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Relationships between Soil Properties and Plant Diversity Indices (Case Study: Lashgardar Protected Rangeland, Malyer, Iran)

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Abstract. Soil moisture is generally regarded as the limiting factors in rangeland production. Although many studies have been conducted to estimate soil moisture in semiarid areas, there is little information on mountainous rangelands in west of Iran. The present study aims to investigate the soil moisture estimation in rangelands as compared to the other land uses over a mountainous area in central Zagros, Iran using remote sensing. The Surface Energy Balance Algorithm for Land was used to compute actual evapotranspiration (ET) and soil moisture by the means of Landsat8 images of March, April, May, June, July, August and September 2013 for diverse land uses in Malayer, Iran. SEBAL algorithm estimates the ET using net radiation flux, soil heat flux and sensible heat flux. The results showed that there was no significant difference between daily ET computed by SEBAL method and Penn man Monteith. Mean Bias Error (MBE) and Root Mean Square Error (RMSE) for daily and hourly ET were 0.15 and 0.39, respectively. The spatial regression was used to detect the relationship between soil moisture index (SMI) and Temperature dryness vegetation index (TDVI) as dependent variables and daily evapotranspiration (ET24) as independent variable. The results revealed that the correlation between SMI and ET24 was positively significant (0.78 to 0.49) and between TDVI and ET24 was negatively significant (-0.74 to -0.46) during the period of rangeland vegetation growth in this area (March to June). SMI in rangelands had the strongest correlation as compared to the other land uses. Thus, SEBAL model is a robust tool to calculate the soil moisture in rangelands by the means of remote sensing.

Key words: Diversity, Richness, Evenness, Soil, Malayer

Introduction

Soil is the main source of essential minerals for organisms. However, soil is subjected to physical and chemical variations in its properties that are affected by such factors as climate and vegetation. The relationships between soil physical and chemical properties and plant vegetation have an impact on broad geographic distribution and diversity of plants. Protection of plants within an ecosystem has a significant impact on the order of plant communities to reach a dominant position; it can also prevent from the deterioration of natural resources by increasing diversity in an ecosystem. Plants as a resource in an ecosystem have a major effect on the organic life, preservation of nature and maintenance of a balanced ecosystem (Mesdaghi, 2004). In recent decade, global environmental meetings on biodiversity and climate change have been the main issues of human environments (Enright *et al*., 2005).

Biodiversity is known as either species diversity or ecosystem diversity; species diversity is the most commonly applied term. Species diversity is an important property of biological communities, which is a function of number of existing species and population of that species in a given geographical area (Krebs, 1999). Soil physical, chemical and topographic factors are effective in species presence or absence (Leonard *et al.,* 1984) .Species presence and distribution of plant communities in a rangeland ecosystem are not accidental; though climate, soil, and human and topographical factors determine its development (Schwilk, 2006).

Soil conditions and climate are factors that have a direct effect on heterogeneity of vegetation (plant diversity) in an area and resilience of those plant communities. Soil is an important factor for distribution of plant communities and sub-communities. Moisture and salinity conditions in the soil are the most important factors to have a negative correlation with species diversity whereas such factors as $CaCo_3$, sand, altitude and slope have a significant positive correlation with evenness (Rostampour *et al.,* 2009). A study was done on the relationship between diversity and environmental factors in Rtvn Fashandak rangelands in Taleghan, Iran and results showed that among the factors, aspect, depth, texture, $CaCo_3$ and potassium contents of soil had a greater impact on species diversity (Zare Chahoki *et al.,* 2009). Another study (ZareChahoki *et al.*, 2008) investigated the relationship between species diversity and environmental factors in Poshtkuh rangelands in Yazd province, Iran. Results showed that texture, available moisture, potassium and Electrical Conductivity (EC) had the greatest impact on species diversity. A study that examined the relationships between species diversity and environmental factors in Sarchah Amari rangelands in Birjand, Iran indicated that EC, gypsum, organic matter, slope, and sand had the greatest impact on species diversity in the area (Yari *et al.*, 2012).

Physical and chemical soil properties in relation to plant vegetation contribute to broad geographic distribution and diversity. Changes in species diversity and production influenced by soil nutrients, available water, soil pH and EC (Zhao *et al.*, 2007) and other factors such as size of plants, soil moisture, nutrient contents, salinity, sand and silt were factors to impact on species diversity (El-sheikh *et al.,* 2010). Other factors as average annual rainfall, soil texture, average annual temperature and altitude were also determined as important factors affecting plant diversity (Pinke *et al.*, 2010).

