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Relationship between Plant Diversity and Soil Characteristics in a Deciduous *Cercis griffithii*.L Site of Northern Zagros, Iran

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Abstract
Of the 49 samples taken, the relationship between surface soil factors with understory vegetation diversity was investigated (Shannon's- H', diversity index) along with the species tree by Canonical Components Analysis (CCA). Soil samples were taken and analyzed for pH, EC, C, K, Na, Mg, N, P, clay, sand, loam and organic matter. Major soil gradients of the study area were determined by Principal Component Analysis (PCA) and were used in additional analyses rather than the original factors, thus avoiding the co-linearity problem. The relationship between understory species diversity with soil gradients were studied by multiple regressions and the species tree by CCA. Results showed that the relationship of soil gradients with understory diversity was best described by a unimodal curve and the species tree by a CCA graph. The most important variables were the soil gradients with understory diversity, clay percentage, silt percentage, N and Mg. Also, within the species tree were clay, silt, sand and organic matter. However, there were unexplained variations in the relationship between soil factors and understory diversity. The remaining variation could partly be explained by the canopy cover.

Keywords: Understory diversity, Regression analysis, Northern Zagros, Soil properties.

رابطه میان تنوع گیاهی و مشخصات خاک رویشگاه جنگلی ارغوان در زاگرس شمالی

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چکیده
به منظور بررسی رابطه میان فاکتورهای خاکی و تنوع گیاهی (شانون، شاخص تنوع) و گونه های درختی بوسیله آنالیز تحلیل تطبیقی متعارف ۴۹ پلات پیاده گردید. با استفاده از آنالیز نمونه‌ها میزان فاکتورهای pH، هدایت الکتریکی، کربن، پتاسیم، سدیم، منیزیم، سدیم، فسفر، رس، شن، سیلت و مواد آلی خاک محاسبه گردید. برای جلوگیری از خطاهای یک طرفه و استفاده از آنالیزهای افزایشی گرادیان‌های خاکی بوسیله آنالیز تحلیل تطبیقی غیر متعارف محاسبه گردید. رابطه میان تنوع گونه‌های زیراشکوب با گرادیان‌های خاکی بوسیله رگرسیون چند متغیره و گونه‌های درختی بوسیله آنالیز تحلیل تطبیقی متعارف مطالعه شدند. نتایج بدست آمده از رابطه گرادیان‌های خاکی با تنوع زیر اشکوب بهترین تاج پوشش را مشخص نمودند و گونه‌های درختی بوسیله گراف‌های آنالیز تحلیل تطبیقی متعارف نشان داده شدند. همچنین نتایج رابطه گرادیان‌های خاکی با تنوع زیر اشکوب، فاکتورهای مهم درصد ماسه، درصد سیلت، نیتروژن و منیزیم و در گونه های درختی ماسه، سیلت، شن و مواد آلی محاسبه گردید. به عبارت دیگر بعضی از متغیرها در رابطه میان فاکتورهای خاکی و تنوع زیر اشکوب توضیح داده نشدند. سطح تاج پوشش تا حدودی این متغیرها را مشخص می‌نماید.

کلمات کلیدی: تنوع زیر اشکوب، آنالیز رگرسیون، زاگرس شمالی، مشخصات خاکی.

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Introduction

The Zagros forests cover an area of 5.05 million km^2 covering the Northwestern region to the South of Iran (Adeli *et al.*, 2008). The main influence of these forests is the water supply, soil conservation, climate change and socio-economical balance of the entire country (Sagebtalebi *et al*., 2004). Zagros is divided into three distinct regions based on the different oak species: northern and southern Zagros. North Zagros is an exclusive site of *Quercus infectoria* mixed with *Q. libani* or *Q. brantii* or both. However, southern Zagros is an exclusive site for *Q. brantii* and various other tree species, consisting of *Cercis griffithii*.L, *Pistacia atlantica, Pyrus syriaca* and *Crataegous pontica*. *Cercis griffithii*.L is one of the most subtly attractive small native trees. *Cercis griffithii*.L can be attractive when mixed with dogwood or other spring flowering trees especially in woodland or naturalized landscapes. It is also very desirable near houses since it is in scale with most one-story homes (Zohary, 1973).

