Ecological Indicators 95 (2018) 117–126

Contents lists available at ScienceDirect

Ecological Indicators

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

Original Articles

Understanding treescape changes as the basis of urban forest planning in fringe areas

Lixin Chen[a,b,1], Liqun Wang[a,1], Ge Li[a], Fengwei Ma[a], Zhiqiang Zhang[a,b,*]

[a] College of Soil & Water Conservation, Beijing Forestry University, Qinghua East Road 35, Haidian District, Beijing 100083, PR China

[b] Key Lab of Soil & Water Conservation, The State Forestry and Grassland Administration of China, Qinghua East Road 35, Haidian District, Beijing 100083, PR China

ARTICLE INFO

Keywords:
Forest landscape dynamics
Urban fringe
Driving factors
Potential space

ABSTRACT

We selected the Mapo-Niulanshan township located in the urban fringe of the Beijing metropolis as a case study with the goals of understanding urban forest change dynamics and locating potential spaces for conserving and developing urban forests, in the context of land use change associated with rapid urbanization. The results revealed an increase in canopy cover and forestland with the urbanization process. There was a significant increase in canopy cover in highly developed areas due to rising landscape needs and regulatory demands. The majority of forestland was converted from farmland and consisted of tree nurseries that usually lacked a recognizable canopy cover in remote sensing images. The influence of population density (POP) was strongest, followed by those of the built-up area ratio (BCOV) and gross industrial production (GIP). These socioeconomic factors had varying effects on the spatial heterogeneity of the urban forest landscape. Most of the areas demonstrated a positive influence of socioeconomic factors on urban forest landscape, especially those adjacent to water bodies and forestland. Based on the R^2 values of the geographically weighted regression (GWR) models, unquantifiable indicators, such as policies and public preferences, were deemed very important in shaping urban forest landscape. According to the minimum cumulative resistance model (MCRM), suitable land for the development of urban forest mainly concentrated in the peripheral regions. Our research confirms that canopy cover must be considered with forestland area in spatial pattern analysis of the urban forest landscape. The results of the socioeconomic influence analysis and the MCRM helps to advance the understanding of urban forestry conservation and could improve policy-making and practices that promote urban forest under the pressure of urbanization.

1. Introduction

Urban forests offer urban dwellers a higher quality of life (Canetti et al., 2018) by delivering an wide array of economic, social, physical, psychological, and environmental benefits (Peckham et al., 2013; Landry and Chakraborty, 2009). However, the presence of urban forest is constrained by urbanization (Fahey and Casali, 2017; Riitters et al., 2002), especially in the urban fringe. In this urban-rural interface, land development is usually associated with a decrease in canopy cover and connectivity. Ongoing urbanization implies an increasing demand for and competition among resources (e.g., land for open spaces, water for irrigated green areas), leading to the trade-offs between land uses, ecosystem preservation and conservation, urban sustainability and economic development. This situation highlights the importance of understanding landscape change dynamics and designing urban forest systems that strengthen the resilience of urban environments and the well-being of their residents in the long-term.

Understanding land use change dynamics has great implications for urban forest conservation. Urban morphology can physically constrain the amount of previous space available to support vegetation cover. For example, intensely developed areas have less space for vegetation and less canopy cover even in forested landscapes (Nowak et al., 1996). Therefore, vegetation cover is among the most sensitive factors to landscape deterioration (Salvati and Bajocco, 2011). However, we cannot conclude that urbanisation does not always have a negative influence on urban forest because it is not only the cause of environmental problems but also a force for regional and global sustainability. For example, cropland has been transformed not only into urban areas, as in the suburbs of Bangkok (Hara et al., 2005) and Southern China (Liu et al., 2005), but also into forest and grassland, as in the Weigou

* Corresponding author at: College of Soil & Water Conservation, Beijing Forestry University, Qinghua East Road 35, Haidian District, Beijing 100083, PR China.
E-mail address: zhqzhang@bjfu.edu.cn (Z. Zhang).

[1] Lixin Chen and Liqun Wang contributed equally to this work.

https://doi.org/10.1016/j.ecolind.2018.07.031
Received 16 April 2018; Received in revised form 14 July 2018; Accepted 15 July 2018

River basin, Gansu Province, Northern China (Xiaofeng et al., 2009). Many residential and commercial areas in the Chicago suburbs were agricultural lands until very recently, while those in the interior of the city are likely to have been urban lands for well over a century. Such lags in development could influence the emergent forests (Fahey et al., 2012). Understanding landscape dynamics from a social perspective is also crucial for urban forest enhancement (Dorning et al., 2015). For example, political factors were found to be more important than individual behaviours in determining canopy cover in Ballarat, Australia (Kendal et al., 2012). In contrast, residents' income (Martin et al., 2004) and the proportion of immigrants (Troy et al., 2007; Szantoi et al., 2012) have been proven to be the major influencing factors in many U.S. cities. A basic understanding of the socioeconomic drivers of forest change (e.g., population increase, urban sprawl, and economic development) is critical for developing effective management plans and predicting the future conditions of urban forests (Bürgi et al., 2005; Velázquez et al., 2003).

