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Full Length Research Paper

The effects of soil characteristics and physiographic factors on the establishment and distribution of plant species in mountain forests (Case study: Asalouyeh, South of Iran)

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The objective of this study was to assess the effects of soil characteristics and physiographic factors (slope, aspect and elevation) on vegetation distribution. We ultimately ascertained the most important characteristics on the establishment, regeneration and distribution of species in Asalouyeh mountain forests south of Iran. Vegetation sampling was performed using a randomized-systematic method and plot area was determined by the "minimal area" method. Data relevant to the presence and abundance of plant species was also analyzed. Plant ecological groups were formed from vegetation data (TWINSPAN) and ordination analysis (DCA). Geographic information system (GIS) was employed for mapping plant ecological groups and for our digital elevation model (DEM). Ordination analysis was performed using DCA to determine the floristic composition of plant ecological groups and samples. To investigate the relationship between vegetation and soil characteristics, soil samples were selected from both organic horizons (0 to 7 cm) and mineral layers (7 to 25 cm). Soil characteristics such as texture, lime, and moisture, as well as pH, EC, N, P, C and KOH were included for analysis by the PCA method. The results showed that the vegetation distribution pattern was primarily related to soil characteristics and elevation. Additionally, the results revealed that the regeneration, establishment, growth, and sustainability of each plant species are dependent on the unique environmental conditions of soil characteristics and physiological factors.

Key words: Forest, soil, establishment, ordination, plant group.

INTRODUCTION

An ecosystem includes both living organisms and the nonliving elements in a set environment. Plants are only one living component of an ecosystem, yet play a vital role in the lives of other organisms as primary producers. Plants are essential in maintaining an ecosystem's ecological balance, and their destruction disrupts the delicate balance between diverse parts. (Zahedi, 1998).Phytosociology highlight a high correlation between plant type and environmental conditions (Asri, 1994 and Poore, 1954), enabling us to discover, the complicated relations of ecosystem parts by studying resources and environment. Plants of similar nature and ecological needs (niche) are associated with each other (Braun-Blanquet, 1983), creating plant ecological groups. Plant communities include one or more ecological groups (Khademi, 2009). TWINSPAN analysis, DCA, PCA were employed to understand relationships between soil

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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; PCA 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 physicochemical soil factors and plant species to determine the most effective factors of separating vegetation types. The aim of the research is to classify plant ecological groups and to study the relationship between vegetation changes and physiographic and soil characteristics. We also aim to identify, the effective edaphic and physiographic factors that influence the regeneration and distribution of each ecological group.

MATERIALS AND METHODS

The area of study was located in the Asalouyeh mountain forests of the Boushehr province, south of Iran (124 ha, 80 to 1200 m elevation, 24 to 26°C average temperature, and 240 to 390 mm average annual precipitation) and has general landscape as semi-Mediterranean open forest with divers range of grass and woody species (Figures 1, 2, 3). For sampling, permanent square plots were delineated by a systematic-random grid. The grid size was 100 m (parallel to elevation contour) and 50 m (perpendicular to elevation contour), and the point of axes merger was selected as the plot center. Plot size was 256 m2, as determined by the "minimal area" (nested plots) method. According to the area and grid size, 248 permanent grids were used as the study area, in which the presence, absence, and abundance factor of vegetation was assessed via the Braun-Blanquet and Van Der Maarel cover-abundance scale (Table 1). Vegetation coverage was studied through clustering analysis with the TWINSPAN program (Hill, 1979). To arrange and analyze plants and sample plots, we employ the DCA method, which associates similar variables, species and sites (sample plots). 63 plots were selected for soil sampling from a less than 75% Sorensen index score for determining soil sampling origins. Biserial correlation coefficient was used for determining correlation between physiographic factors and vegetation cover changes. For the general investigation of soil characteristics (color, horizon size, roots, etc), we selected 20 profile points. We carried out soil samplings from two horizons (0 to 7 and 7 to 25 cm). Soil characteristics including texture, lime content, moisture, pH, EC, N, P, C and KOH were considered and used for analysis by the method. Geographic information system (GIS) and a digital elevation model (DEM) were used for mapping plant ecological groups.

RESULTS

The indicator species within identified groups as well as plot numbers for each are presented in Figure 4. They are reported here as follows: In Group 1 (with 62 plots), indicator species were Ebenus stellata and Rhamnus cathartica. In Group 2 (with 50 plots), the indicator species were Zataria multiflora, Pistacia atlantica, Pistacia khinjuk, Anvillea garcini, and Dodonea viscose. Group 3 (with 46 plots) was composed of four indicator species: Chardinia xeranthemoides, Ephedra pachyclada, Echinops ritrodes and Anthemis brachystephana. Group 4 (with 90 plots) indicator species were Prosopis spicigera, Astragalus eriostylus, Salsola drummondii, Capparis cartilaginea and Gymnocarpus decander. Similarity between ecological groups was assessed through the Sorenson index (Table 2). To distinguish the plots of each group, a map of ecological groups is shown in Figure 5.

