Catena 137 (2016) 126–133

Contents lists available at ScienceDirect

Catena

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

Growth stages affect species richness and vegetation patterns of nebkhas in the desert steppes of China

Weicheng Luo, Wenzhi Zhao *, Bing Liu

Linze Inland River Basin Research Station, Key Laboratory of Inland River Basin Ecohydrology, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China

ARTICLE INFO

Article history:
Received 25 February 2015
Received in revised form 16 September 2015
Accepted 19 September 2015
Available online 29 September 2015

Keywords:
Desert steppes
Nebkha growth stage
Nebkha morphology
Species composition
Species growth form

ABSTRACT

Nebkhas are important indicators of land degradation in desert steppes and play an important role in the ecological and evolutionary dynamics of desert steppe ecosystems. This study examined the relationship between the diversity of plant species and nebkha morphology during different growth stages of the nebkhas. In this study, each nebkha is defined as a self-contained unit. The species composition and vegetation patterns within each unit during different stages of formation were investigated, while also the plant species within the inter-nebkha area of the desert steppe field were examined. Results show that more than 90% of the species within the nebkha units were herbaceous. In developing nebkhas, the increase in nebkha size was associated with an increase in the herb species richness but a decrease in the overall plant density. When nebkha size was constant, similar correlations with species richness or density were found. The richness of species within the inter-nebkha area was significantly higher compared to developing nebkhas during periods of growth, but lower when nebkha development was complete and growth had stalled. The density of species was significantly higher in the nebkhas than the inter-nebkha area during all developmental periods. Thus, nebkhas provide a highly favorable condition for plant recruitment and survival when fully developed. However, when nebkhas are still forming, the inter-nebkha areas provide greater plant support. These results have important implications to biodiversity conservation in desert steppe fields.

1. Introduction

Phytogenic nebkhas, often referred to as coppices (Link et al., 1994; Rango et al., 2000; Wood et al., 1978) or vegetated dunes (Nishimori and Tanaka, 2001; Wang et al., 2008), are mounds of wind-borne sediment associated with the canopies of plants (Batanouny, 2001; Tengberg and Chen, 1998; Vasek and Lund, 1980). They are commonly distributed in arid, semi-arid, and sub-humid regions (Nickling and Wolfe, 1994; Parsons et al., 2003), and their formation is determined by several factors. These factors include: climate change, vegetation degradation, anthropogenic activity and the hydrogeological condition of the local area (Cabrera-Vega et al., 2013; Tengberg, 1995; Yan et al., 2005; Wang et al., 2006). Plant type and sand conditions strongly influence the morphological characteristics of developing nebkhas (El-Bana et al., 2007; Khalaf et al., 1995).

In desert steppe ecosystems, nebkhas are important indicators of land degradation (Cabrera-Vega et al., 2013; Wang et al., 2006). Nebkhas work to combat land degradation by stabilizing soil surfaces, preventing soil erosion and facilitating plant recruitment and survival (Aguiar and Sala, 1999; Brown and Porembski, 1997; Titus et al., 2002; El-Bana et al., 2002). Hence, the stability of the desert steppe ecosystem may be highly dependent upon the formation of nebkhas and their promotion of biodiversity conservation and vegetation restoration (El-Bana et al., 2003). Thus, the development of nebkhas is an important ecological consideration in the environmental studies of desert steppes (El-Bana et al., 2002; Okin, 2013).

The spatial distribution of resources, like soil moisture or nutrients, within the nebkhas is different from those in the surrounding area (El-Bana et al., 2003; Hesp and McLachlan, 2000). Nebkhas contain highly heterogeneous distributions of perennial biomasses (Okin, 2013) and are fertile islands in comparison to the barren land surrounding them (Carrera et al., 2003; Schlesinger et al., 1996; Stock et al., 1999). This is particularly notable in un-grazed land, where species richness and abundance are particularly higher in nebkhas compared to the inter-nebkha area (El-Bana et al., 2003). In conjunction with a poorer soil composition, soil temperature and photosynthetically active radiation are highest in the inter-nebkha area (Domingo et al., 2000), making the conditions within nebkhas more favorable for plant growth. Importantly though, the favorable conditions in the nebkhas are dependent on the surrounding environment since a reduction in vegetation cover between them could cause serious wind and water erosion to the nebkhas (El-Bana et al., 2003).

* Corresponding author.
E-mail address: zhaowzh@lzb.ac.cn (W. Zhao).

http://dx.doi.org/10.1016/j.catena.2015.09.011
0341-8162/

The positive effect of nebkhas on plant abundance and richness within the desert steppe is dependent on nebkha morphology (El-Bana et al., 2003). Plant species richness is significantly related to nebkha size by a single-power function, as predicted by the island biogeography theory. The nature of this relationship within nebkhas is dependent on the identity of the nebkha's host species, since the host species can affect the growth and survival of other species (El-Bana et al., 2003, 2007; Pool et al., 2013). It is known that the interaction between species can significantly affect the species structure and the composition of communities and ecosystems in either a positive or negative manner (Brooker, 2006; Gao et al., 2014; le Roux et al., 2013; Holzapfel and Mahall, 1999; Schenk and Mahall, 2002). For example, relatively larger annual plant species can support the growth of smaller annuals, like shrub nurse-plants (Armas and Pugnaire, 2005). By contrast, the influx of alien species can negatively influence the existing plant community, and cause a reduction in diversity and loss of native species (Levine et al., 2003).

