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Original Article

The function of plant richness and diversity on eco-balancing of upland rangeland on Alborz Mountains (North of Iran)

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ABSTRACT

Ecological equilibrium of upland rangeland is guaranteed by the conserving of vegetation structures which save an ecosystem from erosion. A range ecosystem can be safe with good condition of plant diversity and richness as symbols of ecosystem balancing. In this research, therefore, two aspects of northwest and northeast rangland from the highest uplands of mountain watersheds in northern Alborz [Javaherdeh - Ramsar] of Iran were selected. Vegetation status of rangeland habitats and soil erosion has been evaluated in two types of shrubland and grassland by the Daubenmire and the PSIAC methods. In order to determine the influence of plant diversity and richness on soil erosion and rangeland conditions, the data has been analyzed using multi regression technique and the mean between the two habitats have been compared using the T-test method using the SPSS software. The results showed that both grassland and shrubland habitats have not only had poor conditions but also much soil erosion. The research findings have also shown that the plant diversity and richness in both types are significantly related to soil erosion and rangeland conditions. Some vegetation factors have affected both the habitat condition and soil erosion. It appears that the desirable rangeland conditions can be achieved by control of animal grazing which can then lead to the reduction of soil erosion with the help of vegetation canopy cover.

Key-words: *diversity, richness, ecological equilibrium, rangeland, grassland, shrubland, soil erosion, Alborz, Iran.*

INTRODUCTION

In Darwin's terms, the biodiversity of communities are due to niche diversification of the co-occurring species [10]. Some scientists also believe that diversity begets ecosystem stability [13-25-27-31-42]. Some researches have implied an ecosystem stability-diversity-production relationship [25], or the effects of species richness on ecosystem functioning [69], or relationships between diversity and productivity [Waide *et al*, 1999], and relationship between richness and net primary productivity [4]. It, however, may be there is a positive relationship between species and ecosystem stability [15-32-34-41-64-65], or a negative one [48-55-59] the knowledge of either can lead to a better managment of an ecosystem. Then it is important to distinguish habitat characteristics like habitat heterogeneity [8-19-21-49-60], species composition [70], latitudinal gradients [71] and steep slopes [68].

When an ecosystem exhibits an ecological equilibrium whereit normally incorporates all elements of the habitat like biotic [plant and animal] and abiotic [slope, altitude, aspect, and other abiotic factors] factors, plant diversity and richness – in biodiversity as a whole- are good indicators which determine the health of an ecosystem. It is being observed hat most of the researchers have focused on plant richness-diversity and the other ecosystem capacities; there is very little work that has been done on studying the relationship between plant diversity- richness and soil erosion that this research hints at. It is known that the loss of biodiversity [diversity and richness] on local [56], regional, and global scales have prompted scientists to ask whether these losses impair the ecosystem functions such as biomass production [18], litter decomposition [14-51-67], and resistance to invasion of non-natives plants [Crawley *et al*, 1999; Dukes, 2002]. Then the ecologists architect the ecosystem to sustainability use and maintenance of genetics references on the basis of fieldwork or modelling of ecosystem component e.g. biodiversity [62].

Habitat vegetation has been affected by two kinds of factors; biotic [animal] and abiotic [precipitation, altitude, slope and aspect] factors. The animal grazing or special overgrazing can change plant composition. [1] have implied the effect of intense sheep grazing on plant community in the Andes. [23] too, in his research, has shown that change in the composition of soil and plant species occurs due to high grazing pressure. overgrazing not only increases erosion [17-39] and loss of productivity [12-45], but has also been the cause of the decrease in plant diversity and richness through the decrease of soil moisture [75] and the removal of perennial palatability's species. Moderate grazing of habitats will give plants sufficient richness and diversity with good productivity [9-16-20-24-25-52-66-67] to keep animal husbandry in progress. It is important to realize that animal grazing should not be greatly performed in dry seasons. Grazing intensity at this period can remove perennial grasses [1] in the grassland habitat. We, then, need to study the grassland vegetation [37] to understand how to manage it. The nature of vegetation in shrubland is different as compared to the grassland. Shrub mounds have thick roots. [74] have shown that not only little run-off was probably generated by the intershrub areas that might counteract the negative effects of precipitation, but also, the number of species found on shrub mounds appeared to saturate at levels of precipitation above approximately 200 mm, the long-term average annual precipitation. It has perhaps happened due to good infiltration [58] provided for by the shrub mounds. The shrub mounds can significantly increase the annual plant species richness, biomass and density on species richness [2-3-48-58]. Shrub mounds are generally found on unstable soil and steep slopes where weak sedimentary rocks make the area highly susceptible to erosion and mass movement [68]. Since little research has been done on this topic, there is a need to pay heed to the basic research and at least, the present paper has the objective of throwing more light on the influence of biotic and abiotic factors on ecosystem equilibrium.

