

# Analysis of Spatial Growth Characteristics of Major Cities in Hunan Province, China for Sustainable Urban Management

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## 지속 가능한 도시경영을 위한 중국 후난성 주요 도시의 공간적 성장 특징분석

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Urban space expansion is an important symbol of the urbanization process and has always been an important topic in urban studies. In addition, for sustainable city management, it is important to identify factors that can influence, such as the driving force and direction of urban space expansion, from the stage of establishing an urban development plan. To understand these factors, by observing the expansion process of a specific city, it is possible to sufficiently observe how the urban spatial dimension changes. Through a series of processes, the spatial growth characteristics of the city are analyzed, and the influence and results of important factors are analyzed. For this purpose, this paper examines the changes in the city's outer boundary and land use structure through monitoring data on urban areas of 14 cities in Hunan Province, China from 2000 to 2016. Temporal and spatial regularity according to the urban space expansion of these cities were analyzed, and a preliminary assessment was made on whether the urban space expansion is coordinated with the urban population growth. The assessment result showed: (1) The urban space of most cities has been extended rapidly in 2000-2015 however, the rate and the intensity of urban space expanding has been declining. (2) The construction of the industrial park is the core driving force of the urban space expanding, and the change of the urban space structure is manifested as enclave city expansion because that the industrial park is usually far away from the city center. (3) The population agglomeration is another driving force of the urban space expanding. At this time, the urban space expanding is like boundary extension. (4) Except Changsha city, all of the cities has a high urbanization-area-growth elastic coefficient. It means that most of the cities should enhance the land use degree.

**Keywords :** Hunan Province, Urban Space Expanding, Urban Spatial Growth, Urban City Planning, Sustainable Urban Management

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## 1. Introduction

Since the 1970, Chinese urban spatial growth has progressed at a faster rate than population growth [8]. The rapid spatial growth of cities has become a global phenomenon, and has attracted the attention of scholars in geography, sociology, architecture, and economics, and many related studies have been conducted. This phenomenon has a significant impact on sustainability and environmental changes such as Chinese landscape, city boundaries, traffic increases and many others [10]. Since urbanization and growth of Chinese cities is still a continuous phenomenon, it is necessary to analyze the growth of existing cities for sustainable urban management of newly growing cities. In this regard, the recent urbanization phenomenon in China can be a reference to other countries that are developing along with rapid urban population growth. To have a closer look, there were three main research streams.

The first is about urban spatial growth types. Leorey and Nariidac [6], Camagni et al.[1] studied about urban spatial growth types classification in terms of landscape ecology, urban morphology and others. Majority of scholars in China did plenty of research and studied about large and super-large urban spatial growth in China from an empirical perspective. Deng et al. [3] studied about 13 super-large size cities' spatial expansion during 1990~2000 with conclusion that urban spatial growth were in different forms of liner spreading expansion, leapfrog expansion, single center spread expansion or others. Xu et al. [13], Xie et al. [14], Feng and Chen [4] did research about urban spatial growth types respectively of Nanjing, Beijing and Hangzhou.

Second research stream is about urban spatial growth motivation mechanism. Zhou and Ye [17] and other scholars took 52 super-large cities satellite image map and land usage status image as example, adopted spatial econometrics, topology diagram, basing on that, analyzed super-large size city's expansion features and reasons. Su et al. [11], Wang et al.[12] and other scholars [9,16] adopted different resources to study city's expansion mechanism of Guangzhou and Hangzhou.

Third stream is urban spatial growth measure and prediction model. Liu et al. [7] and other scholars [16] adopted the principle of convex hull to recognize city's spatial expansion types, coming to conclusion that during 1990~2000, main cities in A Hui province expanded in the mode of space-filling. In addition, Ma et al. [8], Che et al. [2] and other scholars [2,7] adopted fractal dimension, compactness index and spatial auto-correlation index to conducts an urban growth space

model. Zhou et al. [16] took Beijing as example, studied Lowry model application in urban spatial structure study in terms of model building, parameter setting and situation simulation.

