Case Study

Identification of "Growth" and "Shrinkage" Pattern and Planning Strategies for Shrinking Cities Based on a Spatial Perspective of the Pearl River Delta Region

Wei Lang[1]; Jiayi Deng[2]; and Xun Li[3]

Abstract: There are two opposing trends in urban development: one is the exponential growth of cities and the other is shrinking cities," which are characterized by a decrease in number of residents. Since the 2008 financial crisis, there have been great changes in the Pearl River Delta (PRD), where growing and shrinking areas coexist. In this paper, we analyze cities' growth and shrinkage in respect of urban construction and economic vitality in the PRD in spatial term. Thus, we define land use changes in urban construction to characterize growth by using Landsat Thematic Mapper data on urban built-up areas of the PRD region in 2000, 2009, and 2013; and we characterize economic activities for vitality by using Defense Meteorological Satellite Program/Operational Linescan System nighttime light data in various years after time continuous correction and vegetation correction, in combination with population data. Four different types of space are identified in this region, namely continuous growth, transformational growth, stationary, and shrinkage. This paper provides policy recommendations and planning strategies for the future development of shrinking cities in China. Shrinkage is considered to be only a short-term stage in the urbanization process faced by most cities in China and abroad. Technological progress and industrial transformation are likely to be critical factors affecting the direction of urban development, where cities can resume growth from shrinkage by revitalizing manufacturing industry and economic activities through education, innovation, and technology. **DOI:** 10.1061/(ASCE)UP.1943-5444.0000612.

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Introduction

In the 1990s, the concept of "shrinking city" was first introduced in Germany. With the gradual acceleration of global de-industrialization in cities, the phenomenon of urban shrinkage has become increasingly common, leading to critical challenges for many metropolises in their development process (Beauregard 2013). Up to 13% of urban areas in the United States and 54% in Europe are currently found to be experiencing population decline (Martinez-Fernandez et al. 2016; Wolff 2018). After more than 30 years of rapid growth, the global financial crisis triggered a decline in the export processing industry in China, with some cities taking a different urban development path from the original rapid development track, eventually leading to two completely different new spatial phenomena of growth and shrinkage (Lang et al. 2016). The National Development and Reform Commission (NDRC) issued key tasks for the New-type Urbanization in 2019 (Chen et al. 2020; Lang et al. 2019a, b), in which the concept of "shrinking city" was first mentioned publicly while restrictions on settlements of migrants in large cities were fully liberalized. Shrinking cities have now formally been incorporated into the national planning vision, with the study of this phenomenon of shrinking cities or regions in China becoming increasingly urgent and important.

Since the reform and opening up, the Pearl River Delta (PRD) region, located in the southeastern coastal areas of China, has witnessed a "growth miracle" in economic and urban development, with an average annual gross domestic product (GDP) growth rate of over 15% between 1979 and 2016, and an increase in the level of urbanization from 16.3% in 1978 to 84.6% in 2016 (Hui et al. 2018). However, the international financial crisis in 2008 resulted in huge impacts on the "export-oriented economy" in this region, with two completely different new spatial phenomena of growth and shrinkage appearing at the same time at the city level. By the end of 2008, more than 4,000 small and medium-sized enterprises in the PRD region had folded, including 1,464 in Dongguan City, 956 in Zhongshan City, 709 in Zhuhai City, 704 in Shenzhen City, and 526 in Foshan City. Cities began to shrink, resulting in large numbers of redundant spaces composed of abandoned buildings and houses, all signs associated with economic slowdown and negative economic growth. Factors included closure of factories and enterprises, substantial increase in urban unemployment, population outflow, rising vacancy rate of urban housing, and decline in utilization rate of infrastructure. On the one hand, new urban areas lack development momentum (e.g., vacant houses and absence of facilities) (Zhao et al. 2019); and on the other, some old urban areas and industrial parks also lack economic development momentum, facing problems such as structural decline, abandoned factories, and vacant houses (Ferdinand and Yu 2016; Iseki 2016).

[1]Associate Professor, Dept. of Urban and Regional Planning, School of Geography and Planning, Urbanization Institute, and China Regional Coordinated Development and Rural Construction Institute, Sun Yat-sen Univ., Guangzhou 510275, China. ORCID: https://orcid.org/0000-0002-3028-2446. Email: langw3@mail.sysu.edu.cn

[2]School Administrator, Office of Equipment and Lab Management, Sun Yat-sen Univ., Guangzhou 510275, China. Email: dengjy57@mail.sysu.edu.cn

[3]Professor, Dept. of Urban and Regional Planning, School of Geography and Planning, Urbanization Institute, and China Regional Coordinated Development and Rural Construction Institute, Sun Yat-sen Univ., Guangzhou 510275, China (corresponding author). ORCID: https://orcid.org/0000-0002-7190-0853. Email: lixun@mail.sysu.edu.cn

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At present, Western scholarly research on shrinking cities is generally more mature, forming a certain network (Audirac 2018a), while research on shrinking cities in China is still in its initial phase with most research focusing on the concept, connotation, and economic performance of shrinking cities, often lacking sufficient data support and specific case analysis. The experience in the West reminds us that cities are likely to shrink in the face of deindustrialization, globalization, suburbanization, and other problems after high and rapid growth (Audirac 2018b). When urban shrinkage is inevitable, ways to promote transformation and development in order to avoid the continuous decline of the regional population and economy are the primary problem faced by local governments.

Most studies on shrinking cities abroad focus on city scale, with the aim of analyzing urban population reduction and economic recession. In actual observation, most cities in China are still in stages of rapid urbanization when compared with urban shrinking, which is only one aspect and a relatively local phenomenon. In the PRD region, growth still dominates, where urban shrinkage is clearly an issue at a regional scale. Therefore, this paper examines the development and change in the PRD region. Although many researchers identify growth and shrinkage by using traditional socioeconomic variables, most data come from the national census or statistical yearbook in China over large scales and long-time spans, making it difficult to accurately reflect the timely changes in the city. In this paper, Defense Meteorological Satellite Program/Operational Linescan System (DMSP/OLS) night light data, LandScan population data, and land use data extracted from Landsat Thematic Mapper (TM) remote sensing images are used to identify growth and shrinkage of the PRD region by building 1×1 km grids.

Regarding the special growth pattern and development background of the PRD region, this paper suggests a method to identify regional growth and shrinkage and analyzes urban economic growth and infrastructure construction patterns to investigate correlations, resulting in regional differences in terms of growth and shrinkage, and delineating the impact of national policy formulation on future urban development. First, using two indicators of urban construction and economic activity to identify growth and shrinkage, this study explores the spatial nature of urban development and change in cities or regions. Second, this paper analyzes the relationship between investment and growth in four types of regions since the reform and opening up, and summarizes characteristics of population, industry, and land use in those regions. Finally, this paper remarks on planning strategies and policies to stimulate the economy in recession areas and growth areas, and the impact of technological advancement on future urban and regional development.

The introduction section of this paper summarizes new trends of urban development in China, and introduces issues, significance, processes, and content. The literature review section evaluates related literature at home and abroad on the definitions of shrinking cities by Chinese and western scholars, the growth and shrinkage of cities, national policies, and regional development. Research methodologies construct an identification and analysis mechanism for examining growth and shrinkage of the PRD region. The results and findings section provide details on the spatial pattern and formation mechanism of growth and shrinkage of the PRD region. Discussions and implications track and identify the evolution of growth and shrinkage of the PRD region, analyzes effectiveness of its policies, and discusses effective responses to planning and policies. The conclusion summarizes this study and offers future implications.

Literature Review

Definition and Concept of Growth and Shrinkage

The concept of "shrinking cities" is derived from the German *Schrumpfende Städte*, which describes the depopulation and economic recession in some German cities during the deindustrialization process of the 1990s (Häußermann and Siebel 1988). Since then, this phenomenon has gradually attracted the attention of British and American scholars, and the term was translated as "Shrinking cities," "Urban Shrinkage," and "Urban Decline." Since the 1950s, many cities in developed countries in Europe and the United States began to face the problem of population decline and economic development recession. Until the early 1990s, more than a quarter of the world's metropolitan economies had experienced or were experiencing shrinkage (Jessop 1992). To date, there is no clear definition of "shrinking city" in the world, and this concept is more likely to comprise a set of various phenomena within a certain region, including the opposite process of natural growth and decay with negative effects (Bernt 2015). Urban shrinkage has recently emerged as an extremely popular topic in urban development and planning; its content and meaning drawing similarities to terms such as "urban decay" (Wolff and Wiechmann 2018). In fact, shrinking cities do not describe reductions in areas or slowdown of the spatial expansion, but a decrease in population and population density within cities (Batty 2016).

Population decline is the main index to define whether a city is shrinking or not, followed by a decline in industrial economy, rises in housing vacancy rates, and abandonment of infrastructure. Shrinking Cities International Research Network (SCIRN) defined shrinking cities, more precisely, as densely populated areas with a population of 10,000 or more that have faced population loss in large areas for at least two years and are undergoing economic transformation and structural crises (Wolff and Wiechmann 2018). The Shrinkage Cities Project defines cities that have lost at least 10% of their population or have an average annual population loss rate of more than 1% as shrinking cities, and those which will temporarily or permanently lose large numbers of residents (Lee et al. 2016). In addition, a shrinking city is an area that has lost more than 25% of its population in the past 40 years, and has vacant and abandoned buildings with different functions, such as residence, commerce, and industry, increasing within it (Schilling and Logan 2008). Urban shrinkage essentially has roots in the continuous loss of population, the spatial decline process of economy, society, environment, and culture that will not stop in the near future and will last for a long time (Beauregard 2009).

Characteristics and Types of Urban Shrinkage

Wiechmann and Pallagst (2012) argued that urban shrinkage and economic decline always occur in regions with structural disadvantages, such as "rust belts" or urban fringe areas with old industrial agglomeration, which are common in developed countries in Europe and the United States. Urban shrinkage in Europe came later than in the United States, but its coverage is vaster. Europe will lose 50 million of its current population by 2050, with a third of the European region currently facing population loss (Nieto et al. 2016; Hartt 2018). Most of these areas are located on the outskirts of cities, most of which have fragile economies, and an aging population. In terms of spatial change, population shrinkage occurs in various parts of the city, where empty and abandoned buildings are mixed with other buildings in use. Such "perforated shrinkage" is like a piece of paper with holes

randomly punched out and the fabric of the city is torn (Mallach et al. 2017).