MATERIAL & METHODS

Study area

The area of the present study is confind to the summer ranges of the Ramsar in Mazandaran Province of Iran. The average annual precipitation is about 700 mm and the climate, based on Emberger method, can be defined as cool-wet climate [below 2800m] to upland climate [>2800m]. Since there are two range types-grass and shrub types-on the upland, two amplitude of a ridge were chosen. Northwest aspect has the type *Astragalus* sp.- *Thymus kotschyianus* and soil texture of loamy-clay- silted with cobblestone. Northeast aspect has *Bromus tomentesus-Trifolium repens* type with loamy-clay texture. Both of these two aspects are located in 2450 m.a.s.l. The grassland habitat has general slope gradient of 53.5%, whereas in shrubland habitat it is 44.6%. Both types are grazing pastures for sheep and goats.

Research method

The study areas have initially been distinguished by topographic map in scale of 1:25,000 and then it has been correlated by field monitoring. The Daubenmire method was selected to analyse rangeland health conditions as it has certain factors of rangeland like percentage of vegetation, litter, soil conservation, plant regeneration, and plant composition [11]. The PSIAC method was selected to analyze soil erosion [47]. Thirty samples was chosen on the basis of statistical method and quadrat size was calculated by minimal area method [5] which was 1 square meter for grassland habitat and 4 square meters for shrubland habitat. Range condition, soil erosion, richness and diversity of plants were used as depended variables and the percentages of total cover of perennial and annual grass, perennial and annual forbs and shrub were independent variables. Plant diversity has been determined by Shannons' Index [46] based of equation
(1):

$$H = -\sum_{i=1}^{s} P_i \times LnP_i \quad (1)$$

Where, the proportion of species[*i*]relative to the total number of species [*pi*] is calculated, and then multiplied by the natural logarithm of this proportion [*Ln Pi*]. The resulting product is summed across species, and multiplied by -1.

Plant richness has been determined by Margalef's Index [Magurran, 2004] based of equation
(2):

$$R = \frac{S-1}{L_n(N)} \quad (2)$$

Where, *R* is richness index, *S* is whole of species, *N* is total of individual species, *Ln* is the natural logarithm.

Standardized coefficients [beta] in regression model were used to specify the effectiveness of each independent variable [38]. It would indicate the effectiveness of each independent variable on variation independent variable. In general, a regression model, equation (3) was applied:

$$y = \alpha x_1 + \beta x_2 + \lambda x_3 + ... + \theta x_n \quad (3)$$

Where, α, β, and λ indicate the effect of independent variable [beta coefficient] and X_1, X_2,…, Xn stand for independent variables itself. These coefficients will be justified the variance variation of depended variables by independent variables. Comparison of mean between two habitats was done by T-test method in SPSS v.17 software [61] . Plant richness and diversity amounts were calculated by Ecological Methodology software.

RESULTS & DISCUSSION

Comparison of the Habitats conditions

The results showed that the rangelands conditions were 40.48 for the grassland habitat as well as 47.7 for the shrubland habitat [Table 1]. Both of them had poor conditions. The soil erosion in shrubland area was 111.24 m3/Km2 per year, which was less than grassland [140.334 m3/Km2 per year] [Table 1]. T-test analysis has shown the difference between soil erosion in both the habitats [Pvalue<0.05] [Table 2].

Correlation between the soil erosion [dependent variable] and rangeland condition [independent variable] has been analyzed by simple regression which showed maximum correlation between them. Pearson correlation for shrubland and grassland were respectiveely 87.1 and 80.9%. On the other hand, there is a high correlation between rangeland condition and soil erosion. The coefficient of determination for the shrubland type was 75.8% and for the grassland type it was 65.4% [Table 3]. The soil erosion, therefore, will increase when rangeland health decreases.

