



Spatiotemporal dynamics of urban expansion in 13 cities across the Jing-Jin-Ji Urban Agglomeration from 1978 to 2015

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ARTICLE INFO

Keywords:

Urbanization
Remote sensing
Comparative study
Urban growth modes
Patch structure
Urban hierarchy

ABSTRACT

The newly implemented national policy “To build a world-class agglomeration of cities with the capital as the core” made the Jing-Jin-Ji Urban Agglomeration attract attention from both the scientific community and society. Here we quantified and compared the magnitude, rates, forms, and dynamics of urban expansion for 13 cities across the Jing-Jin-Ji Urban Agglomeration, and examined the relationship of urban patch structure and hierarchical structure of urban growth over the past four decades. We found that the rates and composition of urban expansion forms (i.e., infilling, edge-expansion and leapfrogging) varied considerably across cities and over time, due to national and regional policies, physical features and the urban administrative hierarchy. The overall annual urban expansion rate for the 13 cities was $5.5 \pm 2.0\%$ (mean \pm standard deviation) between 1978 and 2015. Leapfrogging was the dominant urban expansion form in early period, edge-expansion took the leading role since 1990, and the contribution of infilling was generally less than 40%. Our results revealed that although three major cities (i.e., Tianjin, Beijing and Shijiazhuang) of the Jing-Jin-Ji Urban Agglomeration contributed 36.6% of the urban land area increase of this region, larger cities might not be better positioned for urban expansion. The urban expansion rates of cities were inversely related to city size in general from 1978 to 2015 with exception only from 2005 to 2010. Patch analysis showed that relationship between patch number and patch size derived previously at the national level can be applied to the Jing-Jin-Ji Urban Agglomeration despite the discrepancies in temporal scale and urban administrative hierarchy. This invariant self-organization of urban land patches during the urbanization process might provide insightful information guiding the design, planning, and management of sustainable cities in the capital urban agglomeration of China.

1. Introduction

Urbanization, characterized by demographic changes and urban land expansion, is the most drastic and irreversible form of land use, and its impacts far transcend city’s physical boundaries (Grimm et al., 2008; Wu, 2014). The unprecedented urbanization has resulted in profound changes in landscape (Haas and Ban, 2014), biodiversity (He et al., 2014), biogeochemical cycles (Kaushal et al., 2014) and energy flow (Kennedy et al., 2015) at multiple spatiotemporal scales. More than 50% of the world’s population now live in urban areas and this figure is projected to increase to about 75% by 2050 (United Nations, 2015) with the most increase in developing countries (Bloom, 2011). Cities are particularly vulnerable to increasing extreme climate and weather events (i.e., urban flooding, regional droughts and extreme heat waves) (Hu et al., 2016). Metropolitan areas of developing countries as the primary areas of urbanization, especially the capital regions, might experience severe environmental problems due to massive rural to urban migration and intensive anthropogenic activities. Therefore,

understanding the rates, patterns, causes, and consequences of rapid spatial expansion of cities in developing countries is a formidable challenge in the 21st century (Cohen, 2006; Cobbinah et al., 2015).

China has experienced a rapid urbanization process in recent four decades since the implement of the “reform and opening-up” policy to promote economic growth (Chan, 2010; Wu et al., 2014). The urban administrative hierarchy of China consists of several levels, including provincial, prefectural, county, and township-level cities (Chan, 2010; Li et al., 2013). In contrast to developed countries, rapid urbanization in China is not only paralleled by economic growth but also significantly shaped by administrative means from government at all levels. And as a result, administrative levels in China’s governments pose strong impact on urbanization process (Liu et al., 2012). Because cities with higher administrative status perform better socially and economically than those with lower status, the difference of local government’s administrative status might contribute to the differences in the urbanization level among cities (Wu et al., 2015). Therefore, there is a need to investigate China’s urbanization in the context of urban

