Nature Environment and Pollution Technology
An International Quarterly Scientific Journal | ISSN: 0972-6268 | Vol. 14 | No. 3 | pp. 703-708 | 2015

Original Research Paper

Influence of Fencing Time on Vegetation Community Structure and Species Diversity in Sandy Grassland of Ningxia in China

Xiaodan Liu, Kebin Zhang† and Bilal Ahmad
School of Soil and Water Conservation, Soil and Water Conservation Key Laboratory of Ministry of Education, Beijing Forestry University, Beijing, 100083, China
†Corresponding author: Kebin Zhang

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 15-10-2014
Accepted: 23-11-2014

Key Words:
Fencing time
Sandy grassland
Community structure
Species diversity

ABSTRACT

To investigate ecological restoration processes of sandy grassland, the areas of different fencing time (6, 11, 23 years) and non-fencing area were chosen in Yachi County of Ningxia Hui Autonomous Region. By quadrat method, the vegetation of the study region was investigated for the impacts of different fencing time on vegetation community structure and biodiversity. The type of dominant species in different areas were as follows: annual and biennial herbs (non-fencing area), semi-shrubs (6 years area), perennial herbs and semi-shrubs (11 years area) and perennial herbs (23 years area). The result showed that the values of vegetation coverage, density, biomass and height in fencing areas were higher than non-fencing area. In short-term period of less than 6 years, fencing increases biodiversity and makes community structure more stable, but long-term fencing of more than 11 years is not conducive to vegetation restoration. It suggested that rational uses of grassland such as grazing or cutting can be used in sandy grassland in semi-arid areas.

INTRODUCTION

Grassland degradation has become one of the very important ecological problems in China. In the late 20th century, degradation and desertification of natural grasslands in China have promoted the application of restoration ecology in grassland ecosystem (Mi et al. 2006). Artificial enclosure is one of the means to restore degraded grasslands. In the restoration process of degraded grassland, fencing have many advantages such as less investment and obvious ecological effects, which becomes one of the important measures to vegetation restoration, and is widely used around the world (He et al. 2008). There are many research methods about fencing effects, of which the studies on vegetation community characteristics and biodiversity are still relatively effective ways. Species diversity, which is a measure for the community structure and functional complexity (Bo et al. 2008), is also the best indicator for the degree of ecosystem restoration. Different biodiversity indexes contain complex ecological information (Wang 2007, Zhang et al. 2010). Species diversity is not only affected by the number of species, but also by the spatial distribution of species (Zhao et al. 2007). The study of species diversity helps in good understanding of composition, changes and trends of communities, and reflects the protection status of communities and their environment. So, the relationship between species diversity and environment have become focus of ecology research (Zhang et al. 2008).

Currently, the research of species diversity is focused on the impact of human activities and grazing on grassland community diversity. There are many studies on the effect of short-term fencing in China, but research on desert grassland vegetation restoration under different fencing time in semi-arid areas is very less. Based on the project of national desertification positioning monitoring of China, using the space method instead of time method, four processing methods were adopted: 6, 11 and 23 years area and non-fencing area. The objectives of this study, which was carried out in enclosure areas under different fencing time and these areas not only affected by severe land degradation but also identified as a potential ecosystem restoration site, were to investigate; (1) community structure and species diversity in the study region; (2) how community structure changes with fencing time; (3) the relationship between community structure and fencing time.

OVERVIEW OF THE STUDY AREA

Yanchi county is located in the east of Ningxia Hui Autonomous Region and the southern edge of Mu Us Desert and in the junction zone of four provinces (autonomous regions) of Shaanxi, Gansu, Ningxia and Inner Mongolia. It is located in the coordinates of 37°05'-38°10' N and 106°30'-107°39' E. The north-south distance of the county is 110 km, and east-west distance is 66 km. The whole area of Yanchi county is 8661.3 km^2, which is the largest county in

