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Evaluating the Classical Statistical Methods and Gradient Analysis of Soil-Vegetative Cover Interrelationships (Case Study: Steppe Pastures in Arsanjan County-Fars Province)

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Abstract

The vegetative cover well-establishment subject to matrix governance is inter alia the most important environmental factors. Gaining an insight over the entire factors and comprehending their interrelationships with the quantitative attributes of the vegetative cover can be done through classical statistical methods. But, the existence of some relationships in the hidden structure of the environmental factors render classical statistical methods inefficient and unable to accurately demonstrate these collateral relationships. Therefore, the use of gradient analysis can precisely reveal the hidden structure and then the authentic ecological grouping of the plant species can follows. Based thereon, the most important factors associated with the soil were identified to determine the ecological plant groups inside and outside a protected area both of which featuring similar topographical and climatic conditions. In each area, the measurements of canopy percentage as well as the density and frequency of the plant species based on random-systematic sampling method via placement of 5 transects, 50 meters in length, and placement of 10 quadrats, 1 square meter in area, based on antenna method were carried out so as to better exploit the appearances of the pasture surface. Moreover, the soil samples were taken according to the boundary-layer separation horizons and the type of the extant plants considering the active rooting region from two depth ranges of 0-10 cm and 10-50 cm in a completely systematic manner of the beginning, middle and ending sections of every transect. The regression analysis results indicated that, out of the 6 ecological plant groups from both of the studied areas, there is a relationship between Amygdalus lycioides, Acantholium festuacemum, Artemisia sieberi and stipa barbata and the twelvefold soil variable based on classical statistical methods but no particular behavior was evidenced in the classical statistical methods regarding the two species of Convolvulus acanthocaladus and Ebenus stellata. But, the utilization of PCA and CCA methods and drawing of raster graphs and making of classifications finally led to the identification of the soil factors influencing the establishment of these two species in both inside and outside the conserved area.

Keywords

Gradient Analysis, Protected or Conserved Area, Soil Characteristics, PCA, CCA

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1. Introduction

The relationships between the ecological factors should be well perceived in the natural ecosystems so as to be able to appropriately manage the pasture and rangeland ecosystems. According to the importance of the vegetative cover as the key factor of the pasture ecosystems and considering the

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involvement of the environmental factors in the determination and change of their composition and structure, it is necessary to recognize the most important environmental factors influencing the establishment and the scattering of plant communities. In fact, these factors provide for the establishment of various plant species in the rangelands and pastures. Also, knowing that there is a close relationship between the ecosystem components and that the soil is fully subjected to the climatic factors, living organisms, topography, mother rock and time, the discussions become more connected to the soil-vegetative cover interrelationships [16]. Keeping it in mind that the investigation of the ecological plant groups belonging to conserved areas and otherwise is largely feasible via taking the environmental factors, especially the soil, into account, the classical statistical methods can be utilized to perform regression analyses and unravel the relationships' being statistically significant or not in 95% and 99% confidence level so as to figure out the effectiveness of the soil-related variables on the vegetative cover establishment. But, the presence of some variables featuring hidden structures degrades the accuracy of the classical statistical methods that are mostly incapable of revealing these hidden structures so the task can be assigned to gradient analysis methods in such cases [16]. Thus, the present study adopts an approach to determine the index plant species residing in rangelands inside and outside the specified protected area to, finally, separate the ecological plant species based on vegetative cover variables and soil as well as investigation of the most important soil-related factors influencing the vegetative cover using the statistical classical and non-classical methods. There are numerous studies carried out both inside and outside the country in line with the present study subject matter. [5]. studied the mutual relationships of the soil's physical and chemical characteristics with the dominant rangeland plant species in Mehr-e-Zamin region, Qom Province. Their results indicated that the various soil parameters do not exert identical effects on the plant species and the canopy, amongst the various studied soil-related factors, is maximally correlated with two factors, namely potassium level and horizon thickness rates, and minimally associated with electrical conductivity [1, 7]. dealt with the study of the relationship between the climatic factors, topographic and edaphic factors with the vegetative cover in the mountainous rangelands in Rinne. Their results indicated that the environmental factors of the region have a great effect on the vegetative cover and the soil's physical and chemical characteristics inter alia the various factors exert the highest influence on the region's plant communiteis [3]. Investigated the ecological factors influencing the scattering of the various almond species in Ilam Province. The study results indicated that Amygdalus lycioides and wild almond amygdalus scoparia species reside in four temperate and dry, semiarid and temperate, semiarid and cold and subhumid and cold climatic conditions, and Amygdalus orientalis species are present in two subhumid and cold climates and on higher elevations [4]. [17]. dealt with the investigation of the close relationships between several plant species characteristic of dry regions with some of the various environmental and soil-related factors and determined the most important factors influencing their scattering in a part of Shahriyar's Chaharbaq pastures. His study results indicated that the most important factors influencing the region's scattering of vegetative cover are soil texture, salinity and minerals' percentage, effective soil depth, potassium and nitrogen levels [7]. [20]. applied the geographical information system to investigate the relationship between the plant communities and the physical factors in Chorat sub-basin from Telar watershed in the northern section of Alborz mountain range. The study results indicated that the climatic factors influence the plant types and biological forms and, in the meanwhile, the rangeland plant types are sensitive to the soil factors so the soil-related variables are to be considered as the most important factors behind the region's vegetative cover scattering [17]. [9]. evaluated the relationship between the soil's chemical and physical characteristics with some of Sabzevar region's index plants. The study results indicated that there is a significant relationship between the soil characteristics and the vegetative cover percentage of the various plant species but the correlations between them vary depending on the plant species [10]. Studied the most important environmental factors influencing the scattering of wormwood in steppe pastures of Fars Province. The results of their study showed that the highest environmental factors' occurrence likelihood in respect to Artemisia sieberi, in an elevation gradient of 1900-2200 meter goes to phosphorus, acidity, presence of sand, elevation from sea level, as the preliminary factors, followed by the percentages of lime, gypsum and potassium, as the secondary factors; furthermore, the highest environmental factors' occurrence likelihood in respect to Artemisia aucheri, in an elevation gradient of 2200-2400 meter, belongs to sand, elevation from sea level, as the primary factors followed by the percentages of potassium and clay and the slope as the secondary factors [11]. [8]. studied the relationship between the vegetative cover and environmental factors in dry rangelands on calcareous soils of the eastern Slovakia. In the study, three substantial factors, topography, soil and biological factors were examined. The study results indicated that these three factors because separation in the plant types of the studied region in such a manner that inter alia all the studied factors the sun irradiation intensity, soil depth and slope play determinative roles [16]. Applied principal component analysis (PCA) and regression analysis to investigate the relationships between the plant communities and environmental factors of wetlands and their peripheral regions in the upper and lower sections of Tarim River in a study. Their study results indicated that the plant community distribution is directly correlated with moisture, minerals and organic constituents of the soil [20, 19]. investigated the correlations between the desert plant communities and the soil-related factors in the southern margin of Tongot's Gorban desert by taking advantage of hierarchical classification method and principal component analysis. The results of the PCA indicated that there is a special relationship between the soil-related factors and plant communities in such a way that pH, organic matter and soil salinity were found out as the most important factors bringing about changes in the soils of the various plant communities [19]. Yumin Yo et al (2008) evaluated the vegetative cover in connection with the ecological and geological factors in karstic regions in the southwestern parts of China through making use of conventional comparative analysis. Their results indicated that soil moisture and calcium carbonate play the greatest parts in the region's scattering of vegetative cover. They also expressed that the conventional comparative analysis is a powerful instrument for demonstrating the vegetative cover changes [18].

