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Spatial variation of green space equity and its relation with urban dynamics: A case study in the region of Munich

Chao Xu[a,*], Dagmar Haase[b,c], Didit Okta Pribadi[d], Stephan Pauleit[a]

[a] Chair for strategic Landscape Planning and Management, Technische Universität München, Emil-Ramann-Str. 6, 85354 Freising, Germany
[b] Institute of Geography, Humboldt University Berlin, Unter den Linden 6, 10099 Berlin, Germany
[c] Department of Computational Landscape Ecology, Helmholtz Centre for Environmental Research – UFZ, Permoserstraße 15, 04318 Leipzig, Germany
[d] Center for Plant Conservation Botanic Gardens, Indonesian Institute of Sciences, LIPI, Bogor, Indonesia

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ABSTRACT

Green spaces provide urban residents with numerous environmental and social benefits and are regarded as a fundamental part of sustainable urban development. However, the spatial distribution of green spaces is uneven in most cities and urban regions, which has been considered as an issue of environmental injustice. We present a study in which the spatial variation of green space equity and its relationship with socioeconomic variables were analyzed across different municipalities in the region of Munich, southern Germany. The Gini coefficient was applied as an indicator of green space equity and its relationship with socioeconomic variables was explored by using a geographically weighted regression (GWR) model. Moreover, the impacts of different urban dynamic scenarios on green space equity were comparatively assessed at both the regional and sub-regional zone levels by incorporating a multiple urban dynamic scenario modeling approach. The results indicate that the relationships between green space equity and socioeconomic variables are not always consistently significant over space and the coefficients of GWR reflect great spatial heterogeneity indicating the relationships are locality-specific. At both levels, a higher housing demand scenario tends to increase the spatial inequality of green space distribution. Polycentric urban spatial structure scenarios are found less limiting than monocentric ones in terms of green space equity at the regional scale. Among different urban growth form scenarios ("sprawl", "compact sprawl" or "compact"), "compact" growth is most favorable at both levels in terms of green space equity. However, the other two growth form scenarios perform differently in each sub-regional zone. Therefore, the physical and socioeconomic heterogeneity across space should be considered thoroughly in the process of developing policies for urban development that effectively safeguard access to sufficient green space. This implication is not only crucial for this study region but also of great significance for other urban regions which aim to achieve successful green space planning.

1. Introduction

Green space plays an essential role in sustainable urban development, which can mitigate the negative impacts of the urbanization and positively contribute to life quality of urban residents by providing various benefits to human well-being and supporting biodiversity (Chiesura, 2004; Jim, 2004; Wang et al., 2015). The environmental and social benefits of green spaces have been well acknowledged by a number of research studies (Kabisch and Haase, 2014). The environmental benefits provided by green spaces include, among others, air purification (Jim and Chen, 2008), temperature mitigation (Gill et al., 2007; Rahman et al., 2017), noise reduction (Margaritis and Kang, 2017), carbon storage (Strohbach and Haase, 2012) as well as flood regulation (Zölch et al., 2017). The social benefits involve the provision of recreational benefits (Hong and Guo, 2017), mental and physical health improvement (Coppel and Wüstemann, 2017), fostering the social interaction and integration by offering meeting places for local residents (Bijker and Sijtsma, 2017), increasing the sense of safety (Branas et al., 2011), and alike. Considering these benefits, green space is nowadays more and more regarded as 'green infrastructure,' which has equal importance for cities and city regions as social and technical infrastructures (Pauleit et al., 2017).

Given the link between green spaces and the welfare benefits for residents, sufficient provision of and access to green spaces are recognized as two critical aspects for adequate and healthy living conditions (Wüstemann et al., 2017). In this vein, endeavoring to provide

* Corresponding author.
E-mail addresses: chao.xu@tum.de (C. Xu), dagmar.haase@geo.hu-berlin.de (D. Haase), pauleit@tum.de (S. Pauleit).

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residents with adequate and equitable access to green spaces across the population has been increasingly recognized as an important issue for urban planners, which is also due to growing concerns related to environmental justice (Kabisch and Haase, 2014; Wolch et al., 2014). Traditionally, the primary focus of environmental justice refers to the distribution of toxic-emitting facilities, waste dumps, and other environmental hazards that are disproportionately located near socially disadvantaged groups, while recent studies have expanded the scope of this conception by including issues such as equitable access to green spaces and other natural resources (Boone et al., 2009; Davis et al., 2012; Jennings et al., 2012). However, the green spaces are rarely evenly distributed across space within most cities, which correspondingly results in the disproportionate provision of green spaces to different subsets of urban population (Kabisch and Haase, 2014; McConnachie and Shackleton, 2010). In this regard, assessing and understanding the current status of green space distribution and its variations over space has been drawing increasing attention from scholars and governors, in order to enhance the benefits of green spaces for urban residents (Li and Liu, 2016).

