Assessment of Health Conditions of Mountain Rangeland Ecosystem Using Species Diversity and Richness Indices, Case Study: Central Alborz (Iran)

Mohammad hasan Jouri[A], Dnyan Patil[B], Rivandra S. Gavali[C], Nosrat Safaian[D] and Diana Askarizadeh[E]

[A]Assistant Professor, Islamic Azad University, Nour Branch, Nour, Iran. E-mail: mjouri@yahoo.com
[B]Professor, UGC-Academic Staff College, Pune University, India.
[C]Associate Professor, School of Earth Sciences, University of Solapur, India.
[D]Professor, Sari University of Agriculture Science & Natural Resources, Iran.
[E]Postgraduate Student, Gorgran University of Agricultural and Natural Resources Sciences, Iran.

Manuscript Received: 05/07/2010
Manuscript Accepted: 14/12/2010

Abstract. Based on the importance and role of species diversity and richness as a measurement of the health of an ecosystem; studying of their components can lead to evaluate the health condition of rangeland. This research was carried out in a part of highland mountainous rangeland of Mount Alborz Range in Iran. Diversity and richness were assessed as an ecosystem health indicator. The study area was located between 2200 to 4200 m altitude in north of Iran. The rangeland vegetation was covered by grass as the dominant species along with forbs and cushion like species. The rangeland was grazed by livestock as summer rangelands. The samples were collected in reference, key, and critical areas using transects. The data were analyzed by stepwise regression in that rangeland condition as dependant variable and vegetation form as independent variables. Plant diversity and richness indices were calculated by PAST Software. The results showed that grass species diversity had the highest correlation with the rangeland condition in key site. The cushiony species and the combination of grass and forbs had high correlations with the rangeland condition in both critical and reference sites. The key and critical rangelands had the highest and lowest diversity, respectively. The critical zone was in disequilibrium conditions so the rehabilitation of vegetation cover is recommended for the similar regions. It was concluded that Long-term enclosure can decline the species diversity and richness. Moderate grazing is the best tool to use the grazing land without severe reduction in abundance and biomass of species.

Key words: Diversity, Richness, Rangeland health condition, Central Alborz range, Iran.

Introduction

Rangeland ecosystems are formed by biotic and abiotic factors as instructional components of natural ecosystem. Rangelands provide vital watershed, multiple-use, and amenity land functions (O'Brien *et al.,* 2003). The ecosystem services provided by the rangelands are not valued by the people in general or governments in particular (Han *et al.*, 2008). Although rangeland health is defined as the degree to which the integrity of the soil, vegetation, water and air as well as the ecological processes of rangeland ecosystems are balanced and sustained, most of the scientists believe that diversity begets ecosystem stability (Odum, 1971; May, 1973; Loreau *et al.*, 2001). Species diversity provides energy and material flow and resilience of ecosystem to respond to unpredictable surprises (Solbrig, 1993; Holling *et al.*, 1995). Moreover, some researches have implied on ecosystem stability-diversity-production relationships (Williams and Martinez, 2000) or the effects of species richness on ecosystem functioning (Lechmere-Oertel *et al*., 2005; Humpden and Nathan, 2010) or relationships between diversity and productivity (Waide *et al*., 1999) and relationship between richness and net primary productivity (Bond and Chase, 2002; Sangha *et al*., 2005). There is either positive (McNaughton, 1977; Griffiths *et al*., 2000) or negative (Smedes and Hurd, 1981; Rodriguez and Gomez-Sal, 1994; Pfisterer and Schmid, 2002) relationships between species and ecosystem stability knowing that it can lead to the management of an ecosystem. Since it is impossible to measure everything of potential relevance within an ecosystem, indicators can be used to reduce the number of components that have to be investigated and monitored to determine whether harvesting of resources is carried out in a sustainable manner (Carignan and Villard, 2002). The information gathered by ecological indicators can also be used to forecast future changes in the environment to identify actions for remediation, or if monitored over time to identify changes or trends in indicators (Niemi and McDonald, 2004; Finch and Dahms, 2004). Therefore, species diversity and richness or biodiversity as a whole are good indicators which determine the health of an ecosystem.