2. Method

The study region is located in the vicinity of Arsanjan County in a 120-km distance in the northeast of Shiraz and on the kilometer five of the Arsanjan-Sa'adatshahr road. The region is stretched on 53° 12′ 38″ and 29° 52′ 22″ to 53° 23′ 10″ and 29° 58′ 41″ geographical coordinates. Figure 1 illustrates the study region.

Based on Ambergeh method, the region was found having a semiarid and temperate climate featuring an average rainfall of 250 mm. The protected area is part of Arsanjan's Forestry Plan for conservation of Bonab Jungle. The foresaid region has been protected since 1975. Arsanjan's Forestry Plan has been implemented in line with conservation and reclamation of part of the almond and Persian turpentine tree jungles in Fars Province based on the instructions issued by the Organization of the Country's Jungles and Pastures. The region outside the protected area is situated on the left hand side of the trail road connecting Arsanjan to Sarpaniran and adjacent to the protected area both of which feature similar climatic and topographical characteristics. The region is in the midsection between the summer and winter pastures used by the nomads and traveling clans of Fars Province and a lot of domestic animals graze on the wooded and unwooded pastures [8]. To perform the study, there was made use of a randomized-systematic sampling method with five transects, 50 meter in area, along which there were selected ten one-meter quadrats for both of the protected area and the region at its side. The quantitative vegetative cover variables measured herein included the percentage of land cover as well as the frequency and density of the plants along transects and inside the quadrats. To carry out edaphological studies in every quadrat according to the boundary-layer separation horizons and the type of the extant plants and considering the active rooting region, samples were taken from two depths of 0-10 Cm and 10-50 Cm and then the samples were subjected to physical and chemical examinations. The analysis of the vegetative cover data and the soil data was conducted in PC-Ord software as follows: firstly, the data pertaining to density and frequency were subjected to preliminary preparation and then inserted to Excel and PC-Ord environments in separate for each region. DE trended correspondence analysis (DCA) method was applied to delineate raster graphs and Two-Way Indicator Species Analysis (TWINSPAN) was employed to classify the vegetative cover. According to the weak eigenvalues obtained for the canopy, there was made use of frequency and density data based on DCA method as well as the frequency data in the classification method. The data were inserted in the software environments and then underwent analysis. Also, there was made use of correlation and regression analyses in order to determine the relationships between the soil variables and vegetative cover.

3. Result

Protected Area:

The results obtained from the investigation of the protected area's percentage of vegetative cover indicated that Convolvulus acanthocaladus and Amygdalus lycioides, respectively, account for 3.68% and 3.55% of the vegetative cover. The foresaid species along with Artemisia sieberi and Ebenus stellata were the dominant plant types of the region. The results of the frequency measurements indicated that Ebenus stellata and Lactoca orientalis account for 38% of the perennial plant species residing the region. The results of the investigations on the vegetative cover percentage outside the protected area showed that Convolvulus acanthocaladus and Ebenus stellata account for 6.24% and 3.06% of the prevalent vegetative cover of the region, respectively. Amongst the other plants coexisting the region Artemisia sieberi and amygdalus lyciodes can be pointed out. Table 1 presents the measurement results pertaining to vegetative cover of the plants both inside and outside the protected area. The results of the frequency measurement indicated that Convolvulus acanthocladus and wormwood (Artemisia sieberi) account for 24% and 22% of the vegetative cover, respectively.

Table 1. Measuring the percentages of land cover variables in the protected area and unprotected area.

Measured variable	Protected area	Unprotected area
Canopy	48.75	21.06
Humus	13.89	4.36
Pebble and detritus	1	1.56
Bare soil	37.25	73.02

Also, the diagram (1) depicts the comparison of the measured variables in both inside and outside the protected area.

