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Original Research Paper

Study on the Characteristics of the Vegetation in the Fenced Region of Ningxia in China

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ABSTRACT

Fencing has been used as a main measure for rangeland and pasture rehabilitation all over the world. By quadrat method, the vegetation of Yanchi County of Ningxia Hui Autonomous Region has been investigated for the impacts of different fencing time on vegetation community structure and biomass. The result shows that it increases biodiversity and makes the vegetation community more stable. But long time fencing is not conducive to vegetation recovery. The Biodiversity Index in the edge areas and peripheral areas reached to highest level in the 4th and 5th year after fencing respectively. The Richness Index (R_1) and Comprehensive Diversity Index (D, H) of the edge areas are 22, 2.26, 6.18, and those in the peripheral areas reach to 13, 1.67 and 3.24. Then biodiversity index decreased as fencing time increases. Under different fencing measures, the Biodiversity Index in the core area is the highest. So fencing is an effective measure for vegetation restoration. The vegetation coverage and biomass in the peripheral areas are the largest. This shows that rational uses of grassland are beneficial to vegetation recovery. Strip tillage doesn't have obvious effects on vegetation recovery, and it suggested that grazing or cutting can be used in this region for rangeland and pasture rehabilitation.

INTRODUCTION

Most pastures in the semi-arid areas are natural or half natural ecological systems with grazing as major disturbance. A non-equilibrium dynamic feedback relationship has been developed between cattle and pastures for years (Westoby et al. 1989). And the relationship is very important for drought pasture sustainable management (Oba et al. 2000). But in recent years, due to the sharp increase in the number of cattle, the pastures in arid areas have been degenerated already.

Artificial enclosure is one of the means to restore degraded pastures. As an important measure for pasture rehabilitation, enclosure has been used extensively all over the world (Meissner et al.1999, Turner 1990). Many studies on the impacts of enclosure on pasture rehabilitation indicate that enclosure can greatly improve the productivity of degraded pastures and increase the biodiversity of pasture ecosystem (Li et al. 1995, Yang et al. 2005). Based on the project of national desertification positioning monitoring, this article takes the artificial fenced region in Liu Yangpu of Yanchi County in Ningxia which is one of the farming-pastoral regions suffering from most severe desertification in northern China, as an example, to analyse the differences of the vegetation structure under different enclosure measures and time. It tries to find out the best enclosure measure and its optimal time range for desertification grassland.

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. The geographic position and condition of desertification of the study area is shown in Fig. 1. It is located in the coordinates of 37°042-38°102' N and 106° 302-107°412' E. The north-south distance of the county is 110km, and east-west distance is 66km. 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 hilly land with gentle slopes of the Erdos, the altitude of which is between 1295 and 1951 m. Its annual 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 yearly 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 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 Yanchi County's natural landscape to be the temperate zone prairie and wilderness prairie. The terrain is mainly