The relationship between the number of species and the area sampled is one of the oldest and best-documented patterns in community ecology (He et al., 2005). However, this relationship differs greatly among desert, grassland and woodland areas (Crawley and Harral, 2001; He et al., 2005). Most documentation of these relationships is on coastal or desert systems, while little information is available for desert steppe systems. Even fewer studies have examined the species richness and composition within developing nebkhas or inter-nebkha area in desert steppe fields. Therefore, the aim of this study was to: (1) examine the relationship between plant speciation and nebkha morphology; (2) identify possible vegetation differences between the nebkha and the inter-nebkha area; and (3) determine whether the stage of nebkha development affects the degree of speciation within the nebkhas. To do this, we studied the patterns of species richness and composition within nebkhas formed by *Nitraria tangutorum* and the surrounding inter-nebkha area in the desert steppes of China.

2. Materials and methods

2.1. Study site

The study site was located in a desert steppe field south of Mu Us Sand land (37° 04′–38° 10′ N, 106° 03′–107° 47′ E, 1354 m a.s.l.), in Ningxia, China (Fig. 1). The region typically has a typical temperate continental climate. The annual mean temperature is 9.2 °C. The average annual rainfall is 280 mm, primarily accumulating during the summer and autumn seasons, and the average amount of evaporation totals 2100 mm per year (Zhou et al., 2015). The growing season starts in late April and ends in late September. Grasslands and sandy banks are largely distributed throughout this area, constituting of about 64% and 23% of the total area, respectively. In contrast, forests occupy only 11% of the land area, and croplands make up 2% (Liu et al., 2010). The windy season is from March until May. Wind has significant impacts on the natural environment of this area, and is one of the most prevalent causes of desertification. The prevailing wind directions are westerly and northwesterly, and the average wind speed is about 2.8 m per second (Shen, 2008). The main soil types of this area are aeolian sandy soil and loessial soil. The average nutrient content of the soil in the central

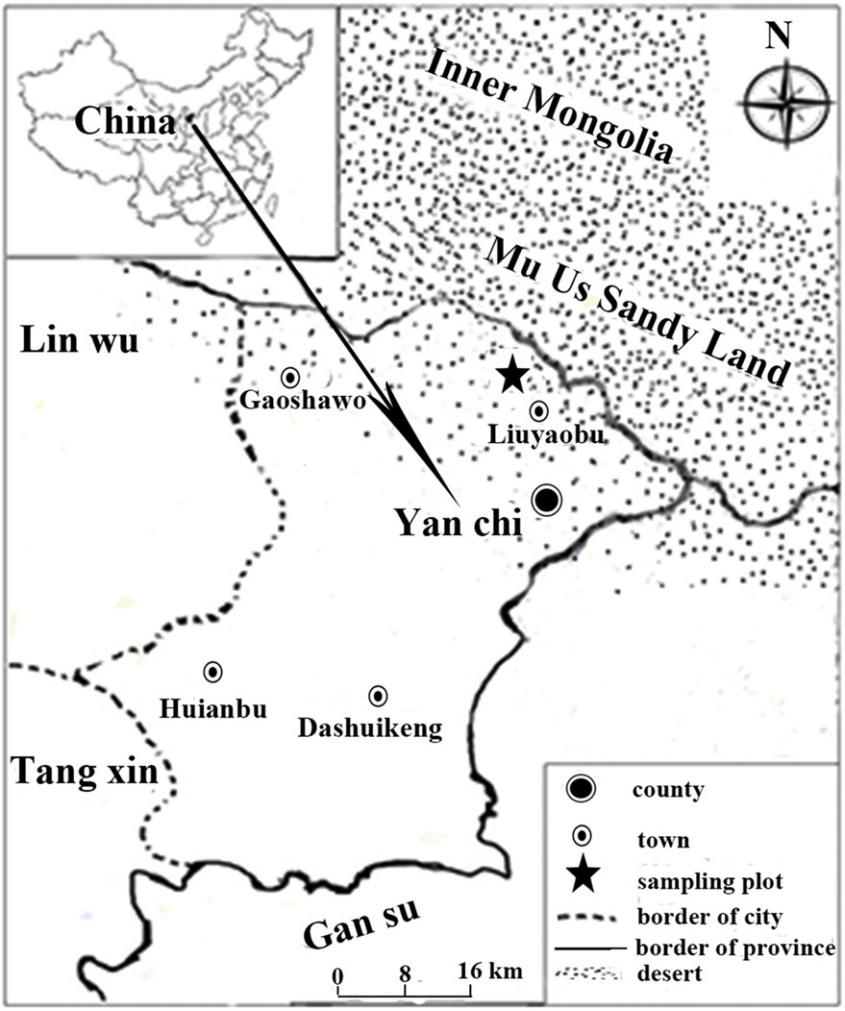

Fig. 1. Location of the study area (Zhou et al., 2015).