

Original Research

Effects of Grassland Tourism on Alpine Meadow Community and Soil Properties in the Qinghai-Tibetan Plateau

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Abstract

Grassland tourism is a new form of grassland utilization based on grassland ecological environments. Tourism is a double-edged sword that can solve poverty in pastoral areas, but it also causes ecosystem degradation. The impact of tourism on alpine grassland was analyzed by the community and soil properties. Results showed that the most immediate influences of grassland tourism are frequent trampling and crushing. Trampling significantly decreases species diversity. Tourism reduced litter biomass, soil nutrient supply and soil enzyme activities, thus adversely affecting the whole plant-soil system. Therefore, this problem should attract decision makers' attention to balance the relationship between tourism management and economic benefits. Our results suggest that the premise of trade-off between economic benefits and environmental protection is controlling the number of tourists during the peak tourism season, which should be factored for achieving a win-win outcome to dispose of ecosystem degradation and poverty in pastoral areas.

Keywords: grassland community; soil properties; grassland sustainability; tourism disturbance

Introduction

Tourism has become one of the fastest growing industries over the last decades in the world. Grassland tourism is a new form of grassland utilization based on grassland ecological environments. Grassland is a widely distributed biome type and covers 41.7% of territory in China [1]. Moreover, grassland is the largest

terrestrial ecosystem and provides both the material basis for animal husbandry production and homes for many ethnic minorities. Grassland is a complex of natural, social and culture landscapes, therefore, grassland tourism is acting as a key development role in many regions [2]. However, the effects of the rapid development of grassland tourism has an obvious double-edged effect on grassland ecosystems.

The pressures from population increase, cultivated land expansion and landscape fragmentation result in the consequence that animal husbandry is incapable of supporting improvements in living standards of

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herders [3]. It is necessary to raise the profile of the issues involved and to improve our understanding of the applied ecology requirement for successful management [4, 5]. Evidently, tourism can integrate these grasslands of marginalized areas with modern society, and benefit pastoral areas by alternative forms of employment and by promoting diversification of a region's secondary industry [2]. Moreover, tourism can increase the income of pastoral households, especially during the peak tourism time. In return, tourism revenue is an essential incentive for local residents to protect the ecology and landscape diversity [6]. Therefore, many researchers generally believe that grassland tourism is an effective way to increase the incomes of the local population and also potentially improve ecosystem protection [7]. With substantial support from governments, grassland tourism has developed rapidly in recent years in China. A large number of tourists go into the pastoral area, which will inevitably have some negative impact on the grassland ecosystem.

Many fixed buildings and hardened road surfaces have been built in view of scenic locations, where a large number of tourists and vehicles arrive during the peak tourist time, and thereby rapid degradation can occur near this infrastructure [2]. The impact of grassland tourism disturbance is directly reflected upon local vegetation and soil [8]. The booming grassland tourism and imperfect management measures have a significant impact on regional grassland biodiversity and ecological environment. The grassland vegetation in tourist spots has been destroyed by frequent trampling and crushing. These effects have resulted in widespread vegetation loss and soil degradation, such as a reduction of plant species diversity and vegetation cover, and deterioration in soil structure and soil nutrients [9-11]. Of particular importance is the fact that tourism disturbance has a large influence on soil physical and chemical properties, such as increased soil bulk density, decreased soil water content and electrical conductivity [12]. There was a close correlation between topsoil physical-chemical properties and plant community characteristics as the disturbance process of tourism activities to grassland were virtually synergistic response processes within the plant-soil system, where the response of a plant system preceded the response of a soil system in the process [13]. Alpine grasslands are located in the northeast margin of the Qinghai-Tibetan Plateau, and serve as a natural ecological barrier of western China [14]. The plateau plays an important role in providing ecosystem-regulating services such as reducing erosion by supporting slope stability and supporting biodiversity and cultural services [15]. In recent years, the tourism industry in alpine grasslands has developed rapidly. According to the analytical results, the construction of a tourist attraction in Sangke Prairie was completed with an investment RMB 21.5 million yuan in 2011 [16]. The development of tourism and the resultant trampling by vehicles and pedestrians has seriously interfered with the ecology and environment of the alpine grasslands.