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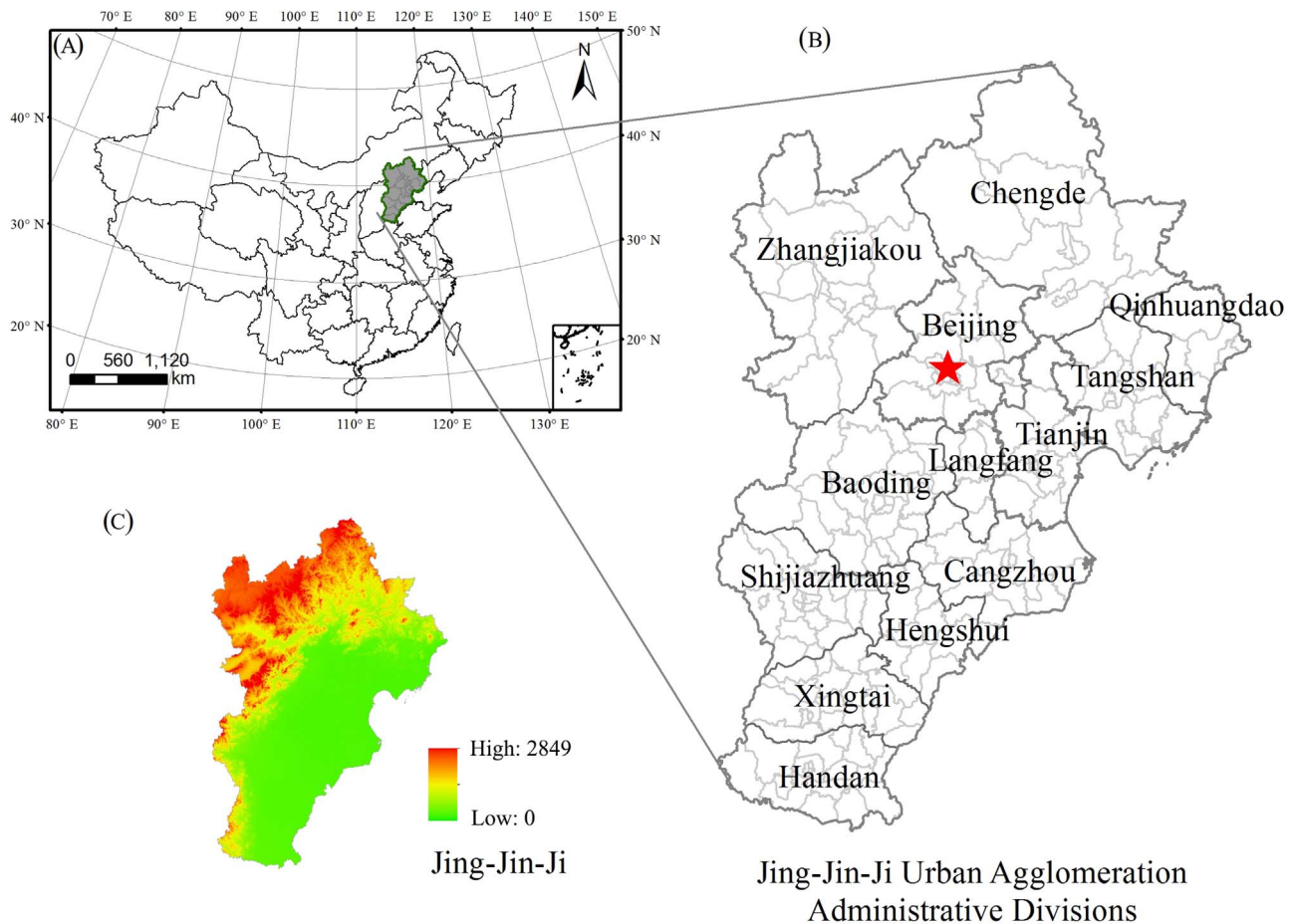


Fig. 1. The location and administrative divisions of the study area: (A) The study area in China, (B) The 13 cities in the Jing-Jin-Ji Urban Agglomeration, (C) Topography of study area.

administrative hierarchy for building robust knowledge and providing guidance for sustainable planning, designing, and managing of Chinese urban expansion. Previous studies found that larger cities might be better positioned than smaller ones for urban expansion owing to their higher ranks in the administrative hierarchy, and greater competitiveness for land-use priority and resource exploitation (Schneider and Mertes, 2014; Zhang et al., 2014). Li et al. (2015) used spatial regime regression to examine the spatial effect of city hierarchy and found that in China between 1998 and 2008, cities ranked higher tend to expand more rapidly. However, Gibrat's law, the well-documented urban expansion theory, states that growth rate of cities are independent of city size (Eeckhout, 2004; Rozenfeld et al., 2008; Jiang and Jia, 2011). Recent studies found that during the entire period of 1978–2010, Chinese cities expansion in terms of urban growth rate showed an inverse relationship to city size, contradicting Gibrat's law (Zhao et al., 2015a). The emergence of various urban agglomeration development strategy and adjustment of city administrative divisions press the necessity to apply spatially explicit methods to understand the new urbanization in contemporary China (Li et al., 2015; Zhao et al., 2015a; Zeng et al., 2017).

The Jing-Jin-Ji Urban Agglomeration as the capital urban agglomeration of China has attracted much attention due to the newly implemented national policy “To build a world-class agglomeration of cities with the capital as the core” (Wu et al., 2015; Zhang et al., 2017). The administrative hierarchy of the Jing-Jin-Ji Urban Agglomeration is quite complete with a set of cities ranging from large (e.g. Beijing and Tianjin) to small. Therefore, the Jing-Jin-Ji Urban Agglomeration provides an ideal place for a synthetic understanding on the impacts of urban hierarchy systems; a comprehensive study on the urban growth characteristics of cities at all administrative levels of the Jing-Jin-Ji

Urban Agglomeration will be of great significance to better understand the urban expansion model of China.

Compared to other important urban agglomerations of China (i.e., the Yangtze River Delta and the Pearl River Delta), there have been fewer spatially explicit studies on urbanization process of the Jing-Jin-Ji Urban Agglomeration (Xie et al., 2017). A comparative study of urbanization process in three major urban agglomerations of China revealed that from 1990 to 2010, the Jing-Jin-Ji Urban Agglomeration showed the highest magnitude and speed of urban growth (Haas and Ban, 2014). Using multi-temporal satellite data, Wu et al. (2015) quantified and compared magnitude of urban expansion in three major cities (i.e., Tianjin, Beijing and Shijiazhuang) of the Jing-Jin-Ji Urban Agglomeration from the late 1970s to 2010. Recently, Zhang et al. (2016) emphasized neighbor-city influence on intra-city urban expansion direction through comparing the spatiotemporal patterns of urban growth in Beijing, Tianjin and Tangshan from the 1970s to 2013. Most of those studies only included several more developed cities of this region or covered relatively short time periods, or not designed to investigate the impacts of the urban administrative hierarchy. Furthermore, spatial and temporal evolution of urban patch structure can reveal the metabolism and mechanism of city evolution and organization (Zhao et al., 2015a,b). Unfortunately, few studies have been conducted to examine patch characteristics (Dietzel et al., 2005; Li et al., 2013; Zhao et al., 2015a,b), let alone the convergence or divergence of urban patch structure in the context of urban administrative hierarchy. There is a dearth of multi-temporal spatially explicit research on the urban land growth, and the hierarchical structure of all major cities in the Jing-Jin-Ji Urban Agglomeration across recent four decades.

In this study, we mapped and quantified the magnitude, rates and spatial patterns of urban expansion for the Jing-Jin-Ji Urban

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