices of diversity and richness with aspect classes were significant. For grasses FTP, only the richness index with aspect classes was significant. For shrubs PFT, only the plant diversity index with aspect classes was significant (Table 8).

Discussion

Flora of the study area

Among the plant families, Asteraceae has the highest number of species, which shows the natural trend of the presence of this family in most parts of the world [16], including other parts of Ardabil Province, where this family was dominant [13]. The second family in the study area is Fabaceae, which is considerably from the palatable species for livestock. Fabaceae has been reported as the dominant family from the Northern slopes of the Sabalan mountains [13], Fandoghlou region [2], and QezelOzan-Kosar elevational gradient [14; 16] in some case studies. According to the results obtained from PFTs, it was found that hemicryptophytes are dominated, which is due to the passage of winter by life-giving buds in such plants from the soil surface and among the winter snow. This is consistent with the results of Ghafari *et al.* [13] and Taheri Niari *et al.* [16], who concluded that the hemicryptophytes were dominant at the Moghan-Sablan and QezelOzan-Kosar elevations gradient in Ardabil Province. Moreover, Ghafari *et al.* [13] and Taheri Niari *et al.* [16], have concluded that the abundance of hemicryptophytes in an area indicates a cold and mountainous climate. In terms of geographical distribution studies, the most vegetative elements of the region were identified in the Iran-Turonian and Iran-Turonian, and Euro-Siberian regions. Another study by Ghorbani *et al.* [23] on the Asteraceae family found that the highest frequency of geographical distribution, as in the present study, was related to hemicryptophytes and the Iran-Turonian and Iran-Turonian and Euro-Siberian vegetation regions.

Effects of topographic factors on species composition and plant diversity

Elevation at the total species level

According to the results in the whole study area, elevation had a significant effect on the density, diversity, richness, evenness, and species dominance indices. With increasing elevation, species density initially increased to 1800-2000 masl, but then decreased to 2600 masl. However, there was no describable trend for plant diversity, richness, evenness, and the dominance of species with increase or decrease of elevation, and mostly they fluctuated. Although Fisher and Fuel [25] concluded that, due to the favorable environment in terms of temperature, the values of species richness were higher at low elevations in Arizona, there is also the lower temperature in comparison with the higher elevation at the study area, however, our results did not show any considerable trend in this regard.

Elevation at the PFTs level

At the level of PFTs of plants, the results showed that in grasses, about the elevation factor, only the Hill evenness indices were significant. This result was similar to the study, conducted by Ming *et al.* [26] who reported that the effect of elevation gradients on plant species diversity in Shennongjia Mountains, central China, and their results showed that the diversity of forbs and woody species decreased with increasing elevation.

Slope

The results of this study showed that with increasing the slope at the total level of plants, the indices of density, species richness, and diversity of Simpson's and Shannon-Wiener have decreased. The evenness indices in this category were the lowest (0.47%). In this regard, it can be concluded that increasing the slope of the region by reducing soil nutrients due to high leaching and also reducing the available plant moisture due to lack of water penetration into the soil, which in turn reduces the species diversity. Jahedi Pour *et al.* [27], in the study of physiographic factors on the diversity of plant species in the Kakhk Gonabad desert ecosystem, reported that slope had a significant effect on species diversity and richness, and declared the slope of 0-20 as the highest species diversity and richness, which is consistent with the results of the present study.

On the other hand, the indices of Margalef's richness, Menhinick's, and dominance increase in the category of 40-60%, which can be attributed to the impassability of the land and, as a result, the inaccessibility of vegetation for livestock due to the slope of the area. Mohammadzadeh *et al.* [29] in the study of the diversity of plant species in the Arasbaran region reported an increase in these indicators with increasing slope, due to the microclimate of the rocks and retaining moisture below them, less human degradation, and the difficulty of steep slopes for livestock grazing.

Aspects

The present study also showed that the aspects of the range at the total plant level have a significant effect on density and evenness. Species richness ($p<0.01$) and Simpson's dominance and diversity ($p<0.05$). Thus, the indices of dominance and species richness in the southwest slope are the highest value compared to other aspects. Vaseghi *et al.* [29] also stated that in Kalat Mountains of Gonabad, South Khorasan, Iran, reported the highest amount of species richness on the southern slopes. Armesto and Martinez [30] stated in the study of the Mediterranean region of Chile, that the species richness was higher in the southern direction.

Simpson's density, evenness, and diversity indices in the north direction had the highest values, which can be attributed to low sunlight and as a result of increased soil moisture and subsequent growth conditions for vegetation in the region. Many studies, including Badano *et al.* [31], have reported significant differences in the northern and southern slopes by studying areas with a Mediterranean climate and the reason for less plant diversity in the southern slopes, they have stated that these slopes are drier than the northern slopes and, consequently, reduced intra-group competition. The study of species diversity in different gradients of elevation, aspects, and slope is an attempt to understand the interactions of vegetation and inanimate environment [32].

