Grassland degradation caused by tourism activities in Hulunbuir, Inner Mongolia, China

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Abstract. The recent increase in the number of tourists has raised serious concerns about grassland degradation by tourism activities in Inner Mongolia. Thus, we evaluated the effects of tourism activities on the vegetation and soil in Hulunbuir grassland. We identified all the plant species, measured the number and height of plant and plant coverage rate, and calculated species diversity, estimated above-ground biomass in use plot and non-use plot. We also measured soil hardness, and collected soil samples for physical and chemical analysis in both plots. The obtained results were as follows: a) the height of the dominant plants, plant coverage rate, species diversity, and above-ground biomass were significantly lower in use plot than in non-use plot, b) Carex duriuscula C.A.Mey., indicator plant for soil degradation, was dominant in use plot, c) soil hardness was significantly higher in use plot than in non-use plot, and spatial dependence of soil hardness was only found in the use plot, d) CEC, TC, TN and pH in the topsoil were significantly lower in use plot than non-use plot. On the basis of the results, we concluded that the tourism activities can be another major cause of the grassland degradation in Inner Mongolia.

1. Introduction
Grasslands in China cover nearly 4 million km², more than 40% of its total land area [1]. In recent years, grassland degradation has become a major environmental problem in China, especially in the arid, semi-arid and dry semi-humid climatic zones. Whereas China was hit by almost 70 sandstorms over the past century [2], the frequency of sandstorms in north China appears to be a direct
consequence of grassland degradation [3-4].

Inner Mongolia is located in northern China and is one of the largest grassland regions in the world. By the end of the 20th century, almost 90% of grassland in Inner Mongolia has been degraded to a varying degree as a consequence of a rapid increase in livestock numbers and economic development [5]. According to previous researches, major causes of this grassland degradation are said to be over-cultivation and overgrazing [6-7].

On the other hand, domestic tourism market has grown with the development of the infrastructure from the 90’s [8] and now grassland tourism is popular in Inner Mongolia. Therefore, there are fears that tourism activities can be another major cause of grassland degradation [9-10]. The objective of this study is to evaluate the effects of tourism activities on soil and vegetation in the grassland in Inner Mongolia.

2. Materials and methods

2.1. Study area
Field experiments were conducted in August, 2010, July and August, 2011. Study area is located in the tourist site of Old Barag Banner (49°15'54"N 119°11'41"E; average elevation, 626m) in the central part of Hulunbuir grassland, Inner Mongolia. The Hulunbuir grassland was chosen as a study site because it is the one of the most popular tourism resources in Inner Mongolia [11]. The mean annual temperature and precipitation in the study site are -5.6°C and 272.8mm. According to the Food and Agriculture Organization (FAO) classification, the soil is classified as Kastanozems. The site was a clipping pasture before changed to tourist site. The business period of this tourist site is from June to August, and according to estimates by the authors, the annual number of visitors is approximately 10,000. We established two experimental plots (use plot and non-use plot) with/without the tourism activities in the study site.

2.2. Vegetation survey
At each plot, we first identified all the plant species within three quadrates of 1 m² randomly, and then, measured the number and height of each plant and plant coverage rate. Above-ground biomass was calculated from the following equation we found in the preliminary experiment:

$$B_i = B_{i1} \times H_i \times S_i$$

where, $B_i$ is the estimated above-ground biomass of species $i$ (g), $B_{i1}$ is the above-ground biomass per unit plant per unit height of species $i$ (g plant$^{-1}$ m$^{-1}$), $H_i$ is the mean height of the species $i$ (m), and $S_i$ is the number of plants in the species $i$ (plant).

