International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:6, No:7, 2012

Soil-Vegetation Relationships in Arid Rangelands (Case Study: Nodushan Rangelands of Yazd, Iran)

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***Abstract*—**The objective of this research was to identify the vegetation-soil relationships in Nodushan arid rangelands of Yazd. 5 sites were selected for measuring the cover of plant species and soil attributes. Soil samples were taken in 0-10 and 10-80 cm layers. The species studied were *Salsola tomentosa, Salsola arbuscula*, *Peganum harmala, Zygophylum* *eurypterum* and *Eurotia ceratoides.* Canonical correspondence analysis (CCA) was used to analyze the data. Based on the CCA results, 74.9 % of vegetation-soil variation was explained by axis 1-3. Axis 1, 2 and 3 accounted for 27.2%, 24.9 % and 22.8% of variance respectively. Correlation between axis 1, 2, 3 and species-edaphic variables were 0.995, 0.989, 0.981 respectively. Soil texture, lime, salinity and organic matter significantly influenced the distribution of these plant species. Determination of soil-vegetation relationships will be useful for managing and improving rangelands in arid and semi arid environments.

***Keywords*—**CCA, Nodushan, Rangelands, Vegetation-soil

I. Introduction

IDENTIFICATION of environmental variables that affect plant growth and distribution is necessary for reclamation and management of arid and semi arid rangelands. Deficiency of precipitation and a high degree of vegetation and soil variability [30] are important features of arid zones. Basically, vegetation landform community patterns are related to some soil properties [31]. Composition [14] and distribution pattern [9] of plants are mainly affected by soil properties. In addition, soil variation pattern is known to be an important factor in competitive and facilitative interactions between plants mainly in arid and semi arid habitats [11] and thus, may affect plant and community distribution. Different soil layers have different effects on plants. Seed germination depends more on the characteristics of upper soil layer, while seedling establishment and plant survival are more affected by the characteristics of lower soil layer. Soil-vegetation relationships have been investigated as one of the major aspects of ecological researches, specially in arid and semi arid environments [17], [32], [14]. Jenny *et al.* (1990) investigated the soil-vegetation relationships at several arid microsites in the Wadi Araba and concluded that water regime and ion specific effects of salinization influenced the pattern of vegetation. Jafari *et al.* (2004) revealed that soil characteristics such as salinity, texture, soluble potassium, gypsum and lime highly affected the distribution pattern of vegetation in Poshtkouh rangelands of Yazd, Iran. El-Ghani and Amer (2003) stated that soil surface sediment, calcium carbonate, soil saturation, pH and organic matter were the main operating edaphic gradients affecting distribution of plant species in a coastal desert plain of southern Sinai, Egypt.

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Understanding the edaphic variables influencing distribution of plant species and communities remains an important goal in ecology of terrestrial ecosystems.

The objective of this study was to identify the relationships between distribution of plant species and edaphic factors. Determination of such relationships is necessary for management and reclamation of rangeland ecosystems. Nodushan rangelands are dominated by *Artemisia sieberi*. *A.sieberi* is a species with a wide ecological amplitude and is one of the most distributed perennial shrubs in central parts of Iran.

II. Material and Methods

A. Study Area

Nodushan rangelands are located in the northwest of Yazd province in center of Iran (31°46′N, 52°24′E to 32°15′N, 53°47′E) between the elevations of 1530m to 3260 m. The mean annual precipitation of the study area ranges from 110 mm to 340 mm. The mean annual temperature is $13\,c^{\circ}$ [5]. To determine soil-vegetation relationships, 5 sites were selected in rangelands of Nodushan. The climate of the sites is arid. The plant species in the sites include:

Site 1: *Artemisia sieberi* Besser. and *Salsola tomentosa* (Moq.) Spach

Site 2: *A.sieberi* and *Salsola arbuscula* Pall.

Site 3: *A.sieberi and Peganum harmala*, Linn

Site 4*: A.sieberi*, *Zygophylum* eu*rypterum* Boiss. and *Acantholimon scorpius* Boiss.

Site 5*: A.sieberi, Eurotia ceratoides* (L.) C. A. Mey, *Iris.songarica.* Schrenk, and *Astragalus glaucacanthus*. Fisch.