A study was done on the impact of some environmental factors on plant diversity in grassy rangeland in Hamadan, Iran (Fattahi and Ildoromi, 2011 & Abbasi kesbi *et al*., 2015). Their Results showed that soil factors and aspect had a significant effect on species diversity. In the short term period, nitrogen cycle had no significant correlation with species diversity but in a long term period, it has been shown that species richness and diversity had a significant correlation with the nitrogen cycle (Kevin *et al.,* 2013).

Biodiversity and richness of plant species were studied in relation to environmental factors of soil and physiography in the Zagros forests in the west of Iran (Mirzaei and Karami, 2015). Results showed that diversity of ground vegetation had a negative correlation with sand percent and it was decreased in a southern aspect in relation to the increased slope, elevation, EC percent and silt percent. In a western aspect, biodiversity of herbaceous species increased as CaCo3 and organic matter increased and salinity and elevation from sea level were decreased (Mirzaei and Karami, 2015).

A comparative research was done on an abandoned ploughed site and a nearby reference site in the semiarid rangelands of Baharkish, Quchan in spring and summer of 2010 (Jankju and Noedoost, 2014). Their result showed no significant difference between the ploughed site and the reference one for species diversity. Therefore, patchy distribution of clonal plants reduced species evenness in the abandoned site.

The effects of aspect and elevation were studied on species diversity of herbaceous plants in the Dashte Zahab in Kermanshah, Iran and records of herbaceous species plants, altitude and aspect were listed from each quadrate (Mahdavi *et al.,* 2012). Their results showed a significant effect of aspect and altitude on diversity and richness of herbaceous plants.

Prober *et al.* (2015) in an investigation on the relationship between plant diversity and soil microbial diversity showed a correlation between plant beta diversity and the diversity of bacterial and fungal communities for environmental factors.

Considering the importance of plant diversity in maintaining a balanced ecosystem and direct and indirect human interests, it is important to recognize the relationships between species diversity and soil factors such as fundamental constituents of a stable ecosystem. Accordingly, this study was done to examine the relationships between soil factors and species diversity in the protected rangelands of Lashgardar, Malayer, Iran.

Materials and Methods

Study area

Lashgardar protected region is located in the mountainous rangelands of Hamedan Province in southeastern Malayer, Iran as it has been shown in Fig. 1. It covers an area of 16000 ha at the geographical longitude of 48°51′34″ to 49°16′53″ and latitude of 34°9′17″ to 34°19′58″. The altitudes of area are 2178-2734 m above sea level with the mean annual temperature of 11.2°C and mean annual precipitation of 316 mm. Rangeland part of this region covers an area of 2000 ha. The slope of region is 30-50% with dominant plant community of *Astragalus effuse- Stipa parvifloral* and soil texture is loam/sand. Exploitation has not been performed in this rangeland to date and plant coverage is appropriate to study the diversity (Safikhani, 2001). This study was performed to obtain the relationship of environmental factor in species diversity and richness in 2013.

