Effective green equivalent—A measure of public green spaces for cities

Abstract

Quantifying the public green space required by urban residents is a fundamental aspect of sustainable urban planning and management. This paper proposes a metric of effective green equivalent (EGE), which is defined as the area of green space multiplied by corrected coefficients of quality and accessibility. Based on the EGE values of individual residents, two city-level indicators are developed: (1) average EGE, which refers to the average level of EGE values of all urban residents within the urban boundary; and (2) an inequality coefficient, which measures the inequality of EGE distribution across the urban area. Three indicators (EGE, average EGE, and the inequality coefficient) were used to measure the real green spaces of the urban residents of Beijing, China. The results showed that the EGE values for individual residents in Beijing follow a normal distribution. The average EGE value is 355.49 ha per resident and the inequality coefficient value is calculated to be 0.24, indicating that the current public green spaces of Beijing can basically meet residents' requirements. These indicators can thus be applied to urban public green space planning practice.

Introduction

Urban green spaces are an indispensable infrastructure in cities and can provide urban residents many essential benefits, including recreation, culture, and education (Bolund and Hunhammar, 1999, Cameron et al., 2012, Smith et al., 2013). Urban residents are entitled to the benefits of conveniently accessible green spaces (Bastian et al., 2012, Chiesura, 2004). Compared with private green spaces, public green spaces (PGS) should play a major role in the urban green system, especially in more densely populated urban areas (Coolen and Meesters, 2012, Niemelä, 2014). As public goods, PGS are important sources of urban residents' environmental welfare, and the quantity of PGS has a huge influence on their quality of life (van Kamp et al., 2003).

A series of measurement approaches have been used to quantify the PGS resources of urban residents. Most of these have simply focused on the total and per capita area to measure the richness of PGS in cities. Moreover, this indicator—per capita area—is inconsistent with the concept of urban PGS as a public good. It is instead incorrectly based on the concept of personal property, which by default divides PGS into equal independent areas in line with the number of residents, and then distributes the PGS throughout the urban system accordingly (Lauf et al., 2014, Witte and Geys, 2011). However, while residents are equally entitled to all of the PGS resources within an urban boundary, factors such as quality and accessibility affect the real benefits acquired (Gupta et al., 2012, Wright Wendel et al., 2012). Therefore, the total area of PGS, without considering quality and accessibility, is an overly optimistic measurement.

Accessibility is thus important. The green area within an accepted range, commonly within walking distance from residential areas, is generally used as a measure of the available PGS resources (Langford et al., 2008, Schipperijn et al., 2010, Villeneuve et al., 2012). However, it may be necessary for multiple-level accessibility to be calculated to obtain the actual green area for each level of user (Barbosa et al., 2007, Wright Wendel et al., 2012). The quality of green space is also an important factor in the calculation of effective PGS (Romero et al., 2012), because high-quality PGS can provide many more benefits than low-quality areas (Tian et al., 2014). Thus, data on the effective area of PGS should be corrected by incorporating quality differences between green spaces (Wendel et al., 2011). For example, ecological green equivalent space is taken as the quality measure for green spaces with different vegetation covers (Liu et al., 2002). These measurements can more reliably quantify the effective urban PGS area from the perspectives of accessibility and quality.

There are few case studies of the integrated evaluation of the accessibility and quality of green spaces in relation to residential PGS resources. In this paper, we develop three new indicators of effective green equivalent (EGE), average EGE, and an inequality coefficient (IC), as supplements for the conventional measurement of green spaces. Section 2 describes the methodology of the proposed indicators. Section 3 documents a case study of Beijing to illustrate the use of these indicators, and Section 4 presents the results of this case study. Finally, Section 5 gives a brief discussion of the effectiveness of these indicators.

Section snippets

Definition of EGE

Here we develop an indicator for measuring the PGS resources that truly benefit every resident. For convenience, the PGS system is denoted as $\{g_k, k = 1, 2, \ldots, n\}$, where g_k is the kth green patch in n independent green patches. Similarly, the population of urban residents is denoted as $\{p_i, i = 1, 2, \ldots, m\}$, where p_i is the ith individual in all m urban residents. We take green patch g_k and resident p_i as an example. Theoretically, the amount of PGS resources that g_k provides for p_i is equal to the

Study site

Beijing has undergone significant economic development and rapid urban expansion over the past 30 years. The population within the major urban districts reached 11,683,200 in 2010 (BMBS, 2011). Private green spaces are still relatively rare, however, so the provision of green space ecosystem services mainly depends on PGS. Our research was conducted in 2010 and is confined to six major urban districts, i.e., Dongcheng, Xicheng, Chaoyang, Haidian, Fengtai, and Shijingshan (Fig. 1). For the PGS

Results

Fig. 3 shows the frequency distribution of the EGE values. The sample size of the EGE values is equal to the population of urban residents; 11,683,200 within the study boundary in 2010. A Kolmogorov–Smirnov test showed that EGE values followed a normal distribution (p-value = 0.7274). This suggests that 68.2% of city residents in Beijing can access a moderate level of green space (ranging from 205.52 to 505.46 ha), and that the remaining residents had access to less (<205.52 ha) or more (>505.46 ha)

Discussion

Applications. The indicators proposed in this study can be applied in urban PGS planning practice. The indicators are able to provide urban planners with quantifiable goals that are sensitive to feedbacks and recognition from urban residents (Weber, 2003, Zylicz, 2007). Planners can also use the indicators to measure PGS and clarify the gaps between goals and the current situation (Moldan et al., 2012, Tanguay et al., 2010). The distribution of indicator values will provide valuable information

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