For the PFTs of forbs, Shannon-Wiener diversity and Margalef's richness in the southwest direction have the highest distribution. Ghorbani *et al.* [33] compared

[DOR: 20.1001.1.23222700.2022.10.4.3.2]

some ecological factors affecting the distribution of *Artemisia fragrans* Wild. and *Artemisia austriaca* Jacq. in the southeastern rangelands of Sabalan, Iran, and among the factors, elevation, and its affected factors, such as slope and aspects, were introduced as important factors in the distribution of these species. Another study by Marsh [34] in New York, USA, found that differences in plant diversity across slopes depended on differences in soil moisture at these slopes.

Conclusion

According to the obtained results, the factor of elevation and slope has the greatest effect and the aspects of the slope have the least effect on the diversity of plant species in the region. Therefore, according to the results of this study, changes in species diversity indices can be used as a criterion to improve the condition of rangelands in the region and to adopt appropriate management programs. Plant diversity assessment is considered because of understanding the structure and function of the ecosystem and its evolution, conservation of gene resources, study, and control of environmental changes, and identification of suitable areas for plant diversity conservation.

Acknowledgments

The authors thank and appreciate the University of Mohaghegh Ardabili, who provided the facilities to do the present study.

Ethical Permissions: None declared.

Conflict of Interests: Authors declare they have no conflict of interest.

Authors' Contributions: Ghorbani A. (First author), Introduction author; Methodologist; Original researcher (25%); Porghorban N. (Second author), Methodologist; Fieldworks; Original researcher; Discussion author (15%); Moameri M. (Third author), Methodologist; Original researcher; Discussion author (15%); Ghafari S. (Forth author), Methodologist; Original researcher; Discussion author (15%); Bidarlord M. (Fifth author), Methodologist; Original researcher; Discussion author (15%). Taheri Niari M.M. (Sixth author), Methodologist; Original researcher; Statistical analyst; Results (15%)

Funding/Support: This research was supported by the grant and research program of the University of Mohaghegh Ardabili.

References

1. Maguran A. E. Measuring biological diversity. Blackwell Publishing. UK. 2004; 256p.
2. Samadi S., Ghorbani A., Moameri M., Abbasi M., Bidarlord M. The impact of invasive species *Leucanthemum vulgare* Lam. on vegetation characteristics of Fandoghlou rangelands in Namin county, Ardabil, Iran, J. Rangeland. 2020; 14(3): 379-392. (In Persian)
3. Chawla A., Rajkumar S., Singh K.N., Brij Lal R.D.S., Thukral A.K. Plant species diversity along an altitudinal gradient of Bhabha Valley in Western Himalaya. J. Mt. Sci. 2008; 5(1): 157-177.
4. Mesdaghi M. Plant Ecology. Publication of Jahade Daneshgahi. 2005; 187p. (In Persian)
5. Motamedi J., Afradi J., Sheidai Karkaj E., Alijanpour A., Emadodin I., Banej Shafiei Sh., Zandi Esfahan E. Environmental factors affecting the structural trials and biomass of *Onobrychis aurea* Bioss. ECOPERSIA 2020; 8(4): 247-259.
6. FAO. Global Forest Resources Assessment Main Report. Food and Agriculture Organization, Rome - Italy. 2020.
7. Karatassiou M., Parissi ZM., Panajiotidis S., Stergiou A. Impact of grazing on diversity of semi-arid rangelands in Crete Island in the context of climatic change. Plants 2022; 11(7): 982p.
8. Jiang Y., Kang M., Zhu Y., Ku G. Plant diversity patterns on Helan Mountain, China. Acta Oecol. 2007; 32(2): 125-133.
9. Zhang J. Population characteristics of endangered species *Taxus chinensis* var. and its conservation strategy in Shanxi, China. Popul. Ecol. 2010; 52(3): 407-416.
10. Wang B., Zhang G., Duan J. Relationship between topography and the distribution of understory vegetation in a *Pinus massoniana* forest in Southern China. Int. Soil Water Conserv. 2015; 3(4): 291-304.
11. Thammanu S., Marod D., Han H., Bhusal N., Asanok L., Ketdee P., Gaewsingha N., Lee S., Chung J. The influence of environmental factors on species composition and distribution in a community forest in Northern Thailand. J. Forestry Res. 2021; 32(1): 649–662.
12. Abbasi Kesbi M., Tataian M.R., Tamartash R., Fattahi B. Species diversity in relation to physiographic factors in Lashgerdar protected region, Malayer, Iran. J. Rangeland Sci. 2017; 7(1): 79-89.
13. Ghafari S., Ghorbani A., Moameri M., Mostafazadeh

