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Vegetation community in relation to the soil characteristics of Rineh rangeland, Iran

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ABSTRACT
The aim of this study was to investigate relationships between soil properties and plant species to determine the most effective factors separating vegetation communities in Rineh rangeland. Three stratifying variables were selected including slop, aspect and elevation. The study area was partitioned by combining these classes to generate homogenous units. 1m^2 quadrates were located at sampling sites in each homogenous unit randomly. Vegetation cover data were recorded using ordinal scale of Daubenmire cover-abundance scores in each quadrate. Soil samples were collected based on area from 0-15, 15-30 cm depths in each sampling site. Total nitrogen, organic matter, pH, total phosphorus, water retention capacity, permanent wilting point, available water capacity, potassium, water holding capacity, $CaCO_3$, saturation moisture, bulk density, real unit weight and percentage of fine earth fragments (sand, silt and clay) were measured. Both classification and ordination techniques were employed including TWINSPAN classification, DCA and CCA. The TWINSPAN classification of the sample sites have resulted in ten groups. According to the results of DCA, length of gradient represented by axis 1 was >5 SD, indicating that CCA was the appropriate ordination method. CCA axis 1 was correlated to phosphorus (-0.460) in the first layer and phosphorus (-0.493), sand (0.533) in the second layer while the CCA axis 2 was correlated to phosphorus (0.394), sand (0.533) in the second layer. The species-environment correlations are higher for the first three canonical axes, explaining 18% of the cumulative variances.

Keywords: *Multivariate analysis, Rineh rangelands, Soil characteristics, Vegetation cover, Iran.*

INTRODUCTION
Investigating the relationship between plant species and environmental variables has been the aim of many ecological studies (Lundholm and Larson, 2003; El Bana and Al-Mathnani, 2009. Ecologists have documented that environmental variables may control plant species distribution and composition (El-Bana et al., 2002, Jafari et al., 2004). Yair and Danin, (1980) claimed that available water as a primary factor may affect the distribution of species. Probability, annual precipitation, soil properties and topography are the most important factors that govern water availability (Li et al., 1998). The amount and availability of soil moisture affects rooting depth, soil water potential, absorption and distribution of nutrients (Jafari et al., 2004). Plant growth can be improved by increasing soil depth, organic matter content and water holding capacity as well as by decreasing in soil pH and $CaCO_3$ content (Shaukat et al., 1981). He et al., (2007) demonstrated that organic matter, total nitrogen, silt and clay content, elevation, Kira moisture index and relative humidity are the most important factors related to the presence of plant species in Alxa Plateau.
Presence and absence of plant species can be

used as bioindicators of soil conditions. Since both presence and distinguish ability of species are significantly related to soil conditions, it is essential to quantify the effects of these factors for conservation, management and development of natural resources. In Iran, rangelands, the largest of ecosystems and main sources of foliage, cover an area about 90 million hectares. There have been many ecological studies which aim to find the relation between plant species composition and environmental factors in rangelands (Jafari et al., 2004, Jafarian et al 2008). This study was an effort to investigate relationships between vegetation and soil in some of the mountain rangelands located in the southern slopes of the Damavand Mountain (the highest summit in Iran).

TWINSPAN analysis, DCA, CCA were employed to understand relationships between soil variables and vegetation in the present study. TWINSPAN analysis is a numerical method for the classification of vegetation samples into similar groups (Oksanen and Minchin, 1997). DCA is an indirect gradient analysis technique; CCA is a direct gradient analysis. This technique greatly improves the power to detect specific effects of cross variable association and has been shown to be a robust model for detecting the relationship between species and their environment (Palmer, 1993). The overall aim of this study was to understand relationships between physico-chemical soil factors and plant species to determine the most effective factors of separating vegetation types.

MATERIALS AND METHODS

Description of the study area:

The Rineh Rangeland (Fig.1) is located in the southern slopes of the Damavand Mountain (the highest summit in Iran) (35˚51'30"N to 35°55'30"N, 52°02'E to 52°10'E) and covers an area of approximately 463.882 ha and elevation ranges between 2070 and 3640 meters a.s.l. It is dominated by several plant species such as: *Onorychis corunata, Astragalus ochrodeucus, Astragalus microcephalus, Thymus kotschyanus, Ferula gummosa, Astragalus sieversianus, Poa bulbosa, Perennial grasses*. It is characterized by Trachyandesitic lava flows. Soil texture is clay loam. Climate is cold semi-humid based on Domarttan method. Mean annual precipitation is about 625 mm and mean annual temperature is about 12.79 °C (Jafarian et al., 2008).

