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Influences of land use history and short-term nitrogen addition on community structure in temperate grasslands

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ABSTRACT

Better understanding of plant community structure in relationship to land use history and nitrogen (N) will facilitate grassland conservation and projections of community succession under future N deposition. We conducted a field experiment in northern China to examine the influence of 2-year N addition on species composition and community structure in three temperate grasslands with different land use history: steppe fenced for two years (ST), steppe fenced for five years (SF), and old field grassland fenced for five years (OF). The results showed previous farming reduced species diversity and plant cover, which is mainly caused by decrease in perennial grasses (PG) and forbs (PF). Nitrogen addition increased plant cover, especially the PG cover, but had little effects on species diversity. Nitrogen enrichment also has a tendency to alter community composition by decreasing proportional cover of PF but increasing that of PG and annuals and biennials (AB), suggesting enhanced dominance of PG under increasing N deposition. Irrespective of the short-term (2 years) experimental periods, our findings highlight the dominant role of land use history in structuring plant community, and have valuable implications for grassland conservation and model projections of ecosystem succession under global scenarios of N deposition in the semi-arid grasslands.

1. Introduction

At the regional scale, the pattern of vegetation and the distribution of dominant species are largely dependent on land use history (Foster, 1992; Foster et al., 2002; Neill et al., 2007). Historic land use commonly influences plant community succession (Benjamin et al., 2005; Connell and Slatyer, 1977; Foster, 1992). Altered species diversity and community invasibility are likely result from impacts of land use history (Bonet, 2004; Dutoit et al., 2003; Kulmatiski et al., 2006). Better understanding the effects of land use history on vegetation are critical for interpreting current ecological patterns and developing effective conservation and management strategies (Swetnam et al., 1999). In spite of the importance of land use history, its impacts on plant community are often neglected in semiarid grasslands where plant species and community are sensitive to land disturbance (Zheng et al., 2009; Zhou et al., 2006). Given that previous land use may influence species diversity and dominant life forms of plants (Knapp, 1992; Xu et al., 2010), it is expected that community structure and composition will vary with land use history.

Nitrogen is the most limiting nutrient for terrestrial plants, improved N availability generally influences the community composition and alters vegetation pattern (Duprè et al., 2010; Rajaniemi, 2003; Tilman, 1987). Especially in semiarid area, the grasslands were sensitive to N enrichment (Bai et al., 2008; Yang et al., 2011). Enrichment in N will decrease species richness and density of plant community (e.g., DiTomasso and Aarssen, 1989; Gough et al., 2000; Patrick et al., 2008; Stevens et al., 2004; Yang et al., 2011) and influence the succession of grasslands (Kolb et al., 2002; Tilman, 1987). Furthermore, due to their inherent differences in N use strategies, various plant species and functional groups may show differential growth responses to N enrichment (Xia and Wan, 2008), leading to altered inter-specific competitive relations (Joyce, 2001) and changes in abundance and dominance of difference plant species and functional groups (Niu et al., 2009, 2010; Tilman, 1987). As the main source of N input in semiarid area in north China, airborne N is estimated up to 80–90 kg ha^{-1} yr^{-1} (He et al., 2007) and higher N deposition would occur in the future (Zhang et al., 2008). Increasing atmospheric N deposition is influencing the community structure and productivity

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in natural grasslands (Bai et al., 2008; Yang et al., 2011). However, it is still not clear how increased N impacts species composition and community structure in grasslands under secondary succession. Since the limitation of N in semiarid grassland and the higher efficiency in N utilization of grass species relative to other species (Niu et al., 2008; Yuan et al., 2005), it is reasonable to hypothesize that N addition will increase the vegetation coverage and stimulate the dominance of grasses.

In Inner Mongolia in northern China, grasslands represent the natural vegetation type and play important roles in providing ecological services and maintaining sustainable socio-economic development of the local area (Kang et al., 2007). However, the grassland has degenerated seriously since 1950s because of overgrazing and reclamation for farming. The Chinese government carried out policies of abandoning grazing and farming since the end of last century to prevent grasslands from further degradation. As a result, the natural steppe fenced after overgrazing and the old field grassland succeeding after farmland abandonment are the two most common grassland types in Inner Mongolia. Nevertheless, previous studies in this area mainly focus on the steppe; few studies discussed the old field and compared the two grassland types as well as the same grassland type with different restoration time after disturbance.

In this study, we simulated N deposition by adding N in three grasslands with different land use history and monitored the community structure and species composition in two consecutive growing seasons. We addressed the following specific questions: (1) what are the differences in community structure between grasslands with different land use history? (2) how do community structure and species composition respond to N addition in the short term?

