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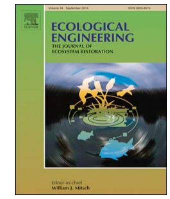

Evaluation of semiarid grassland degradation in North China from multiple perspectives

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A R T I C L E I N F O

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A B S T R A C T

There has been increasing interest in grassland ecosystem degradation resulting from intensive human activity and climate change, especially in arid and semiarid regions. Species composition, grassland desertification, and aboveground biomass (AGB) are used as indicators of grassland degradation. In this study, we comprehensively analyzed variations in these three indicators of grassland degradation in semiarid grassland in North China, on multiple time scales. Since 1984, species composition has become simpler and species indicative of grassland degradation, such as *Potentilla acaulis* and *Artemisia frigida*, have become dominant. These changes indicate that serious grassland degradation has occurred since 1984. Grassland degradation was also analyzed on shorter time scales. Analyses of interannual variations during 2005–2015 showed that desertification decreased and average AGB in the growing season increased over the study area, indicating that grassland was recovering. However, analyses of species composition indicated that grassland was actually degrading during this period. Analyses of spatial variations showed that the position of slightly desertified grassland shifted and formed a band in the west, where the lowest AGB in the growing season was recorded. Grassland AGB decreased in most parts of the south and east (~ 20 g/m^2 per decade) but increased in other regions from 2005 to 2015. Climatic factors had critical effects on grassland degradation, showing that simpler species composition mainly resulted from an increase in average temperature and a decrease in average precipitation over the past 30 years. And in recent decade, increased precipitation and decreases both in temperature and potential evapotranspiration relieved desertification and increased AGB overall. This study thus revealed that ecosystem structure degenerated seriously in the long-term, but AGB increased in the short-term mainly due to increases in both indicator species for grassland degradation and species with strong resistance to drought tolerance. Thus, this study suggested there had distinct difference in grassland degradation identified by above three indicators at different time-scales, and multiple perspectives should be considered to accurately assess the state and characteristics of grassland degradation.

1. Introduction

Natural grasslands cover 4 × 10^8 hm^2 worldwide, accounting for 13% of the world's grassland area and 41% of the whole area of China. Almost 80% of the grassland in China is in arid and semiarid regions (Kang et al., 2007). Grassland is the largest terrestrial ecosystem in China and it has a high ecological and economic value. It plays a critical role in regional climates, biodiversity, conservation, provision of ecosystem services and socioeconomic development, and is also the main target of eco-environmental conservation, especially in Beijing-Tianjin-Hebei regions (Wu et al., 2014; Zhao et al., 2015). Numerous studies have shown that various grasslands in China have seriously degraded under long-term overgrazing and human disturbance (Li et al., 2015; Sarula et al., 2013; Wang et al., 2015). The continual degradation of grasslands has caused a series of problems, including grassland desertification, biodiversity loss, and the loss of carbon sinks. These problems threaten animal husbandry, ecological security, and sustainable development in China (Man et al., 2016).

Although many recent studies have focused on the indicators which are used to define grassland degradation, there is still debated regarding definition of grassland degradation at different temporal and spatial scales. Generally, decreases in both grassland biomass and vegetation coverage have been used to explain the degeneration of ecosystem function (Zhang et al., 2011; Wang et al., 2014). However, these estimates are far from comprehensive since they make no consideration of ecosystem structure. Also, several studies have suggested that species composition does not change during the transition stage of thicketization of grasslands, because the intensive interaction between shrub

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patches and grass patches maintains biomass and diversity at low levels in an unstable ecosystem (Peng et al., 2013). Therefore, there are two main gaps in previous findings, one was the research on grassland degradation in semiarid grassland of North China is insufficient and weak, and the other was that one simple perspective or single indicator is inaccurate to estimate grassland degradation. Moreover, the patterns of grassland degradation are distinctive between the long-term and short-term scales.

To address in-depth analyses from multiple perspectives to explore the characteristics of grassland degradation accurately and comprehensively, these three indicators including species composition, desertification and aboveground biomass (AGB), are considered at the inter-decades, inter-annual, and intra-annual scales, respectively. Thus, the main objectives of this study were (a) to evaluate the accuracy of AGB, grassland desertification, and dominant species composition as indicators of grassland degradation on different temporal and spatial scales, respectively, (b) to discuss the differences and similarities among these indicators of grassland degradation, and (c) to explore the potential driving factors for changes in these indicators on multiple scales.

