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Built-up land efficiency in urban China: Insights from the General Land Use Plan (2006–2020)

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ABSTRACT

The rapid expansion of built-up land has been the major feature of land use changes in China and has led to built-up land vacancy and inefficient land use. This paper used a Data Envelopment Analysis (DEA) model to analyze the changes in built-up land efficiency in 336 cities in China from 2005 to 2012 during the implementation of National General Land Use Plan (2006–2020) (NGLUP). The results showed that the built-up land input–output efficiency of most cities declined, and more than half of the cities had excessive inputs of built-up land. Even in the most developed region of China, the built-up land efficiency was relatively low. The paper argues that the NGLUP failed to control the expansion of built-up land and to promote intensive land use. The allocation of built-up land designated by the Plan was not reasonable, and economic development has greatly relied on land inputs, which need to be improved. The paper finally suggests that the built-up land indices should be appropriately directed toward economically underdeveloped regions in central and western China, and the establishment of a withdrawal mechanism for inefficient land would better promote the efficient allocation of built-up land.

1. Introduction

The transformation of natural, open or agricultural land into built-up land is one of the major features of land use changes in most urbanized countries and regions (Angel, Parent, Civco, Blei, & Potere, 2011; Michael, Noor, & Figueroa, 2014), but particularly in developing countries (La Rosa, Barbarossa, Privitera, & Martinico, 2014; Wang, He, Liu, Zhuang, & Hong, 2012). The inefficient land use patterns that are commonly associated with increases in population growth that accompany suburban and exurban development, or urban sprawl, have been identified as a significant cause of the rapid loss of arable land in many areas (Kropp & Lein, 2012; Mariola, 2005; Salvati, 2014). The expansion of built-up land and the associated land use have numerous effects on ecological and social systems (Foley et al., 2005; Yu, Wu, Zheng, Zhang, & Shen, 2014), such as a concentration of the population, traffic jams, housing shortages, resource shortages, biodiversity reductions, "heat island" effects, noise, and pollution (Kandziora, Burkhard, & Mueller, 2013; Schetke, Haase, & Koetter, 2012; Scolozzi & Geneletti, 2012; Verbyla, Oakley, & Mihelcic, 2013). It is therefore crucial to design appropriate methods to establish effective control of urban growth (Carlow, 2014; Delmelle, Zhou, & Thill, 2014; Oliveira, Andrade, & Makse, 2014). For example, in the U.S., more than one hundred cities and counties have adopted urban growth boundaries (UGBs) or similar policy initiatives to manage built-up area expansion (Kim, 2013). Through zoning, land development permits and other land-use regulations, UGBs demarcate urban and rural uses and aim to contain urban development within predefined boundaries (Bhatta, Saraswati, & Bandyopadhyay, 2010; Hepinstall-Cymerman, Coe, & Hutyra, 2013; Long, Han, Lai, & Mao, 2013).

As the largest developing country in the world, China has experienced unprecedented rapid development of its economy and society since the reform and opening-up in 1978 (Deng & Huang, 2004; Yin, Shi, & Wang, 2013). With the accompanying drastic changes in land use patterns and land cover status, the rapid expansion of built-up land has become the major feature of land use changes in the country (Yu, Shu, et al., 2014; Zhang, 2014). Infrastructure construction, the development of township and rural enterprises and industrial and commercial development have all aggravated land conversions for non-agricultural uses (Chen, Gao, Xu, & Chen, 2014; Gao, Wei, Chen, & Chen, 2014; Liu, Liu, & Qi,

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2015). Statistical data show that the urban population of China increased from 172.45 million people in 1978 to 777.82 million people in 2012, with increases in the urbanization level from 17.92% to 52.57% and in the number of cities from 193 to 660 during this period. The land surrounding cities often contains fertile soil and consists of high productivity arable areas. The expansion of built-up land to occupy this arable land is inevitable and aggravates the contradiction of a "large population with relatively little arable land". From 1980–2010, the amount of built-up land expanded by 5.52×10^6 hm^2, which accounted for 3.18×10^6 hm^2 of the arable land in China (Liu, Kuang, et al., 2014). In 2012, the per capita arable land in China was 0.1 ha, which was less than half of the worldwide average. In addition, the aggressive expansion of built-up land has caused sustained and intense disturbances and transformations for humans as well as a certain degree of severe threats to the regional ecology and sustainable development of the social economy (Chan & Yao, 2008; Zhai, Li, & Chen, 2015). Controlling the expansion of built-up land based on scientific precepts to alleviate the pressure on arable land production and the negative impacts of urban sprawl on the ecological environment in China has attracted global attention and has become a hot research topic (Peters, Weber, Guan, & Hubacek, 2007; Tan et al., 2014).