B. Data Collection and Analysis

5 sites were selected in rangelands of Nodushan for determination of the soil-vegetation relations. Within each site, four parallel 100m transects were located. The vegetation cover of plant species was estimated in 15 equidistantly located 2×2.5m quadrats along each transects (60 quadrats in each site). In the middle of each transect a soil sample was taken between 0-10 cm and 10-80 cm layers (40 samples in 5 sites). The measured soil characteristics include electrical conductivity (ECe) (measured by conductivity meter), pH in saturation extract (determined by pH meter), texture (determined by Bouyoucos hydrometer), organic carbon (measured using Walkely and Black titration) and lime (determined based on total neutralizing value). To analyze the relationship between edaphic attributes and plant species, canonical correspondence analysis (CCA) was used. In CCA, two matrices were used. one matrix was composed of the cover values for species and the other was composed of values of soil variables. Since, *A.sieberi* is the dominant species in the study sites and almost all the arid parts of Nodushan

rangelands, it was excluded from the ordination calculations. In addition, the study sites do not share common species and each is covered by only two species except sites 4 and 5. Therefore, to efficiently determine the soil-vegetation relationship, CCA was performed based on the edpahic factors and the second dominant species in the study sites.

CCA [13] is a procedure for simultaneously analyzing mixed species and environmental data. This multivariate statistical procedure uses linear canonical equations with multiple dependant and independent variables. The significance of species-environment correlation was determined by Monte Carlo test (1000 permutations). Pcord software was used to perform CCA. The soil characteristics of the study sites and the cover of plant species are presented in tables 3 and 4 respectively.

III. Results

The relation between species cover and edaphic factors was analyzed by CCA. In interpretation of the CCA diagram, the following points should be noted [29]: The environmental variables are represented by arrows. The arrow for an environmental variable points in the direction of maximum change of that environmental variable across the diagram, and its length is proportional to the rate of change in this direction. Environmental variables with long arrows are more strongly correlated with the ordination axes than those with short arrows, and so more closely related to the plant species or pattern of community variation shown in the ordination diagram. Species that are unrelated to the ordination axes tend to be placed in the center of the ordination diagram. Based on the CCA results, 74.9 % of vegetation-soil variation was explained by axis 1-3 (Table1). Axis 1 (Eigenvalue :0.669) accounted for 27.2% of variance. The factors corresponded to the first axis were pH and clay in the first soil layer (0-10 cm), organic matter in the second layer (10-80 cm), sand, silt and lime in both layers (Table II). Lime in the first layer had the highest correlation with this axis.

24.9 % of variation was explained by axis 2 (Eigenvalue:0.579). Organic matter in the first layer and ECe in both layers were represented by the second axis among which, ECe in the first layer had the highest correlation with this axis. 22.8% of variance was explained by the third axis (Eigenvalue : 0.522).

PH and clay in the second layer were associated with the third axis among which clay in the second layer had the highest correlation with this axis. Correlation between axis 1, 2, 3 and species-edaphic variables were 0.995, 0.989, 0.981 respectively. Monte Carlo test for the first three axis was highly significant ($P<0.001$).

To better explain and analyze the most important edaphic factors influencing the vegetation cover, the position of species are described based on axis I - II (Fig1) and I - III (Fig2). The cover of *S.tomentosa* was positively correlated with salinity in both soil layers, sand content in the first layer and pH and clay in the second layer and negatively correlated with organic matter in the first layer. Salinity in the first layer was more effective on this species than salinity in the second layer.

S.arbuscula was positively associated with a high salinity (ECe) in both layers, and sand content in the second layer and negatively associated with organic matter in both layers, and pH and clay in the second layer. The cover of *P.harmala* was negatively related with ECe in both layers and positively related with organic matter in the first layer. *E.ceratoides* was positively correlated with soil sand content in both layers and negatively correlated with lime, clay, silt and ECe in both layers and pH in the first layer. *Z.eurypterum* had a positive relationship with lime, pH, organic matter and silt in both layers and a negative relationship with sand content in both layers.

International Journal of Biological, Life and Agricultural Sciences
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TABLE I
CANONICAL CORRESPONDENCE ANALYSIS FOR ENVIRONMENTAL DATA

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.669	0.579	0.522
Variance in species data			
% of variance explained	27.2	24.9	22.8
Cumulative % explained	27.2	52.1	74.9
Pearson Correlation, Spp-Envt	0.995	0.989	0.981

TABLE II
CORRELATIONS FOR THE ENVIRONMENTAL VARIABLES IN CCA

	CCA AXIS		
Environmental variables	1	2	3
p.H (1)	**-0.929**	-0.077	0.170
p.H (2)	-0.156	-0.360	**-0.741**
Sand (1)	**0.868**	-0.100	-0.473
Sand (2)	**0.717**	0.170	0.669
Silt (1)	**-0.869**	0.073	0.468
Silt (2)	**-0.778**	-0.363	-0.499
Clay (1)	**-0.387**	0.206	0.247
Clay (2)	-0.230	0.401	**-0.793**
Electrical conductivity (1)	0.226	**0.968**	-0.076
Electrical conductivity (2)	0.179	**0.696**	0.656
Lime (1)	**-0. 974**	0.001	0.208
Lime (2)	**-0.946**	-0.314	-0.065
Organic matter (1)	-0.473	**-0.806**	0.060
Organic matter (2)	**-0.609**	-0315	-0.606

Signs 1 and 2 indicate the first (0-10 cm) and the second (10-80 cm) soil layers respectively.

