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Effect of overgrazing and enclosure on ecosystem functioning and biological capacity in the typical steppe

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Introduction

Overgrazing is one of the most important human-induced causes for arid and semi-arid grassland degradation, which can result in widespread deterioration of biodiversity, ecosystem services and destroys soil structure (Louhaichi *et al.* 2012). Overgrazing is likely to reduce a plant's individual aboveground biomass (AB) directly through influence on the phenotype plasticity of different traits and indirectly through the allometric relationships among plant that can have impacts on grassland productivity and biodiversity. Grazing can reduced nutrient cycling by inhibiting the growth of palatable and nutrient-rich species with high litter quality and promoting the dominance of those nutrient-poor or chemically defended species with low litter quality that slow rates of nutrient cycling. However, fencing and the exclusion of domestic livestock is the most common management tool used for restoring vegetation productivity in degraded grassland (Liu *et al.*, 2007a, b). Although some previous studies have predicted that overgrazing may lead to a shift to dominant species and change soil nutrient content and nitrogen mineralization rate, the mechanisms underpinning this shift and change are very clear. We addressed the following objectives to determine the effects of overgrazing and exclusion from grazing on communities composed of dominant species (*L. chinensis* and *S. grandis*), and on soil nutrient content and nitrogen mineralization rate?

Materials and Methods

The study was conducted in Baiyinxile ranch, Xilinguole of Inner Mongolia, China (115°32'E, 43°26'N). Long-term, freely-grazed land and non-grazing (grazing-excluded) land were established in 1983 for long-term ecological observation and research in a typical steppe grassland. The grazing land, measuring more than 200 ha in area, is situated adjacent to the grazing-exclusion land and grazed all year round by more than 1000 sheep and goats for greater than 50 years. Therefore, the stocking rate in this region is about 3.0 sheep per hectare. Plant and soil sampling were collected in overgrazed and non-grazed area. Phenotypic functional traits of the *L. chinensis* and *S. grandis* plants were measured in a shaded laboratory room after the entire of the aboveground portions of the plants individual were clipped to the soil surface in the field. Harvested biomass for each species was oven-dried at 65 °C for 48 h and then weighed and aboveground net primary productivity (ANPP) was calculated as the sum of above-ground biomass for all plant species. Total organic C in soil and plant samples was analysed by the Walkley–Black modified acid-dichromate FeSO₄ titration method (Amundson *et al.*, 1988.) Total N in plant and soil samples was determined following Kjeldahl digestion by a Nitrogen Analyzer System (KJELTEC 2300 AUTO SYSTEM II, Foss Tecator AB, Höganäs, Sweden). Total P was determined by the H₂SO₄-HClO₄ fusion method (Liu *et al.*, 2007a, b).

Results and Discussion

Effect of grazing and enclose grazing on above-ground biomass: Compared with enclosed, overgrazing decreased biomass (leaf, stem, and the whole plant) of *L. chinensis* and *S. grandis* (Table 1). The large reduction of two main dominant species (*L. chinensis* and *S. grandis*) above-ground biomass caused by overgrazing supported previous studies in Inner Mongolia (Zheng *et al.*, 2010).The above-ground biomass of plant community was higher in enclosure than in overgrazing.

Table 1 Effect of grazing and enclosure on above-ground biomass of *S. grandis* and *L. chinensis* in the typical steppe (g/individual)

	<i>S. grandis</i>		<i>L. chinensis</i>	
	Grazing	Enclosure	Grazing	Enclosure
AB	1.16b	8.73a	0.38b	1.06a
Stem	0.30b	4.16a	0.18	0.17
leaf	0.78b	2.62a	0.20b	0.89a
Fruit	0.08b	1.96a		

AB: above-ground biomass; the lower case showed significant between grazing and enclosure ($P < 0.05$).

Effect of grazing and enclosure on soil property: Compared with enclosure, overgrazing increased ($P < 0.05$) soil PH value, whereas overgrazing decreased ($P < 0.05$) soil water content, organic matter, TN (total nitrogen) and TP (total phosphorus). No difference ($P > 0.05$) was found for soil AP (available phosphorus) content between grazing and enclosure (Fig. 1). The decrease in soil organic matter and TN with overgrazing may have contributed to the soil surface being exposed to wind erosion, decreased vegetation cover and litter accumulation (Su *et al.*, 2005). This, in turn, could have resulted in losses of C and N from overgrazing in the Inner Mongolia grassland (Steffens *et al.*, 2008). The anticipated grazing effects on soil P were observed in our study largely due to the change in defoliation, soil compaction and nutrient removal.

