Habitat International 56 (2016) 84–95

Contents lists available at ScienceDirect

Habitat International

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

Urban green spaces, their spatial pattern, and ecosystem service value: The case of Beijing

Liyan Xu [a, b], Hong You [a], Dihua Li [a], Kongjian Yu [a, *]

[a] *Peking University, China*
[b] *Massachusetts Institute of Technology, USA*

A R T I C L E I N F O

Article history:
Received 11 January 2016
Received in revised form
16 April 2016
Accepted 25 April 2016
Available online 6 May 2016

Keywords:
Urban green spaces
Ecosystem service
Spatial pattern
Landscape Ecological Metrics (LEM)
Hedonic Price Model (HPM)
Beijing

A B S T R A C T

Green spaces provide various kinds of ecosystem service functions. Though some of them, such as the carbon-sinking and biodiversity preservation functions are of value to everyone, others, especially those related to aesthetic and recreational functions, only benefit people who have direct access to green spaces. In urban settings, where ecosystem services in the second category prevail, this means the spatial dimension of urban green spaces, including their richness, accessibility, shape configuration, and distributional characteristics, may considerably influence the realization of their ecosystem service value, and is therefore subject to scrutiny. In this paper, we study how the spatial pattern of urban green spaces influence the realization of their ecosystem service value by utilizing the Hedonic Price Modeling (HPM) method. Taking Beijing as the case, we use the price and other information in the city's developable land transaction records from 2000 to 2004 to construct the HPM, and use Landscape Ecological Metrics (LEM) as proxies of the spatial characteristics of urban green spaces. Four LEMs are used to measure the above mentioned spatial characteristics of urban green spaces. While subject to certain shortcomings in data quality and quantitative estimations of the magnitude of the spatial effects cannot be made, results show that most spatial characteristics of urban green spaces do influence their ecosystem service value as embedded in land value, except for the shape configuration characteristic for which the study yields no result. Further, specifically for Beijing, results indicate that in order to effectively realize their ecosystem service value, green spaces should occupy between 2.20% and 13.40% of the total urban area, located within a 50–550 m range from other developments, with green space patches so divided that each patch occupies more than 3.00% but less than 62.50% of the total green space area, and the ecosystem service value will be at the optimal level when each patch occupies 20.00% of the total green space area. Lastly, we stress the practical significance of the findings, urging an integration of the spatial patterns aspect of urban green spaces in urban planning practices.

1. Introduction

Urban areas across the world have been facing threatens from environmental degradation (McMichael, 2000), and the situation is especially severe in fast urbanizing and industrializing developing countries, such as China (Stern, Common, and Barbier, 1996; Liu & Diamond, 2005; Economy 2011). Environmental degradation not only causes physical harms like air and water pollution (Booth & Jackson, 1997; Shao, Tang, Zhang, & Li, 2006), but also inflicts mental problems to the urban residents (Jiang, Zhang, and Sullivan, 2015), and thus constitutes an urgent issue to address.

Green spaces, including forest, grassland, farmland, etc., play a crucial role in the global ecosystem, and urban green spaces in particular are commonly regarded as a remedy to the urban environmental problems. They help remove air and water pollution (Jim & Chen, 2008; De Ridder et al., 2004), preserve biodiversity (Mörtberg & Wallentinus, 2000), and create an amenable atmosphere which benefits people's physical and mental health (De Vries et al. 2003; Hillsdon, Panter, Foster, & Jones, 2006; Jim & Chen, 2006; Jiang, Larsen, Deal, & Sullivan, 2015).

An interesting question, though, is how much value have urban green spaces realized in improving the environment. Technically, a feasible way to answer the question is by evaluating the ecosystem service value generated by urban green spaces (Gómez-Baggethun & Barton, 2013). However, in the absence of a market for urban

* Corresponding author.

http://dx.doi.org/10.1016/j.habitatint.2016.04.005
0197-3975/

green spaces, one needs non-market evaluating methods to estimate the former's value in monetary terms (McConnell & Walls, 2005). Seminal works of this kind can be attributed to Costanza et al. (Costanza et al. 1997), who invented a constructed willingness-to-pay method to estimate the service value of the global ecosystem. This study established a "unit value"-based paradigm for evaluating the value of ecosystem services, which despite some innate drawbacks (Bingham, Bishop, & Brody, 1995; Pearce, 1998), has since been widely applied in ecosystems of various types and scales (Rapport, Gaudet, & Karr, 1998), and green spaces in particular, with a fairly large geographical coverage (Costanza, Stern, & Fisher, 2004; Cilliers, Cilliers, Lubbe, & Siebert, 2012; Bateman et al. 2013).

However, the "unit value"-based method is built implicitly on the assumption that the ecosystem service value is independent of the spatial dimension. This may hold true at the global or other very large scales, as in the case of the above mentioned Costanza et al.'s work. But at smaller scales, the assumption is not as sound from a landscape ecology perspective, which states though some ecosystem service functions, such as carbon sinking, are location-insensitive, others are not. Indeed, as Forman (Forman, 1995) noted, green space patches with different spatial attributes (richness, accessibility, shape configuration, and distributional characteristics) may have different ecological functions in a landscape, and they therefore should convey varied amount of ecosystem service value. For example, Xie et al. (Xie, Xiao, & Lu, 2006) demonstrate that the soil and water preservation service of forests is much less important in plains than in slope terrains, thus is of less ecosystem service value in the former case. Particularly, in urban contexts, where the most prominent ecosystem service functions are regarding the aesthetic and recreational aspects, the spatial dimension matters even more profoundly. It is therefore necessary to study the relationship between the spatial pattern of urban green spaces and their ecosystem service value, a subject the existing literature sheds little light on.