Ningxia accounting for 16.7% of the total area of Ningxia. The southern part of the county is higher than the northern part. The southern part is the Loess hilly area and the middle is a hilly land with gentle slopes of the Erdos, which is a typical transition zone between cropping and nomadic area, the altitude of which is 1295-1951 m. The county belongs to the typical temperate continental climate, its annual average temperature is 8.1°C, the annual highest average temperature is 34.9°C while the lowest is -24.2°C. The yearly average frost-free period is 165 days and the annual average precipitation is only 250-350 mm. The precipitation decreases progressively from southeast to northwest. With typical temperate of middle continental climate, Yanchi County is under drought with few rainfalls and it is windy and sandy at the same time. The evaporation is intense and the sunshine is sufficient. All the conditions mentioned above make the natural landscape of Yanchi County to be the temperate zone prairie and wilderness prairie. The terrain is mainly denuded peneplane. The soil type is primarily siero-zem, then dark humus soil and sandy soil, loess, a little salt clay, white bentonite and so on. The vegetation in Yanchi belongs to European-Asian grassland and Central Asia subregions. It is the transitional area of central China's grassland. The vegetation types there include thickets, grasslands, meadows, sandy vegetation and desert vegetation. Among them, the amount of thickets, grasslands and sandy vegetation is the largest with wide distribution. There is no natural forest in Yanchi County. It only has a few artificial forests and a large shrub area including *Salix psammophilia* and *Caragana microphylla.* Grasslands can be divided into dry grassland and desert grassland, typical steppe include *Stipa grandis*, *Stipa bungeana*, *Agropyron crisatum*, *Thymus serphyllum* var. *mongolicus* and so on. Desert grassland includes *Caragana tibetica*, *Oxytro pisaciphylla*, *Nitraria sibirica* and *Kalidiu foliatum.*

MATERIALS AND METHODS

Sample plot choosing: The study area is located in the semi-arid desertification area and in the southwest edge of the Mu Us desert. Due to the fragile ecological environment, desertification grassland vegetation is easy to be damaged. According to the space method, instead of time method, the study sites were divided into 6 years area, 11 years area, 23 years area and non-fencing area (contrast area). The 23 years enclosure area was the first batch of China desertification demonstration area of the early 90's in twentieth century which was eliminated from human and livestock disturbance completely by means of the barbed wire fence. The 6, 11 years enclosure areas were selected from the area where the Chinese government had implemented phased large-scale enclosure after 2003. While the non-fencing area was selected adjacent peripheral to the fencing areas, which was often disturbed by human activities and livestock. The various study plots have the same natural conditions such as relative flat terrain, same soil type, etc. The plots and habitat conditions are given in Table 1.

Field investigation: Using sample lines and sample approaches, the four sample lines were emplaced respectively in four selected sites during the plant growth peak in July 2014. Each sample line had layout of every 30m with 1m × 1m quadrat, so four sample lines had 40 quadrats which were investigated. For each quadrat, plant community types and characteristics values: species number, plant number, height, coverage, biomass, etc. were recorded.

Data processing methods: Communities vegetation characteristics were analysed by using SPSS 16.0 ANOVA and Duncan multiple comparisons.

Calculation of plant importance value: The importance value indicates the relative importance of plant species in the community by the comprehensive quantity of characteristic values (Li et al. 2008). Importance value is also a key indicator to measure the plant species in the community. So this paper takes importance value as the basis. The formula is as follows:

$$I = \frac{A + H + C + F + B}{5}$$

Where, I = importance value, A = relative abundance, H = relative height, C = relative coverage, F = relative frequency, B = relative biomass.

Biodiversity measures: Species richness was measured by Margalef index (Guo et al. 2005):

$$Ma = (S - 1) / \ln N$$

Table 1: Location and habitat conditions of experiment sites.

Sample plot	Latitude N	Longitude E	Elevation/m	Community name
6 years area	37°49'50"	107°23'56"	1368	*Artemisia ordosica*
11 years area	37°50'44"	107°24'15"	1365	*Artemisia ordosica + Heteropappus altaicus*
23 years area	37°50'45"	107°24'04"	1366	*Heteropappus altaicus*
non-fencing area	37°50'47"	107°23'47"	1363	*Sophora alopecuroides*

Diversity of species was measured by Shannon-Wiener index (Zhang 2011):

$$H = -\sum_{i=1}^{s} Pi \ln Pi$$

Ecological advantages was measured by Simpson index (Wang et al. 2004):

$$D = 1 / \sum_{i=1}^{s} Pi^2$$

Community evenness was measured by Pielou index (Ma et al. 1995):

$$E = H / \ln S$$

In the four formulas, P_i represents the ratio of importance value ($P_i = N_i / N$), N_i the importance value of plant i in quadrats, N the sum of plant importance value in the region, S is the number of plant species in a transect.

