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Uneven growth of urban clusters in megaregions and its policy implications for new urbanization in China

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ABSTRACT

Megaregions have become the principal geographic units for countries to participate in the global economy, which is often a composite of numerous urban clusters which are distributed in different cities. In China, a megaregion is regarded as a key urbanization platform, according to the National Plan on New Urbanization published in 2014. In this context, it is imperative to understand the spatial patterns of and the changes occurring in megaregions. For instance, what are the universal rules or differences related to urban cluster growth between different megaregions in the process of rapid urbanization, and are there differences in the growth of urban clusters with different sizes? Focusing on these issues, this study discusses the uneven growth of clusters in five of the largest megaregions in China using the rank-size rule, based on land-cover data interpreted from time-series satellite imagery during the period 1990–2010. The results show that the cluster size distribution of each of these megaregions obeyed the rank-size rule, and the size distribution of the clusters became more uneven and was tilted toward larger clusters between 1990 and 2010. These factors should be considered in the implementation of the National Plan on New Urbanization in China and the designation of urban macro planning and urban layout optimization in other countries those are experiencing rapid urbanization.

1. Introduction

The world is increasingly becoming an urbanized society, and more than half of its population now lives in urban areas (UN DESA, 2014). Urban land for housing and industrial activities is also expanding dramatically. Some authors think that the area of the world's land needed for urban development will triple if population density declines at a 1% annual rate, based on the assumption that the world's population will double (Angel et al., 2011). Most of the urban expansion in the coming decades will take place in the developing world. Urban land expansion has the potential to dramatically modify the local atmospheric environment, contribute to global warming (Kalnay and Cai 2003; Oke 1973), affect ecosystem function and services (Capello and Faggian, 2002; Vitousek et al., 1997), and encroach on fertile arable land (Cai, 2000; Gu et al., 2015; Schneider, 2005; Zhong et al., 2014).

To better mitigate the negative effects of urban growth, urban spatial pattern have been paid more attention by many scholars in the field of urban studies (Kasanko et al., 2005; Murakami et al., 2005; Ward et al., 2000), which have used various methods, including cellular automata (Li et al., 2003; Ke et al., 2015) and the SLEUTH model (Bihamta et al., 2015; Herold et al., 2003; Jantz et al., 2010). These models concentrate on estimates of the location of new urban cells (Li et al., 2003a,b). However, the differences in the growth of urban clusters of different sizes have often been ignored, although recently some authors have focused on this issue at the intra-metropolitan level (Fragkias and Seto, 2009).

In the existing literature related to urban spatial pattern, megaregions have become increasingly important because they are regarded as the principal platform for countries to participate in global competition (Abrantes et al., 2016; Liu, 2012; Osman et al., 2016). A megaregion is often defined as a chain of roughly adjacent metropolitan areas or urban clusters, and their surrounding areas, which are linked by various networks, including highway and rail (Marull et al., 2013; Taubenböck and Wiesner, 2015). In the developed world, the megaregions include such well-known examples as the Northeast megaregion of the USA, Tokyo, Los Angeles, London, Paris, Frankfurt-Stuttgart, Milan-Rome-Turin and Amsterdam-Rotterdam (Marull et al., 2013). In the developing world, more and more megaregions are emerging, such as São Paulo and Rio de Janeiro (Ortega et al., 2015; Taubenböck and

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Wiesner, 2015).

China, as one of the largest developing countries, is experiencing a rapid growth in both the number of megaregions and their population. In 2014, the Central Committee of the Communist Party of China and the State Council officially issued the National Plan on New Urbanization which put forward an urban development strategy using the megaregion as the principal urbanization platform (CCCPC and SC, 2014). The main objectives of megaregion planning include: to optimize the megaregions in East China, to foster megaregions in Central and West China, and to promote coordinated development of cities of different sizes. In 2015, China planned to develop 20 megaregions across the country.

To optimize or foster megaregions in China, it is necessary to understand the growth features of different clusters. For instance, what are the similarities and differences related to urban cluster growth among different megaregions in the process of rapid urbanization, and, in a megaregion, what are the differences in the growth of urban clusters of different sizes? And how to harmonize the growth of these clusters?

To reply this problem, it is necessary to understand the features of urban growth at the cluster level in megaregions. This study therefore examined the characteristics of cluster growth in five major mega-regions in China based on land-use data interpreted from time-series satellite imagery during the period 1990–2010, to aim to answer questions. First, were there any similarities in urban cluster evolution in the five megaregions? Second, what were the differences in urban cluster evolution between the five megaregions, and third, which grew more quickly, large or small clusters? Through answering these questions, this study hopes to provide some policy implications for new urbanization in China and also for urban macro planning and urban layout optimization in other countries.