The correlations table shows that rangeland condition in the both types of the shrubland and grassland has reacted to the soil erosion [Table 4]. Beta correlation also shows that there is an inverse relationship between the soil erosion and rangeland condition. The soil erosion is decreased by increasing the desirable condition of rangeland.

Vegetation characteristics were also analyzed which includes percentage of annual grass and forb, perennial grass and forbs, and shrub. There were some differences between two habitats. For example, cover percentage of annual grass and shrub was higher in shrub land than in grassland [Fig. 1]. Cover percentage of perennial grass and forb also was higher in grassland than in shrubland.

Soil erosion analysis

Soil erosion and Indices

On the basis of multi-regression analysis, diversity and richness indices have a relation to the soil erosion in shrubland [79.4%]. On the other hand, Indices have stated about 63.3% of variance changes of the soil erosion. F- Fishers have also justified the relationship between the soil erosion [dependent variable] and the Indices [independent variables]. It is highly correlated to the soil erosion and indices [90.2%] in grassland habitat. R-square is 81.3% and F-Fishers statistic also is 58.83 [p-value<0.001] [Table 5]. It has shown that the indices of diversity and richness robustly depend on the soil erosion's situation.

Table 6 has expressed a model of regression between the soil erosion [dependent variable] and the Shannon and Margalef's indices [independents variables]. The regression model for shrubland habitat is as equation (4):

$$Y = -0.41(M) - 0.51(S) \quad (4)$$

Where, [*Y*] is the soil erosion, [*M*] is Margalef's index and *S* is Shannon's index. It has been found that the variation of soil erosion has been justified by plant diversity [0.51] and richness indices [0.41]. Both of them have reversed relationship with dependent variable. So, if the amount of plant diversity and richness were reduced, then the soil erosion would increase. It clarifies that the plant diversity and richness were less [Fig. 1] which can not presently protect of the soil erosion. Model regression in grassland is defined as equation (5):

$$Y = -0.18(M) + 0.99(S) \quad (5)$$

Where, the plant diversity [0.99] and richness indices [0.18] have justified the variations of soil erosion in grassland habitat. The richness index has a reverse relationship to the soil erosion, and the plant diversity index has a direct relationship to it in which the richness is in good level [Fig. 1]. Since the different species stocks can better protect the soil surfaces by their roots structures; the habitat condition requires the increasing of diversity for the protection of the soil erosion. Increasing of the richness makes the condition of grassland unhealthy. It is because of homogeneity of formation including *Bromus tomentesus* and *Trifolium repens* dominants. On the other hand, the most parts of grassland habitat are covered by two mentioned formation whose increasing can reduce the protection of soil by reduction of root dispersal as opposed to grasses and forbs which have surface roots compared to shrubs or bushy tress.

Soil erosion and vegetations traits

It is important to note that soil erosion has been reacted by the plant diversity and richness indices. Nevertheless, it is more important to note which kind of vegetation formation has impacted to the soil erosion of habitats. Multi-regression analysis has shown that the shrub, annual forb, annual grass, and perennial covers in shrubland and also the canopy of perennial grasses, perennial forbs and annual grass in grassland are highly related to the soil erosion. Statistical static of R, R^2, and F have shown the highest relationship between the dependent [vegetation traits] and independent [habitats] variables [Table 7].

Model regression has been formed by variables in shrubland which is given in equation (6):

$$Y = -0.86(Sh) - 0.27(AF) + 0.57(PF) + 0.23(AG) \quad (6)$$

Where, *Y* is the soil erosion in habitats as dependent variable, *Sh* is shrub cover which has the highest influence on dependent variable, *PF* is perennial forb which has the second highest influence on *Y*, *AF* is annual forb, and *AG* is annual grass which has the worst effect on soil erosion [Table 8]. Covers of shrub and annual forb have an inverse relationship to the dependent variable so that increasing in the cover causes decreasing in the soil erosion of habitats. Covers perennial forb and annual grass

also have a direct relationship with soil erosion. The fieldwork visions have shown that the perennial forbs are palatable [e.g. *Trifolium repens*] which animals like to graze them as they have less cover than the others in shrubland habitat [Fig. 1]. Then, these plants can not conserve the soil erosion. Although the annual grass has high cover [Fig.1] in this habitat, it can not provide sufficient canopy cover to protect the soil surface from precipitation. Hence, it has an inverse relationship to the soil erosion. The soil protection, therefore, is provided for by the shrub covers which have a strong and deep roots in the shrubland habitat.