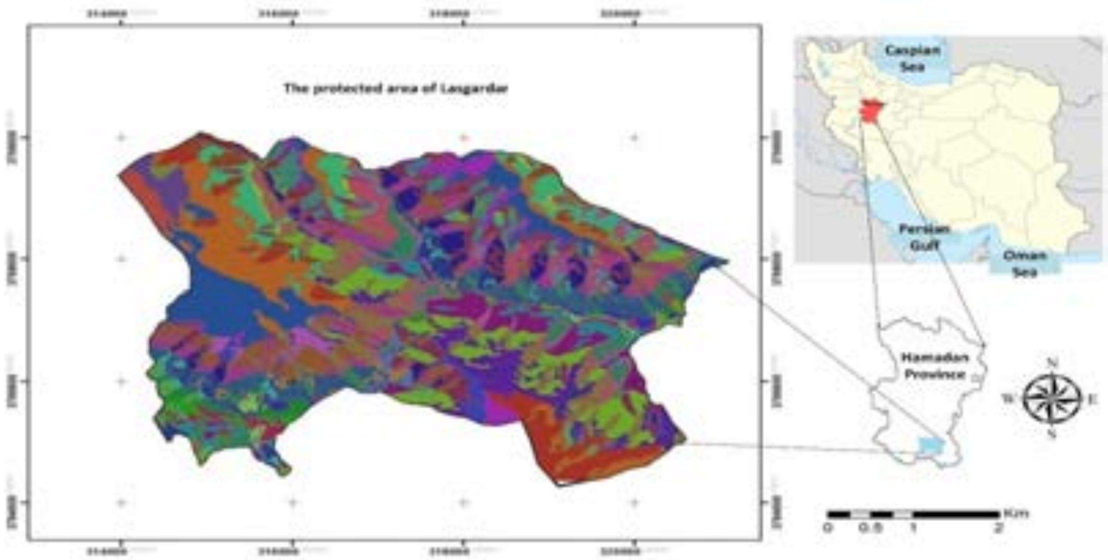

Fig. 1. Map of Lashgardar region in the mountainous rangelands in Malayer, Hamadan Province, Iran

Research Method

Base maps were overlaid to show such information as elevation, slope and aspect. Working units with the same elevation, slope and aspect in the area were selected. In order to record vegetation and environmental factors in each homogenous working unit, two transects were established on the slopes perpendicular to each other with the length of 100 m and sample plots were random-systematically established on them. Area and number of required plots were determined using the minimum area and statistical methods (Mesdaghi, 2005). A total of 240 square plots, each of 2 m^2 were considered in the study area. Species, canopy cover and species richness were recorded in each plot. After data collection, species diversity, richness and evenness were determined using the following equations:

Species richness was estimated using Menhenic equation (Shannon & Wiener, 1949).

$$R = \frac{S}{\sqrt{N}} \quad \text{(Eq. 1)}$$

Where:

N=number of individuals in a plot

S=number of species

R=species richness.

Species diversity was estimated using Shannon-Wiener index (Shannon & Wiener, 1949).

$$pi = ni / N \quad \text{(Eq. 2)}$$

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \quad \text{(Eq. 3)}$$

Where:

H′=Shannon-Wiener index

p_i=relative abundance of a given species in a plot

S= number of species.

Species evenness index was calculated to reflect the distribution of individual plants among species using the j Paolo index;

$$j = \frac{H}{H_{Max}} \quad \text{(Eq. 4)}$$

Where:

j: Paolo evenness

H: Shannon-Wiener index

H_{Max}=maximum possible value of Shannon-Wiener index which equals to $H_{Max} = Ln(s)$.

In addition, soil samples were taken according to the depth of surface and subsurface of soil horizons at the depths of 0-10 and 10-30 cm in each plot (Taghilu *et al.,* 2010). Soil samples were transferred to the laboratory, soil properties such as moisture content, texture, OC, OM, $CaCo_3$, bulk density, pH and EC were determined based on the existing methods (Carter and Gregorich, 2007).

Statistical Analysis

Data normality was tested using Kolmogorov-Smirnov method. Pearson correlation method was used to calculate the relationships between soil factors and three diversity indices (diversity, richness and evenness) at two soil depths of 0.0-10 and 10-20 cm. Six separate multiple regression analyses were used for species evenness, diversity and richness as the independent variables and soil properties at two soil depths as independent variables. All statistical analyses were conducted by SPSS18.

Results

One hundred and five plant species belonging to 81 genera and 27 families were recorded in the study area. Most of these species belonged to the family Leguminosae and the genus *Astragalus*. The dominant species in the study area were mainly herbaceous.

Correlation between diversity indices and soil factors

The results of Pearson correlation (Table 1) showed the negative correlations between species diversity and sand percent at both soil depths ($P<0.01$). In contrast, positive correlations were obtained between silt percent and species diversity at both depths of 0-10 and 10-30 cm ($P<0.01$). There were negative correlations between species diversity with OM and OC at upper soil depth (0-10 cm) and between species diversity and clay and $CaCo_3$ at lower soil layer (10-30 cm) ($P<0.01$). A positive correlation was obtained between species diversity and OM in lower soil layer ($P<0.05$) (Table 1).