The map of physiographic factors (aspect, slope, elevation) was generated from the digital elevation model (DEM). These three maps, representative of these three physiographic variables, were also correlated with ecological grouping map. The optimal classification degrees for physiographic factors (Figures 6, 7 and 8) were determined. Biserial correlation coefficient showed that elevation factors have high correlation (> 90%) with vegetation cover changes, while slope (< 30%) and aspect factors (< 5%) show low correlation values. Additionally, a combined map of vegetation cover and elevation was generated. This map includes units that show ecological group positioning relative to latitudinal changes of the study area (Figure 9).

DCA analysis showed place position of plant species, thus associating plant species that exhibit high similarity (Figure 10). Moreover, PCA analysis results uncovered the relationship between vegetation cover changes (ecological groups), soil characteristics and physiographic factors (Figures 11 and 12).

DISCUSSION

Our results show that the first grouping of plants starts from 600 m above sea level up upper altitude boundaries. The second group shows a distribution within 300 to 600 m (a.s.l). Group 3 begins from the foot of the mountain to 600 m above sea level. We thus determined that Group 3 is specifically adapted for the elevation range from the mountain foot to 300 m above sea level. Additionally, Groups 1 and 3 show a high tolerance to altitude (elevation) changes. Group 2 plants are only found in the 300 to 600 m range, indicative of limited tolerance. This class is common between Groups 2 and 3, highlighting joint properties between the species within these groups. The results show that vegetation cover changes hardly correlate with slope and aspect factors. However, Group 2 shows a special correlation with south and west directions and 30 to 70% slope. DCA analysis results reveal that species near to each other (P. khinjuk, Salvia reuterana and Fagonia indica) share considerable similarity. PCA results determined that establishment and growth of Group 1 species were grouped by sharing influences of elevation factors and C, moisture, and C:N