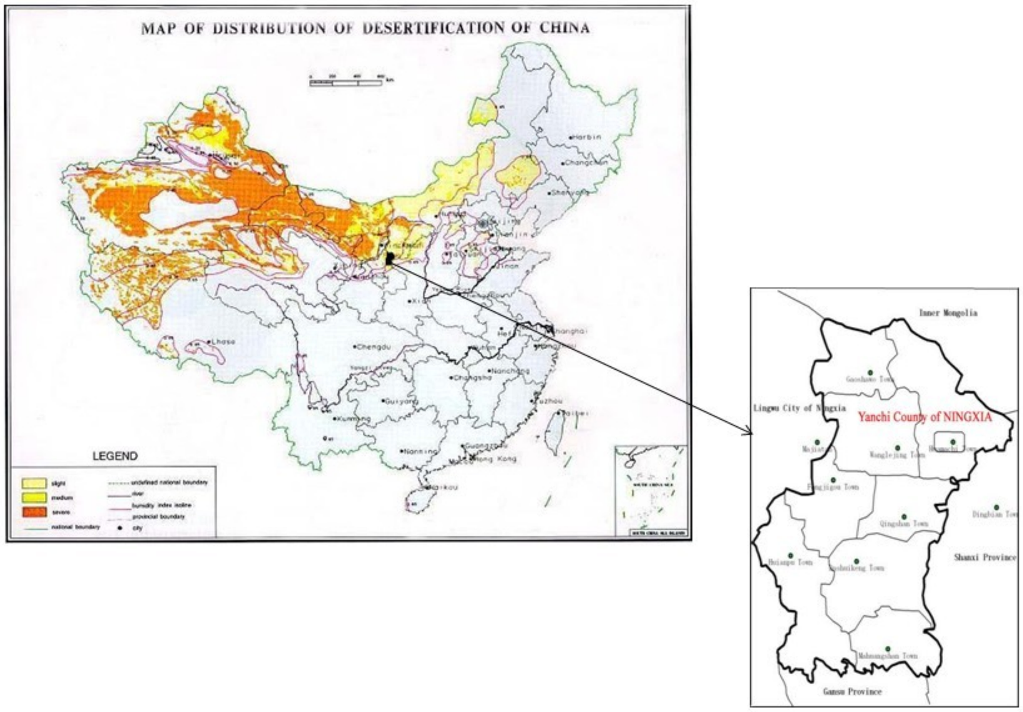

Fig. 1: The geographic position and condition of desertification of the study area in China.

denuded peneplain. The soil type there is primarily sierozem, then dark humus soil, 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 distributions. There is no natural forest in Yanchi County. It only has a few artificial forests, highwood and large area shrub 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*, *Thymusserphyllum* var. *mongolicus* and so on. Desert grassland includes *Caragana tibetica*, *Oxytro pisaciphylla*, *Nitraria sibirica* and *Kalidiu foliatum* (Zhang et al. 2004).

MATERIALS AND METHODS

Sample Plot Choosing

By referring to the achievements of the National Desertification Localization Monitoring Project and based on the land use types and the types of desertification control projects, we chose typical areas for fixed sample plots and located them with GPS for positioning monitoring. The artificial fenced region in Liu Yangpu was chosen as study area. Three processing methods were adopted: core area (E), edge area (E1) and outside area (E2). Wild animals and livestock feeding have been ruled out completely from core area by barbed wire fence since 1991. Enclosure measures have been taken in the edge area since 2002. Enclosure measures have also been taken in the outside area since 2002, but the area is still affected by human interference and herding. Three types of processing methods are at a straight line, so its natural conditions are basically the same.

Field Investigations

In this study, the investigation was done in each July from 2004 to 2009 in the aspects of plant species, quantity, degree of coverage, height and biomass, etc. The investigation method is to arrange quadrats randomly in the direction of belt transect and the size of the quadrat is 1 m × 1 m. There are 10 squares respectively in E, E1 and E2. Since 2005, parts of plot in E and E1 have been ploughed. Six quadrats have been made in the new ploughing areas.

Data Processing

Calculation of plant importance value: Importance value indicates the relative importance of plant species in the community by the comprehensive quantity of characteristic values. Importance value is also a key indicator to measure the

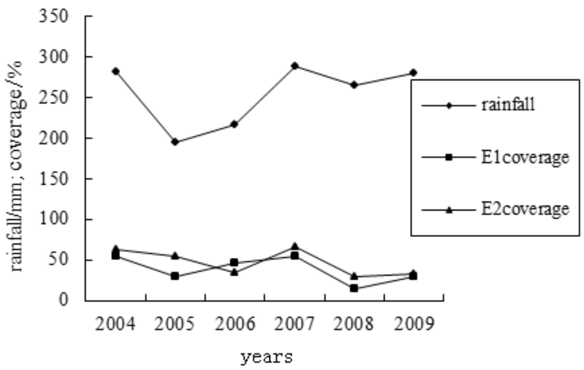

Fig. 2: The changes of vegetation coverage with rainfall.