Urban Growth and Urban Shrinkage

With the emergence of urban recession in the United States in the early 1970s, urban growth seems to be constantly reversed (Harvey 1978), and the number of shrinking cities increasing (Leo and Brown 2000). When the Ruhr industrial zone in Germany lost a large number of people due to industrial declination, the region transitioned old industries toward science and technology, and established a "technological road," linking economic centers and research centers in the region (De Long and Summers 1991). Faced with shrinkage caused by de-industrialization, Manchester in the UK promoted the rise of education, media, sports, and other industries through a series of urban cultural revival plans and cultural infrastructure construction, and finally, successfully transformed the city into the "capital of creative industries" (Williams 2000). Pittsburgh in the United States also suffered a serious economic recession in the process of de-industrialization, but through the vigorous development of high-tech, education, health care, and various cultural industries it has not only successfully created a new image of the city but reshaped its vitality, known as the "Pittsburgh Renaissance" (Amekudzi et al. 2003). However, since the decline of traditional industries, Detroit was unable to rid itself of economic and population recession and had to declare bankruptcy. Since the 1990s, due to institutional changes and many other factors, the former West Germany is developing prosperously, while the former East Germany is facing the plight of economic recession, population loss, and rising unemployment rate (Dubeaux and Sabot 2018). Therefore, growth and shrinkage should be placed in the same dimension to explore the stage of urban development in different regions.

Identification of Growth and Shrinkage

Population change is the most direct and important index to identify a region's growth and shrinkage internationally, with many scholars also implementing other economic-related indicators to supplement their findings. Turok and Mykhnenko (2007) defined shrinkage in terms of cities where population increase rate is lower than the national average. Beauregard (2009) divided cities and regions of different scales into three spatial types of growth, stability, and shrinkage according to the population size of American cities. Kabisch et al. (2012) classified European cities into five categories: high growth, slow growth, revival, temporary shrinkage, and continuous recession, with demographic change as the main indicator. Wiechmann and Pallagst (2012) classified the growth and shrinkage of cities according to two dimensions of population and economy based on the definition of urban shrinkage by SCIRN, where the shrinking cities in Europe are divided into three types: continuous shrinkage, segmental shrinkage, and temporary shrinkage according to the length of population loss time. Long and Wu (2016) used permanent population data from the Chinese census of 2000 and 2010 to identify 180 shrinking cities nationwide.

Henderson et al. (2012) found high correlations between lighting intensity and GDP at the national level. The DMSP/OLS nighttime light data were applied for identifying urban agglomerations, estimating urban population density (Elvidge et al. 1997; Zhuo et al. 2009; Small et al. 2011), tracking speed and type of urbanization, measuring urban electricity and other energy consumption, and greenhouse gas emissions levels (Townsend and Bruce 2010), reflecting the level of regional economic vitality (Chen and Nordhaus 2011; Florida et al. 2012). Meanwhile, LandScan population data is an important data source for planning and management in many countries that use LandScan population data to conduct series of empirical research. Dobson et al. (2000) used LandScan data to quickly assess and judge the population risk and visualized it. McKee et al. (2015) combined demographic (age, gender) data with LandScan data to predict the population size of the United States in 2030 and 2050, and the findings are expected to provide a scientific basis for urban infrastructure planning and long-term climate change response.

Formation and Driving Forces of Urban Shrinkage

The formation of shrinking cities can be summarized through the following four aspects: (1) in the context of globalization and de-industrialization, many old industrial cities in Europe and the United States are running out of resources and are unable to adapt to development needs of economic transformation and industrial upgrading, resulting in large numbers of unemployment and migration (Blanco et al. 2009); (2) the structural transformation of the economy under the influence of institutional change has made it impossible for state-owned enterprises in cities of Eastern Europe and the former Soviet Union to survive in the wave of private ownership, which has led to factory closures, population outflow, and urban shrinkage (Turok and Mykhnenko 2007); (3) an aging population accompanied by a declining birth rate and a large number of the young labor force migrating out have jointly led to serious negative population growth in cities (Chan et al. 2016); (4) influenced by suburbanization, residents and industries in North American cities are gradually gathering in the periphery, leading to the decline of inner cities (Beauregard 2009). In general, urban shrinkage is affected by multiple factors such as de-industrialization, globalization, resource depletion, social system transformation, aging population, suburbanization, and so on.

Growth and shrinkage are naturally evolving in the process of urban development, and their theoretical origin can also be explained from the perspective of urban life cycle and urban development stage theory (Martinez-Fernandez et al. 2012; Haase et al. 2014). The decline of urban areas is inevitable mainly because urbanization always goes going through four stages: generation, growth, decline, and extinction (Mallach 2017). Birch (1971) believes that the city life cycle theory includes five stages: development, transformation, degradation, decline, and renewal. Wallbaum et al. (2011) believe that urban development has a remarkable cyclical feature, from growth to stability or even recession and then to growth again. Shrinkage is an important part of the urban development process, where central urban areas are expanding compared with the population decline in urban peripheries. Urban shrinkage is actually a cyclical process and is rooted in a broader cycle of growth and shrinkage (Hollander et al. 2009).

In China, urban shrinkage has gradually attracted the attention of many scholars, who have set up the Shrinking City Research Network of China (SCRNC) to enthusiastically and proactively research the issue. Economic recession is felt in developed cities in eastern coastal areas as well as in underdeveloped cities in western areas. There are only differences in the degree of shrinkage between urban centers and peripheral areas. Urban shrinkage in China is more complex and has the characteristics of regional heterogeneity (Long and Wu 2016). Studies in China are still in initial stages, mostly conducted at city or regional levels. To a certain extent, breadth and depth are simple and inadequate content factors to investigate the spatial nature of growth and shrinkage and apply research methods on identification and classification. Therefore, for the basis of identifying the mechanism of growth and shrinkage

in the PRD region, this paper adopts a refined quantitative analysis method to explore the spatial pattern and evolution process of urban development, as well as changes before and after the financial crisis.

Research Methodologies

Study Area

The PRD region is one of the three largest urban agglomerations in China, with a land area of 56,000 km^2. As of the end of 2018, the total permanent population of the PRD region reached 70 million, accounting for 60% of the total population in Guangdong Province. The PRD region is becoming the largest urban area in the world (Ye 2013). The PRD region has not only created miraculous economic growth, but also brought about rapid urbanization. The urban district is the core component of a city and the center of urbanization, therefore, the nine prefecture-level cities in the PRD region are the case study areas, namely, Guangzhou, Shenzhen, Foshan, Dongguan, Zhongshan, Zhuhai, Jiangmen, Zhaoqing, and Huizhou. Although some cities have adjusted their administrative divisions, this paper employs the municipal districts of cities in 2010 as the analysis base map, and data changes in other years were adjusted to the base map (Fig. 1).

Research Data

DMSP/OLS Nighttime Light Data

In this paper, the DMSP/OLS remote sensing data from the National Oceanic and Atmospheric Administration (NOAA) of the United States are used, which include 22 annual data from 2000 to 2013 from four satellites (NOAA 2000–2013). Its spatial resolution is about 1 × 1 km grid, and its brightness value is 0–63. The larger the value, the higher the brightness. In order to eliminate the problems of unstable light source, lack of in-orbit radiometric calibration and supersaturation, the Harvard University Dataverse was used for data partition, and this paper selects the base year to carry out mutual correction and interannual continuity correction for selected regions to exclude the influence of regional differences. Referring to Elvidge et al. (2007) interannual correction model, a region with stable social and economic development and a large coverage, high intensity, wide range of nighttime light was selected. The satellite data of a specific year in this region were used as benchmarks, and the interannual correction coefficient (1) was obtained by quadratic regression of other satellite data, and the coefficient obtained by regression will be widely used in interannual correction of different regions in the study area. This can be represented as

$$DN_{\text{cali}} = a \times DN^2 + b \times DN + c \tag{1}$$

where DN_{cali} = the corrected value of time series of a pixel; DN = the original pixel value; and a, b, c = regression coefficient. Data were processed for desaturation using the vegetation correction with Enhanced Vegetation Index (EVI) data of Moderate Resolution Imaging Spectroradiometer (MODIS) from 2000 to 2013. Data include 16-day average normalized difference vegetation index (NDVI) and EVI standard products with a resolution of 250 m. Compared with NDVI, which is sensitive to chlorophyll, EVI is more suitable to reflect changes of canopy vegetation, including leaf area index (Arnold and Gibbons 1996; Slonecker et al. 2001). Based on nighttime light data desaturation method using the EVI index, this study undertakes vegetation correction on top of time series corrected data, as follows:

$$D = DN_{\text{norm}} - \text{EVI} \tag{2}$$

$$\text{EANTLI} = (1 + D)/(1 - D) \times DN_{\text{cali}} \tag{3}$$

where DN_{cali} = the pixel value after the time sequence correction; DN_{norm} = the pixel value obtained after the normalization of DN_{cali}; EVI = the vegetation index value; and EVI-adjusted nighttime light index (EANTLI) = the value obtained after the time sequence correction and vegetation correction of a certain pixel. Finally, the abnormal values of nighttime light data are excluded, where the abnormal value of the largest are assigned as the maximum values in the calendar years, and all the negative values in the calendar years are assigned to 0, and then a mean value is obtained from two data images of the same year, which can be represented as

$$DN_i = (\text{EANTLI}_1 + \text{EANTLI}_2)/2 \tag{4}$$

where EANTLI_1 and EANTLI_2 = the values after a pixel time series correction and vegetation correction respectively; and DN_i = the merged pixel value.

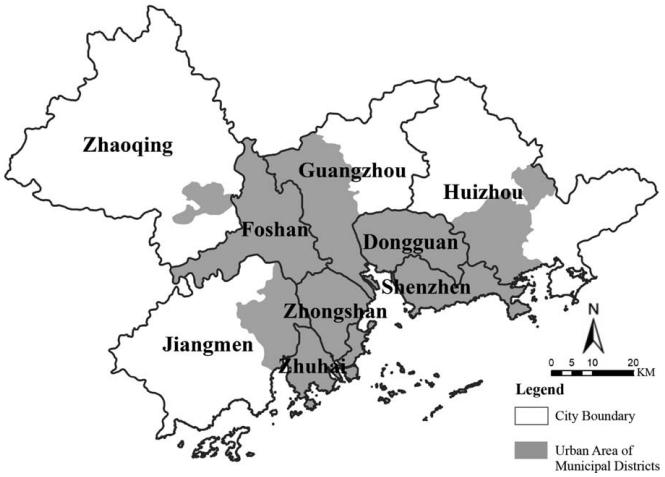

Fig. 1. Study area in the PRD region.

LandScan Population Data

The LandScan global population statistics database was developed by the Oak Ridge National Laboratory (ORNL) of the US Department of Energy (ORNL 2000–2015). At a spatial resolution of approximately 1 × 1 km, this data shows the distribution of the population in the built environment (referring to the average stay in the area for more than 24 h). The values in its cells represent the total number of people in the average or environmental population distribution (Fig. 2).