These forests are located in the Mediterranean phytogeographical region (Zohary, 1973). A characteristic and vital component of Mediterranean deciduous forests is the diversity of understory vegetation and tree species. The distribution and abundance of plant species in these systems has been linked to complex environmental gradients, especially moisture and soil fertility (Jazireii and Ebrahimi, 2003), light availability and canopy structure (Beatty, 1984; Collins *et al.*, 1985). The relationship between species richness and other environmental factors, such as light and soil parameters, has been less studied (Schuster and Diekmann, 2005).

In recent years, ecological studies have been used for environmental factor analyses. According to the study, ecologically, *Quercus Libani* Oliv in the region of Marivan, showed effective environmental factors in the separation of ecological species groups based on discriminant multiple analyses which included: aspect, pH, menhenic index, terrain index, landform and elevation. Aspect and elevation were distinguished as the most important environmental factors in the separation of groups and associations (Basiri, 2003). The results of the ecological studies demonstrated that environment factors are effective in the separation of ecological species groups based on discriminant multiple analyses (Mirzai *et al.*, 2007, Rezaipour, 2008).

In addition to the recent ecological studies of the Zagros forest, no information is available on ecological characteristics of the *Cercis griffithii*.L. Therefore, the purpose of this research is as following:

(a) Studying the edaphic gradients in *Cercis griffithii*.L site.
(b) Studying the edaphic gradients in study area.
(c) Analyzing univariate relationships between edaphic gradients and species diversity.
(d) Testing whether the data variation remaining unexplained in the multiple models is related to other parameter than soil factors.

Materials and Methods

Study area: This research was conducted in the Hajij forests located at an elevation of 1100-720m above sea level and with an annual average temperature of 15.16 °C, in the western region of Iran. The *Cercis griffithii*.L site, is about 45 km from Paveh, in Kermanshah Province ($33^{\circ} 28'$W, $46^{\circ} 39'$N Fig. 1).

Figure 1. Location of the study area.

The forest overstory of the study site is dominated by *Cercis griffithii*.L and other tree species included: *Quercus infectoria* and *Q. brantii*. *Pistacia atlantica, Pyrus syriaca* and *Crataegous pontica*. The climate of the site is classified as that of a Mediterranean type and is characterized by dry summers and cool winters. The mean annual rainfall is 587 mm that occurs as follows: 44.9% in winter, 29.5% in autumn, 25.5% in spring and merely 0.1% in summer; the average temperature is 15.16^{o}C. Soil texture of the study area is sandy clay loam according to US soil taxonomy.

Data acquirement: Forty- nine samples with a systematic random sampling design were considered. For each sample four quadrates of 2.25 m^2 (totally 196 quadrates) were established and species coverage was assessed in each quadrate. Areas of samples were chosen by using species/area curve. For tree's crown 1200 m^2 were measured for computing percentage of tree crown coverage.

Composite soil samples were collected from below the litter to a depth of approximately 25cm in all samples from four different locations, each sample consists of four cores taken with auger. Prior to chemical analysis, the soils were air dried, crushed and passed through a 2mm sieve. The soil analyses were done at the Tarbiat Modarres University Soils Testing Laboratory. The following test were conducted; pH (pH meter method %), EC (EC meter) three part article-size classes (clay, silt, and sand in % according to International Soil Science Society (ISSS) classification), organic matter (OM) (%, Walkey and Black method), N total (%, Kjeldahl method), P (ppm, Olsen method), K, Ca, Mg (ppm, Flame Photometry) and $CaCo_3$ (Volume method).

Data analysis: Species tree by Canonical components analysis (CCA) and Shannon's ($H^{/}$) diversity index were calculated for 49 samples to describe the diversity of the ground vegetation in the data (Table 1).

Table 1. Explanation of calculation.