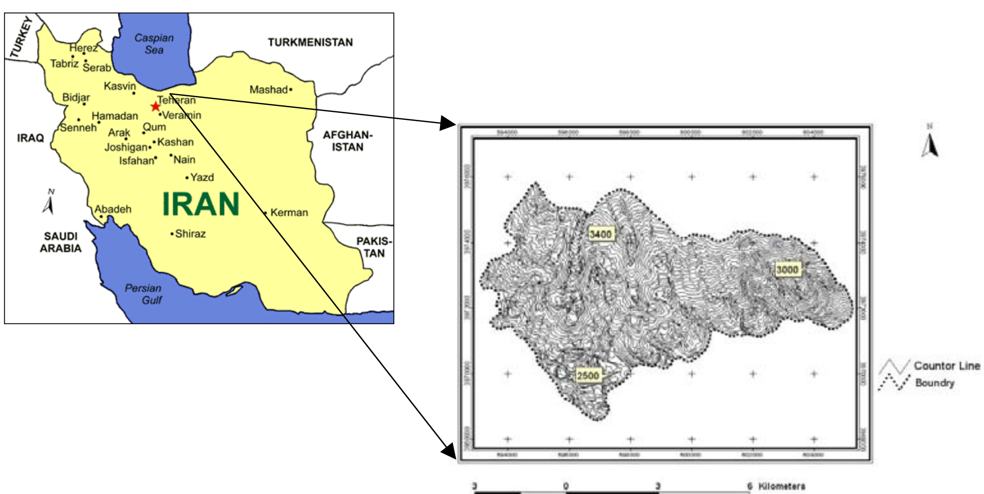

Fig 1. Geographical position of study area

Data collection:

Equal-stratified sampling procedure was used for data collection (Hirzel and Giusan, 2002). Primarily four stratifying variables were selected including slope, aspect, elevation and geology but later geology was eliminated; because the lava flows are Trachyandesitic in the whole study area. Digital Elevation Model was produced using Idrisi and Arc view software and slope, aspect and elevation maps were created. Then each was split to several classes. The study area was partitioned by combining these classes to generate 37 homogenous units and 75 sampling sites in these units. Ten 1m^2 quadrates were distributed in each sampling site randomly. Vegetation cover data was recorded using ordinal scale of Daubenmire cover-abundance scores in each quadrate.

Four soil samples were collected from 0-15 and 15-30 cm depths in each sampling site. The samples were air-dried and passed through a 2 mm sieve to prepare them for experiments. The methods that were applied were: Bouyoucos hydrometer method for soil texture (Bouyoucos, 1962), Kjeldahl method for total nitrogen (McGill and Figueiredo, 1993), and the modified Walkley-Black wet oxidation procedure for organic carbon content. Multiplying the soil organic carbon by 1.72 resulted in soil organic matter (Nelson and Sommers, 1982), pH in a soil/water ratio 1:1, total phosphorus was determined colorimetrically after wet digestion with H_2SO_4+$HClO_4$, water retention capacity at -33 kPa (field capacity) and permanent wilting point at -1500 kPa were estimated using pressiplate. Available water capacity was measured as the difference between field capacity and permanent wilting point, potassium was determined after extraction with 1N ammonium acetate adjusted with pH 7 (Simard, 1993), water holding capacity was calculated by multiplying PWP by 1.85, $CaCO_3$ was measured following the procedure outlined in Page et al. (1982), saturation moisture as the difference between weight of saturated and the Oven-dried (at 105°C for 24 h) soil, also bulk density and real unit weight were measured.

Data analysis:

Both classification and ordination techniques were used to an effective analysis of the vegetation and related soil characteristics. In order to understand the species – soil relationship, sample plots with generally similar species were classified into a few groups by means of two-way indicator species analysis (TWINSPAN) based on untransformed Daubenmire cover-abundance scores (Ali & Malik, 2010). The TWINSPAN groups were subjected to an ANOVA based on soil factors to find out significant variations among these groups.

