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The effects of different restoration measures on plant diversity and carbon sequestration in pastoral ecosystem

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Abstract:

Pature management measures such as fencing, the application of farmyard manure, and mechanical drilling have been implemented to address pasture degradation. This study explored the response patterns of grassland vegetation communities and soil nutrients under different restoration methods and compared the effects of these interventions.

The experiment was conducted in 2023 on degraded pasture in Chenbalhu Banner, Hulunbeier City, Inner Mongolia Autonomous Region. Four treatments were applied: control (CK), fencing (WF), farmyard manure (NJF), and mechanical drilling combined with farmyard manure (DNJF). In August of the same year, plant and soil surveys were conducted to evaluate the short-term restoration effects on plant community characteristics, biodiversity, and soil carbon and nitrogen content.

The results showed that WF, NJF, and DNJF significantly increased vegetation cover, density, and above ground biomass compared to CK, with notable improvements in community height and above ground biomass ($P < 0.05$). These treatments effectively enhanced plant diversity in degraded pastures, with WF having the most pronounced impact.

Analyzing plant functional groups revealed that perennial grasses exhibited the highest summed dominance ratio under WF, reaching 80.57%. All restoration methods promoted the growth of perennial grasses and increased the summed dominance ratio of C4 plants, thereby improving the light-use efficiency of the plant community. DNJF showed the greatest improvement in soil organic carbon and total nitrogen content

compared to WF and NJF. Correlation analysis indicated that DNJF strengthened the positive relationship between vegetation communities and soil nutrients.

In summary, the three restoration methods—fencing, farmyard manure application, and mechanical drilling combined with farmyard manure—had significant effects on degraded pastures. Fencing notably enhanced plant diversity, farmyard manure significantly boosted grassland productivity, and mechanical drilling effectively improved soil fertility. Among the methods, mechanical drilling combined with farmyard manure proved to be the most effective for the sustainable management of degraded pastures in Hulunbeier.

Introduction

Overgrazing is a key driver of grassland degradation, characterized by imbalances in grassland ecosystem structure and a diminished ability for self-regulation (Li B, 1997). This degradation is evident in reduced vegetation biomass, alteration in species composition, in increased soil compaction, higher sand content, and lower organic matter levels (Deng Y et al. 2021).

These changes adversely affect grassland productivity, leading to decreased outputs of agricultural products like livestock and herbs, while also compromising ecological functions such as air purification, water retention, soil conservation, and biodiversity protection (Zhang F, et al 2022). To mitigate pasture degradation, researchers have explored various restoration treatments, including no-tillage replanting, rational grazing, artificial grassland establishment, fencing, plowing, and fertilization, evaluating their effectiveness, advantages, and limitations (Gu C, et al. 2022, Yu S., et al. 2019, Sun X, 2024). Each restoration method has specific applications, benefits, and constraints. Based on the characteristics of the study area, this research focuses on three treatments: fencing, farmyard manure application, and mechanical drilling combined with farmyard manure.

Given the negative impacts of pasture degradation on both productivity and ecology, as well as the economic challenges of restoring extensive grassland areas, identifying cost-effective restoration strategies is crucial. This study examines degraded pastures in Chenbaerhu Banner, Hulunbuir City, Inner Mongolia Autonomous Region, using three treatments: fencing, farmyard manure, and mechanical drilling combined with farmyard manure. The study comprehensively analyzes the responses of vegetation characteristics, soil nutrients, and the interaction between vegetation and soil to these treatments, providing a scientific basis for optimizing ecological pasture restoration.

Methods

1.1 Study area

The study area is located in Wuzhuer Gacha, West Wuzhuer Sumu, Chenbaerhu Banner, Hulunbuir City, Inner Mongolia Autonomous Region, China (latitude 48°48′–50°12′N, longitude 118°22′–121°02′E). The research site is situated within a family pasture that has experienced severe degradation due to year-round grazing. This has led to low vegetation, reduced coverage, and a decline in high-quality forage species such as *Leymus chinensis*, along with decreased plant diversity.

1.2 Field sampling and sample collection

The experiment, initiated in May 2023, was conducted on a flat land plot with four treatments: control (CK), fencing (WF), farmyard manure (NJF), and mechanical drilling combined with farmyard manure (DNJF). Four transects were established, corresponding to the four treatments, each covering an area of 50 m × 600 m. A 10 m isolation zone was maintained between the transects to prevent cross-contamination. Farmyard manure consisted primarily of sheep and cow manure. Specialized soil drilling machinery was

used for the mechanical drilling treatment, designed to drill and loosen the grassland soil. The drilling parameters included a depth of 10 cm, a hole diameter of 5 cm, and a width of 7 cm.

