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Soil-Vegetation Relationships in Hoz-e-Soltan Region of Qom Province, Iran

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Abstract: The objective of this study was to find the effective soil variables on the distribution of vegetation types in Hoz-e-Soltan region. Study area was located in the saline region of Qom province. After delimitation the study area and determining plant types, sampling of soil and vegetation were done by randomized-systematic method. The area of quadrants was identified according to the minimal area procedure and the kind of plants distribution. Among vegetation properties, cover percentage and density were estimated quantitatively. Soil was sampled at 0-20 and 20-60 cm depths. Measured soil factors included texture, electrical conductivity (EC), acidity (pH), lime, soluble ions such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, CO_3^{2-} and HCO_3^{-}. In order to find the relationship between soil factors and vegetation properties and also to determine the most effective factors on the distribution of plant types, multivariate procedures, i.e., principal component analysis (PCA) and canonical correspondence analysis (CCA) were used. Results showed that there was a specific relationship between soil variables and plant types. The most effective factors on the separation of different communities were soil salinity and texture.

Key words: Iran, rangelands, salinity, soil characteristics, vegetation types

Introduction

Without an exhaustive understanding of saline land ecosystems, we cannot have a logical and correct utilization of these areas. Every kind of changes in the existent components of a natural ecosystem, especially plants and soil, finally leads to the gradual changes in whole of that. Therefore, the importance of separation and classification of plant communities in these ecosystems, their limitations as well as their relations with other components of ecosystem become more clear (Hoveizeh, 1997). Those kinds of plants that grow on the saline soil are referred as halophytes. In coastal marshes, there is a zonation of halophyte communities (Chapman, 1974). In addition, arid areas of the world consist of broad saline regions where various halophyte communities establish on them (Breckle, 1986).

Different studies have revealed that although competition influences the growth and distribution of the plants, but soil characteristics are of high importance in distribution of salt lands plants. Plant composition of saline lands based on a multivariate approach have been studied by Abd El-Ghani (1998,1999, 2000); Dargi and El-Demerdash (1991); Moustafa and Zaghloul (1996); Shaltout *et al.* (1995) and Springuel *et al.* (1997). Based on these studies soil characteristics have a main role in the distribution of plant species. Among soil characteristics, salinity is the most effective factor.

As mentioned above, the main purpose of this research was to investigate the relationship between soil characteristics with plant species to determine the most important factors affecting the separation of vegetation types. The another objective was to identify the soil characteristics that are indicator of specific species. By knowing the relationships between soil and vegetation of a given area, it is possible to apply these results for other similar regions and recommend the suitable guidance for management, reclamation and utilization of saline lands.

Materials and Methods

The study area was saline land in Qom province, located in margin of playas Hoz-e-Soltan and Namak. The area has been recognized as arid area with 126.6 mm annual average of rainfall.

With attention to research aims and due to survey of vegetation factors and soil characteristics, study area was delimitated in Hoz-e-Soltan and Namak playas. Based on field surveys, dominant vegetation types were determined. Sampling was performed in the key area of each vegetation type using randomized-systematic method. Plot size was determined for each vegetation type using minimal area method. Considering variation in vegetation and environmental variables, 10 plots in each vegetation type with a distance of 30 m from each other were established. Floristic list, density and canopy cover percentage of species were recorded. Soil samples were taken from 0-20 and 20-60 cm layers. Measured soil factors included texture (determined by hydrometery method), pH in saturation extract (determined by pH meter), electrical conductivity (determined by electrical conductivity meter), lime (determined by calcimetry), soluble calcium and magnesium (determined by titration with solution EDTA method), soluble chlorine (determined by titration with $AgNO_3$), soluble carbonate and bicarbonate (determined

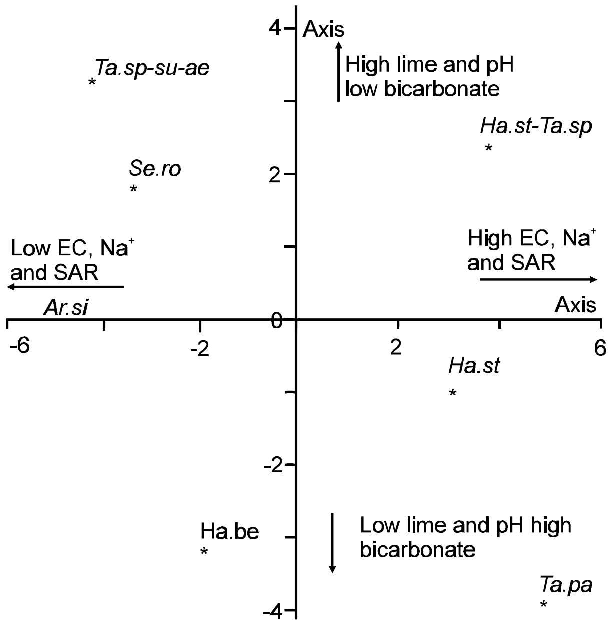

Fig. 1: PCA-ordination diagram the vegetation types related to soil characteristics in the study area. For vegetation types abbreviations, see Appendix

by titration with H_2SO_4 using metilorange and phenolphthalein respectively) and soluble sodium and potassium (determined by flame photometry method).