Preliminary DCA analysis was made to check the magnitude of change in species composition along the first ordination axis (i.e., gradient length in standard deviation (SD) units). DCA estimated gradient length >5 SD, which showed a modest unimodal response and thus the appropriateness of CCA. CCA analysis was used to determine the relationships between the floristic compositions and the soil variables in the study area. Distribution-free Monte Carlo test permutation (1000 permutations) was used to analyze signification of species-soil correlation and Eigen values of first canonical axis. Prior to analysis all variables were assessed for normality and appropriate transformations were performed. These analyses were employed using the default setting of computer program PC_ORD for windows version 4.14 (McCune and Mefford, 1999).

RESULTS

TWINSPAN:

A total of 107 species were recorded in the area, including 82 genera and 26 families. The TWINSPAN classification of the 75 samples sites using Daubenmire cover-abundance scale resulted ten groups (Fig 2) as follows:

Ferula gummosa - Astragalus ochrodeucus, *Artemisia fragrans - Stellaria holostea, Astragalus sieversianus - Agropyron repens, Astragalus sieversianus - Ferula gummosa, Astragalus ochrodeucus - Glyceria aquatica, Astragalus ochrodeucus - Thymus kotschyanus, Thymus kotschyanus - Astragalus microcephalus, Onorychis corunata - Thymus kotschyanus, Acantholimon demawendicum - Onorychis corunata, Onorychis corunata - Festuca ovina* .

These species were the dominant species in the study area. Analysis of variance showed significant differences for soil characteristics in all groups of TWINSPAN (Table 1).

Multivariate analysis:

Fig 3 shows the ordination results of the DCA analysis of the sample sites. The 75 site scores are plotted along axes 1 and 2, and are represented into ten groups that resulted from TWINSPAN analysis. The results of DCA showed that linear response models were dropped because of the gradient along the first axis was longer than 4 SD units. The length of the gradient represented by axis 1 was >5 SD. Hence CCA was the appropriate ordination method to be used. Eigenvalue of the first axis of DCA was high (Eigen = 0.7292), indicating that it captured the greater proportion of the variations in species composition among stands. Significant correlations along first three axes were stronger than the higher order axes.