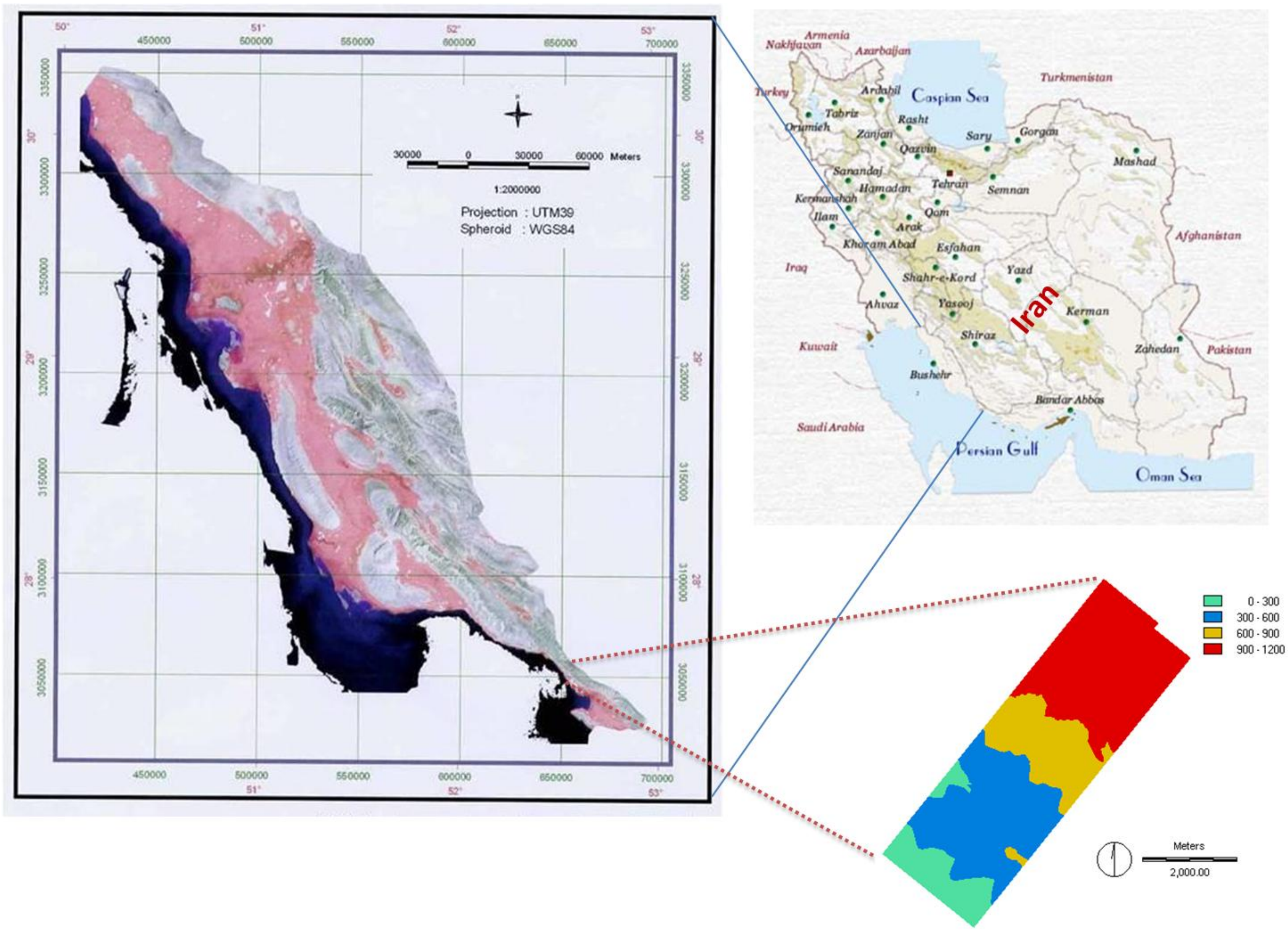

Figure 1. Map and location of the study area, geo-referenced map (left section) is Bushehr province in South West of Iran and classified map (study area) is located around city of Asalouyeh.

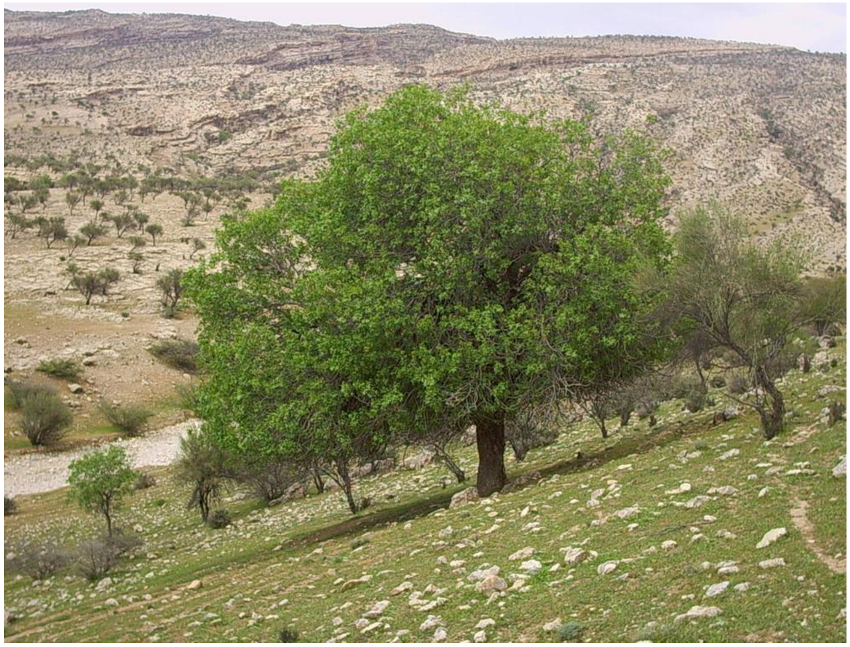

Figure 2. General landscape of the study area in growing season.