To analyze the soil characteristics in relation to the variation of vegetation types, multivariate procedures i.e. principal component analysis (PCA) and canonical correspondence analysis (CCA) were used. PCA is the ordination technique that constructs the theoretical variable that minimizes the total residual sum of squares after fitting straight lines to species data. PCA does so by choosing the best values for the sites. To apply PCA, data standardization is necessary if we are analyzing variables that are measured in different units. Also, species with high variance, often the abundant ones, therefore dominate the PCA method, whereas species with low variance, often the rare ones, have only minor influence on the method. These may be reasons to apply standardized PCA, in which all species receive equal weight. Therefore, data were standardized by centered and standard deviation (Jongman, 1987). Eigenvalues for each principal component was compared to a broken-stick eigenvalue to determine if the captured variance summarized more information than expected by chance. Broken-stick eigenvalues have been shown to be a robust method for selection of nontrivial components in PCA (Jackson, 1993). Principal components are considered useful, or nontrivial, if their eigenvalue exceeds that of their broken-stick counterpart (Legendre, 1998).

CCA is the new technique that selects the linear combination of environmental variables that maximizes the description of the species scores. On the other hand, CCA chooses the best weights of the environmental variables. This gives the first CCA axis. In CCA, composite gradients are linear combination of environmental variables, giving a much simples analysis and the non-linearity enters the weighted averaging. Canonical ordination is easier to apply and requires less data than regression. It provides a summary of the species-environment relations.

Data matrix of soil characteristics and vegetation types were made. The windows (ver.3.0) of PC-ORD (McCune and Mefford, 1997) was used for ordination of vegetation types in gradient of soil characteristics by CCA and PCA methods.

Results

PCA: In order to find the most effective factors on the separation of vegetation types, PCA was used. As it is shown in Table 1, PC1 and PC2 are accounted for 70.95% of vegetation variations that is caused by soil characteristics. From 70.95% of variations, PC1 and PC2 include 45.06 and 25.89%, respectively. According to correlation coefficients between factors and components, PC1 includes electrical conductivity, soluble sodium and sodium absorption ratio (SAR) of the first and the second layers (0-20 and 20-60 cm), chlorine and carbonate of the first layer and loam of the second layer. Therefore, PC1 can be considered as an indicator of soil salinity and texture. Factors of lime and pH of two layers as well as bicarbonate of the second layer are mostly correlated with PC2. Since PC1 explains the majority percentage of vegetation variation, then soil salinity and texture are the most effective factors on the separation of plant types, while lime and pH lie in the second position.

Fig. 1 represents the diagram of types distribution in relation to soil variables in PC1 and PC2. According to the diagram, we can refer to some points as follows:

1 Distance between the indicator points of vegetation types shows the degree of similarity and dissimilarity of soil characteristics.
2 Considering in PC1, all coefficients of the soil characteristics that were significant, are positive. Therefore, plant sites situated in positive direction of one axis have direct relationship with PC1 factors and vice versa. In the second principal component (PC2), coefficient factors in soil pH and lime is positive, although, in bicarbonate is negative. This object should be considered in analysis.
3 The distance between indicator points of the vegetation types with axis is representative of the relationship power in explanation of variations. Whatever the length of vector loading that indicate the vegetation types, is bigger and angle between

Table 1: Results of principal component analysis applied to the correlation matrix of the vegetation-soil characteristics in the study area. For abbreviations and units, see Appendix

Axis	Eigenvalue	% of Variance	Cum. % of Var.	Broken-stick Eigenvalue
1	12.616	45.058	45.058	3.927
2	7.248	25.887	70.946	2.927
3	3.066	10.950	81.896	2.427
4	2.452	8.756	90.653	2.094
5	1.602	5.721	96.374	1.844
6	1.015	3.626	100.000	1.644
7	0.0	0.0	100.000	1.477
8	0.0	0.0	100.000	1.334
9	0.0	0.0	100.000	1.209
10	0.0	0.0	100.000	1.098