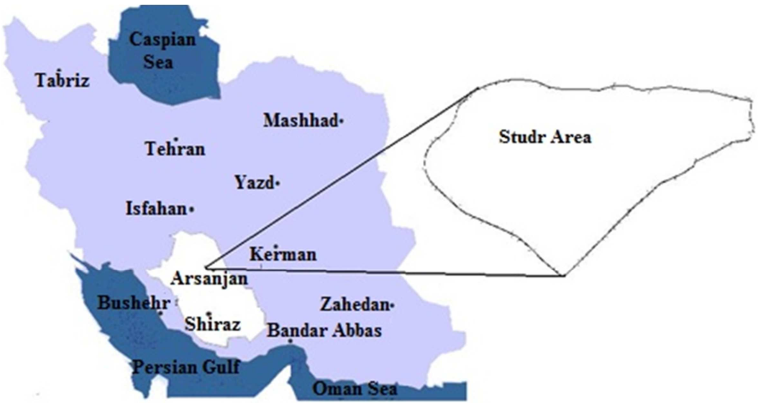

Figure 1. The study region's position.

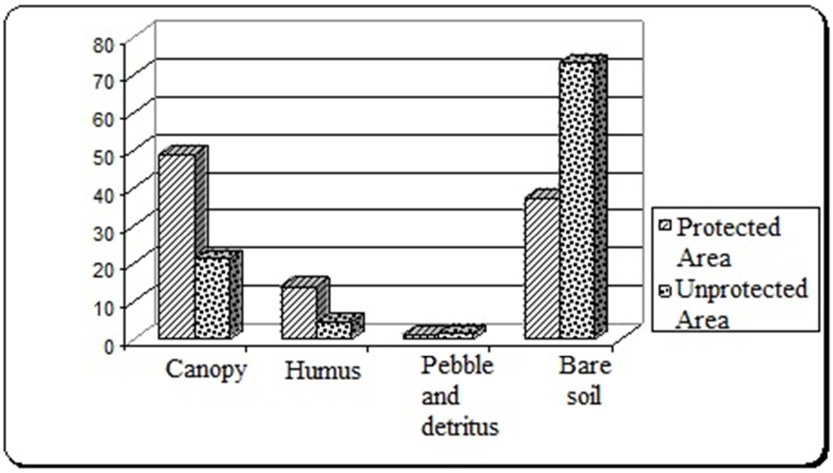

Figure 2. Measuring the land cover variables in the protected and unprotected areas.

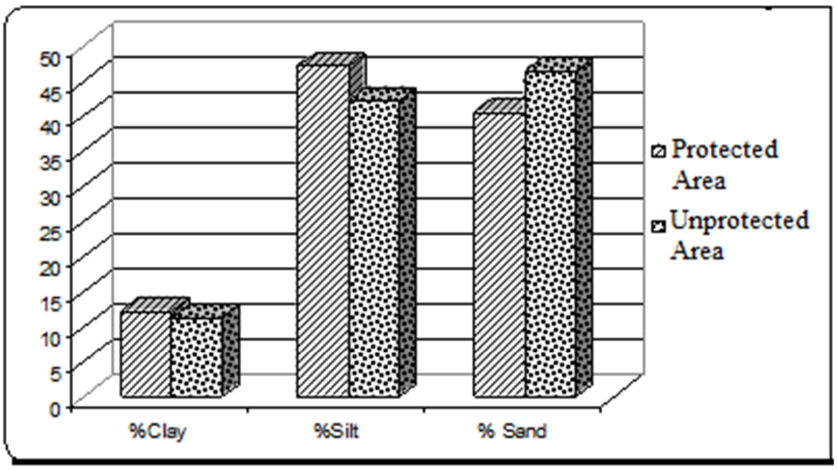

Figure 3. Comparing the soil texture components of the protected and unprotected areas.

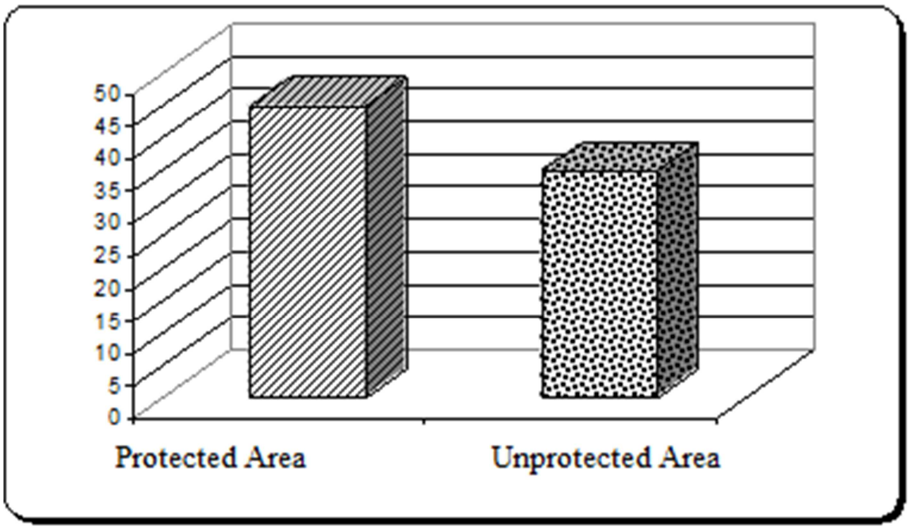

Figure 4. Comparing the lime factors in protected and unprotected areas.

