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Vegetation and soil property response of short-time fencing in temperate desert of the Hexi Corridor, northwestern China

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ABSTRACT

Overgrazing has caused serious soil degradation, vegetation destruction, and wind erosion in temperate desert areas of northwestern China. To address this, the Livestock Enclosure Scheme was implemented in 2004 to allow for self-recovery of the overgrazed desert. The aim of this study was to investigate the effect of livestock enclosure on the restoration process by examining changes in the ecological environment of a temperate desert recovering from overgrazing. Vegetation parameters and soil properties under grazing site, 5-year fenced site, and 9-year fenced site were examined in the degraded desert in the Hexi Corridor of China. The results showed that vegetation coverage, height, plant density, richness, diversity, and litter biomass all improved after 5 years of fencing, demonstrating that short-time fencing had a positive effect on vegetation restoration in the temperate desert. Furthermore, 9 years of fencing significantly increased soil organic C (SOC), total N (TN), and total P (TP) in the 0–20 cm soil profile, while available N (AN) and available P (AP) showed the reverse trend. The values of soil C and N storage after 9 years of fencing were almost 5.55 Mg ha^{-1} and 0.69 Mg ha^{-1}, respectively. Enhanced vegetation caused reductions in soil water near the soil surface (0–30 cm) where vegetation uptake mainly occurred. These findings could offer insight into the development of effective strategies for protecting and enhancing the resilience of a livestock-disturbed temperate desert.

1. Introduction

Desertification is one of the main types of ecological degradation problem in arid and semi-arid areas across the globe (Cao et al., 2011; Su et al., 2005; Schönbach et al., 2011). Overgrazing by livestock and herbivores causes highly intensified desertification, grassland degradation, and nutrient depletion in these areas (Deng et al., 2014b; Jeddi and Chaieb, 2010; Manzano and Navar, 2000). The effect of overgrazing on plant species and soil properties is destructive. Previous studies have demonstrated that overgrazing can decrease vegetation coverage, develop invasive species, and reduce vegetation biodiversity (Fernández-Lugo et al., 2013; Pei et al., 2008). Soil physical, chemical, and biological properties are all modified by excessive livestock grazing, which include a reduction in soil infiltration as a result of trampling, changes to soil hydrological processes, and an enhancement of susceptibility to wind erosion (Steffens et al., 2008; Zhao et al., 2005). Together, these lead to lower productivity and resilience of grasslands. Therefore, research on some ecosystem management actions is urgently needed for the severely degraded desert.

Promotion of ecological restoration is an important step in the successful recovery of degraded ecosystems (Jones, 2013). It has been shown that degraded grasslands enter self-recovery state, if the damaging practice ceases for an acceptable length of time (Li et al., 2009). For this reason, some ecosystem rehabilitation strategies, such as Grain for Green in the Loess Plateau of China, have recently been implemented to reverse the unfavorable trend (Deng et al., 2014a; D. Wang et al., 2014). Fencing, as a means of reducing grazing, is considered an effective management practice to restore vegetation and soil parameters in degraded meadow and steppe (Han et al., 2008; Wu et al., 2010). The effect of fencing on vegetation parameters has been the focus of several recent studies, which found that livestock exclusion increases vegetation cover, plant composition, and biomass accumulation (Korkanc, 2014; H.L. Zhao et al., 2007). Studies focused on the effects of fencing on soil hydrological processes and soil nutrient cycling, which demonstrated that favorable grassland strategies improve the capacity of soil infiltration and increase soil fertility in grasslands with semi-arid environment (Mekuria and Aynekulu, 2013; D. Wang et al., 2014; Yuan et al., 2012). However, conclusions drawn about the favorable restoration process have been limited by the lack of the evidence about the starting conditions at these study sites (Su et al., 2005; Zhao et al., 2005; Pei et al., 2008).

In northwest China, desert grasslands are widely distributed and near to 6.56×10^7 hm^2 (M. Wang et al., 2014). The Hexi Corridor in Gansu Province represents a typical gravel desert ecosystem. The major landscape types of this region are the peripheral desert, desert-