Principal components

Factor	PC1*	PC2*	PC3	PC4	PC5	PC6
Clay1	0.1574	0.1223	0.0279	-0.4627	-0.1761	0.0456
Clay2	0.1494	0.0071	0.4417	-0.1599	-0.0838	0.2125
Loam1	0.1811	0.1550	-0.2943	0.0907	0.2779	0.0498
Loam2	0.2603	0.0387	-0.2018	-0.0160	0.0678	0.0361
Sand1	-0.2025	-0.1832	0.2280	0.0981	-0.1863	-0.0302
Sand2	0.1471	0.1898	0.0923	0.4228	-0.0279	0.0169
Lime1	-0.0015	0.3012	-0.1856	-0.1952	0.2229	-0.2508
Lime2	0.1222	0.3032	-0.1522	-0.1174	0.0467	-0.1915
pH1	0.1443	0.2918	0.064	0.0980	-0.0070	-0.2809
pH2	0.2005	0.2574	0.0352	0.0117	0.0722	0.0144
EC1	0.2308	-0.2089	-0.0021	0.0328	0.0611	-0.0545
EC2	0.2238	-0.2022	-0.0972	0.0608	-0.2132	-0.2110
Na1	0.2344	-0.1804	0.0393	-0.0459	0.1433	0.1675
Na2	0.2564	-0.0640	0.0415	0.2202	-0.0571	-0.1060
K1	0.1147	-0.0327	0.3349	-0.3136	0.1395	-0.4548
K2	0.1309	-0.1227	0.3724	-0.0509	0.3770	-0.1230
Ca1	0.1353	-0.1701	-0.2685	0.1631	-0.3673	-0.2370
Ca2	0.1352	-0.2676	-0.1156	0.0414	0.0322	-0.4477
Mg1	0.1170	-0.2390	-0.1345	-0.3527	0.0944	0.1953
Mg2	0.2668	-0.0358	0.0415	0.1861	0.0288	0.0288
Cl1	0.2388	-0.1414	-0.0845	-0.1453	-0.1319	0.1843
Cl2	0.2540	0.0510	-0.0784	0.0380	0.2927	0.0879
Co1	0.2350	0.1622	0.0323	0.1883	0.0152	0.1472
Co2	0.0963	0.1841	0.4033	-0.0298	-0.2841	-0.0831
Hc1	-0.0197	-0.3041	0.0228	0.0916	0.4341	-0.0283
Hc2	-0.01906	-0.2253	-0.0151	0.2151	-0.0853	-0.2170
SAR1	0.24.95	-0.1377	0.0611	-0.0109	0.1374	0.1856
SAR2	0.2603	-0.0372	0.556	0.2110	-0.0927	-0.0515

*: Nontrivial principal component as based on broken-stick eigenvalue.

Table 2: Results of canonical correspondence analysis for vegetation-soil data

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.123	0.024	0.021
Variance in species data			
% of Variance explained	52.5	10.2	9.1
Cumulative % explained	52.5	62.6	71.8

vectors with axis is smaller, there is more correlation between vegetation types, with axis and relation power.

Those types that are in right side of second axis, have a positive tendency to soil salinity and medium texture. These types are *Halocnemum strobilaceum-Tamarix sp.*, *Halocnemum strobilaceum* and *Tamarix passerinoides*, that prefer saline soils with a medium texture. *Tamarix sp.-Suaeda aegyptica*, *Artemisia sieberi*, *Seidlitzia rosmarinus* and *Halostachys belangeriana* types are located in left side of second axis and show a reverse relation with salinity and medium texture. *Artemisia sieberi* type is affected only by first axis (soil salinity) and has a strong negative relation