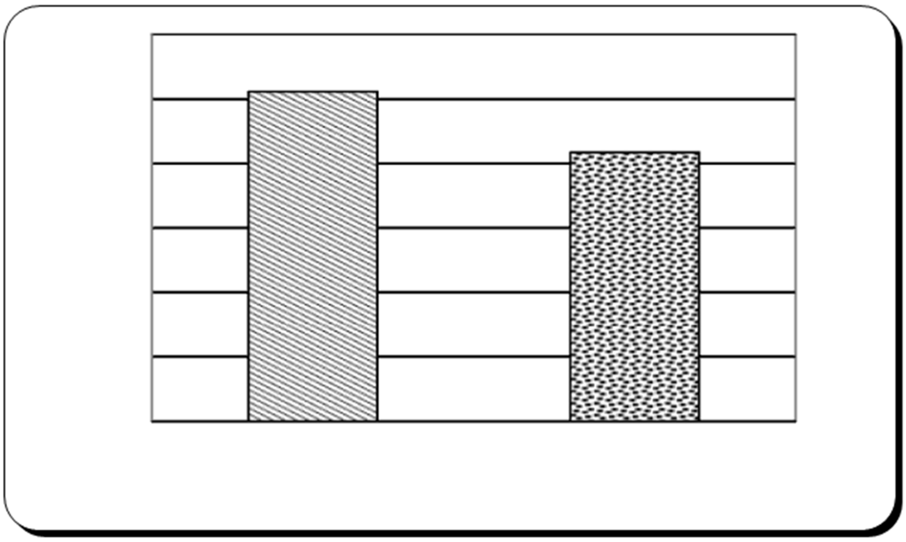

Figure 5. Comparing the gypsum factors in the protected and unprotected areas.

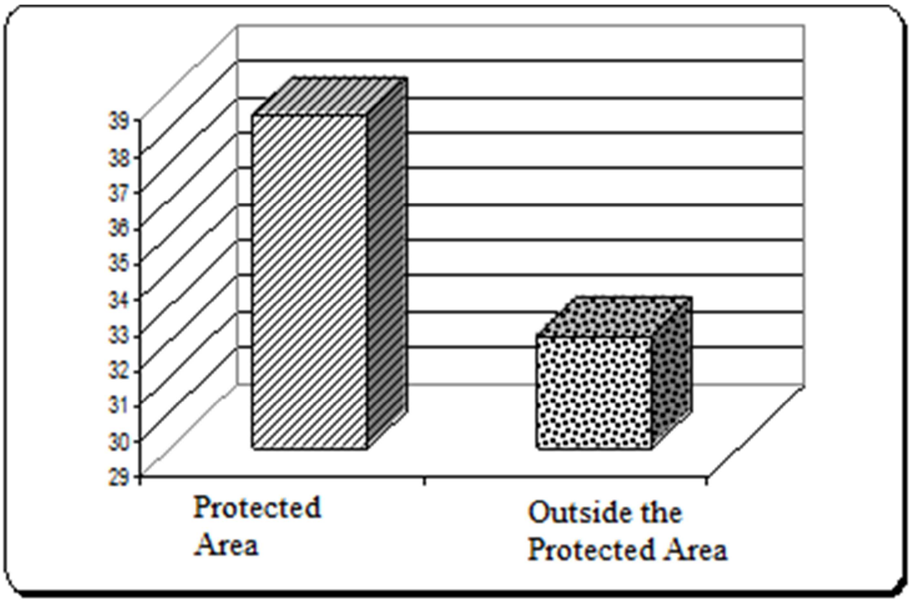

Figure 6. Comparing the basic saturation factor in protected area and unprotected area.

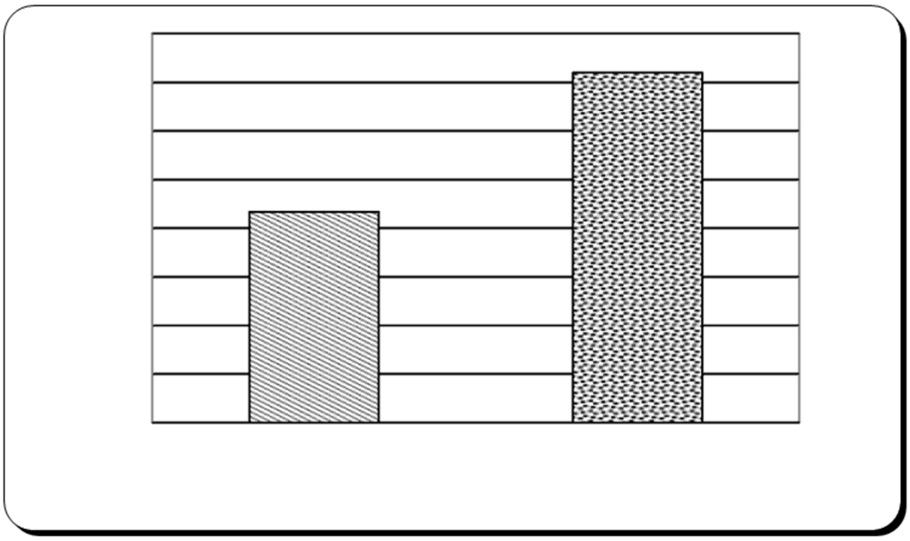

Figure 7. Comparing the organic carbon factor in the protected and unprotected areas.