Land Use Data

In this study, land use in the PRD region in 2000, 2009, and 2013 were extracted by Landsat TM remote sensing image data (Fig. 3), where changes in land use were characterized by the index of urban built-up areas that are defined as the area of built-up land in a single grid counted (built-up areas per 1 × 1 km). The total area of all municipal districts in the PRD region is about 23,355 km^2, the built-up areas of which is about 2,607 km^2 at end of 2000 and 6,915 km^2 at end of 2013, respectively. Spatial resolution of data is about 30 m from 1983 up to recent years. The object-oriented method was selected to process Landsat TM remote sensing image data, with built-up areas in the PRD region extracted by eCognition software, which include image segmentation, object hierarchy, classification rules and information extraction, visual interpretation, and

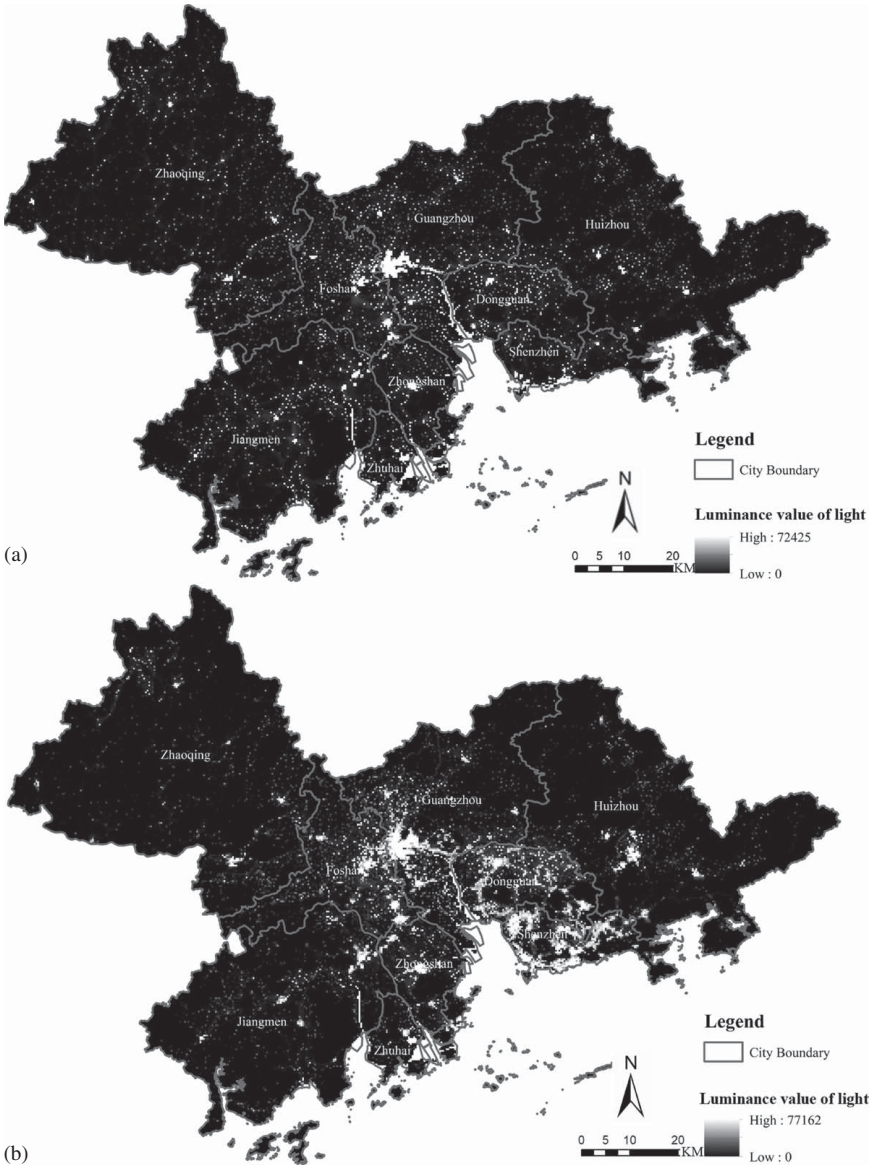

Fig. 2. 1 × 1 km grid population map of the PRD region in (a) 2000; and (b) 2015.

correction, thereby eliminating machine recognition errors and improving data accuracy. In order to validate eCognition in extracting urban built-up areas, 100 known plots were randomly selected as verification samples by visual interpretation of the original images combined with field investigation, and it was found that 97% of the plots could be correctly identified. Meanwhile, 100 plots were randomly selected as samples from the results, which indicates 95% accuracy.

Analysis Methods

DMSP/OLS nighttime light data was used to reflect the economic level of the study area, and the LandScan population grid data provided by ORNL was used to demonstrate population distribution. Using corrected DMSP/OLS nighttime light remote sensing image, LandScan population grid, and land use data extracted by Landsat TM, the light value, total population, and built-up areas in the PRD region were quantitatively analyzed in 1 × 1 km grid units. The spatial grid matching of light data and population data was carried out by means of ArcGIS and Bilinear interpolation method. The light intensity and population were counted at the grid scale, and the following formula was synthesized as a comprehensive indicator to characterize economic vitality (EV):

$$\mathrm{EV} = DN_i \times \mathrm{POP} \tag{5}$$

where EV = the economic vitality value of a single grid; DN_i = the light intensity value of a single grid after a series of pre-processing; and POP = the population quantity of a single grid. Nighttime light data was superimposed on population data as a new indicator of economic vitality in order to avoid erroneous estimates of the economic level of the region due to natural disasters or high-brightness economic activities. By calculating the composite EV index and urban built-up area index, the growth and shrinkage of the PRD region are divided into four different spatial types according to the grid average value as the measurement standard. The spatial pattern and development evolution of growth and shrinkage at grid scale in the PRD region from 2001 to 2009 and from 2009 to 2013 were investigated. In addition, *China's Urban Statistical Yearbook*, *China's Statistical Yearbook*, and the statistical yearbook at the municipal level were also used to analyze the growth and shrinkage of the region's population, industry, and land use along time series (see Fig. 10 in Appendix).

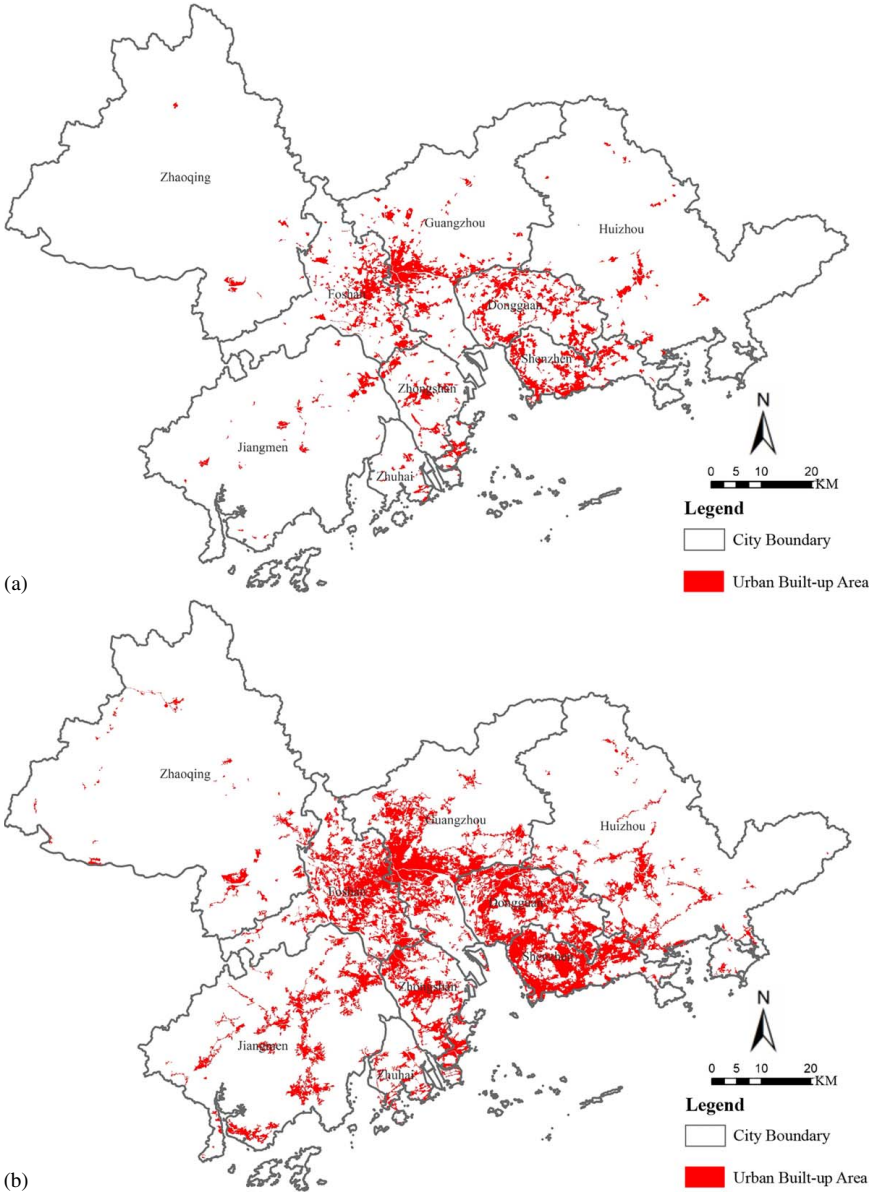

Fig. 3. Land use map of built-up areas in the PRD region in (a) 2000; and (b) 2013.

Results and Findings

Spatial Patterns of Growth and Shrinkage

Growth and shrinkage of the PRD region are identified and classified in regard to the two major indicators of urban economic vitality and urban construction. As seen in Fig. 4, there are 23,355 grids in the municipal districts, of which 11,754 grids represent built-up land and account for 50.33%, with nonbuilt-up land accounting for 49.67%. According to the four-quadrant method, 499 (4.25%) grids showed expansion growth; 1,722 (14.65%) grids showed aggregation growth; 7,087 (60.29%) grids showed aggregation stability; and 2,446 (20.81%) grids showed expansion shrinkage. In terms of overall spatial distribution, Guangzhou and Foshan were found to have stable agglomeration areas, mostly concentrated in the center of the city (see Table 1). Agglomeration growth areas are mainly distributed in Shenzhen and Dongguan border areas, with sporadic distribution in the central area of various cities. Land use in these areas is basically saturated, urban built-up land and mainly at inventory status. Expanded growth areas are few, sporadically distributed in cities that have certain vigor and newly built land (e.g., Guangzhou's university city, Huizhou's Daya Bay). The expansion shrinkage areas are mainly situated in industrial agglomeration areas (e.g., Shenzhen's Baoan District, Zhongshan's Xiaolan, Dongfeng, Nantou, and other specialized towns). Growth and shrinkage areas are highly mixed, which characterizes the region with perforation shrinkage.

