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Soil respiration in a desert steppe varies by different grazing regimes in northern China

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Introduction

Recent studies have identified soil respiration as one of the most important research topics (Thomey *et al*., 2011) because it is the second largest flux between terrestrial ecosystems and the atmosphere, and plays an important role in regulating the soil carbon (C) pool and ecosystem C-cycling (Saiz *et al*., 2006). Soil respiration represents the carbon dioxide (CO_2) released from the soil surface, generated mainly from a combination of the metabolic activity of roots and microorganisms. Soil temperature, soil water content, plant growth, soil carbon (C) and nitrogen (N) contents all affect soil respiration. In this water-limited ecosystem, we hypothesize that soil respiration will vary with different types of grazing management and that this variation is regulated by grazing-induced changes in abiotic (soil temperature and soil water content) and biotic (plant above-ground and below-ground production) factors.

Materials and Methods

The experiment was conducted in Xisu Banner (42°16′45″N，112°47′44″E, 1184 m a.s.l.), in the desert steppe region in Inner Mongolia, China. Nine paddocks (100 m×1200 m) were fenced off for this grazing experiment in 1999. A randomized complete block design was used comprising three different types of grazing and there were three blocks. The grazing regimes were continuous grazing (CG), seasonal rotational grazing (RG) and no grazing (E), with stocking rates of 1.25, 1.25 and 0 sheep ha-1 month-1, respectively. The grasslands were grazed for six months (June - November) in every year. The measurements were conducted in 2010 and 2012, respectively a dry and a wet year compared with the long-term average rainfall. The CG treatment was grazed for 6 months during the period from June to November each year including 2011 in which no data were collected. The seasonal rotational grazing schedule was from 15 to 29 June, 11 to 25 August and 7 to 21 November in every year. Soil respiration was measured twice a month, from late May to early October, using a Li-Cor 8100 IRGA (Li-Cor, Lincoln, NE, USA). PVC collars (11 cm in diameter and 5 cm in height) were permanently inserted 2–3 cm into the soil to measure soil respiration at each plot. Soil temperature was measured at 10 cm from each PVC collar by a thermocouple probe connected to the LI-Cor 8100, and soil gravimetric water content was determined by sampling soil at 0–10 cm using a soil core 3.5 cm in diameter. The weight loss from drying the soil samples at 105°C for 24 h was used to calculate soil moisture content.

Results and Discussion

Soil microclimate: Soil temperature at a depth of 10 cm was higher in 2010 than in 2012 (P<0.001, repeated ANOVA, Table 1). Soil temperature at a depth of 10 cm was highest under continuous grazing, and lowest under no grazing (P<0.001). The higher precipitation in 2012 than 2010 led to a significantly higher soil water content in 2012 than 2010 (P<0.001). The soil water content was the highest in the no grazing treatment for both years (P<0.001, Table 1). The soil temperature was the highest in the continuous grazing (CG) in 2010 (Fig.1*a*), whereas soil temperature was the highest in rotational grazing (RG) in 2012 (Fig.1b). Compared with enclosure (E), continuous grazing (CG) and rotational grazing (RG) was decreased the soil water content (Fig.1d).

The effect of grazing treatments on soil respiration: Soil respiration was found to be higher in 2012 than in 2010 (P<0.001, Table 1) averaged over all grazing treatments. Compared with no grazing, rotational grazing significantly decreased soil respiration and continuous grazing further decreased it, averaged over the two years (P<0.001). Compared with no grazing, soil respiration was lower under continuous grazing (by 23.0%) and rotational grazing (by 14.1%) in the studied desert steppe, which is consistent with the results of other grassland studies (Rey *et al*., 2002). The seasonal pattern of soil respiration was with a marked decrease under all grazing treatments in the dry July of 2010 compared with the wet July of 2012 (Fig. 1*e* and *f*). When analyzed separately by year, soil respiration was the greatest in the no grazing treatment in 2010 (Fig. 1*e*), whereas the highest value was found under rotational grazing in 2012 and a marginally significant difference was detected between grazing types (P<0.1, Fig. 1 *f*). In the arid and semi-arid grasslands of northern China, soil water content is the primary limiting factor for plant growth (Chen and Wang, 2000) and microbial activity (Liu *et al*., 2007). In our study, a higher soil water content (Fig.1*d*) with no grazing or under rotational grazing may lead to greater plant production, below-ground C allocation and soil C content (Table 1), providing more C substrate for the activities and respiration of plant roots and soil microorganisms (Liu *et al*., 2007).

Table 1. Response of soil temperature (at 10 cm) in the plant-growing season (T), soil gravimetric water content (0–10 cm) (SW) and soil respiration (Rs) to grazing regimes during two hydrologically-contrasting growing seasons in a desert steppe in Inner Mongolia.