A growing body of literature has been contributing to the research on green space equity. The majority of these studies have mainly focused on associating the spatial disparities of green space provision or accessibility with different social groups based on socioeconomic status (Barbosa et al., 2007; Kimpton, 2017), racial/ethnic or religious characteristics (Comber et al., 2008), migration background (Schüle et al., 2017), age (Shen et al., 2017), (dis)ability (Byrne et al., 2009; You, 2016), population density (Xiao et al., 2017) and other axes of difference. For example, Li and Liu (2016) analyzed the relationships between neighborhood socioeconomic disadvantage and urban public green space availability at the district level in Shanghai, China and highlighted that urban public green space provision and accessibility were lower in districts with higher levels of neighborhood socioeconomic disadvantage. The other strand of literature characterizes and compares the degree of green space equity among different resident groups within a city (Kabisch and Haase, 2014) or different cities at the national level (Wüstemann et al., 2017) by employing equality indicators. However, the complexity of how the green space equity varies along spatial or socioeconomic gradient has been somehow limited (Wei, 2017). Thus, a knowledge gap still exists regarding the spatial relationship between the green space equity of different spatial units (e.g., districts or municipalities) and their socioeconomic characteristics.

Among a number of existing indices which measure an unequal distribution, the Gini coefficient has gained a broad application in different fields. The Gini coefficient is prevalent in economics to measure inequality of income distribution (Molero-Simarro, 2017), which has also been applied to assess inequality of sustainable urban development (Li et al., 2009), biodiversity (Barr et al., 2011), carbon dioxide emissions (Chen et al., 2016), and also in the context of green space provision. For example, Kabisch and Haase (2014) and Xing et al. (2018) explored the inequality of green space distribution for different resident groups by applying the Gini coefficient in the city of Berlin, Germany and Wuhan, China, respectively. In addition, Yao et al. (2014) analyzed the inequality of urban green space distribution across the urban area in Beijing, China, while Wüstemann et al. (2017) compared the inequalities in green space provision across German major cities. Compared to other studies which focus on the spatial disparities of green space provision (Kimpton, 2017; Li and Liu, 2016), applying the Gini coefficient is a simple way to get an overview of the overall degree of inequality (Kabisch and Haase, 2014), particularly when attempting to associate the spatial inequality with other socioeconomic variables quantitatively.

Currently, research tends to focus on the assessment of the status quo of green space equity, rather than the analysis of urban development processes which provides a fuller understanding of the changes and is a useful approach to assess the impacts of proposed policies or planning strategies (Wei, 2017). It has already been underlined in the literature that the dynamics of urban development have extensive influence on green space availability and distribution (Nor et al., 2017; Sun et al., 2017; Zhao et al., 2013). Consequently, green space equity will also be affected by the process of urban dynamics. As a recent global phenomenon, the ongoing urbanization presents a challenge to urban planning which, in turn, offers great opportunities for sustainable urban management to incorporate the improvement of life quality through equitable provision of green spaces (Gavrilidis et al., 2017; Kabisch and Haase, 2014). In practice, the causes of the unequal distribution of green spaces may differ from place to place, but optimizing the provision and accessibility and reducing the spatial and social inequality should be primary goals of green space planning (Wei, 2017), which is also of great concern to urban residents (Wang et al., 2018). Bearing this in mind, understanding the impacts of different urban dynamics on green space equity enables the assessment of current policies and offers useful reference and guidance for green space planning. It is also crucial for policymakers and planners in providing appropriate services, supports and opportunities for local residents (Wei, 2017).

Against this backdrop, this study aims to contribute to characterize and analyze how green space equity varies across spatial and socioeconomic gradients and to understand the changing process of green space equity under different scenarios of urban dynamics. To this end, the region of Munich, a regional planning unit in Bavaria, southern Germany, was selected as the study area. The green space equity for each municipality of this region was measured to investigate its relationship with socioeconomic variables over space. Then, multiple urban dynamic scenarios were developed and the green space equity under different scenarios were compared. The specific objectives of this paper are: (1) to describe and quantify the pattern of green space equity and its spatial relation with socioeconomic variables at the municipality level; (2) to examine the impacts of different scenario of urban dynamics on green space equity at the regional level as well as at different sub-regional zones; and (3) to provide a robust indicator for assessing the spatial equity of green space distribution that could contribute to sustainable green urban planning.

2. Data and methods

2.1. Study area

The region of Munich is one of the eighteen planning regions in Bavaria, Southern Germany, according to the Bavarian state development scheme. It covers a total area of 5504 km^2 with a population of 2.85 million by the end of 2015, distributed over the Munich city and 186 municipalities that belong to eight administrative districts ("Landkreise") (Fig. 1). With an average annual population growth rate of approximately 1.0% over the past decade, this region is considered as one of the fastest growing and most economically competitive regions in Europe. The region's population is projected to be almost 3.2 million in twenty years by 2034 (Bavarian State Office for Statistics, 2015) which will inevitably lead to the urban growth not only near the city of Munich but also throughout the region. In addition to urban growth, other possible urban development pathways such as urban shrinkage that generates a number of vacant lands and brownfields were also involved by introducing multiple urban dynamic scenarios.

The regional land use and land cover data are derived from high-resolution aerial photographs (with a ground resolution of 0.2 meters), from which more detailed land use information can be detected. The settlement areas were classified into low-density settlements (such as row housing, single-family housing, and detached houses) and high-density settlements (representing multistory housing and multistory blocks). The regional distribution of green spaces of the year 2013 is shown in Fig. 1. Here, green spaces are defined as land uses of "parks and green spaces", "allotment gardens", "cemeteries" and "forests". Other land use categories which could potentially serve as green spaces