Classifications and Interpretations

Expansionary Growth Areas: Guang-Fo Cross-Border Area

The Guang-Fo cross-border area is composed of adjacent subdistrict units, town streets, and rural areas of Guangzhou and Foshan, a spatial organization of certain geographical scope. Guangzhou-Foshan has always been an economic, political, cultural, and social integration area. Driven by regional integration, the core of the Guang-Fo cross-border area appears to have an obvious growth trend. As seen in Fig. 5(a), construction of a cross-shaped main road in this area was basically completed in 2001, and land use functions are mainly residential and green spaces. By 2009, road

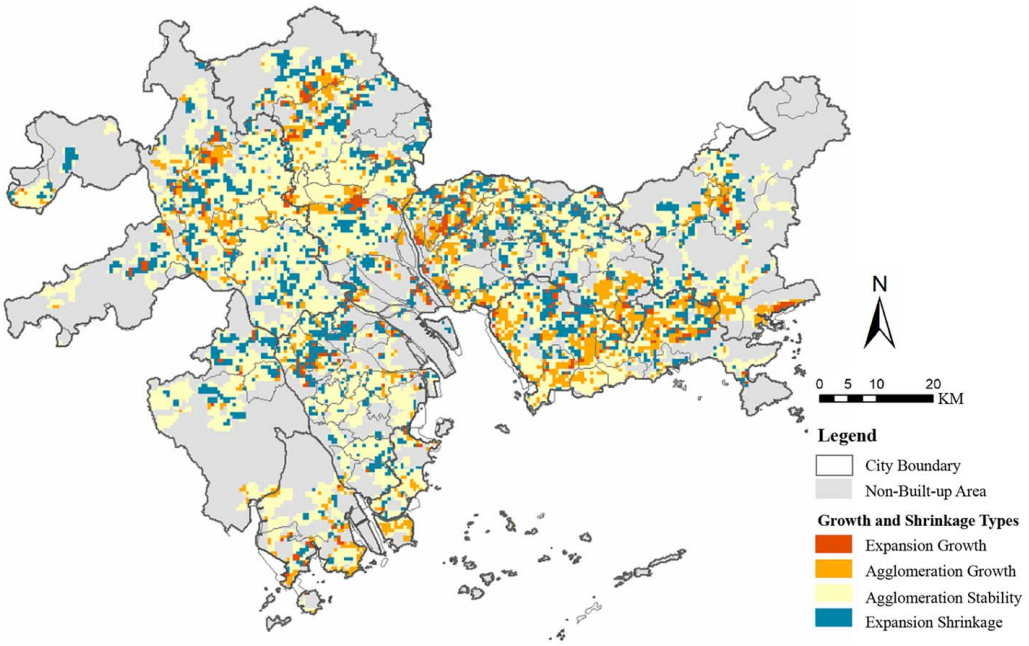

Fig. 4. Spatial pattern of growth and shrinkage of municipal districts in the PRD region from 2001 to 2009. Notes: the mean values of the EV index of economic vitality and urban construction index (urban built-up area) are taken as the origin values of x-axis and y-axis respectively, and the four-quadrant classification method is used to identify different space types in the region.

Table 1. Main characteristics of four types of growth and shrinkage areas

Space type	Typical area	Economic	Demographic	Land use
Expanded growth	University towns, development zones, port-vicinity areas, airport economic zones, and cross-border areas.	The economy continues to grow due to preferential policies or transportation and location advantages.	Population continues to grow in accordance with industrial development.	Built-up areas expand rapidly, attracting industry and population.
Agglomeration growth	Science and technology parks, high-tech zones, convention and exhibition parks.	High-tech industry or modern service industry lead and promote economic growth by technological progress.	Population continues to rise and is optimized to high degree educated population.	Land use expansion slows down, and the efficiency of land use is improving.
Agglomeration stability	Central urban areas, manufacturing, commercial and trade towns.	The third industry and the trade service drive the industrial transformation, and the economic development is stable.	Population remained stable, and population outflow in some areas.	Built-up areas are basically saturated and land use relies on replacement of stock land.
Expanding shrinkage	Traditional manufacturing town, manufacturing base, peripheral high-tech zone, and peripheral areas of the PRD region.	Traditional low-end manufacturing industry relies on exogenous economy or located on the periphery, and the economy declines due to central polarization.	Population outflow is serious, and jobs are decreasing.	Built-up areas expand rapidly, with a large number of vacant buildings or inefficient industrial parks.

network construction had formed a more complete connectivity system, while built-up areas expanded and formed a continuous development zone. With the development of industrial parks, land use function changed from single to mixed. In addition, the cross-border industrial economy has formed good cooperation and interaction, and regional industries are rich in diversity, including flower science and technology parks, advanced manufacturing industries such as automobiles and ships, and supporting industries such as logistics parks.

Agglomeration Growth Area: Shenzhen Nanshan Science and Technology Park

The park was founded in 1996 and now covers an area of 6.5 km^2 [Fig. 5(b)]. The park has evolved into a high-tech industrial cluster with technological innovation at the core, attracting a large number of high-end talents while continuously creating output value for urban economic development. In 2001, the infrastructure and supporting lifestyle facilities were improved and put into use. The total industrial output value of the park reached RMB 63 billion, an increase of 38% since 2000, and 6.3 times that of the initial establishment. By 2009, there were 399 enterprises, with a total industrial output value of CNY 255 billion (16.1% of the city), and the number of employees at 273,000 at the end of the year. Between 2001 and 2009, the built-up areas remained largely unchanged, but with the entry of numerous science and technology enterprises, land use efficiency has been greatly improved, and total industrial output value has been increasing.

Agglomeration Stable Area: Guangzhou Yuexiu Central District

In 2001, construction of office buildings, residential buildings, commercial facilities, and various kinds of infrastructure were

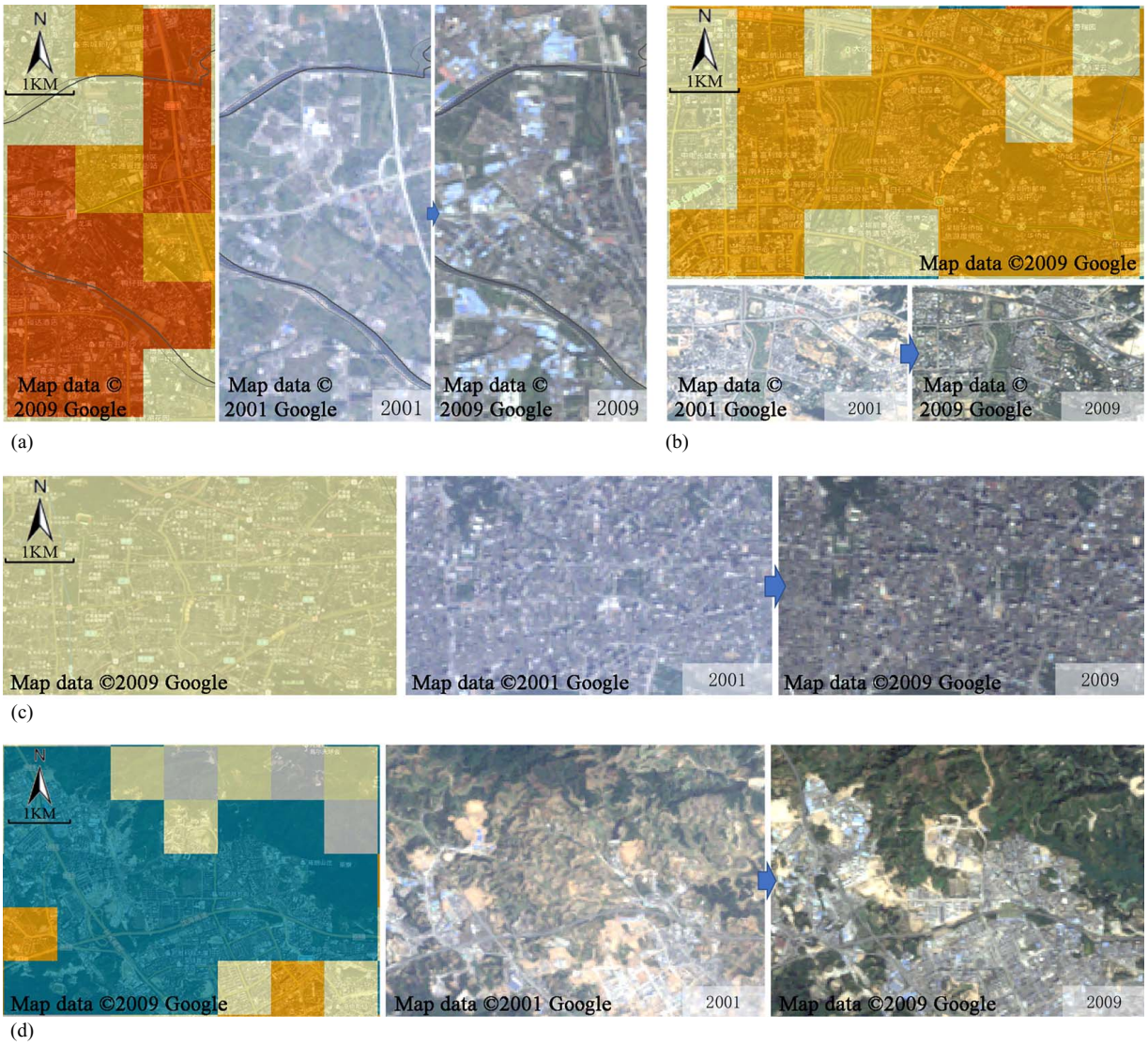

Fig. 5. Nighttime light value growth and land use changes (2001 versus 2009): (a) Guang-Fo cross-border area; (b) Shenzhen Nanshan Science and Technology Park; (c) Guangzhou Yuexiu Central District; and (d) Shenzhen Baoan manufacturing base. (Map data © 2001, 2009 Google.)

completed, forming a high-density built-up environment in the urban area [Fig. 5(c)]. By 2009, with little land available for developmental uses, the landscape of urban areas did not change much, and urban development mainly took the form of the functional replacement of stock land. This industry-oriented economy has a strong ability to resist crisis; the international financial crisis did not greatly perturb economic development. Nearly saturated land use has brought about a stable regional population structure, sufficient infrastructure, and development of commerce and trade industries, along with a stable employment structure making the overall development of Yuexiu District regional stable.

Expansion Shrinkage Area: Shenzhen Baoan Manufacturing Base

Since the reform and opening up, the manufacturing industry has become the main industrial output. Local governments invested heavily financially in urban construction to attract more enterprises, and a large number of industrial parks came into being. In 2009, Baoan District attracted 1,906 enterprises, creating a large industrial park cluster [Fig. 5(d)]. In 2001, the cross-shaped road network was built, enabling factories along the road to form a small-scale cluster. In 2009, the urban built-up areas expanded northward, where factory buildings were densely located. Subsequently, small- and medium-sized enterprises dominated, and the proportion of small-scale enterprises with less than 300 people comprised 79.27%. As a result of the international financial crisis in 2008, the number of such enterprises decreased from 3,607 in 2002 to 1,906 in 2008, a decrease of 47.16%. The number of employees shrunk from 1.17 million in 2002 to 550,000 in 2008. The relocation of industries and population led to a sharp decline in the economic vitality of this area, leaving a large number of vacant factories.