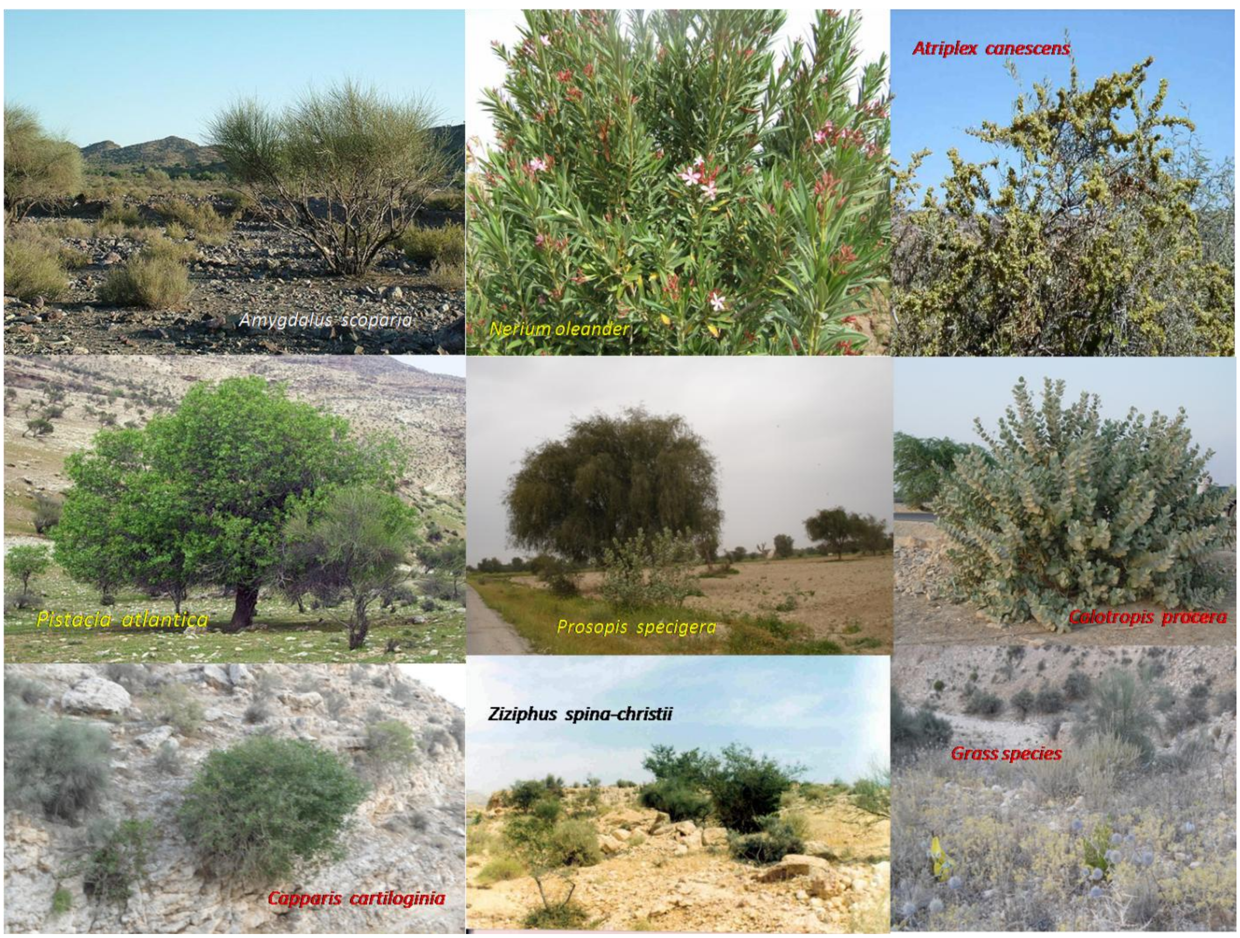

Figure 3. Photos of some main plant species in the area.

Table 1. Van Der Marel cover-abundance scale.

Code	Cut level	Cover range (%)	Average of cover range (%)
1	0	0 -1	0.5
2	1	1 - 2.5	1.75
3	2.5	2.5 - 5	3.75
4	5	5 - 12.5	8.75
5	12.5	12.5 - 25	18.75
6	25	25 - 50	37.5
7	50	50 - 75	62.5
8	75	75 - 100	87.5

The original purpose of this phytosociological technique was to describe and classify the plant communities based on floristic composition.

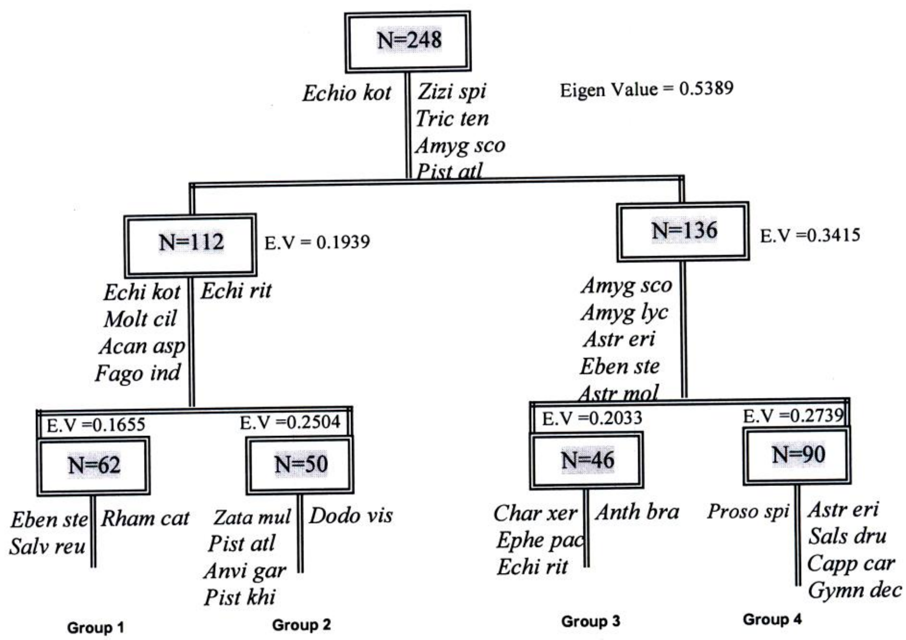

Figure 4. Indicator species within plant ecological groups; vegetation cover analysis was carried out in 7 divisions and 4 ecological groups were recognized. The Eigen value was not significant beyond these four groups.

Table 2. Sorenson index (%) between plant ecological groups.

Group number	1	2	3	4
1	-	96	57	38
2	-	-	62	44
3	-	-	-	77
4	-	-	-	-

Excess of the Sorenson index between Groups 1 and 2 underlines high similarity, which we identify with only Group 1.

ratio n both horizons, lay in the shallow horizon, and clay in second horizon. Group 2 species associated under effects of slope factor, sand and lime in both horizons.

Distribution and growth of Group 3 species associated mainly under effects of soil phosphate levels, pH, EC in the mineral part of soil (horizon b), and sodium in shallow

Figure 5. Map of ecological groups; location of each plant ecological groups in the area from the foot of the mountain up to upper altitude boundaries.

