Land Use Policy 68 (2017) 531–551

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Urban expansion in 30 megacities of China: categorizing the driving force profiles to inform the urbanization policy

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ARTICLE INFO

Keywords:
Urban expansion
Spatial determinants
Driving forces profiles
Data mining
Self-organizing map
Urbanization policy

ABSTRACT

Currently, land use policy makers in developing countries face the challenge to control urban expansion in a rational and sustainable manner. In this context, understanding the urban expansion process and its determinants is essential for designing land use planning and governance strategies. This paper presents a methodological framework based on data mining techniques for exploring the determinants of urban expansion. We employ the Random Forest regression to apportion the relative importance for 33 determinants of urban expansion across 30 megacities in China. Analysis is facilitated by a dataset of urban land information in period 1993–2012 (derived from time-series nighttime light imageries) as the independent variable, and an equivalent dataset of 33 determinants of four categories (economic, demographic, social and natural) as exploratory variables. Results show that the relative importance of determinants varies with cities but shows some similarities. Greatest contribution is observed for the economic determinants, followed by social determinants. Demographic and natural determinants have comparative relative importance. In general, economic, social, and demographic determinants have increasing contribution to urban expansion, but the natural determinants show declining influence on urban expansion with time. Four clusters are identified by a Self-Organizing Map among the 30 megacities, with respect to the driving forces profiles. Urban expansion in these four clusters is respectively dominated by demographic, social, natural, and economic determinants. Based on these profiles, the land use planners can revised the original 'top-down' land-driven development model and formulate more locality-oriented measures to control urban expansion in an orderly manner.

1. Introduction

1.1. Background: urban expansion and urbanization policy in China

World's urban population began to boom at unprecedented rate from the 1950s and has nearly quintupled during the past three decades (UN-Habitat, 2013). Over 50% of the total world's population inhabits in urban areas (UN-DESA, 2011) and the figure is expected to reach 70% by 2050 (UN-Habitat, 2013). The most apparent consequence of the massive rural-to-urban migration is the very rapid urban expansion and city growth. Statistics indicate that global urban land currently amount to 0.4 million km^2 and will exceed 0.7 million km^2 in 2010. In many Asian countries, urban expansion exhibits very fragmented characteristics, radiating to all directions from the urban city center to surrounding suburb in the form of leapfrogging (Su et al., 2017; Tian, 2015). Land use policy makers thus face the challenge to control urban expansion in a rational and sustainable manner. In this context, understanding the urban expansion process and its determinants is essential for designing urban planning and governance strategies.

It has been observed that China has the largest magnitude and highest rate of urban expansion worldwide (Seto et al., 2011). Thus, China should provide an ideal example for exploring the determinants of urban expansion. Additionally, urban expansion in China differs with that in many countries around the world, due to the long development under a planned economy. In the 1980s, the Chinese central government formulated the urbanization policy that promotes small-size cities, develop medium-size cities, and control large cities. Since the later 1990s, the central government has lifted the ban on controlling large cities, and successively launched the 'increasing urbanization level' policy in 1998 and 'improving the role of large cities in economic development' policy in 2001. Local governments attempt to maximize the benefits from land leasing and cater to the push for land acquisition from developers (Tian, 2015). Within the land finance regime, local finance, urban expansion, and central power reshuffling are reinforced and interconnected with each other (Tian, 2015). Policy makers have to face the pressure of land control and sustainability. Under such

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http://dx.doi.org/10.1016/j.landusepol.2017.06.020
Received 13 March 2017; Received in revised form 2 June 2017; Accepted 22 June 2017

circumstances, the 'National New-type Urbanization Plan' was released in 2014 that advocated coordination urbanization in China. Under this new policy, the significant role of large cities has been acknowledged and at the same time rational urban expansion is required during the process of socioeconomic development.

1.2. Determinants of urban expansion: literature review and conceptual framework

Urban expansion occurs at a diversity of geographical scales (Kuang et al., 2014; Li et al., 2013; Müller and Sikor, 2006; Su et al., 2011a, 2011b; Zhang et al., 2011). Characteristics of urban expansion generally vary from region to region (Kuang et al., 2014; Li et al., 2013a, 2013b, 2013c; Müller and Sikor, 2006; Su et al., 2011a, 2011b; Zhang et al., 2011). The characteristics of urban expansion are often locality-specific, however, the magnitude of expansion can be navigated by principle determinant such as economic, social, demographic, planning and policy, and natural rewards (Zhang and Su, 2017). In particular, policy makers have to understand these principle determinants and make a choice for balance. For example, planners encourage intensive development and control urban expansion in a sustainable manner (Su et al., 2017). Policy makers have to find the solutions to the conflicts between economic development and ecological conservation, and have to consider the sociodemographic structure and natural restrictions. Fig. 1 features the conceptual framework for understanding the determinants of urban expansion under the context of land use policy.

