Effect of Some Environmental Factors on Plant Species Diversity in the Mountainous Grasslands (Case Study: Hamedan - Iran)

Bakhtiar Fattahi[*] and Ali Reza Ildoromi

Malayer University, Department of Rangeland and Watershed Management Engineering, Malayer-Iran

Abstract Species diversity is an index for sustainability of rangeland ecosystems. We studied the effect of environmental factors (soil properties and aspects) on plant species diversity in Zagros mountainous rangelands (vegetation type: *Festuca ovina-Astragalus parrowianus*) in the west of Hamadan in March–July 2009. For this purpose, four aspects were defined in the study area. Vegetation types were studied by physiognomic-floristic method in the field. The factors of vegetation were measured by transects using a systematic-randomized method. Five transects (100 m) and five plots along each transect were used. One soil sample (composition, 0–40 cm) in each plot was collected by a randomized method and assessed the following factors: pH, OM, N, EC, P, K and texture in the laboratory. The multiple regression method was used to investigate the relationship between species diversity (dependent variables) and soil and topographical factors (independent variables). Results showed that soil characteristics and aspects had significant effects on diversity in which north, east and west aspects as well OM, N, EC and clay were the most prominent factors influencing diversity.

Key words: *Grassland, Iran, Mountainous rangeland, Plant Diversity, Zagros*

1   INTRODUCTION

In order to understand the relationships between ecological elements of rangeland and improved principles of range management, it is necessary to study plant species diversity (Marini Lorenzo *et al.*, 2007). Species diversity of plants can be divided into two main components: 'richness', which represents the number of species in a given area, and 'evenness', which represents the variability in species abundance (Magurran, 2006; Triin Reitalu *et al.*, 2009). Species richness is considered as a prominent factor of productivity and stability (Cristofoli, 2010; X. Gong *et al.*, 2008) and predominantly controlled by local factors, and only secondarily by factors operating at the landscape level (Wright *et al.*, 2003; Marini Lorenzo *et al.*, 2007). Many studies have

shown that abiotic environmental factors, such as topographic parameters, can be important sources of variation of plant diversity (Bennie *et al.*, 2006; Marini Lorenzo *et al.*, 2007). Grassland diversity is strongly affected by environmental factors; e.g. soil and topography (Cristofoli, 2010; Marini Lorenzo *et al.*, 2007). Some theoretical studies have suggested that there is a direct positive relationship between species evenness and species richness; recent empirical studies reveal that the relationship between species richness and evenness is not always positive (Stirling and Wilsey, 2001; Triin Reitalu *et al.*, 2009).

Species evenness and richness also differ in their responses to local habitat factors (Ma, 2005; Wilsey and Stirling, 2007), suggesting

that the two diversity components may vary independently and be influenced by different ecological processes. For example, Wilsey and Stirling (2007) showed that, while the richness component of plant species diversity in prairie microcosm communities was sensitive to migration rates, the evenness component was more sensitive to changes in the intensity of competition. Additionally, they showed that while species richness may be influenced by the availability of seed sources in the surrounding areas, species evenness is more likely to be affected by the abiotic and biotic properties of local habitats (Triin Reitalu *et al.*, 2009). Several other studies have concluded that species evenness may show a stronger association (than species richness) with ecosystem stability and function (Mattingly *et al.*, 2007). Soil nutrients have been shown to be an important factor for plant diversity (Zechmeister *et al.*, 2003; Camilla *et al.*, 2007).

Chemical and physical soil properties are related to natural soil characteristics, and influence both species richness and evenness of vascular plants (Myklestad, 2004; Marini Lorenzo *et al.*, 2007). It is well established that the phosphorus (P) and nitrogen (N) content of soil is an important determinant for the reconstruction or conservation of species-rich rangelands (Cristofoli, 2010; Marini Lorenzo *et al.*, 2007).