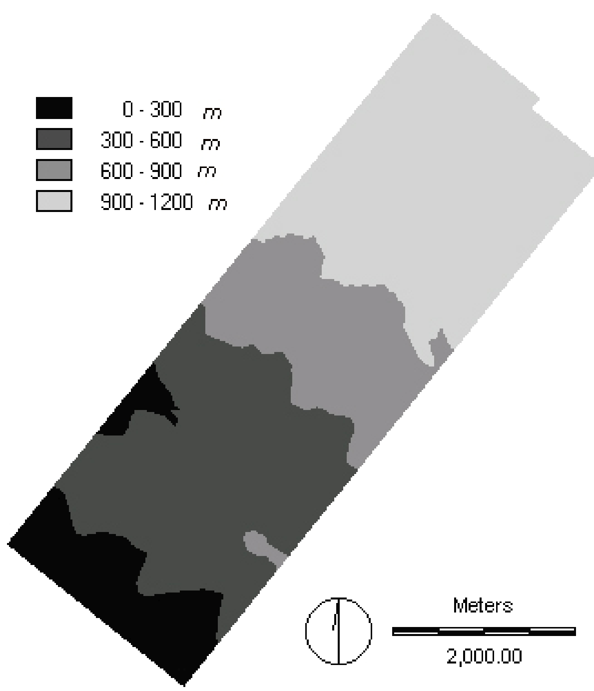

Figure 6. Hypsometric map of the study area; this map categorized on four classes - black color is foot of the mountain and white grey color is more than 900 m above sea level.

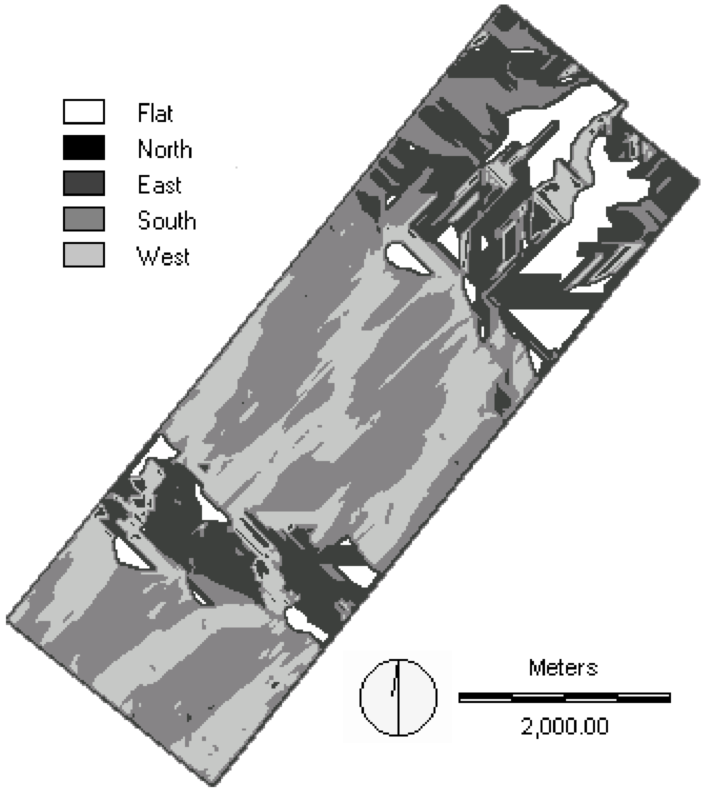

Figure 7. Aspects map of the study area; classified with five main aspects.

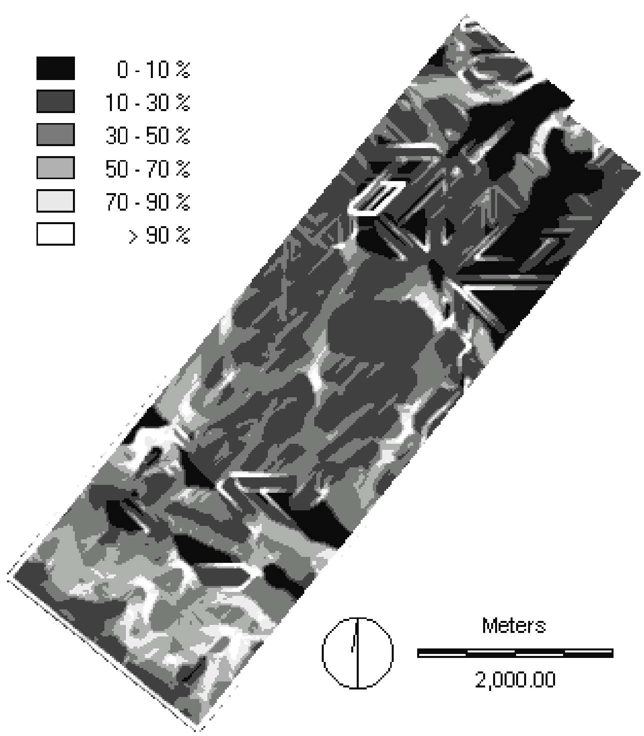

Figure 8. Slope map of the study area; classified on six levels in relation to study area conditions.