Index	*Reference*	*Formula*
Shannon's ($H^{/}$)	Peet, 1974	$H^{/} = -\sum_i p_i \ln(p_i)$
p_i is the proportion of species i in the community; Shannon's ($H^{/}$) is the total number of species;		

We subjected the twelve soil variables to a principal component analysis (PCA), based on the correlation matrix of the variables, to produce a smaller number of uncorrelated soil axes. Principal component (PC) axis scores were used as synthetic soil variables in further data analyses. This method produces hypothetical variables (components), accounting for as much variation in the data as possible (Kooch *et al.*, 2008). The components are linear combinations of the original variables. Ordination axes are statistically independent, so PCA ensures that multiple regressions do not have the collinearity problems that would arise from testing contributions of all 12 soil variables simultaneously. For this, PC-ORD software was used (McCune and Mefford, 1999). To examine the relationship between species diversity and soil variables, regression analysis was applied. We only used linear and quadratic models, as other model types did not serve the purpose of our study aiming at discriminating between straight and hump-shaped relationships. The model with the highest adjusted r^2 was regarded as the one fitting the data best.

Results

Canonical components analysis (CCA) was applied to the taxonomic site data, in order to identify the major gradients of between-site variation in soil chemistry and species tree (Jongman *et al.*, 1987). Three CCA components, which accounted for 38.4% of the variability in the twelve soil parameters, were retained (Table 2). Axis 1 includes the species *Quercus brantii*, *Ficus johanis* Boiss, *Cercis griffithii*.L, *Daphne mucronata Royle*, *Acer monspessulanum L. subsp. Assyriacum (Pojark.) Rech. F.*, *Salix spp*, *punica granatum*, *Paliurus spina-christy* and *Amygdalus orintalis Duh* from the *Quercus brantii* and *Ficus johanis* Boiss group had positively correlated with clay percentage and negatively correlated with sand percentage.

Scores on Axis 2 that were positively correlated with organic matter include the species *Cercis griffithii*.L, *Cerasus mahalab* (L.*) Miller, Daphne mucronata Royle, Acer monspessulanum L. subsp. Assyriacum (Pojark.) Rech. F., Amygdalus orintalis Duh* from the *Pistacia atlantica Desf. Subsp. Mutica (Fish & C. A. May) Rech* group. Scores on Axis 3 included species *Quercus brantii, Pistacia atlantica Desf. Subsp. Mutica (Fish & C. A. May) Rech. F, Pistacia atlantica Desf. Subsp. Mutica (Fish & C. A. May) Rech. F, Daphne mucronata Royle, Amygdalus scoparia Spach, Salix spp, punica granatum, Tamarix spp and Amygdalus orintalis Duh* of the *Cercis griffithii*.L group which were positively correlated with Ca and negatively correlated with silt.

Principal Components Analysis (PCA) was applied to the soil chemical data, in order to identify the major gradients of between-site variation in soil chemistry (Jongman *et al.*, 1987). Four PCA components, which accounted for 71.97% of the variability in the twelve soil parameters, were retained (Table 2).