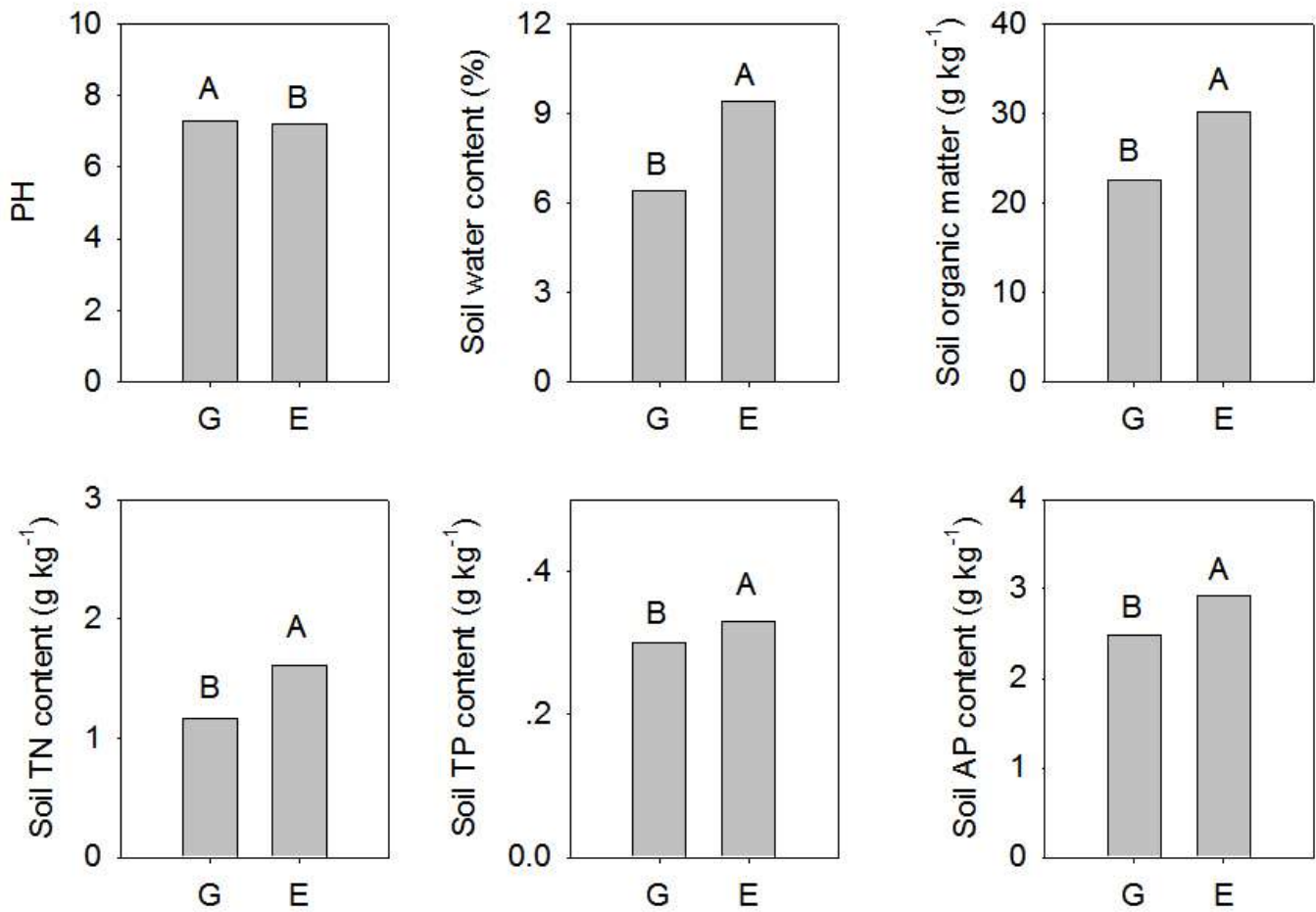


Fig.1 Effect of grazing and grazing enclosures on soil PH value, soil water content (%), soil organic matter, TN (total nitrogen), TP (total phosphorus) and AP (availability phosphorus) in the typical steppe.

Effect of grazing and grazing enclosures on De novo assembly and transcriptomic profiling of *S. Grandis*: By de novo assembly we obtained 94,674 unigenes. A total of 13,221 unigenes showed differences ($P < 0.05$) in response to grazing, of which 6283 unigenes were upregulated and 6938 unigenes were downregulated. These differentially expressed genes (DEGs) were classified into 51 functional categories, which belong to three main GO ontologies: molecular function, cellular component and biological process (Fig.2).

