STUDYING THE EFFECT OF ELEVATION AND EDAPHIC VARIABLES ON VEGETATION COMPOSITION IN KHEZRABAD RANGELANDS USING PRINCIPAL COMPONENT ANALYSIS (PCA)

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Abstract. A major scientific challenge in plant ecology is to identify and quantify the strength of environmental factors that are responsible for the distribution and abundance of plant species within and among ecosystems. Hence, this study is focused on relation between plant communities and environmental variables in Khezrabad region of Iran. Based on field surveys, eight vegetation types including *Artemisia sieberi-Acantholimon erinaceum*, *Artemisia sieberi-Hertia angustifolia*, *Artemisia sieberi-Launea acanthodes*, *Artemisia sieberi-Salsola tomentosa*, *Artemisia sieberi-Zygophyllum atriplicoides*, *Artemisia aucheri-Astrgalus albispinus*, *Artemisia sieberi-Fortuynia bungei*, *Haloxylon aphyllum* were identified. With respecting to the present variance between vegetation and environmental factors, four samples were established in each vegetation type in 0–30 cm depth. The studied soil variables affecting plant communities were texture, EC, pH, Na^+, k^+, Cl^-, Ca^{2+}, Mg^{2+}, SP, O.M, $CaCO_3$, HCO_3^- and CEC. Among the topographic conditions, elevation was recorded in sampling regions as well. Data matrix of environmental factors and vegetation type was made using the windows (ver. 4.17) of PC-ORD. Results according to PCA showed that in the study area, among different environmental factors, the distribution of vegetation types was most strongly correlated with some agents such as soil texture, salinity and sodicity. In fact, soil texture controls distribution of plant species by affecting moisture availability, ventilation and distribution of plant roots. Beside, soil salinity and sodicity because of habitat condition, plant ecological needs and tolerance range can have negative affect on plant diversity. In addition, results indicated that increasing of elevation had negative effect on plant distribution. However, soil characteristics have more influence on vegetation separation than to the elevation in this study.

Keywords: environmental factors, Khezrabad rangelands, PCA, vegetation types.

INTRODUCTION

Understanding how environmental factors influence the distribution of vegetation allows environmental managers to plan for issues such as climate change, ecological restoration and intensified land use [3]. Both biotic and abiotic factors are considered to be effective in distribution of plant communities [38]. However, topography, climate and soil are three important environmental abiotic factors controlling vegetation composition in rangelands [16]. Hence, inter-relation between plant communities and environmental factors are complex, reflecting simultaneous changes in factors such as soil moisture, salt content and soil stability [34]. Change in the existent components of a natural ecosystem, especially plants and soil, leads to gradual variations in the shape, composition and structure of such communities. Therefore, studying the classification and the inter-relation between the different plant communities in response to the environmental factors are demand [15, 33].

The soil properties can strongly influence the plant growth due to soil is a function of climate, organisms, topography, parent material and time [14, 16]. Jenny [17] for the fist time explained that soil parent materials and time of soil development are the two main factors powerfully affecting the plant composition. In addition, soil chemistry has been reported to affect plant species composition through levels of salinity [1, 26], pH, calcium and organic carbon [2]. Low species richness has been recorded where levels of salinity and $CaCO_3$ are high [2], while species composition and richness patterns have also been linked to trends in community development through time (succession) as soil conditions for plant growth improve in association with increasing soil depth, organic matter and water holding capacity, and decreasing pH and $CaCO_3$ [27].