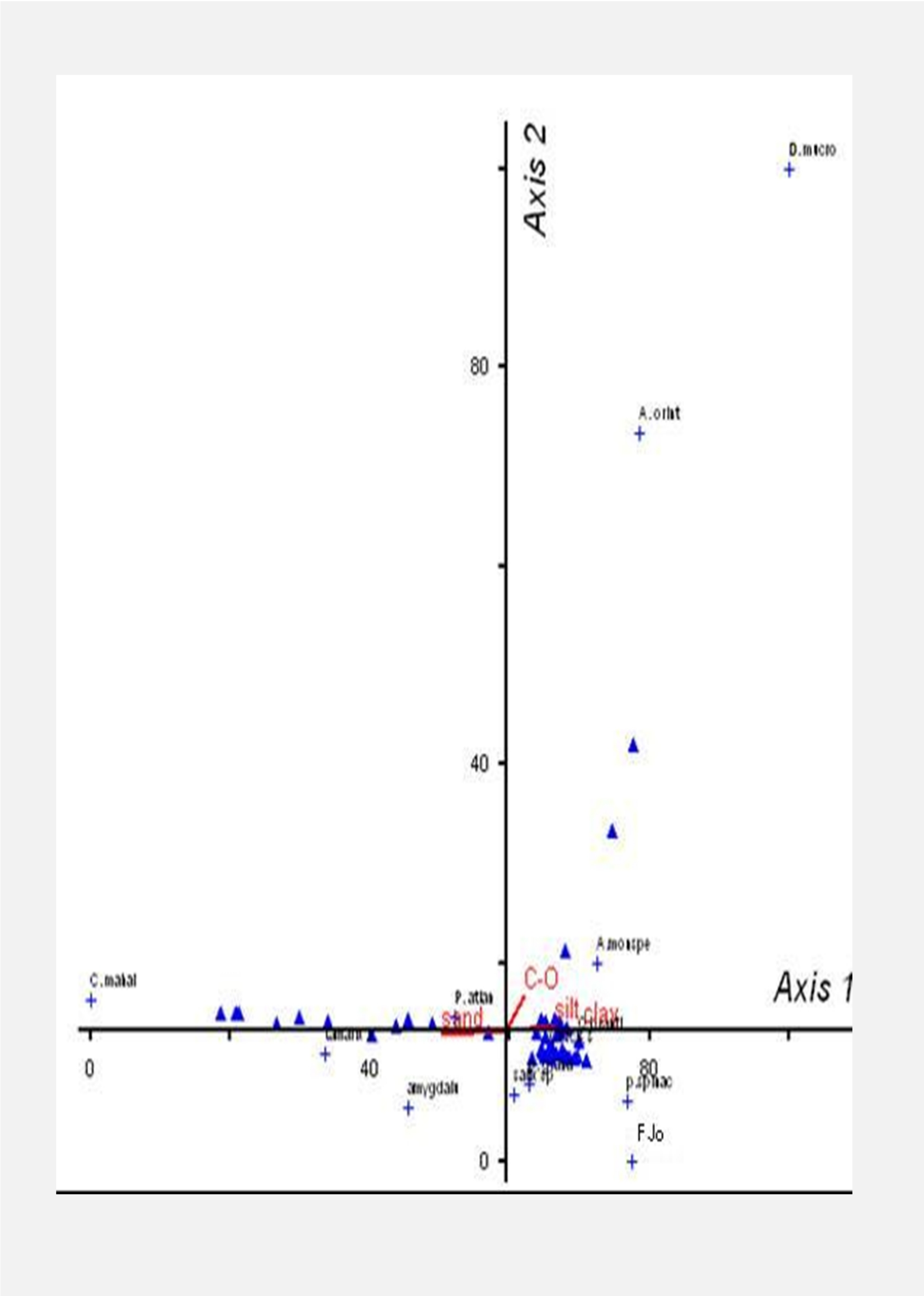

Figure 1. Graph of a principal component analysis based on the correlation Matrix between soil variables.

Table 2. Results of a principal component analysis based on the correlation matrix between soil variables.

Eigen value	Axis 1	Axis 2	Axis 3	
	0.318	0.187	0.067	
Percentage of Variance	21.3	12.5	4.5	
Cumulative %	21.3	33.9	38.4	
Clay	0.713	-0.010	-0.193	
Silt	0.444	0.116	-0.355	
Sand	-0.589	-0.093	0.315	
pH	0.323	-0.054	0.251	
Electric Capacity	0.383	-0.031	0.012	
$Caco_3$	0.266	-0.283	-0.104	
Organic Matter	0.176	0.746	0.034	
N	0.130	0.329	-0.396	
Mg	0.213	0.003	-0.142	
K	0.100	0.059	-0.344	
Ca	0.293	0.034	0.431	
P	-0.157	0.284	-0.232	

Values on the body of the table represent the correlation coefficients of the original variables with each PCA axis.

Table 3. Results of a principal component analysis based on the correlation matrix between soil variables.

Eigenvalue	Axis 1	Axis 2	Axis 3	Axis 4
	3.89	2.13	1.42	1.18
Percentage of Variance	32.46	17.75	11.85	9.89
Cumulative %	32.46	50.21	62.07	71.97
Clay	0.38	-0.12	-0.35	0.18
Silt	0.43	0.09	-0.19	-0.03
Sand	-0.46	-0.02	0.27	-0.05
pH	0.00	-0.40	-0.46	-0.32
Electric Capacity	-0.29	-0.29	0.36	-0.03
$Caco_3$	-0.01	-0.35	-0.20	0.46
Organic Matter	0.16	0.14	-0.20	-0.57
N	0.37	0.23	0.30	-0.06
Mg	0.30	-0.22	0.36	0.16
K	0.27	0.16	-0.01	0.13
Ca	0.13	-0.42	0.32	-0.49
P	0.09	0.51	0.00	-0.13

Values on the body of the table represent the correlation coefficients of the original variables with each PCA axis.

