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Effects of shrub patch size succession on plant diversity and soil water content in the water-wind erosion crisscross region on the Loess Plateau

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ABSTRACT

The shrub patch pattern has important influence on the ecosystems in the arid water-wind erosion crisscross regions. The objective of this study was to examine the effects of vegetation pattern of shrub spot patch on species diversity and soil water content at the sand in slopes in water-wind erosion crisscross region on the Loess Plateau. In this study, the shrub patch size was classified to four size classes, contrasting with bare land patch, and herbaceous plants, and soil water content of the shrub patch were measured in each patch. The Shannon–Wiener indices were 0.364 and 1.074 respectively in small and large patches, which were higher than 0.231 in the bare land patch. The Richness index was 1.41 in bare land patch, which was lower than 1.704 in small shrub patch and 4.370 in large shrub patch. The above- and below-ground biomass and surface soil water content were also significantly ($p < 0.05$) higher in the shrub patch than that in the bare land patch. These results suggest that the shrub patch could significantly increased species diversity, the above- and below-ground biomass, and surface soil water content. Based on these results, the soil was aggregated in shrub patch and the vegetation pattern was successive and each cycle of vegetation pattern was benefited by its previous stage in the water-wind erosion crisscross region on the Loess Plateau.

1. Introduction

The arid and semiarid regions cover about one third of the Earth's land surface, especially the water-wind erosion crisscross region on the Loess Plateau, and they are heavily influenced by desertification (D'Odorico et al., 2013). Landscapes of water-limited systems are mosaics of fertile vegetative patches and crusted soil of low productivity (Sheffer et al., 2007). Bands (Merino-Martín et al., 2012), rings (Ravi et al., 2007), stripes (Mauchamp et al., 1993) and spots (Couteron and Lejeune, 2001) are the common vegetation patterns of ecosystems, and they are characterized by the size and shape. There are some discussions about the importance of their present study. Some scholars studied the interactions among factors such as overgrazing, recovery from anthropogenic disturbance (Segoli et al., 2008; Archer, 2010; Daryanto et al., 2013), increases in CO_2 and N deposition, reduced fire frequency and long-term climate change (Eldridge et al., 2011). In different aspects, the vegetation patterns also have various process and mechanism. Under spot vegetation pattern in the denser plant areas, runoff and sediment transport processes result in the formation of heterogeneous landscape with a mosaic of nutrient rich soil patches – known as "fertility islands" - bordered by unfertile bare soil (Charley and West, 1975). These vegetation patterns can efficiently prevent the erosion of water and soil. There are many researches on the desert shrub patch, mainly about plant community (Koyama et al., 2014;) and the soil property (Ludwig et al., 2005; Hu et al., 2009; Vásquez-Méndez et al., 2010; Zhao et al., 2010). In arid ecosystems, it was common to find islands of fertility associated with individual shrub plants (Garcia-Moya and McKell, 1970). The shrub vegetation displayed a pattern of higher soil organic matter and mineral nutrients in the vegetation patches compared with the low-cover matrix (Garcia-Moya and McKell, 1970; Rostagno et al., 1991; Mazzarino et al., 1996). Vegetated patches and their dominant shrub plants serve as protection from grazing for preferred plant species and protection from predation for small animals (Jaksić and Fuentes, 1980). However, studies of patch succession dynamics in arid and semi-arid environments have been comparatively scarce, especially the shrub spot patch at the sand in slopes.

Artemisia ordosica is one of the dominant shrubs in the semi-arid regions of China, and is an excellent sand-fixing shrub in Mu Us Desert, thereby playing an important role in fixing sand, maintaining biodiversity and ecosystem stability in the region (Yang et al., 2008). Considering the importance of the vegetation pattern of the *A. ordosica* shrub canopy patch in semi-arid regions, there is lack of research on the effects of the *A. ordosica* shrub canopy patch on the plant community and soil water content in sand in semi-arid regions. *A. ordosica* is the dominant

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species of the plant community succession in the semiarid regions. *A. ordosica* is a squat shrub and grows in a vegetation patch pattern with individual clumps of plants up to 180 cm across the canopy. Its tangled branches and stems are woody and corky (Huang et al., 2010). *A. ordosica* is long-lived about 10 years and the population recruitment was generally realized by reproduction from seed. At present, many researchers are studying the effects of *A. ordosica* on wind erosion (Yang et al., 2014). Therefore, the *A. ordosica* shrub patches could prevent the erosion of soil, and provide comfortable environment beneath the shrub canopy for the herbaceous plants. In order to manage the shrub patches to deal with the conundrum of the deteriorating environment in arid and semiarid regions; clarification of the mechanism, progress and law that governs vegetation patterns is needed.

Based on the above studies, we assumed that the shrub patches may increase the species diversity and the above- and below-ground biomass, and prevent the erosion of soil and that vegetation pattern of the shrub patches may cycle together with the accompanying herbaceous plants, and the difference of the microsites formed by different sizes shrub individuals may contribute to the cycling (formation, development and decline of shrub patch). So, we hypothesized that the plant species diversity, above- and below-ground biomass, and the soil water content should be greater under shrub canopies than that in their respective interspaces, and the shrub patches will appear in the environment with the dynamics of soil water in the water-wind erosion crisscross region on the Loess Plateau.