Elevation, slope and aspects are three environmental factors affecting soil and climate. So that elevation is often used as an indirect predictor of temperature and evapo-transpiration. In mountainous terrains variations in slope, aspect, and radiation can significantly alter the relationship between elevation and temperature. Therefore the role of elevation, slope and aspects in soil properties such as its depth, moisture and organic matter content is completely complex [16, 3]. However, vegetation cover has strong relationship with temperature and soil moisture. Other soil characteristics directly or indirectly, influence the two mentioned parameters. Rooting depth, soil water potential, absorption and distribution of nutrients are influenced by the amount and availability of soil moisture [16]. So that, Liu & Zhou [19] pointed out to the soil moisture and salt content as two important factors controlling distribution pattern of plant communities in Qinghai province of China. Similarly, Jafari et al. [16] revealed that the vegetation distribution pattern in Poshtkouh rangelands of central Iran was mainly related to soil texture and moisture contents. They also pointed out to the role of other soil characteristics such as salinity, soluble potassium, gypsum and lime in vegetation composition of the region. Heydari & Mahdavi [13] studied biodiversity of plant species in related to physiographic factors (aspect, elevation above sea level and slope percentage) in Melah Gavan area in Ilam province of Iran. They reported that biodiversity and richness are maximum in southern aspect (0-25 slop percentage) and minimum in eastern aspect. Also low and upper altitudes had the most and least biodiversity, respectively. Enright et al. [10] reported that physical factors have more influence on plant communities than the soil chemical factors and human induced factors through soil moisture content. They believe that soil moisture is more influenced by soil physical characteristics such as slope and being stony. However, soil moisture is influenced by both soil physico-chemical properties including texture, clay mineralogy, structure, soluble salts, organic carbon content, gravel, depth, temperature, topography and microtopography [16]. Similarly, Soleimani et al. [28] showed that environmental factors such as, geology, soil and climate had sensible influence on vegetation change in northern slopes of Alborz mountain range of Iran. Also they indicated that the range types of vegetation changes were related to the geology and its formation types. Brosofske et al. [8] investigated relationship of the environmental factors and vegetation to manage of ecosystem and showed that knowledge of the different effects of environmental factors on vegetation helps to improvement and development the ability for predicting the human's disturbances on vegetation. Therefore, understanding relationships between ecological variables in a given ecosystem helps us to apply these findings in management, reclamation, and development of similar regions [16].

As mentioned above, the main purpose of this research was to investigate the relationships between environmental factors with plant species to determine the most important factors affecting the separation vegetation types. The other aims were to identify limiting factors in establishment of vegetation in order to determine the suitable methods for land reclamation, and also introduce adaptable species according to the soil characteristics in the study area.

MATERIALS AND METHODS

The study area (Khezrabad region) is located in the western south part of Yazd-Ardakan plain between 31°, 52′ to 32°, 12′ in northern latitude and 53°, 48′ to 54°, 08′ in eastern longitude as a rectangular shape which covers 16900 ha. This area reaches to Shirkouh mountain range from western south direction and Yazd-Ardakan road from eastern north direction. Khezrabad region is located at approximately 30 km of the Taft city of Yazd province in central Iran. Fig. 1 illustrates the location of the study area. The maximum and the minimum elevation levels are 2783 m and 1131 m, respectively. This zone has been recognized as arid cold area. The annual rainfall is between 100 and 134 mm. Mean temperature of the region is 13.2 °C. The study area was located on the EW slope with mean slope 6%.