Up to now, scholars have done deep studies about urban spatial growth. Studies with large cities have generated lots of interests. However, study on comparison among different cities is much less. Therefore, it is necessary to study the differences and common factors between different cities expansion to achieve sustainable urban management for other cities. Adopting existing research method, this paper did analysis about main cities in Hunan Province on topic of urban spatial growth in terms of time span and regional area, in order to explore common features of cities' spatial expansion in certain area. Hunan Province is the 7th most populous province in China, with a population of 68.8 million, slightly larger than South Korea and similar in area to the Korean Peninsula, twice the size of South Korea. The situation in Hunan Province, where the population density continues to increase in Changsha next to Yangtze River, is similar to that of Seoul next to Han River. Research questions are as follows.

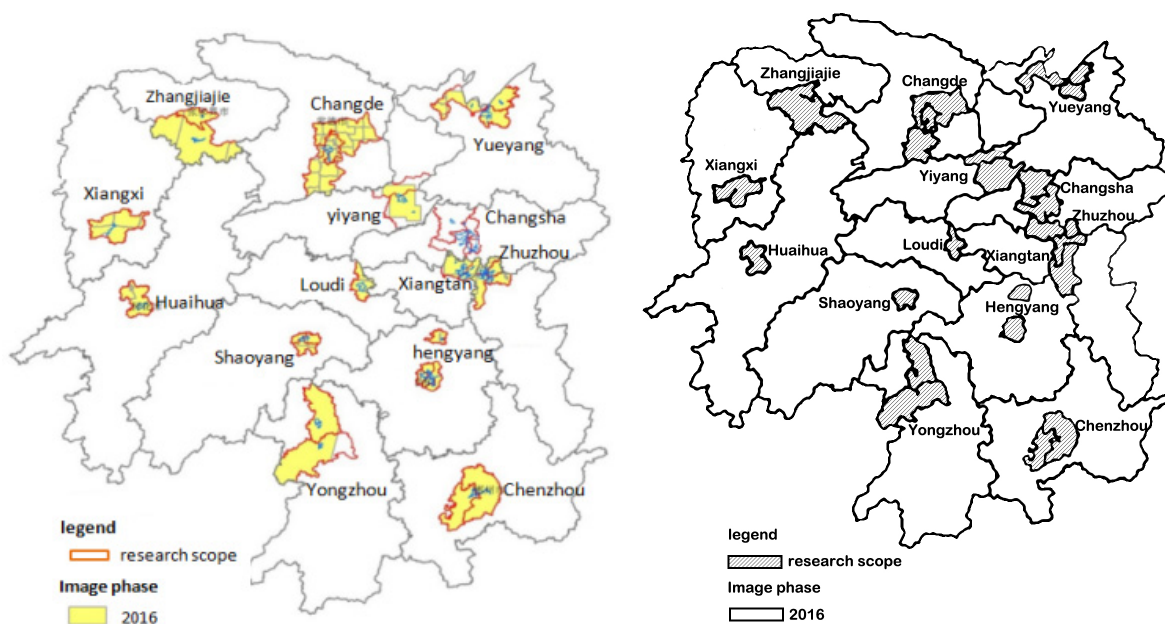
1. What are the drivers of urban space growth in major cities in Hunan?
2. What are the types of urban space growth in major cities in Hunan?
3. What are the common characteristics of urban space growth in major cities in Hunan?

To find answers of these questions, the scope of the study and data collection method are explained in the next section with the analysis based on the data. Section three explains the results and more evaluations. Last section shows the conclusion and enlightenment.

## 2. Research Method

This paper is based on monitoring data of 14 cities in Hunan Province, China. Among them, monitoring scope of prefecture-level city refers the city's municipal district. In addition, monitoring scope of district and autonomous prefecture refers the city's government residential county area. Visualization of the scope is as demonstrated as <Figure 1>.

With image data from Google map and Baidu map (higher



<Figure 1> City Boundary Data of 14 Cities in 2016

than 5 meters resolution) and reference data, city boundary data of 14 cities at prefecture level and above during the years of 2000, 2005, 2010, 2015 and 2016 were extracted. With image (higher than 1 meter resolution) and reference data, city boundary data, urban area scope and urban internal structure information of 14 cities at prefecture level and above of year 2016 were extracted.

Through collection of existing census result of geographical conditions, the latest fundamental geographical monitoring result, upon analysis about related information, this paper studies the urban land usage spatial structure transformation of cities at prefecture level and above. Furthermore, the paper studies spatial and temporal regularity and coordination quality of 14 cities at prefecture level and above in Hunan province.

