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How does sprawl differ across urban built-up land types in China? A spatial-temporal analysis of the Beijing metropolitan area using granted land parcel data

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ABSTRACT

The inner structure of urban built-up land sprawl (UBLS) is crucial for the level and quality of urbanization. This paper attempts an in-depth analysis of the inner structure of UBLS based on site data of granted built-up land parcels within the Beijing Metropolitan Area from 2001 to 2012. Structure entropy analysis and kernel density estimation (KDE) are employed to characterize the spatial-temporal variation of different types of UBLS and to summarize their patterns. The results reveal that during the sprawl process, residential land expanded rapidly in the first half of the study period while industrial land expanded rapidly in the second half. Residential land sprawl illustrated "radial sprawl", with a trend of "living suburbanization"; commercial land tended to follow the pattern of "ribbon sprawl along the main roads"; and industrial land sprawl was scattered in a "leapfrog sprawl" pattern. These results reveal the particular characteristics of the coexistence of market mechanisms and government macro-control of the land market in China. The land analysed in this study does not present the high-efficiency circle-layer land-use structure. Driven by top-down power allocations and the GDP-dominated views of local governments, the land supply inclined toward structural imbalance, which generated a disordered urban spatial structure. Hence, we suggest formulating a market-driven land supply mechanism to adjust the land-use supply structure, which has important implications for optimizing urban land-use structure.

1. Introduction

Urbanization, a consequence of socioeconomic development under specific circumstances, has increasingly become a major issue facing many metropolitan areas (Coisnon, Oueslati, & Salanié, 2014; Estoque & Murayama, 2015; Halleux, Marcinczak, & Krabben, 2012; Haregeweyn, Fikadu, Tsunekawa, Tsubo, & Meshesha, 2012; He, Okada, Zhang, Shi, & Zhang, 2006; Lund, 2013). As an important characteristic of regional urbanization, urban sprawl is a comprehensive reflection of factor flows between cities and of the evolution of urban systems (Belanche, Casaló, & Orús, 2016; Deal & Schunk, 2004; Gennaio, Hersperger, & Bürgi, 2009). As the ultimate embodiment of urban sprawl, urban land use structure evolution is closely related to urban socio-economic development and the ecological environment; the intersection of these factors can be defined as urban built-up land sprawl (UBLS) (Angel, Parent, Civco, Blei, & Potere, 2011; Lichtenberg & Ding, 2009; Puertas, Henríquez, & Meza, 2014). Creating an appropriate inner structure for UBLS is related to the efficient allocation of land resources as well as to healthy and orderly socio-economic development inside a certain region (Angel & Blei, 2015; Hassan & Lee, 2015).

Current studies of urban sprawl cover a wide range of topics and analyse the concept from multiple angles (Jaeger, Bertiller, Schwick, Cavens, & Kienast, 2010; Alnsour, 2016), including the form (Altieri, Cocchi, Pezzi, Scott, & Ventrucci, 2014; Jacobson, 2011), path and extent of sprawl as well as intensity measurement (Vaz & Nijkamp, 2015; Hamidi & Ewing, 2014) and influence assessment (Bhatta, Saraswati, & Bandyopadhyay, 2010; Disperati & Virdis, 2015; Kang et al., 2013; Mendiola, González, & Cebollada, 2015; Wu, Hu, & He, 2009). In terms of study methods and scale, Remote sensing (RS) and GIS technologies have become the two most common methods of demonstrating the dynamics of urban sprawl (Bae & Ryu, 2015; Dorning, Koch, Shoemaker, & Meentemeyer, 2015; Jat, Garg, & Khare, 2008). With these tools, many researchers have conducted relevant studies and made significant achievements.

Urban land-use spatial structure and the mechanism of its evolution have always been the key issues for urban land use and urban sprawl. Numerous studies of urban land-use spatial structure involve

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geography, economics, sociology, and other fields. With the rise of the Industrial Revolution, theories such as Concentric Zone Theory (Blumenfeld, 1949; Harris & Ullman, 1945), Polycentric Theory (Zou, Mason, & Zhong, 2015), Spatial Equilibrium Theory (Lind, 1973; Samuelson, 1952; Wieand, 1987), and others have been addressed by the fields of urban geography and economics (Marshall & Marshall, 2010). Moreover, studies of urban land-use structure have focused on the static perspective (including size and spatial form) (Wu, Ye, Shi, & Clarke, 2014; Inostroza, Baur, & Csaplovics, 2013), the inner and outer driving mechanisms (Xu, Tang, Fan, Bennett, & Li, 2011; Wu & Zhang, 2012; Shu, Zhang, Li, Qu, & Chen, 2014; Salvati, 2015; Pijanowski et al., 2014), urban land-use structure efficiency (Burgalassi & Luzzati, 2015; Jacobs-Crisioni, Rietveld, & Koomen, 2014), and the rationality of urban land-use structure (Fan & Myint, 2014; Paulsen, 2012). Furthermore, studies examining how urban land is divided into different land-use types mainly focus on the differences in distribution patterns among residential land (Kowalski & Paraskevopoulos, 1990; Muth, 1969), industrial land (Kowalski & Paraskevopoulos, 1990), etc. from the perspective of land rents and land prices.