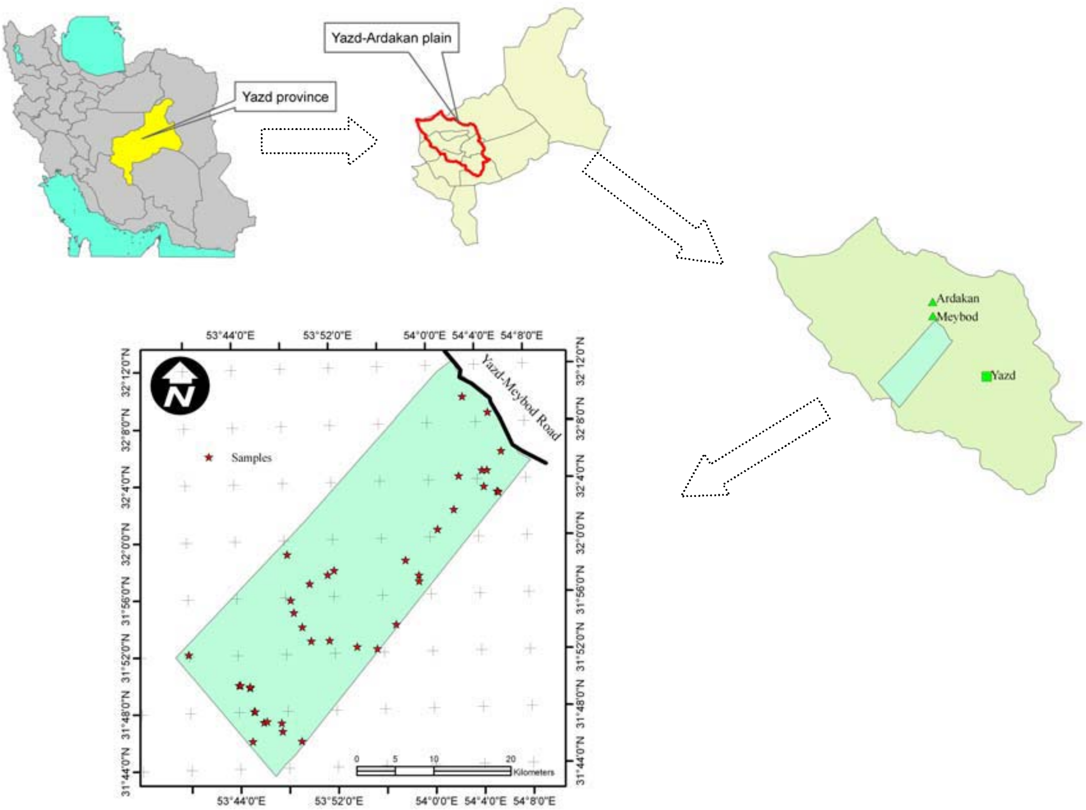

Figure 1. Situation of studied region and soil sampling distribution

After preliminary studies of geological (1:100000, 1:250000) and topographical maps, using GPS, according to field surveys, different vegetation types were recognized in the region. In each vegetation type, soil and vegetative characteristics were identified inside quadrats situated along two 250 m transverse transects. With regarding to present variance of vegetation and environmental factors, four samples were selected in each vegetation type. Sampling was done according to randomized systematic method and then, soil sampling was taken at each quadrat from depths of 0-30 cm.

The percentage of soil particles (particle size distribution) were determined by the Bouyoucos hydrometer method. The EC and pH values were measured using conductivity meter (PW-9527 Philips) and pH meter (EYELA-2000) after preparation of saturation pastes of the soil samples respectively. Organic carbon was determined by the Black [7] method. The percentage of saturation moisture (SP) and calcium carbonate were measured using gravimetric method and volumetric method respectively. Soluble calcium and magnesium determined by titration with soluble EDTA method. Soluble chlorine measured by titration with $AgNo_3$. Soluble carbonate and bicarbonate determined by titration with H_2SO_4 using methylorange and phenolph thalein, respectively. CEC determined by means of Rhoades, (1982) method. Soluble sodium and potassium measured by flame photometry method [29]. In quadrat positions, altitude was also recorded using compass method [16]. All sampling sites were located in the eastern- western aspect.

At first it was needed to develop data matrix between environmental factors (topography and soil) and vegetation type. Ordination of vegetation types in gradient of environmental factors was made using windows (ver. 4.17) of PC-ORD [22]. Principal component analysis (PCA) was used to analyze relationship among environmental factors and vegetation components. PCA is the ordination technique that constructs the theoretical variable that minimizes the total residual sum of squares after fitting straight lines to the species data. PCA does so by choosing 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 a abundant Ones, there fore dominate the PCA Solution, whereas species with low variance, often the rare Ones, have only minor influence on the solution. These may be reasons for applying the standardized PCA, in which all species receive equal weight. Therefore, date was centered and standardized by standard deviation. Eigenvalues for each principal component was compared to a broken-Stick eigenvalue to determine if the captured variance Summarized more in formation than expected by chance. Broken–stick eigenvalues have been shown to be a robust method for selection of non- trivial components in PCA. Principal components are considered useful, or non- trivial, if their eigenvalue exceeds that of their broken–stick counterpart [16].

RESULTS

The effect of 15 environmental factors on distribution of plant communities was studied using PCA method. Table 1 and Fig. 2 demonstrate the results of PCA ordination. Also Table 2 shows some soil physico-chemical characteristics along with elevation levels of study area in different vegetation types. As shown in Table 1, the levels of Broken-stick eigenvalues for the first two principal components (PC1 and PC2) are more than other components. So that, the levels of Broken-stick eigenvalues for PC1 and PC2 are 3.318 and 2.318, respectively (Table 1). Also, the results showed that these two principle components together accounted for 80.03% of the total variance in data set, because according to Table 1 the percentage of variance for the first and second principle components are 51.43 and 28.60 respectively. Therefore, both of them determinedly contain more variance than expected by possibility. However, the first principle component (PC1) significantly has more accounted variance compared with the second principle component (PC2). Hence, the first principle component show significant superiority between other principle components and can be considered as the most important component for representing the variation of the eight vegetation types.