Similarity measure: Similarity coefficient was measured by Sorenson index (Wang et al. 2012)

$$C_S = 2c/(a+b)$$

In this formula, a is the number of species in the A transect, b is the number of species in the B transect while c is the number of common species in A and B transacts.

RESULTS AND ANALYSIS

The influence of fencing time on community species composition: *Salsola ruthenica* was the dominant species in non-fencing area with importance value as 20.62. After enclosure, dominance of *Salsola ruthenica* increased after the first drop i.e., 6.44 in 10 years area, up to 14.32 in 23 years. In 6 years fencing area, *Artemisia ordosica* was the dominant species, with importance value as 23.34, while the importance values of other major vegetation were generally lower than that in non-fencing area. In 11years area, *Artemisia ordosica* and *Heteropappus altaicus* were the dominant species; their importance values were 28.23 and 19.45 respectively, of which *Heteropappus altaicus* dominance increased significantly. In 23 years area, *Heteropappus altaicus was* the dominant species, its value was 20.81, while annual herb *Salsola ruthenica* had also higher importance value (Table 2).

From the point of view of plant functional groups, compared with the non-fencing area, in 6 years fencing area, perennial herbs reduced dominance and dominance of major vegetation gradually became even. While in 11 years and 23 years enclosure areas, the dominance of perennial herbaceous gradually improved, especially *Heteropappus altaicus* had a significant increase. Compared with non-fencing area, in 6 and 11 years fencing areas, the dominance of semi-shrubs gradually increased, and significantly reduced in 23 years enclosure area. After fencing, dominance

Table 2: Importance value of community under different enclosure years.

Plant name	Importance value			
	6 years area	11years area	23years area	Non-fencing area
Perennial herb				
Ixeris chinensis	10.79	9.69	10.21	6.82
Heteropappus altaicus	7.26	19.48	20.81	4.11
Corispermum hyssopifolium	4.77	4.05	0.55	15.94
Sophora alopecuroides	1.55	3.54	1.51	5.63
Astragalus melilotoides	/	2.19	3.81	3.56
Cleistogenes chinensis	/	1.27	0.91	1.39
Agropyron cristaturn	9.64	/	0.9	8.41
Leymus secalinus	/	/	12.03	/
Psammochloa villosa	/	/	3.6	/
Scorzonera divaricate	10.95	/	8.03	/
Saussurea amara	/	/	0.11	/
Agropyron mongolicum	/	/	0.46	6.06
Oxytrapis psammocharis	/	/	0.49	/
Ixeris chinensis	2.65	/	1.69	/
Haplophyllum	/	1.08	/	1.27
Cephalanoplos segetum	/	/	/	0.16
Euphorbia esula	1.34	/	/	/
Semi-shrub				
Cynanchum komarovii	/	/	/	0.42
Caragana korshinskii	/	0.74	/	/
Lespedeza davurica	0.65	0.33	3.98	/
Artemisia ordosica	23.34	28.23	2.38	12.48
Annual herb				
Artemisia hedinii	/	7.12	3.93	/
Bassia dasyphylla	/	/	/	0.32
Artemisia macrocephala	2.39	/	/	/
Setaria viridis	10.46	6.4	7.05	5.35
Salsola ruthenica	8.55	6.44	14.32	20.62
Euphorbia humifusa	2.44	0.47	1.51	4.08
Cuscuta chinensis	2.13	0.42	0.19	/
Incarvillea sinensis	1.09	8.55	1.53	3.38

Table 3: Vegetation number characteristics in different enclosure years.