2. Materials and methods

2.1. Study sites and design

The study site was located at the Liudaogou watershed (110°21′–110°23′E, 38°46′–38°51′N, H: 1080–1270 m) of Shenmu County in the southern part of the Mu Us desert, it belongs to the water-wind erosion crisscross region on the Loess Plateau. There is continental semiarid and seasonal wind climate, with an average annual precipitation of 437 mm. Most of the precipitation falls mostly from June to September during intense rainstorms. Mean annual potential evapotranspiration is 785 mm. The soil of this study is an Aeolian sandy soil (particle size was >0.05 mm), which suffers wind erosion in spring and winter, and water erosion in summer and autumn (She et al., 2014). As such, the Chinese government implemented “the Grain to Green” program to reduce soil erosion in 1998 in the study region (Xu et al., 2006).

At the study site, the dominat species was *Artemisia ordosica* (*A. ordosica*, with some common species, such as *Artemisia sphaerocephala*, *Salix cheilophila*, *Lespedeza davurica*, and *Astragalus adsurgens*). *A. ordosica* is a squat shrub and grows in a vegetation patch pattern with individual clumps of plants up to 180 cm across the canopy. Its tangled branches and stem are woody and corky (Huang et al., 2010). *A. ordosica* is long-lived about 10 years and the population recruitment is generally realized by reproduction from seed. A single shrub plant can facilitate the development of the understory herbaceous species (Callaway, 2007) by decreasing abiotic stress or grazing damage (Facelli and Temby, 2002; Weedon and Facelli, 2008; Cushman et al., 2010). Four categories of *A. ordosica* shrub patch size (canopy diameter) were designed in this study: Small Shrub Patch (SSP) (<60 cm), Middle Shrub Patch (MSP) (60–95 cm), Large Shrub Patch (LSP) (>95 cm), Dead Shrub body Patch (DSP) (>95 cm) patches. Canopy diameter (diameter of the crown of the shrub) was measured at 40 cm above ground level.

2.2. Plant community investigations

In each quadrat, all green, aboveground plant parts of each species was cut, collected, and put into separate labeled envelops. To measure the belowground biomass, we used Complete Excavation method (get the entire root from the soil) to collect the entire root, and we measured the depth and width of the root. The roots and aboveground plant parts were dried at 65 °C for 24 h and weighed to determine the dry biomass.

The Richness Index, Shannon–Wiener diversity index and Pielou evenness index of the patches communities were calculated using the following functions (Stirling and Wilsey, 2001):

Richness index (R):

$$R = S$$

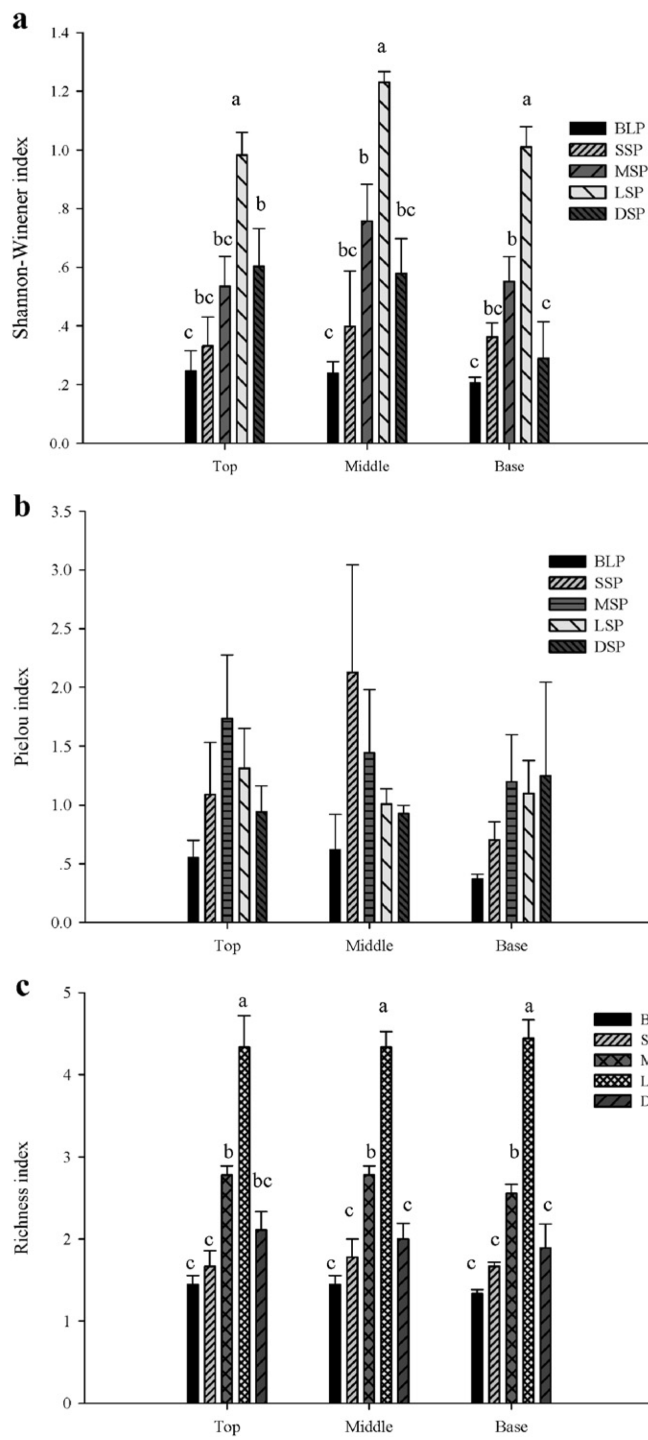

Fig. 1. Shannon–Wiener index (a), Pielou evenness index (b) and Richness index (c) of five patches at three different positions at the slope. Different letters indicate significant differences at $p < 0.05$ among the different patches at the same position at the slope.