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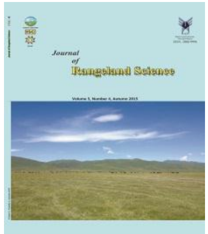

Research and Full Length Article:

Plant Diversity and Richness in Relation to Environmental Gradient in Zagros Ecosystems, West of Iran

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Abstract. Plant diversity is essential to maintain the health of planet's ecosystems. Conservation of biodiversity is necessary for the ecological stability and productivity in natural ecosystems. The aim of this research was to study the biodiversity and richness of plant species (including trees, shrubs and grasses) related to the environmental factors (soil and physiography) in the forests of Zagros, west of Iran. This study was conducted in Manesht-Ghalarang protected area in the north of Ilam province, Iran. For this purpose, some plots with a systematic distribution were selected and vegetation (trees and herbaceous), soil factors (organic matter, pH, electrical conductivity, limestone, nitrogen, potassium, phosphorus, bulk density and soil texture) and physiographic ones (slope, aspect and elevation from sea level) were measured. Results showed that the diversity of ground vegetation had a negative correlation with sand percent and it was decreased by the increased slope, elevation, EC percent and silt percent in the southern aspect. In the northern aspects, richness and diversity of ground vegetation were decreased with the increased elevation from sea level. While the tree species diversity was increased by increasing the elevation. In western aspects, the biodiversity of herbaceous species increased as $CaCo_3$ and organic matter were increased and salinity and elevation from sea level decreased. Also, the diversity of tree species in these aspects had positive reactions to potassium percent in soil.

Key words: Biodiversity, Soil, Herbaceous species, Zagros

Introduction

Zagros forests constitute more than 40% of Iranian forest and are located in the west of Iran. They have Mediterranean-type environment and supports the oak-dominant deciduous forests. Diverse topographic, climatic and other environmental conditions have produced a high biological diversity in these forests. These forests have been highly exploited in recent decades by human impacts (Bazyar *et al*., 2013). The most important destructive factors of forests are intensive livestock grazing, high utilization of woods for fuel, conversion of forests into agricultural lands and seed collection (Jazirehi and Rostaghi, 2003). Also, in the forests of Zagros, the reduction of oak trees is another serious problem that threats the future situation of these forests. Few years ago (2009-2012), at least 10% of Oak trees had been declined or dried (Ahmadi *et al*., 2014). Scott *et al*. (1998) stated that the reduced diversity of species and ecosystems is due to separation, minimization of sites and changes in soil use. They also stated that for avoiding this reduction, we will need ecological factors and requirements. In fact, plant species with similar ecological requirements have been taken together to create the desired plant communities. Vegetation characteristics such as diversity, richness and social accountability are influenced by the environmental factors. Physical properties of soil and physiographic factors are the most effective factors in separating the vegetation units. Physiographic factors with impacts on the amount of soil moisture, soil chemistry and other factors play an important role in the distribution of plant species (Enright *et al*., 2005).

Among the most effective agents in the diversity, we can point to different agents of soil and physiography whereas many scholars had studied this field–diversity of ground vegetation species connected to the chemical and physical agents of soil (Krzic *et al*., 2003; Small and McCarthy, 2005), topography (Huebner *et al*., 1995), elevation from sea level (Grytnes and Vettas, 2002; Fisher and Fuel, 2004), aspect (Bale *et al*., 1998; Badano *et al*., 2005) and slope (G-Campo *et al*., 1999; Ebrahimi, 2002). Although there are some studies on the relationship between plant diversity and environmental factors in the forest of Zagros (Heydari and Mahdavi, 2009; Heydari *et al*., 2013; Bazyar *et al*., 2013), there is little information about biodiversity in this area in different aspects. In addition, the reactions of vegetation species were different from those of woody species. This study aims to determine the correlations between diversity and richness of woody and herbaceous species and soil physicochemical characteristics in different geographic aspects in the forests of Zagros, Iran.

Materials and Methods

Study area

This study was done in the Manesht-Ghalarang protected area located in the north of Ilam city with longitude 46˚39' and latitude 33˚27'-33˚28' in Ilam province, Iran (Fig. 1). The mean annual temperature and precipitation are 16.7˚ and 538.4 mm, respectively.