## 2.1 Expansion Coverage in 14 Cities in Hunan Province

In 2016, total coverage area of 14 cities was 768.34 km<sup>2</sup>. By the time, coverage area of provincial capital city Changsha was 212.2 km<sup>2</sup>, being largest city of the Province. The smallest one was Xiangxi at west of Hunan province, whose coverage area was 13.74 km<sup>2</sup>, being 1/15 of Changsha in term of coverage area. Urban area coverage in Hunan Province had significant regional characteristics, which was urban area centered Changsha (at north east of geographic center) and was in radial decline to outer-ring. Coverage in northwest was rela-

tively small. From the angle of urban coverage expansion, during past 16 years, cities had coverage area increased by 351.8 km<sup>2</sup> which is increase of 84.45% compare with 416.54 km<sup>2</sup> in 2000. Year 2005~2010 was the period when urban grew at highest speed. Within 5 years, 14 cities had coverage expansion by 33.2%. Comparing city with city, during 2000~2016, top expansion cities were Changsha, Xiangtan, Zhuzhou, Hengyang and Changde. Expansion in northwest and southwest area was relatively small scale.

## 2.2 Analysis about Hunan Province Urban Spatial Growth Speed and Intensity

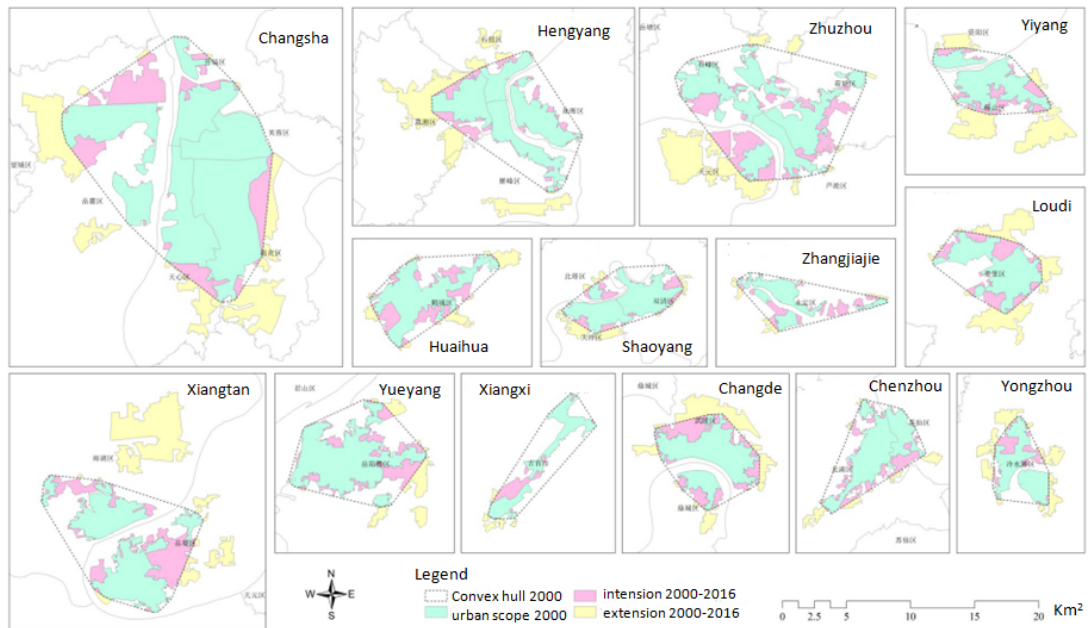
### 2.2.1 Urban Spatial Growth Speed

Urban spatial growth speed refers to each city's urban region increase speed at certain period. It indicates the expansion speed difference in certain period and can be demonstrated in formula, which is adjusted from previous researches [1, 3, 13, 14]:

$$V_i = \frac{\Delta U_{ij}}{(\Delta t_j)} \times 100\% \quad (1)$$

$V_i$  refers to growth speed;  $\Delta U_{ij}$  refers to urban expansion area of study unit no.  $i$  at time period of  $j$ ,  $\Delta t_j$  is time span in time period of  $j$ .