Vegetation surveys were conducted using sampling methods during the plant growth period in August 2023. For each sample plot, the species present, their height, coverage, and density were recorded. Following plant sampling, soil samples were collected using a soil drill at two depth layers: 0–15 cm and 15–30 cm. Soil bulk density, soil organic carbon, and total nitrogen content are analyzed. The biodiversity of the sample plots was calculated using the following indices and Plant functional groups were classified based on life forms, water ecological types, and photosynthetic pathways. To quantify the dominance of functional groups within the community, the Summed Dominance Ratio (SDR4) was used as a comprehensive indicator. Data were analyzed using Excel 2021 and SPSS 22.

Results

2.1 Plant Community Characteristics and Species Diversity Under Different Restoration Treatments

2.1.1 Impact of Different Restoration Treatments on Community Characteristics

The plant community height and aboveground biomass were significantly higher under the WF, NJF, and DNJF treatments as compared to the CK treatment ($P < 0.05$). After applying WF, NJF, and DNJF, community height increased by 57.98%, 50.23%, and 57.83%, respectively, compared to CK. The increase in aboveground biomass was most pronounced under NJF, with a growth rate of 110.6% higher than that observed under WF and DNJF (Figure 1d).

There were also significant differences in the effect of the restoration treatments on the dominant species *Leymus chinensis*. Under NJF treatment, the height, density, and aboveground biomass of *Leymus chinensis* were significantly better than those under the other treatments ($P < 0.05$). In contrast, the density, coverage, and above-ground biomass of *Leymus chinensis* were lower under the WF treatment than under the other restoration methods.

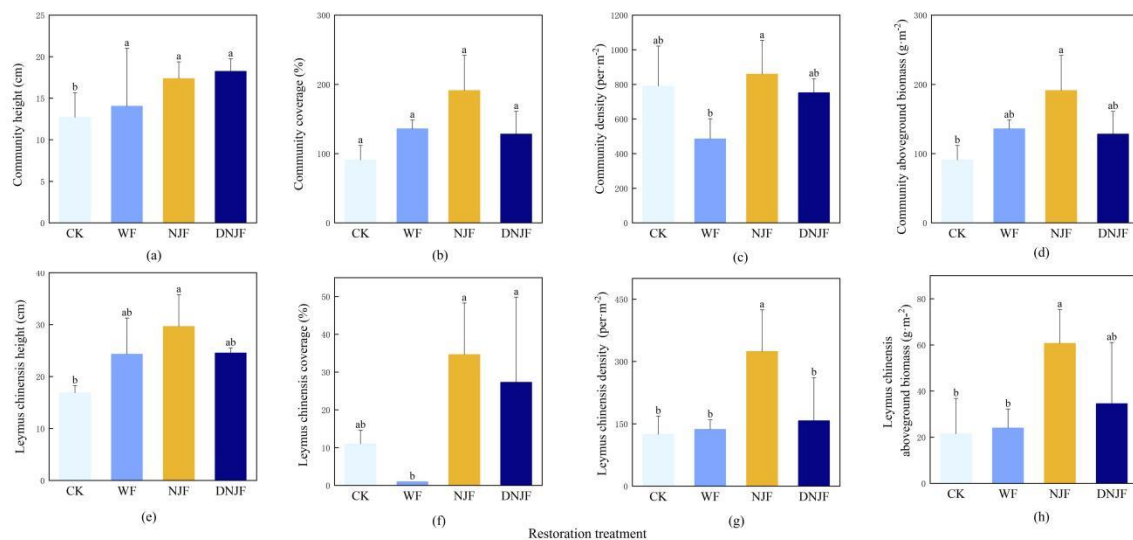


Figure 1 Effects of different restoration treatments on plant community characteristics

2.1.2 Impact of Different Remediation Treatments on the Alpha Diversity of Community Species

The Margalef richness index was significantly higher under the WF treatment than under the other treatments ($P < 0.05$) (Figure 2). The Pielou evenness index was highest under the CK treatment, followed by the DNJF and NJF treatments. The lowest Pielou evenness index was observed under the WF treatment. This suggests that, although species richness increased under WF, the uniformity of species distribution decreased.