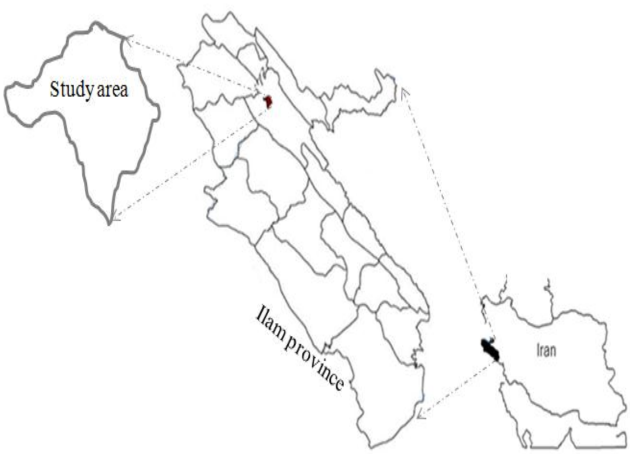

Fig. 1. Location of study area in the west of Iran

Sampling method and analysis

We design some transects with a systematic distribution in different aspects (north, south and west) of Manesht-Ghalarang protected area. In total, 67 (20×20 m) plots were systematically selected (24 plots in north, 21 plots in west, and 22 plots in south). In each plot, the woody species and their cover percent were recorded. For soil sampling in central part of each plot, soil samples were taken in 0-15 cm depth and then mixed with each other. Soil samples were air-dried, passed through a 2mm sieve and prepared to measure physical–chemical properties. The soil Electrical Conductivity (EC) and pH were measured in the deionized water (1:5 and 1:2.5 soil/water ratio, respectively) (McLean, 1982). The soil texture was hydrometrically measured and the bulk densities were gravimetrically measured. Total N was determined by the Kjeldahl method (Bremner, 1996). The available P was determined using the NaHCO solution according to the method presented by Watanabe and Olsen (Watanabe and Olsen, 1965). Exchangeable Ca, K and Mg were analyzed using inductively coupled plasmaatomic emission spectroscopy (Kalra and Maynard, 1991). Total organic matter was determined using a wet oxidation technique (Walkley and Black, 1934).

Plant biodiversity was measured using two indices including Shannon-Wiener diversity index and richness index (Menhink index) (Equations 1 and 2) (Fahimipoor *et al*., 2010).

$$H' = -\sum_{i=1}^{s} PiLn(Pi) \qquad \text{(Equation 1)}$$

$$R = S \qquad \text{(Equation 2)}$$

Where

H'=Shannon diversity index,

p_i's =Proportion of all observations in the i^{th} species category,

S =Number of plant species,

R=Menhink's richness index

Kolmogorov–Smirnov test was utilized for a normal distribution and Levens' test was applied to determine homogeneity of variances. The differences between the aspects regarding diversity indices and environmental factors were analyzed using one-way ANOVA and mean comparisons were made by the means of DMRT method. The Pearson correlation analyses were performed with respect to the relationships between the richness, diversity and environmental factors considering normal data (Zar, 1999). The data were analyzed using SPSS 16 statistical software package.

Results

In general, 202 plant species belonging to 53 genus and 29 families were identified in this region. Poaceae family and *Bromus* genus had the highest frequencies. Results showed that *Picnomon auarna*, *Bromus danthonia*, *Bromus tectorum* and *Bromus sterlilis* had the highest frequencies, respectively. Results also showed that *Quercus brantii* had the highest presence and cover percent among tree species.

The results showed that the western aspects were of higher limestone percent than southern aspects whereas higher values of other environmental factors such as C/N (10.32 S vs. 8.98 N) and bulk density (1.51 S vs. 1.33 N) were obtained in the southern aspects. Also, the results showed that in the northern aspects, organic matter (6.94 N vs. 3.6 S) and K (134 N vs. 110 S) were higher than those of southern aspects (Table 1).

According to the results of this study, the highest and lowest values of herbaceous diversity (2.35 S vs. 1.94 N) and richness (16.55 S vs. 9.85 N) were given for the southern and northern aspects, respectively (Table 1).