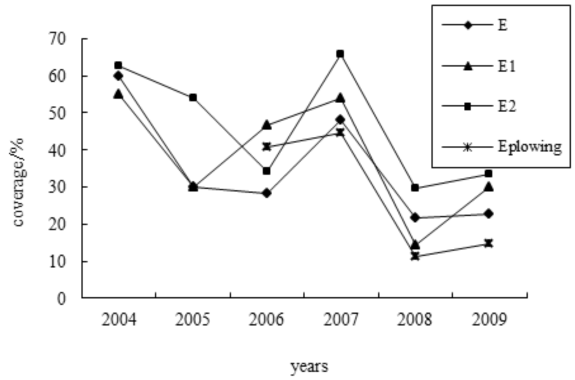

Fig. 3: Vegetation coverage under different fencing measures (%).

plant species in the community. So this article takes importance value as the metric. The formula is as follows (Zheng et al. 2005):

$$I = \frac{A + H + C + F + B}{5} \quad ...(1)$$

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

Biodiversity measures:

Abundance index: $R1 = S$ ...(2)

Measure ecological advantages by Simpson index (Ma et al. 1994).

$$D = 1/\sum p_i^{\,2} \quad ...(3)$$

Measure diversity of species by Shannon-Wiener index

$$H = \sum - p_i \ln p_i \quad ...(4)$$

Measure community evenness by Pielou index

$$E1 = H / \ln(s) \quad ...(5)$$

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.

RESULTS AND ANALYSIS

Comparison and Analysis of Plant Growth Situation in Different Years

The influence of enclosure time on species diversity: Abundance index reflects how rich plant species in the sample plot. Plant species richness degree of the sample plot depends on various ecological and non-ecological factors, such as conditions of soil nutrients, soil water content, habitat gradient, landform, human activities and so on. The main limiting factor for plant growth of the research area is soil moisture. From the Table 1 we can see that abundance index of the edge area and outside area increases first and then decreases. R1 of the edge area dropped slightly from 2004 to 2005 but continues to rise in the following years; in 2007 it reached to maximum 22 and then reduced sharply. R1 of the outside area began moving up from 2004 and ascended to maximum 13 in 2006; then in the following two years it began to drop and in 2009 it again increased a little. Abundance index rose at first because fencing prevents the destruction by humans so that the pastoral vegetation recovered and species diversity increased. After reaching to the maximum rate it began to decrease because the dominant species in the fencing area occupy most of the resources as fencing lasts. This makes the other specialized kinds of species to lose living space and eventually vanish (Table 1).

Comprehensive diversity index is influenced by abundance index and evenness index. It reflects regional vegetation characteristics and plant species diversity. From the Table 1, we can see that the comprehensive diversity index does not change much. D, H of the edge area are rising first and then reducing. The maximum value of diversity appeared in 2007. But considering the rainfall was rich in 2007, the change of comprehensive diversity index was not obvious. D, H of the outside area rose at first and then decreased. Little bounce back appeared in 2009. Its maximum value occurred in 2006. This is in line with the change of abundance

Table 1: Diversity indexes of plant community under different fencing time.

	E_1				E_2			
	R_1	H	D	E_1	R_1	H	D	E_1
2004	15	2.13	5.94	0.8	4	0.65	1.52	0.36
2005	13	2.08	5.49	0.81	6	1.13	2.32	0.63
2006	16	1.92	5.18	0.69	13	1.67	3.24	0.65
2007	22	2.26	6.18	0.73	11	1.5	3.23	0.63
2008	12	1.94	5.65	0.8	8	1.31	2.56	0.63
2009	12	1.98	5.64	0.8	10	1.49	3.46	0.65

Table 2: Vegetation coverage under different fencing time (unit: %).

	2004	2005	2006	2007	2008	2009
E_1	55±9.1	30±2.4	46.8±14.7	54±19.1	14.5±12.8	30±17.5
E_2	62.5±13.2	53.8±25.6	34.2±13.1	65.8±16.5	29.8±18.2	33.5±22.5

Note: the numbers in the table are means ± standard deviatins. The following are the same.

Table 3: Biomass under different fencing time (unit: kg/hm^2).

	2004	2005	2006	2007	2008	2009
E_1	4183±1128	1955±411	1556±781	3197±1775	691±427	1778±722
E_2	5220±1067	4018±1384	1475±920	3591±1472	1513±1277	1865±955

Table 4: Diversity indexes under different fencing measures.