There is a small change in formation of model regression in grassland habitat which is given in the equation (7):

$$Y = -0.34(PF) - 0.05(AG) - 0.66(PG) \quad (7)$$

Where,[*Y*] is the soil erosion of grassland, *PF* is cover of perennial forb, *AG* is cover of annual grass and *PG* is cover of perennial grass. All covers, indeed, have inverse relationship to independent variable [Table 8]. Moreover, perennial grasses and forbs have the most roles to justify the variance variation of the soil erosion. Actually, *Bromus tomentesus* and *Trifolium repens* species are the dominated species which perform to conserve the soil surface from precipitation in this habitat. The model, however, has also shown that all species formation do not have enough canopy cover to protect the surface ground. The habitat condition is less than normal condition [Table 1]. Then this ecosystem requires to be managed via land management. Although the [table 1] has shown poor conditions in both habitats, the canopy cover of shrub mounds can remain in winter season in the shrubland habitat and regenerate in early spring. Hence, they can protect the sub-surface of soil from snow and drainage. The perennial grasses and forbs, and annual grass, with small surface-root, grow only in spring and summer. Consequently, they can not conserve the soil surface form drainage.

Habitats condition's analysis

Rangeland condition and Indices

Rangeland condition is significantly correlated to the plant diversity and richness indices. There is a 97.7% correlation between the rangeland condition and indices in shrubland habitat. About 95% changes of the rangeland condition have been justified by indices. Furthermore, the grassland habitat's condition show a high relation between indices and rangeland condition [85%]. Determination coefficient is 72.3% in grassland habitat versus 95% in the shrubland habitat. F-Fisher statistic is significant between rangeland condition and indices on both grassland and shrubland [Table 9].

Based of previous description, the regression model in the shrubland habitat has been formed by the equation (8):

$$Y = -1.06(M) + 0.86(S) \quad (8)$$

Where,[Y] is the rangeland condition,[M]is the richness index which has highly justified variance of rangeland condition and it also has an inverse relationship with rangeland condition. If individual stocks of species increase, then the rangeland condition will decrease. Dominant species in this habitat is the shrubs. When the canopy cover of the shrub increases, it is clear that the rangeland condition will decrease. Specially, most of the shrub species are unpalatable for animal grazing. S is plant diversity index which has a direct relationship to the rangeland condition. If the kinds of plant species increase, then the rangeland condition will also increase [Table 10-Fig. 1].

The rangeland condition and indices in grassland habitat has a regression model as $Y = 0.96(M) - 1.49(S)$ equation. Where,[Y] is the rangeland condition,[M]is Margalef's index which has a direct relation to rangeland condition. since presently, the grassland habitat has enough plant diversity [Fig.1] it needs to increase the plant richness to proliferate the rangeland condition. Therefore, by increasing of plant richness as S symbol shows, rangeland condition will also increase. The plant diversity has brawnily justified changes of rangeland condition at this habitat. It also has an inverse relationship to the rangeland condition [Table 10]. When the rangeland conditions tend to ward good condition, then the plant diversity will increase.

Rangeland condition and vegetations traits

There is a high correlation between rangeland condition and vegetation factors in both shrubland and grassland habitats. The determination coefficient has also shown that variances of rangeland conditions have been justified by covers percentages of vegetation formations [Table 11].