2. Methods

2.1. Study sites and experimental design

The study sites were located in Duolun county (116°17′ E and 42°02′ N, elevation 1324 m a.s.l.), in the typical steppe zone of Inner Mongolia Plateau. This area belongs to a typical agro-pastoral ecotone with semiarid monsoon climate of moderate temperature zone (Fig. 1). Mean annual precipitation is 385.5 mm and mean annual temperature is 2.1 °C, with mean monthly temperature ranging from −17.5 °C in January to 18.9 °C in July. Soil is chestnut (Chinese classification) or Calcis-orthic Aridisol in the US Soil Taxonomy classification.

The traditional land use practices in the study area are livestock grazing and farming. The over-grazing and intensive farming on the regional grasslands since the middle of the last century resulted in severe land degradation and desertification (Liu and Tong, 2003; You et al., 2003). To protect the environment from further degradation, the local government has executed the policies of banning grazing and fallowing of cultivated land since 2000 (Zhou et al., 2006).

In April 2005, three grassland sites (approximately 100 m away from each other) were selected for study based on different land use history: steppe fenced for two years (ST), steppe fenced for five years (SF) and old field fenced for five years (OF). All the sites had been used for grazing freely before the OF was converted to farmland in early 1980s. *Sesamum indicum* L., *Avena chinensis* Metzg., *Triticum aestivum* L., and *Fagopyrum sagittatum* Gilib. were prevalently cultivated in OF during the time of farming until it was abandoned in 2000. The SF and ST were overgrazed until they were fenced in 2000 and 2003 respectively. Dominant plant species in the ST were *Stipa krylovii* (C_3 grass), *Artemisia scoparia* Waldst. et Kit. (C_3 forb), and *Agropyron cristatum* L. (C_3 grass), while in the SF,

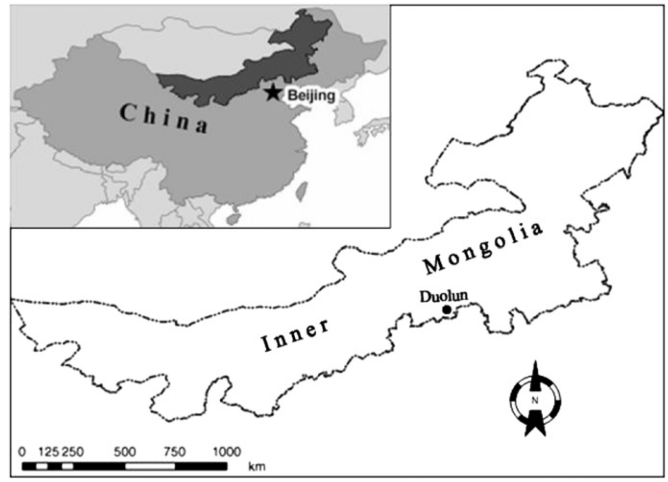

Fig. 1. Location of the study area.

Artemisia frigida Willd. (C_3 forb), *A. cristatum*, and *S. krylovii* were the most dominant species. In the OF, *A. cristatum* was the most dominant species followed by *A. scoparia*. The significant differences in soil characters existed between the SF and the OF (Xu et al., 2010). The values of soil organic carbon content was higher in the SF than the OF (15.68 and 12.92 mg g^{-1}, respectively; $P < 0.01$). Soil total phosphorus, total nitrogen and inorganic nitrogen content were greater ($P < 0.01$) in the SF (0.32, 1.63 mg g^{-1}, 13.17 mg kg^{-1}, respectively) compared with the OF (0.26, 1.24 mg g^{-1}, 10.03 mg kg^{-1}, respectively). The steppe (1.21 g cm^{-3}) had lower ($P < 0.001$) soil bulk density than the old field (1.39 g cm^{-3}).

During 2005 to 2006, four levels of N (total 0, 5, 10, 15 g N m^{-2} yr^{-1}, with urea) were evenly applied to the plots (8 m × 8 m, separated by 1 m wide corridors) in a randomized block design in each of the three grasslands. Each block was replicated seven times at the site. Nitrogen was applied by scattering urea granules twice a year in initial stage (early May) and midseason (late June) of growing season when the need of N is most intense for plant.

2.2. Plant community measurement

In July 2005 and 2006, plant density, species richness were determined within a permanent quadrat of 1 m × 1 m in each plot. Plant cover was measured within the same quadrat by putting a 1 m × 1 m metal frame with 100 equally distributed grids above the canopy (Dong et al., 1996). For the analysis convenience, species were classified into functional groups on the basis of life form: annuals and biennials (AB), perennial grasses (PG), and perennial forbs (PF), based on life forms. The plant functional groups are different in plant stature, rooting depth, water and nutrient use efficiency, and C:N:P stoichiometry (Bai et al., 2004). Species evenness (E) was used to describe the diversity traits of communities, which were calculated as:

$$E = \left(-\sum P_i \ln P_i\right) \Big/ \ln S$$

Where P_i is the relative importance value of species *i*, *S* is the total number of species.

2.3. Statistical analysis

Repeated measured ANOVAs were used to analyse the effects of N addition, land use history and their interaction on community