Table 1. Diversity indices and environmental factors in different aspects (Mean ± SD)

Factors	Western	Northern	Southern
Limestone (%)	16.56 ± 5.40 a	10.32 ± 2.11 b	13.10 ± 3.11 b
Organic matter (%)	4.54 ± 2.10 b	6.94 ± 2.13 a	3.60 ± 1.23 b
pH	7.22 ± 1.10 a	7.24 ± 0.90 a	7.26 ± 2.11 a
EC (mmhos.cm^{-1})	6.40 ± 2.1 a	6.50 ± 1.9 a	6.40 ± 1.2 a
N (%)	0.30 ± 0.10 a	0.34 ± 0.07 a	0.23 ± 0.04 a
C/N (%)	8.53 ± 2.31 b	8.98 ± 2.43 b	10.32 ± 3.11 a
K (ppm)	120.0 ± 43.0 ab	134.1 ± 53.1 a	110.0 ± 44.0 b
Bulk density (gr.cm^{-3})	1.41 ± 0.20 b	1.33 ± 0.09 b	1.51 ± 0.06 a
Clay (%)	27.60 ± 9.4 a	32.30 ± 10.2 a	30.60 ± 9.21 a
Silt (%)	44.36 ± 10.3 a	42.10 ± 9.6 a	43.40 ± 11.2 a
Sand (%)	55.63 ± 12.2 a	57.86 ± 14.3 a	56.50 ± 10.11 a
Slope (%)	52.30 ± 14.2	46.45 ± 9.8	44.90 ± 9.8
Elevation a.s.l (m)	1668 ± 120	1750 ± 100	1708 ± 110
Herbaceous diversity	2.04 ± 0.21 a	1.91 ± 0.05 b	2.35 ± 0.08 a
Herbaceous richness	11.61 ± 1.5 b	9.85 ± 2.5 b	16.55 ± 4.3 a
Tree diversity	0.78 ± 0.11 b	0.96 ± 0.04 a	0.80 ± 0.03 b
Tree richness	3.45 ± 1.11 b	3.70 ± 1.50 a	3.32 ±1.11 b

The means of rows (between aspects) followed with the same letters has no significant differences (P<0.05)

Relationships between environmental factors and plant diversity

The correlation analysis among the environmental factors, plant diversity and richness was done separately in different aspects (north, west and south) considering the fact that the richness and diversity of woody species and ground vegetation depend on various factors.

Southern aspect

The results showed that diversity of herbaceous species had a negative correlation with elevation (r= -0.45), slope (r= -0.45), EC (r= -0.48) and sand percent (r= -0.45) while it had a positive correlation with silt percent (r= 0.40) and organic matter (r= 0.47). So, the richness and diversity of herbaceous species increased with the increased organic matter. It was also decreased as the elevation and slope percent increased. Results also showed that diversity of woody species had a negative correlation with slope percent (r= -0.40) so that it decreased as the slope increased. Also, the diversity and richness of woody species in this amplitude also had a positive correlation with stone percent (r= 0.35 and r= 0.59, respectively) (Table 2).

Table 2. Pearson correlation of richness and diversity of trees and herbaceous species and environmental factors in the southern aspect

Factors	Herbaceous		Trees	
	Richness	Diversity	Richness	Diversity
Limestone (%)	0.241	0.261	0.311	0.303
Organic matter (%)	0.471*	0.405*	0.243	0.195
pH	0.311	0.231	0.327	0.213
EC (mmhos.cm^{-1})	-0.451*	-0.476*	-0.240	-0.278
N (%)	0.190	0.188	0.256	0.074
C/N (%)	0.035	0.117	-0.085	-0.054
K (ppm)	0.110	0.359	-0.206	-0.225
Bulk density (gr.cm^{-3})	-0.338	-0.318	-0.355	-0.287
Clay (%)	-0.252	-0.298	0.312	-0.262
Silt (%)	0.252	0.399 *	0.297	0.228
Sand (%)	-0.452*	-0.319	-0.297	-0.328
Gravel (%)	-0.016	0.278	0.349	0.309
Stone (%)	0.417	0.345	0.591**	0.345*
Slope (%)	-0.454*	-0.397*	-0.412*	-0.403*
Elevation a.s.l (m)	-0.446*	-0.306	-0.301	-0.352

* and **= significant at 5% and 1% probability levels, respectively

Northern aspect

Results in the northern scope showed that diversity and richness of herbaceous species had a negative correlation with elevation from sea level (r= -0.42 and -0.44, respectively). Diversity of woody species had a positive correlation with elevation from sea level (r=0.45) while it had a negative correlation with slope percent (r= -0.41) whereas there were no significant correlations between chemical and physical characteristics of soil and diversity indices of plant species (Table 3).