The regression model in shrubland habitat has been shown by the given equation (9):

$$Y = -0.76(Sh) - 0.41(AF) \quad (9)$$

Where, Y is the rangeland condition, Sh is the shrub cover that has inverse relationship to dependent variable in which increasing of the shrub cover can decrease to the rangeland condition; AF is annual forb that has less effect to the rangeland condition. The model has shown that we do not have sufficient cover percentage of perennial grasses and forbs in shrubland habitat. Then rangeland condition has decreased in this habitat because the perennial grasses and forbs are more grazeable as herbaceous forage in rangeland ecosystems. There is a simple regression model in grassland that has formed as equation (10):

$$Y = +0.91(PG) \quad (10)$$

Where, Y is rangeland condition and PG is perennial grasses which have directly correlated to dependent variable. Therefore, if the amount of cover percentage increases in grassland habitat, then the rangeland condition will be a good condition [Table 12]. Because canopy of the perennial grasses show dominance in this habitat [Fig. 1], so we have the best relationship between rangeland condition and them. Actually, the most dominated perennial grasses include *Bromus tomentesus*, *Dactylis glomerata* and *Festuca ovina* withthe most percentage of cover is for Bromus tomentesus species. This species is more resistant against environmental condition and grazing,. Hence, it can occupy most of the area of grassland area.

CONCLUSION

Based on climatology, annual precipitation is high in study areas. It might theoretically have sufficient diversity and richness [2-3-43-57]. However, the results showed that both habitats have poor conditions. Although climate has a big role to perform in the study area as a function component, animal grazing is effectively causing a decrease in the plant diversity and richness. Grazing, as an effective component, can change plant composition and expanse of the annual plant on the basis of grassland condition's scores. Then, it can have direct impact on soil cover and it also indirectly increases the soil erosion [17-39]. The result showed a high degree of relationship between the soil erosion and the rangeland condition with indices and vegetation traits in which the indices has positive relationship with habitat situation [15-32-34-41-64-65] in good condition or negative relationship 48-55-59] to the soil erosion, as a stability index of ecosystem, in poor condition of rangeland. Therefore, an imbalance between plant species can be caused the changing of rangeland ecosystem's equilibrium as ecosystem health/stability [13-25-27-30-31-42]. Similar to our comparative literature review, there have been many researches about relationship between biotic and abiotic factors of an ecosystem. End results, the plant diversity and richness are suitable indices to survey of ecosystem health. Hence, the knowledge of stage seral can be useful to create a systemic regulation as managing tools in each natural ecosystem.

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Table 1. comparative status between two habitats

Habitats conditions	Rangeland score	Rangeland condition	Soil Erosion $M^3 / Km^2.yr$
Shrubland	47.7	poor	111.2433
Grassland	40.48	poor	140.334

Table 2. T-test analysis in two habitats based of the soil erosion and habitats conditions

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
Soil Erosion								Lower	Upper
Equal variances assumed	1.46	0.23	-3.8	58	0	-20.32	5.33	-30.9	-9.6
Equal variances not assumed			-3.08	56.96	0	-20.26	5.33	-30.93	-9.6
Rangeland Condition									
Equal variances assumed	0	0.98	2.01	58	0.05	7.22	3.6	0.02	14.42
Equal variances not assumed			2.01	57.85	0.05	7.22	3.6	0.02	14.42

Table 3. Correlation between Soil erosion and Rangeland condition

Soil erosion*	Predictors**	$R^{(a)}$	$R^{2\,(b)}$	$F^{(c)}$	$Sig._{(for\ F)}$
Shrubland type	rangeland condition	87.1	75.8	87.84	0.000
Grassland type	rangeland condition	80.9	65.4	52.95	0.000

* and **: Dependent and independent variables

(a)Person coefficient, (b) Justification coefficient and (c) F-Fisher statistic

Table 4. correlations situation between dependent and independent variables

Habitats	Constant				
	B	Sig.	t	Beta	Sig.
Shrubland	131.33	0.000	-4.35	-0.87	0.000
Grassland	67.27	0.000	-6.6	-0.80	0.000

Table 5. Correlation between Soil erosion and indices

Soil eresion	Predictors	R	R^2	F	$Sig._{(for\ F)}$
Shrubland Habitat	Margalef and Shanon	79.4	63.3	23.07	0.000
Grassland Habitat	Margalef and Shanon	90.2	81.3	58.83	0.000

Table 6. Justification of the soil erosion in habitats by indices features

Habitats	Constant		Margalf index's feature			Shannon index's feature		
	$B^{(a)}$	Sig.	B	Beta	Sig.	B	Beta	Sig.
Shrubland	2039.5	0.000	-217.7	-0.41	0.006	-835.3	-0.51	0.001
Grassland	109.35	0.000	-0.819	-0.18	0.457	12.21	0.99	0.000