Table 1 also shows the correlation between variables and components. According to this table some soil physico-chemical property including EC, Clay, Ca+Mg, Na^+ and Cl^- are the most important environmental factors affecting the first principle component (PC1). Moreover according to this table can be concluded that, all of these soil properties have negative effect on vegetation distribution in the region. Therefore soil salinity and sodicity as well as its heavy texture can be consider as the most limiting factors in related to plant growth in the study area. Also, PC1 comprise about 51.43% of total variance. Consequently, among all of environmental variables, the mentioned soil characteristics dominantly control the distribution of vegetation types in Khezrabad region.

On the basis of correlation between variables in the second principle component (PC2), elevation and sand content show the most relationship between other environmental factors with plant distribution. In addition according to axis 2, it is clear that the correlations between elevation and plant distribution (-0.3457) is negative, while the soil sand content is positively correlated (0.3404) with plant diversity. Consequently, with increasing of elevation level and decreasing of sand content in the region the plant diversity will reduce.

Fig. 2 presents a scheme of eight vegetation types against their values for axis 1 and 2. According to this diagram the distance between the indicators points of vegetation types show the degree of connection between environmental factors. In another word, this distance is relationship power in the explanation of variations. Whenever the length of vector loading (as indicator of the vegetation types) is bigger, the angle between vectors and axis is smaller. Therefore, the correlation between vegetation types with axis and relation power is move [36]. With regarding to PC1, all coefficients of the environmental factors are negative. Therefore, those plant sites that are lying in the positive direction of axis 1 have opposite relationship with PC1 factors. In the second principal component (PC2), coefficient for, elevation is negative, while for sand are positive (Fig. 2). More explanation about this diagram is that three species including *Ar. aucheri-As. albispinus*, *Ar. sieberi-He. angustifolia* and *Ar. sieberi-*

Ac. erinaceum belong to the fourth quarter of the co-ordinate axis. Moreover, on the basis of this diagram the mentioned vegetation types show opposite connection with all of the factors that are related to PC1 and also factor of Sand in PC2. As mentioned above, relation power depends on the length of vector loading and the angles between vectors and axes. Therefore, it can be told that *Ar. aucheri-As. albispinus* type is more related PC2 than PC1, while *Ar. sieberi-He. Angustifolia* is more related to PC1 than PC2. Furthermore, in related to *Ar. sieberi-Ac. erinaceum*, the influences of environmental variables are rather similar in axes 1 and 2 (Fig. 2).

The findings of this research showed that *Ha.ap* type grows in different environmental condition in the region compare with other studied vegetation types. With respecting to the location site of *Ha.ap* type on the third quarter of the diagram, this vegetation type has high correlation with the first axis. Consequently, this type has the most relation with those variables which are related to the first axis. These variables are clay content, EC, Ca^{2+}, Mg, Na^+ and Cl^-. As a result, these soil physico-chemical properties are the most important environmental factors that affect the distribution of *Ha.ap* type in the region. In addition with attention to Fig. 2, the *Ha.ap* type has larger distance from the second axis of the diagram. Hence, due to soil sand content and the level of elevation are related to this axis (axis 2), it seems that *Ha.ap* type has a weak relation with these environmental factors.

Table 1. PCA applied to the correlation matrix of the environmental factors in the study area.

Axis	Eigenvalue	% of Variance	Cum.% of Var.	Broken-stick Eigenvalue
1	7.715	51.432	51.432	3.318
2	4.290	28.597	80.029	2.318
3	1.472	9.817	89.849	1.818
4	1.022	6.812	96.657	1.485
5	0.255	1.701	98.358	1.235
6	0.168	1.119	99.477	1.035
7	0.078	0.523	100	0.868
8	0	0	100	0.725
9	0	0	100	0.600
10	0	0	100	0.489