Vegetation number characteristics	Different fencing areas			
	Non-fencing area	6 years area	11 years area	23 years area
biomass (g/m^2)	158.17±58.13a	239.79±193.07a	266.97±196.56a	194.62±160.82a
coverage (%)	20.59±11.25a	30.71±21.50a	36.56±24.94a	22.33±10.40a
density (plant/m^2)	113.4±66.12a	141.4±115.95a	135.5±164.69a	116.3±83.20a
height (cm)	14.06±4.12a	16.35±4.45a	16.46±6.50a	15.29±13.95a

of annual herb increased after the first decrease. Generally speaking, enclosure measures can increase the diversity of plant functional groups.

The influence of enclosure time on community vegetation characteristics: It was observed that (Table 3) different vegetation characteristics represented a certain change in trend. The values of biomass, coverage, density and height all were the biggest in 6 and 11years areas, followed by 23 years fencing area, while the lowest appeared in the non-fencing area. ANOVA and Duncan multiple comparison results showed that there was a difference to vegetation characteristics of different fencing areas, but the difference was not significant at 0.05 level.

The influence of enclosure time on species diversity: It was observed that species richness index fluctuated trend in different enclosure time, and species diversity index first increased and then decreased, while community evenness index had reduced gradually, but the reduced magnitude was small (Table 4). In 6 years fencing area, community richness and species diversity all increased, but with enclosure extension, species diversity reduced in 23 years area. In 23 years fencing area, *Heteropappus altaicus* was the single dominant species, which resulted in lower species diversity and evenness. After the implementation of the enclosure, grassland suffered reduction interference, which increased plant diversity. However, due to different vegetation ecological adaptability and competitiveness, after many years of enclosure, a small number of species had the dominance in community, diversity decreased, and community appeared instable, and a small amount of biennial weed would invade.

There were fluctuation in trends of species similarity coefficient for different enclosure areas (Table 5). The lowest similarity appeared in 6 years fencing and non-fencing areas. The reason was that annual and biennial weeds gradually changed to *Artemisia ordosica* community, which resulted in the largest species change and minimum similarity. In 11 years enclosure area, due to succession from *Artemisia ordosica* and gradual transition to *Heteropappus altaicus*, the status of dominant species was weakened and promoted the growth of other species, which had high similarity with the non-fencing area. In 23 years area, the dominant species had a transition to *Heteropappus altaicus*, although some annual and biennial weeds appeared, there was a big difference with the non-fencing area, which resulted in similarity decrease. There were transitions of dominant species in 6 and 11 years areas, and changes of other species, which caused similarity decrease. While for 6 and 23 years fencing areas, they were suitable for the growth of the non-dominant species, which made two types of areas highly similar.

Table 4: Species diversity in different enclosure years.

Index Type	Non-fencing area	6 years area	11 years area	23 years area
Species richness	2.877	2.249	2.433	2.064
Shannon-Wiener index	2.304	2.386	2.409	2.482
Simpson index	8.028	8.694	8.945	9.076
Community evenness	0.795	0.853	0.843	0.823

Table 5: Similarity coefficient in different enclosure years.

Type	Non-fencing area	6years area	11years area	23years area
Non-fencing area	1	0.591	0.734	0.635
6 years area		1	0.655	0.726
11 years area			1	0.702
23 years area				1

DISCUSSION AND CONCLUSION

Fencing is one of the effective means of restoring degraded grasslands. The influence of enclosure measures on degraded grassland ecosystem is reflected in changes in vegetation community structure, biodiversity and micro-ecological environment (Shan et al. 2008). The research found that fencing for a certain period could promote the growth of vegetation, such as 6 and 11 years enclosure areas, due to avoiding the outside interference which promotes good vegetation growth. In long-term fencing, vegetation appeared to undergo succession from *Artemisia ordosica* to *Heteropappus altaicus*, and there were a lot of biological soil crusts formed in 23 years fencing area. The experimental studies on biological soil crusts (Lu et al. 2007, Lu et al. 2008) showed that there was significant negative correlation between crust coverage and vegetation coverage. In 23 years enclosure area, due to the higher crust thickness and coverage, it competed with surrounding plants for water, nutrient and growth space. It appeared that mutual promotion growth relationship became mutual competition. And crust coverage and soil infiltration depth also showed a significant negative correlation. The presence of biological crusts prevented the penetration of water into the deep, which resulted in the shallow trend of soil moisture, and made the spread of deep-rooted shrub species decline and shallow roots semi shrubs, annual herbaceous vegetation grow. Vegetation growth become worse, and coverage, density decline. Long-term enclosure makes substances and energy exchange slow in grassland ecosystem, resulting in soil nutrients, required for the growth of vegetation, not be updated and supplemented, and ultimately lead to a decline of grassland productivity.