Diversity and richness of plants are reduced by abiotic (slope, feature, altitude, latitude, soil properties, etc) and biotic (animal and human) factors along the time. The animal grazing or special overgrazing, however, can change plant composition. Adler and Morales (1999) have implied the effect of intense sheep grazing on plant community in the Andes. Continuous overgrazing not only increases erosion (Harden, 1993; Bestelmeyer *et al.,* 2003) and loss of productivity (Eckholm, 1975; Parker and Alzérreca, 1978), but also decreases the species diversity and richness (Wright *et al*., 2003; Pueyo *et al*., 2006), plant functional diversity (Campbell *et al*., 2010) and removes the palatable perennial species. Moderate grazing of habitats, however, will give plants sufficient richness and diversity with good productivity (Grime, 1973; Connell, 1978; Huston, 1979; Loreau, 2000; Tilman *et al*., 2001). Species diversity was lower when range condition was either poor or excellent, however, it was higher when range condition was good (Zheng *et al*., 2007). Understanding the problems and constraints which these evolutionary dynamics pose for ecosystems is a key component in managing them sustainably (Costanza *et al.,* 1993). The biodiversity elements (e.g. species) can help to conduct the conservation of ecosystems (Simelane, 2009) because conservation of biodiversity is an important measurement in maintaining the sustainability (Zhang *et al*., 2010). Therefore, there is a need to study the rangeland vegetation traits including species diversity and richness (McIntyre and Lavorel, 1994) to understand how to manage the rangeland ecosystem. Ecosystem health indicators are valuable tools for evaluating site-specific outcomes of collaboration based on the effects of collaboration on ecological conditions (Muñoz-Erickson *et al.,* 2007) which is considered in this research. This case study illustrates an extensive application of an assessment technique that its results contribute to an understanding of rangeland degradation (Miller, 2008).

Materials and Methods

Study area

The land investigated in this research is located in the summer ranges of Polour village (Mazandaran Province, Iran) near Damavand summit as central Alborz Mt. The range site area was about 8700 hectares between latitudes of 35° 55´ and 36° 09´ N and longitudes of 50° 59´ and 52° 07´ E. The minimum and maximum height points of Polour region are 2400 and 4200 meters from the sea level, respectively (Fig. 1). The average annual precipitation is about 650-750 mm. Based on Emberger's method, the climate condition can be classified as cool-dry. The empirical reports have shown that the glacial periods in Polour are between 60 and 90 days. Most snowing occurs during Nov to Feb. The study area is located on Alborz Mountain which is appeared at ca. 12 Ma in the Arabia-Eurasia collision zone (Guest *et al.*, 2006). Basically, these mountains are extended from Paleo-Tethyan Ocean in early Plaeozoic time (Alavi, 2004). This region has been affected several times by historical and recent earthquakes (Ashtari Jafari, 2007). The Polour site is located on Damavand summit that is a volcanic mount. Most of the area is covered by limestone, Dolomite, Tuff and conglomerates stones. All of the study area (reference, key and critical) is almost covered by grasses and shrubs along with forbs in which subjective vision is shown that most shrubs are found on critical area along with unpalatable species. The key area, on the other hand, had more perennial grasses and forbs and the reference area finally has mostly perennial-native grasses.

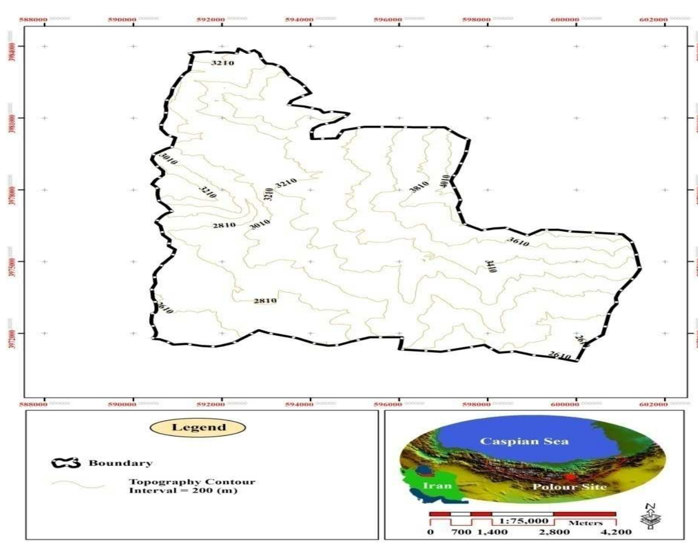

Fig. 1. The location of study area and its contour line

Research Method

After preliminary studies of topographic maps (1:25,000) using GPS, the research site was designated. To determine the variations in health condition of the rangeland, a reference, key and open areas were chosen for collecting the field data. Reference and key areas were closed to grazing for near 40 (2 ha) and 18 (20 ha) years, respectively. The floristic list is primarily prepared by monitoring and collecting the unknown species in each site. Calculated by statistical formula, 30, 45, and 60 recording samples were collected from reference, key and grazingland areas, respectively (Valizadeh and Moghaddam, 2006):

$$N = \frac{t^2 \times s^2}{p^2 \times \overline{X}^2}$$

Where:

N=is the number of required samples,
t= is calculated by T-student table from statistical books,
p=is the p-value level (0.05 for this study),
$\overline{X}$ = is the mean of data set, and
s^2= is variance value calculated by following formula:

$$s^2 = \frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}$$

X can be calculated in terms of weight, percentage or frequency of dominated species in a given stand area. N is the primary number of quadrates. The recordable data were species cover and frequency, litter, stone, basal area and bare ground percentages that are obtained in each quadrate. Quadrate size was found by minimal area method (Cain, 1932; modified by Hopkins, 1957; Cain and Castro, 1959) as it was 1 m^2. Rangeland condition is obtained by modified-Daubenmire method (Bassiri, 2000) which has certain factors of rangeland like percentage of vegetation, litter, soil conservation, plant regeneration and plant composition. Species diversity was determined by Shannons' Index based on the following formula:

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

Where the proportion of species is relative to the total number of species (pi) is calculated, and then a multiplied by the natural logarithm of this proportion (Ln Pi). The resulting product is summed across species, and multiplied by -1. Plant richness was also determined by Margalef's Index based on the following formula:

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

Where:

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

Considering the above-mentioned recordable data from proposed regression models, standardized coefficients (beta) were used to specify the effectiveness of each independent variable on depended variable so that the following regression model was applied:

$$y = \alpha x_1 + \beta x_2 + \lambda x_3 + .. + \theta x_n$$

Where alpha, beta and gamma indicate the effect of independent variable (beta coefficient) and X1, X2,…, and Xn stand for independent variables itself. The correlation coefficient between depended and independent variables was obtained by $SPSS_{17}$ (SPSS, 2008) software. Plant richness and diversity were calculated by PAST v.1.9 (Hammer and Harper, 2006).

Results and Discussion

Rangeland condition vs. vegetation factors

Analysis of rangeland condition showed that it was fail, good, and moderate for critical, key, and reference areas, respectively (Table 1). Vegetation elements including shrub, annual and perennial forbs and annual and perennial grasses had the highest correlation with rangeland condition scores in all three sites (Table 2). As shown in (Table 2), the relationships between depended variable (rangeland condition) and independent variables (vegetation forms) are highly significant. It can be interpreted that variation of rangeland condition are justified by vegetation form in which increasing the life-form of plants can protect the rangeland health as well as support the fertility of soil. The individual analysis of critical, key, and reference areas showed that shrub (Sh), perennial forb (PF), and perennial grass (PG) highly justified the variation of rangeland condition (RC) in the critical area explained by the following equation:

RC=0.86Sh+0.36PF+0.30PG (Table 3).

Therefore, rangeland condition in this area is positively dependent on shrub cover that mostly formed by *Astragalus*, *Acantholimon*, *Acanthophyllum*, *Onobrychis*, and *Thymus* genera. The perennial grass and forb proportion in vegetation cover should also increase to guarantee the health condition of rangeland.

In the key area, however, shrub, perennial grass (PG) and Annual grass (AG) had the highest correlation with rangeland condition based on the following equation:

RC=-0.65Sh+0.58PG-0.22AG. (Table 4)

Hence, increasing of shrub and annual grass or decreasing of perennial grass can decline the rangeland health from suitable condition. As it is understood, the health condition of this site is good condition that is covered by suitable and palatable species. The existing shrubs refer to some decades ago which by closing the site to grazing, the shrubs have been replaced by grasses through ecological succession.

In reference area, there are perennial grasses that justify the variation of rangeland health condition based on the following equation:

RC=0.95PG (Table 5) .

After long time enclosure of the reference area, the endemic species returned to climax or subclimax condition. Observations showed that tall wheat grass *Agropyron elongatiforme* Drobov, *Hordeum bulbosum* L. and sheep's fescue *Festuca ovina* L. are the perennial grasses which have dominated the site. It is obvious that all these species are palatable grazing livestock. This section precisely showed that rangeland conditions of studied areas had a strong relationship with life-form of vegetation in which the native species can determine the health condition of rangeland ecosystem.