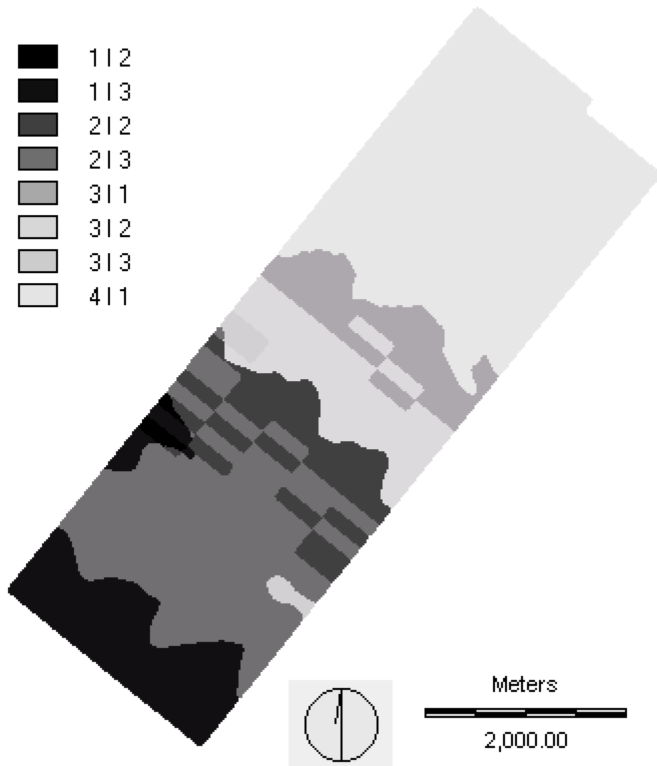

Figure 9. Combined map of vegetation cover and altitude from sea level; left hand numbers are classes of altitude and right hands are group numbers.

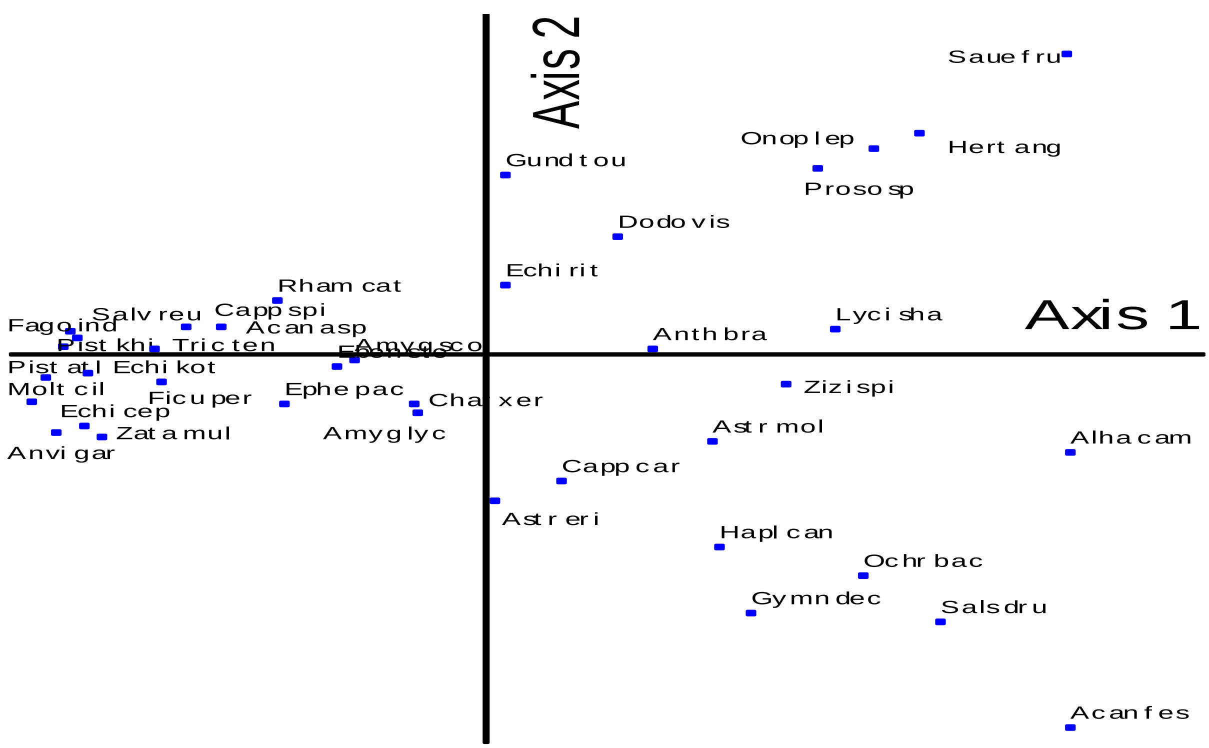

Figure 10. Result of DCA analysis; place position of each plant species identified in relation to first and second axis.