	E				E_1				E_2				Eplowing			
	R_1	H	D	E_1	R_1	H	D	E_1	R_1	H	D	E_1	R_1	H	D	E_1
2004	10	1.85	4.54	0.8	15	2.13	5.94	0.8	04	0.65	1.52	0.36				
2005	08	1.64	3.92	0.79	13	2.08	5.49	0.81	06	1.13	2.32	0.63				
2006	20	2.14	5.42	0.71	16	1.92	5.18	0.69	13	1.67	3.24	0.65	20	2.05	4.94	0.68
2007	31	2.49	8.07	0.73	22	2.26	6.18	0.73	11	1.5	3.23	0.63	27	2.24	6.15	0.68
2008	19	2.36	7.67	0.8	12	1.94	5.65	0.8	08	1.31	2.56	0.63	12	2.03	6.05	0.82
2009	16	1.84	3.85	0.66	12	1.98	5.64	0.8	10	1.49	3.46	0.65	12	2.2	7.62	0.89

index R1. The overall changes of comprehensive diversity index illustrate that plant diversity increases under enclosure measures.

Evenness index reflects homogeneous degree of plant space distribution. The bigger the evenness index is, the more homogeneous the spatial distribution of plants is. The smaller the evenness index is, the more concentrated plant distribution is. Community evenness degree and community advantage degree are two opposite concepts. The higher the community advantage degree is, the more obvious the community dominant species are. The individual number and coverage degree of the dominant species higher than average kind of coverage significantly and community evenness degrees reduced (Cao et al. 2000). From the Table 1 we can see the change of evenness index every year is not obvious, except for 2004. The evenness index of the outside area in that year is low.

The influence of enclosure time on vegetation coverage: Table 2 indicates that the maximum of the coverage of edge area and outside area appeared in 2004 and 2007 respectively. Generally speaking, the vegetation coverage of 2008 and 2009 is lower than that of the previous years. This is mainly because the microbiotic or soil crusts prevent water infiltration as the length of enclosure time increases. The growth trend of vegetation coverage is slowing. This is similar to the conclusion in the studies on Maowusu sandland by Wang et al. (1994) and Li et al. (1999). Vegetation coverage is influenced greatly by rainfall, especially rainfall in plant growth season (Fig. 2). 2004 was a wet year and the rainfall in June and July was higher by 38% than the average. Rainfall of June and July in other years were about equal except for 2008 in which it rained little. So if we rule out the year 2004, the vegetation coverage reached to the secondary maximum in 2005 and 2006.

The influence of enclosure time on biomass: From the Table 3, we can see that the biggest biomass of the edge area and outside area ($4183kg/hm^2$ and $5220kg/hm^2$ respectively) appears in 2004. Then biomass was dropping year by year. The biomass improved greatly in 2007 but dropped dramatically in 2008 and rebounded slightly in 2009. The main reason of persistent decrease of biomass is that most plants are perennials with deep roots with increasing length of enclosure time. So underground biomass increases each year and the new part of ground biomass reduce. Soil crust also has impacts on water infiltration and thus affects vegetation growth. So the pastures taking enclosure measures for some years should be used appropriately. Otherwise, long-term enclosure will reduce economic value of the pasture. In addition, rainfall affects plant biomass considerably.

Comparison and Analysis of Plant Growth Situation Under Different Enclosure Measures

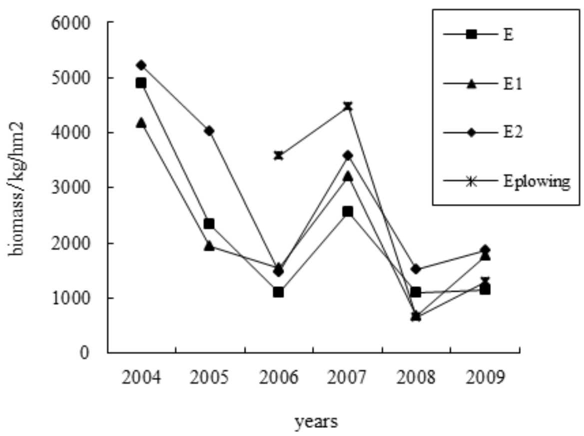

Fig.4: Biomass under different fencing measures (unit: kg/hm^2).