Results of the correlation analysis between species richness and soil factors showed that species richness were negatively and positively ($P<0.01$) correlated with sand and silt at both depths of 0-10 and 10-30 cm, respectively (Table 1). There were positive correlations between species richness and OC at both depths of 0-10 and 10-30 cm and between species richness and OM at upper layer (0-10 cm) ($P<0.05$). The species richness was negatively correlated with both clay and $CaCo_3$ at lower soil layer (10-30 cm) ($P<0.05$) (Table 1).

Results of Pearson correlation between species evenness and soil factors showed a positive correlation between species evenness and OM at both depths of 0-10 and 10-30 cm (Table 1). Species evenness was positively and negatively correlated with silt and $CaCo_3$, respectively in the samples taken at the depth of 0-10 cm ($P<0.01$). Species evenness was negatively correlated with sand and clay percent at the depth of 10-00 cm ($P<0.01$). There were no significant correlations between moisture content, soil density, EC and soil pH with species diversity, richness and evenness at two different depths (Table 1).

Table 1. Correlation between soil factors and species diversity, richness and evenness at two different depths

Soil Factors	Species Diversity		Species Richness		Species Evenness	
	0-10 cm	10-30 cm	0-10 cm	10-30 cm	0-10 cm	10-30 cm
Sand (%)	-0.378**	-0.289**	-0.296**	-0.308**	-0.040^{ns}	-0.344**
Silt (%)	0.541**	0.347**	0.358**	0.327**	0.438**	0.010^{ns}
Clay (%)	0.132^{ns}	-0.390**	0.121^{ns}	-0.187*	-0.122^{ns}	-0.303*
$CaCo_3$ (%)	-0.062^{ns}	-0.340**	-0.122^{ns}	-0.177*	-0.339**	-0.088^{ns}
Organic matter (%)	0.204**	0.152^{ns}	0.217*	0.164^{ns}	0.352**	0.181^{ns}
Organic carbon (%)	0.215**	0.107^{ns}	0.271*	0.193^{ns}	0.106^{ns}	0.176^{ns}
Moisture content	-0.167^{ns}	-0.125^{ns}	0.117^{ns}	0.090^{ns}	0.061^{ns}	0.079^{ns}
Density	-0.138^{ns}	-0.147^{ns}	-0.120^{ns}	0.047^{ns}	-0.002^{ns}	-0.042^{ns}
EC	-0.100^{ns}	-0.084^{ns}	-0.125^{ns}	0.107^{ns}	-0.055^{ns}	-0.077^{ns}
pH	-0.011^{ns}	-0.075^{ns}	-0.033^{ns}	-0.131^{ns}	-0.113^{ns}	-0.047^{ns}

*, ** = Significant at 5% and 1% probability levels, respectively.

Regression analysis of diversity indices and soil factors

Six separate multiple regression analyses were conducted for species evenness, diversity and richness as the independent variables and soil properties at depths of 0-10 and 10-30 cm as independent variables. The results of regression analysis are presented in Table 2.

The results of regression model for species diversity as independent variables showed significant effects of sand and silt at depths of 0-10 cm and clay, $CaCo_3$ and OM at depths of 10-30 cm (Table 2). Therefore, it was suggested that soils having those properties would lead to increase the species diversity

The results of regression model for species richness as independent variables showed significant effects of sand, silt and OC at depths of 0-10 and silt, clay and $CaCo_3$ at depths of 10-30 cm (Table 2). Therefore, it was suggested that soils having those properties would lead to increasing species richness

The results of regression model for species evenness as independent variables showed significant effects of silt and $CaCo_3$ at depths of 0-10 and OM and sand at depths of 10-30 cm (Table 2). Therefore, it was suggested that soils having those properties would lead to increase the species evenness.

There was a good agreement between correlation and regression analysis and in both analyses, some soil properties such as moisture, density, EC and soil pH were not included in regression model and had no correlation with three diversity indices.

Table 2. Results of multiple linear regressions for species evenness, diversity and richness as the independent variables and soil properties at depths of 0-10 and 10-30 cm as independent variables.