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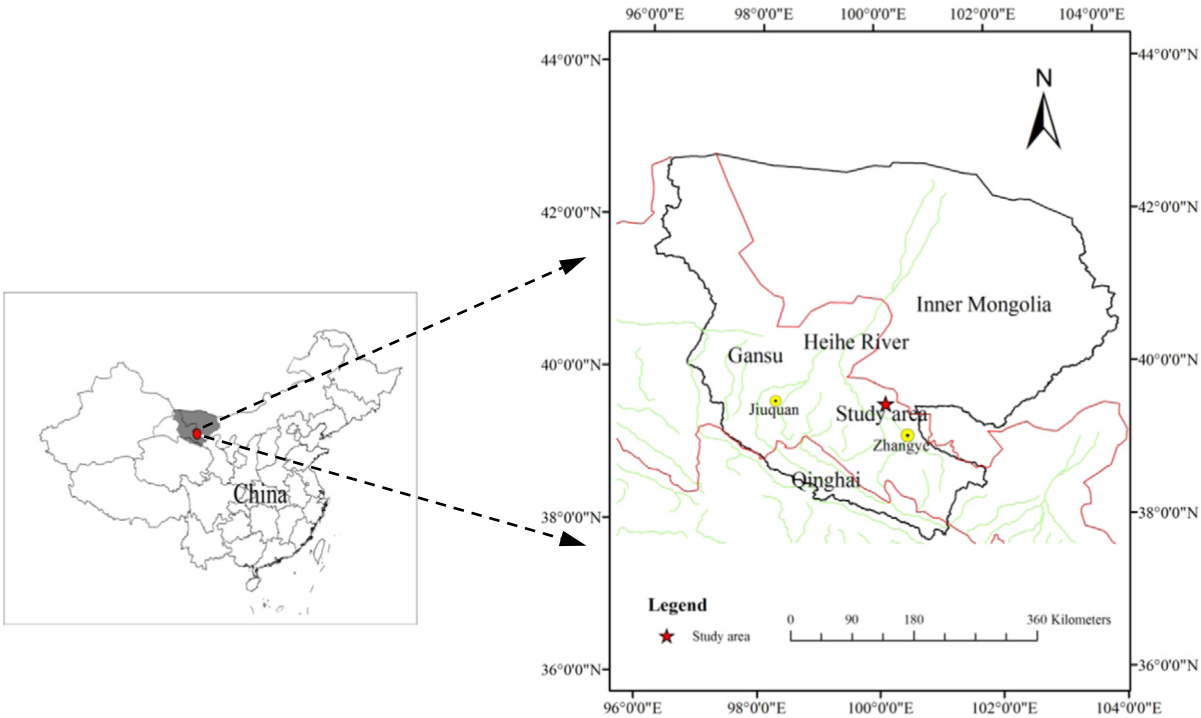

Fig. 1. Location of study area.

oasis ecotone, and central oasis; with the desert playing a crucial role in maintaining the stable ecological environment and agriculture productivity of the desert-oasis region (Zhang and Zhao, 2014). Over the years, livestock grazing has led to the destruction of scattered vegetation in this region, which led to serious environmental conditions such as desertification and wind erosion. Although a grazing restriction has been implemented since 2004 in this area, little is known about the effects of grazing exclusion on vegetation characteristics and soil properties. In addition, the desert ecosystem in the Hexi Corridor has unique features: the vegetation structure, composition, and function all differ in comparison to other meadow steppes in Tibet and steppes in Inner Mongolia (Pei et al., 2008; Shang et al., 2013; Wu et al., 2010). There is scarce precipitation, limited shrubs with shallow roots, large gravel content and coarse soil, and highly intensified wind erosion (M. Wang et al., 2014); therefore, the development of vegetation and soil restoration will be different from other grasslands. Given the unique attributes of the Hexi Corridor and the environmental impact this region has encountered from overgrazing, examination of the effects of grazing exclusion on vegetation recovery and soil properties will offer important insights into the value and direction of ecological restoration efforts.

In this paper, a typical fenced region within the desert was chosen as a study case. The objectives of this study were: (1) to investigate the change of vegetation parameters after implementing Livestock Enclosure Scheme; and (2) to analyze the effect of grazing exclusion on soil properties in the desert region of northwestern China.

2. Materials and methods

2.1. Study area

The study was performed in a typical desert in the middle reaches of the Heihe River Basin, which is 1405 m above sea level and located in the Hexi Corridor of Gansu Province (100°07′ E, 39°24′ N) (Fig. 1). The study region belongs to the Linze Inland River Basin Research Station, Chinese Ecosystem Research Network. The southern piedmont is an inclined oasis plain, and the northern is the margin of the Badain Jaran Desert. The zonal soil is classified as gray-brown desert soil (Table 1), derived from diluvial–alluvial materials of the denuded monadnock. Due to highly intensified wind, the surface layer is strongly eroded and covered by coarse gravels. The aboveground vegetation is discontinuous and covers with scarce sub-shrub patches surrounded by bare areas (Fig. 2a). The study area had been fenced since 2004 and was protected for the purpose of re-vegetation and reclamation. The dominant shrubs are *Reaumuria soongorica* (Pall.) *Maxim.* and *Nitraria sphaerocarpa Maxim.*, with a few herbaceous species such as *Allium mongolicum Rgl.*, *Bassia dasyphylla* (Fisch. and Mey.) *Kuntze.*, *Zygophyllum*

Table 1
Soil physical properties of study area.

Soil depth (cm)	Soil types	Soil particle size distribution (%)			Bulk density (g cm^{-3})
		Sand (0.05–2.00 mm)	Silt (0.002–0.05 mm)	Clay (<0.002 mm)	
0–20	Gray-brown desert soil	87.21 ± 2.23[a]	8.82 ± 1.90	3.32 ± 0.18	1.63 ± 0.02
20–40		91.25 ± 1.76	5.91 ± 1.98	2.82 ± 0.37	1.62 ± 0.02
40–60		92.97 ± 1.12	3.97 ± 0.94	3.08 ± 0.02	1.66 ± 0.02
60–150		87.28 ± 3.60	8.63 ± 3.24	3.63 ± 0.21	1.68 ± 0.01

[a] Values represent means followed by the standard error.