TABLE III
EDAPHIC CHARACTERISTICS OF THE STUDY SITES

	Study Sites				
Edaphic characteristics	1	2	3	4	5
pH(1)	7.3	7.38	7.59	7.9	7.06
pH(2)	7.83	7.43	7.78	7.75	7.72
Sand (1)%	69.4	57.4	63.4	53.4	71.4
Sand (2)%	73.4	83.4	77.4	70.4	77.4
Silt (1)%	21.3	33.3	27.3	37.3	21.3
Silt (2)%	17.3	11.3	17.3	22.3	16.3
Clay (1)%	9.3	9.3	9.3	9.3	7.3
Clay (2)%	9.3	5.3	5.3	7.3	6.3
Electrical conductivity (1) (ds/m)	16	10.7	0.673	0.78	0.72
Electrical conductivity (2) (ds/m)	1.98	5.3	1.17	1.047	0.87
Lime (1)%	17.57	22.8	22.8	34.8	12.82
Lime (2)%	13.57	13.5	23.57	43.3	15.3
Organic matter (1)%	0.0758	0.107	0.458	0.427	0.275
Organic Matter (2)%	0.275	0.153	0.229	0.382	0.305

Signs 1 and 2 indicate the first (0-10 cm) and the second (10-80 cm) soil layers respectively. Organic matter was calculated by multiplying %organic carbon by a factor of 1.724.

TABLE IV
THE COVER PERCENTAGE OF THE PLANT SPECIES IN THE STUDY SITES

Study sites	*Artemisia sieberi*	*Salsola tomentosa*	*Salsola arbuscula*	*Peganum harmala*	*Zygophyllum eurypterum*	*Acantholimon scorpius*	*Eurotia ceratiodes*	*Astragalus glaucacanthus*	*Iris songarica*
1	6.6	1.1	-	-	-	-	-	-	-
2	9	-	1.4	-	-	-	-	-	-
3	5.2	-	-	2.62	-	-	-	-	-
4	12.9	-	-	-	2.6	1.9	-	-	-
5	10.4	-	-	-	-	-	2.1	0.52	2

IV. DISCUSSION

The results showed that a variety of edaphic factors highly influence the distribution and establishment of plant species in arid environments. *Z.europterum* reflected the soils with a high lime, pH, silt and organic matter and a gradient of soil from light sand to heavy clay. Lime can influence the availability and uptake of nutrients such as Nitrate-N [16], phosphorus, calcium, magnesium and potassium [22] by plants, and can increase the pH of the soil [27]. Biologically, lime influences soil organisms and thereby increases the effect of organic matter and nitrogen in the soil [7]. *S.tomentosa* was found to be an important indicator of the soils with a high salinity, a light surface texture, a low surface organic matter and a gradient of subsurface layer from light sand to heavy clay. *S.tomentosa* has been classified as xerohalophytic species [2] in arid climates. *S.arbuscula* was recognized as an important indicator of the soils with a high salinity and a low organic matter, and a light subsurface texture. *S.arbusculla* has been classified as both xerohalophytic [1] and psammophytic species [20] in arid zones. Soil salinity is known as one of the important factors affecting distribution [3] and composition [8] of plants in arid environments. It highly influences plant germination, root elongation [19] and growth, osmotically, by direct toxicity and by ionic imbalance [24]. In addition, the amount of mineral nitrogen decreases with increased salinity [21] based on salinity affects on microorganisms activities. *E.ceratoides* reflected light soils with a low salinity and a gradient of decreasing lime. Some studies have shown that *E.ceratoides* occurs in a variety of calcareous, gypsiferous and slightly saline (ECe < 5.29 ds/m) soils from light to heavy texture [25]. Soil texture has been found to influence plant composition [4] and distribution under the same climatic conditions [23] and to limit arid and semi-arid plant dynamics by affecting local soil moisture regimes [28]. Soil texture can affect the movement and availability of air and water in soil [15], water supply and the rate and depth of leaching (e.g., NO3-N) [12]. *P.harmala* was characterized by the light soils with a low salinity and a relatively high surface organic matter.