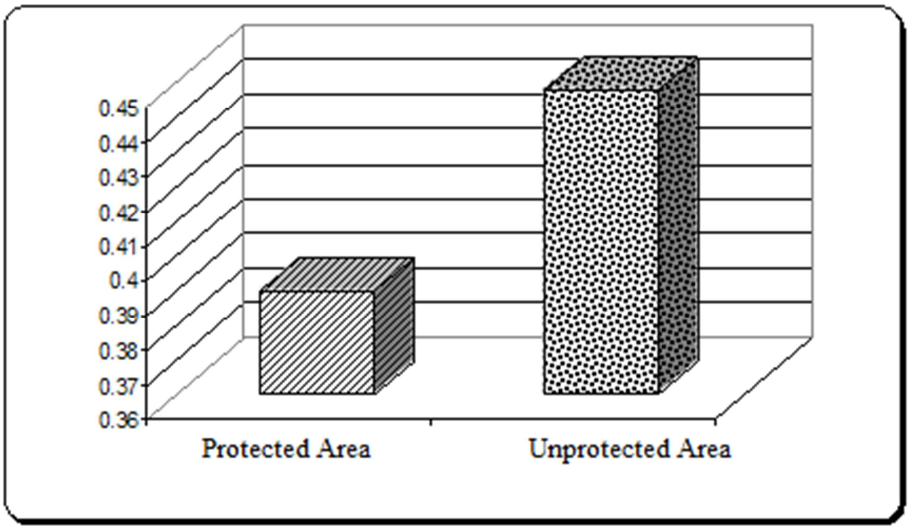

Figure 8. Comparing the electrical conductivity in the protected and unprotected areas.

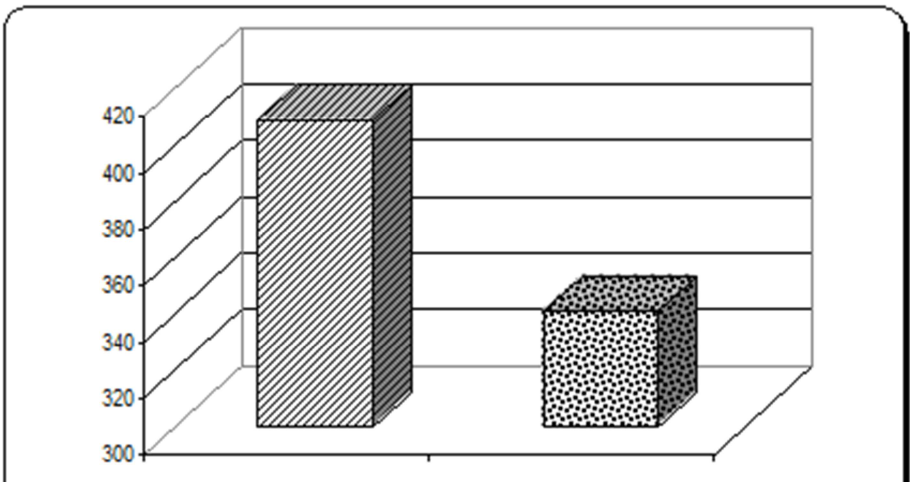

Figure 9. Comparing potassium factor in the protected and unprotected area.

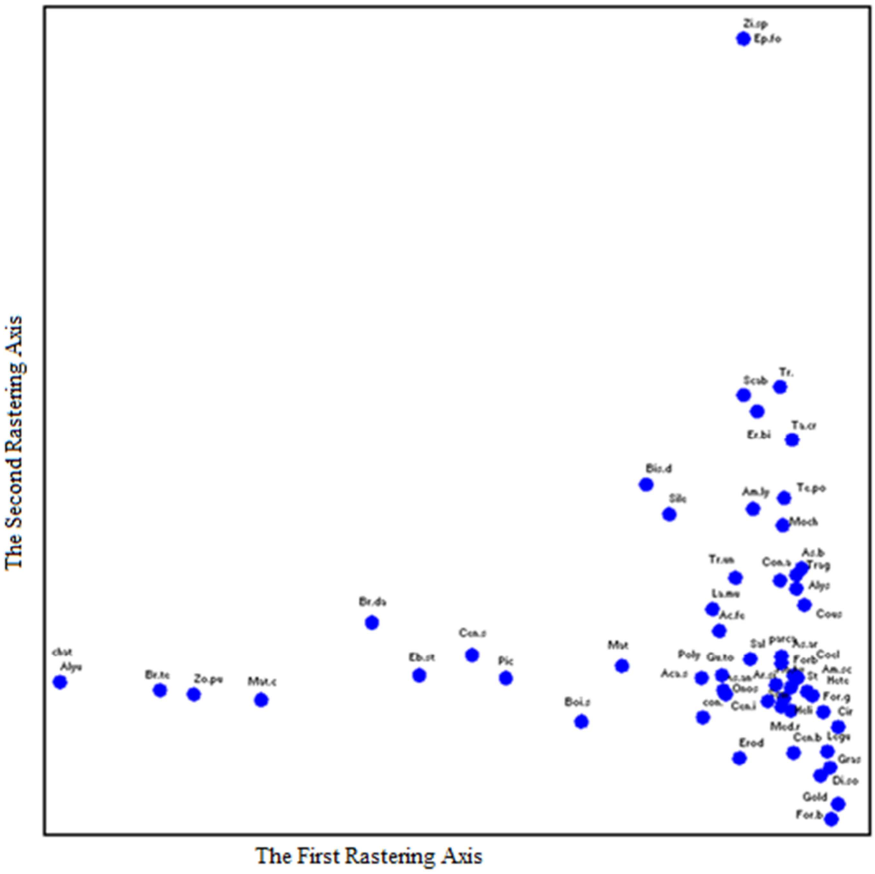

Figure 10. Preliminary rastering of the plant species based on PCA method.