Land use planning may enable a balance between environmental and stakeholder needs by influencing the dynamics of land use change (Verburg et al., 2002). Such planning could include adjustments in land use structuring and/or the optimization of city layouts. As an important component of the ecological land, urban forestland is the main factor that contributes to urban ecosystem services, such as biodiversity enhancement. The integration of urban land use into the decision-making process will benefit urban and regional sustainable development (Goldstein et al., 2012). Therefore, estimating the development potential of urban forests under rapid urbanization with a balanced approach can realize the goal of fostering urban development while conserving ecosystem services and ultimately to achieve the sustainable development of resilient cities (Yeh and Huang, 2009). In recent years, the minimum cumulative resistance model (MCRM) has been applied to plan urban ecological land (Adriaensen et al., 2003; Qian and Dai Liang, 2014) because of its simple data structure, fast algorithms, and visual results. Therefore, this model is considered to be suitable to assess the potential and feasibility of an area for forestland.

In the coming decades, the urban fringe will increase in China (Seto et al., 2012; Li et al., 2015) and in many developing countries due to their growing socioeconomic status. In urban ecosystems, peri-urban forestry is seen as a powerful tool to improve environmental quality and ecosystem functions in the face of urbanization (Nowak and Walton, 2005). The change in canopy cover is complex in terms of the spatial and temporal landscape patterns within the urban fringe. However, knowledge of the effects of urbanisation intensity on forest landscape patterns in the suburban area remains largely superficial. Moreover, there is a pressing need to determine the relationship between the loss or the establishment of urban forest and the urbanisation process, considering the increasing trend in urban expansion. In this study, we selected the Mapo-Niulanshan area, Beijing, China, as a case study because these two towns have been undergoing drastic changes in land use patterns after being designated the focus of development by the Beijing municipal government. Beijing has been a classic example of rapid urbanisation. Meanwhile, the city experienced urban forest increase as a result of large ecological projects over the past decades. Therefore, we hypothesized that land use changes might foster the growth of urban forestland under the influences of the spatially-varied urbanization factors also in the fringe area. Moreover, we aimed to locate potential land for the development of urban forests in the urbanisation process. The rational planning of the forestland increases the ecosystem connectivity which is vital for the increase of the urban biodiversity. Our study provides a practical procedure for urban forestland planning and constitutes an important supplement to government-dominated planning. To the best of our knowledge, this is the first study focusing on the decadal change in urban forest in the urban fringe area, and the location of potential land for urban forest development.

2. Methods and materials

2.1. Site description

The two adjacent towns of Mapo and Niulanshan cover an area of 7029 hm^2 (40°00′–40°18′ N, 116°28′–116°58′E) in the Shunyi District, in suburban Beijing, China. This region was designated the key urban development area by the municipal government, according to the Master Plan of Beijing issued in 2016. Both towns have a semi-humid continental monsoon climate. The annual average temperature is 11.5 °C, ranging from −19 °C in the winter to 40 °C in the summer, creating four distinct seasons. The annual precipitation averages 625 mm, 75% of which occurs during summer. The annual relative humidity is 58%, and the frost-free period is 195 days. The local soils are cinnamon soil characterized by sand and sandy loams with high agricultural value. There were 66,000 permanent residents, among which 26,000 were farmers in 2015. Traditional agriculture has been shifted to modern agriculture over the past 3 decades, characterized by tourism, recreational and eco-friendly activities. Historically, the region has been an intensive agricultural area due to its flat terrain on the floodplain of the Chaobai River. Consequently, there are no remnant natural forests. Poplar trees (*Populus* ssp.) were exclusively planted as farmland shelter belts, fast growing plantations for timber harvesting, roadside shelterbelt and neighbourhood trees in the residential villages.

2.2. Land use analysis and the urban development gradient map

The study period was from 2001 to 2015. Land use and tree canopy cover data for 2001 and 2015 were interpreted from IKONOS and Worldview-2 remote sensing images, respectively. The spatial resolutions were 1 m for the IKONOS images and 0.5 m for the Worldview-2 images. Standard pre-processing procedures, including atmospheric and radiometric correction, topographic correction and georeferencing, were performed before land use and canopy cover were interpreted. In accordance with the Beijing Planning and Land Resources Regulation Committee, the land parcels were classified into seven types based on their purpose/state of use: farmland, built-up land, forestland, water bodies, orchard, grassland and brown field. The forestland included areas such as bushland (canopy cover > 40%), woodland (canopy closure > 10%), early age plantation (< 5 years old), burn-up land and tree nursery land. The brown field contained areas such as bulldozed undeveloped land, stock dumps, and bare land. The bulldozed undeveloped land consisted of land that was bulldozed but not yet built on, and most of it represented an intermediate stage of rapid urbanisation. Ground-truth verification of the visually interpreted results was performed on the spot by on-site land use investigation and tree canopy measurements.

A dynamic canopy cover indicator (K) (Peijun et al., 2010) was used to analyse the rate of change in canopy cover per year from 2001 to 2015:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

where U_a and U_b are the canopy cover areas of the specific land cover type at the start and end date, respectively, and T is the time scale under consideration.

To analyse the influence of the degree of urban development on the changes in urban forests, we developed an urban development gradient map based on the land use information generated using the remote sensing images, including separate indices of road density, green space and built-up areas (Qureshi et al., 2010). All the indices were then weighted and combined using map algebra in ArcGIS 10.2 (ESRI's ArcGIS© software, U.S.) to create a single development gradient map.