The lack of research attention on the issue not only constitutes an academic gap, but has also inflicted negative influences in real-world practices. The argument above suggests that urban planners and managers should pay as much attention to the spatial dimension of urban green spaces as the quantity. However, despite certain degrees of academic coverage, the notion appears not quite commonly appreciated in practice, resulting an overemphasis on the latter and neglect of the former in many occasions (Haase et al. 2014). For example, some large cities in China have adopted an "occupation/compensation balance of urban green spaces" policy,[1] requiring developers who destruct urban green spaces to create new ones elsewhere. In practice, however, for quite understandable reasons, such make-up green spaces usually locate in the exurbia or even remoter areas. Such practices, letting alone the obvious political ecological problem they imply (Heynen, Perkins, & Roy, 2006; Wolch, Byrne, & Newell, 2014), cause losses in ecosystem service value, too, as urban green spaces' ecosystem service functions, such as the city beautification and micro-climate control, are only meaningful where population concentrates, and the loss of such services in the city center cannot be "compensated" by as large, or even larger green spaces in remote areas where their ecosystem service value hardly realizes.

In this paper, we study the relationship between urban green spaces' spatial pattern and the ecosystem service value they convey. Specific spatial characteristics to be examined include the richness, accessibility, distribution, and shape configuration of urban green spaces. Using empirical data from Beijing, China, we construct quantitative models to examine the spatial effects, and also explore their practical implications. We hope our work will not only contribute to the academic literature, but also have practical impacts and could thus help build a better urban environment.

The paper is organized as follows. Section two provides a review of relevant studies and methods. Section three discusses the modeling approach, measurement of spatial characteristics, and data issues. Section four presents the results, with detailed demonstration of the spatial effects resulting from different richness, accessibility, distribution, and shape configuration variables. Section five offers further analysis on the quantified estimation of the spatial effects, as well as discussions on the possible reasons for the non-significant results. We conclude the paper in section six with a summary of the study and discussions on the study's practical implications.

2. Evaluating the ecosystem service value of urban green spaces and the influence of their spatial patterns: a literature review

As there does not exist a market for urban green spaces in most occasions, people's willingness-to-pay for urban green spaces could only be measured through indirect approaches (McConnell & Walls, 2005). The price of real estate, for example, is a commonly used proxy, which is considered to include a "green space premium" – the willingness-to-pay for accessibility to urban green spaces so as to enjoy the ecosystem service they provide. The Hedonic Price Model (HPM) (Chau, Ma, & Ho, 2001) is a typical method to separate out the "green space premium" from real estate prices.

HPM assumes that the price of a commodity, such as an apartment unit or a land parcel, includes the contributions from its various innate and environmental characteristics (Lancaster, 1966). Therefore, one may identify the willingness-to-pay for each feature involved using analytical techniques such as multivariate regression. Specifically, for urban real estates, their prices are usually considered to consist of the contributions from three categories of characteristics: the structural (such as the size of a land parcel or the unit plan type of an apartment), neighborhood (such as the transportation accessibility), and environmental (such as nearby amenity and recreational facilities) variables (Poudyal, Hodges, & Merrett, 2009). A typical Hedonic Price Model is thus formulated as follows:

$$\ln p_i = \beta_0 + \sum \beta_j S_{ij} + \sum \beta_k N_{ik} + \sum \beta_l E_{il} + \varepsilon_i \tag{1}$$

where $\ln p_i$ denotes the logarithm of the price of the i-th real estate object, S_{ij} denotes its j-th structural variable, N_{ik} denotes its k-th neighborhood variable, and N_{ik} denotes its l-th environmental variable. β_0, β_j, β_k, β_l, and ε_i are the respective estimates of regression coefficients and the residual term.

Therefore, the HPM can be used to evaluate the value of urban green spaces when they serve as the environmental variables in Equation (1). Loads of works of this sort have been done during the past half-century (McConnell & Walls, 2005), covering various green space types such as natural habitats, parks, planted forests, wetlands, and farmlands. The divergent influences of different green space types have also been widely discussed (Bolitzer & Netusil, 2000; Neumann, Boyle, & Bell, 2009).

Particularly, regarding the urban green spaces, the subject of this study, detailed studies have been conducted concerning their influence on real estate value (Bolitzer & Netusil, 2000; Poudyal et al.,

[1] For example, *Guidelines for the Basic Ecological Control Line Management* for the city of Wuhan, see http://www.wuhan.gov.cn/frontpage/pubinfo/PubinfoDetail.action?id=1201205242201590014; and *Regulations on Urban Green Spaces* for the city of Qingdao, see http://rules.yuanlin.com/Html/Detail/2012-2/1599_2.html.