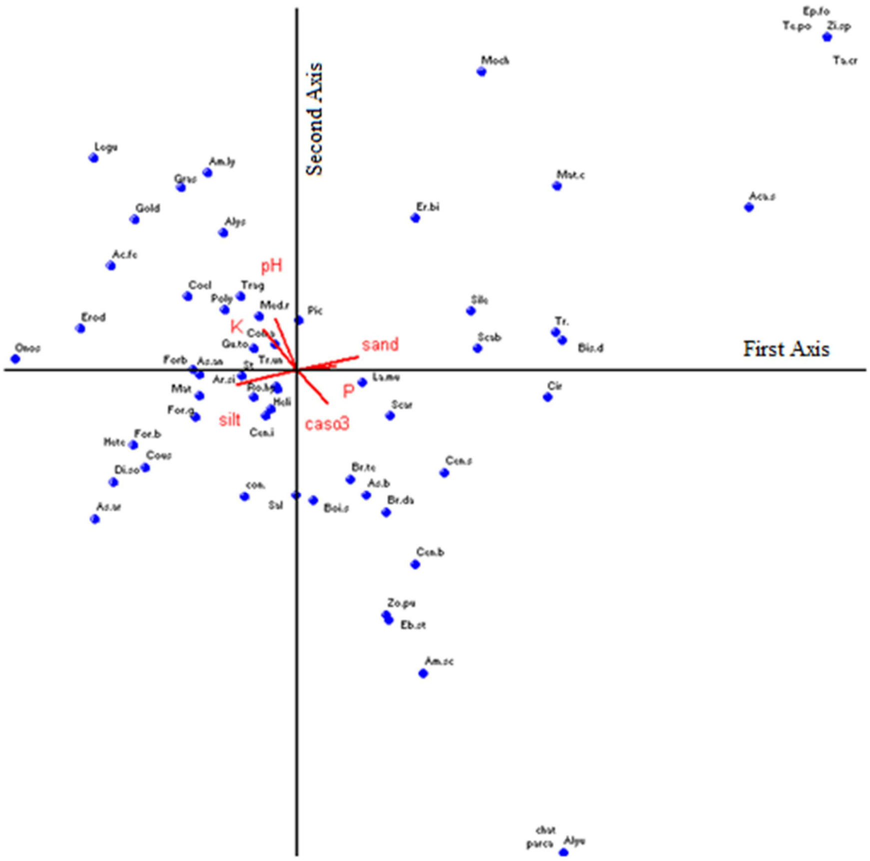

Figure 11. The results of Monte Carlo test based on CCA method.

A) The Measurement Results of Soil's Physical and Chemical Properties:

The measurement results of the soil's physical and chemical characteristics are given in table 2 and displayed in diagrams (3), (4), (5) and (6).

Table 2. Comparing the measurements of the physical and chemical characteristics of soil in protected and unprotected areas.

Soil characteristics	Protected area	Unprotected area
Sand percentage	46.5	40.7
Silt percentage	42.2	47.1
Clay percentage	11.3	12.3
Lime percentage	45.1	35
Gypsum percentage	1.023	0.834
Basic saturation percentage	38.4	32.2
Organic carbon percentage	0.434	0.72
Electrical conductivity	0.39	0.448
Nitrogen percentage	0.043	0.071
Phosphorus percentage	15	17.73
Potassium percentage	409.2	341.2

B) The Results of Correlation Test between Canopy Percentage and Soil Variables:

The correlation test results of the relationship between the soil variables and canopy are summarized in separate in table 3.

Table 3. Correlation coefficients of the soil variables with the canopy percentage of the indicator species of the protected and unprotected areas.

Indicator genus	Amygdalus	Ebenus	Acantholimon	Artemisia	Stipa	Convolvolus
$Caso_4$%						
Protected area	0.337	-0.243	0.717 ***	0.165	-0.249	-0.373
Unprotected area	0.664 **	-0.144	0.504	-0.451	-0.779	-0.166
$Caco_3$%						
Protected area	0.007	0.057	0.314	-0.298	0.781***	-0.036
Unprotected area	0.434	0.081	0.667**	-0.063	0.129	-0.241
Clay%						
Protected area	0.352	0.043	-0.374	0.328	0.432 *	0.020
Unprotected area	-0.371	0.140	-0.413	0.151	0.394	-0.250
Silt%						
Protected area	0.204	0.257	0.178	0.433 *	0.247	-0.127
Unprotected area	-0.521	0.473	0.042	0.473	0.429	0.007
Sand%						
Protected area	-0.575 *	-0.259	0.005	-0.551 **	-0.426 *	0.109
Unprotected area	0.626 *	-0.506	0.090	-0.510	-0.544	0.073
N%						
Protected area	-0.348	-0168	-0.312	-0.191	-0.145	0.099
Unprotected area	0.028	-0.256	-0.348	-0.156	-0.186	0.015
P%						
Protected area	-0.242	-0.209	-0.265	0.241	-0.251	0.074
Unprotected area	-0.489	-0.259	-0.508	0.641 **	-0.204	0.057
K%						
Protected area	-0.085	-0.171	-0.501 **	0.557 **	0.294	-0.003
Unprotected area	-0.621	-0.216	-0.597 *	0.802 ***	-0.016	-0.122
OC%						
Protected area	-0.125	-0.161	-0.304	-0.180	0.152	0.096
Unprotected area	0.021	-0.253	-0.352	-0.152	-0.184	0.018
SP%						
Protected area	0.054	0.196	-0.193	0.443 *	0.498 **	-0.125
Unprotected area	-0.720 **	0.403	-0.405	0.478	0.569 *	-0.159
EC						
Protected area	-0.190	-0.330	-0.268	.0.341	-0.277	0.088
Unprotected area	-0.324	-0.470	-0.433	0.677 **	-0.396	0.026
pH						
Protected area	0.229	-0.047	0.332	0.160	0.106	-0.381 *
Unprotected area	-0.207	0.262	-0.184	-0.013	0.536	-0.340

C) The Regression Analysis Results and Regression Model Offering:

The regression results and regression model offering findings of the indicator species both inside and outside the protected area along with the twelvefold soil variable are tabulated in table 4.