Dependent variable	Depth	Independent variables	B	SE	Standardized B	P value
Species Diversity	0-10 cm	Constant	4.156	0.260		
		Sand	-0.915	0.123	-0.526	**
		Silt	0.511	0.101	0.356	**
	10-30 cm	Constant	1.841	0.247		
		Clay	-0.341	0.138	-0.227	*
		$CaCo_3$	-0.642	0.141	-0.410	**
		OM	0.203	0.076	0.263	**
Species Richness	0-10 cm	Constant	7.791	0.588		
		Sand	-2.124	0.572	-0.572	**
		Silt	0.666	0.211	0.217	**
		OC	0.909	0.198	0.410	**
	10-30 cm	Constant	8.365	1.213		
		Silt	1.497	0.284	0.449	**
		Clay	-2.323	0.358	-0.717	**
		$CaCo_3$	-1.272	0.232	-0.494	**
Species Evenness	0-10 cm	Constant	1.106	0.800		
		Silt	0.222	0.042	0.430	**
		$CaCo_3$	-0.337	0.017	-0.177	**
	10-30 cm	Constant	0.800	0.066		
		OM	0.065	0.020	0.284	*
		Sand	-0.076	0.036	-0.185	*

*, ** = Significant at 5% and 1% probability levels, respectively.

Discussion

Plant establishment and changes in species diversity are brought about by environmental factors such as soil properties affecting the growth bed of plants. Some soil factors have a positive impact and some have a limiting effect such that conditions are specific to a localized area and this contributes to species composition and diversity.

Sand increases soil permeability and causes the rapid drying out of soil and clay resulting in a compacted soil surface that prevents from water penetration into the soil (El-sheikh *et al.,* 2010). These two factors cause excessive dryness and have a negative impact on species presence. Conversely, higher presence of species was evident in the areas with high silt content because silt causes more water storage around plant roots. Thus, silt can have a positive relationship with diversity and richness due to the creation of moderate conditions of permeability and water retention. In general, the effect of soil texture on the distribution of plant species is due to the influence of moisture on the soil. Abed ElGhani and Amer (2003) stated that a difference in moisture content changes the structure and ventilation of soil. The results of this study also showed that diversity had a positive relationship with silt whereas sand and clay had a negative relationship. The results of present study are in accordance with those reported in other researches (Xiaoli *et al.,* 2010; Azarnivand *et al.,* 2007; Mirzaei *et al.,* 2008; Zare Chahoki *et al.,*2009; Mahdavi *et al.,* 2010). Another factor that demonstrated an influence on species diversity and richness was $Caco_3$, which had a negative relationship with species diversity and richness. Pauli *et al.* (2003) investigated soil nutrients in limestone soil and considered their impact on plant structure and communities in USA and showed that the abundance and status of species and plant communities in soil with higher $Caco_3$ changed according to the reductions of soil nutrients. They also showed that the abundance and status of species and plant communities reduced in the limestone soil that is compatible with the obtained results of our study. In this regard, Zare Chahoki *et al.* (2009) showed that plant diversity had a negative correlation with $Caco_3$. Similarly, Jafari *et al* .(2006) and Zare Chahoki *et al.* (2008) suggested $Caco_3$ as a limiting factor which was an important factor in separating vegetation types and species composition. Organic material was determined as the next most important factor affecting the diversity and species richness. OM is important for biochemical activity in the soil. It provides a suitable place for the activity of soil microorganisms that may allow the increased amounts of microorganisms and better diversity of activity. Increased amounts of nutrients and organic compounds in the soil are also beneficial by allowing the increased absorption and maintenance capacity of soil nutrients. Physical effects of OM on soil are to increase the organic colloids, surface area, and exchange capacity, water holding capacity and overall physical conditions of the soil. The amount of organic carbon from plant litter improves physical-biological properties of soil. A study on plant species in China demonstrated that OC and N had a positive effect on species coverage and distribution and that OC and soil OM were dependent on the presence of species (Xiaoli *et al.,* 2010). Soil type, vegetation type and climatic conditions not only affect soil quality but they also affect the amount of OM in an area. It has been reported that soil OM and plant litter have a crucial role in providing carbon and energy for heterotrophic microorganisms (Karimzadea, 2010). This energy improves the soil and increases micro-organic activity in soil that serves to improve plant diversity and composition of plant communities.