Table 1. The Rangeland condition in the three sites

Site	Visual Score	Range Condition
Critical area	33	Fail
Key area	70	Good
Reference area	61	Moderate

Table 2. Illustrated tables of correlation and ANOVA for rangeland condition's score of sites and predictors

Site	Predictors (Life form)	R	R^2	F	Sig.$_{(for F)}$
Critical area	Shrub, perennial forbs & perennial grass	92.9	86.4	54.91	0.000
Key area	Shrub, perennial grass, annual grass	90.1	81.1	37.16	0.000

Reference area	Perennial grass	90.5	81.8	126.2	0.000

R=Pearson correlation, R^2= Coefficient of determination, F= Fisher's statistic, Sig. = P-value

Table 3. Beta coefficient of rangeland condition as dependant variable with vegetation form as independent variables in the critical area

Vegetation form	B	Standard (Beta)	Sig.
Constant	12.65	-	0.000
Shrub	0.39	0.862	0.000
Perennial forb	0.34	0.362	0.000
Perennial grass	1.80	0.303	0.001

Table 4. Beta coefficient of rangeland condition as dependant variable with vegetation form as independent variables in the key area

Vegetation form	B	Standard (Beta)	Sig.
Constant	66.90	-	0.000
Shrub	-0.062	-0.650	0.000
Perennial grass	0.123	0.588	0.000
Annual Grass	-0.101	-0.220	0.021

Table 5. Beta coefficient of rangeland condition as dependant variable with vegetation form as independent variables in the reference area

Vegetation form	B	Standard (Beta)	Sig.
Constant	27.25	-	0.000
Perennial grass	1.46	0.905	0.000

Rangeland condition vs. diversity and richness indices

Species diversity and richness indices have a highly negative and significant correlation with rangeland condition in all three study sites (reference, key and critical sites) (Table 6). All Beta coefficients were significant to rangeland condition in (P<0.05) (Table 7). So, species diversity and richness indices can well explain the variation in health condition of rangeland ecosystem (RC) with species diversity (DI) and richness indices (RI) (Table 7).

All richness and diversity indices in the three sites were negatively correlated to rangeland condition so that increasing of them can decrease the health condition of rangeland ecosystem as mentioned by Zheng *et al.* (2007). Many researchers had also point out that diversity and richness of plants decline along with advancement of ecological succession as in the climax condition, especially for grass and forbs communities; it is less than the moderate condition (reviewed by Akbarzadeh, 2005). Nevertheless, the equations show that diversity and richness indices are good ecological indicators to show the health condition of rangeland ecosystem.

Table 6. Illustrated tables of correlation and ANOVA for rangeland condition's score of sites and predictors

Site	Predictors	R	R^2	F	$Sig._{(for\ F)}$
Critical area	Margalef and Shanon	88.2	77.8	47.23	0.00
Key area	Margalef and Shanon	94.4	90.0	135.27	0.00

Reference area	Margalef and Shanon	89.1	79.3	51.78	0.00

R=Pearson correlation, R^2= Coefficient of determination, F= Fisher's statistic, Sig. = P-value

Table 7. Beta coefficient of rangeland condition with diversity and richness indices in the three sites as abstracted from three output tables of SPSS

Diversity and richness indices	Critical area			Key area			Reference area		
	B	Beta	Sig.	B	Beta	Sig.	B	Beta	Sig.
Constant	150.4		0.000	76.2		0.000	126.0		0.000
Margalef index	-35.72	-0.31	0.011	-0.26	-0.53	0.006	-36.64	-0.67	0.000
Shannon index	-48.02	-0.65	0.000	-4.15	-0.73	0.000	-15.83	-0.32	0.006

Table 8. Equation of rangeland condition (RC) as dependant variable with species diversity (DI) and richness indices (RI) as independent variables in the three studied areas

Site	equation
Critical area	$RC = -0.31DI - 0.65RI$
Key area	$RC = -0.73DI - 0.53RI$
Reference area	$RC = -0.32DI - 0.67RI$