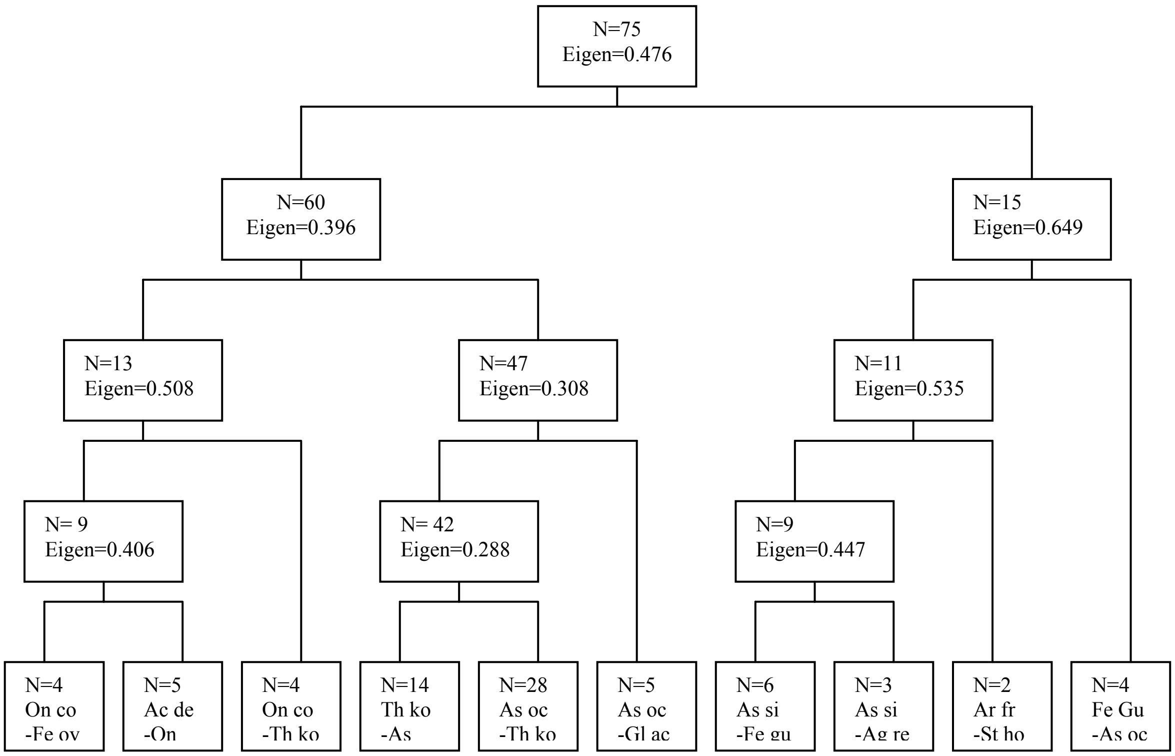

Fig 2. Dendrogram of TWINSPAN for vegetation in the study area.

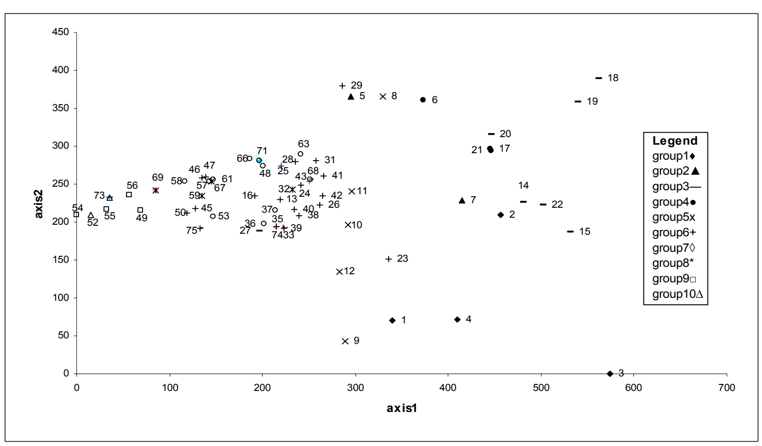

Fig 3. DCA ordination diagram of the first two axes showing the distribution of the 75 sample sites with their TWINSPAN groups.

Table 1. Mean, standard deviation and ANOVA *F* and P values of the soil variables in the ten vegetation groups by TWINSPAN