The influence on regional climate, rainfall and other natural factors is quite different — especially when vegetation degradation factors are often neglected or its impact is overshadowed by lucrative tourism revenue. The aim of this study was to analyze (1) the impact of tourism in alpine grassland on community property and (2) the impact of tourism in alpine grassland on soil property and soil enzyme activities. The results will contribute to provide a reference for tourism development, management and environmental protection in alpine grasslands.

Material and Methods

Study Area

The study site is located in Sangke Prairie tourist spot, within Xiahe Country, Gansu Province (102°21'–102°29'E, 34°59'–35°09'N, 3050 m), with a 70 km² grassland area and a typical cold-humid climate. According to data available for the period 2010-2015 at the study site from the National Meteorological Information Center of China, the mean annual temperature is 4°C and mean annual precipitation is 32 mm. The main natural grassland type is alpine meadow and the dominant plants are mainly *Poa annua*, *Potentillae chinensis*, *Polygonum aviculare*, and *Artemisia subulate* in the study site.

The experiments were conducted in a tourist spot including the viewing area (disturbed), where visitors can enter and play, and the fencing area (undisturbed) where visitors are not allowed in. Both disturbed and undisturbed areas were gentle slopes with the same slope aspect. In the middle of August 2017, when the grassland community biomass peaked, five 20 × 20m plots were randomly selected in both disturbed and undisturbed areas and five 1 × 1m quadrat were examined at 5m intervals along the transect in each plot.

Aboveground Plant and Soil Sampling

In each quadrat, all green aboveground plant parts for each individual species, as well as the entire litter layer, were cut, collected and put into envelopes and tagged [5]. Species richness embodied the number of species in each quadrat. Soil samples were collected with a soil drilling sampler (3.8 cm i.d.) corer at three points in the quadrats of each plot. The samples in soil layer were collected at intervals of 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm. The samples from the same layer were mixed to produce one mixed sample in a quadrat. All the soil samples were air-dried and sieved through a 2-mm screen, and roots and other debris were removed by hand. Soil bulk density of each soil layer was measured using a soil bulk sampler with 100 cm³ volume stainless steel cutting rings, with three replicates in each quadrat [4]. Soil moisture content was measured by taking soil samplers with three sites

randomly chosen for sampling at each quadrat and all samples were weighed in aluminum boxes and then oven-dried at 105°C to constant weight. Soil moisture content was calculated as the proportion of mass loss during oven-drying to a constant weight after drying. Soil total nitrogen was determined using the modified Kjeldahl method [17], total phosphorus was measured by the methods of Miller and Keeney [18], and soil organic carbon was assayed by dichromate oxidation [19]. Soil urease, sucrase, and phosphatase enzyme activities were measured by sodium carbolate colorimetric method, 3-5 dinitrosalicylic acid colorimetric method, and phenylene-disodium phosphoric acid colorimetric method, respectively [20]. Each analysis was carried out in three replicates.

Statistical Analyses

The differences between the aboveground biomass, richness and litter biomass for disturbed and undisturbed grassland were examined by t-tests following ANOVA. All data were expressed as the mean±standard error (s.e.). The differences in soil total nitrogen content,

total phosphorus content, soil organic carbon content, and soil enzyme activities between disturbed and undisturbed were assessed by using analysis of variance and significant differences evaluated at 0.05 and 0.01 levels. All of the statistical tests were carried out using SPSS version 12.0 (SPSS Inc., Chicago, IL, USA).

Results and Discussion

Effects of Tourism on Plant Community Characteristics

The richness was 13.33 ± 1.15 in disturbed grassland, which was significantly lower than that in undisturbed grassland (17.67 ± 2.52) at the peak growing season ($P < 0.05$; Fig. 1a). Tourism interference significantly decrease aboveground biomass and litter biomass with an average decrease rate of 56.12% and 52.83%, which indicated that disturbed grassland significantly decreases plant biomass compared to undisturbed grassland ($P < 0.05$; Fig. 1(b, c)).