Table 4. Regression equations.

Indicator species name	Regression equation	R^2
Amygdalus lycioides	$0.63Caco_3+0.22Caso_4+0.194clay+0.103Silt -0.21Sand-0.152 N-0.157 OC+0.069 K-0.119 P+0.01 SP-0.077 EC-0.097pH+1.788$	63%
Ebenus stellata	$0.275Caco_3+1.849Caso_4+3.729Clay+14.887Silt+20.043Sand-5.957 N+5.687 OC+0.524K+0.57P+2.928 SP-2.573EC-8.46pH$	81.3%
Acantholimon festucacemum	$0.516Caco_3+0.387Caso_4-0.281Clay-0.15Silt+0.279Sand-0.019\%N+\%OC-0.213\%K-0.053\%P-0.232\%SP+0.033EC-0.025pH+ 1.103$	51.6%
Artemisia sieberi	$-2.304Sand+1.123 K+0.927Caco_3+0.129Caso_4+0.174Clay-0.379Silt-0.152N-0.132OC-0.15P+0.221SP+0.155EC-0.053pH+1.181$	
Stipa barbata	$-2.694Caso_4-0.026Caco_3-0.038Clay-0.041Silt+0.086Sand-0.6N-0.083 OC-0.177 K-0.176 P-0.033 SP+0.2EC-0.242pH+4.42$	78.4%
Convolvulus acanthocladus	$91.891-0.689Caco_3-5.894Caso_4-5.204Clay-13.406Silt-15.955Sand+4.974 N-4.367 OC-2.943 K+1.55 P+1.009 SP+2.248EC-21.024pH$	

Also, the results of the direct gradient analysis aimed at the determination of the dominant ecological plant group in relation to the most important environmental factors were obtained by making use of PCA method in PC-Ord software environment. These results have been presented in Figure 10.

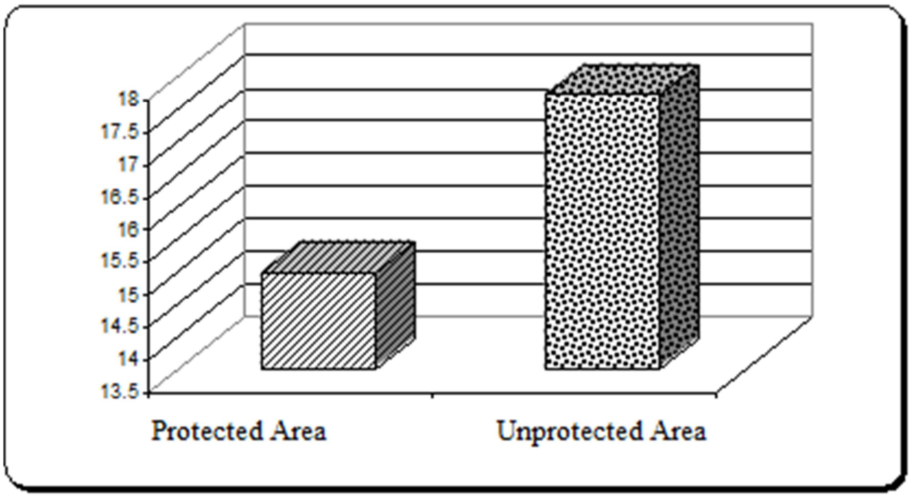

Figure 12. Comparing the phosphorus factor in protected and unprotected areas.

To perform the final grouping and verify the raster graphs based on PCA method using TWINSPAN classification method, the final ecological grouping was again evaluated. The results indicated that Acantholimon festuacemum and Ebenus Stellata, as a primary group, are two most dominant species living in the region; furthermore, Artemisia sieberi and Convolvulus acanthocladus were found in TWINSPAN outputs as not being left or right differentials but as species completely scattered as regional-level groups even in respect to annual species. In this grouping, Acantholimon and Amygdalus were obtained as right differential that is consistent with what was found based on PCA method. To determine the most important environmental factors influencing the formation and establishment of the major ecological groups of the region, CCA method and Monte Carlo test were employed. The results of these tests have been demonstrated in figure 11.

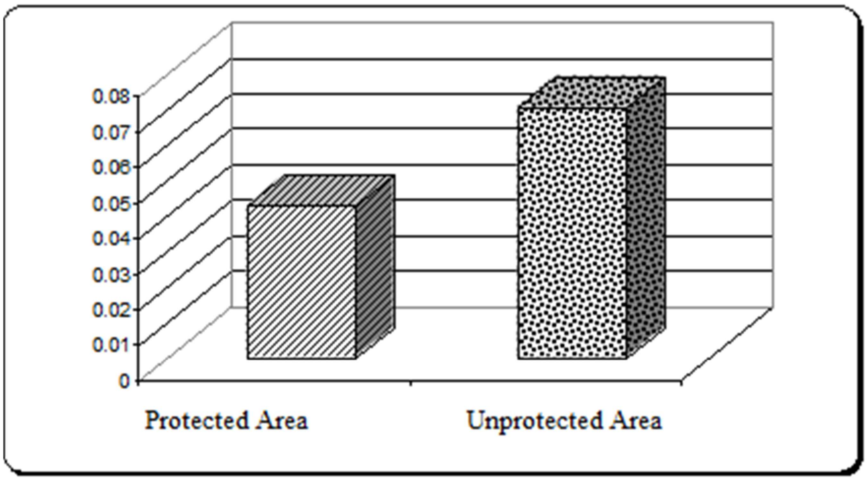

Figure 13. Comparing nitrogen factor in protected and unprotected areas.