2. Study areas

In China, there are four traditional megaregions, including Jing (Beijing), Jin (Tianjin) and Tangshan (JJT), the Yangtze River Delta (YRD), the Pearl River Delta (PRD) and Central-Southern Liaoning (CSLN). And Wuhan (WH) is also selected in this study, which is a new megaregion. CSLN and WH belong to Northeast China and Central China, respectively. The others are located in the eastern coastal regions (Fig. 1). Until now, there has not been an accepted approach to spatially define megaregions (Taubenböck and Wiesner, 2015). In this study, the scopes of megaregions are defined based on the following factors. First, the scopes of traditional megaregions of China are taken into account. Second, the areas of these megaregions should be almost equal, which makes them comparable for studying their evolutionary features. Third, the scope of WH as a new megaregion is consistent with its Urban Master Plan, 2006–2020 (Fig. 2).

Table 1 shows the major features of these five megaregions which vary in area from 48.0 to 60.0 thousand km^2. The population of the YRD megaregion was approximately 89.1 million and the greatest of the five in 2010. The urban population of the five megaregions accounted for one quarter of that of China as a whole in 2010, although the corresponding share of land area was only about 2.7%. The megaregions all had very high urbanization rates, which were much higher than the average level (49.7%) in 2010, according to the sixth census of China (OSNC, 2011). In the PRD, the urbanization rate was the highest and touched 82% in 2010.

3. Data and methods

3.1. Urban land use

The basic data were extracted from the 1:100,000 spatial resolution digital land-use maps for 1990, 2000 and 2010. They were obtained from the Landsat Thematic Mapper (TM) remotely sensed data, which was interpreted by the Resources and Environment Data Center (REDC), CAS. The out-door survey and random sample check testified that the average accuracy for land use map was over 90% (Liu et al., 2014, 2003a,b).

In this study, the cluster definition from Fragkias and Seto (2009) is used to extract urban clusters: “a cluster is not a settlement per se but a spatially interconnected set of pixels, or a number of contiguous urban areas”. Thus, in a megaregion, a large city may be composed of one or more clusters.

3.2. Rank-size rule

Since the early 1910s, considerable research effort has focused on the evolution of city size distributions in different countries (Carlos, 2000; Ettlinger, 1984; Gangopadhyay and Basu, 2009; Okabe, 1979; Soo, 2005), since city sizes obey a simple power law or Pareto distribution. This has been proved in many countries, including the USA, China, Switzerland, Brazil and India (Gangopadhyay and Basu, 2009; Lee and Li, 2013). In recent years, this simple power law (also called rank-size rule) has also been used to express urban cluster size distribution (Fragkias and Seto, 2009). It can be defined as:

$$S_i = S_1 R_i^{-q} \quad q > 0 \tag{1}$$

where S_i is the area of cluster i, S_1 is the prime cluster with the largest area in the study region, R_i is the rank of cluster i and q is a parameter. If $q < 1$, it stands for a region in which intermediate clusters are relatively large. If $q > 1$, it implies dominance by large clusters, while $q = 0$ implies all clusters have the same area, and $q = \infty$ means that there is only one cluster (Richardson, 1973). In most cases, q is not constant over time (Brakman et al., 1999). Eq. (1) is usually estimated in logarithmic form:

$$\ln S_i = \ln S_1 - q \ln R_i \tag{2}$$

In general, rank-size distributions are well approximated by a power law in the upper tail of the distribution (Bosker et al., 2008). Thus, this study selected 200, 500 and 1000 of the largest urban clusters for each megaregion to study the evolution of cluster size distribution by eliminating the lower tails of the distributions.

4. Results and discussion

4.1. Cluster growth

Over the past two decades, the five megaregions have witnessed rapid spatial growth. In the 1990s, the total area of the clusters of the five megaregions as a whole expanded by 32.2%, from 19.0 thousand km^2 to 25.1 thousand km^2. In the 2000s, the total area of the clusters expanded by 29.8% (Fig. 3). Thus, between 1990 and 2010, the clusters increased by 13.6 thousand km^2, which accounted for 24.6% of the total increase in the built-up areas of the country as a whole (55.2 thousand km^2) (Liu et al., 2014).

There were significant differences in cluster growth across the five megaregions. Clusters in the CSLN megaregion had the lowest growth rates. In the 1990s and 2000s, the areas of clusters here increased by 7.9% and 3.8%, respectively (Fig. 3). In contrast, the growth rates in both the YRD and PRD megaregions were much higher than the average levels of the five megaregions.

4.2. q Value changes and uneven growth

Through examining the distribution of 200, 500 and 1000 of the largest urban clusters for each megaregion, this study found that the cluster size distribution fitted the rank-size rule well for all five megaregions in all years, and the coefficients of determination were all greater than 0.97 (Fig. 4).

Between 1990 and 2010, all q values in the rank-size rule increased