Tourism Interference Effects on Soil Physical and Chemical Properties

Soil moisture content was significantly affected by tourism interference (Fig. 2). Soil moisture in disturbed grassland was lower than undisturbed grassland across 0-40 cm soil profile, especially in the 0-10 cm and 10-20 cm soil layer. Soil moisture in undisturbed grassland was significantly higher than in disturbed grassland ($P < 0.05$). However, compared to soil moisture content, soil bulk density and soil compaction showed the increasing trend in disturbed grassland, where the two physical properties in disturbed grassland were significantly higher than in undisturbed grassland across 0-40 cm soil profile ($P < 0.05$; Table 1).

Tourism interference led to a decrease in soil chemical properties. Soil total nitrogen content and soil organic carbon content reduced remarkably

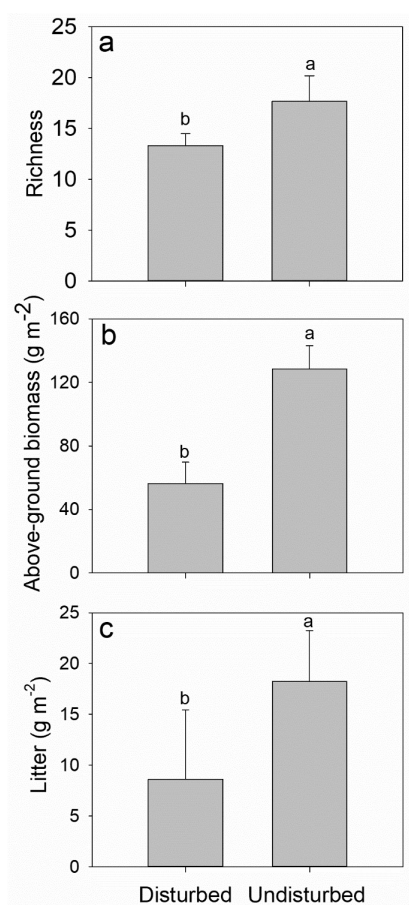


Fig. 1. Effect of tourism (disturbed) and fencing (undisturbed) on richness a), above-ground biomass b) and litter biomass c) of grassland communities; the bar represents mean±s.e. (n = 25) and the significant differences between disturbed and undisturbed are indicated by lowercase letters ($P < 0.05$).

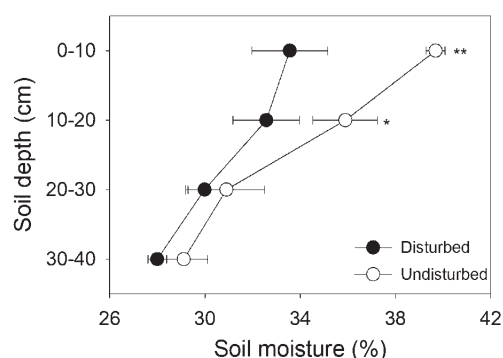


Fig. 2. Effect of tourism (disturbed) and fencing (undisturbed) on soil moisture content; bar represents mean±s.e. (n = 25), and significant differences between disturbed and undisturbed grasslands are indicated by symbols: **, $P < 0.01$ and *, $P < 0.05$.

Table 1. Effects of tourism (disturbed) and no-tourism fencing (undisturbed) on soil physical properties (mean \pm s.e., n = 25) of different soil depths.

	Soil depth(cm)	Disturbed	Undisturbed
Bulk density (g cm ⁻³)	0-10	1.18 \pm 0.13*	0.85 \pm 0.18
	10-20	1.21 \pm 0.09*	0.96 \pm 0.11
	20-30	1.33 \pm 0.12*	1.09 \pm 0.10
Soil compaction (kPa)	0-10	655.67 \pm 25.87**	533.72 \pm 30.23
	10-20	709.36 \pm 35.86**	468.91 \pm 33.65
	20-30	725.36 \pm 36.64*	668.05 \pm 20.78

Note: Significant differences between disturbed and undisturbed grasslands are indicated by symbols: **, P<0.01 and *, P<0.05.

in disturbed grassland in the 0-40 cm soil profile (Fig. 3(a, c)). Tourism interference significantly reduced the total phosphorus content in deep soil (20-40 cm; P<0.05), although there were no changes in shallow soil (0-20 cm; Fig. 3b).