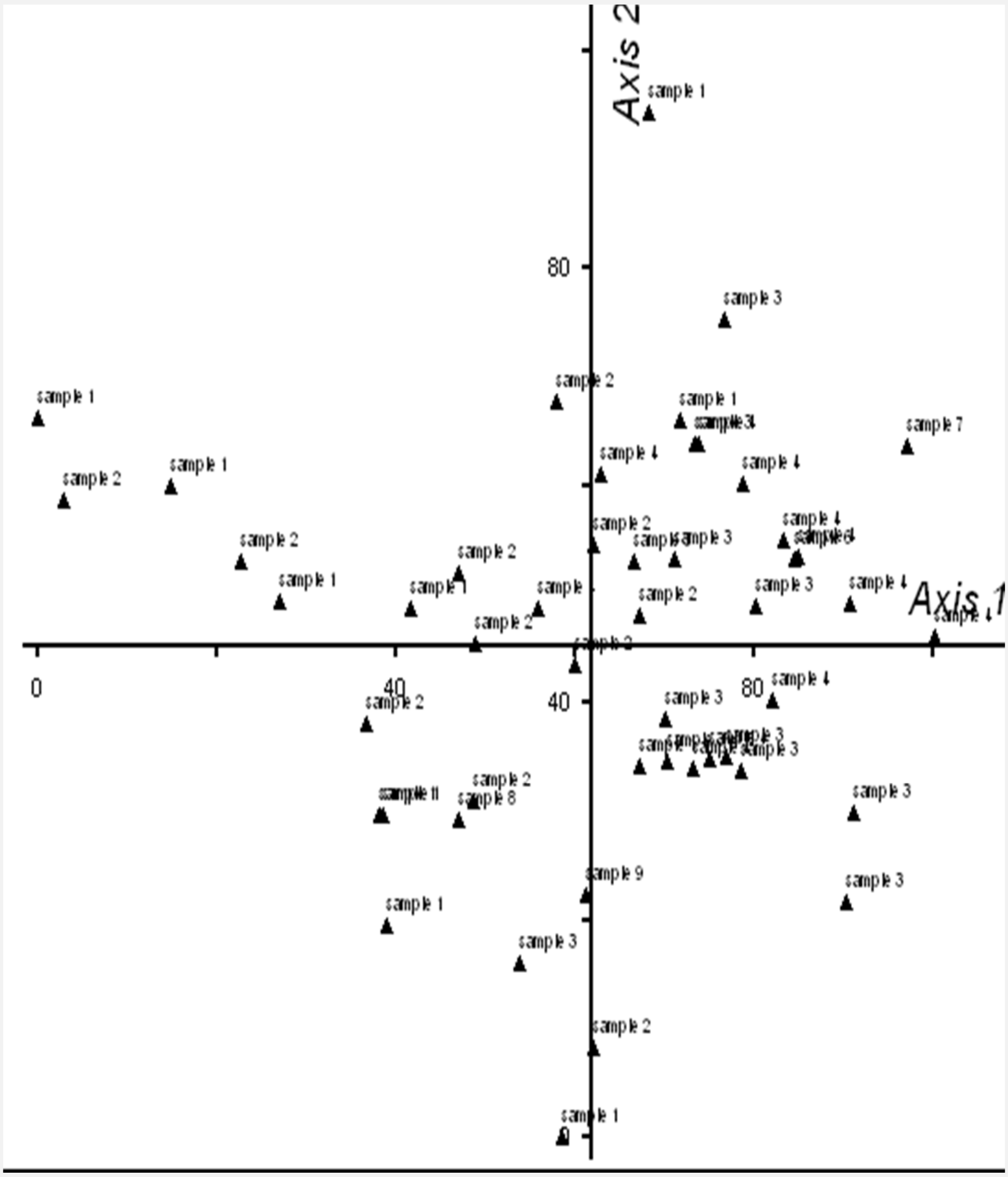

Figure 2. Graph of a principal component analysis based on the correlation matrix between soil variables.