Species diversity is regarded as one of the most central criteria in biodiversity assessments and in decisions about management priorities for grasslands. However, the majority of studies on the impact of landscape and environmental variables on plant species diversity in grasslands have focused on the assessment of species richness (Lindborg and Eriksson, 2004; Helm *et al.*, 2006; Cousins *et al.*, 2007; Öster *et al.*, 2007; Johansson *et al.*, 2008) and species evenness is less often considered in such studies (Foster and Tilman, 2003; De Bello *et al.*, 2006; Aavik *et al.*, 2008; Triin Reitalu *et al.*, 2009). Plant species richness in

natural grasslands has been shown to be associated with habitat area, with habitat connectivity (Helm *et al.*, 2006; Öster *et al.*, 2007), with the type and intensity of current management and with habitat land-use (Johansson *et al.*, 2008). Species evenness in natural grasslands has been shown to be influenced by management intensity, and by changes in management regime (De Bello *et al.*, 2006; Aavik *et al.*, 2008). Species evenness and richness in semi-natural grasslands may also be expected to differ in their response to landscape properties (Triin Reitalu *et al.*, 2009). The assemblage of plant species in natural grasslands is often related to abiotic factors such as soil and topography (Cousins and Eriksson, 2002; Camilla *et al.*, 2007).

On slopes, differences in species composition were explained by resource availability, especially water (Badano *et al.*, 2005; X. Gong *et al.*, 2008). By monitoring long-term vegetation change, due to the edaphic factors, south-facing slopes maintained more stress-tolerant and light-demanding flora in British chalk grasslands (Bennie *et al.*, 2006; X. Gong *et al.*, 2008). The difference of plant species composition and productivity, long-term operating soil weathering, and erosion processes are usually accelerated on south-facing slopes (Rech *et al.*, 2001), resulting in different soil properties of north- and south-directed slopes (Bochet and García-Fayos, 2004; X. Gong *et al.*, 2008)

Given this background, in order to assess the relevance of the environmental factors (soil properties and aspects) and species diversity, we surveyed vegetation parameters and soil characteristics of northern, eastern, southern and western slopes of Zagros mountainous rangelands (vegetation type: grass-shrub) under local management practices in 2009. We hypothesized that species diversity depended strongly not only on soil characteristics, but also on topography.

2   MATERIALS AND METHODS

2.1   Study area

The study area was located in the mountainous rangeland of Zagros, central Iran (34° 45′ 18″ – 34° 49′ 24″ N; 48° 9′ 8″ – 48 12′ 20″ E), the western district of the Hamadan province with ca. 2700 ha. The climate was midway between semi-arid and semi-humid with a mean rainfall of 450 mm y^{-1}. The mean annual temperature was 10–12°C (max: 34°C; min: –15°C). Mean altitude is 2045 m (max: 2586 m; min: 1840 m). Clay-loam and sandy-loam are the dominating soil types. The study area is grazed by sheep with light grazing intensity.

2.2   Sampling method

Aspect and slope maps were prepared on the basis of topographical maps (at a scale of 1:25,000) and aerial photographs (at a scale of 1:20,000) using Arc GIS version 9.1. All maps were combined to locate ecological units, using GIS. In each aspect throughout the study area five ecological units were identified. Five transects (100 m) and five plots (2.5 m^2) at each transect were used in each unit. Size and number of plots were determined by 'minimal area' and 'statistical' methods, respectively.

Vegetation data were recorded in May–July 2008 in a systematic-randomized method. Vegetation types were studied by the physiognomic-floristic method (Fattahi *et al.*, 2008). Species diversity was calculated by the Shannon-Wiener method:

$$H' = -\sum_{i=1}^{S} P_i L_n P_i \qquad (1)$$

Where; H' is the Shannon-Wiener diversity index, Pi is the relative frequency of the ith species (Magurran, 2004).

In each plot composite soil samples were taken by the randomized method at a depth of 0–40 cm, during June 2009. Soil pH, total phosphorus content (P), total potassium (K), total nitrogen (N), organic matter (OM), electrical conductivity (EC) and texture (clay, silt, sand) were measured in each of the soil samples.

2.3 Statistical analysis

Relationship between species diversity with soil characteristics and topography (aspects) was investigated by multivariate analysis. We used the 'multi-regression enter' method that suitable for quantity variables such as species diversity. (Kalantari, 2002). Soil and topographical characteristics were considered as independent variables. The total variation revealed by the two models was divided into the two groups of explanatory variables – soil and topography – using a multivariate regression analysis, as implemented in SPSS, version 15.0.

3   RESULTS

Results showed that the dominant vegetation type was grass-shrub land (*Festuca ovina-Astragalus parrowianus*). Furthermore, from field data we identified 25 Family, 132 Genus and 242 Species. The average values of species diversity and soil characteristics in different aspects are shown in Table 1.

All of the variables presented linear relations with species diversity; thus, there are two regression models for investigation of relationship species diversity with soil and topography (Table 2). Species diversity was introduced as a dependent variable and soil and topography components introduced as independent variables. Two model regressions have been presented for species diversity: (1) with soil characteristics; and (2) with aspects.

