Landscape and Urban Planning 120 (2013) 25–33

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research paper

Spontaneous urban vegetation and habitat heterogeneity in Xi'an, China

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HIGHLIGHTS

- Spontaneous urban vegetation in public spaces in Xi'an, China contained 84% native plant species.
- Most species were generalists, and likely will not contribute to biodiversity conservation initiatives.
- These species could be used in urban greening initiatives in polluted areas.
- Species diversity increased with the number of distinct microhabitat types at a site.
- Incorporation of habitat heterogeneity into urban greening could promote greater plant species diversity.

ARTICLE INFO

Article history:
Received 19 April 2013
Received in revised form 18 July 2013
Accepted 1 August 2013

Keywords:
Plant community
Urban ecology
Non-metric multidimensional scaling
Environmental heterogeneity
Trampling

ABSTRACT

Plant growth and survival can be challenged by harsh urban conditions. There is little published on the spontaneous vegetation in urban China, but studies in other parts of the world show the persistence of native species in built-up areas, and document ecosystem services provided by spontaneous vegetation. Here we describe spontaneous vegetation in urban Xi'an, in northern central China, and quantify the relationships between species diversity and composition, and environmental variables representing productivity, spatial habitat heterogeneity and disturbance. A total of 95 plant species were recorded belonging to 75 genera and 37 families. Family and species diversity were positively related to soil depth and microhabitat heterogeneity, and negatively related to trampling intensity. Variation in species composition was mainly related to trampling intensity and distance from the city center. Microhabitats were weakly differentiated by species composition, likely because several common generalist species were found throughout the city in a variety of microhabitat types. While some of the most frequently encountered species in the spontaneous vegetation of Xi'an are considered non-native and invasive, some of these may be capable of surviving difficult conditions in revegetation projects and could have some benefits in challenging urban environments.

1. Introduction

China has some of the oldest continually inhabited cities in the world, and has seen a huge expansion of urban populations in the last decade. While it is widely accepted that cities can host substantial amounts of "biodiversity", it is well known that native species diversity declines toward the urban center, non-natives become more relatively abundant, habitats become more patchily distributed and anthropogenic disturbances can be severe (McKinney, 2002, 2006; Turner, Lefler, & Freedman, 2005). Nevertheless, built-up areas can be important for the conservation of plant biodiversity (Goddard, Dougill, & Benton, 2009; Godefroid & Koida, 2007). Studies of urban plant communities in China have highlighted the trend toward greater richness of non-native species in cities compared to smaller settlements (Wang, Meng, Zhu, & Zhang 2009), and the high prevalence of species considered invasive in cities (Zhao, Ouyang, Zheng, et al., 2010). Chinese cities stand out in their very high population density, and severe air and water pollution (Shao, Tang, Zhang, & Li, 2006), making them challenging for plants and urban biodiversity in general. Nevertheless, native species still make up around 50% of the flora in large cities such as Beijing in northern China (Zhao, Ouyang, Zheng, et al., 2010) and urban vegetation can contribute to a variety of economically important ecosystem services such as filtering of air and water (Jim & Chen, 2009). The majority of urban ecology research done in China

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0169-2046/$ – see front matter
http://dx.doi.org/10.1016/j.landurbplan.2013.08.001

has been in the south (but see Wang et al., 2009; Zhao, Ouyang, Zheng, et al., 2010) and focused on urban forest or tree communities (Guan & Chen, 2003; Jim, 1998).

Urban vegetation can be divided into three major categories: planted vegetation in managed areas, including parks and street trees, remnant natural habitats, and spontaneous vegetation. Planted vegetation is found along streets, in parks and institutional green spaces. Urban planted vegetation is a product of landscape architecture with the intention of improving the esthetic of urban areas, or to promote other services such as shading, visual buffering, or trapping of dust. Remnant natural habitats in urban areas are composed of natural habitat types such as forests which were preserved despite surrounding urban development, and are very uncommon if not altogether absent in northern Chinese cities. Urban spontaneous vegetation consists of plants not intentionally propagated by humans, but not considered remnants of natural habitats. Urban spontaneous vegetation can be found in any type of green space within a city as well as growing on hard surfaces such as walls, pavings and rooftops. Patches of spontaneous vegetation range in extent from large vacant lots or brownfields (De Sousa, 2006; Millard, 2004) to very small, such as in pavement cracks or sidewalks (Lundholm, 2011; Woodell, 1979). Recent work suggests that spontaneous vegetation can contribute important ecosystem services in urban areas, such as habitat for insects and other arthropods (Robinson & Lundholm, 2012). In China, many plant species found in urban areas have utilitarian value as medicine, food and ceremonial objects (Flora of China, 2010). While there is very little published on spontaneous urban vegetation in China, a few studies have shown that native species do occur spontaneously in cities (Jim & Chen, 2010; Zhao, Ouyang, Zheng, et al., 2010).