Axis 1 was positively correlated with clay percent, silt percent, N and Mg negatively correlated with sand percent and Electric Capacity. Scores on Axis 2 were positively correlated with P. Scores on Axis 3 were positively correlated with Electric Capacity, N, MG and Ca and negatively correlated with clay and pH; Axis 4 with $Caco_3$ was positively correlated with Organic Matter and Ca negatively correlated.

Neither linear nor quadratic regression models were significant for Axes 2, 3 and 4 for the Shannon index. However, Axis 2 showed a relationship with species diversity (linear model equation is SI=0.342+0.044Axis2: $p<0.000$, $r^2=0.165$, quadratic model equation SI=0.313+0.46Axis2-0.014Axis2^3: $p<0.000$, $r^2=0.247$ Fig. 3).

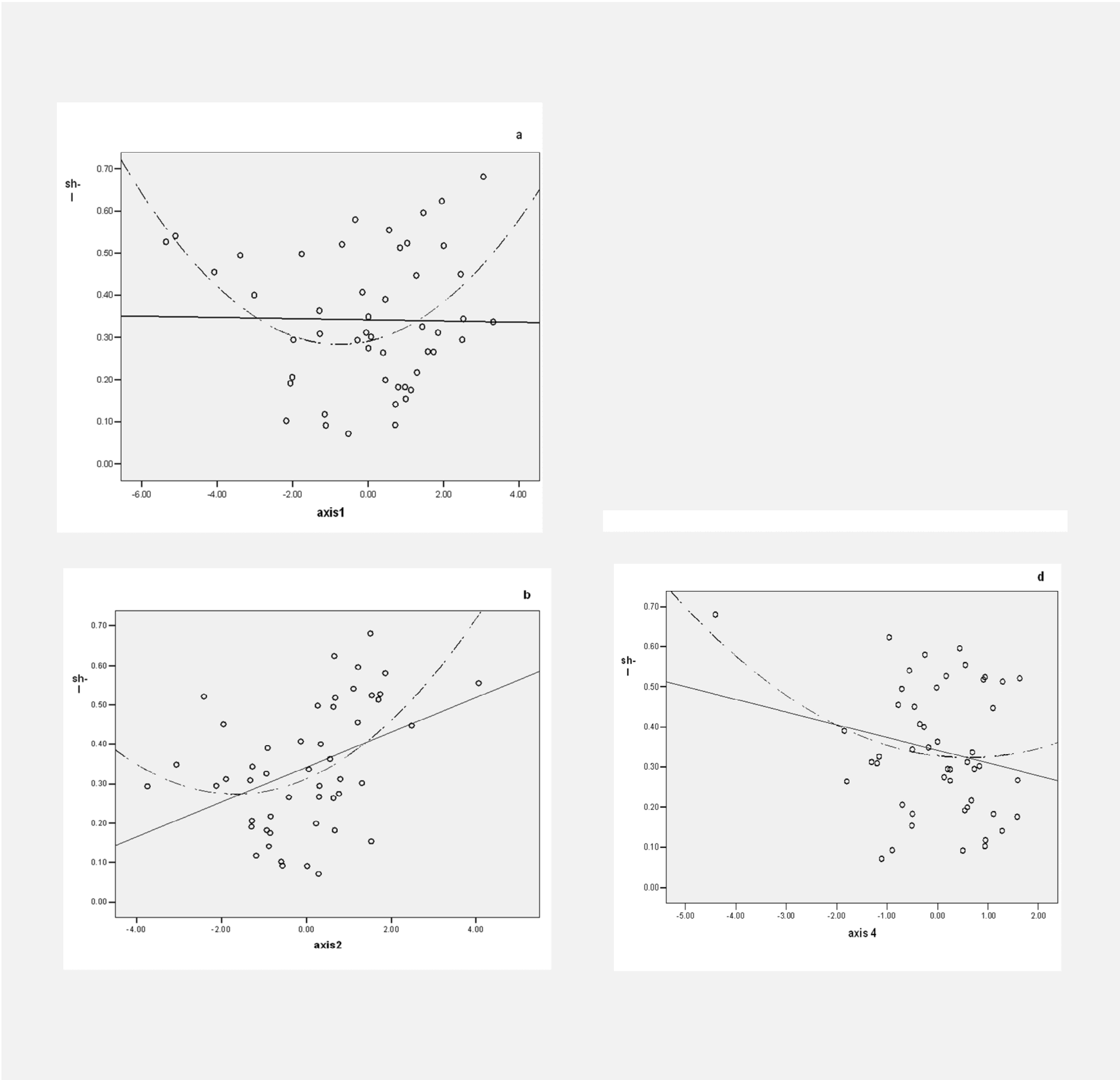

Figure 3. Multiple regression analysis for studying the relationship between understory diversity and soil gradients.

Results indicate that there was remaining variation that could not be explained by the measured edaphic parameters.

Table 4. Person correlation between crown cover and residuals of linear and quadratic regression models.

	r^2	Sig
linear	0.165	**0.00**
quadratic	0.247	0.00

The correlation of the residuals, generated with the regression analysis of understory diversity and soil gradients, with the one factors related to habitat configuration showed that tree coverage played an important role in the determination of species diversity. Tree coverage was significantly negatively correlated with the residuals of both models (Table 3).

Discussion

The hump-backed pattern acknowledges that species diversity increases from low to moderate soil fertility and declines again when fertility rises to high levels. We discovered the unimodal relationships between understory diversity and soil surface parameters. As productivity is the sum (or product) of many environmental factors, it is not surprising that these have a distinct, mostly quadratic relation with species diversity. According to Tilman (1982) and Rosenzweig (1995), the unimodal model generally describes the relationship between environmental factors and species diversity better than the alternative models. Also, according to Axis 3, CCA can demonstrate results showing for *Cercis griffithii*.L that were positively linked with Organic Matter and negatively linked with silt. This analysis shows that the species diversity increases with increasing Clay, Organic Matter and Ca soil. This can be explained by the fact that species diversity is, to a considerable extent, due to the high proportion of Clay, Organic matter and Ca perennials.