Table 1 The average value of species diversity and soil characteristics.

Factor \ Aspect	North	East	South	West
Species diversity	2.85	2.46	1.97	2.35
pH	7.2	7.25	7.40	7.30
OM	1.218	0.873	0.758	0.765
N	0.11	0.08	0.07	0.071
P	16.23	21.62	29.68	7.31
K	143.66	200.83	155.83	151.5
EC	0.173	0.240	0.178	0.155
Clay	10.33	7.41	4.91	6.16
Silt	31.56	29.78	37.7	35.61
Sand	56.6	64.2	47.4	48.2

Table 2 Regression models summary.

Model	R	R-square	Adjusted R-square
Soil	0.808	0.652	0.664
Topography	0.602	0.362	0.513

Table 3 Analysis variance of regression models.

Model		Sum of squares	df	Mean square	F
Soil	Regression	0.773	10	.077	9.045**
	Residual	0.401	43	0.009	-
	Total	1.147	53	-	-
Topography	Regression	0.645	4	0.161	7.252**
	Residual	0.381	7	0.054	-
	Total	1.06	11	-	-

Analysis of the data (Table 2), showed that R coefficient exhibited correlation of the observed value of the dependent variable with its anticipated value based on the regression model. R-square depicts part of variance of species diversity that explained by soil or topography. Both R and R^2 values change between 0 and 1. Due to numerous independent variables, the main effect of soil characteristics on species diversity was shown by 'Adjusted R Square'. ARS elucidate partial dispersion of species diversity that explained by linear regression model. As shown in Table 3, in each regression model the total observed variation is partitioned: (1) a part illustrated by the linear regression model (Regression), and (2) a part that the linear regression model cannot explain (Residual).

As shown in Table 4, neither of the B values is zero; thus, all soil and topography components affected species diversity; but considering F and significant values, total nitrogen content (N), organic matter (OM), clay and electrical conductivity (EC) from the soil components were significantly correlated with species diversity; so they had significant effect on species diversity. Likewise, pH, silt, total phosphorus, sand, total potassium and CaO_3 had no significant correlation with species diversity. In addition, from topography components, with the exception of the south aspect, total aspects significantly correlated with species diversity. Positive B-value sign means that when the value of independent variables increases, the anticipated value of dependent variables will increase (direct relation). In contrast, negative B-value sign means that when the value of the

independent variable decreases, the anticipated value of the dependent variable will decrease (contrary relation). In general, the regression model has shown:

$$\hat{y}=a+b_1x_1+b_2x_2+ \ldots b_nx_n \qquad (2)$$

where $\hat{y}$ = anticipated value of dependent variable; a = constant value; b = coefficient regression; and x = value of independent variable.

According to the Table 4 and Eq. (2), regression models of species diversity show:

1) Regression model of species diversity with soil components:

$$\hat{y}=-5.32+2.009OM+17.8N-1.73EC+0.001Clay \qquad (3)$$

Regression model of species diversity with topography component (aspects):

$$\hat{y}=0.181+0.078N+0.126E-0.064w \qquad (4)$$

Table 4 The values of coefficients and components of regression models.

Variable		Unstandardized coefficients		*T*	Sig.
		B	Std. Error		
Soil	Constant	-1.12	1.8	-0.622	0.04*
	pH	0.653	0.298	2.191	0.06
	OM	2.009	1.35	1.488	0.005**
	N	17.8	13.67	1.302	0.007**
	P	0.005	0.003	1.666	0.08
	K	0.006	0.002	3	0.14
	EC	-1.73	1.04	1.663	0.04*
	Clay	0.001	0.09	0.011	0.03*
	Silt	0.033	0.010	3.33	0.07
	Sand	0.021	0.009	2.333	0.1
Topography	Constant	0.181	0.0093	19.462	0.09
	North (N)	0.078	0.081	0.962	0.004**
	East (E)	0.126	0.083	1.518	0.05*
	South (S)	-0.135	0.083	1.626	0.12
	West (W)	0.064	0.081	0.790	0.03*