There have been many studies on effects of enclosure on diversity. Some think that fenced grazing help increase vegetation diversity (Li et al. 2013, Zhao et al. 2004), but due to less herbivorous animals, a small amount of the vegetation will become a dominant species, which inhibit the growth of other plants, and lead to diversity decrease (Gao et al. 2012, Begona et al. 2005, Shi et al. 2007). This is similar to the conclusions of this study, the highest species diversity appeared in 6 and 11 years fencing areas, which indicates that when number of species get certain value, vegetation achieve balance to absorption and utilization of resources, species diversity and grassland productivity become the maximum. But in 23 years area, with community structure and micro-environment changes, vegetation is affected by recession and species diversity decreases.

In arid and semi-arid areas, the studies in the Horqin sandy land (Jiang et al. 2013) showed that the most appropriate fencing time was 6 years. And the research (Shan et al. 2008) showed that 14 years was appropriate enclosure time on the condition of enclosure in growing season and mild grazing in non-growing season. Other studies (Zhao et al. 2011, Pang et al. 2013, Li et al. 2013) in fencing grassland in Ningxia showed that 5 years was a suitable enclosure time. The above discussions show that long-term, single enclosure management make grassland ecosystem degradation. It is suggested that modest disturbances such as ploughing, mowing and mild seasonal grazing are needed after 11 years enclosure.

By studying vegetation community structure and species diversity under different fencing time, it has been discovered that: (1) Under different fencing time, succession of the dominant species is followed: annual and biennial herb (not-fencing area), semi shrubs (6 years fencing area), semi shrubs and perennial herbs (11 years fencing area), perennial herb (23 years fencing area). (2) Compared with non-fencing area, vegetation characteristic values were significantly increased in 6 and 11 years fencing areas, and there were slightly higher values in 23 years area, but the difference was not significant. This study suggests that 6-11 years is appropriate enclosure time for grasslands in semi-arid areas.

ACKNOWLEDGEMENTS

This research has been financed by the National Natural Science Fund Projects (No. 31400619) of China and National Desertification Monitoring Program (No. 660550), State Forestry Administration of China. Thanks to my tutor for his guidance and correction of this paper. I am also grateful to other classmates for their generous help in the field investigation.

REFERENCES

Bo, Y.J., Zhang, X. and Ai, H.J. 2008. Species diversity in the wind sandy grass shoal area of Yulin region. Bulletin of Soil and Water Conservation, 28(4): 80-85.

Begona, P., Isabel, D.P. and Juan, T. 2005. The effect of grazing abandonment on species composition and functional traits: The case of grassland. Basic & Appl. Ecol., 6(2): 175-183.

Guo, Y.P., Zhang, J.T. and Liu, X.Z. 2005. Study on the species diversity of the plant community in Tianlong Mountain, Shanxi. Journal of Shanxi University (Natural Science Edition), (2): 205-208.

Gao, R.M., Shi, X.D. and Guo, Y.D. 2012. Community stability evaluation of Riparian forest of the upper reaches of Wenyuhe in Shanxi, China. Chinese Journal of Plant Ecology, 36(6): 491-503.

He, Y.H., Zhao, H.L. and Liu, X.P. 2008. Soil physical and chemical characteristics of sandy meadow in natural restoration process. Journal of Soil and Water Conservation, 22(2): 159 -161.

Jiang, D.M., Miao, R.H. and Toshio, O. 2013. Effects of fence enclosure on vegetation restoration and soil properties in Horqin sandy land. Ecology and Environmental Sciences, 22(1): 40-46.