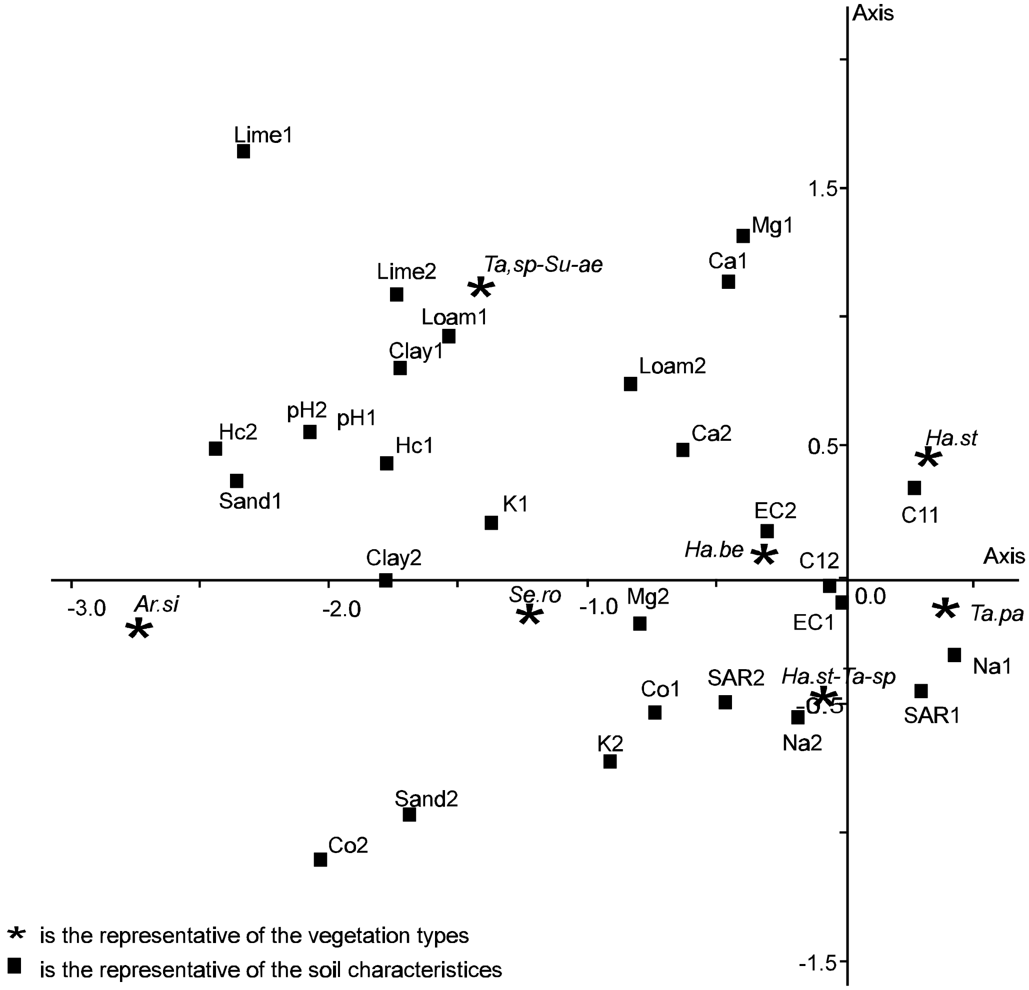

Fig. 2: CCA-ordination diagram of the vegetation-soil characteristics. For vegetation types and variables abbreviations, see Appendix

Table 3: Results of Monte Carlo test for species-soil correlations

Axis	Spp-Soil Corr	Mean	Min.	Max.	P
1	0.917	0.667	0.452	0.863	0.0100
2	0.874	0.752	0.329	0.912	0.1600
3	0.951	0.553	0.261	0.831	0.0100

P = Proportion of randomized runs with species-soil correlation greater than or equal to the observed species-soil correlation; i.e., P = (1+no. Permutations > = observed)/(1+no permutation)

with salinity. In addition, this type prefers fine texture.

Considering the situation of point indicator of the vegetation types in relation to second axis, then, *Halocnemum strobilaceum-Tamarix sp*., *Tamarix sp.-Suaeda aegyptica* and *Seidlitzia rosmarinus* types that are located in the upper part of the first axis have direct relation with lime and pH and reverse relation with bicarbonate soluble ions. *Tamarix passerinoides*, *Halocnemum strobilaceum* and *Halostachys belangeriana* types that are located in the lower part of the first axis (negative side of second axis) have a negative relation with lime and pH, while, show a positive relation with bicarbonate.

CCA: According to Table 2, first and second axes explain 52.5 and 10.2% of variation, respectively. In addition, correlation between the first and second axes with species-soil characteristics are 0.92 and 0.87 respectively. Results of Monte-Carlo test (Table 3) show that the correlation between variables with first axes is highly significant (P = 0.01).