In urban core areas where built, hard surfaces dominate, spontaneous vegetation is distributed across multiple distinct kinds of microhabitat (Lundholm & Marlin, 2006; Woodell, 1979). Microhabitats are differentiated by physical features, disturbance frequency and other abiotic variables (e.g. Jim & Chen, 2010). For example, the “cracked wall” microhabitat can be contrasted with the “smooth wall” microhabitat by the amount of rooting space available (de Neef, Stewart, & Meurk, 2008). The wall base microhabitat is differentiated by the sidewalk microhabitat by the level of trampling and likelihood of soil accumulation. One of the distinguishing features of urban environments is the close proximity of microhabitats with different physical conditions, suggesting that spatial heterogeneity is quite extreme at fine spatial scales. Heterogeneity in urban areas results from differences in socioeconomic, cultural, climatic, edaphic and topographical characteristics (Alberti et al., 2003; Kinzig, Warren, Martin, Hope, & Katti, 2005; Bigirimana, Bogaert, De Canniere, Lejoly, & Parmentier, 2011; Pickett & Cadenasso, 2009), but such studies rarely consider fine spatial scales and few studies have attempted to assess how environmental heterogeneity influences species diversity in urban vegetation. While species diversity is widely expected to be positively correlated with environmental heterogeneity (Lundholm, 2009), this relies on specialization of species on particular types of habitat and the ability of species to reach appropriate sites. In urban environments, dispersal limitations may prevent species from reaching certain sites or local species pools may be dominated by a few generalists such that habitat heterogeneity is largely unrelated to species diversity, but this has rarely been directly tested.

The main goal of this study was to characterize urban spontaneous vegetation of a variety of habitats in built-up areas in Xi’an, north central China. We used randomly selected sites along publicly accessible streets to quantify the relative importance of environmental heterogeneity, and other important variables linked with disturbance intensity and fertility, as predictors of plant species and family diversity.

2. Methods

2.1. Study site

This study took place in the built-up areas of the city of Xi’an, China (34°23′–34°08′ N, 108°47′–109°07′ E). The city is located in the central northern region of China in Shaanxi Province. The study sites were located within the third ring road except for the Southern Chang’an area; a newly developed area that includes the Shaanxi Normal University new campus (Fig. 1). The geophysical conditions within the city represent a temperate semi-arid climate influenced by the East Asian monsoon. The city has an average elevation of 400 m with the annual mean air temperature being 14.1 °C, while the annual rainfall is 578 mm (Climatemps, 2011).

Inhabited since 6000 BC, from 255 to 206 B.C., Xi’an was the site of Xianyang, the capital of the Qin dynasty (World Encyclopedia, 1980). The fundamental structure of the city is a regular grid. The development pattern of the city has been concentric expansion from the walled city core. Currently the urban area of Xi’an covers approximately 1000 km^2.

Xi’an is located in a river valley with the Loess Plateau to the north and the Qinling mountains to the south. The core of the city has been urbanized for thousands of years; however since industrialization, urbanization has been consuming agricultural lands around the urban core. Urban vegetation occurs in the many managed green spaces within urban Xi’an consisting of parks, institutional green spaces, planted beds and trees and vegetation along streets. These managed green spaces consist primarily of non-native species. There is very little likelihood of remnant natural habitats existing in the urban areas of Xi’an due to the history of intensive agriculture surrounding the city. Urban spontaneous vegetation is common and can be found in managed green spaces as well as a variety of microhabitats within the city including rooftops, sidewalks and walls.

2.2. Sampling design

Sample sites were selected using a grid placed over the city (Fig. 1). Each square of the grid was 2740 m by 3070 m. Squares that were at least 50% within the third ring road were chosen as well as eight squares in the southern Chang’an District; a total of 60 grid squares were selected (Fig. 1). The eight squares in the Chang’an District were chosen to increase the sample size of the study and were considered appropriate because the Chang’an District displays a similar level of urbanization as the area within the third ring road.

One sample site was chosen within each square by randomly selecting a point from a 10 × 10 grid within the square, and determining the approximate latitude and longitude for the point. Each site was then given an alphabetic label randomly. The sites were sampled between June 7th and August 4th 2010 in order of their random label to avoid bias caused by sampling different geographic areas in the city at different times of year.

A Garmin Geko 101 Global Positioning System (GPS) device was used to locate the sample sites for sampling. The GPS reported accuracy between 5 and 50 m. Due to the urban nature of the study the exact coordinates were rarely available for sampling. The closest publicly accessible location (usually sidewalk parallel to a street) was chosen as the sample site and the GPS co-ordinates of this new location were recorded. Each site was also randomly assigned an aspect of north, south, east or west. Here, aspect refers to the surrounding buildings: a north-facing aspect means that a building or wall the site was in between the north side of a shade-casting building and the street parallel to the building. When sites were selected, the closest location to the random GPS coordinate which had the appropriate aspect was chosen. In some cases, this