Evolution of Growth and Shrinkage in the PRD Region Since the Financial Crisis

From 2009 to 2013, a total of 1,358 (11.55%) grids showed expansion growth, 1,889 grids (16.07%) showed agglomeration growth, 5,816 grids (49.48%) showed agglomeration stability, and 2,691 grids (22.90%) showed expansion shrinkage in the PRD region. Overall, most areas of the PRD region still exhibit stable development, of which the areas of Dongguan and Shenzhen (agglomeration stable areas) have expanded significantly, while the proportion of agglomeration growth areas has increased, with a large area concentrated in the northwest area of Shenzhen, Shunde District of

Foshan, and Huicheng District of Huizhou. Compared with the previous stage, the proportion of expanding growth areas increased significantly, mainly concentrated in Hengqin of Zhuhai, Baiyun of Guangzhou, and scattered in Shunde of Foshan, Nanhai, and other places. The proportion of expanding shrinkage areas increased slightly, mainly distributed in the peripheral areas of the PRD region, such as Zhaoqing, Jiangmen, Huizhou, and other urban fringe areas. In addition, Zhongshan central urban area showed a significant shrinkage trend, and Sanshui, Nanhai, and Chancheng districts of Foshan City appeared to display perforated shrinkage (Fig. 6).

During the five years of adjustment since the financial crisis, the spatial pattern of growth and shrinkage in the PRD region has changed, especially in Dongguan and Shenzhen. Most towns and streets in Dongguan have returned to a stable state of low economic vitality and low urban construction. In contrast, Baoan district in Shenzhen has completely shaken off the haze of economic crisis and shown a wide range of transformation and growth. Red areas indicate that regional development is moving from shrinkage to regrowth, green areas indicate that regional development is gradually returning to stability, and black areas indicate that regional development is in a long-term recession. In shrinkage areas between 2001 and 2009, 777 grids (31.75%) grew again, 1,577 grids (64.45%) stabilized, and 93 grids (3.80%) declined. In particular, more than 95% of shrinking areas gradually restored stability or achieved regrowth, with only a few areas experiencing long-term recession. The distribution of declining areas is relatively scattered within cities, while regrowth areas are mainly concentrated in Shenzhen Baoan and Foshan Shunde. At the same time, the largest areas appear to have restored stability, and are distributed widely with the risk of potential shrinkage, mainly concentrated in Dongguan and Zhongshan (Fig. 7).

Expansion growth areas accompanied by rapid economic and land use growth are mainly concentrated in university towns, development zones, or industrial parks and integrated areas relying on large-scale transportation infrastructure construction. While land use in agglomeration growth areas is saturated, the economy is still developing in limited space and land efficiency is rising. Expansion growth areas are mainly concentrated in science and technology parks driven by innovation, high-tech zones, or industrial spillover border areas and exhibition parks driven by modern service industry. Low-level development of economy and land use in agglomeration stable areas is mainly distributed in the central old urban areas and specialized towns that realize the transformation of manufacturing industry. The expansion shrinkage areas are still expanding outward as economic development declines are mainly distributed in the traditional manufacturing base dominated by the export processing industry, specialized towns, or peripheral areas of cities that are greatly affected by central polarization.

Policy Analysis of Regrowth and Restoration of Stable Growth Areas

Regrowth Area (Shrinkage → Growth): Baoan District of Shenzhen City

Between 2009 and 2013, most areas showed a lower level of urban construction and land use efficiency improved significantly [Fig. 8(a)]. In addition, regional economic vitality gradually moved from low or negative growth before 2009 to the momentum of re-emerged high-speed growth. Most areas change from agglomeration shrinkage before 2009 into agglomeration growth or expansion growth mode after 2009. Influenced by the international financial crisis, regional development experienced a short shrinkage process but under the strong policy guidance of the local government, the region quickly regained its vitality and showed transformation to growth. Driven by the policy, advanced manufacturing industry developed and was dominated by the electronic communication equipment manufacturing industry. A substantial proportion of the tertiary industry showed a trend of gradual increase. Thus, under the guidance of the local government's active industrial and talent policy, successful transformation of industrial development has led to steady improvement of economic vitality, with highly skilled and talented individuals constantly gathering in this area.

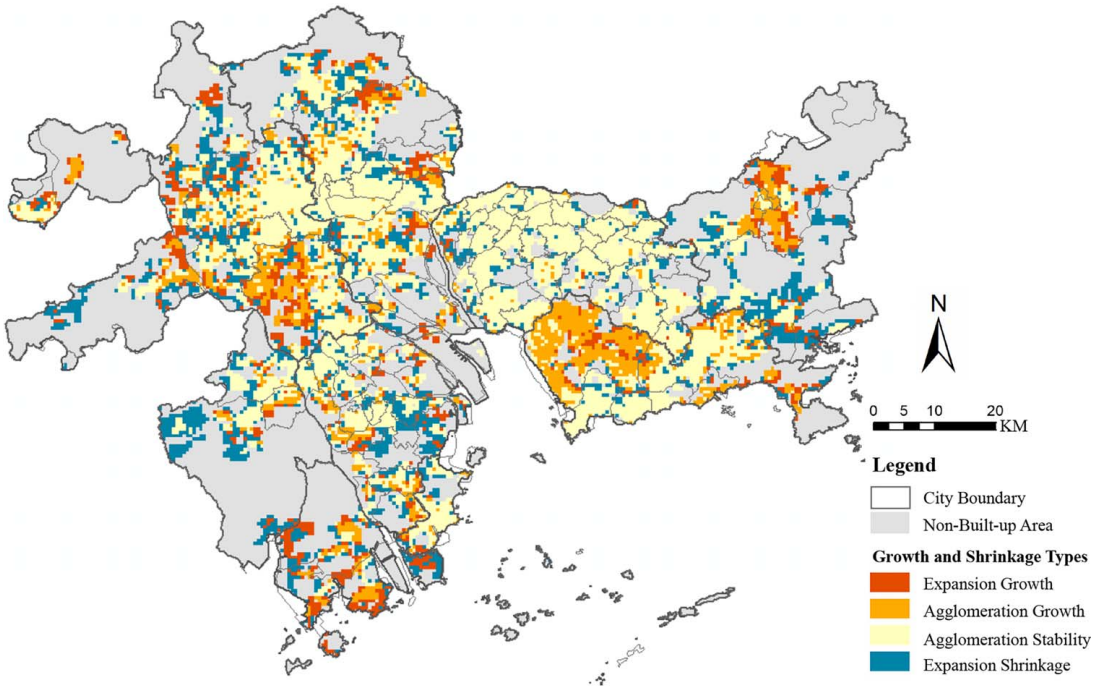

Fig. 6. Spatial pattern of growth and shrinkage in the PRD region from 2009 to 2013.

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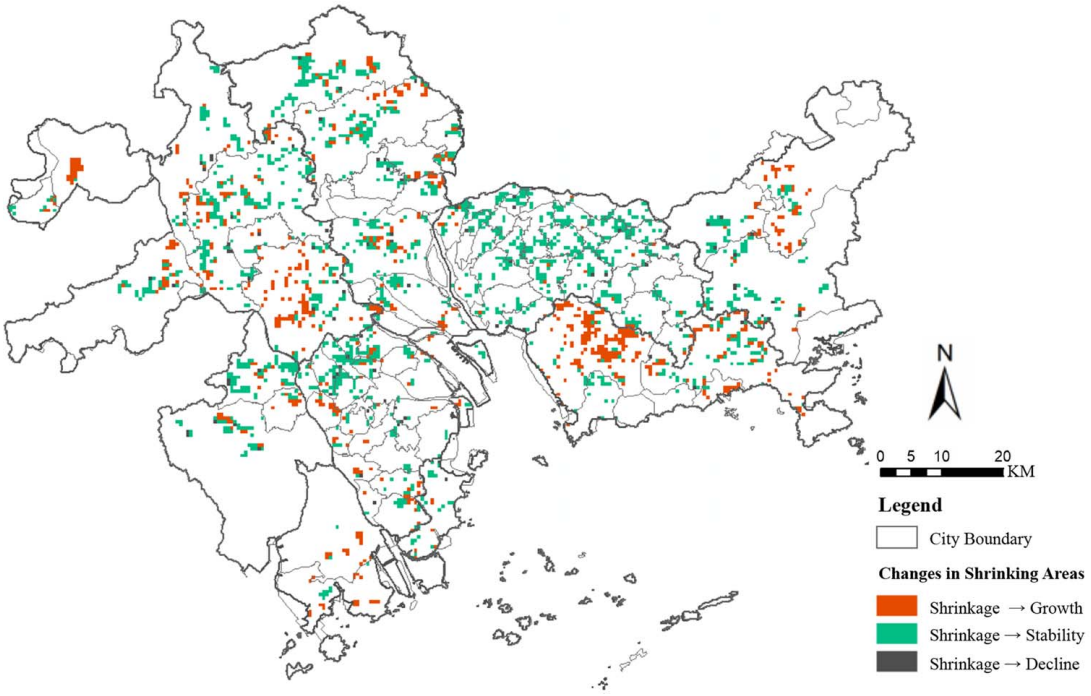

Fig. 7. Analysis of the development and change of the shrinking areas in the PRD region from 2009 to 2013.