In summary, from the perspective of urban sprawl patterns, current research on urban land-use spatial structure involves theoretical discussions. Scholars either consider built-up land as a whole (Bao & Wang, 2009; Jaeger et al., 2010; Lv & Huang, 2013) or confine their research to a certain type of built-up land (Kuang, Liu, Dong, Chi, & Zhang, 2016; Tian & Qiao, 2014; Wu, Zhang, & Liu, 2010; Yu, Song, & Hu, 2012; Yu, Zhang, & Dong, 2013). They study urban sprawl and urban land-use structure mainly from the macroscopic and static perspective (i.e., the quantitative structure and layout pattern) (Lu, Yang, Jing, Li, & Wen, 2010), which cannot effectively quantify the dynamic process of urban land-use structure change or display the spatial interdependence of each type of land-use. Additionally, the limited classification efficiency and accuracy of the RS-GIS method for land-use research creates difficulty when attempting to identify the inner structure of UBLS according to specific land-use types (Zhang, Su, Xiao, Jiang, & Wu, 2013), especially for goals aimed at controlling the sprawl effects of various types of built-up land (i.e., industrial, residential and commercial land). Therefore, the complete inner structure and spatial-temporal characteristics of UBLS patterns are not yet fully understood.

The essence and core of urban land allocation has been the scientifically based granting of urban built-up land to form the appropriate inner structure of UBLS. It is important to further the study of UBLS by classifying the sprawling built-up land into different types and grasping its inner structure. This should help urban managers establish the scientific and targeted Land-use Planning and Land Supply Project (Hui, Leung, & Yu, 2014). Therefore, this study of the inner structure of UBLS will help to increase urban land-use efficiency and improve the sustainability of urban development.

Beginning in the 1980s, China's urban areas entered a period of hyper-rapid growth (Shen, 2005; Zhou & Ma, 2003). This indicates that UBLS is inevitable in China and that the development of various industries will make the inner structure of UBLS more complicated (Lu, Yao, Li, Liu, & Gao, 2007; Wang & Min, 2009). In addition to the rapid spatial expansion of their urban built-up areas, Chinese cities are also significantly restructuring their urban spatial forms (Ding & Zhao, 2014). According to China's urban land reform, since July 1, 2002, all land granted for commercial, tourism, entertainment, and so-called commodity housing purposes has been required to pass through a regulated and open tender, auction or listing process (Du, Thill, Peiser, & Feng, 2014; Huang, Wei, He, & Li, 2015). Urban built-up land entered a process of marketization. However, one distinct difference between China and other countries is that market mechanisms and government macro-control are the two main driving forces of the Chinese land market, i.e., the granting of residential and commercial land has been fully marketized, while the granting of industrial land is still controlled by the government; this will deeply affect the transformation of China's urban structure (Yue, Liu, & Fan, 2013). Hence, the study of UBLS based on granted land parcels involves not only market behaviour but also government behaviour.

Therefore, this paper characterizes the spatial-temporal variations among different types of UBLS and summarizes their patterns qualitatively and quantitatively using the method of structure entropy analysis combined with kernel density estimation (KDE). The purpose is to refine the study of UBLS by examining its urban inner structure. Moreover, the driving mechanisms and the problems of the process of urban sprawl are addressed. The paper attempts to answer this research question: how does sprawl differ across different types of urban built-up land in China? The results of this study enable us to provide theoretical guidance on improving land market mechanisms, assessing urbanization progress scientifically, optimizing the inner structure of built-up land, and promoting sustainable urban development in Beijing. The analysis uses unique urban built-up land granting records within the Beijing Metropolitan Area from 2001 to 2012. Beijing is well suited to the purpose of this study because it is a typical mega city undergoing the urban sprawl and the transformation from a planned economy to a socialist market economy and because it has relatively good data records that are unavailable in many other cities.

The rest of this paper is organized as follows. Section 2 introduces the study area, data sources and processing. Section 3 describes the methods we use to outline the spatial-temporal dynamics of different types of UBLS in Beijing. Section 4 measures the temporal and spatial changing patterns of UBLS from 2001 and 2012, including overall pattern and each types of urban built-up land pattern. Section 5 draws the conclusions of the paper and discusses the problems during the urban sprawl in Beijing, as well as suggests appropriate urban expansion direction.

2. Study area and data processing

2.1. Study area

As the capital of China, Beijing is well known worldwide as a famous ancient city and an international metropolis. It is also China's political, cultural and economic centre. The total territorial area of the city is approximately 1.641 million ha, which includes an urban area of 0.137 million ha and a built-up area of 0.129 million ha. In terms of topography, 38% of the area is mountainous and the remainder is plain (Beijing Statistical Bureau, 2012). Under the conditions of resource endowments and economic development, a fierce contradiction between the city's limited land resources and its rapid population and construction growth is becoming increasingly apparent. Sub-regions in Beijing are at distinctly different stages of development, which emerge out of different regional land-use changes. To alleviate different types of land-use-related contradictions, it is crucial to renovate Beijing's urban spatial structure.

Following the tentative plan concerning "*Two axes-two belts -multiple centers*" and "*City Sub-region Division*" in *Beijing Urban Master Planning* (UMP), and the principle of "*Optimizing urban areas*, *developing suburbs*", the government divided the whole of Beijing into four *Development Priority Zones* (DPZs) in 2006. These are the *Capital Core Functional Zone* (CCFZ), *Expanding Urban Functional Zone* (EUFZ), *New Urban Development Zone* (NUDZ), and *Ecological Conservation Development Zone* (ECDZ) (shown in Fig. 1). Among the DPZs, the CCFZ functions as the national political and cultural centre and the centre of services for the party and government, citizens, intercultural communications, science and educational development. The EUFZ functions as the centre of trade, finance, real estate, research, etc.; it is an important area for developing a modern manufacturing industry, high-tech industry and modern agriculture. The NUDZ is mainly intended to receive industries and populations evacuated from the central urban areas. The ECDZ provides an ecological barrier and water resource protection area for the city; its primary role is to strengthen protection of the ecological environment and develop eco-friendly industries.