# Influence of grassland management on carbon allocation in a semiarid temperate steppe

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## Introduction

Grazing lands in North China are often excessively grazed and widely degraded, while hay-making lands appear to be in relatively good condition due to grazing exclusion, but they are facing a continuous loss of nutrients in the harvested biomass. In semiarid grass-lands, plant productivity and community composition are significantly altered by grazing and haying. Grazing mostly leads to negative effects on aboveground productivity, however root biomass seems to increase with moderate grazing (Gao *et al.* 2009; Derner *et al.* 2006), although responses can vary. Aboveground biomass removal can increase C3 grass dominance and productivity (Hofer and Bragg 1981). Grazing exclusion is a valuable mechanism of sequestering soil C (He 2008). However, grazing can change C allocation patterns and affect the amount of C entering the soil. Here we examine the potential effects of common management practices (exclusion with fencing, grazing and hay-making) on semiarid grasslands above- and below-ground C pools. The primary objective of this study was to evaluate the potential of grazing exclusion and annual last-summer haying in previous grazing lands on the storage of C in semiarid grasslands of northern China.

## Methods

This study was conducted in a semiarid temperate steppe in Duolun County, Inner Mongolia, China. Long-term mean annual precipitation and temperature are approxi-mately 383 mm and 2.1°C. The dominant plant species were perennial plants, including *Stipa krylovii*, *Artimesia frigida*, and *Potentilla acaulis*, *Cleistogenes squarrosa*.

The fencing lands were fenced from 2003, and completely excluded livestock grazing. The hay-making lands were cut at the end of the growing season every year from 2003 to the time of the study. The grazing lands were moderately grazed by cattle. We selected five 50 m transects at each management area. Five random sampling quadrats (1 × 1 m) and five root and soil cores were collected manually to 40 cm with a root sampler (80 mm diameter) and a soil sampler (50 mm diameter) respectively at 10 m intervals along each 50 m sampling transect in 2011. The plant biomass and C storage were measured. Data analyses were done with SPSS version 16.0 (SPSS Inc., Chicago, IL, USA).

## Results and discussion

Hay-making lands had significantly greater aboveground biomass, especially increased *Stipa krylovii* biomass ($P$<0.05) in comparison to the other management practices. This result was consistent with the finding of Hofer and Bragg (1981). Seven years of exclusion resulted in significantly increased litter biomass and standing dead biomass (Table 1). Similar to the biomass results, C pool in aboveground biomass and root was significantly higher in fenced and hay-making lands relative to grazing lands. However, the amount of C stored in soil decreased significantly with the introduction of fencing (Table 2). The grasslands subjected to fencing were mature in terms of aboveground productivity, including vegetation, litter, standing dead and roots. Total carbon storage in biomass and soil after 8 years of grazing exclusion decreased significantly mainly due to a loss of SOC. The relatively lower C storage in fenced lands resulted in an increase in aboveground biomass relative to grazing lands that likely caused greater competition for resources and greater consumption of SOM (He 2008). Animal traffic and machinery enhances physical breakdown and incorporation of litter into the soil, which can increase

**Table 1. Dominant species biomass, aboveground total biomass, ground litter biomass, standing dead biomass and roots biomass in fenced, grazing and hay-making lands in this study.**

| Biomass (g/m$^2$) | Management types | | |
|---|---|---|---|
| | Fenced lands | Grazing lands | Hay-making lands |
| *Stipa krylovii* | 13.58±2.57a | 7.86±1.73a | 40.28±8.58b |
| *Artimesia frigida* | 53.01±9.47a | 62.18±10.61a | 57.35±13.49a |
| *Potentilla acaulis* | 12.17±3.93a | 13.66±3.68a | 12.91±6.22a |
| *Cleistogenes squarrosa* | 5.21±1.93a | 6.29±0.95a | 17.63±4.18b |
| Aboveground | 118.96±3.03b | 103.79±6.84a | 139.00±4.89c |
| Ground litter | 48.97±10.08b | 31.19±3.92ab | 14.77±0.87a |
| Standing dead | 20.46±5.05b | 4.43±0.77a | 11.82±5.37ab |
| Root (0-40 cm) | 2039.60 ± 137.76b | 1511.52 ± 125.93a | 1961.11 ± 221.26ab |

**Table 2. Carbon distribution among different pools in fenced, grazing and hay-making lands**

| C pool | Management types | | |
|---|---|---|---|
| | Fenced | Grazing | Hay-making |
| Plant ($g/m^2$) | 52.07±2.01b | 40.23±2.98a | 57.44±5.28b |
| Litter ($g/m^2$) | 19.37±1.13c | 11.38±3.32b | 2.92±0.14a |
| Standing dead ($g/m^2$) | 8.06±0.36c | 1.70±0.15b | 2.54±0.09a |
| Root ($kg/m^2$) | 0.62±0.07b | 0.44±0.04a | 0.60±0.05b |
| Soil microbial biomass (mg/kg) | 544.80± 125.69a | 563.71± 120.85a | 365.00± 59.91a |
| SOC (g/kg 0-40 cm) | 13.32±1.24a | 16.58±1.22ab | 17.55±1.69b |
| SOC ($kg/m^2$ 0-40 cm) | 6.49±0.28a | 7.95±0.31b | 7.27±0.25ab |

the rate of decomposition of litter and transfer of C and nutrients into the soil (Naeth 1991). In grazing lands, there is a higher carbon input from roots, litter and standing dead, while the fencing treatment strongly decreased this input and promoted aboveground allocation (Liu, 2012). In Addition, higher microbial biomass carbon (Table 2) further indicated higher organic matter inputs from plant litter and root exudates in the grazing soil (Bird 2002).

## Conclusion

The results indicated that long-term grazing lands that are fenced to exclude grazing could be construed as proper management for increasing vegetation productivity, but not for soil C sequestration. However, grazing increased the amount of C entering the soil, and changed C allocation patterns. Annual last-summer haying has potential for grassland restoration and sustaining C sequestration in semiarid grassland.

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