Tourism Interference Effects on Soil Enzyme Activities

Tourism interference resulted in a significant decrease in soil urease and phosphatase activities in the 0-40 soil profile (Fig. 4a). Soil urease and phosphatase activities were 1.18 \pm 0.21 mg g⁻¹ d⁻¹ and 292.32 \pm 23.10 mg g⁻¹ d⁻¹ in undisturbed grassland, which were significantly higher than 0.67 \pm 0.11 mg g⁻¹ d⁻¹ and 236.61 \pm 20.02 mg g⁻¹ d⁻¹ in disturbed grassland (P<0.05). The changes of soil sucrase activity mainly occurred in the surface soil (0-10 cm; Fig. 4c). Tourism interference significantly decreased the sucrase in 0-10 cm soil layer (P<0.05), but there were no obvious effects in the 10-40 cm soil layer (P>0.05).

Increased leisure time and private vehicle use have led to a greater use of natural and semi-natural habitats for recreation. As a result, a series of new problems have arisen, such as an urgent need to assess the impact of recreation on the environment. The

most direct impact of tourism on grasslands has been frequent trampling and crushing, resulting in decreases in species diversity of grassland communities. The primary reason was various levels of resistance by plant species against animal trampling [21]. The most resistant species is graminoids, which were matted or caespitose in virtue of matted and rosette forbs were moderately resistant, while the least resistant plants were erect forbs [22]. Tourism trampling has led to the gradual disappearance of some less-resistant forbs, thus reducing the richness index of the community. The effects of tourism disturbance on species composition in the community could lead to community degradation [23, 24]. Moreover, tourists picking and damaging plant seedlings or flowers affects the reproduction and regeneration of plants, which directly leads to a decline in community productivity and species richness. Although some studies have also shown that proper trampling is beneficial to the development of grassland, this needs to be achieved by controlling the number of tourists in tourist areas, where it is in contradiction with the purpose of increasing tourism revenue by increasing visitors. This issue should attract decision makers attention to balance the relationship between management and economic benefits of grassland tourism.

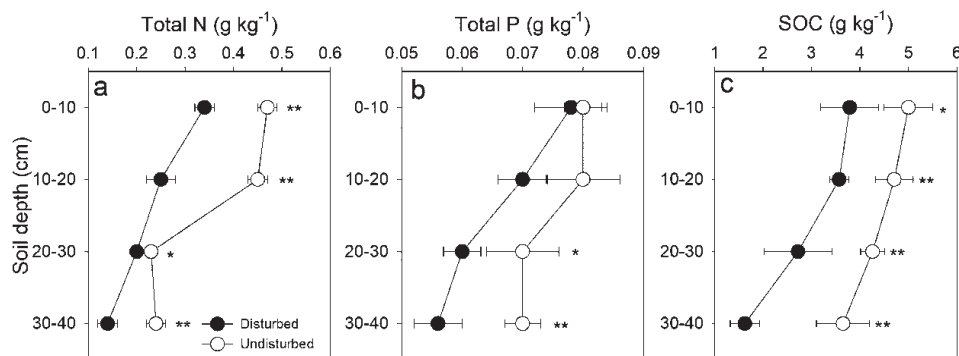


Fig. 3. Effect of tourism (disturbed) and fencing (undisturbed) on soil total nitrogen content a), soil total phosphorus content b) and soil organic carbon content c); the bar represents mean \pm s.e. (n = 25), and significant differences between disturbed and undisturbed grasslands are indicated by symbols: **, P<0.01 and *, P<0.05.