Table 3. Pearson correlation of richness and diversity of trees and herbaceous species and environmental factors in the northern aspect

Factors	Herbaceous		Trees	
	Richness	Diversity	Richness	Diversity
Limestone (%)	0.194	0.213	0.311	0.303
Organic matter (%)	0.211	0.234	0.243	0.195
pH	-0.161	0.111	0.327	0.213
EC (mmhos.cm^{-1})	-0.103	-0.101	-0.240	-0.278
N (%)	0.071	0.171	0.256	0.074
C/N (%)	0.258	0.223	-0.085	-0.054
K (ppm)	0.124	0.301	-0.206	-0.225
Bulk density (gr.cm^{-3})	-0.113	-0.112	-0.355	-0.287
Clay (%)	-0.178	0.145	0.312	-0.262
Silt (%)	-0.022	-0.095	0.297	0.228
Sand (%)	0.022	0.095	-0.297	-0.328
Gravel (%)	-0.344	-0.353	0.349	0.209
Stone (%)	0.268	0.155	0.291	0.245
Slope (%)	0.258	-0.311	-0.412*	-0.413*
Elevation a.s.l (m)	-0.435*	-0.416*	0.401*	0.452*

*= significant at 1% probability levels

Western aspect

In the western aspects, the richness of herbaceous species increased with the increased limestone and organic matter percent and the decreased soil salinity, bulk density, slope and elevation from sea level. On the other hand, the diversity of woody species had a positive correlation with K (r= 0.453) so that the diversity of tree species increased as K values increased. Also, the richness of tree species increased with the increased elevation from sea level and stone percent (Table 4).

Table 4. Pearson correlation of richness and diversity of trees and herbaceous species and environmental factors in the Western aspect

Factors	Herbaceous		Trees	
	Richness	Diversity	Richness	Diversity
Limestone (%)	0.398*	0.251	0.172	-0.190
Organic matter (%)	0.409*	0.286	0.294	0.202
pH	-0.280	-0.188	-0.381	-0.191
EC (mmhos.cm^{-1})	-0.512**	-0.401*	-0.387	-0.347
N (%)	0.207	0.363	0.185	0.095
C/N (%)	0.182	0.073	0.039	-0.006
K (ppm)	0.386	0.208	0.364	0.453*
Bulk Density (gr.cm^{-3})	-0.437*	-0.284	-0.335	-0.329
Clay (%)	-0.176	0.128	0.036	0.206
Silt (%)	0.314	0.254	0.356	0.231
Sand (%)	-0.014	0.054	0.356	0.231
Gravel (%)	0.231	0.171	-0.401	-0.541
Stone (%)	0.173	0.120	0.422*	0.456
Slope (%)	-0.415*	-0.321	0.014	0.137
Elevation a.s.l (m)	-0.470*	-0.267	0.451*	0.373

* and **= significant at 5% and 1% probability levels, respectively

Discussion

Physic-chemical properties and physiographic characteristics of soil are the main effective factors in the existence of plant species (Enright *et al*., 2005). Our results showed that in the southern aspects, soil texture had a significant correlation with plant diversity. So by the increased sand percent, the herbaceous diversity was decreased. Sand increased the soil infiltration and caused a progressive dehydration (Bay Bordi, 1993). So in the southern aspects due to high solar radiation, it has a negative effect on the presence of plant species (G-campo *et al*., 1999). But there were more species where the silt level was high (silt causes more storage of moisture in the roots of plants). Gron groft *et al*. (2003) in a similar study in five regions showed that there was a low diversity in those regions where there was a higher level of sand.

Results also showed that the enrichment and diversity of woody plants had a positive correlation with rock and stone percent. This may cause an increase in diversity and richness of these species. It is possible that rock and stone percent play a protective role in a way that the soil erosion is avoided and proper conditions are provided for the seeds of trees and other species.

Also**,** results showed that there was a negative correlation between the diversity and richness of woody species and slope percent in the southern aspects. One of indirect factors that affect the existence of species positively or negatively is the slope of region. Increased slope results in the leaching of soil and excessive drainage; therefore, it has negative effects on the richness and existence of woody species.