Factor	1	2	3	4	5	6
Elevation	0.2331	**-0.3457**	-0.0701	0.2068	0.1413	-0.2101
Sand	0.2294	**0.3404**	0.2348	-0.0047	0.2408	-0.0824
Silt	-0.1248	-0.3680	-0.3805	0.1271	**-0.4956**	0.1222
Clay	**-0.3027**	-0.2541	-0.0343	-0.1123	0.0243	0.0147
SP	-0.2542	-0.3175	0.1265	0.0083	**0.3696**	-0.1967
O.M	0.1822	-0.3638	-0.2812	-0.1533	0.0994	**-0.3938**
Lime	0.1010	-0.0668	0.3334	**0.8444**	-0.1456	-0.1612
pH	0.3368	-0.1209	0.0043	-0.0855	-0.2509	**-0.3597**
EC	**-0.3382**	0.1042	-0.1472	0.1308	0.1784	-0.2274
Ca^{2+}+Mg^{2+}	**-0.3511**	0.0297	0.1442	-0.0400	-0.0310	-0.2574
Na^+	**-0.3448**	-0.0247	0.2132	-0.0449	-0.0831	-0.2266
K^+	-0.0982	0.2292	**-0.6036**	0.3258	0.4364	-0.0858
HCO_3^-	0.2818	-0.2316	0.2123	-0.2009	**0.3145**	-0.1600
Cl^-	**-0.3405**	-0.0413	0.2415	-0.0530	-0.0744	-0.2040
CEC	-0.0538	-0.4384	0.1789	0.1201	0.3327	**0.5838**

With regarding to Fig. 2, the position of three types of *Ar. sieberi-Zy. atriplicoides*, *Ar. sieberi-Sa. tomentosa* and *Ar.sieberi-La.acanthodes* is in the first quarter of the diagram. Also among these types, *Ar. sieberi-Zy. atriplicoides* type has a strong relation with PC1 due to the length of vector and angle between vector and this component (PC1). However, because all of the characteristics which are in PC1 have a negative coefficient hence, should be said that this type has a divers strong relation with PC1 characteristics such as EC, Na^+, Cl^-. In *Ar. sieberi-Sa. tomentosa* type environmental characteristics is approximately similar in axes 1 and 2. Another type which is in the first quarter, (*Ar. sieberi-La. acanthodes* type) has more relation with indicator environmental characteristics of the second axis (elevation and sand) than axis 1. This relation is positive for the factor of sand, while this relation is a diverse relation with elevation. In addition, environmental characteristics are approximately similar in the first and second components (PC1 and PC2) for *Ar. sieberi-Fo. bungei* type as well as *Ar.sieberi-Sa. tomentosa* type although, their position in the quarters is different. However, *Ar. sieberi-Sa. tomentosa* type has a direct relationship with characteristics such as sand and inversely related to elevation.

DISCUSSIONS

The connection between plant growth and soil physico-chemical properties such as texture and salinity has been reported by different researchers [11, 12, 16, 18, 23, 30, 36]. For example, Zegeye et al. [37] showed that the interdependency of vegetation type and soil chemical properties lead to a variety of species, vegetation types and distribution of plant communities in south-central Ethiopia. Similarly, Youssef & Al-Fredan [32] stated that the occurrence, distribution and composition of plant species form the different ecological groups, are related to the degree of soil salinity and/or heterogeneity of substrate in the

Table 2. Soil physico-chemical characteristics along with elevation values in various vegetation types of study area.

Vegetation Type	EC	pH	Lime	SP	Sand	Silt	Clay	[a]OM
Ar.au-As.al	0.59	8.14	18.75	27.59	40.07	35.17	24.76	0.88
Ar.si-Ac-er	0.42	8.24	32.80	24.24	43.80	37.00	19.20	0.64
Ar.si-Zy.at	0.43	8.09	37.62	24.05	64.16	22.00	13.84	0.34
Ar.si-Sa.to	0.93	8.18	20.58	20.90	67.61	19.60	12.79	0.34
Ar.si.Fo.bu	14.33	7.85	22.60	22.17	52.04	29.20	18.76	0.21
Ar.si-la.ac	0.92	8.08	23.41	19.07	65.30	22.00	12.70	0.24
He.ap	17.56	7.68	23.06	31.96	34.16	32	33.84	0.10
Ar.si-He.an	0.70	8.04	23.82	22.81	53.26	28.50	18.24	0.34

