Rediscovering Chinese cities through the lens of land-use patterns

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A B S T R A C T

Urbanization is a complex spatial phenomenon involving significant compositions and interactions in land use. Yet, only few studies have quantitatively examined multidimensional urban land-use patterns with insights into land use policy, particularly in the context of China's rapid urbanization process. This paper aims to investigate the urban land-use patterns in China by employing multiple measurements with multi-sourced data, including Spatial Entropy and Dissimilarity Index, and a combination of cellular-automata (CA) modeling and Structural Equation Modeling (SEM). The results show that land-use patterns in China are characterized from more mixed (Beijing, Shanghai) to less segregated (Xiangyang, Tangshan, and Guiyang), and the most segregated (Chongqing), which can be categorized into three typical types: economically led, government led, and geographically constrained. The findings also indicate that residential sector has correlation with GDP and urban built-up area; public sector is driven by GDP, urban built-up area, and paved road area; and commercial sector is related to GDP and paved road area. Furthermore, land-use patterns are not only determined by economic forces, but also subject to China's land policies that formulated based on its unique social and political characteristics. It reveals the complex spatial characterization of urbanization in China, where government still plays an important role in facilitating the land use allocation. The research sheds light on understanding land use policy for land-use patterns reconfiguration in the context of New-Type Urbanization towards better planning and governance.

1. Introduction

In the past two decades, measuring the composition and configuration of land use is the most frequently debated subject in urban planning and land use policy, specifically, describing the features of land use pattern (Alberti and Waddell, 2000; Ewing and Cervero, 2010; Song et al., 2013; Gehrke and Clifton, 2017). Rapid urbanization has profoundly changed land use pattern in China, which vice versa exerts influence on socio-economic development, population growth, city growth, etc. (Liu et al., 2014). Urbanization has been a prominent phenomenon in China's economic development since the country adopted the "reform and opening" policy in 1978. The urban population of China has researched to 813.47 million (58.52%) in 2017 (National Bureau of Statistics of China, 2018). With the power devolving gradually from the central government to the municipalities, land-use patterns and urbanization processes of China's cities have undergone fundamental transformation (Gaubatz, 1999; Lang et al., 2016a,b). Such transition of Chinese cities to more post-industrial forms is much like that seen in the USA, Canada, Australia, and Europe (Schneider et al., 2005), of which our understanding is still inadequate (Batty, 2008).

Unfolding complex urbanization makes it clear that the quantitative understanding, optimization, and adjustment of land use pattern of cities is a major issue for sustainable land use (Verburg et al., 2004). Urban spatial restructuring of land-use patterns have been analyzed for the past few decades, seen in such studies as Li and Yeh's (2004) study of the spatial structuring of land-use patterns in the Pearl River Delta of South China; Liu et al.'s (2010) exploration of the impact of land-use changes on sustainability in Jiangsu Province; Long and Zhang's (2015) discussion of land-use pattern scenarios; Kuang et al.'s (2016) examination of the driving forces behind rapid and massive urbanization and industrialization in China. Nevertheless, the lack of solid understanding of land-use patterns issues makes it difficult to address the ongoing challenges of the volatility and complexity of land use policy in China (Long, 2014). Therefore, the situation poses a number of challenging questions to the country: 1) How to correctly depict the general situation of urbanization and consequential spatial phenomenon in China? 2) How to adapt a quantitative approach to address the distinctive features of land-use patterns in Chinese cities? and 3) what are the underlying drivers of forming land-use patterns?

Land use pattern forms the basic spatial layout of a city as a result of the interactions of government intervention and market forces. The

Fig. 1. Locations of study cities.

driving factors that influence the magnitude and extent of land-use patterns are often related to the functioning of local and national policy and demographic conditions (Verburg et al., 2004). From urban planning perspective, the land-use patterns represent the structural and functional differences of socio-economic development. Researchers have recently formulated a foundation to understand the causes and consequences of land-use formation and the simplified mechanisms that facilitates the optimization of land-use patterns and allocation of land resources (Long et al., 2012a,b; Long and Zhang, 2015). Previous studies limited their focus to changes in land use (Longley and Mesev, 2000), yet few studies have quantified land use mix and sprawl degree in urban China (Tian et al., 2017), understood uneven urban expansion with natural cities (Long et al., 2018), and examined the relationship between land-use patterns and a suite of social and economic underlying factors (Comer and Greene, 2015), as well as related planning and policy affects urbanization and shapes land-use patterns (Wei and Zhang, 2012).

Measuring urban land-use patterns is a key part of spatial metrics (Herold et al., 2005) that are commonly used to quantify the shapes and patterns of a city (Hargis et al., 1998). Recent studies have emphasized the use of spatial metrics to assess land-use patterns and interpret their planning policy (Seto and Fragkias, 2005; Tsai, 2005; Song et al., 2013; Lang et al., 2016a,b; Gehrke and Clifton, 2017). As an effective spatial metrics, entropy has provided us a powerful tool for researching the spatial organization of cities (Batty and Longley, 1994), characterizing urban form (Schneider and Woodcock, 2008; Taubenböck et al., 2009), representing the heterogeneous characteristics of urban area (Alberti and Waddell, 2000), and quantifying the degree of mix and sprawl (Ewing and Cervero, 2010). In addition, researchers have employed dissimilarity index to detailed characterize the spatial allocation of land use diversity (Ewing and Cervero, 2010) and entropy to evaluate the degree of urban sprawl (Li et al., 2013).

Spatial Entropy (SE) measures the degree of urban sprawl (Batty, 1976) and determines urbanization occurs in a compact or expansive (aggregate or dispersed) mode (Jiao, 2015), while Dissimilarity Index (DI) helps to define the efficiency of mixing land-use sectors and measure the degree of evenness in the distribution of land use (Decraene et al., 2013b). The combination of these two measures provides a straightforward method to investigate the urban land-use patterns that results from dispersion and segregation mechanisms. The importance of this cellular automata (CA) model emphasizes the reconstruction of cities from the bottom-up with SE and DI values. Thus, in this research, we are adapting Decraene et al.'s (2013b) CA model to study a selection of Chinese cities.

This paper attempts to integrate the use of CA, Python, ArcGIS, and R Programming and addresses the following research objectives: 1) to quantify urban land-use patterns through SE and DI; 2) to identify the interconnected major urban factors for the formation of land-use patterns; and 3) to investigate the relationship between the emerging land-use patterns and its associated land use policy. China's rapid urbanization is often accompanied with a lack of competent control and regulation, leading to informal development and incompatible land use function. For stimulating sustainable development at the new agenda of China New-Type Urbanization (Lang et al., 2016a,b), a better understanding of land-use patterns and its driving forces are the key to empowering local governance and implementing effective and well-timed land use policy. Therefore, this study contributes to enlighten the applicability of analysis generalization to land use policy corroborating within the planning literature.

To begin with, the preceding part of this paper introduced of urbanization and spatial metrics. In the following section, the study area is presented along with methods for processing of the data. The issues of measurements and their applications in the analysis and modeling of urban land use are discussed. This section also describes the measurements in detail, including their mathematical formulae. The findings are presented in Section 3. Section 4 begins with an interpretation of land-use patterns, followed by an analysis of the corresponding influence factors. In Section 5, conclusions are drawn with reference to the mechanisms of urbanization and recommendations for selecting appropriate planning policies are provided for future use.