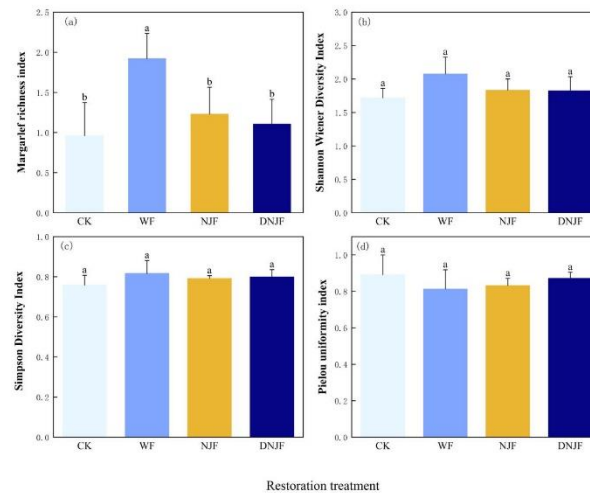


Figure 2 The impact of different restoration treatments on plants diversity

2.2 Impact of Different Restoration Treatments on the Summed Dominance Ratio of Plant Functional Groups

2.2.1 Summed Dominance Ratio of Community Life Form Functional Groups

The summed dominance of perennial forbs under WF treatment was significantly higher than that of CK, with an increase of 100.03%. Additionally, all three restoration treatments (WF, NJF, and DNJF) significantly reduced the ratio of sedges ($P < 0.05$). Specifically, the sedge ratio decreased by 38.59%, 24.14%, and 28.92%, respectively, as compared to CK. The ratio of annual grasses under NJF and DNJF treatments was significantly higher than CK, with increases of 216.63% and 284.32%, respectively (Figure 3a)..

2.2.2 Summed Dominance Ratio of Raunkiaer's Life Form Functional Groups

The summed dominance ratio of geophyte plants under WF treatment was the highest among the Raunkiaer life form functional groups (Figure 3b). In contrast, among the other three treatments, geophyte plants had the highest ratio under CK and NJF treatments. The summed dominance of geophyte plants in CK and NJF was significantly higher than in WF ($P < 0.05$), which was 1.74 times and 1.79 times greater, respectively.

2.2.3 Summed Dominance Ratio of Community Water Ecological Type Functional Groups

When categorizing plants based on their adaptability to water conditions (Figure 3c), xerophyte plants dominated the grazing plant communities. The summed dominance ratio of xerophyte plants under WF treatment was significantly lower than under CK and DNJF ($P < 0.05$), with reductions of 25.73% and 21.94%, respectively.

2.2.4 Summed Dominance Ratio of Community Photosynthetic Pathway Functional Groups

C3 plants dominated the plant communities under all treatments. However, the summed dominance ratio of C4 plants was higher after NJF treatment compared to the other treatments, with a significant increase of 1.47 times over WF ($P < 0.05$) (Figure 3d).

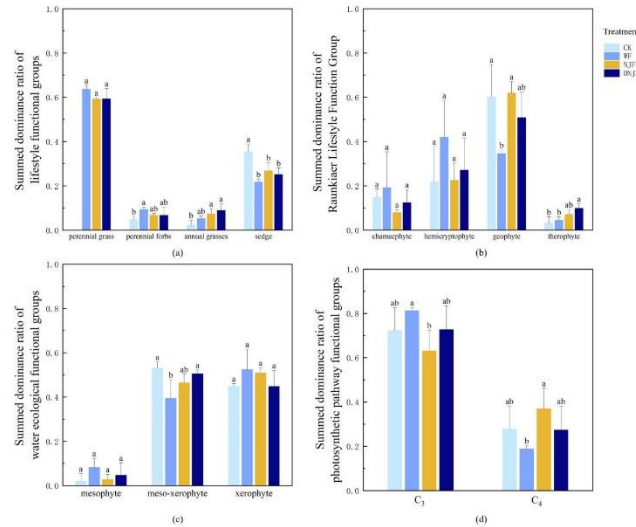


Figure 3 The impact of different restoration treatments on the comprehensive advantage ratio of plant functional groups