Results of CCA ordination are represented in Fig. 2. Each soil characteristic indicate specific vegetation types. *Halocnemum strobilaceum*, *Tamarix passerinoides*, *Halocnemum strobilaceum-Tamarix sp.* and *Halostachys belangeriana* types are associated

Appendix: Units and abbreviations of the vegetation types and soil characteristics in the figures and tables

Artemisia sieberi	*Ar.si*
Halostachys belangeriana	*Ha.be*
Halocnemum strobilaceum	*Ha.st*
Halocnemum strobilaceum-Tamarix sp.	*Ha.st-Ta.sp*
Seidlitzia rosmarinus	*Se.ro*
Tamarix passerinoides	*Ta.pa*
Eigenvalue	Eign.
Clay (%)	Clay
Loam (%)	Loam
Sand (%)	Sand
Lime (%)	Lime
pH (potential hydrogen)	pH
Electrical conductivity (ds/m)	EC
Sodium ion (Na^+) [meq/li]	Na
Potassium ion (K^+) [meq/li]	K
Calcium ion (Ca^{2+}) [meq/li]	Ca
Magnesium (Mg^{2+}) [meq/li]	Mg
Chlorine (Cl^-) [meq/li]	Cl
Carbonate (CO_3^{2-}) [meq/li]	Co
Bicarbonate (HCO_3^-) [meq/li]	Hc
Sodium absorption ratio (SAR)	SAR

Code 1 is related to the soil characteristics were measured in the first layer (0-20 cm). Code 2 is related to the soil characteristics were measured in the second layer (20-60 cm) (for Table 1).

with soil characteristics such as EC, effective ions on salinity (chlorine and sodium). These types prefer soils with high saline soluble ions. In contrast, soils with low salinity is indicator of *Artemisia sieberi* type. *Seidlitzia rosmarinus* type lies between two mentioned groups that prefer medium condition in soil characteristics. Also, limy soils with medium texture indicate *Tamarix sp.-Suaeda aegyptica*.

Discussion

Soils of the study area are considered as saline soils which have caused low plant diversity in the area. It is because of that plants can absorb their necessary ions only when there is a constant ionic ratio among existing ions in the soil, otherwise roots will not be able to absorb soil ions and this causes a disturbance in plants growth and distribution. Low diversity of plants in the study area is an evidence for this material. In addition, high soil salinity and unsuitable structure are other reasons that make difficulty in the establishment and regeneration of saline land plants. Only high adaptability plants to salinity can grow in the mentioned conditions. *Seidlitzia rosmarinus, Tamarix sp., Halocnemum strobilaceum, Halostachys belangeriana* and *Artemisia sieberi* are the plants that grow in saline soils of the study area.

Results demonstrate that there is a specific relationship between soil characteristics and the separation of the vegetation types. Soil salinity and texture are the two main factors that cause separation of the types in the study area. This result has been supported by the works of Flowers (1975); Maryam *et al.* (1995); Ungar (1968); Kassas (1975); Jafari (1989); Moghimi (1989) and Caballero *et al.* (1994). These researchers found that distribution of plants in a given region is a function of soil salinity. Abu-Ziada (1980) showed that there is a strong relationship between plants distribution patterns with soil salinity and moisture. In the current study, it was revealed that soil salinity and its variation are of the most important factors in the classification of vegetation. In addition, different researchers (Zohary and Orshan, 1949; El-Sheikh and Yousef, 1981) have emphasized on the role of soil moisture as a key element on the distribution of plants. As noted earlier, soil texture was found as an effective variable on the vegetation types separation. This is due to texture influence on the amount of moisture and available nutrient of soil that consequently influences growth and distribution of plants.

PCA analysis indicates that *Halocnemum strobilaceum-Tamarix sp*. type has a direct relationship with salinity, lime, pH and loam. The types of *Tamarix sp.-Suaeda aegyptica* and *Seidlitzia rosmarinus* have a direct relationship with lime and pH and a reverse relationship with salinity and loam. *Artemisia sieberi* type is affected by salinity and texture, that is, this type has a negative relationship with salinity and loam percentage. *Halostachys belangeriana* type has a negative relation with soil salinity, loam percentage, pH and lime. *Tamarix sp*. and *Halocnemum strobilaceum* are the plant types that are affected directly by salinity and loam, while these types show a reverse relationship with lime and pH.

CCA analysis shows that the plant types of *Halocnemum strobilaceum, Tamarix passerinoides, Halostachys belangeriana* and *Halocnemum strobilaceum-Tamarix sp*. are indicators of saline lands with a fine texture soil. By contrast, *Artemisia sieberi* type is an indicator of soils with lower salinity and coarse texture. *Seidlitzia rozmarinus* type lies between two mentioned groups, while *Tamarix sp.-Suaeda aegyptica* type tends to grow on soils with medium salinity and high amount of lime.

It should be noted that these results are belonged to the study area in Qom, but it is possible to generalize them to other similar regions for reclamation and rehabilitation purposes. Focusing next studies to find indicator factors of each species, helps us to determine the optimum, maximum and minimum ranges of these factors for each species.

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