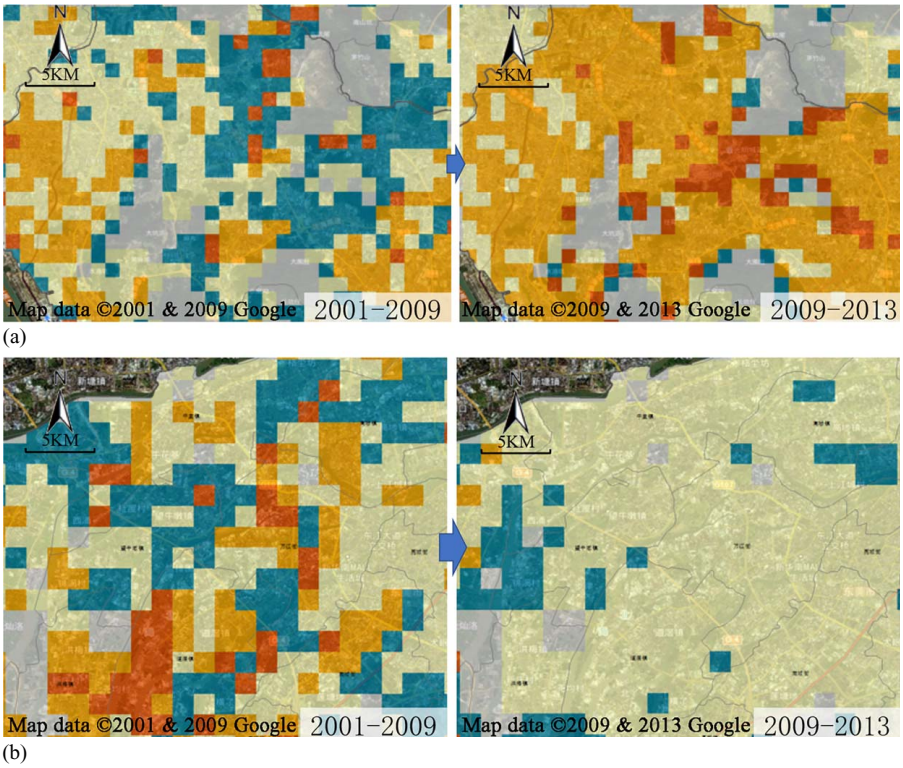

Fig. 8. Changes in spatial development: (a) Baoan District of Shenzhen City; and (b) Shuixiang Area of Dongguan City. (Map data © 2001, 2009, 2013 Google.)

Restoration of Stable Growth Areas (Shrinkage → Stability): Shuixiang District of Dongguan City

Since 2008, the agglomerated manufacturing enterprises in the region have been greatly impacted, and the decline in external demand makes it difficult for enterprises to continue as they depend long-term on export trade development. Large numbers of factories and enterprises have closed down, and the rising unemployment rate has been exacerbated by population outflow. The Shuixiang area layout exhibits perforation shrinkage. Although most areas have changed from expansion shrinkage into agglomeration stable areas, before and after 2009 respectively, there are still some areas that show a trend of continued recession [Fig. 8(b)]. The local

government has improved industry and economy in this area through active policy guidance, but this development still lacks ability to sustain growth momentum. In 2013, economic development of this area was still highly dependent on the secondary industry, the growth of the tertiary industry was relatively slow, and the actual effect of innovation-driven growth is not significant. Between 2008 and 2013, the migrant population generally declined as policies implemented by local governments to attract the migrant population were largely ineffective, as were effects of talent policies. The spatial characteristics of the two types of transformation are summarized in Table 2.

Validity of Spatial Analysis and Field Investigation

In the empirical analysis of growth and shrinkage in the PRD, the results of multisourced data analysis were verified by combining with the field investigation. The reliability of the spatial analysis results is validated through demonstrating and comparing with an onsite survey, where we investigated a number of different types of areas, including the areas not discussed in detail previously. For example, expanded growth areas include Guangzhou University Town, Daya Bay Economic and Technological Development Zone of Huizhou City, Bogue Port Area of Dongguan City, Airport Economic Zone of Guangzhou City, and the Cross-border Area of Guangzhou and Foshan city; agglomeration growth areas include Shenzhen Nanshan Science and Technology Park, Core Area of Foshan Nanhai High-tech Park, Dongguan Fenggang Area, Guangzhou Pazhou Exhibition Park; agglomeration stability areas include Guangzhou Yuexiu Central District, Foshan Shunde Lecong Professional Town; expanding shrinking areas include Water Township Area in the northwest of Dongguan City, Zhongshan Xiaolan Hardware Professional Town, Shenzhen Baoan Manufacturing Base, Huizhou Zhongkai High-Tech Zone, peripheral areas of PRD; regrowth areas include Baoan District of Shenzhen City and Shunde District of Foshan City; restoration of stable growth areas include Water Township Area in the northwest of Dongguan city and Zhongshan Xiaolan Hardware Professional Town. Meanwhile, spatial data has been preprocessed and calibrated to reduce systematic errors, and the mean value is adopted to avoid remote sensing data errors using the continuous data in the section "Research Data."

Discussions and Implications

Spatial Nature of Growth and Shrinkage in the PRD Region

The mismatch between urban development and economic activities has led to growth and shrinkage in cities and regions (see Fig. 9). Since the reform and opening up, the PRD region has been increasingly exhausting land consumption over the past 40 years of fast urbanization, leaving less land for future urban development. For example, the intensity of land use reached 16.5% in 2013, among which Shenzhen has the highest development intensity, nearly 50%. Shenzhen, Dongguan, Zhongshan, Foshan are higher than 30% of the international warning line, and Zhuhai and Guangzhou are also close. The urban land use for construction in the PRD region was about 1,570 km^2 in the 1980s, and it reached 8,534 km^2 in 2013 with an almost fivefold increase. However, at the same time, land use is scattered and fragmented, and has low concentration productivity. The average land use efficiency is about ¥596 million/km^2, which is half of that in developed countries.

When urban development and economic activities grow at a high speed, expansion growth areas maintain an efficient and orderly development, and are likely to benefit with the support of national policies, superior regional transportation location, and population agglomeration formed by regional integration. When the speed of urban development is slower than that of economic growth, production activities of cities continue to gather in a limited space, forming an agglomeration growth area. When the speed of urban development and economic development are synchronous, but both at low levels, the area presents a stable state of development, and these kinds of agglomeration stable areas are likely to be situated in the urban center with saturated land use and stable structure of development. When the speed of urban development is faster than the speed of economic growth, there are two different forms of expansion and shrinkage: (1) while economic growth slows down, urban development is still growing and urban land use expands outward, which may lead to a large amount of inefficient land use, such as a large number of empty cities and ghost cities; (2) economic recession accompanied by closure of factories and enterprises may lead to a large number of vacant buildings appearing in the area, showing a layout of perforated shrinkage.

Table 2. Spatial characteristics of the two types of transformation in the PRD region

Type of changes	Shrinkage → Growth (Regrowth areas)	Shrinkage → Stabilization (Areas of stability restored)
Typical areas	Shenzhen Baoan District, Foshan Shunde District, etc.	Dongguan Shuixiang District, Zhongshan Xiaolan Town, etc.
Historical features	Brand advantages, high energy consumption, low output industrial agglomeration, low level of product science and technology; over-expanded, extensive, and inefficient land use, decentralized industrial areas; low profiled labor force gathering.	Small and medium-sized township enterprises, mainly rely on processing and highly depend on external economy; rural urbanization results small-scale and extensive village-level industrial parks with scattered and mixed space; rural labor forces and migrant workers flows.
Policy characteristics	Emphasizing scientific and technological progress and innovation, accelerating the development of high-tech industries and modern service industries; promoting the integration of informatization and industrialization and intelligent production; by "three old renewals" transformation to provide space for new industries; attracting high-level and high-skilled talents, providing with allowances and living security.	Promote transformation and upgrading of traditional industries and encourage innovation and brand agglomeration; eliminate backward production capacity and enterprises with high pollution and high energy consumption; renew and replace stock land and improve built environment for attracting investment; emphasize full employment of the transferred rural labor forces and facilitate migrant workers.
Actual effect	Economic vitality rises, population return, and regional growth resumes; transition to tertiary industry, development of intelligent industry and innovation; high-level and highly skilled talents increasingly gather.	Economy recovers and stabilizes but lacks sustained growth momentum; economic growth depends on the secondary industry, and innovation drive is not significant; population outflow slows down, but migrant labor forces continue to decline.

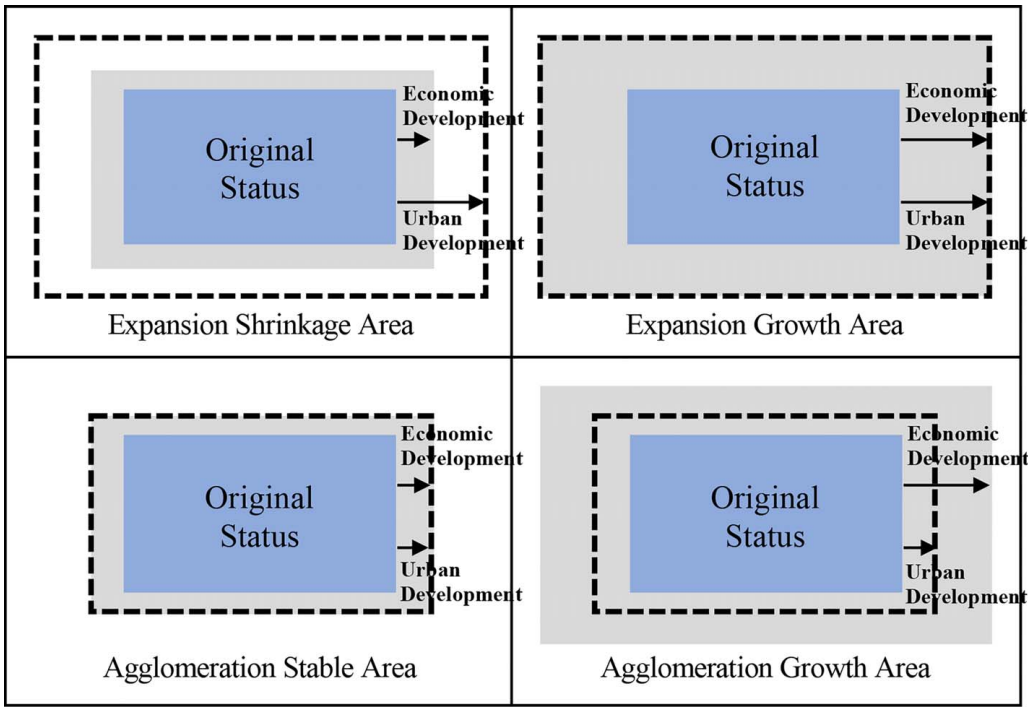

Fig. 9. Classifications of four types of development areas in relation between urban construction and economic activity.

Hypercycle of Changes in Growth and Shrinkage

The process of urbanization also appears to be periodic, with shrinkage and growth guided by economic and urban periodic changes. Urban shrinkage can actually be understood as a short-term stage phenomenon rooted in a broader cycle of growth and shrinkage. Urban shrinkage is an inevitable stage of the urban development cycle, although this process of urban decline is short term. After a period of urban shrinkage, due to policy, industrial transformation, and other reasons, cities undertake different development trends, and this differentiation time node is regarded as the key turning point. Since the 2008 financial crisis, Detroit experienced a shrinkage process characterized by the decline of manufacturing industry, followed by urban development failing to recover. With the bankruptcy of the Auto City in 2013, the city directly entered a long-term recession stage. Pittsburgh was also hit hard after the financial crisis, and the city began to decay. However, unlike Detroit, the city experienced a brief shrinkage, and through the implementation of industrial restructuring policy and urban renewal strategy, it rejuvenated and transformed through redevelopment. In this process, Pittsburgh only stayed in a short cycle of recession, and the city quickly regained vitality and upward development.