		TWINSPAN Groups										**Soil**
P	**F**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**Variable**
0.014	2.55	6.51±0.13	6.7±0.14	6.34±0.2	6.31±0.21	6.63±0.36	6.48±0.29	6.6±0.09	6.6±0.4	7.09±0.15	7.13±0.2	pH1
0.087	1.56	1.83±0.1	1.87±0.27	1.98±0.3	1.78±0.27	2.04±0.68	3.03±2.4	1.86±0.2	1.78±0.21	1.86±0.21	2.11±0.21	Caco31
0.012	2.21	47.33±3.34	39.87±6.38	50.53±1.22	46.29±4.78	39.59±9.01	27.98±10.9	39.69±8.15	37.52±12.08	29.21±0.97	26.65±7.32	P1
0.141	2.04	0.19±0.03	0.19±0.03	0.25±0.04	0.19±0.05	0.19±0.1	0.13±0.06	0.22±0.07	0.17±0.1	0.09±0.03	0.11±0.03	N1
0.878	0.65	580.3±182.8	399.6±117.2	531±109.4	410.8±138.8	411.7±141.8	360±45.9	542±176	420.5±255	280.5±58.7	232.8±3.48	K1
0.74	0.74	3.44±0.67	2.89±0.82	4.8±0.99	3.61±1.06	3.37±1.81	2.33±1.36	3.95±0.85	2.95±1.85	1.76±0.22	1.86±0.82	Som1
-	-	48.13±6.87	44.16±5.11	56.64±6.07	49.31±18.81	46.98±13.95	39.86±12.05	50.58±4.65	48.03±15.49	27.31±9.89	32.95±3.87	SM1
0.077	1.6	2.43±0.07	2.54±0.18	2.43±0.06	2.5±0.19	2.48±0.16	2.48±0.13	2.47±0.12	2.41±0.22	2.84±0.17	2.76±0.15	Rs1
0.217	1.77	1.56±0.09	1.49±0.05	1.72±0.17	1.58±0.17	1.56±0.14	1.64±0.14	1.73±0.25	1.59±0.1	1.73±0.17	1.63±0.18	Rb1
0.293	1.26	42.33±5.47	49.49±17.34	33.01±6.39	38.28±10.31	43.45±15.48	47.46±8.84	38.99±14.42	46.77±18.42	60.06±7.78	58.59±7.8	Sand1
0.346	1.22	23.57±4.73	23.66±10.34	35.7±4.11	32.07±6.74	30.25±11.47	26.2±7.9	35.69±4.16	27.8±10.6	21.72±4.24	18.8±5.72	Silt1
0.323	1.34	34.1±5.26	26.9±10.98	31.29±2.28	29.65±4.56	26.27±6.58	26.16±5.6	25.32±14.41	25.43±8.78	18.22±3.54	22.61±3.51	Clay1
-	-	21.45±2.09	19.13±4.03	25.42±1.99	20.73±3.56	21±6.10	16.94±5.12	24.03±2.79	19.37±7.53	13.2±6.06	12.98±3.16	Fc1
-	-	14.59±1.06	13.23±1.2	16.78±1.69	12.97±2.01	12.64±4.24	11.9±4.27	14.32±1.12	12.85±5.91	7.43±2.9	8.66±2.2	Pwp1
-	-	8.18±0.54	5.9±3.87	8.64±0.91	7.76±2.63	8.46±3.28	5.04±1.9	9.71±2.06	6.53±2.45	5.76±3.16	4.31±1.07	Aw1
-	-	26.99±1.95	23.87±2.63	31.05±3.13	21.06±3.9	23.39±7.84	20.27±8.67	26.49±2.07	23.76±10.94	13.75±5.37	10.18±6.81	Wc1
0.714	0.82	6.59±0.12	6.62±0.28	6.33±0.28	6.32±0.22	6.59±0.36	7.02±0.29	6.62±0.11	6.67±0.35	7.26±0.06	7.13±0.1	pH2
0.141	1.44	1.63±0.3	2.08±0.14	1.89±0.28	1.75±0.29	2.53±2.12	5.89±4.93	1.49±0.05	1.83±0.22	3.28±1.97	2.92±0.56	Caco32
0.157	1.43	48.06±1.65	37.55±11.82	47.6±2.48	42.61±6.41	32.38±12.22	20.47±10.47	26.25±3.88	31.72±13.54	20.7±18.8	24.2±4.47	P2
0.707	0.82	0.15±0.01	0.16±0.03	0.18±0.04	0.13±0.03	0.14±0.06	0.14±0.05	0.14±0.02	0.12±0.06	0.07±0.02	0.07±0.01	N2
0.05	2.07	606±238	258.6±82.2	421.5±127.9	375±175.5	325.7±152.9	319.6±118.9	348.3±154.4	338.2±161.3	271.5±38.9	173.8±21.5	K2
0.255	9.35	1.69±0.46	2.34±0.49	2.89±0.86	2.13±0.82	2.19±1.04	2.05±0.75	2.16±0.55	1.65±0.82	1.15±0.19	0.815±0.43	Som2
-	-	51.66±5.22	47.87±5.19	50.48±5.48	41.56±7.57	43.04±9.19	41.99±8.66	45.34±2.87	44.56±9.63	33.42±4.74	35.69±2.91	SM2
0.141	1.44	2.46±0.07	2.55±0.17	2.29±0.1	2.4±0.14	2.47±0.15	2.46±0.08	2.41±0.13	2.37±0.13	2.69±0.2	2.78±0.08	Rs2
0.29	1.36	1.67±0.19	1.62±0.16	1.65±0.19	1.66±0.14	1.6±0.18	1.74±0.2	1.77±0.31	1.62±0.09	1.67±0.18	1.53±0.15	Rb2
0.649	0.88	46.31±12.53	43.04±17.13	27.87±5.2	33.2±7.39	42.62±15.33	47.64±1.73	25.17±8.08	36.96±18.37	66.84±7.07	64.13±12.17	Sand2
0.136	1.67	22.61±6.91	23.82±9.09	35.13±2.99	34.47±5.25	29.83±9.87	22.07±7.13	35.97±3.02	29.93±9.55	14.36±5.66	15.4±5.04	Silt2
0.04	2.53	30.42±5.04	33.14±11.38	37±4.28	32.32±4.78	27.63±7.63	30.29±9.48	38.85±7.24	33.11±11.22	18.8±1.41	20.43±8.87	Clay2
-	-	25.92±3.92	21.1±3.18	21.56±1.76	19.34±3.63	19.28±4.91	20.79±6.29	20.29±1.08	19.87±2.75	12.37±6.05	11.56±4.06	Fc2
-	-	14.07±0.81	13.91±4.52	16±2.18	12.58±3.49	12.18±3.73	14.11±4.65	13.26±1.63	14.14±2.98	6.82±4.37	8.08±2.89	Pwp2
-	-	6.1±1.43	7.19±2.83	5.55±0.43	6.95±1.51	7±2.44	6.67±2.07	7.03±2.55	5.72±2.05	5.55±1.68	3.57±1.21	Aw2
0.051	18.96	26.03±1.5	25.74±8.36	29.6±4.03	32.27±6.45	22.51±6.91	20.55±10.8	24.53±3.02	26.17±5.5	10.17±2.97	6.61±2.24	Wc2