According to <Figure 1> and <Figure 2>, cities are different



<Figure 2> 14 Cities' Urban Spatial Growth Types (2000~2016)

from others in term of urban spatial grown speed. During sixteen years from 2000, Changsha city, Xiangtan city, Zhuzhou City, Hengyang City and Changde City were 5 cities whose speed ranked highest. Their expansion speed was 5.22 km<sup>2</sup> P.A., 2.39 km<sup>2</sup> P.A., 2.67 km<sup>2</sup> P.A., 1.91 km<sup>2</sup> P.A. and 1.65 km<sup>2</sup> P.A. respectively. Seeing from time quantum, 2006~2010 was the period when most cities grew fastest. Cities Zhuzhou, Xiangtan, Hengyang, Yiyang and West Hunan area experienced their highest expansion speed during 2011~2015. Seeing from city's expanded area, most cities have gone through the dramatic fast expansion period. In addition, convex hull

decision making includes cities' terrain and roadways.

### 2.2.2 Urban Expansion Intensity

Urban expansion intensity refers to each city's annual expansion percentage at certain period comparing with that at base period. It indicates the growth percentages of different cities in term of expansion speed as shown in <Table 1>. It can be demonstrated in formula which is adjusted from previous researches [1, 3, 13, 14]:

$$N_i = \frac{\Delta U_{ij}}{(\Delta t_j \times M_i)} \times 100\% \quad (2)$$

<Table 1> 14 Urban Growth Review During 2000~2016 of 14 Cities in Hunan Province

Cities	Growth Area (km <sup>2</sup> )	Growth Percentage	Growth Speed km <sup>2</sup> /year	Extension Area Percentage	Growth Type
Changsha	83.58	4.06%	5.22	55.20	Extension
Zhuzhou	38.29	6.12%	2.39	34.71	infilling
Xiangtan	42.73	8.32%	2.67	36.04	infilling
Hengyang	30.63	5.07%	1.91	69.43	Extension
Shaoyang	7.54	2.85%	0.47	53.55	Extension
Yueyang	19.82	3.61%	1.24	39.93	infilling
Changde	26.43	7.42%	1.65	54.99	Extension
Zhangjiajie	6.91	4.92%	0.43	26.70	infilling
Yiyang	22.81	8.85%	1.43	73.22	Extension
Chenzhou	19.88	6.85%	1.24	35.31	infilling
Yongzhou	15.87	5.23%	0.99	69.54	Extension
Huaihua	12.08	4.12%	0.76	35.85	infilling
Loudi	20.44	7.70%	1.28	64.84	Extension
Xiangxi	4.79	3.34%	0.30	31.51	infilling

Among them,  $N_i$  refers to urban expansion intensity;  $\Delta U_{ij}$  refers to urban expansion area of study unit number  $i$  at period  $j$ ,  $\Delta t_j$  refers to time span of period  $j$ ;  $M_i$  refers to total coverage area of unity number  $i$  at period  $j$ .

Along 2000~2016, 14 cities' land usage expansion intensity had distinctive difference with each other. Among them, Yiyang City, Xiangtan city, Loudi City, Changde City and Chenzhou city had a total expansion rate higher than 100%; and the rate was only at 45.67% and 53.52% respectively in Shaoyang and west Hunan area. As can be seen from table 1 and 3, from 2006 to 2010 was the period when most cities expansion were at their peak apart from Xiangtan City, Zhangjiajie City, Chenzhou City and Xiangxi, whose peak time were the next five years from 2011 to 2015. As shown from cities' structure transformation, during past 10 years, Hunan Province has experienced expansion from high speed to low.

### 2.2.3 Analysis about Types of Urban Spatial Growth

A certain city's ground contour refers to convex polygon at minimum size which covers the whole city area as well as its peripheral contour. Convex area refers to city area or its potential control area. We can adopt the principle of convex hull to recognize city's land expansion type, i.e. infilling type or extension type. Along the process of city used land expansion, if the area inside the convex hull is large than outside, it is infilling type of expansion; otherwise, it is extension type of expansion.

Generally from 2000 to 2016, half of cities at prefecture level and above grew by extension while half by infilling. Among them, cities such as Changsha, Hengyang, Shaoyang, Changde, Yiyang, Yongzhou and Loudi grew by extension while other cities grew by infilling. Generally speaking, extension grow cities had significant urban spatial form transformation in past 10 years while infilling grow cities not so significant. Anyhow, land usage compactness had certain degree of increase.