Planning Strategies and Policy Responses

As 5 billion people are projected to live in cities by 2030, the challenge of shrinking cities will continue to thrive and grow. As part of the *2030 Agenda for Sustainable Development*, the *Sustainable Development Goals* are a universal call to make cities and communities resilient and sustainable (Sustainable Development Goals 2019). There needs to be a well-recognized agenda to enhance urban resilience toward shrinkage (Chen et al. 2020), where all urban actors can jointly strengthen efforts to reshape shrinking cities by integrating urban and regional planning across the country. In China, the *Outline of National Land Use Plan* (2016–2030) stipulates that the intensity of land use in 2030 should not exceed 4.62%, and urban area should be limited to 116,700 km^2 (Li et al. 2020). Thus, it is necessary to optimize the spatial structure, control land use supply, and promote urban renewal in the PRD region. In practice, the three old renewals projects (old towns, old factories, and old villages) are becoming increasingly important. Guangdong Province has been carrying out the "three old renewals" since 2009 (Li et al. 2019). By the end of 2019, 32,293 ha of land use has undergone the "three old renewals" with investment of ¥1.106 trillion. Therefore, in the face of urban shrinkage and growth, cities need to promote urban renewal to transform the old factories and enrich the urban renewal policies.

First, cities should set up special funds for the large number of processing and trade enterprises that have developed since the reform and opening up to enhance their transformation and upgradation. Second, cities should promote technological progress, encourage innovation development, realize famous brand driving, set up special funds for science and technology to promote the high-quality development of export brand projects, and promote the integration of informatization and industrialization in order to speed up the upgrading of the electronic information industry. Third, efforts must be made to facilitate the integration and transformation of old factories' land use, promote renewal and replacement of stock land, provide financial and tax incentives and subsidies for attracting entry of large-scale high-quality projects such as advanced manufacturing, high-tech industries and producer services, and further strengthen the frameworks of attracting investment. Fourth, cities need to set up strict functional zoning of economic development areas to avoid a "work-agriculture" mixed land use model and carry out extensive renovations of polluting enterprises that are outdated. In general, the local government-led industrial policy should continue to promote exogenous economic development, with emphasis on scientific and technological innovation to promote industrial transformation and trade upgrading through construction of the industrial park to attract high-quality foreign investment. In terms of the talent policy, the management system should improve necessary services in areas that migrant workers live in, such as hospitals and schools for their children.

Policies aimed at attracting talent with high levels of skills and degrees are relatively weak, and most focus on providing rewards. Fifth, it is necessary to increase green infrastructure, enrich urban green space systems, make complete use of idle land and vacant houses, improve accessibility to urban green space, and increase neighborhood access (Chen et al. 2019a, b).

Conclusion

This paper constructs an analysis framework of growth and shrinkage of the PRD region and identifies different development trends in the region. At the same time, based on the empirical study, we explore spatial patterns and the development evolution of growth and shrinkage in the PRD region before and after the 2008 financial crisis. The growth rate differences between urban construction and economic activity lead to either growth or shrinkage. Using the nighttime light data, population data, and land use data, the EV index and the index of urban built-up areas are built to identify growth and shrinkage patterns of the PRD region. Finally, four different types of growth and shrinkage are analyzed, and basic characteristics of perforated shrinkage are found in the whole region through study cases.

Although shrinkage is a short-term phenomenon, shrinkage area may resume regrowth or fall to long-term decline. Historical roots and policy guidance are important factors affecting growth, stability, or recession in shrinkage areas. Policy guidance of local government and its actual effect determine different trends of development and change in the shrinkage area. On the one hand, the regrowth area of Shenzhen Baoan, Foshan Shunde has historical characteristics of high industrial energy consumption, low output, low level of science and technology, and decentralized layout. After the financial crisis, the local government vigorously promoted innovation and development with intelligent production policies that have achieved good results, regional economic growth, and population return. On the other hand, Dongguan Shuixiang area, Zhongshan Xiaolan town are typical cases of recovered stable areas with processing trade-based small and medium-sized enterprises, highly dependent on the external economy, and associated with historical characteristics of mixed industrial land. After the economic crisis, relevant policies of local governments to promote the transformation and upgrading of traditional superior industries and eliminate backward production capacity had little effect, and these areas have gradually restored stability but still lack growth momentum.

The shortcomings of this study are mainly reflected in the use of satellite remote sensing data in the acquisition process due to cloud cover, radiation, reflectivity, and other uncontrollable factors, and there thus exists a certain degree of system error. In future studies, the combination of traditional official statistics and new satellite remote sensing data could be considered to jointly identify regional growth and shrinkage. In fact, the spatial phenomenon of the coexistence of growth and shrinkage occurs not only in the PRD region, but also in many other regions across China, such as the Beijing-Tianjin-Hebei region, the Yangtze River Delta region, the northeast China region, and the central region. Comparative studies will help deepen the understanding of the typical types and classifications of growth and shrinkage. At present, the topic of urban growth and shrinkage in China is increasingly attracting the attention of governments at all levels as well as academia. Most research stays limited at the level of phenomenon description, and with a lack of in-depth exploration of the process of urban evolution and its nature of growth and shrinkage, these issues are worth further study and discussion.

Appendix. The Analytical Framework of this Study

Fig. 10 shows the analytical framework of this study, which constructs an analysis framework of growth and shrinkage of the PRD region and identifies different development trends in the region. The spatial pattern and development evolution of growth and shrinkage at the grid scale in the PRD region from 2001 to 2009 and from 2009 to 2013 were investigated. Economic vitality (EV) and urban built-up area index were used to analyze the growth and shrinkage of the region's population, industry, and land use along time series.

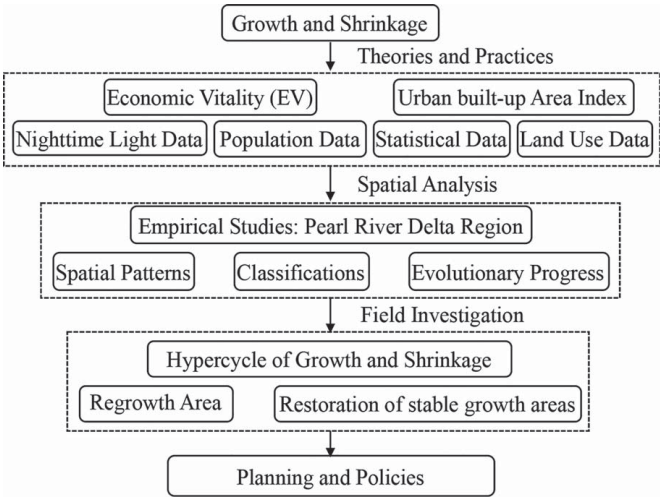

Fig. 10. The analytical framework of this study.

Data Availability Statement

Some or all data, models, or code used during the study were provided by a third party. (Nighttime light data, https://www.ngdc.noaa.gov/eog/dmsp/downloadV4composites.html; LandScan population data, https://landscan.ornl.gov/landscan-datasets). Direct requests for these materials may be made to the provider as indicated in the Acknowledgments.

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References

Amekudzi, A., S. McNeil, and H. N. Koutsopoulos. 2003. "Assessing extra jurisdictional and areawide impacts of clustered brownfield developments." *J. Urban Plann. Dev.* 129 (1): 27–44. https://doi.org/10.1061/(ASCE)0733-9488(2003)129:1(27).