P<0.05 is significant probability %95

DCA axis 1 showed significant correlations with field capacity (-0.818), water holding capacity (-0.813), permanent wilting point (-0.751), silt (-0.704), sand (0.745), nitrogen (-0.707) and phosphorus (-0.723) in the first layer and nitrogen (-0.765), silt (-0.764), water holding capacity (-0.760) and field capacity (-0.743) in the second layer of soil, suggesting that DCA axis 1 represented physical soil characteristics – soil fertility factors gradients. DCA axis 2 was significantly correlated with pH (0.879) in the second layer, hence this axis showed pH gradient.

From the intra-set correlations of soil factors with the first three axes of CCA, it can be noted that CCA axis 1 was correlated to phosphorus (-0.460) in the first layer and phosphorus (-0.493) and sand (0.533) in the second layer while the CCA axis 2 was correlated to phosphorus (0.394) and sand (0.533) in the second layer. This fact becomes clearer in the ordination biplot (Fig. 4 and 5). The results of CCA ordination biplot (Fig. 4) suggested an association between vegetation and the measured soil factors. Fig 5 shows a better representation of soil distribution variables. They were represented by arrows pointing in the direction of maximum variation, with their length proportional to the rate of change.

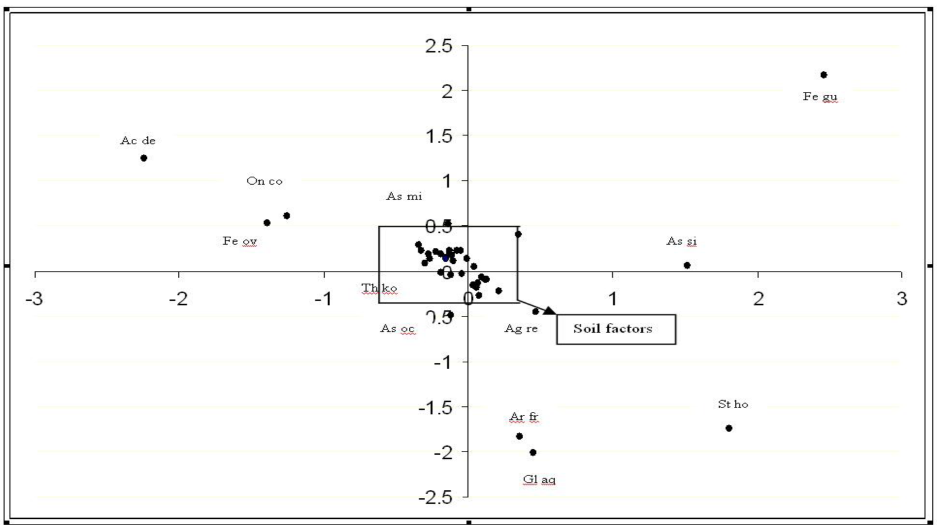

Fig 4. CCA ordination biplot of the first two axes showing the distribution of 12 dominant species with the soil variables.