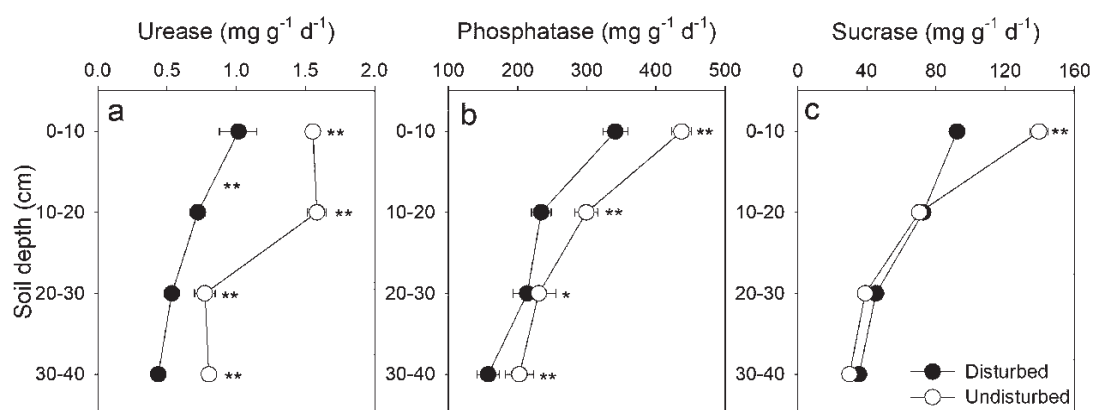


Fig. 4. Effect of tourism (disturbed) and fencing (undisturbed) on the activities of urease a), phosphatase b) and sucrase c); the bar represents mean±s.e. (n = 25), and significant differences between disturbed and undisturbed grasslands are indicated by symbols: **, $P < 0.01$ and *, $P < 0.05$.

Tourism activities impose a number of important habitats stresses, including changes in soil composition and mechanical damage. A large number of tourists have trampled the soil, resulting in an increase in compactness and bulk density. Soil compaction aggravates the loss of nutrients, eventually leading to changes in soil structure and fertility, and may also have a certain effect on the growth and development of plants and the quality of the ecological environment [12]. However, in undisturbed areas the absence of trampling results in successional development with litter accumulation, alteration of microclimate. Our results showed that tourism activities reduce litter biomass, soil nutrient supply and enzyme activities in soil, thus adversely affecting the whole plant-soil system. Previous studies have shown that the decrease of litter biomass directly affects the plant-soil feedback loop and reduces soil nutrients [4, 5, 11]. The decrease of litter biomass and soil total porosity result in the reduction of soil infiltration capacity and the aggravation of soil erosion [25, 26]. Tourist trampling has a significant effect on soil properties, including greater soil nutrient losses and the reduce of potential nutrient inputs, which was caused by the influence of photosynthetic tissue and subsequent respiration of assimilated soil nutrients. Our study showed that soil organic carbon, soil total nitrogen and total phosphorus significantly decreased in the disturbed area. In addition, our result showed that the undisturbed area had higher plant diversity than the disturbed area. Conservation of species diversity contributes to soil organic carbon and total nitrogen accumulation [11, 27]. Moreover, that excessive trampling may lead to the possibility of an outbreak of insect disasters in the grasslands [28]. Domestic waste from tourism also has a negative impact on the grassland environment.

Tourism's impacts on the grassland community are diverse and not easily detected due to their nature of complexity and interconnectivity. Tourism disturbance is an important factor impacting community species

diversity, productivity and soil physical and chemical properties. Tourism activities must be effectively managed for grassland communities' future sustainable utilization and development. Some effective measures should be taken to achieve a win-win outcome to dispose of ecosystem degradation and poverty in pastoral areas. The monitoring system of grassland diversity, productivity and soil properties should be perfected for providing useful information for effective management in grassland tourism. On the premise of trade-offs between economic benefits and environmental protection, controlling the number of tourists in the peak tourism time should have attached importance. Some recovery measures (such as fencing, seeding, fertilization) should be applied to speed up the recovery of communities in severely degraded areas.

Conclusions

Grassland tourism is a new form of grassland utilization based on grassland ecological environment. The most direct impact of tourism on grasslands are frequent trampling and crushing. Trampling has an obvious negative effect on species diversity decrease of grassland communities. Our results showed that tourism is able to reduce litter biomass, soil nutrient supply and soil enzyme activities, thus adversely affecting the whole plant-soil system. Therefore, this problem should influence decision makers in balancing the relationship between management and economic benefits of grassland tourism. Our results suggest that on the premise of trade-offs between economic benefits and environmental protection, controlling the number of tourists at peak tourism time should be factored into achieving a win-win outcome to dispose of ecosystem degradation and poverty in pastoral areas.

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Conflict of Interest

The authors declare no conflict of interest.

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