Therefore, in these forests, a certain effect is not only a prerequisite for the occurrence of many species in the ground vegetation (Christensen and Emborg, 1996; Pausas and Austin, 2001) but is also responsible for site heterogeneity that allows adaptation for many species to develop (Standova´r, 1998; Halpern and Spies, 1995). The majority of the mineral nutrients that are released from the Shale and Limestone are transported to the plants root system by the ground water. The mineralization processes required a certain level of soil moisture while, at the same time, it was assisted by the high pH-values. The influence and the effect of the saturation soil moisture on the species composition and diversity thus has to be evaluated differently in the *Cercis* forests than those of other forests. There is fundamentally a greater nutrient supply and an invariably higher organic matter supply resulting from the leaf input of *Pyrus syriaca* and *Crataegous pontica*, which lives symbiotically with other organic matter fixers. These findings are closely linked with the phenomenon that the majorities of the *Cercis* forest species are categorized as NO_3-plants and are therefore bound to sites where nitrate is the principal source of nitrogen (Zahreddine, 2007). These species are to be found on soils where nitrifiers are active due to a weakly alkaloid to neutral pH-value of the soil.

According to Pausas and Austin (2001) calcium, in particular, is the most important exchangeable cation in the soil that influences soil pH-value and controls the availability of other nutrients. Calcium also controls soil aggregates and has an important role in producing stability in soil structure. Soil structure and moisture percentage increases as the crown density increases, beneath the strongly shading canopy of the oak trees (see Brunet *et al.*, 1997). These findings confirm the results of the investigations by Brosofske *et al.* (2001) on the dependence of species diversity on the forest ground vegetation of various soil conditions. While the understory layer diversity varied significantly with increasing soil fertilities at our study site, edaphic and crown cover features showed the most pronounced influence on understory dynamics. Site variability is likely to be an important determinant of the understory disturbance response (Collins *et al.*, 1985; Meier *et al.*, 1995; Roberts and Gilliam, 1995). Ultimately, it is suggested that the Cersis griffithii. L in its native sites will establish itself and grow in a loamy soil with a high moisture and pH= (6.6-8.1), which is a particular aspect of the northern, northeastern and northwestern regions of the country.

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