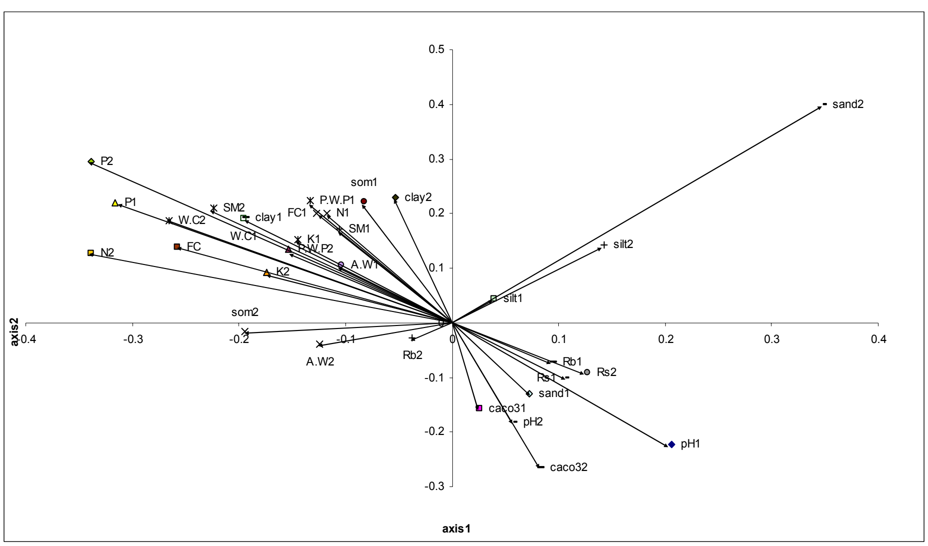

Fig 5. CCA ordination diagram of the first two axes showing the distribution of the soil variables.

Sand and silt percentages in the second layer are the indicators of habitat of *Astragalus sieversianus* and *Ferula gummosa*. Species of *Artemisia fragrans, Stellaria holostea*, *Agropyron repens, Glyceria aquatica* and *Astragalus ochrodeucus* are in relation to pH of the first layer and $CaCo_3$ content, pH and bulk density in the second layer. Soil organic matter and available water in the second layer are indicators of habitat *Thymus kotschyanus.* Habitats of *Acantholimon demawendicum, Onorychis corunata* and *Festuca ovina* are indicated by phosphorus in the first and second layer and nitrogen, saturation moisture, water holding capacity and field capacity in the second layer of soil. The percentage of clay in the second layer, organic matter and permanent wilting point in the first layer are the indicators of *Astragalus microcephalus.*

The successive decrease of the eigenvalues of the first three CCA axes (Table2) suggested a well-structured data set. These eigenvalues were somewhat lower than those for the DCA axes that indicated important explanatory site variables are not measured and included in the analysis (McDonald et al 1996; Monier et al 2003). The species-environment correlations are higher for the first three canonical axes, explaining 18% of the cumulative variances.

Table 2. Results of CCA analysis for soil factors

Axis 3	Axis 2	Axis 1	
0.394	0.441	0.529	**Eigenvalue**
5.2	5.9	7.0	**% of variance explained**
18.2	12.9	7.0	**Cumulative % explained**
0.931	0.930	0.888	**Pearson correlation, Spp-Env**

A test for significance found the F-ratio for the eigenvalue of axis 1 and the trace statistics to be significant ($P<0.01$), indicating that observed patterns did not arise by chance. Results of Monte Carlo test are given (Table 3).

Table 3. Results of Monte Carlo test for species-environment correlations

P	Mean	Eigenvalue	Axis
0.0030	0.318	0.529	1
0.0010	0.275	0.441	2
0.0010	0.246	0.394	3

DISCUSSION

Relationships between distribution of plant communities resulting from TWINSPAN classification and soil characteristics were investigated using ordination techniques in this study. Phytosociological and soil studies help us in understanding the formation of plant communities. Such relationships are important because generally when we relate each other to underlying factors a better picture of the relationships results. The distributions of vegetation more closely resemble to the changes in the soil characteristics (Kabir et al., 2010). Results of DCA and CCA showed that distribution of communities is correlated with some soil variables. These characteristics can divided to three groups: 1) factors related to soil texture (sand, silt and clay percentage) 2, factors related to soil moisture (saturation moisture, field capacity, permanent wilting point, available water and water holding capacity) and 3) factors related to soil fertility (organic matter, nitrogen and phosphorus). The relation between species distribution and the characteristics of the upper mineral soil layer(s) has been reported in many scientific documents. Kumar, (1996) found the relation between species distribution and soil physical factors like soil moisture and texture and El-Ghani, (1998) reported a close relationship between plant species composition and soil chemistry (pH, calcium and organic carbon). Organic matter content as a pivotal soil fertility factor can affect phytodiversity (Zhang et al., 2010). Our findings also indicated the importance of soil organic matter in top soil layers for plant species distribution. The increases in soil nutrients (OM, TC, TN, and AK), improvement in site conditions (community cover, depth of litter, depth of humus, soil water content) and decrease in soil bulk density indicated the natural habitat restoration following abandonment. The changes were mainly attributable to the development of vegetation and interaction between soil and vegetation (Zhang et al., 2010).

