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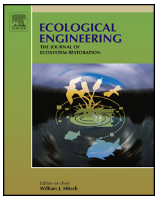

Effects of grazing regime on vegetation structure, productivity, soil quality, carbon and nitrogen storage of alpine meadow on the Qinghai-Tibetan Plateau

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ABSTRACT

Grazing regime has an important effect on grassland ecosystem. however, the mechanisms how alpine meadow vegetation, soil quality responds to this management regime remain unclear. A short term field experiment (4–5 years) was conducted to quantify the impact of different grazing management regimes (fencing (NG), grazing rest in growing stage (RG), traditional grazing (TG) and continued grazing (CG)) on alpine meadow of the Qinghai-Tibet Plateau (QTP) and investigated vegetation structure, soil physicochemical properties, C and N storage regarding grazing regime, during two consecutive years: 2014 and 2015. Our results revealed that the above-, below-ground and litter biomass, plant coverage in NG were significantly higher than those in RG, TG and CG in 2014 and 2015. The NG significantly increased the diversity, evenness and richness indexes when compared to CG, while NG significantly decreased those indexes compared with RG. Meanwhile, litter biomass and plant coverage had no significant difference between RG and TG in 2014 and 2015, and the above- and below-ground biomass had no significant difference between RG and TG in 2014, but RG significantly increased the above- and below-ground biomass compared with TG in 2015. The NG, RG and TG sites all significantly improved the bulk density, soil compaction in 0–30 cm soil depth, available nitrogen and available potassium concentrations in 0–10 cm soil layer compared with CG site. NG, RG and TG all significantly increased the soil water content, total nitrogen, total phosphorus and available phosphorus in 0–30 cm soil depth compared with CG site. The C and N storage in vegetation, 0–40 cm soil depth and whole ecosystem were significantly increased in NG, RG and TG compared with CG in both years. Our results demonstrated that fencing is the most suitable grazing management regime on alpine meadow of the QTP. However, taking into account other factors such as: use and update of grassland resources, economic income stability of herdsmen, the grazing rest in the growing stage enable to promote the efficient use of grassland resources, maintaining alpine ecosystem and preventing it from further degradation or desertification is the best one.

1. Introduction

The Qinghai-Tibet Plateau (QTP), the highest, largest, and most unique type of plateau in the world, is known as the roof of the world. About 85% of the QTP is alpine grasslands, which are conventionally served as the vital grazing land for Tibetan sheep and yak (Zhao et al., 2009; Dong et al., 2010; Mekuria and Aynekulu 2013). Besides animal husbandry production, alpine grasslands also have vital ecosystem services function, for example, biodiversity maintaining, soil and water conservation and carbon storage (Zhao et al., 2009; Dong et al., 2010; Wen et al., 2013; Luan et al., 2014; Raiesi and Riahi 2014). However, because of anthropogenic and natural factors, the alpine grasslands of the QTP have been degraded seriously in recent decades (Dong et al., 2012a; Wang et al., 2015b). The previous researches reported that about 90% of the alpine grasslands have been degraded, and 35% of them have been badly degraded into black-soil-type grassland on QTP (Dong et al., 2010; Harris 2010; Dong and Sherman 2015).

Livestock grazing is one of the most essential means of grassland utilization worldwide (Dong et al., 2011). At present, the local grazing regime intends to maximize animal live weight gains per hectare (ha), which may bring higher economic benefit in the short

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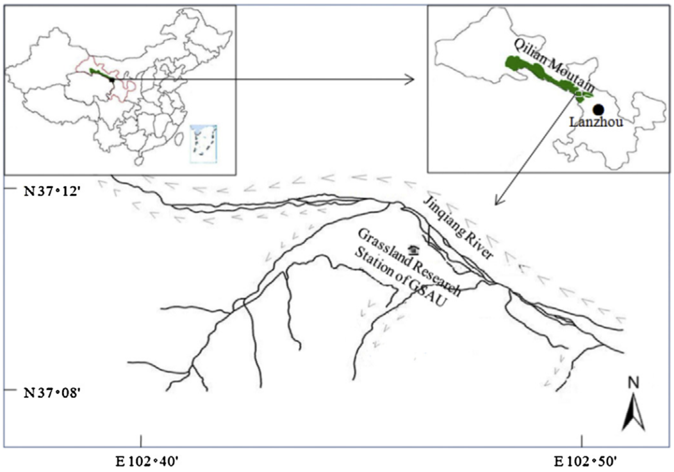

Fig. 1. Location of the study area.

period (Miao et al., 2015). However, from the standpoint of either ecology or economics, this grazing management strategy does not meet the requirements for sustainable grassland-based animal production (Ren et al., 2008). The typical overgrazed pattern is that herbivore grazed continuously in the whole growing stage, even all the year-round in same grassland (Wang and Fu 2004; Klein et al., 2008; Cui and Graf 2009). This unreasonable grazing pattern not only reduces ability of the ecosystems resilience, but also jeopardizes the dependent herdsmen's basic subsistence. Therefore, it is essential to determinate the reasonable grazing patterns and arrange the grazing period to ensure the grassland healthy and sustainable utilization (Zhao et al., 2009).