2.3 Impact of Different Remediation Treatments on Soil Carbon and Nitrogen Nutrients

The DNJF treatment had a significant effect on increasing soil organic carbon content in the top 0-15 cm soil layer ($P < 0.05$), with a 29.64% increase compared to CK (Figure 4a). The WF and NJF treatments increased organic carbon content by 26.19% and 23.32%, respectively, compared to CK. Among these, DNJF showed the most significant increase in organic carbon content. In the 15-30 cm soil layer, all three remediation treatments increased soil organic carbon content as compared to CK; with WF, NJF, and DNJF increased by 18.14%, 22.56%, and 20.53%, respectively. All three remediation treatments had a positive effect on increasing the total nitrogen content in the soil for both the 0-15 cm and 15-30 cm layers (Figure 4b). In the 0-15 cm soil layer, WF, NJF, and DNJF increased total nitrogen content by 8.46%, 14.97%, and 26.03%, respectively, compared to CK. In the 15-30 cm soil layer, the NJF and DNJF treatments increased total nitrogen content by 4.06% and 42.89%, respectively, compared to CK.

2.4 Impact of Different Remediation Treatments on the Correlation Between Plant and Soil Nutrients

Aboveground biomass, litter dry weight, community height, community coverage, species richness, the Margalef richness index, Shannon-Wiener index, and Simpson index were all negatively correlated with soil nutrients in both the 0-15 cm and 15-30 cm soil layers of CK treatment (Figure 5).

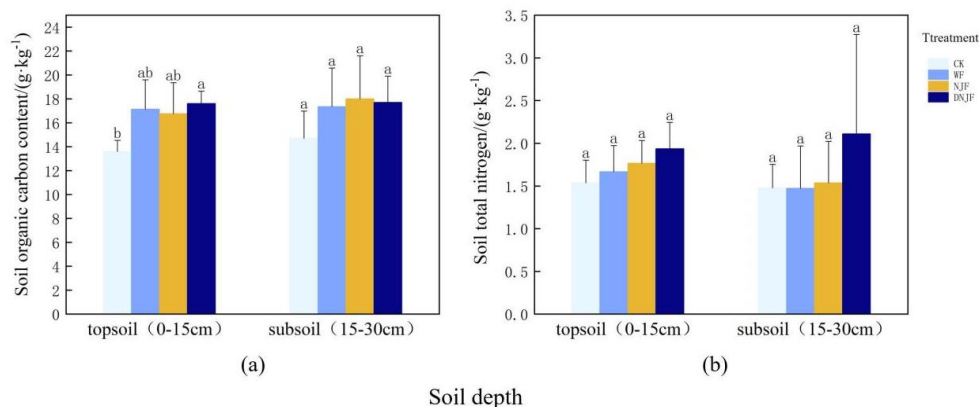


Figure 4 Effects of different remediation treatments on soil carbon and nitrogen nutrient content

Compared to CK, after the WF treatment, the correlation between vegetation indices and soil nutrients generally showed a downward trend, except for litter dry weight, community coverage, and community density. After the NJF treatment, there was a positive correlation between aboveground biomass, community height, and total nitrogen content in the 0-15 cm soil layer. Finally, following the DNJF treatment, the correlation between the Margalef richness index, Shannon-Wiener index, Simpson index, and soil nutrients became positive. Notably, compared to other remediation treatments, the positive correlation between plants and soil nutrients was strengthened under DNJF treatment.

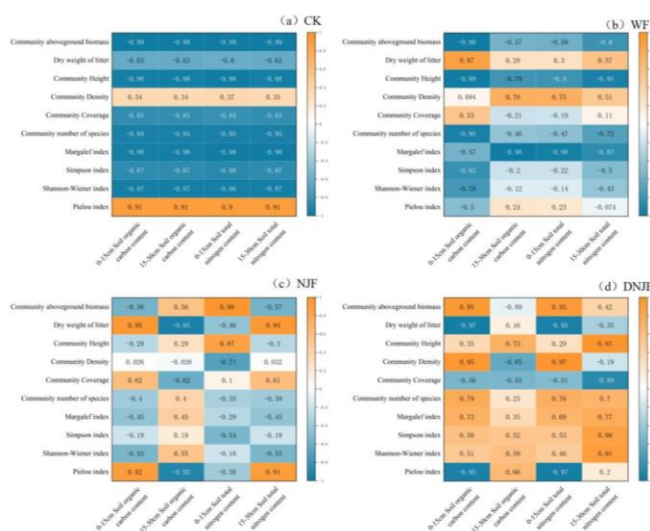


Figure 5 Correlation between Plant Community Characteristics and Soil Nutrients under Different Restoration Treatments in pasture