In the early 1990s, the Chinese government implemented a land management and planning system through the General Land Use Plan to protect the arable land and control the scale of built-up land. However, this Plan cannot effectively stop the rapid loss of arable land and the uncontrolled expansion of built-up land (Qian, 2015; Zhong, Mitchell, & Huang, 2014). In 2006, the Chinese government issued a new General Land Use Plan (2006–2020) and further strengthened control of the scale of built-up land. In addition to the continuous application of the "national-provincial-municipal-county-township" land quota differentiation and its control methods, the Ministry of Land and Resources of the People's Republic of China also applied three indices, including the amount of urban and suburban built-up land, the occupation of arable land for construction, and urban industrial and mining land per capita, to constrain the excessive expansion of built-up land at all levels of local government. However, due to the continuous and rapid development of industrialization and urbanization, the increase in urban and suburban built-up land in China from 2006 to 2012 was 2.64×10^6 hm^2, including an annual increase of 0.38×10^6 hm^2, i.e., 1.15 times higher than that proposed in the General Land Use Plan. New built-up land occupied approximately 3.74×10^6 hm^2, of which 1.87×10^6 hm^2 was transformed from arable land, i.e., 1.4 times higher than that proposed in the General Land Use Plan. In 2012, urban industrial and mining land per capita was 149 m^2, which was even higher than in 2005 and was contrary to the General Land Use Plan. Serious land situations require an objective improvement in the efficiency of built-up land use and a reduction in the occupation of farmland for urban expansion. Such improvements require a determination of the space allocation of land resources to optimize the country's overall interests and develop a corresponding spatial pattern of land development. However, the supply of new built-up land is strictly controlled by the planning indices and by the planning management measures. These allocation mechanisms often depend on the interests of the central and local governments (He, Huang, & Wang, 2014; Lv, Zhong, Huang, Zhang, & Tian, 2012) but overlook the relationship between the allocation of built-up land and the efficiency of the land use (Du, Cai, & Liao, 2010; Qian & Wong, 2012; Qian, 2013). Consequently, production factors such as built-up land do not exert the greatest benefit for economic growth (Zhong, Huang, & Wang, 2010), resulting in difficulties developing an intensive and efficient land use pattern (Shen & Zhou, 2014).

Scholars have proposed a few frameworks to evaluate the implementation of the General Land Use Plans in China (Chen, Yang, Chen, Potter, & Li, 2014; Xu et al., 2015; Zhang, Zhang, & Qu, 2008). Most of these studies aimed to determine whether and to what extent the intent, goals and outcomes of the plans have been achieved, including analyses of the planning indices system and the special allocation of land use (Hong, Li, Li, Zhang, & Zhang, 2013; Huang, Lin, Liang, & Zhao, 2008; Wang et al., 2013). The impacts of the implementation of the Land Use Plans on environmental quality and the ecosystem have also attracted significant attention and have become a major research focus (Chen, Gao, et al., 2014; Chen, Yang, et al., 2014; Lai & Huang, 2005; Zhao, Huang, & Zhang, 2014). In addition, the consequences of the control of built-up land have been analyzed and discussed (Feng, Wu, Han, & Wu, 2010; Xu, Huang, Zhao, Gao, & Li, 2010). However, efforts are still needed to examine land use efficiency, particularly with regard to built-up land, to tackle land use problems and determine directions for future reform in China's land management. Rapid urbanization has profoundly changed the spatial-temporal pattern of land use in China. Built-up land is an important foundation of socio–economic activities. Built-up land efficiency not only affects regional economic development but also regional sustainable development. A better understanding of built-up land efficiency in different regions is necessary to manage the land use allocation, rapid urbanization and sustainability challenges in China. This study aims to evaluate the input–output efficiency of built-up land in different cities of China in 2012 in combination with the quota allocation of built-up land in *The Outline of the National General Land Use Plan (2006–2020)* to analyze the existing problems in planning management and in the index control pattern of built-up land and to suggest some solutions for improvement. The remainder of the paper is organized as follows: Section 2 provides general information on the study area and describes the data and methods. The results are presented in Section 3, and Section 4 contains the discussion and conclusions.

2. Data and methodology

2.1. Introduction of the Data Envelopment Analysis (DEA) model

In this study, the purpose of analyzing the expansion efficiency of built-up land is to consider built-up land as one of the input elements to evaluate its role in socioeconomic development and to investigate the series of consequences of regional built-up land input. This study also conducted a comparative analysis on the regional differences in built-up land input and output efficiency. We employed the Data Envelopment Analysis (DEA) model for the analysis and evaluation. DEA is an efficient evaluation method that was developed based on a relatively efficient concept. It can assess and sort the relative effectiveness of various decision-making units of the same type (Olesen, 2006).

Let the number of cities involved in built-up land efficiency in the evaluation be K and the types of input and output indices in the evaluation index system be L and M, respectively. Let x_{jl} represent the amount of the first input resource in the jth city and y_{jm} represent the amount of the mth output in the jth city; then, the application model of DEA in the nth city ($n = 1, 2, \ldots, k$) is as follows:

$$
\begin{cases}
\min\left(\theta - \varepsilon\left(e_1^T s^- + e_2^T s^+\right)\right) \\
s.t. \sum_{j=1}^{K} x_{jl}\lambda_j + s^- = \theta x_l^n \quad l = 1, 2, \cdots, L \\
\sum_{j=1}^{K} y_{jm}\lambda_j - s^+ = y_m^n \quad m = 1, 2, \cdots, M \\
\lambda \geq 0 \quad n = 1, 2, \cdots, K
\end{cases} \tag{1}
$$