### 2.2.4 Urban Spatial Growth Direction and Projects

Reviewing 14 cities' urban spatial growth direction and projects, that cluster of industrial zone and technological development zone or high-tech industrial park is the main reason for urban enclave growth as shown in table 2. It apparent that, industries cluster to suburban was core driving force to urban spatial growth in past 10 years. During the period, suburban industrial usage land increased rapidly. Urban spaces

grew by extension or in enclave growth mode. On the other hand, city's residential and office usage land mainly grew in boundary expansion mode except Wangcheng district in Changsha city. The district can be classified as enclave urban growth featured by population and residential suburbanization.

<Table 2> 14 Urban Cities Growth Direction and Projects in Hunan Province

Cities	The main function of the Urban expansion area
Changsha	New urban area; Economic development zone; Land for public use
Xiangtan	Economic-technological development area
Hengyang	New and high-tech Industrial Development Zone
Shaoyang	Residential land
Yueyang	Industrial park
Changde	Economic-technological development area(N); Residential land(S)
Zhangjiajie	Economic development zone
Yiyang	New and high-tech Industrial Development Zone
Chenzhou	Industrial park
Yongzhou	Economic development zone, Residential land
Huaihua	Residential land(N), Industrial park(S)
Loudi	Industrial park(N); Residential land(others)
Xiangxi	Residential land

## 3. Primary Evaluation

### 3.1 Population Cluster Coordination

Land usage coefficient of elasticity is an index reflecting coordination relationship between urban growth and population & economy development. It is presented by urban land increase ratio divided by urban population increase ratio. According to related study findings, 1.12 is a rational ratio of China urban growth coefficient of elasticity [15]. If the ratio is lower, growth speed is lower and vice versa. As shown in table 3, during 2000~2005, four cities (Changsha, Hengyang, Shaoyang and Loudi) coefficient was lower than 1.12. During 2005~2010, two cities coefficient was lower than 1.12. One of them was Yueyang,, whose population increased negatively, and the coefficient of elasticity was negative. The other one was Zhangjiajie whose coefficient of elasticity was lower than 1.12. It is found urban land expansion was further speed up; along 2010~2015, three cities (Xiangtan, Hengyang and

Changde) population grew negatively, while two cities (Changsha and Yueyang) coefficient of elasticity was lower than 1.12. Along 2015~2016, four cities (Zhuzhou, Xiangtan, Yueyang and Zhangjiajie) population increase negatively, and five cities (Changsha, Hengyang, Huaihua, Loudi and Xiangxi) coefficient of elasticity was lower than 1.12. Reviewing coefficient of elasticity of 2000~2016, Changsha was the only city in Hunan province whose coefficient of elasticity is lower than 1.12, Changde and Yiyang were higher than 10. It demonstrates the conclusion that, urban land increase is higher than urban population increase and more intensive usage of land should be reinforced.

<Table 3> Urban Land Increase Coefficient of Elasticity during 2000 ~ 2016

Cities	2000~2005	2006~2010	2011~2015	2016	2000~2016
Changsha	0.189	1.99	0.41	0.65	0.81
Xiangtan	1.261	1.68	-693.93	-4.14	3.15
Hengyang	0.908	1.99	-2.06	0.14	2.52
Shaoyang	0.972	52.49	1.38	2.36	2.31
Yueyang	3.031	-2.85	0.23	-0.89	2.35
Changde	5.745	17.98	-54.38	7.20	14.41
Zhangjiajie	1.569	0.11	8.07	-0.89	4.01
Yiyang	7.475	13.19	11.81	14.46	10.63
Chenzhou	1.879	6.72	2.90	4.67	3.57
Yongzhou	10.237	3.24	5.11	3.75	5.74
Huaihua	1.309	4.29	2.54	0.00	2.36
Loudi	0.875	6.68	3.02	0.26	3.54
Xiangxi	2.902	1.48	3.42	1.05	2.85

### 3.2 Urbanization Quality

During the studied period, especially between 2005 and 2010, urban spatial growth was at a very rapid rhythm. However, reviewing recent years' urban spatial growth intensity and speed, major cities have gone through the rapid growth stage. However, urbanization quality in those cities were not high. Land urbanization is far ahead to population urbanization. Cities such as Yiyang, Changde, Zhangjiajie and Yongzhou had kept ranking top on population per square meter land in the past sixteen years. However, seeing from variation trend in term of population per square meter land, apart from Changsha, all other cities declined in general. Many cities focuses on urban spatial extension, but attention to urban renewal or urban quality improvement are not enough. Urban is unable to play its cluster effect role. Some cities comes

up with negative population increase, land usage efficiency is relatively low.