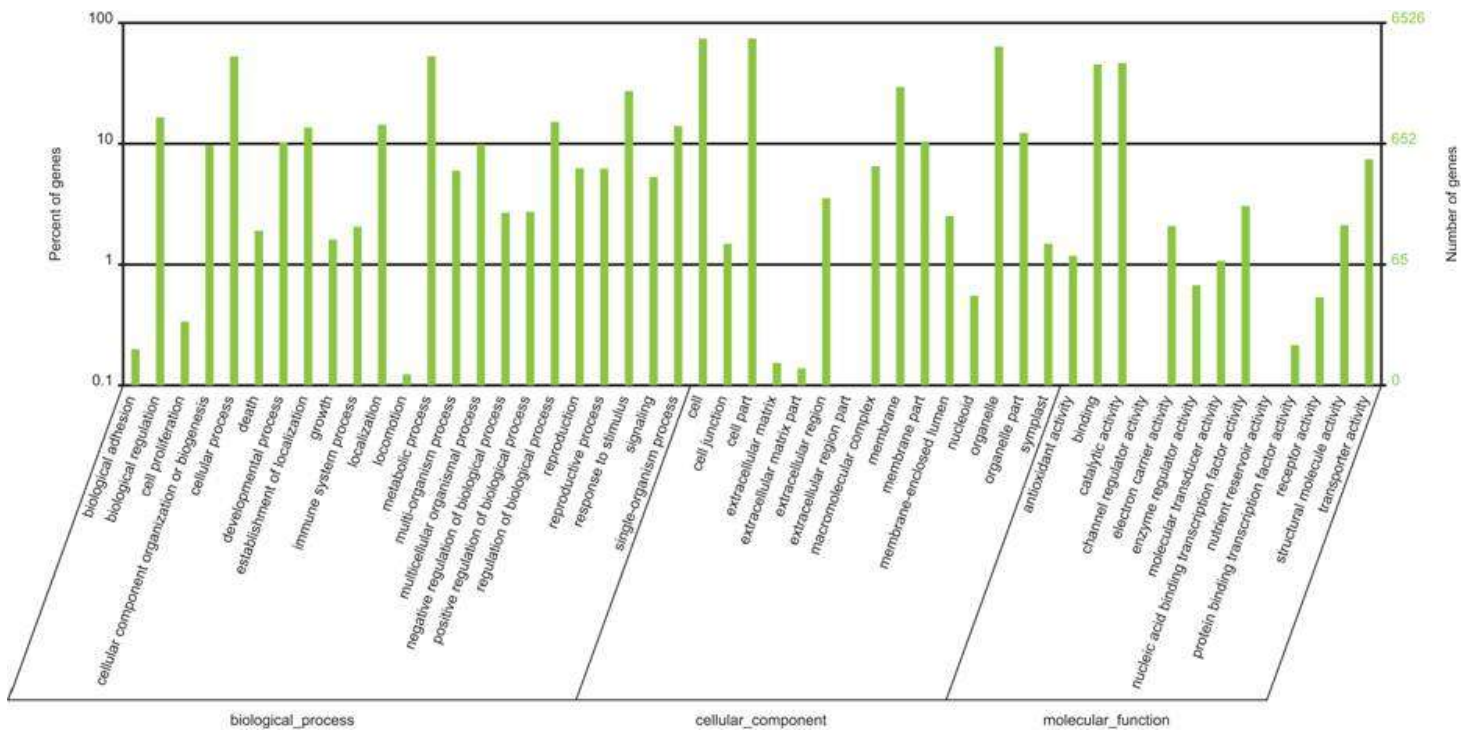


Fig. 2 Histogram of the GO (gene ontology) classification of the *S. grandis* DEGs. The DEGs were grouped into three ontologies: molecular function, cellular component and biological process. The y-axis indicates the percentage (left) and number (right) of genes in each term.

Conclusion

A decline was showed in the biomass (leaf, stem, and the whole plant) of *L. chinensis* and *S. grandis* as a result of overgrazing. Overgrazing led to dwarf of *L. chinensis* and *S. grandis*. Compared with enclosed grazing, overgrazing was significant decreased soil OC, TN, TP in our study. The soil nitrogen mineralization rate was higher in overgrazing than in the enclosures, and the change in soil nitrogen mineralization rate was consistent with soil microbial nitrogen mineralization rate. Effects of enclosures on De novo assembly and transcriptomic profiling of *S. grandis*, a total of 13,221 unigenes showed significant differences in expression under the overgrazing condition, with a threshold false discovery rate ≤ 0.001 and an absolute value of $\log_2 \text{Ratio} \geq 1$. These differentially expressed genes (DEGs) were assigned to 43,257 GO terms and were significantly enriched in 32 KEGG pathways ($q\text{-value} \leq 0.05$). The alterations in the wound-, drought- and defense-related genes indicate that stressors have an additive effect on the growth inhibition of *S. grandis*. Our findings suggest that reducing the stocking rate and restoring the vastly degraded steppes are essential to sustain native steppe biodiversity, ecosystem functioning, and biological capacity in the typical steppe.

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