Diversity index vs. vegetation life-form elements

The results showed that diversity and richness indices were highly correlated with rangeland condition. It is important which elements of vegetation life-form have significant relationship with indices. The regression analysis of diversity index as dependant variable with vegetation life-form in all three sites showed that there was highly significant correlation between them (P<0.01) (Table 9). Then, it is possible to form the equation on the basis of robust correlation. The result for critical area has shown that shrub, perennial grass, forb and annual grass correlate to diversity index, so that its equation was as follows:

DI=-0.86Sh-0.45PF-0.37PG-0.26AG. (Table 10)

It is fair condition in this site that there is scarce species based upon observation and species abundance. Consequently, health condition of critical site needs to tend toward moderate condition as increasing of species diversity. Species diversity index, as a result, has negatively correlated to all kinds of life form that requires high presences of all species. On the basis of equation, the maximum variation of diversity index is justified by shrub and perennial forbs. The most mentioned life forms based on collected data and floristic list are unpalatable and unsuitable for grazing. Because of overgrazing of critical area, species cover and frequency are in short supply as Wright *et al.* (2003) and Pueyo *et al.* (2006) have emphasized it.

In key area, as a matter of fact, perennial grass, shrub and annual forbs are highly correlated to species diversity, in which the equation of this connection was:

DI=0.42Sh-0.55PG+0.29AF (Table 11).

Although the highest variation of diversity index is influenced by perennial grasses, diversity based upon Beta coefficient, it will decrease if these species increase. This site can have maximum diversity when it's good condition shifts to moderate condition. There was no grazer in this site to graze the species. Hence, the tendency of present species was going to unify the species as perennial grass of this site and reference site. On the other hand, increasing of shrub and annual forbs can increase the diversity under good condition till these species are saturated to excellent condition. It, therefore, needs to graze for reducing the perennial grass. Some researchers have also pointed out that the moderate condition of rangeland has more diversity and richness (Grime, 1973; Connell, 1978; Huston, 1979; Loreau, 2000; Tilman *et al.*, 2001).

Reference area has a high correlation with shrub, perennial forbs, perennial and annual grasses, respectively. The equation of this linkage was:

DI=-0.89Sh-0.31PG+0.84PF+0.26AF (Table 12).

Shrub and perennial grasses have negatively correlated to diversity. It means that increasing of these elements can decline the diversity. After 40 year exclosure, the native species e.g. shrub and perennial grass have been dominated in the reference area. It, therefore, does not allow the other species to establish e.g. forbs as they are positively correlated with diversity. Although the rangeland condition is moderate, it shows versa resilience from climax condition. The health condition of this site precisely proves that desirable condition of health is not climax condition. This result is similar to the results reported by Zheng *et al.* (2007). It, however, is not the same as the others (Grime, 1973; Connell, 1978; Huston, 1979; Loreau, 2000; Tilman *et al.*, 2001) because the homogenizing of life form in this site leads to the forefend of other species.

Table 9. Results of correlation and ANOVA for diversity index of sites and predictors

Site	Predictors (life form)	R	R^2	F	$Sig._{(for\ F)}$
Critical area	Shrub, perennial forb & grass, annual grass	92.5	85.5	36.83	0.000
Key area	Shrub, perennial grass, annual forb	88.6	78.5	31.55	0.000
Reference area	Perennial grass, annual forb, shrub, perennial forb	91.7	84.1	33.17	0.000

R=Pearson correlation, R^2= Coefficient of determination, F= Fisher's statistic, Sig. = P-value

Table 10. Beta coefficient of diversity index as dependant variable with life form of vegetation as independent variable in the critical area

Life Form	B	Standard (Beta)	Sig.
Constant	1.700	-	0.000
Shrub	-0.005	-0.860	0.000
Perennial Forbs	-0.005	-0.457	0.000
Perennial Grass	-0.030	-0.377	0.000
Annual Grass	-0.020	-0.267	0.006

Table 11. Beta coefficient of diversity index as dependant variable with life form of vegetation as independent variable in the key area

Life Form	B	Standard Beta	Sig.
Constant	1.430	-	0.000
Shrub	0.006	0.421	0.000
Perennial Grass	-0.020	-0.552	0.000
Annual Forbs	0.030	0.290	0.009

Table 12. Beta coefficient of diversity index as dependant variable with life form of vegetation as independent variable in the reference area

Life form	B	Standard Beta	Sig.
Constant	1.25	-	0.000
Shrub	-0.04	-0.893	0.001
Perennial forbs	0.02	0.840	0.007
Perennial grass	-0.01	-0.313	0.019
Annual grass	0.05	0.260	0.047

Richness index vs. vegetation life-form elements

Diversity index by itself is possibly not a good indicator to describe the health condition of rangeland ecosystem. The gathering of richness index with diversity, however, can describe the ecosystem condition as well. The regression analysis has shown that there was low coefficient of determination between richness index and life forms of vegetation, for critical and reference area (Table 13).