Species diversity was obtained from Shannon-Wiener diversity index [12], while dominant species was estimated by dominance analysis [13].
2.3. Soil survey and physico-chemical analysis

Soil hardness of the topsoil was measured every about 400 m² with five replicates (434 points in the study site) using the Yamanaka-type soil hardness tester (Fujiwara Scientific Co., Japan). We also collected soil samples from each soil horizon up to 1 m deep in both plots. The collected soil samples were air-dried and passed through a 2mm pore-size sieve for physical and chemical analysis. Finely ground soil samples were also prepared for the analysis of total carbon (TC), and total nitrogen (TN) using elemental analyzer (NC-800-13N; Sumika Chemical Analysis Service Co., Japan). The pH of soil-water suspension at a ratio of 1:5 were measured by the glass electrode method after shaking the mixtures for 1 hour, and the electrical conductivity (EC) of the solutions were then determined. Soil particle size distribution was determined by a sieving and pipette method. Cation exchange capacity (CEC) was determined using the Semi-Micro Schollenberger method, and the contents of exchangeable Ca, Mg, Na, and K were quantified by atomic absorption spectrophotometry (AA-160; Shimadzu Co., Japan).

2.4. Statistical and geostatistical analyses

The difference of mean values of the number and height of dominant plants, species number, above-ground biomass, plant coverage rate, species diversity and soil hardness between use plot and non-use plot were tested using t-test at a probability level of 0.05. Statistical Analysis was performed using R2.12.2 [14].

According to Yanai and Kosaki (2000) [15], a semivariogram was used to evaluate the spatial variability of the soil hardness and two indices were calculated: the Q value (an index of the degree of development of spatial dependence at the sampling scale), and the range (an index of the limit of spatial dependence). Geostatistical analysis was conducted with GS+ Version 9 for Windows [16].

3. Results and discussion

3.1. Effects of tourism activities on vegetation

_Artemisia frigida_ Willd. (Asteraceae), _Potentilla acaulis_ L. (Rosaceae), and _Carex duriuscula_ C.A.Mey. (Cyperaceae) are regarded as indicator plants for grassland degradation [17]. _C. duriuscula_ and _L. chinensis_ (a variety of high-quality grass) was dominant in non-use plot, but only _C. duriuscula_ was dominant in use plot [10]. The height of the dominant plants, plant coverage rate, species diversity, and above-ground biomass were significantly lower in use plot than in non-use plot, and it was the height of the dominant plants that was mostly affected by tourism activities [10] (Table 1). Therefore, the height of the dominant plants, plant coverage rate, species diversity, and above-ground biomass will be the good indices for evaluating the effects of tourism activities on vegetation in the tourist site.
Table 1. Information of vegetation in both plots of the study area (the data from [10]).

| Plant coverage rate | Above-ground biomass | Plant species diversity index | Height of dominant plant | No. of dominant plant |
|---------------------|----------------------|-------------------------------|--------------------------|----------------------|
| Use plot            |                      |                               |                          |                      |
| Mean ± SE           | 48.2±3.7             | 44.0±4.9                      | 5.0±0.8                  | 0.7±0.3              |
| Non-use plot        | 71.6±2.5             | 65.0±3.2                      | 8.4±1.4                  | 1.6±0.2              |
|                      |                      |                               | 27.8±2.7                 | 34.7±1.4             |
|                      |                      |                               | 15.7±0.4                 | 45.0±13.6            |
|                      |                      |                               | 13.4±2.0                 | 187.8±33.0           |
|                      |                      |                               |                          |                      |
| L.c                 | 10.0±0.4             | 10.9±0.8                      | 8.8±0.2                  | 33.6±16.0            |
| S.b                 | 33.2±18.0            | 23.4±11.0                     | 35.5±15.5                | 20.5±9.1             |
| C.d                 | 552.6±101.2          | 450.0±136.0                   | 13.4±2.0                 | 187.8±33.0           |
| p                   | ***                 | **                          | n.s.                    | ***                 |

***: p<0.001     **: p<0.01  *: p<0.05  n.s.: not significant
L.c: L.chinensis; S.b: S.baicalensis; C.d: C.duriuscula

3.2. Effects of tourism activities on soil chemical properties

Table 2 shows the physical properties in both plots. According to the USDA system, the particle size distribution was classified as sandy clay loam in use plot, and sandy loam~loam in non-use plot. Since the fine sand and silt are prone to wind erosion, degradation of vegetation will easily lead to severe wind erosion [18].

