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Effectiveness of afforested shrub plantation on ground-active arthropod communities and trophic structure in desertified regions

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ABSTRACT

In desertified regions, the mobile sand land, and afforested shrubland of different ages (i.e., 6, 15, 24 and 36 years) in addition to the naturally restored grassland were selected in order to evaluate their consequences on taxonomic and trophic structures, and the diversity of ground-active arthropods. The taxa-specific responses to the land conversion were found within functional groups. The activity density of predator Labiduridae and Carabidae, and herbivore Tenebrionidae decreased, while that of herbivore Melolonthidae and omnivore Formicidae increased markedly ($p < 0.05$) from the mobile sand land to the afforested shrubland, regardless of shrubland ages. The taxa richness of herbivores also increased markedly ($p < 0.05$) from the mobile sand land to the afforested shrubland, regardless of shrubland ages. However, there was little effect of land conversion on the activity density and richness of detritivores due to the lack of litter on the surface of soils. Different functional groups of ground-active arthropods responded in a different way to the land conversion. The total density and Simpson index decreased, while the taxa richness and Shannon index increased markedly ($p < 0.05$) from the mobile sand land to afforested shrubland, regardless of shrubland ages. It was suggested that the afforested shrub plantations of different ages had similar implications on the trophic structure and diversity indices as was close to the naturally restored grassland (except for Shannon index). The Shannon index in the grazed afforested shrubland of 24 years that was close to the naturally restored grassland was markedly ($p < 0.05$) lower compared with the other afforested plantations. In conclusion, the afforested shrubland was an option for the stabilization of mobile sand land and biodiversity recovery of degraded ecosystems, regardless of shrub ages. Furthermore, the grazing management on afforested shrubland could improve the effectiveness of this recovery process.

1. Introduction

In arid and semi-arid areas, the sandy grassland is susceptible to land degradation and has undergone severe desertification primarily due to heavy grazing combined with climate change (Li et al., 2004; Zhao et al., 2005). Desertification in addition to drought which is directly related to the degradation of vegetation cover, soil degradation, and nutrient depletion, is causing great ecological concerns about the management on desertification reversion (Mekuria et al., 2007; Nyssen et al., 2004; Zhao et al., 2010). The widespread afforestation program has been reported as an effective management for the stabilization of mobile sand land and the recovery of degraded arid ecosystems, and plays an important role in rehabilitating desertified ecosystems (Jiang et al., 2007; Su and Zhao, 2003). In addition, the rate of transition from an afforested plantation to natural vegetation depends on the aboveground and belowground processes (Wardle et al., 2004). It was found that the afforested shrubs aboveground acting as "fertile island" indicated an improvement of soil properties and herbaceous vegetation in mobile sand land (Zhao et al., 2007). Correspondingly, these changes in environmental variables acting as living conditions and food sources for soil animals might have fundamental effects on the composition, abundant distribution and trophic structure of soil biota community belowground.

In the desertified regions, the perennial desert shrubs selected as the afforested plantations were found to become "hot spots", acting as a pronounced biological "hub" in determining soil community (Cushman et al., 2010; J.L. Liu et al., 2012; Liu et al., 2012a,b). The improved shrubland habitat maintained significantly higher abundance and group richness diversity of soil arthropods compared with the mobile sand land (Liu et al., 2013). This was ascribed to the multiple functions that the shrubs served as primary producers and providers of resources as well as modulators of the physical environment (e.g., microclimate, soil nutrient and water availability) beneath their canopies (Shachak et al., 2008; Wang et al., 2011). These ecological functions were combined to create a favorable microhabitat with relatively mild microclimates, secure oviposition sites, high resource availability and shelter, thereby resulting in a greater degree of arthropod

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activity and colonization in areas under shrubs in comparison to the open spaces between shrubs (Titus et al., 2002; Liu et al., 2011). The activities of soil organisms played key roles in various ecosystem functions such as soil structure dynamics and decomposition of organic matter (Lavelle and Spain, 2001). As reported, the shrub patches in mobile sand land facilitated soil arthropod assembly and acted as "Arthropod Island" that was directly correlated with the food web structure and ecological function (Zhao and Liu, 2013). Shrub plantation age indicated significant influences on the diversity of ground arthropods though that depended on seasonal changes (Liu et al., 2013). However, the recovery effectiveness and extent of ground-active arthropods along the chronosequence of afforested shrub plantations remained unclear, relative to the naturally restored grassland.

The goal of this study was to describe the changes of taxonomic and trophic structures, and biological diversity of ground-active arthropods in the mobile sand land along a chronosequence of afforested shrublands (6, 15, 24 and 36 years) relative to the naturally restored grassland.