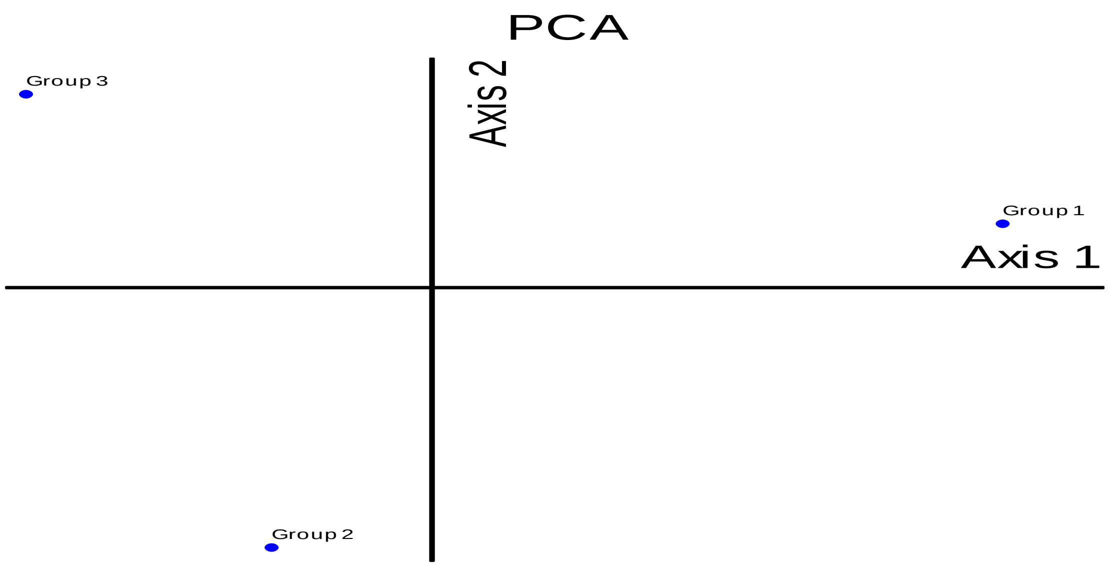

Figure 11. PCA analysis of plant ecological groups with regard to soil properties and physiographic factors, each group show positive or negative characteristics of first and second axis.

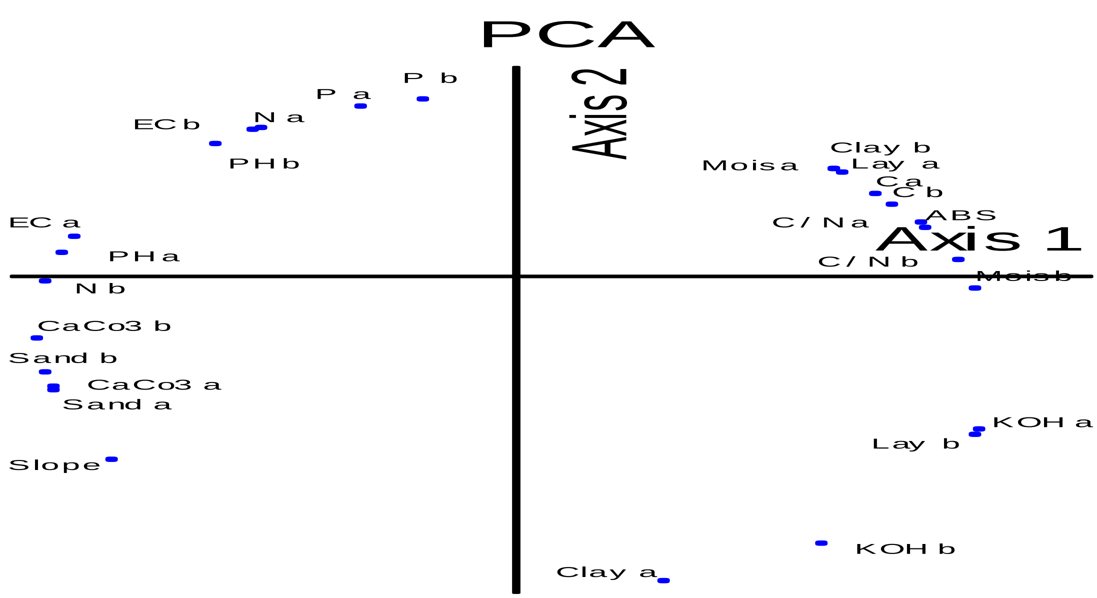

Figure 12. Position of soil properties and physiographic factors in plant ecological groups in relation to positive or negative parts of the axis.