However, many previous researches of alpine meadow on the QTP have focused primarily on the community and soil characters change under various grazing intensities and/or different degradation gradient. The effects of grazing regime on vegetation structure and soil quality of alpine meadow remain questionable. Therefore, in this research, we compared the vegetation structure, productivity, soil physicochemical properties, C and N storage of alpine meadow among fencing grassland, grazing rest in growing stage grassland, traditional grazing grassland and continued grazing grassland on the QTP in order to choose the best one in terms of maintaining diversity, ecosystem services as well as economic income stability of herdsmen. The assessment of different grazing patterns can help us avoiding negative effect and promoting the utility efficiency of alpine grassland resources.

2. Materials and methods

2.1. Site description

Field experiment was conducted at the Tianzhu Alpine Grassland Research Station of Gansu Agricultural University (GSAU), which is located in Zhuaxixiulong Township, Tianzhu Tibetan Autonomous County of Gansu Province, PR China (37°11′N, 102°47′E, and 2960 m above sea level). The study area was on the northeast edge of the QTP (Fig. 1) with a typical alpine climate. Annual precipitation is 416 mm (mainly from July to September). The average annual temperature is −0.1 °C (−18.3 °C in January and 12.4 °C in July). There is no absolute frost-free period throughout the year. The length of plant growing stage is about 120 days, ranging between May and September. The type of the grassland is alpine meadow. The species richness in this meadow of vegetation is high with 14–22 species per m^2. The dominate species are perennial graminoid and cyperaceae species, such as *Elymus nutans*, *Poa crymophila*, *Stipa aliena*, *Achnatherum inebrians* and *Kobresia humilis*. The accompanying species include compositaes and gentianaceaes species, such as *Artemisia smithii*, *Heteropappus altaicus*, *Leontopodium nanum* and *Gentiana straminea*. The soil type belongs to alpine meadow soil, with a soil bulk density is $0.73\,\mathrm{g\,cm^{-3}}$; soil organic carbon is $138.45\,\mathrm{g\,kg^{-1}}$; total nitrogen is $4.31\,\mathrm{g\,kg^{-1}}$; and total phosphorus is $0.65\,\mathrm{g\,kg^{-1}}$.

2.2. Experimental design and field sampling

2.2.1. Experimental design

The area encompassing the study sites had been conventionally used as winter grassland, with grazing mainly from October to following June by Tibetan sheep and yak prior to 2010, and was slightly degraded. The four grazing treatments were established in early April 2010 with a similar condition: fencing (NG), grazing rest in growing stage (RG), traditional grazing (TG) and continued grazing (CG). In each treatment, there were three 50 m × 50 m monitoring sites (approximately 100 m away from each other) with similar condition were established. The NG site, fenced all year round, has been completely excluded livestock grazing. The RG site, was fenced from 20 April to 20 September, and was grazing during the other time, with a livestock density of 8.33 heads of Tibetan sheep per ha in the grazing stage. The TG site was fenced from 20 June to 20 September, and was grazing during other times, with a livestock density of 8.33 heads of Tibetan sheep per ha in the grazing stage. The CG site was continued grazing throughout the year with a livestock density of 8.57 heads of Tibetan sheep per ha. The grazing experiment was started on 20 April 2010.

2.2.2. Field sampling

Field survey was undertaken in September of 2014 and 2015, when the plant reached its maximum height. We established 10 random sampling quadrates (1 m × 1 m) in each site for a total of 30 quadrates per treatment grassland, and each quadrate location was at least 1 m from the margin to avoid the edge effect. In each quadrate, plant species, coverage, height, density of the respective species, aboveground, belowground biomass and litter biomass were measured and recorded. Aboveground parts of the green plants of the respective species were harvested by clipping to the soil surface, and collecting all litter in each quadrate. All the aboveground plant samples were placed into envelopes and then tagged, respectively. All the green plant samples were immediately dried at 105 °C for 30 min, then oven-dried at 60 °C for 48 h and weighed.

Belowground biomass was measured by a 10-cm-diameter soil drill sampler to take 0–40 cm soil samples (divide into 4 layer, and each layer is 10 cm) at each site after aboveground material and litter were harvested. For a total of 10 cores in each site, and 30 cores per treatment grassland, the 10 cores samples collected from the same layer in the same site were mixed together into one sample, and then divided into two parts. Then, the soil samples were transferred to the laboratory with airtight plastic bags where one portion of samples were immediately washed to remove the stones and roots, all the belowground biomass was immediately dried at 105 °C for 30 min, then oven-dried at 60 °C for 48 h and weighed. The other portion of samples were air-dried and sieved through 2 mm mesh sieve to remove the visible roots and debris for testing of chemical properties. Soil bulk density (0–10, 10–20, 20–30 and 30–40 cm) was measured by a stainless steel cutting ring (5 cm diameter and 5 cm high) in each quadrate after aboveground material was harvested for a total of 10 cores in each site, and 30 cores per treatment grassland. The soil compaction was measured in the field by using the soil compaction instrument (SC-900 USA Digital display type soil compactness instrument) along the diagonal of each site, there were 20 points in each site, and 60 points per