Vegetation Type	Ca^{2+}+Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	CEC	elevation
Ar.au-As.al	4.92	2.29	0.17	3.58	3.60	11.78	2638.17
Ar.si-Ac-er	4.21	1.37	0.20	3.43	1.80	11.19	2630.75
Ar.si-Zy.at	4.80	1.10	0.18	3.40	2.75	10.35	2350.00
Ar.si-Sa.to	7.14	3.89	0.42	3.60	4.64	7.32	1685.40
Ar.si.Fo.bu	16.38	150.46	0.75	2.14	133.66	6.22	1371.20
Ar.si-la.ac	7.55	6.56	0.33	2.80	3.80	5.2	1498.50
He.ap	41.80	187.36	0.85	2.31	251.81	11.32	1141.43
Ar.si-He.an	5.38	2.57	0.19	3.20	4.90	11.05	1875.00

For vegetation types and variables abbreviations and soil characteristics units, see Appendix A.
a $OM = 1.72 \times OC$

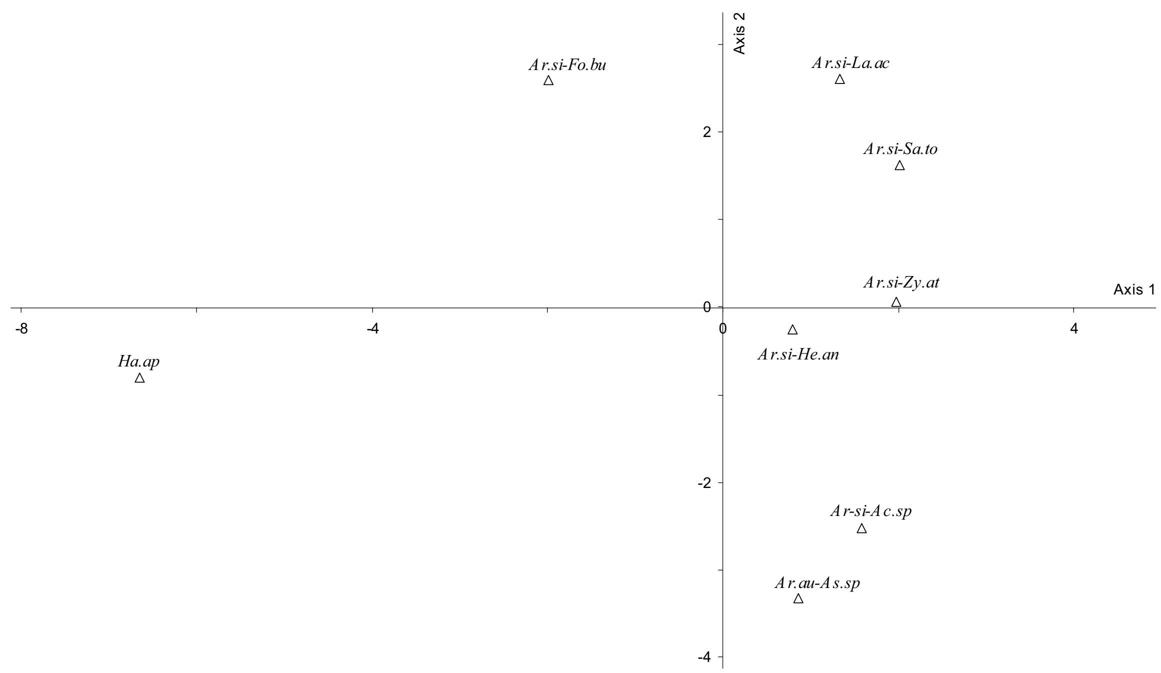

Figure 2. PCA-Ordination diagram of the vegetation types related to the environmental factors in the study area. For vegetation types abbreviations, see Appendix A

stabilized sandy substratum which supported the recorded types of halophytic and/or xerophytic species.

The importance of sandy texture for plant growth especially at arid and semi-arid regions is well documented. Majority of clayey soils have ventilation problems and most of the crops have difficulties for growing in these kinds of soils. In addition, increasing of macro pores is so important for equilibrium between air and water into the soils. The balances among air and water in soil lead to more crop productivity. Hence, increasing of sand content with rising of macro pores will enhance the infiltration rate which leads to reduction of runoff volume and velocity. Also, decreasing from surface evaporation by enhancing the infiltration rate by increasing of sand content is so important in arid and semi-arid areas for increasing crop growth. Storing of water needing for crops during the growth season by preventing of evaporation is a basic rule of sand content into the soil [6]. Zare Chahouki [35] similarly showed that saturation moisture percentage as a function of soil texture and soil depth was so effective in the yield of plant species. The similar results were reported by Youssef et al. [34] during their investigations on vegetation of the coastal areas in Saudi Arabia.