soil, moreover, pH and EC in the first section of soil (horizon a) showed less of an effect on vegetation changes in Group 3 species. Our results highlight that the regeneration, establishment, growth, sustainability of each plant species are related to the special conditions of soil characteristics and physiological factors; thus, each species requires, special environmental conditions (physiographic factors and soil characteristics) to flourish. PCA analysis determined that the location of plant groups in the herbaceous layer (3 plant groups through TWINSPAN analysis), relative to the first and second axes of independent variables of soil and physiographic factors, show considerable variability. Groups 1 and 3 differ, showing properties in the positive and negative parts of the first axis, respectively. Group 2, however, exhibits properties in the positive half of the second axis. Results pertaining to the herbaceous layer from DCA analysis show that species in Group 1 are included based on coverage percent and quantity. These include *Agropyron pectinform*, *Centaurea bruguierena*, *Hyparhenia* *hirta* and *Cripsis schoenoides*, which conform to soil and physiographic properties of the right side of the first axis. Surveying the PCA analysis for the herbaceous layer indicates that the middle, right portion of the first axis placed soil variables, such as Clay a and b, to indicate physical properties of soil in horizons A and B. In fact, these species need wet soil, and show distributions in situations where there are higher contents of clay in soil, allowing ample preservation of moisture. Indicator species in sample plots of Group 2, including Bromus danthoniae and Paronychia arabica, cluster within positive properties of the second axis. The results of PCA analysis also show that soil and physiographic variables including C/N a, C/N b, C a, C b, pH a, PH b, Clay a, P a, P b, and N a N b form a group that shows properties to the right of the first axis, exhibits soil fertility properties in both horizons A and B, and shows physical properties of soil in horizon A. In the sample plots of Group 3, indicator species include *Tragus recemosus* and *Schismus arabicus*, which mirror positive properties of the second axis and negative properties of the first axis. Our results further show that altitude (ABS) indicates positive properties of the second axis and negative properties of the first axis. Thus, this group is exclusively influenced by changes in altitude. In the sample plots of Group 4, indicator species include *Stipa capensis*, *Poa sinaica* and *Veronica acrotheca*. These species show negative properties in the first axis, and notably, is the opposite of Group 1 in soil and physiographic properties. This observation remained consistent in all regions and on different soil.

In the sample plots of the fifth group, indicator species include *Nepeta glomerulosa, Parapholin incurva, Calendula persica, Aizoon canariense* and *Cleome oxypetala*. Group 5 clusters to properties that show as negative on the first axis and axes. The results of PCA analysis for the herbaceous layer show that these species are affected by the potassium hydroxide variable in both KOH a and b layers. The 6th group, including Vulpa myuros, Biebersteinia multifida and Descurainia sophia, associate with positive properties of the first axis and negative properties of the second axis. They are, thus, shown to be influenced by a combination of soil variables (Mois b, Mois a, Lay b, Sand b, Sand a) and soil lime parameter ($CaCO_3$ a and $CaCO_3$ b) and physiographic properties (slope). Results of PCA analysis of tree layers demonstrate that the location of plant groups, (derived from analysis of TWINSPAN) in the tree and small tree layer show significant variability with their relation to the first and second axes of independent, physiographic soil variables. The first and second groups are opposite, while the third group shows positive properties on the second axis and negative properties on the first axis. Classification from DCA analysis regarding sample plots and plant species in the tree and shrub layer showed that for the first group consists of the following indicator species: *Prosopis specigera, Dodona* viscosa, *E. ritrodes*, *Gundelia tournefortii, Saueda fruticosa, Onopordon leptolepis* and *Hertia angustifolia*.

Results of PCA analysis for this layer show that soil fertility (C a, C b, C/N a) and, physical properties of the soil (Lay a, Clay b, Mois a) were important for this group's survival. For sample plots in the second group, indicator species were P. atlantica, Amygdalus scoparia, Z. multiflora, *Anvelia garcini* and *E. stellata*. According to PCA results for this layer, soil fertility properties (EC a, pH a, N b) were found to be important. Species present in areas of nitrogen-rich soil have balanced physicochemical properties. For sample plots in the third grouping, indicator species included *C. cartilaginea* and *A. eriostylus*. PCA results show that clay in the upper horizon of soil (Clay a) is an establishing factor for this group, and like the herbaceous layer, these members have direct contact with moisture in topsoil in sample plots of the fourth group, indicator species were *Alhaji cameleorum*, *Salsola dromundi* and *Astragalus mollis*. PCA results attributed a combination of physical and fertility of soil properties to group these species. Fifth group sample plot indicator species include Ziziphusspina-christii, *A. eriostylus*, *Lycium shawi* and *A. brachystephana*. According to PCA analysis in this layer, the properties of subsurface soil horizons (C/N b and Mois b) influence group formation. Additionally, the high ratio of carbon to nitrogen shows that this mineral-rich soil plays a factor in group classification. This group mostly flourishes on valley surfaces, nether land, and relatively flat areas between hills that are of sufficient moisture and rich in sediment via water erosion.

The results regarding the moisture effect seem consistent with those of Veen and Molnar (2001), and soil fertility data match with results from Isaac (2006) and Hardtle and Muler (2004). Rostami (2007) and Khademi (2009) attributed elevation to poignantly affect plant species distribution. The study, as presented, confirm their hypothesis. Rostami (2007) also claimed that slope plays a role in distribution, and a study by Veen and Molnar (2001) showed that physicochemical factors help establish plant species into groups. Rashvand (2001) showed the effect of environmental factors in grouping plant species in the Boushehr province. The results are also consistent with studies. of Ahmadi (1986), Cardona (1998), De Boer(1992), Epron (1999), Fu(2004), Johnston (1992), Kassnacht (1997), Laurance (1999), Pastor (2004), Rachhpal (2005) and Smolander (2002).

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