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Effects of grassland degradation and precipitation on carbon storage distributions in a semi-arid temperate grassland of Inner Mongolia, China

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ABSTRACT

Environmental degradation influences carbon (C) cycling and storage in grassland ecosystems by altering vegetation productivity. However, the impacts of different degradation intensities on vegetation–soil C distributions in grasslands have not been well documented. We measured C storage in soil, roots, and plants under light, moderate, and severe degradation levels in a typical steppe region of Xilinhot, Inner Mongolia, China in 2011 and 2012. Grassland C storage was highest in soil, followed by roots, and then aboveground plant biomass. Grassland degradation and precipitation significantly influenced C storage distributions. During the dry year (2011), total C storage in vegetation and soil was highest under light degradation. Carbon storage in aboveground plant biomass and roots increased with degradation intensity. During the wet year (2012), C storage was highest in aboveground plant biomass and roots under light degradation. Root biomass tended to be concentrated in the soil surface during the wet year.

1. Introduction

Grassland ecosystems store 20% of the terrestrial carbon (C) pool (Lal, 2004; Nosetto et al., 2006), and thus play an important role in the global C cycle (Wu et al., 2010a). Anthropogenic activities and climate change can influence C storage by promoting conditions for C mineralization (Bontti et al., 2009). Nearly half of the world's grasslands are experiencing environmental degradation, which threatens ecosystem productivity and C cycling/storage (Gang et al., 2014; Kimble et al., 1995) by increasing the accumulation and decomposition rates of organic matter in soil (Kimble et al., 1995). Research on the impacts of degradation on grassland C cycling is necessary to help prevent or mitigate future ecological problems.

In China, natural grasslands account for ~41% of the national land area (Wang et al., 2005) and store ~12.7% of the terrestrial C pool (Su et al., 2015). Semi-arid temperate grasslands in northern China, which account for 78% of the national grassland area (Chen and Wang, 2000), are experiencing increasingly severe degradation (Li et al., 2003), mainly from grazing (Li et al., 2011; Zhu et al., 2016). The impacts of grazing on grassland C cycling (Mcsherry and Ritchie, 2013) have been reported as positive (Derner et al., 2006), negative (Golluscio et al., 2009; Wu et al., 2010a), or neutral (Cui et al., 2005). Grazing directly alters litter input as well as decomposition and mineralization rates, and indirectly affects soil physical, chemical, and hydraulic properties and microenvironmental conditions, which ultimately influence the soil C balance (Gill, 2007; Medina et al., 2007). Grazing also may alter plant C distributions by promoting C partitioning to shoots as a physiological adjustment to recover leaf area (Medina-Roldán et al., 2008). In addition, grazing can cause a shift in plant community composition, which may alter soil properties and C storage, and consequently affect biomass production and ecosystem functions (Jobbágy and Jackson, 2003; Wei et al., 2009; Wang et al., 2016). Grazing intensity determines the level of degradation, and the impacts of different degradation levels on C cycling are varied. Precipitation can also influence grassland C cycling by impacting plant growth and soil water content (Wang et al., 2003; Bai et al., 2010). Higher precipitation can promote plant growth, and thus

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increase aboveground C storage in semi-arid areas. More precipitation also increases soil water content, which enhances soil C storage in semi-arid areas (Wiesmeier et al., 2013). The impacts of different degradation and precipitation levels on grassland C storage have not been well documented, and relevant research is necessary.

Grasslands in the steppe area of Xilinguole League in Inner Mongolia are fragile environments and sensitive to climate change. Due to long-term unsustainable human activities and climate change, ecological and environmental deterioration in this region are serious problems. To better understand the effects of grassland degradation on C storage, we measured changes in vegetation and soil C storage in degraded grasslands dominated by *Stipa grandis* in the Xilin Gol League of Inner Mongolia, China. The objectives of our study were to investigate the impacts of variations in vegetation–soil C storage under different degrees of degradation in the semi-arid Inner Mongolian grasslands of China.