The variation of richness has just been justified by shrub in the critical area so that its equation was:

RI=-0.62Sh. (Table 14)

There are many unpalatable shrub species, as it has been mentioned before, which occupy the extend area of present rangeland. Increasing of shrub species abundance can decrease the richness. In the other view, overgrazing of this area is so extensive that omits the other palatable species frequency.

Change rate of richness index in the key area has been balanced by perennial grass, shrub, annual and perennial forbs, respectively. Hence, the equation between dependent and independent variables was

RI=-0.62PG+0.29Sh+0.24AF-0.20PF (Table 15).

As the rangeland condition is good in this area, there is enough species diversity.

Although perennial grasses highly justified the variation of richness, the reverse relationship of them demonstrates that increasing of perennial grass, e.g. perennial forbs declines the richness as they unify the frequency of species. The field visions also confirm that perennial grass and forbs are dominated in this site.

Perennial grasses are the only species that justify the gradient of richness index in the reference area. As there are perennial grasses that influence the richness, the equation, therefore, is

RI= -0.75PG. (Table 16).

Although there are many species as diversity in this site, presence of perennial grass accurately corroborates that these species have occupied the area. Increasing of them, therefore, reduces the richness index. As a result, closing of rangeland can decrease the amount and frequency of species. The rangeland ecosystem is like a puzzle which grazing is one of the puzzle's components. Sustainable management should arrange best grazing (the only effective component) program on the grazingland. Ironically, it couldn't handle this task alone as well. Many researches emphasize on moderate grazing as it protects the ecological aspects of the land (Grime, 1973; Connell, 1978; Huston, 1979; Loreau, 2000; Tilman *et al.*, 2001). Hence, long-term exclosure declines the ecological capacity of rangeland ecosystem.

Table 13. Results of correlation and ANOVA for richness index of sites and predictors

Site	Predictors (life form)	R	R^2	F	Sig.$_{\text{(for F)}}$
Critical area	Shrub	62.5	39.1	17.95	0.000
Key area	Shrub, perennial grass, annual forb, perennial forb	92.4	85.3	36.3	0.000
Reference area	Perennial grass	75.2	56.6	36.5	0.000

R=Pearson correlation, R^2= Coefficient of determination, F= Fisher's statistic, Sig. = P-value

Table 14. Beta coefficient of richness index as dependant variable with life form of vegetation as independent variable in the critical area

Life form	B	Standard Beta	Sig.
constant	1.54	-	0.000
Shrub	-0.002	-0.625	0.000

Table 15. Beta coefficient of richness index as dependant variable with life form of vegetation as independent variable in the key area

Life form	B	Standard Beta	Sig.
constant	2.890	-	0.000
Shrub	0.012	0.295	0.002
Perennial grass	-0.057	-0.617	0.000
Annual Forbs	0.040	0.247	0.016
Perennial Forbs	-0.126	-0.204	0.050

Table 16. Beta coefficient of richness index as dependant variable with life form of vegetation as independent variable in the reference area

Life form	B	Standard Beta	Sig.
constant	1.75	-	0.000
Perennial grass	-0.021	-0.752	0.000

Conclusion

Conservation of rangeland health is found by its elements e.g. biodiversity, species diversity and richness (Simelane, 2009; Zhang *et al.,* 2010). Study of rangeland variation traits including species diversity and richness (McIntyre and Lavorel, 1994) is the way to understand how to manage the rangeland ecosystem as they are valuable-ecological indicators of rangeland ecosystem health (Muñoz-Erickson *et al.,* 2007). This paper has showed that diversity and richness indices are countable tools for evaluating site-specific outcomes and considerable elements to know the ecological condition of ecosystem. It also shows that overgrazing can decline the frequency and diversification of plant species reported by many researchers (Wright *et al.,* 2003; Pueyo *et al.,* 2006 and Campbell *et al.,* 2010). Long-term exclosure can decline the species diversity and richness. Moderate grazing is the best tool to use the grazingland without severe decrement in abundance and biomass of species. Key area also requires reducing the range grazing capacity on the basis of ecological potential.

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