Ecological Engineering 90 (2016) 372–381

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Effects of grazing exclusion on plant community and soil physicochemical properties in a desert steppe on the Loess Plateau, China

Guang-yu Zhu[a], Lei Deng[a,*,1], Xi-biao Zhang[b], Zhou-ping Shangguan[a,*,1]

[a] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Northwest A&F University, Yangling 712100, Shaanxi, PR China
[b] College of life science and technology, Longdong University, Qingyang 745000, Gansu, PR China

ARTICLE INFO

Article history:
Received 11 June 2015
Received in revised form 27 January 2016
Accepted 4 February 2016
Available online 20 February 2016

Keywords:
Fencing
Plant diversity
Soil particle
Soil carbon
Soil nitrogen
Soil phosphorus

ABSTRACT

Although fencing is an effective restoration strategy used to achieve the global sustainability of grassland ecosystem, it is unclear from the literature whether fencing results in positive effects on soil physicochemical properties, plant diversity and the relationship between soil particle and soil chemical properties in a desert steppe on the Loess Plateau. Therefore, we selected fenced communities and grazed communities to study the effects of grazing exclusion on desert grassland on the Loess Plateau in China. Our results indicate that plant coverage, plant height, richness index, above- and below-ground biomass, root/shoot ratio, the number of grasses and the number of perennials increased significantly, whereas litter biomass, the number of forbs and annuals significantly decreased after approximately 12 years of fencing. Fencing also resulted in marked increases in ammonium nitrogen (AN) in the 0–10 cm soil depth, soil organic carbon (SOC), total nitrogen (TN), nitrate nitrogen (NN), clay and silt in the 0–30 cm soil depth and soil total phosphorus (TP) in 0–100 cm soil depth. Our results also indicated that SOC, TN, NN, clay, silt, sand and belowground biomass were significantly affected by land use type, soil layer and their interaction between land use type and soil layer. However, AN was affected by only land use type, and TP was affected by land use type and soil layer but not their interaction. In addition, there was s significant correlation between soil chemical properties (SOC, TN, TP, NN, AN) and soil particles (silt, clay and sand) in the 0–5 cm soil depth. As part of our ongoing research, this paper can produce substantial ecological benefits by contributing to the development of a more scientific strategy for grassland management on the Loess Plateau.

1. Introduction

Grazing is widely recognized as a primary ecosystem driver in grassland (UNCCD, 2004). However, overgrazing has resulted in severe degradation and desertification of semi-arid grasslands in Northern China over the last decades (Wiesmeier et al., 2009). Although severe drought, water erosion, and environmental degradation are well known in the semi-arid Chinese Loess Plateau (Wei et al., 2015), overgrazing because of mismanagement is a major driver for biodiversity loss (Chillo et al., 2015), lower plant height, lower canopy cover, lower plant species abundance and lower aboveground biomass (Xu et al., 2014). Overgrazing also causes the degradation of soil chemical and physical properties by reducing plant cover and increasing soil compaction and erosion (Chartier et al., 2013) as well as soil heterogeneity (Su et al., 2006) and decreasing the total mycorrhizal colonization of *Scea. grandis* (Wang et al., 2014b). Therefore, appropriate grazing management is important for the rational utilization of grassland resources (Zheng and Sun, 2011).

To restore the degraded grassland in northern China, under the country's Tenth Five-Year Plan, a host of sustainable development initiatives were introduced (Deng and Shangguan, 2014). Foremost among them was the Returning Grazing Land to Grassland (GLG) policy (Deng and Shangguan, 2014). As a consequence of this policy, the grassland in this area has improved (Deng et al., 2014a, 2014b). Several studies have demonstrated that this project could significantly increase SOC stocks (Deng et al., 2014b; Wu et al., 2015) and net primary productivity (NPP) values (Song et al., 2012; Deng et al., 2014a; Wu et al., 2015), enhance the vegetation index

* Corresponding authors. Tel.: +086 29 87019107; fax: +086 29 87012210.
E-mail addresses: denglei011124@163.com (L. Deng), shangguan@ms.iswc.ac.cn (Z.-p. Shangguan).
[1] These authors contributed equally and should be considered as co-corresponding authors.

http://dx.doi.org/10.1016/j.ecoleng.2016.02.001
0925-8574/

(EVI) (Xiao, 2014; Fan et al., 2015; Li and Lu, 2015), leaf area index (Xiao, 2014; Fan et al., 2015), and the fraction of photosynthetically active radiation absorbed by canopies (Xiao, 2014) as well as control soil erosion (Dang et al., 2014) and combat land degradation (Wu et al., 2015). Overgrazing has a number of negative effects, often including undesirable vegetation increases (Louhaichi et al., 2009), reduced vegetation cover (Deng et al., 2014a), biomass reduction (Louhaichi et al., 2012), species diversity reduction (Louhaichi et al., 2012; Deng et al., 2014a), and reduced soil carbon (Deng et al., 2014a). However, grazing may increase biomass production in plant communities with a high re-growth potential (Olofsson and Oksanen, 2002; Deng et al., 2014b). such as perennial grassland (Loeser et al., 2004), or in plant communities with long evolutionary histories and low productivity (Milchunas and Lauenroth, 1993).