This research indicated that in the northern amplitude by the increased height from sea, ground vegetarian species would be decreased. Many previously done studies reported similar results (Ebrahimi, 2002; Fisher and Fuel, 2004). Higher temperature in low amplitude causes higher richness (Hejazy *et al*., 1998; Fisher and Fuel, 2004; Grytnes *et al*., 2002). It is remarkable that the increases of richness and diversity of tree species depend on the increased height above sea. By looking at the results concerning woody and ground herbs in this study, we can conclude that perhaps human factors in the past caused that woody (tree) species grew towards the heights while herbs tend to low lands. In fact, diversity and richness of woody species in low lands are a little eliminated. This is a progress in which diversity and richness of vegetation species in low lands of studied zone have increased. Thus, a good diversity of woody species in low lands of this area is possible in future. The correlation between diversity of woody species and slope was negative like southern latitudes.

According to the results and as reported by Pauses and Austin (2001), there is a positive correlation between limestone percent and diversity of under-story vegetation species in western amplitude. Calcium is the most important factor in soil that controls other food constituents. It is possible that the presence of lime in this amplitude caused the increased number of species and the enhanced Calcium rate. Schuster and Diekmann (2005) in Northwestern forests of Germany found the same results as well. In addition, our study showed negative correlations of herbaceous diversity with EC in the western and southern aspects. It was a limiting factor that stopped the activity of organisms in soil (Jafari, 2000). Probably, salt accumulation in soil had caused the elimination of sensitive species. El-Ghani (1998) in the east of Egypt showed that salinity had a negative effect on the richness of species. In addition, we found a good response of vegetation species to chemical and physical factors of soil while woody species had a proper response to physiographical and physical properties of soil.

Conclusion

According to the results of this study, physicochemical properties of soil had different effects on the richness and biodiversity of plant species in different aspects. So, in the southern aspects, soil texture had significant effects on biodiversity while in the northern aspects, the elevation had effects on biodiversity. Therefore, we should have different programs for each aspect to conserve more plant species. Also, the results showed that diversity and richness of plant species decreased with the increased elevation from sea level. As a result, forest managers should insert intensive conservation programs at low elevations.

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رابطه تنوع زیستی و غنای گونه‌های گیاهی با عوامل محیطی در اکوسیستم‌های جنگلی زاگرس در غرب ایران

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چکیده. تنوع زیستی گونه‌های گیاهی برای حفظ سلامتی اکوسیستم‌های کره زمین ضروری است. حفاظت از تنوع زیستی یک ابزار ضروری در پایداری و افزایش تولید اکوسیستم‌های طبیعی است. هدف این تحقیق بررسی رابطه بین غنا و تنوع زیستی گونه‌های درختی و علفی با عوامل فیزیکو-شیمیایی خاک و فیزیوگرافی در جنگل‌های زاگرس بود. برای این منظور، پلات‌هایی با پراکنش منظم در منطقه حفاظت شده مانشت و قلارنگ در شمال شهر ایلام پیاده و پوشش گیاهی (درختان و گونه‌های علفی)، عوامل خاکی (ماده آلی، اسیدیته، هدایت الکتریکی، آهک، نیتروژن، پتاسیم، فسفر، وزن مخصوص ظاهری و بافت خاک) و فیزیوگرافی (شیب، جهت جغرافیایی و ارتفاع از سطح دریا) برداشت شد. نتایج نشان داد که تنوع و غنای گونه‌های علفی زیراشکوب در دامنه‌های جنوبی با درصد شیب، ارتفاع از سطح دریا، درصد شن شوری خاک همبستگی منفی و با سیلت همبستگی مثبت دارند. در جهت‌های شمالی، غنا و تنوع زیستی گونه‌های علفی زیر اشکوب با افزایش ارتفاع از سطح دریا کاهش یافت. در حالی‌که تنوع گونه‌های چوبی در این دامنه‌ها با افزایش ارتفاع افزایش یافت. همچنین نتایج نشان داد که تنوع زیستی گونه‌های گیاهی زیر اشکوب در جهت‌های غربی با آهک و ماده آلی همبستگی مثبت و با شوری، وزن مخصوص ظاهری، شیب و ارتفاع از سطح دریا همبستگی منفی داشت. همچنین در این دامنه تنوع گونه‌های درختی با پتاسیم خاک همبستگی مثبتی نشان داد.

کلمات کلیدی: تنوع زیستی، خاک، گونه‌های علفی، زاگرس