R., Bidarlord M. Composition and structure of species along altitude gradient in Moghan-Sabalan rangelands, Iran. J. Mt. Sci. 2018; 15(6): 1209-1228.
14. Ghorbani A., Taheri Niari M.M., Moameri M., Bidar Lord M., Ghafari S. The study of the effect of topographic factors on vegetation diversity indices in QezelOzan rangelands of Ardabil. J. Rangeland 2020; 14(4): 551-566. (In Persian)
15. Moghaddam M.R. Ecology of Terrestrial Plants. University of Tehran publications. 2006; 702 p. (In Persian)
16. Taheri Niari M.M., Ghorbani A., Bidar Lord M., Ghafari S. Structural analysis of flora composition in altitudinal gradient of QezelOzan-Kosar altitudes rangelands, Ardabil Province. J. Toxon. Biosis. 2018; 10(34): 53-72. (In Persian)
17. Ghorbani A., Dadjoo F., Moameri M., Bidar Lord M. Study the relationship of net primary production with physiographic factors in Hir and Neour altitudes in Ardabil Province. J. Rangeland 2018; 12(1): 73-88. (In Persian)
18. Mirzaei Mossivand A., Ghorbani A., Zare Chahoki M.A., Keivan Behjou F., Sefidi K. Study of flora, life form, chrotype, diversity species along *Prangos uloptera* DC. in comparison with the control area (Case study: South East Khalkhal county, Mianroudan habitat). Renew Nat. Resour. Res. 2016; 7(1): 67-81. (In Persian)
19. Samadi Khangah S., Ghorbani A., Moameri M. Relationship between ecological species groups and environmental factors in Fandoghlou rangelands of Ardabil, Iran. ECOPERSIA 2021; 9(2): 131-138.
20. Raunkiaer C. The Life Form of Plant and Statistical Plant Geography. Clarendon Press, Oxford. 1934.
21. Margalef's R. Diversity, stability, and maturity in natural ecosystems. In: Van Dobben, W.H. & Lowe-McConnell, and R.H. (eds.) Unifying Concepts in Ecology. Junk, The Hague 1975; 1(1): 152-160.
22. Krebs C.J. Ecology, The experimental analysis of distribution and abundance. 5th Ed. Benjamin Cummings, Menlo Park. 2001; 801p.
23. Ghorbani A., Porghorban N., Ghafari S. Introducing medicinal plants of Asteraceae family in Ardabil Province. The First National Conference of Medicinal, Aromatic and Spicy Plants, Gonbad Kavous University. 2016;1(1): 1-11. (In Persian)
24. Santos B.A., Barbosa D.C.A., Tabarelli M. Directional changes in plant assemblages along an altitudinal gradient in northeast Brazil. Rev. Bras. Biol. 2007; 67(4): 777-779.
25. Fisher M.A., Fuel P.Z. Changes in forest vegetation and arbuscular mycorrhizae along a steep elevation gradient in Arizona. For. Ecol. Manag. 2004; 200(1-3): 293-311.
26. Ming C., Chen W.L., Tina Z.Q., Xie Z.Q. Altitudinal pattern of plant species diversity in Shennongjia Mountains, central China. J. Integr. Plant. Biol. 2005; 47(12): 1431-1449.
27. Jahedi Pour S., Koocheki A., Nassiri Mahallati M., Rezvani Moghaddam P. The effect of physiographic factors on plant diversity of natural desert ecosystems in Kakhk Gonabad. Desert Ecosyst. Eng. J. 2017; 5(13): 1-12. (In Persian)
28. Mohammadzadeh A., Basiry R., Torahi A.A., Dadashian R., Elahian M. Evaluation of diversity of plant species in Arasbaran area using non-parametric measures with respect to topographic factor of slope: a case study of aquiferous land of Ilgina and Kaleibar Rivers. Iranian J. Biology 2015; 27(4): 728-741. (In Persian)
29. Vaseghi P., Ejtehadi H., Zokaei M., Jouharchi M.R. Floristic studies, life form and chorology of plants in Kalat highlands of Gonabad, Khorasan Razavi Province, east of Iran. J. Sci. (Kharazmi University). 2008; 8(1): 75-81. (In Persian)
30. Armesto J.J., Martinez J.A. Relation between vegetation structure and slop aspect in the Mediterranean region of Chile. J. Ecol. 1978; 66(3): 881-889.
31. Badano E.I., Cavieres L.A., Molinga Montenegro M.A., Quiroz, C.L. Slope aspect influences plant association patterns in the Mediterranean matorral of central Chile. J. Arid Environ. 2005; 62(1): 93-108.
32. Hua Y. Distribution of plant species richness along elevation gradient in Hubei Province, China. International Institute for Earth System Science, Nanjnng Uni. 2004.
33. Ghorbani A., Abbasi Khalki M., Asghari A., Zare Hesari B. Compare of effective ecological factors in distribution of *Artemisia fragrans* Willd. and *Artemisia austriaca* Jacq. In southeast of Sabalan. J. Rangeland 2015; 9(2): 129-141. (In Persian)
34. Marsh W.M. Landscape Planning: Environmental Applications. John Wiley and Sons, Inc. New York. 1991; 212-219.

[DOR: 20.1001.1.23222700.2022.10.4.3.2]