Arnold, C. L., Jr., and C. J. Gibbons. 1996. "Impervious surface coverage: The emergence of a key environmental indicator." *J. Am. Plann. Assoc.* 62 (2): 243–258. https://doi.org/10.1080/01944369608975688.
Audirac, I. 2018a. "Introduction: Shrinking cities from marginal to mainstream: Views from North America and Europe." *Cities* 75: 1–5. https://doi.org/10.1016/j.cities.2017.10.012.
Audirac, I. 2018b. "Shrinking cities: An unfit term for American urban policy?" *Cities* 75: 12–19. https://doi.org/10.1016/j.cities.2017.05.001.
Batty, M. 2016. "Empty buildings, shrinking cities and ghost towns." *Environ. Plann. B: Plann. Des.* 43 (1): 3–6. https://doi.org/10.1177/0265813515619858.
Beauregard, R. A. 2009. "Urban population loss in historical perspective: United States, 1820–2000." *Environ. Plann. A: Econ. Space* 41 (3): 514–528. https://doi.org/10.1068/a40139a.
Beauregard, R. A. 2013. "Shrinking cities in the United States in historical perspective: A research note." In *Shrinking cities*, edited by K. Pallagst, T. Wiechmann, and C. Martinez-Fernandez, 49–57. London: Routledge.
Bernt, M. 2015. "The limits of shrinkage: Conceptual pitfalls and alternatives in the discussion of urban population loss." *Int. J. Urban Reg. Res.* 40 (2): 441–450. https://doi.org/10.1111/1468-2427.12289.
Birch, D. L. 1971. "Toward a stage theory of urban growth." *J. Am. Inst. Planners* 37 (2): 78–87. https://doi.org/10.1080/01944367108977361.
Blanco, H., et al. 2009 "Shaken, shrinking, hot, impoverished and informal: Emerging research agendas in planning." *Prog. Plann.* 72 (4): 195–250. https://doi.org/10.1016/j.progress.2009.09.001.
Chan, E. H., A. Wang, and W. Lang. 2016. "Comprehensive evaluation framework for sustainable land use: Case study of Hong Kong in 2000–2010." *J. Urban Plann. Dev.* 142 (4): 05016007. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000346.
Chen, T., W. Lang, and X. Li. 2020. "Exploring the impact of urban green space on residents' health in Guangzhou, China." *J. Urban Plann. Dev.* 146 (1): 05019022. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000541.
Chen, T., E. C. Hui, J. Wu, W. Lang, and X. Li. 2019a. "Identifying urban spatial structure and urban vibrancy in highly dense cities using georeferenced social media data." *Habitat Int.* 89: 102005.
Chen, T., W. Lang, and X. Li. 2019b. "Exploring the impact of urban green space on residents' health in Guangzhou, China." *J. Urban Plann. Dev.* 146 (1): 05019022.
Chen, X., and W. D. Nordhaus. 2011. "Using luminosity data as a proxy for economic statistics." *Proc. Natl. Acad. Sci.* 108 (21): 8589–8594. https://doi.org/10.1073/pnas.1017031108.
De Long, J. B., and L. H. Summers. 1991. "Equipment investment and economic growth." *Q. J. Econ.* 106 (2): 445–502. https://doi.org/10.2307/2937944.
Dobson, J. E., E. A. Bright, P. R. Coleman, R. C. Durfee, and B. A. Worley. 2000. "Landscan: A global population database for estimating populations at risk." *Photogramm. Eng. Remote Sens.* 66 (7): 849–857.
Dubeaux, S., and E. C. Sabot. 2018. "Maximizing the potential of vacant spaces within shrinking cities, a German approach." *Cities* 75: 6–11. https://doi.org/10.1016/j.cities.2017.06.015.
Elvidge, C. D., et al. 2007 "The Nightsat mission concept." *Int. J. Remote Sens.* 28 (12): 2645–2670. https://doi.org/10.1080/01431160600981525.
Elvidge, C. D., K. E. Baugh, E. A. Kihn, H. W. Kroehl, and E. R. Davis. 1997. "Mapping of city lights using DMSP operational linescan system data." *Photogramm. Eng. Remote Sens.* 63 (6): 727–734.
Ferdinand, A. V., and D. Yu. 2016. "Sustainable urban redevelopment: Assessing the impact of third-party rating systems." *J. Urban Plann. Dev.* 142 (1): 05014033. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000271.
Florida, R., C. Mellander, and T. Gulden. 2012. "Global metropolis: Assessing economic activity in urban centers based on nighttime satellite images." *Prof. Geogr.* 64 (2): 178–187. https://doi.org/10.1080/00330124.2011.583590.
Haase, A., D. Rink, K. Grossmann, M. Bernt, and V. Mykhnenko. 2014. "Conceptualizing urban shrinkage." *Environ. Plann. A: Economy Space* 46 (7): 1519–1534. https://doi.org/10.1068/a46269.
Hartt, M. D. 2018. "How cities shrink: Complex pathways to population decline." *Cities* 75 (38): 38–49. https://doi.org/10.1016/j.cities.2016.12.005.
Harvey, D. 1978. "The urban process under capitalism: A framework for analysis." *Int. J. Urban Reg. Res.* 2 (1–3): 101–131. https://doi.org/10.1111/j.1468-2427.1978.tb00738.x.
Häußermann, H., and W. Siebel. 1988. "Die schrumpfende Stadt und die Stadtsoziologie." In *Soziologische stadtforschung*, edited by J. Friedrichs, 78–94. Wiesbaden: VS Verlag für Sozialwissenschaften.
Henderson, J. V., A. Storeygard, and D. N. Weil. 2012. "Measuring economic growth from outer space." *Am. Econ. Rev.* 102 (2): 994–1028. https://doi.org/10.1257/aer.102.2.994.
Hollander, J. B., K. Pallagst, T. Schwarz, and F. J. Popper. 2009. "Planning shrinking cities." *Prog. Plann.* 72 (4): 223–232.
Hui, E. C., X. Li, T. Chen, and W. Lang. 2018. "Deciphering the spatial structure of China's megacity region: A new bay area—The Guangdong-Hong Kong-Macao Greater Bay Area in the making." *Cities* https://doi.org/10.1016/j.cities.2018.10.011.
Iseki, H. 2016. "Equity in regional public transit finance: Tradeoffs between social and geographic equity." *J. Urban Plann. Dev.* 142 (4): 04016010. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000328.
Jessop, B. 1992. "Regulation und Politik. Integrale Ökonomie und integraler Staat." In *Hegemonie und staat*, edited by A. Demirovic, H. Krebs, and T. Sablowski, 232–262. Münster: Westfälisches Dampfboot Verlag.
Kabisch, N., D. Haase, and A. Haase. 2012. "Urban population development in Europe, 1991–2008: The examples of Poland and the UK." *Int. J. Urban Reg. Res.* 36 (6): 1326–1348. https://doi.org/10.1111/j.1468-2427.2012.01114.x.
Lang, W., T. Chen, and X. Li. 2016. "A new style of urbanization in China: Transformation of urban rural communities." *Habitat Int.* 55: 1–9. https://doi.org/10.1016/j.habitatint.2015.10.009.
Lang, W., T. Chen, E. H. Chan, E. H. Yung, and T. C. Lee. 2019a. "Understanding livable dense urban form for shaping the landscape of community facilities in Hong Kong using fine-scale measurements." *Cities* 84: 34–45.
Lang, W., Y. Long, T. Chen, and X. Li. 2019b. "Reinvestigating China's urbanization through the lens of allometric scaling." *Physica A* 525: 1429–1439.
Li, X., F. Zhang, E. C. Hui, and W. Lang. 2020. "Collaborative workshop and community participation: A new approach to urban regeneration in China." *Cities* 102: 102743.
Lee, J. S., S. Won, and S. Kim. 2016. "Describing changes in the built environment of shrinking cities: Case study of incheon, South Korea." *J. Urban Plann. Dev.* 142 (2): 0501501. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000305.
Leo, C., and W. Brown. 2000. "Slow growth and urban development policy." *J. Urban Affairs* 22 (2): 193–213. https://doi.org/10.1111/0735-2166.00050.
Li, X., E. C. Hui, T. Chen, W. Lang, and Y. Guo. 2019. "From Habitat III to the new urbanization agenda in China: Seeing through the practices of the "three old renewals" in Guangzhou." *Land Use Policy* 81: 513–522. https://doi.org/10.1016/j.landusepol.2018.11.021.
Long, Y., and K. Wu. 2016. "Shrinking cities in a rapidly urbanizing China." *Environ. Plann. A: Economy Space* 48 (2): 220–222. https://doi.org/10.1177/0308518X15621631.
Mallach, A. 2017. "What we talk about when we talk about shrinking cities: The ambiguity of discourse and policy response in the United States." *Cities* 69: 109–115. https://doi.org/10.1016/j.cities.2017.01.008.
Mallach, A., A. Haase, and K. Hattori. 2017. "The shrinking city in comparative perspective: Contrasting dynamics and responses to urban shrinkage." *Cities* 69: 102–108. https://doi.org/10.1016/j.cities.2016.09.008.
Martinez-Fernandez, C., I. Audirac, S. Fol, and E. Cunningham-Sabot. 2012. "Shrinking cities: Urban challenges of globalization." *Int. J. Urban Reg. Res.* 36 (2): 213–225. https://doi.org/10.1111/j.1468-2427.2011.01092.x.
Martinez-Fernandez, C., T. Weyman, S. Fol, I. Audirac, E. Cunningham-Sabot, T. Wiechmann, and H. Yahagi. 2016. "Shrinking cities in Australia, Japan, Europe and the USA: From a global process

to local policy responses." *Prog. Plann.* 105: 1–48. https://doi.org/10.1016/j.progress.2014.10.001.

McKee, J. J., A. N. Rose, E. A. Bright, T. Huynh, and B. L. Bhaduri. 2015. "Locally adaptive, spatially explicit projection of US population for 2030 and 2050." *Proc. Natl. Acad. Sci.* 112 (5): 1344–1349. https://doi.org/10.1073/pnas.1405713112.

Nieto, J. R., L. S. D. da Silva, V. Murtinho, C. Rigueiro, and A. Gonçalves. 2016. "Conceptual model for the sustainable rehabilitation of medium-size inner cities in Europe: Coimbra, Portugal." *J. Urban Plann. Dev.* 142 (3): 04015023. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000303.

NOAA (National Oceanic and Atmospheric Administration). 2000–2013. "Nighttime Light Imagery." Defense Meteorological Satellite Program (DMSP)/Operational Linescan System (OLS) database. Accessed June 5, 2017. https://www.ngdc.noaa.gov/eog/dmsp/downloadV4composites.html.

ORNL (Oak Ridge National Laboratory). 2000–2015. "LandScan High Resolution global Population Data Set." Dept. of Energy. Accessed June 5, 2017. https://landscan.ornl.gov/landscan-datasets.

Schilling, J., and J. Logan. 2008. "Greening the rust belt: A green infrastructure model for right sizing America's shrinking cities." *J. Am. Plann. Assoc.* 74 (4): 451–466. https://doi.org/10.1080/01944360802354956.

Slonecker, E. T., D. B. Jennings, and D. Garofalo. 2001. "Remote sensing of impervious surfaces: A review." *Remote Sens. Rev.* 20 (3): 227–255. https://doi.org/10.1080/02757250109532436.

Small, C., C. D. Elvidge, D. Balk, and M. Montgomery. 2011. "Spatial scaling of stable night lights." *Remote Sens. Environ.* 115 (2): 269–280. https://doi.org/10.1016/j.rse.2010.08.021.

Sustainable Development Goals. 2019. "The 2030 Agenda for Sustainable Development." *United Nations Conference on Housing and Sustainable Urban Development*. Accessed May 3, 2020. https://www.un.org/sustainabledevelopment/.

Townsend, A. C., and D. A. Bruce. 2010. "The use of night-time lights satellite imagery as a measure of Australia's regional electricity consumption and population distribution." *Int. J. Remote Sens.* 31 (16): 4459–4480. https://doi.org/10.1080/01431160903261005.

Turok, I., and V. Mykhnenko. 2007. "The trajectories of European cities, 1960–2005." *Cities* 24 (3): 165–182. https://doi.org/10.1016/j.cities.2007.01.007.

Wallbaum, H., S. Krank, and R. Teloh. 2011. "Prioritizing sustainability criteria in urban planning processes: Methodology application." *J. Urban Plann. Dev.* 137 (1): 20–28. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000038.

Wiechmann, T., and K. M. Pallagst. 2012. "Urban shrinkage in Germany and the USA: A comparison of transformation patterns and local strategies." *Int. J. Urban Reg. Res.* 36 (2): 261–280. https://doi.org/10.1111/j.1468-2427.2011.01095.x.

Williams, G. 2000. "Rebuilding the entrepreneurial city: The master planning response to the bombing of Manchester City centre." *Environ. Plann. B: Plann. Des.* 27 (4): 485–505. https://doi.org/10.1068/b2626.

Wolff, M. 2018. "Understanding the role of centralization processes for cities–Evidence from a spatial perspective of urban Europe 1990–2010." *Cities* 75: 20–29. https://doi.org/10.1016/j.cities.2017.01.009.

Wolff, M., and T. Wiechmann. 2018. "Urban growth and decline: Europe's shrinking cities in a comparative perspective 1990–2010." *Eur. Urban Reg. Stud.* 25 (2): 122–139. https://doi.org/10.1177/0969776417694680.

Ye, L. 2013. "Urban transformation and institutional policies: Case study of mega-region development in China's pearl river delta." *J. Urban Plann. Dev.* 139 (4): 292–300. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000160.

Zhao, L., S. Shen, J. Luo, and G. Zhu. 2019. "Solutions for new town development predicaments from a comparison analysis of spatial evolution." *J. Urban Plann. Dev.* 145 (4): 04019015. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000524.

Zhuo, L., T. Ichinose, J. Zheng, J. Chen, P. J. Shi, and X. Li. 2009. "Modelling the population density of China at the pixel level based on DMSP/OLS non-radiance-calibrated night-time light images." *Int. J. Remote Sens.* 30 (4): 1003–1018. https://doi.org/10.1080/01431160802430693.