2. Materials and method

2.1. Ethics statement

A scientific research and collecting permit were obtained for the study from the Science and Technology Department of Yanchi County, Ningxia in 2013. No specific permits were required for the described field study. Our study did not involve endangered or protected species. Voucher specimens were deposited in the Key Laboratory for Restoration and Reconstruction of Degraded Ecosystems in Northwestern China of Ministry of Education, Ningxia University.

2.2. Study area

The study was conducted in northern Yanchi county (37°04′–38°10′ N and 106°30′–107°41′E), which is located at the southwest fringe of Mu Us sandy land in the Ningxia Hui autonomous region, China (Fig. 1). The study region is a typical agro-pasture transition zone

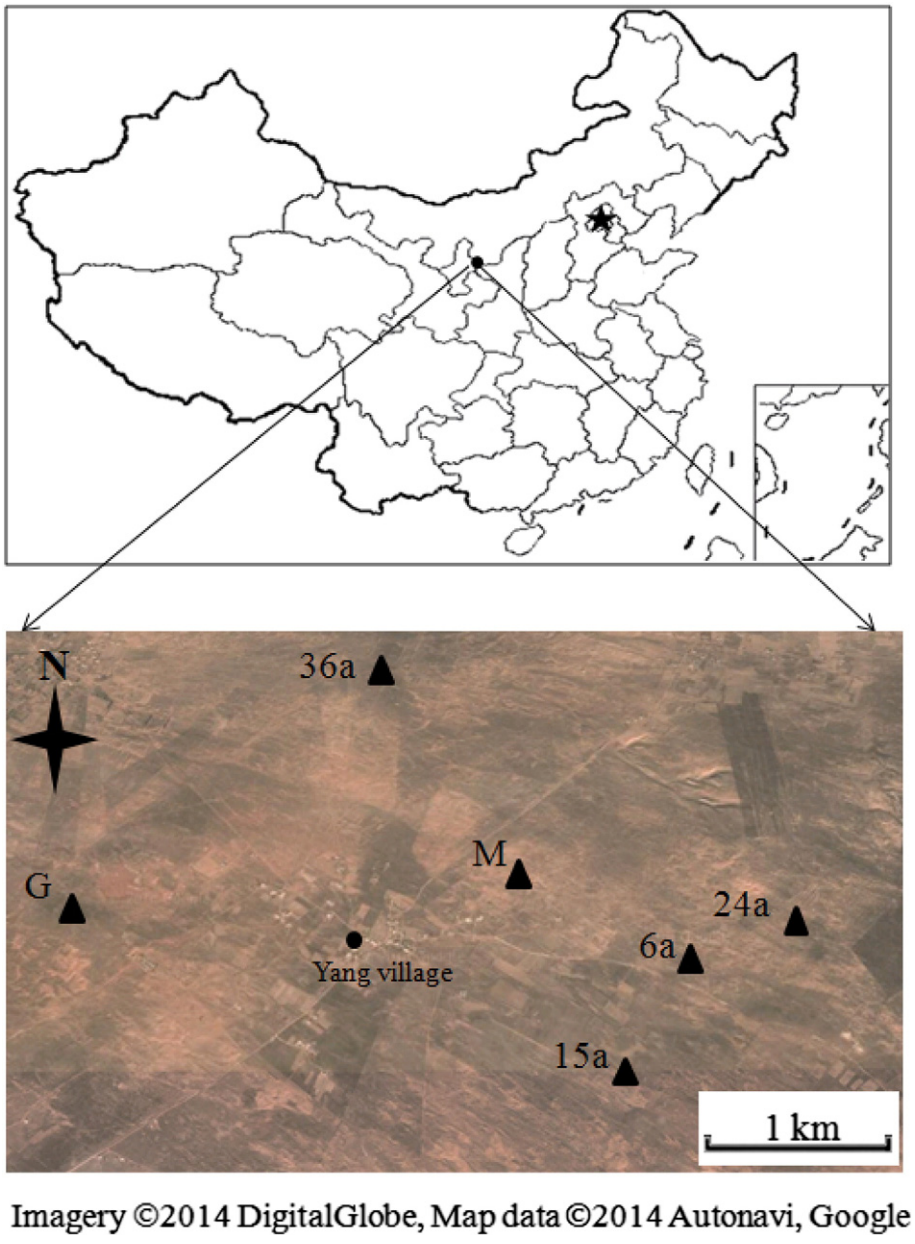

Fig. 1. Location of study area (●) and sampling sites (▲) in northwestern China.