4. Discussion

The study results indicated that there are 26 families, 79 genus and 109 species living as the flora constituents of the region. In spite of a multiple-year drought, the mean canopy percentage of the protected area was 48.75 which were 21.06% for the region adjacent to the protected area. Generally, the results of the vegetative cover quantitative characteristics measurements showed that Convolvolus acanthocladus and amygdalus lycioides in the protected area and Convolvolus acanthocladus and Ebenus stellata in the region at the side of the protected area are the major dominant species types. According to the history of the region that is amongst the last spots of Turanian Iran's dried forests, changes were found in the vegetative cover dynamics in the course of time in such a manner that amygdalus lycioides species have been previously present in the substrate of the Persian turpentine trees. But the ecological outcome stemming from the absence of these trees due to overexploitation led to the establishment of Ebenus Stellata in a vast area of the region. The results of the measured soil variables were reflective of the significant relationship between Amygdalus lycioides species presence and the percentage of gypsum resulting from the region's geological formations; in addition, there was not found any significant relationship between the species presence and the other soil-related variables. In the meantime, due to the occurrence of erosion in the region just outside the protected area, the resultant sand was found exerting a considerable effect in the establishment of the species in such a way that due to the existence of canopy and annual species in the protected area, especially during spring the humus resulting thereof acts as a protective layer and the active rooting of the plants causes the soil particle to disintegrate and finer rather than coarser particles will be formed accordingly. The same issue has made the sand percentage of the soil profile in the protected area be negatively associated with plant species which was found positive in the unprotected area. Due to the high presence of potassium in Iran's soil and its important role in plant nutrition, more scattering and diversity come about where this element is found in abundance. And, this same effect of potassium was well evidenced in the scattering of the wormwood species. [7] Introduces soil's content of potassium as one of the characteristics contributing to the larger fertility and scattering of the habitats of Artemisia species. Also, [20] mentions the amount of potassium existent in the soil as the characteristic of the soil in the habitats of Artemisia. And, [7] in his study enumerates the amount of potassium as one of the important characteristics of the soil where shrubs are more prevalent., as well, states that the high potassium to magnesium ratio is appropriate for the growth of shrubs while the low potassium to magnesium ratio is more auspicious for the growth of grasses. According to the high correlation found between potassium and Artemisia Sieberi prevalence, the present study results also showed that there is a positive relationship between the species scattering and the increase in potassium levels. There was not found any significant relationship between Ebenus Stellata and any of the soil parameters measured based on classical methods of correlation test and this might have been due to the hidden structure of the soil variables considering the classical statistical methods. The hidden structures were completely revealed in the gradient analyses in such a way that there was found a significant relationship between the phosphorus and gypsum percentages with special species growth in the protected area.

5. Conclusion

As for Convolvolus Acanthocladus, factors other than the twelvefold soil variables were found having an effect and this was documented in the gradient analysis the results of which indicated that the species is meaningfully correlated with the percentage of silt existent in the soil texture. Regarding Acantholimon festuacemum, the results indicated that there is a positive and intensively significant correlation between $Caso_4$ and the species in the protected area. In other words, the species scattering increases per every unit increase in gypsum level, whereas the same relationship was not found outside the protected area. The species was found positively correlated with $Caco_3$. The regression equation offered herein, as well, produced significant results for the soil's variable of $Caco_3$. The results of the correlation analysis indicated that there is a positive relationship between the soil moisture both inside and adjacent to the protected area with Stipa Brabata while a negative and highly significant relationship was evidenced between the species and lime in the protected area; but, the relationship did not hold outside the protected area. Generally, based on the results obtained from raster graphs and classification operation, it was found out that the dominance of the ecological groups Acantholimon and amygdalus is highly correlated with the soil acidity and potassium content; and, Artemisia and Convolvolus ecological group's prevalence is highly correlated with the silt percentage of the soil texture and, lastly, there was figured out a significant association between the dominance of Ebenus stellata species and the soils content percentage of phosphorus and gypsum. According to the identicalness of the vegetative cover data obtained in the regression and correlation tests, there was found an indirect difference between the results obtained thereof with the results of the gradient analysis. The nature of the regression analysis in terms of the elements constituting the equation is in such a way those equations were resulted according to the independence of soil variables and dependence of the plant canopies that cannot be used for introducing the most important soil variables so that the prevalent ecological groups can be identified.

The results of the present study are suggestive of high correlation between potassium and Artemisia Sieberi species prevalence whereas the indirect gradient analysis results are reflective of the correlation between soil's silt percentage and the foresaid species prevalence. In addition, it was found based on the indirect gradient analysis that there is a correlation between the ecological group composed of Amygdalus and Acantholimon with the acidity and potassium percentage and that it was found in the indirect gradient analysis (correlation and regression analysis) that there is a negative relationship between potassium and ecological group Acantholimon Festuacemum and the regression equation offered for both of the abovementioned species is indicative of the significant relationship between the two of them and the $Caco_3$ variable. Based on CCA method, it was found out that there is a correlation between Convolvolus acanthocladus with the soil's percentage of silt and this same finding was not confirmed in the correlation tests. Also, critical component analysis (CCA) indicated that the ecological group Ebenus Stellata is correlated with the percentages of phosphorus and gypsum while the indirect gradient analysis was not suggestive of any significant correlation between the foresaid species and any of the measured soil parameters. Moreover, the regression model designed herein for the general evaluation of Ebenus Stellata species establishment did not offer significant results. In addition, the results illustrated in figure 11 show that in the four coordinate spots, the most important soil variables influencing the prevalence rates of ecological groups Acantholimon and Amygdalus are acidity and potassium percentage which is reduced to silt percentage for the ecological group Artemisia and Convolvolus and, finally, the percentages of phosphorus and gypsum for the ecological group Ebenus Stellata.

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