Table 3 shows the soil chemical properties in both plots. For OC of the topsoil, the concentration in non-use plot was 18.2 g kg⁻¹, which was obviously higher than 14.3 g kg⁻¹ in the use plot. The same tendency was found for TN and CEC. These decreases should be related to the difference in the above-ground biomass in both plots. In the use plot, vegetation was sparse, and often, the bare ground was seen where the tread pressure of tourists appears to be high. In the contrary, vegetation in the non-use plot was relatively exuberance because of the low tread pressure of tourists and grazing pressure. The CaCO₃ content was 0.1~19.2 g kg⁻¹ in the use plot, while it was zero in the non-use plot. Reflecting the results, EC and pH in the non-use plot were lower than those in the use plot. For the exchangeable bases, the Ca contents were higher than the other bases and Na was not accumulated in both plots. Because soil degradation (decrease in OC, TN, CEC) should be closely related to the degradation of vegetation caused by tourism activities, it was concluded that tourism activities can degrade soil chemical properties in Hulunbuir Grassland.

Table 2. Soil particle distribution in both plots of the study area.

| Location | Depth (cm) | Horizon | Rock fragment | Sand (2-0.2) | Silt (0.05-0.002) | Clay (<0.002) | USDA system | International system |
|----------|------------|---------|---------------|--------------|-------------------|--------------|--------------|----------------------|
| Use plot | 0-43       | A       | 0.0           | 2.2          | 33.2              | 17.6         | 30.8         | 16.1                 | Loam                 | CL                   |
|          | 40-63      | Bk      | 0.0           | 2.2          | 23.2              | 15.5         | 35.5         | 23.4                 | Loam                 | CL                   |
|          | 63-90      | BCk     | 0.0           | 8.2          | 36.1              | 9.6          | 25.6         | 20.5                 | Sandy clay loam      | CL                   |
|          | 90-100+    | Ck      | 0.0           | 4.4          | 26.6              | 13.4         | 33.3         | 22.4                 | Loam                 | CL                   |
| Non-use plot | 0-43   | A       | 0.0           | 0.8          | 34.5              | 16.9         | 30.1         | 17.7                 | Sandy loam           | CL                   |
|          | 40-63      | AC      | 0.0           | 0.9          | 26.3              | 15.5         | 30.1         | 27.1                 | Clay loam            | LiC                  |
|          | 80-90+     | C       | 0.0           | 0.4          | 25.2              | 18.9         | 34.2         | 21.3                 | Loam                 | CL                   |
3.3. Effects of tourism activities on soil hardness

The mean soil hardness in the use plot was 23.0 mm (pressure unit) that was significantly higher than that in the non-use plot (17.6 mm) (P<0.001). This result was consistent with that of Wu et al. (2004) [6] in which they categorized Xilingol grassland of Inner Mongolia into four types according to the degree of degradation by grazing (non-degradation, light degradation, moderate degradation, severe degradation) and showed that soil hardness was 12.1, 18.5, 19.4, and 20.4 mm, respectively. Since the soil hardness in the use plot (23.0 mm) was higher than that in the grassland classified as “severe degradation” (20.4 mm), the tourism activities can degrade surface soil more seriously than the grazing. In the use plot, high soil hardness was found on the footpaths (30 mm) formed by the trampling of the tourists where the vegetation coverage rate was 0%, and around the aobao (place of worship) (27 mm), horse tying post (23 mm), and large yurt (24 mm).

Figure 1 shows the semivariogram of soil hardness in the non-use plot and use plot. The range in the use plot was 111 m (P<0.001) and the Q value was 0.7, indicating high spatial dependence. In contrast, spatial dependence was not found in the non-use plot. These results suggested that the tourism activities degraded surface soil within the range of 111 m in the study site.

![Figure 1. Semivariogram of soil hardness in both plots of the study area.](image-url)
4. Conclusions

The effects of tourism activities on soil and vegetation in Hulunbuir grassland was evaluated in this study. On the basis of the above-mentioned results, we concluded that the tourism activities can be another major cause of the grassland degradation in Inner Mongolia. We also found that when tourism facilities (yurt, horse tying post, and so on) are moved to avoid further land degradation by tourism activities, they should be moved more than 111 m away from the original location because the range of the soil hardness in the use plot was 111 m.

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