(a) Line gradient

Table 7. Correlation between the soil erosion and vegetations traits

Soil erosion in habitats	Predictors	R	R^2	F	$Sig._{(for\ F)}$
Shrubland	Shrub, annual forb and grass, perennial grass.	98.3	96.7	183.04	0.000
Grassland	perennial grass, perennial forb, annual grass	99.4	98.8	724.52	0.000

Table 8. Justification of the soil erosion in habitats by vegetations traits

	Shrubland Habitat's features			Grassland Habitat's features		
	B	Beta	Sig.	B	Beta	Sig.
Constant	110.97	-	0.000	165.59	-	0.000
Shrub	-0.003	-0.86	0.000	-	-	-
Annual forb	-0.02	-0.27	0.000	-	-	-
Perennial forb	0.03	0.57	0.000	-0.51	-0.34	0.003
Annual grass	0.005	0.23	0.000	-0.29	-0.05	0.022
Perennial grass	-	-	-	-0.666	-0.66	0.003

Table 9. Correlation between the rangeland condition and indices

Rangeland conditions	Predictors	R	R^2	F	Sig.$_{(\text{for F})}$
Shrubland Habitat	Margalef and Shanon	97.5	95	255.83	0.000
Grassland Habitat	Margalef and Shanon	85.0	72.3	73.4	0.000

Table 10. Justification of the rangeland condition in the habitats by indices

Rangeland condition	Constant		Margalf index's feature			Shannon index's feature		
	B	Sig.	B	Beta	Sig.	B	Beta	Sig.
Shrubland habitat	-392.4	0.000	-193.1	-1.06	0.000	470.7	0.86	0.000
Grassland habitat	52.25	0.000	5.87	0.96	0.000	-12.09	-1.49	0.000

Table 11. Correlation between rangeland condition and vegetations factors

Rangeland conditions	Predictors	R	R^2	F	Sig.$_{(\text{for F})}$
Shrubland Habitat	shrub, annual forb	99.3	98.7	999.81	0.000
Grassland Habitat	perennial grass	91.3	83.3	139.52	0.000

Table 12. Justification of rangeland condition in habitats by vegetations factors

	Shrubland Habitat's feature			Grassland Habitat's feature		
	B	Beta	Sig.	B	Beta	Sig.
Constant	48.32	-	0.000	21.89	-	0.000
Shrub	-0.003	-0.76	0.000	-	-	-
Annual forb	-0.004	-0.41	0.000	-	-	-
Perennial grass	-	-	-	0.615	0.91	0.000

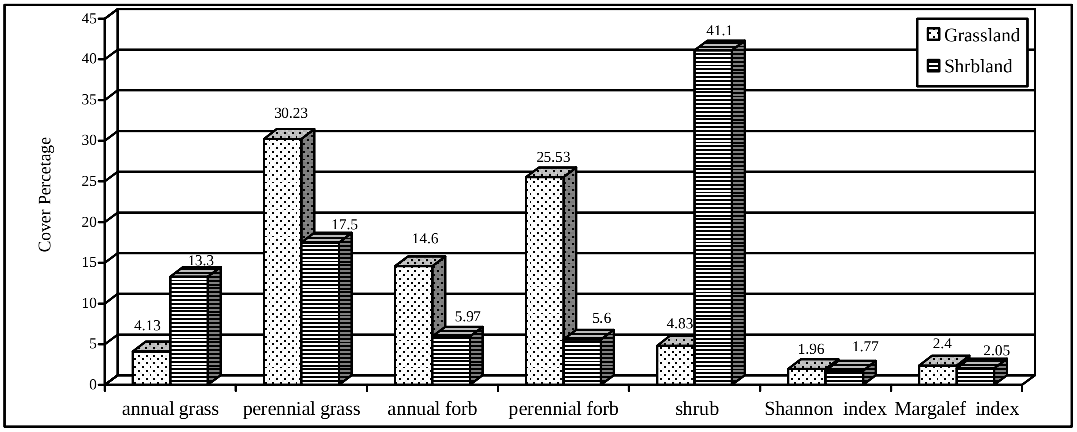

Fig. 1. Comparative condition of two habitats based upon the vegetation traits