Recent research has focused on the effects of fencing on vegetation characteristics (Liu et al., 2015), vegetation succession (van Rooyen et al., 2015), community structure (Huallachain et al., 2014), quantitative phytosociological character (van Rooyen et al., 2015) and plant diversity (Vuorio et al., 2014). In addition, many studies have focused on the effects of fencing on soil physical and chemical properties (Su et al., 2004; Wu et al., 2010; Wang et al., 2014a), soil C and N cycling (Frank and Groffman, 1998; Herman et al., 2003; Miller et al., 2014) and soil C and N storage (Qiu et al., 2013; Deng et al., 2014b). However, few studies have investigated fencing's effects on soil–plant community composition, diversity and productivity, soil properties, soil particle size, and the relationship between soil particle size and soil chemical properties as a whole.

In this study, we examined the effect of a grazing exclusion (approximately 12 years) on grassland vegetation and soil properties in a desert steppe of the Loess Plateau. The objectives of this study were (1) to determine the quantitative phytosociological character, soil chemical properties and the soil particle size distribution, (2) to make clear the relationship between soil particle size distribution and soil chemical properties, and (3) to specify the effects of soil layer, land use type and their interaction on soil properties in the study area. Although grassland restoration is a long-term and complex ecological process (Hastings et al., 2007), we expect that short-term fencing can continue to significantly improve the vegetation and soil indicators.

2. Materials and methods

2.1. Study site

The experimental site is located in Huan County, Gansu Province, China (106°50.4′E, 36°8.4′N, 1650 masl) (Fig. 1) in the northern Loess Plateau. The study area receives a mean annual rainfall of 359 mm. The site's soil type is aeolian sandy soil, and the region receives more than 60% of its total rainfall during the July–September period. Wind erosion and the subsequent desertification are widespread in this area. The area's semi-arid temperate continental monsoon climate produces a mean daily temperature of 9.2 °C, a mean annual total of 2600 sunshine hours, a mean annual evaporation of 2000 mm, and 200 frost-free days per year on average.

The vegetation type is temperate desert grassland. The dominant perennial grasses are *Leymus secalinus*, *Pennisetum flaccidum* and *Stipa bungeana*. The main perennial forbs are *Artemisia capillaries*, *Heteropappus altaicus*, *Lactuca indica* and *Potentilla bifurca*. The main perennial legumes are *Astragalus adsurgens*, *Lespedeza daurica* and *Medicago sativa*, and the main annual plants are *Agriophyllum squarrosum*, *Corispermum puberulum* and *Setaria viridis*. The grass plants revive in mid-late April, remain reasonably productive from late June to late August, and wither in mid-late September.

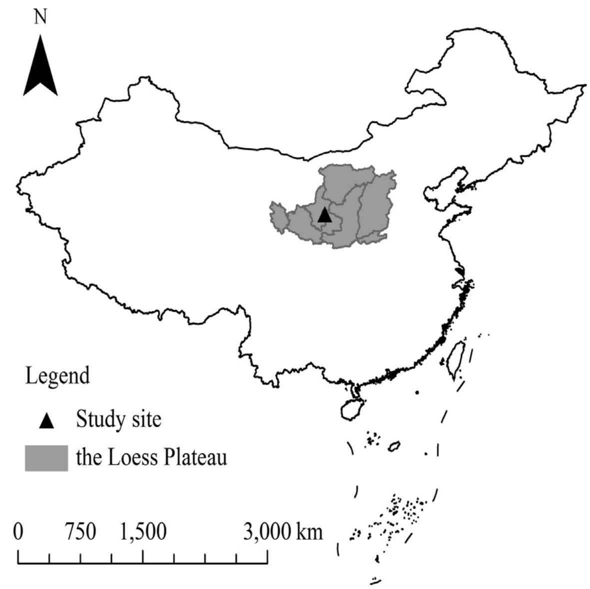

Fig. 1. Location of study site on the Loess Plateau, China.

In the study area, the implementation of the Returning Grazing Land to Grassland is the responsibility of the local government and typically assumes the form of specific projects, such as grazing prohibitions and the fencing of large parcels of grassland (Deng and Shangguan, 2014). However, sheep and cattle grazing continue near human settlement, and illegal sheep and cattle grazing frequently occurs at night on unfenced land that is distant from residential areas.

2.2. Experimental design and sampling

2.2.1. Experimental design

Within the experimental area, samples were collected in mid-August (2013), when the biomass had reached its peak. Using the line transect method, nine 10 m × 10 m blocks within open-grazing and fenced communities areas were randomly selected. The fenced communities were established in 2001, and approximately 12 years of grazing exclusion had passed since fencing. The grazed communities were unfenced, free-grazing communities. In total, there were 18 study blocks. Two adjacent 1 m × 1 m quadrats were established in the center of each block. One quadrat was used for overall investigation (i.e., the overall quadrat), and the other quadrat was used for individual species investigation (i.e., the sub-quadrat). The overall quadrats were investigated with respect to the entire quadrat community's aboveground-biomass, belowground-biomass, litter, canopy coverage, height and soils. The sub-quadrats were investigated with respect to the entire quadrat community's species composition, height, plant density (i.e., the number of individuals per square meter) and the aboveground-biomass of individual species. Humans could freely interfere in the grazed communities, whereas in the fenced communities, there was no external interference.

2.2.2. Biomass measurement, soil sampling and determination

In this study, the biomass measurement and the soil sampling procedures were the same as those used in previous studies (Deng et al., 2014a, 2014b). Soil organic carbon (SOC) content was determined by the $K_2Cr_2O_7$–H_2SO_4 oxidation method (Nelson and Sommers, 1996). Soil total nitrogen (TN) content was assayed