In related to the role of topography on plant distribution it was discovered that elevation gradients create varied climates, along with resultant soil differentiation, promote the diversification of plant species [9, 20]. Many studies have investigated species richness along elevation gradient across habits and taxa [4, 31]. In general, as identified by Rahbek [24, 25], there are three main patterns: a monotonic decline in species richness from low to high elevation, a hump-shaped pattern with a high species richness at mid-elevations, or essentially a constant from the lowlands to mid-elevations followed by a strong decline further up. However, in the present study elevation was negatively correlated with vegetation distribution. In contrast Barnes [5] noted that elevation and the distribution of plant species were strongly positively correlated with each other. He also found soil organic content co-varied with surface elevation.

However, in the present study the soil characteristic was more effective on vegetation separation in the region than to the elevation. Similarly, Makarenkov & legender [21] investigated the habitat condition of the three range species, namely, *Festuca ovina*, *Cachrys ferulacea*, and *Bromus tomentellus* in related to edaphic, climatic and topographic conditions, using ordination methods in Vahargan river catchment. Results indicated that edaphic factors were the most effective one in the separation of the three habitats. Climatic and topographic variables were in the next orders of importance.

On the basis of our results, between various environmental variables some agents such as soil texture, soil salinity and sodisity and also elevation were the most effective factors controlling vegetation distribution in the Khezrabad region. In fact, soil textue controls distribution of plant species by affecting moisture availability, ventilation and distribution of plant roots [16]. In arid regions, water is the most effective factors on distribution of plant. Therefore, soil moisture has an important role in composition of the plant species [39]. The affect of soil salinity and sodicity on vegetation distribution is well documented [32, 37]. However, in the present study the soil characteristic was more effective on vegetation separation in the region than to the elevation.

In addition, in the present study, PCA results indicated that those types which where located in the right part of the first component (PC1), such as *Ar. sieberi-He. angustifolia*, *Ar. sieberi-Zy. atriplicoides*, have a divers relationship with indicator environmental characteristics. Consequently, it can be said that this types prefer soils with low salinity and coarse texture. Also, for the second component (PC2), the types which where located in below part of this component, including *Ar.aucheri-As.albispinus*, *Ar. sieberi-He. angustifolia* and *Ar.sieberi-Ac.erinaceum*, have a negative relationship with indicator environmental characteristics of this component (PC2). Therefore, it can be said that this types prefer living in environments with high elevation and soils with a pre-fine texture. For example, the types of *Ar. sieberi-La. Acanthodes*, *Ar. sieberi-Sa. tomentosa* and *Ar. sieberi-Fo. bungei* are reflecting the soils with coarse texture and low elevation. Moreover, the type of *Ar. sieberi-He. Angustifolia* as well as *Ar. sieberi-Zy. atriplicoides* type is located in the soils with low salinity level while, the type of *Ha.ap* can growth in the soils having high salinity levels. Consequently, can be concluded that each plant species have its specific relations with environmental variables [16].

Appendix A

Units and abbreviations of the vegetation types and environmental factors in the figures and tables:

Na^+	Sodium ion (Na^+) (meq/1)
Cl^-	Chlorine ion (Cl^-) (meq/1)
K^+	Potassium ion (K^+) (meq/1)
Ca^{2+}	Calcium ion (Ca^{2+}) (meq/1)
Mg^{2+}	Magnesium ion (Mg^{2+}) (meq/l)
O.M	Organic Matter (%)
Lime	Calcium carbonate (%)
SP	Saturation percentage (%)
HCO^-_3	Bicarbonate (meq/l)
CEC	Cation exchange capacity (meq/100g)
Ar.au-As.al	*Artemisia aucheri-Astrgalus albispinus*
Ar.si-Ac-er	*Artemisia sieberi-Acantholimon erinaceum*
Ar.si-Zy.at	*Artemisia sieberi-Zygophyllum atriplicoides*
Ar.si-Sa.to	*Artemisia sieberi-Salsola tomentosa*
Ar.si.Fo.bu	*Artemisia sieberi-Fortuynia bungei*
Ar.si-La.au	*Artemisia sieberi-Launea acanthodes*
He.ap	*Haloxylon aphyllum*
Ar.si-He.an	*Artemisia sieberi-Hertia angustifolia*

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