Discussion

All three restoration treatments promoted the growth of key vegetation indicators, such as aboveground biomass, but their specific effects on plant communities varied. Grassland fencing, a common method for protecting and managing grasslands, restricts human activities and livestock grazing. This approach can enhance the ecological status of grasslands, boosting productivity and biodiversity (Diao Z et al. 2011, Liu T, Yang J, Yang J, et al. 2019). Our results showed that fencing significantly increased aboveground biomass

and had the most pronounced effect on vegetation diversity compared to other treatments. From a community composition perspective, fencing increased the proportion of perennial grasses. However, the improvement in the growth of the dominant species, *Leymus chinensis*, was not significant. Liu Hongmei's study (Hongmei L et al. 2022) indicated that under fenced conditions, the germination rate of *Leymus chinensis* seeds is lower due to the absence of livestock trampling, which may affect seedling establishment. The higher proportion of drought-tolerant plants under fencing, as compared to other treatments, aligns with findings by Yin Guomei et al. (2014) in Hulunbuir. The plant community in fenced areas seems more suitable for arid and semi-arid environments, but it does not restore *Leymus chinensis* to a dominant position. This suggests that further research is needed to determine optimal fencing periods for effective grassland restoration.

Acknowledgements

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References

- Li B. (1997) Grassland degradation and its prevention and control measures in northern China[J]. Chinese Agricultural Science, (06):2-10.
- Deng Y, Li F, Yao S, et al. (2021) Vegetation and soil characteristics of degraded grasslands to varying degrees and their interrelationships[J]. Grassland science, 38(07):1260-1269.
- Zhang F, Li H, Yi L, et al. (2022) Spatial drivers of grassland degradation on surface soil organic carbon, total nitrogen, and total phosphorus in alpine meadows of Sanjiangyuan National Park[J]. Journal of Ecology, 42(14):5586-5592.
- Gu C, Jia Z, Du B, et al. (2022) Overview and Prospect of Ecological Restoration Measures for Degraded Grasslands in China[J]. Journal of Ecological Environment, 31(07):1465-1475.
- Yu S, Xu D, Xu A, et al. (2019) The impact of different restoration measures on soil carbon and nitrogen storage in desert grasslands of Ningxia[J]. Acta Prataculturae Sinica, 28(03):12-19.
- Sun X, Du H, Hasbat'er, et al. (2024) Effects of root cutting + fertilization on the grass yield and seed bank of *Leymus chinensis* artificial grassland.[J]. Chinese Journal of Grassland, 46(06):77-85.
- Kou S, Xiao M. (2019) Soil AM fungi diversity and its correlation with soil factors in degraded grasslands of Hulunbuir.[J]. Green Technology, (4):1-6.
- Wang D, Song Q, Liu Z, et al. (2022) Effects of land use on soil microbial community structure in Hulunbuir grasslands.[J]. Grassland Science, 39(03):421-430.
- Zhang H, Bao H, He Z, et al. (2023) Analysis of ecological environment quality changes and trends in Inner Mongolia from 1990 to 2021: A case study of Chifeng, Inner Mongolia. [J]. Arid Zone Research, 40(02):326-336.
- Wang X, Yan R, Deng Y, et al. (2014) Effects of grazing on the temperature sensitivity of soil respiration in *Stipa baicalensis* meadow grasslands.[J]. Environmental Science, 35(5):1909-1914
- Kuang M, Zhou G, Zhou M, et al. (2024) Environmental drivers of species diversity and productivity in alpine grasslands of Tibet.[J]. Journal of Ecology, 44(14):6254-6264.
- Diao Z, Feng Z, Xu L, et al. (2011) Changes in plant diversity inside and outside fencing: A case study of Huihe Nature Reserve. [J]. Soil and Water Conservation Research, 18(5):148-151.
- Liu T, Yang J, Yang J, et al. (2019) Effects of fencing on plant communities and soil nutrient changes in desert grasslands.[J]. Chinese Journal of Grassland, 41(5): 86-93.
- Hongmei L, Yanling W, Yingxin L, et al. (2022) Free-Grazing versus Enclosure Lead to an Increase in the Germination of the *Leymus chinensis* Seed Bank in the Hulunbuir Grassland[J]. Agronomy, 13(1):22-22.
- Yin G, Zhang Y, Wang M, et al. (2014) Short-term fencing effects on community characteristics and species diversity in meadow grasslands.[J]. Chinese Journal of Grassland, 36(03):61-66.