Properties influenced by organic matter include: soil structure, nutrients (e.g., transformation of nitrogen), moisture holding capacity and diversity and activity of soil microorganisms. *P.harmala* is known to be an indicator of degraded rangelands. This species mainly appears following the repeated and heavy grazing specially near the livestock concentration areas [6]. K, Ca and pV in sandy soils have also been recognized as the important factors affecting distribution of *P.harmala* [26]. The study of soil-vegetation relationships can be very useful for detecting and analyzing composition and distribution pattern of plants in relation to edaphic factors. It also will be a guidance for managing and reclaiming degraded rangelands in arid and semi arid environments. The findings on the plant and soil relations in the study area will help investigators to efficiently select adaptable species for improving and restoring this area and similar areas.

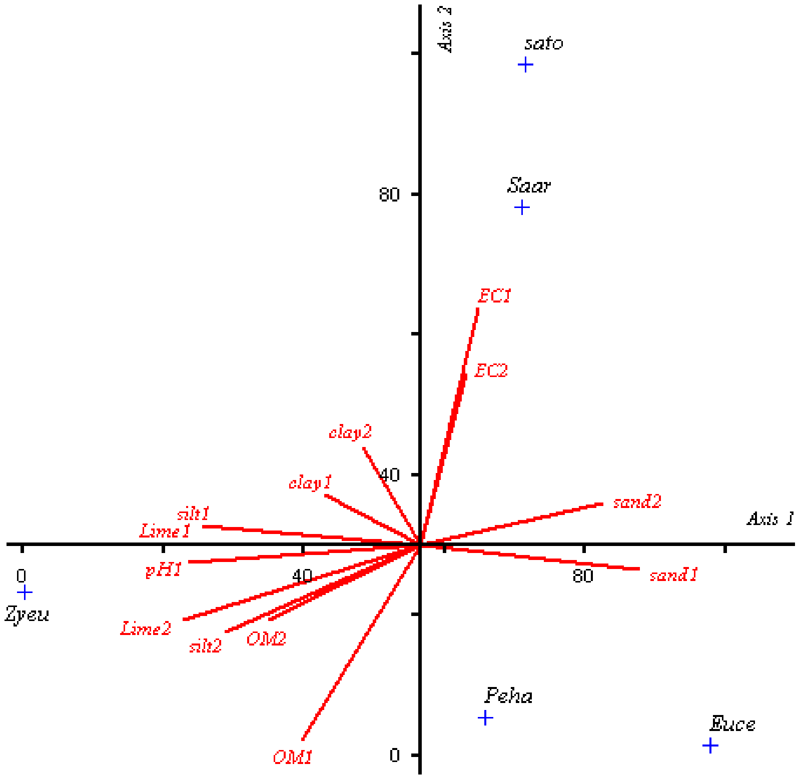

Fig. 1 CCA-ordination of species in relation to edaphic variables based on axis I and II

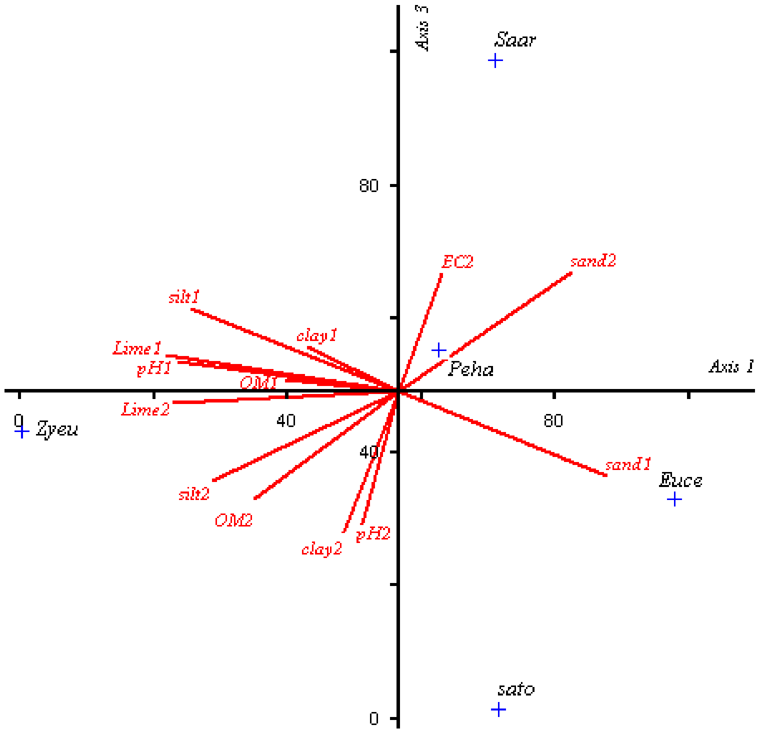

Fig. 2 CCA-ordination of species in relation to edaphic variables based on axis I and III

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