		T (^{o}C)	**SW** (%)	**Rs** (μmol m^{-2} s^{-1})
Grazing regimes	Continuous grazing	17.1^{a†}	7.16^{b}	1.04^{c}
	Rotational grazing	16.2^{b}	7.30^{b}	1.16^{b}
	No grazing	15.0^{c}	7.76^{a}	1.35^{a}
Year	2010	17.5^{a}	6.51^{b}	0.87b
	2012	14.7^{b}	8.30^{a}	1.49^{a}
		Level of significance		
	Treatment	<0.001	<0.001	<0.001
	Year	<0.001	<0.001	<0.001
	Treatment × Year	<0.001	0.01	<0.001

†Values in the columns indicated by different letters are significantly different (P<0.05)

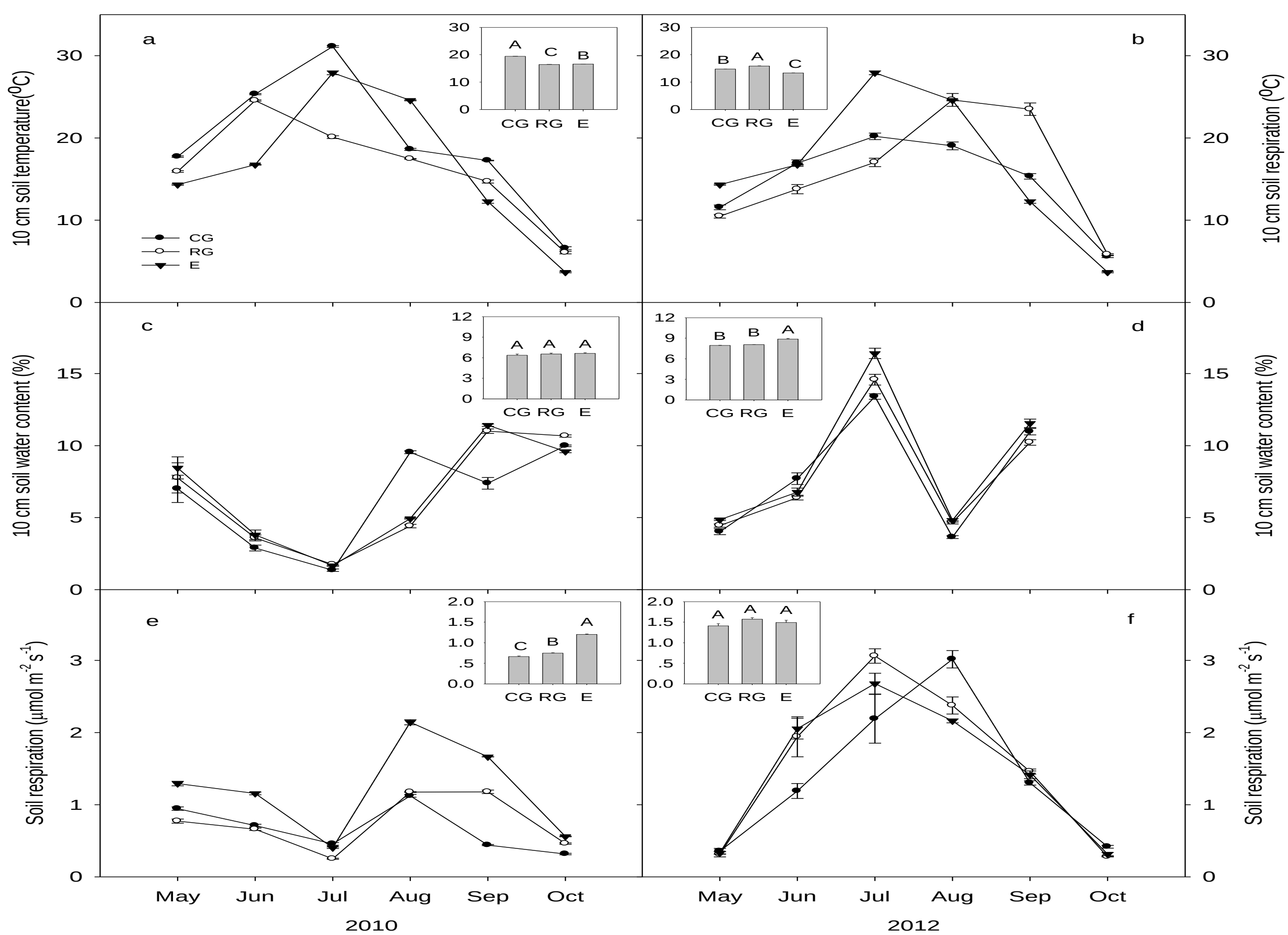

Fig. 1. Seasonal dynamics and means (insert: mean ± SE) of soil temperature (*a*, 2010), (*b*, 2012), soil gravimetric water content (*c*, 2010), (*d*, 2012), and soil respiration (*e*, 2010), (*f*, 2012). The grazing regimes are continuous grazing (CG) rotational grazing (RG), and no grazing (E).

Conclusion

Compared with no grazing, the soil respiration was decreased by 23.0% under continuous grazing and 14.1% under seasonal rotational grazing. A significant decrease in soil respiration was observed under both continuous grazing and in seasonal rotational grazing in the dry growing season, but no significant difference was detected in the wet growing season. In the wet year, only a non-significant difference in soil respiration was observed between different grazing types.

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