4 DISCUSSION

Many of the environmental factors tested in the present study were significantly associated with species diversity. The highest species diversity was found in the north aspect with significantly higher values of OM, N, and clay and with lower pH value (Table 1). The 'R' coefficient (Table 2) indicated that the regression models can anticipate values of species diversity with confidence, e.g. 80% and 60% based on soil and topography components, respectively. As shown, in the variation partitioning, 65% and 36% of species diversity variation was related to soil and topography components, respectively, i.e. indicated that the chosen variables explained a large amount of the total variation. Thus, on a regional scale, the dominant gradients of variation in overall grassland community composition are related to soil factors (Cristofoli *et al.*, 2007). The results of the partial regression models showed that topography and soil component were both positively associated with species diversity (Table 2). As summarized in Table 4, total nitrogen content (N), organic matter (OM), clay and electrical conductivity (EC) from soil components were positively significantly correlated with species diversity (indeed, the soil model indicated that EC affected species diversity negatively). Because of this, the characteristics serve to improve soil structure and fertility and consequently affect growth, regeneration and establishment of plants. Soil pH, P, K, silt and sand had no significant

effects on species diversity (Reitalua *et al.*, 2009); hence they are not determinative factors for vegetation.

Aspects such as the north, east and west presented were most significantly associated with species diversity, while the south aspect was the only significant topographical variable with a negative effect on species diversity (M. Lorenzoa, 2007; Reitalua, *et al.*, 2009). Aspects had a direct influence on vegetation composition (Andrieu, 2007). South aspect percept received more solar radiation, less precipitation and soil depth; thus, these factors led to higher soil temperature, less humus and lower soil fertility. These provided unsuitable conditions for growth and regeneration of plants and their species diversity compared with other aspects. Based on this information, the hypothesis of this study was confirmed completely (Lorenzoa, 2007; Reitalua *et al.*, 2009).

5 CONCLUSION

In general, this study highlighted the relationships between topographic and soil characteristics, and vegetation diversity of the investigated grassland, and revealed how these factors affected the diversity. Also, it has illustrated that soil characteristics have a more important role than topography in vegetation diversity. Diversity measures reflect species abundance and richness and may provide additional information on the ways in which plant communities respond to habitat conditions. Based on these results, range mangers should give specific consideration to soil changes or erosion. Any tendency to soil degradation should be resisted. Soil conservation is one of the most important range management principles. It can help in grazing management, vegetation and wildlife conservation. We suggest that the assessment of species diversity should be used more often – as a complement to the assessment of vegetation – in monitoring projects and empirical studies.

6 ACKNOWLEDGEMENT

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تأثیر برخی عوامل محیطی بر روی تنوع گونه‌ای گیاهی در گراسلندهای کوهستانی (مطالعه موردی: همدان-ایران)

بختیار فتاحی و علیرضا ایلدرومی

چکیده تنوع گونه‌ای شاخصی برای پایداری اکوسیستم‌های مرتعی است. در این تحقیق اثر برخـی فاکتورهـای محیطـی (خصوصیات خاک و جهت دامنه) بر روی تنوع گونه‌ای در مراتـع کوهسـتانی زاگـرس (تیـپ گیـاهی -*Festuca ovina Astragalus parrowianus*) در غرب همدان در سال ۱۳۸۹ بررسی شد. برای این منظور چهار جهت اصلی در منطقـه مورد مطالعه تعیین گردید. تیپ گیاهی به روش فیزیونومیک-فلورستیک در عرصه شناسـایی شـد. فاکتورهـای پوشـش گیاهی در روش نمونه‌برداری سیستماتیک تصادفی با استفاده از ترانسکت اندازه‌گیـری شـدند. تعـداد ۵ ترانسـکت ۱۰۰ متری و ۵ پلات در امتداد هر ترانسکت در هر واحد نمونه‌برداری مستقر گردید. در هر پـلات یـک نمونـه خـاک ترکیبـی (عمق ۴۰-۰ سانتی‌متر) به صورت تصادفی برداشت شـد و فاکتورهـای: pH, OM, N, EC, P, K و بافت نمونـه‌هـا در آزمایشگاه اندازه‌گیری شد. برای بررسی ارتباط میـان تنـوع گونـه‌ای (متغیـر وابسـته) و فاکتورهـای خـاک و توپـوگرافی (متغیرهای مستقل) از روش رگرسیون چندگانه استفاده شد. نتایج نشان داد که ویژگـی‌هـای خـاک و جهـت دامنـه اثـر معنی‌داری بر روی تنوع گونه‌ای دارند. دامنه‌های شمالی، شرقی و غربی و هـم‌چنـین OM, N, EC و مقـدار رس تـأثیر بیشتری بر روی تنوع داشته‌اند.

کلمات کلیدی: گراسلند، ایران، مراتع کوهستانی، تنوع گیاهی، زاگرس