Results of this study suggested that vegetation distribution was definitely affected by soil texture. The influence of soil texture on vegetation distribution has been claimed by other researchers (Jafari et al., 2004, Kabir et al, 2010). Soil texture may affect soil or productivity via influence on the soil water holding capacity, infiltration rate, moisture availability for plants and consequently plant nutrition (Sperry and Hacke, 2002). Soil moisture as a factor that affected distribution of plant species has been reported by Monier, et al. (2003). In agreement with El-Ghani (1998), our findings also showed that the soil organic matter, nitrogen and phosphorus contents were the key elements in vegetation distribution.

Lu et al. (2006) claimed that soil moisture content, pH, soil organic matter and available potassium may determine the distribution patterns of shrubs and herbs at Tibetan Plateau. Using multivariate analysis methods is useful in determination of relationships between species and environmental factors, because CCA was used commonly by many researchers to investigate this relationship concurrently (Jafari, et al., 2004, Monier, et al 2003, El-Bana and Al-Mathnani, 2009). As a result, primarily geology variable in the study area was eliminated because it was unique in the total study area. This can be the reason for non significant differences of soil characteristics between TWINSPAN vegetation groups and interpretation of 18% of total variance by first three axes of CCA. Therefore uniform parent material, as a factor affecting soil formation, leads to almost similar soil in the total study area.

Findings of this research help management, reclamation and development of this area and semi-humid rangeland ecosystems. Determining the effective factors which influence plants distribution can decrease time and cost. Also, it is necessary to study the relationship between other environmental variables (climate and physiographical variables) and management practices (grazing intensity and trampling) with vegetation distribution in Rineh rangeland.

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مطالعه ارتباط بین جوامع گیاهی و ویژگی‌های خاک در مراتع رینه ایران

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چکیده

هدف این مطالعه بررسی ارتباط بین ویژگی‌های خاک و گونه‌های گیاهی برای تعیین عوامل موثر بر جوامع گیاهی مراتع رینه است. منطقه مورد مطالعه بر اساس متغیرهای شیب، جهت و ارتفاع به واحدهای همگن تقسیم شد. در سایت‌های نمونه‌برداری واحدهای همگن پلات‌های ۱ متر مربعی بطور تصادفی مستقر شد. در هر پلات داده‌های پوشش گیاهی بر اساس مقیاس پوشش فراوانی دابن مایر برداشت شد. نمونه‌های خاک از دو عمق ۰-۱۵ و ۱۵-۳۰ سانتیمتری خاک در هر سایت نمونه‌برداری جمع‌آوری شدند. ویژگی‌های نیتروژن کل، فسفر کل، پتاسیم، ماده آلی، pH، آهک، رطوبت اشباع، ظرفیت زراعی، نقطه پژمردگی، رطوبت در دسترس، ظرفیت نگهداری آب، وزن مخصوص ظاهری و حقیقی، درصد شن، سیلت و رس در آزمایشگاه اندازه‌گیری شدند. روش‌های طبقه‌بندی و رسته‌بندی شامل طبقه‌بندی TWINSPAN و رسته بندی DCA و CCA بر داده‌ها اعمال شدند. با استفاده از طبقه بندی ۱۰ گروه گیاهی در منطقه شناسایی شدند. بر طبق نتایج آنالیز DCA طول گرادیان محور اول SD ۵ < بوده که نشان می‌دهد آنالیز CCA روش رسته بندی مناسب برای داده‌ها است. محور اول CCA با فسفر در لایه اول و فسفر و شن در لایه دوم درحالیکه محور دوم با فسفر و شن در لایه دوم همبستگی داشتند. ارتباط بین گونه و محیط برای ۳ محور اول کانونیک بالاتر بوده و ویژگی‌های خاک ۱۸ درصد از تغییرات کل را توجیه کردند.