2. Materials & methods

2.1. Study area

The study area lies in the Xilin River Basin of China's Inner Mongolia Autonomous Region (44°10′N, 116°22′E) (Fig. 1). The area has a temperate continental climate with cold, dry winters and warm, wet summers. The annual average temperature is 2.6 °C, and the monthly mean temperature ranges from −18.8 °C (minimum in January) to 21.2 °C (maximum in August). The mean annual

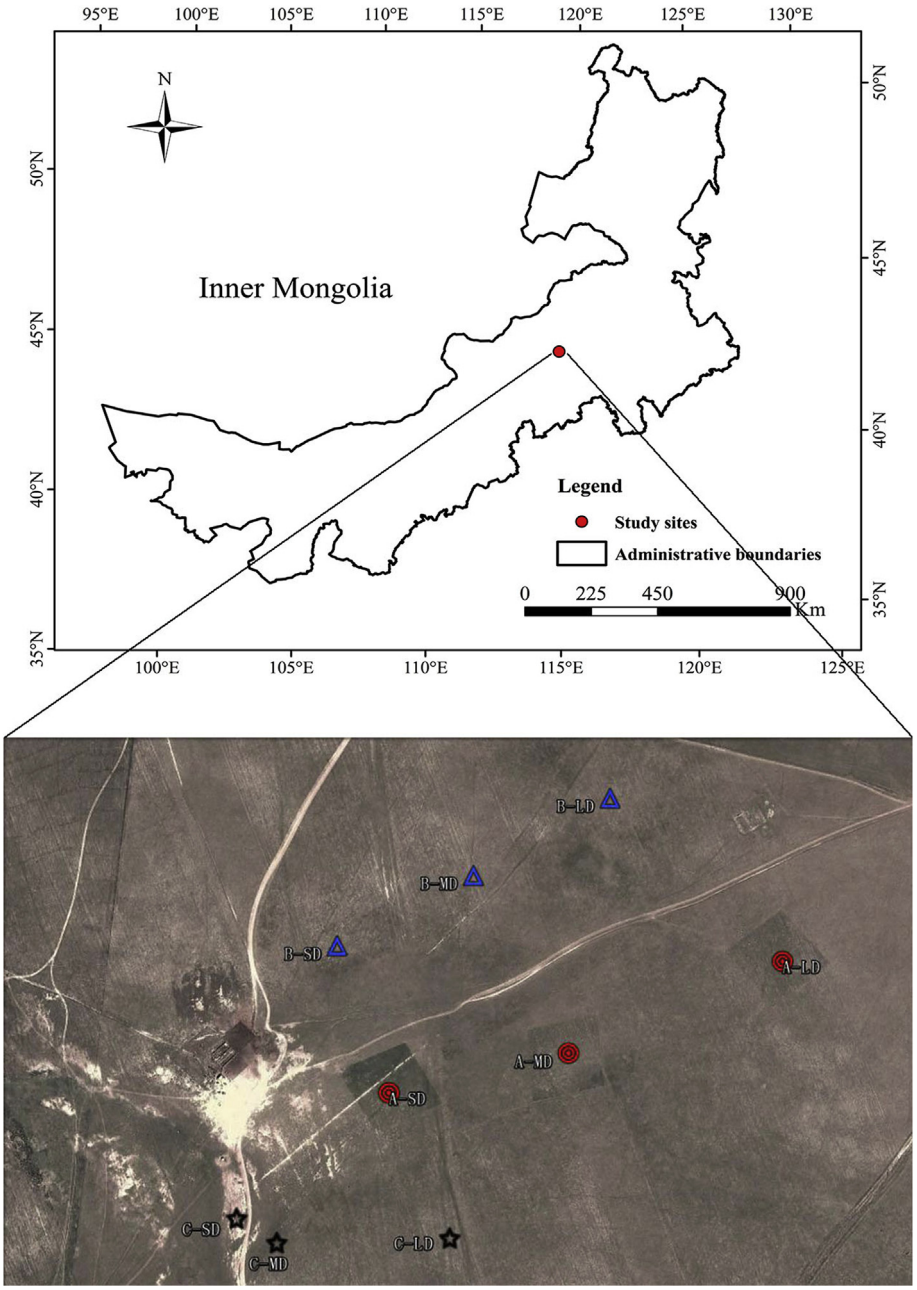

Fig. 1. Location of the study area and study sites. A, B, and C represent three transects. Site degradation levels: LD, light; MD, moderate; and SD, severe.