The influence of enclosure measures on species diversity: From the calculation results of biological diversity index under different enclosure measures (Table 4) we can see that the trend of the change of species diversity, ecological dominance index and community evenness is about the same in 2004 and 2005, that is, edge area>core area>outside area. In 2006 and 2007, the diversity indexes of core area are the highest; that of edge area and new ploughing area are the second highest; that of outside area are lowest. The changed trend of species diversity and ecological advantage degree are the same in 2008, i.e. core area>new ploughing area>edge area>outside area. And the trend of community evenness index is new ploughing area>core area = edge area>outside area. The changed trend of species diversity index in 2009 is core area>new ploughing area = edge area>outside area. The changed trend of ecological dominance index and community evenness is the same, that is, new ploughing area>edge area>core area>outside area. From this, we can see that as the length of enclosure time increases, the composition of plant communities tend to become complex and species diversity increases. Species number in community distributes unevenly and community is not in a steady state due to the gradual outstanding position of dominant species. From the changing state of each index of new ploughing area, we can see that appropriate utilization of pasture benefits for vegetation recovery.

The influence of enclosure measures on vegetation coverage: From Fig. 3 we can see that the vegetation coverage of outside area is the largest except for 2006. Second is the vegetation coverage of edge area; only in 2004 and 2008 the vegetation coverage of core area is bigger than that of the edge area. And the vegetation coverage of new ploughing area has minimum value except for 2006. Overall speaking, the vegetation coverage is outside area>edge area>core area>new ploughing area. This phenomenon is mainly because surface crust limits soil water infiltration as the length of enclosure time increases. Although outside area closed, activity of human or animal destroys earth crust occasionally. While although new ploughing area do not have crust, its soil structure has been destroyed and some seeds been turned elsewhere while turning over. Therefore, vegetation coverage is less.

The influence of enclosure measures on biomass: From Fig. 4 we can see the biomass of outside area is obviously higher than that of edge area under several enclosure measures. Average biomass for the years in edge area is slightly higher than that of core area. In the first two years, the biomass of new ploughing area is high, but in 2008 it dropped sharply to 643kg/hm^2. This is mainly because the rainfall in June and July, which is plant growth season, is less. The soil structure of new ploughing area is destroyed and the water retention of soil is poor. The low soil moisture content is against to plant growth. Biomass improved in 2009 and is higher than that of the core and edge area.

DISCUSSION AND CONCLUSION

By studying community biodiversity index under different enclosure measures, we discovered that the biodiversity of core area is the largest. This suggests that enclosure can improve biodiversity and make community composition stable.

The analysis of community biodiversity, vegetation coverage and biomass of different enclosure time shows that long-term enclosure is not conducive to vegetation restoration. Biological diversity index reaches to maximum at the fourth or fifth year, and then reduces gradually. According to the sustainability of grassland ecosystem theory, grassland should not be fenced timelessly. After some time with fencing, grassland should be used. And the length of time should be based on the degree of grassland degradation and the situation of grassland recovery (Zheng et al. 2005, Cheng et al.1995, Cheng et al. 1998). For the study, the fencing cycle should be four to five years. The overall trend of vegetation coverage and biomass is down.

Vegetation coverage and biomass of the outside area are the largest under different enclosure measures. This shows the appropriate use of pasture vegetation benefits to vegetation restoration. Community biodiversity and productivity cannot be increased significantly by long-term complete enclosure.

The research on vegetation characteristics of the new ploughing area shows that ploughing can increase biodiversity and improve community evenness, but its effect is not significant. Vegetation coverage and biomass of new ploughing area are less than three other areas. So ribbonlike ploughing is not a very good means for pasture use of Yanchi. The study suggests that proper herding or mowing should be allowed every four years or five years.

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