2. Materials and methods

2.1. Study area description

The study area, located in the northeast of North China's Inner Mongolia, is a transition zone from mountains to high plains (Fig. 1). Its terrain slopes from southeast to northwest with altitudes of 600–800 m above sea level. This area experiences a temperate continental monsoon climate. According to meteorological observation for many years, the annual mean precipitation is approximately 300–500 mm, and annual average temperature is −2.4 to −2.2 °C. The growing season is generally from May to September when 80% of annual precipitation occurs and the mean temperature is 19.7–37.7 °C. The main vegetation types are meadow steppe and montane forest steppe (including forest steppe and grassland). And the dominant plant species are *Leymus chinensis* (*L.chinensis*), *Stipa baicalensis* (*S. baicalensis*), and *Cleistogenes squarrosa* (*C. squarrosa*) over study area. According to field surveys, the productivity and diversity of the grassland ecosystem has declined dramatically in recent years. The natural grassland covering 81.2% of total land area, whereas the areas of degraded grassland and desertification is accounting for nearly 53% of natural grassland. Meanwhile, grassland degradation has affected the distribution of temperature, water, and physicochemical properties of soil in this study area (Li et al., 2015; Wang et al., 2015; Wang et al., 2017).

2.2. Sampling and meteorological data preparation

Two field datasets were used to investigate the vegetation community during the peak growing period of semiarid grassland in North China. One dataset was from 75 plots (1 m × 1 m) sampled from July 11 to July 24, 2015. The other dataset was from 55 randomly selected plots (1 m × 1 m) sampled from July 27 to August 8, 2016. The survey parameters recorded in each plot were amount, coverage, height, and density of all plants, height and coverage of plant communities, and location (longitude, latitude, and altitude). The AGB were clipped at ground level in the two random 0.25m^2 quadrats within each plot, and then dried to constant weight at 60 °C before measuring dry weight (Coyle et al., 2008). In all quadrats, vegetation coverage was measured by the cable method (Ren, 1998).

Monthly precipitation, temperature, and other climatic factors (wind speed at 10-m height, sunshine duration, and relative humidity) in and around the study region were recorded at four meteorological stations of the China Meteorological Data Service Center (CMDC) from

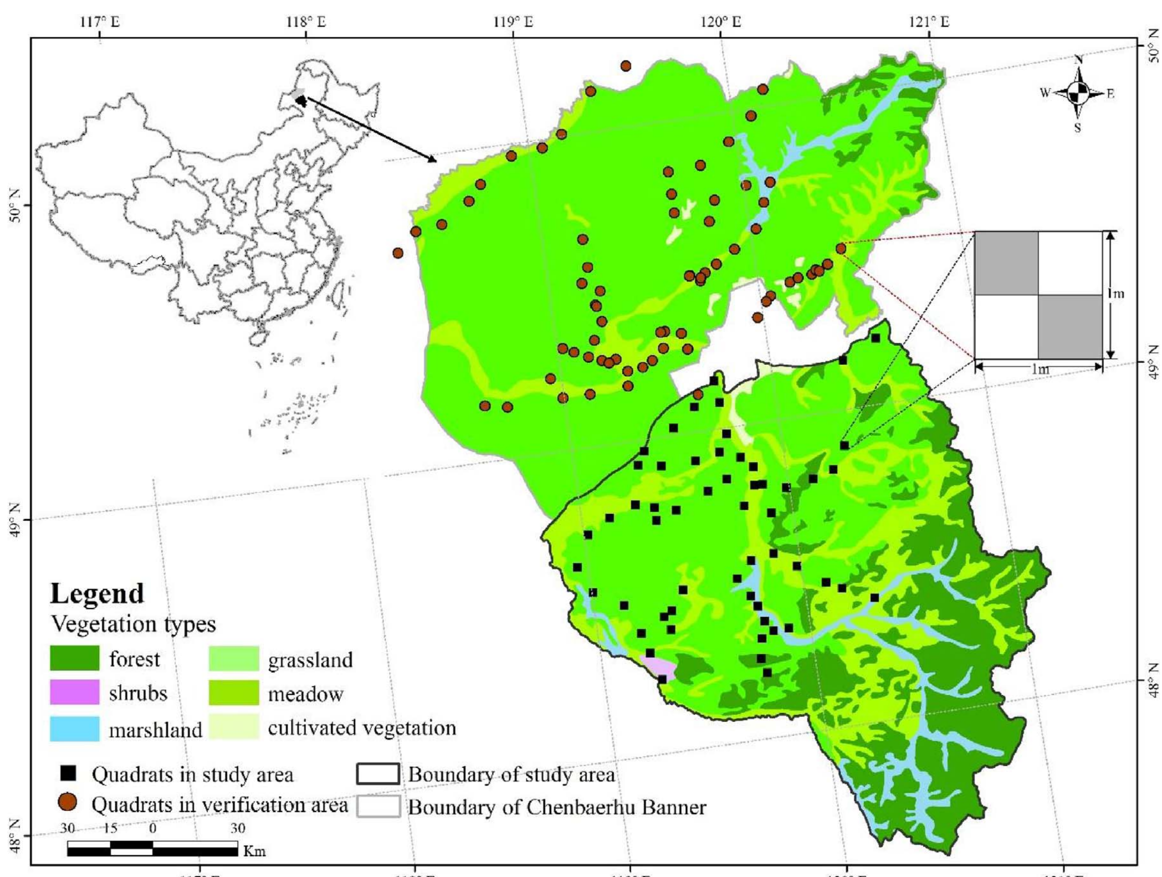

Fig. 1. Spatial distribution of sampling sites and vegetation types in the study area.