Li, R., Zhang, K. B., Liu, Y. F., Wang, B.T., Yang, X. H. and Hou, R. P. 2008. Community spatial distribution pattern of wetland ecosystem in a semi-arid region of northwestern China. Journal of Beijing Forestry University, 30(1): 6-13.

Lu, X.J., Zhang, K.B. and Li, R. 2007. The study on main factor about influence of the living beings form covers in agriculture and animal husbandry of the North Interlocks. Research of Soil and Water Conservation, 14(6): 1-4.

Lu, X.J., Li, R. and Zhang, K.B. 2008. Influence of surface coverage on soil infiltration in the farming-grazing transitional zone. Bulletin of Soil and Water Conservation, 28(1): 1-5.

Li, F., Zhou, G.Y. and Yang, L.C. 2013. Effect of fence on biodiversity and stability of the main plant communities in the Qinghai Lake area. Research of Soil and Water Conservation, 20(4): 135-140.

Li, X.B., Chen, L. and Li, G.Q. 2013. Influence of enclosure on *Glyeyrrhiza uralensis* community and distribution pattern in arid and semi-arid areas. Acta Ecologica Sinica, 33(13): 3995-4001.

Mi, W.B. and Xie, Y.Z. 2006. The comprehensive summarization of ecological restoration and reconstruction. Research of Soil and Water Conservation, 13(2): 49-53.

Ma, K.P., Huang, J.H. and Yu, S.L. 1995. Plant community diversity in Dongling Mountain, Beijing, China: II species richness, evenness and species diversities. Acta Ecologica Sinica, 15(3): 268-277.

Pang, J.L., Zhang, K.B. and Wang, H.X. 2013. Effects of artificial enclosure on vegetation composition and plant diversity in arid and semi-arid region: Yanchi County, Ningxia as an Example. Journal of Northeast Forestry University, 41(2): 40-43.

Shan, G.L., Xu, Z. and Ning, F. 2008. Influence of enclosure year on community structure and species diversity on a typical steppe. Acta Pratacu Lt. Urae Sinica, 17(6): 1-8.

Shi, F.S., Wu, N., and Luo, P. 2007. Effect of enclosing on community structure of subalpine meadow in northwestern Sichuan, China. Chinese Journal of Applied & Environmental Biology, 13(6): 767-770.

Wang, Z.H. 2007. Dynamic principle of ecosystem restoration based on plant diversity. Chinese Journal of Applied Ecology, 19(9): 1965-1971.

Wang, L. and Zhang, J.T. and Shangguan, T.L. 2004. Species diversity of mountain meadow of Lishan and the relation with the soil physicochemical properties. Chinese Journal of Applied and Environmental Biology, 10(1): 18-22.

Wang, L., Xu, D.M. and Zhang, J.J. 2012. Effects of enclosure on composition of plant community and species diversity of desert steppe. Pratacultural Science, 29(102): 1512-1516.

Zhang, J.Y. and Zhao, H.L. 2010. An example for study on vegetation stability in sandy desertification land: determination and comparison of resistance among communities under a short period of extremely aridity disturbance. Acta Ecologica Sinica, 30(20): 5456-5465.

Zhao, C.Y., Wang, T. and Dong, Z.B. 2007. Plant diversity and its relationship with habitat in Korqin sandy land. Pratacultural Science, 24(4): 11-18.

Zhang, L., Xin, F. and Yu, L.L. 2008. Plant species diversity of the island forest in Amarsh in the Sanjiang Plain, China. Journal of Plant Ecology, 32(3): 582-590.

Zhu, X.Z. and Zhang, J.T. 2007. Application and assessment on the methods of species diversity measurement with absolute abundances. Journal of Beijing Normal University (Natural Science), 43(20): 72-75.

Zhang, J.T. 2011. Quantitative ecology (the 2nd version). Beijing: Science Press, 94-99.

Zhao, H.L., Zhang, T.H. and Zhao, X.Y. 2004. Effect of grazing on sandy grassland ecosystem in inner Mongolia. Chinese Journal of Applied Ecology, 15(3): 420-424.

Zhao, F., Xie, Y.Z. and Ma, H.B. 2011. Effects of enclosure on species diversity and soil organic matter of typical steppe. Pratacultural Science, 28(6): 887-891.