Conclusion

The results of this study show that species diversity and richness had a negative correlation with sand and a positive correlation with silt and OC at the first depth; in addition, they also showed a negative correlation with sand, clay, $CaCo_3$ and a positive correlation with silt, OM and OC at the second depth. Furthermore, results of correlations between soil factors and evenness showed a negative correlation between $CaCo_3$ and evenness and a positive correlation between both OM and silt with evenness at the first depth; there was a negative correlation between both sand and clay with evenness and a positive correlation between OM and evenness. Results of regression analysis indicate the predictions for species diversity, richness and evenness by soil factors demonstrating that soil factors make a substantial contribution to species diversity and richness. According to the results, soil factors had a greater impact on species diversity, richness and evenness at the first depth than that for the second depth. This greater influence at the first depth could have been due to the influence of environmental changes in the soil as well as types of species in the area, which were mostly herbaceous and had a more appropriate response to changes in the soil due to better root development in soil samples taken at the upper soil depth. Also, in our study, it was obtained that plant litter is effective in richness diversity. Among soil factors for species diversity, it was obtained that sand had a negative impact whereas silt, OC and OM had a positive impact at the first depth. In the second depth, sand, clay and $CaCo_3$ had negative impacts whereas the effect of silt was positive. Other variables did not have a significant impact. In order to investigate species richness in soil factors, a similar experiment was repeated and the obtained results revealed that silt, OC and OM had a positive impact and sand had a negative impact at the first depth whereas clay, $CaCo_3$ and sand had a negative relationship and silt had a positive impact in the second depth. Other factors did not affect species richness. In the investigation of species evenness, it was obtained that silt and OM had a positive impact and CaCo3 had a negative impact at the first depth. Also, sand and clay had a negative impact in the second depth. According to the present discussion, it can be concluded that studying species diversity indices and identifying soil factors affecting the changes in species diversity have applications in efficient management and sustainable development of natural resources as well as the reclamation of rangelands with similar ecological conditions to those of the study area. Furthermore, the diversity indices applied in this study could use information gathered through monitoring in a specific period for the application in the management and improvement plans for natural resources.

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بررسی رابطه بین فاکتورهای خاک و شاخص‌های تنوع گونه‌ای (مطالعه موردی منطقه حفاظت شده لشگردر، ملایر)

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چکیده. خصوصیات فیزیکی و شیمیایی خاک در ارتباط با پوشش گیاهی باعث تنوع گیاهی و پراکنش جغرافیایی گیاهان می‌شود. این تحقیق در سال ۱۳۹۲به بررسی رابطه عوامل خاکی با شاخص‌های، تنوع گونه‌ای در مراتع حفاظت شده لشگردر ملایر پرداخته است. در واقع شناخت ارتباط بین تنوع گونه‌ای و عوامل محیطی نقش مهمی در مدیریت اکوسیستم‌ها دارد. پس از تعیین واحدهای کاری با مشخصات شیب، جهت و ارتفاع معین، نمونه‌برداری به صورت تصادفی-سیستماتیک و با استقرار ۲ ترانسکت عمود بر هم به طول۱۰۰ متر در هر یک از واحدها انجام شد. در طول هر ترانسکت ۱۰ پلات ۲ مترمربعی مستقر گردید و با تعیین درصد پوشش گیاهی، شاخص‌های یکنواختی، غنا و تنوع گونه‌ای - محاسبه شد. همچنین در هر پلات، نمونه‌برداری خاک از دو عمق ۰ تا ۱۰ و ۱۰ تا ۳۰ سانتی‌متری انجام شد. خصوصیات فیزیکو- شیمیایی نمونه‌های خاک شامل رطوبت، بافت، کربن آلی، ماده آلی، آهک، وزن مخصوص ظاهری، pH وEC در آزمایشگاه تعیین شد. جهت تعیین ارتباط بین تنوع، غنای گونه‌ای و یکنواختی با عوامل خاکی از آنالیز همبستگی و رگرسیون چند متغیره در نرم افزار $SPSS_{18}$ استفاده شد. نتایج نشان داد که بین عوامل خاکی با تنوع و غنای گونه‌ای ارتباط معنی‌داری وجود دارد ($P<0.05$) که این ارتباط در عمق اول (۰-۱۰) قوی‌تر بود. از بین عوامل خاکی افزایش سیلت، کربن و ماده آلی موجب افزایش و درصد آهک، شن و رس خاک موجب کاهش تنوع و غنای گونه‌ای گردید.

کلمات کلیدی: تنوع گیاهی، غنای گونه‌ای، یکنواختی، خاک، ملایر