A large body of literature has examined the determinants of urban expansion, and the geographical scales can be generally categorized into two levels: pixel level based on spatially explicit data, and administration level (e.g., county, city, province, and nation) based on spatially aggregated data. Nevertheless, determinants of urban expansion across different cities and regions have not been fully investigated and compared (Seto et al., 2011; Zhang and Su, 2016). With respect to the methodological approach, empirical-statistical models have been commonly applied, including the ordinary least squares regression (Chen et al., 2014; Chen et al., 2016a, 2016b; Gao et al., 2016; Liu et al., 2016; You, 2016; Zhang and Su, 2016), hierarchical regression (Su et al., 2016), geographically weighted regression (Shafizadeh-Moghadam and Helbich, 2015), spatially autoregressive regression (Tan et al., 2014; Zhang et al., 2013), analytic hierarchy process (AHP) (Thapa and Murayama, 2010), structural equation modeling (Eboli et al., 2012), and logistic regression (Li et al., 2013a, 2013b, 2013c; Zhou et al., 2013). These empirical-statistical methods typically formulate parametric models in reference to a well-established theory, and estimate the parameters of the hypothesized models by using the collected data (Müller et al., 2013). Although robust and easy to understand, the empirical-statistical approaches are often criticized for depending too much on expert knowledge. It greatly challenges the empirical-statistical methods that comprehensive and consistent knowledge is absent for the unban expansion process. Growing recognition has been raised for the complexity and nonlinearity in the interactions and feedbacks of urban expansion and a set of determinants (Müller et al., 2013; Parker et al., 2008; Redo et al., 2012; Turner et al., 2007; Verburg, 2006; Wang et al., 2016). However, the empirical-statistical models are incapable to address multimodal data as well as nonlinear relationships (Müller et al., 2013; Redo et al., 2012; Wang et al., 2016). In addition, the overfitting problem can emerge when high dimensional or too many variables are incorporated into the empirical-statistical models (Müller et al., 2013; Redo et al., 2012). These major shortcomings pose overwhelming obstacles for empirical-statistical models to generate accurate and reliable estimations. Such situation becomes worse when out-of-sample predictions are involved, which would greatly lower the model generality (Müller et al., 2013).

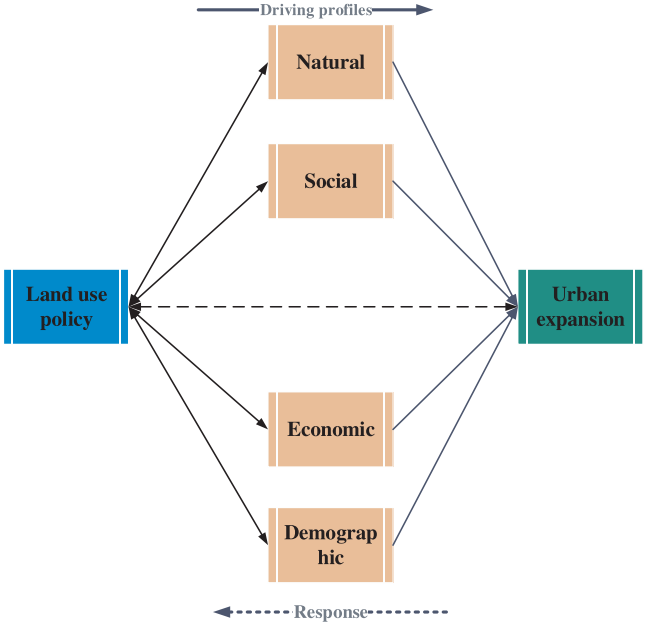

Fig. 1. Conceptual framework for understanding the determinants of urban expansion under the context of land use policy.

1.3. The present study

This paper focuses on the urban expansion in urbanizing China. Given the vast territory of China, cities and regions differ greatly in biophysical and socioeconomic characteristics. The key objective of this study is to uncover the differences and similarities in the driving mechanism governing urban expansion among 30 Chinese megacities (Fig. 2). These cities act as capitals of corresponding provinces, the highest administrative level in China, and represent the biophysical and socioeconomic variations across China. For example, megacities in the western region are characterized by high elevation and hilly terrain, while those in the eastern region are featured by low elevation and plain. In addition, megaregions along the eastern coast are highly urbanized and populous, while those in the northeastern and northwestern are relatively lagged in socioeconomic development. Two rich datasets including urban land use data and socioeconomic data are relied to perform the analysis. We first use the Random Forest (RF) regression to analyze the determinants of urban expansion and apportion their relative importance in the 30 cities; and then utilize the Self-Organizing Map, a category of unsupervised computational neural networks, to categorize the 30 cities according to the relative importance of different determinants. In this way, we move forward from determinant identification to driving forces profiles categorization. This specific research paradigm has opportunity to advance the understanding of urban expansion and further provide deeper spatial insights for land use policy.

2. Materials and method

2.1. Data sources

Time-series urban land data (1993–2012) for 30 megacities (Fig. 3) are obtained from Zhang and Su (2016), which extracted the urban land cover from DMSP-OLS (The Operational Line-scan System (OLS) sensor of the Defense Meteorological Satellite Program (DMSP)) nighttime images. Compared with other sensors, the DMSP-OLS images are reliable data sources for extracting large-scale time-series urban land cover information, considering its appropriate spatial resolution temporal granularity (Zhang and Su, 2016). The DMSP-OLS images were first calibrated and then subjected to the empirical thresholding approach for urban land extraction (Zhang and Su, 2016). The average of producer's accuracy reached 90.6% (Zhang and Su, 2016). For details of