### 3.3 Core Driving Forces

Industry usage land in suburban area increases by a substantial margin and industry cluster has been the core driving force to urban spatial growth in Hunan Province. In term of spatial layout, since Industry Parks are mainly designed in enclave layout, urban spatial growth also goes in one or two main directions. Main stream of urban growth is no more sprawl mode. However, it shall be pointed out that, industry park planning and construction has its positive effect of urbanization and urban spatial growth promotion; the negative point is, idle farmland and land resource waste in development zone is a common phenomenon existing.

Urban population cluster is another important driving force to urban spatial growth. Residential land grows through boundary expansion. Different cities in Hunan Province have different residential and office usage land growth features. Apart from Wangcheng District in Changsha City which is enclave city zone featured of population and residence sub-urbanization, other cities normally grow in the way of boundary expansion. Along with existing city area's extension speed lowers down, cities' promotion on development and quality shall be achieved through regeneration of village in city and optimization and adjustment of internal structure.

## 4. Conclusion and Enlightenment

In the past 10 years, main cities in Hunan Province have experienced a dramatic urban spatial growth. However, city's development quality is not high as a common phenomenon. It is urgent to restrict population urbanization and land urbanization to a rational percentage. Otherwise, sustainable urban management will become more difficult. On policy level, government must guide cities to conserve and use the existing land more intensively. To achieve this, cities must remove institutional barriers existing in population urbanization, adequately release the population cluster function of villages and towns. Meanwhile, cities can achieve control upon urban land from over-rapid growth by meaningful policy making and implementation, land usage programming, land resource monitor and etc. Additionally, an idea about population growth and urbanization in large and small cities can be earned. Large



cities also expand rapidly, but small and medium-sized cities often grow much larger over the same period. In addition, urban expansion and population growth are also related to changes in weather, state-led industrialization and growth policies, economic development incentives, and policies to increase agricultural productivity [15]. The relationship with these items can be viewed as a future research direction. It should be studied how the various impacts of Chinese cities, such as air pollution and traffic congestion, are manifested by city type. Understanding the social, environmental and economic impacts of these urban forms is also an area that requires further investigation.

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## References

- [1] Camagni, R., Gibelli, M.C., and Rigamonti, P., Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion, *Ecological Economics*, 2002, Vol. 40, No. 2, pp. 199-216.
- [2] Che, Q., Duan, X., Guo, Y., Wang, L., and Cao, Y., Urban spatial expansion process, pattern and mechanism in Yangtze River Delta, *Acta Geogr. Sin.*, 2011, Vol. 66, pp. 446-456.
- [3] Deng, X., Huang, J., Rozelle, S., and Uchida, E., Growth, population and industrialization, and urban land expansion of China, *Journal of Urban Economics*, 2008, Vol. 63, No. 1, pp. 96-115.
- [4] Feng, J. and Chen, Y., Spatiotemporal evolution of urban form and land-use structure in Hangzhou, China: evidence from fractals, *Environment and Planning B: Planning and Design*, 2010, Vol. 37, No. 5, pp. 838-856.
- [5] Lee, H.F., Fok, L., and Zhang, D.D., Climatic change and Chinese population growth dynamics over the last millennium, *Climatic Change*, 2008, Vol. 88, No. 2, pp. 131-156.
- [6] Leorey, O.M. and Nariidac, S., A method of measuring shape, *The Geographical Review*, 1999, Vol. 64, No. 4, pp. 555-563.
- [7] Liu, J., Wang, X., and Zhuang, D., Application of convex hull in identifying the types of urban land expansion, *Acta geographica sinica - Chinese edition*, 2003, Vol. 58, No. 6, pp. 885-892.
- [8] Ma, R., Gu, C., and Pu, Y., Urban spatial sprawl pattern and metrics in south of Jiangsu Province along the Yangtze River, *Acta geographica sinica - Chinese edition*, 2007, Vol. 62, No. 10, p. 1011.
- [9] Seto, K.C., Fragkias, M., Güneralp, B., and Reilly, M.K., A meta-analysis of global urban land expansion, *PloS one*, 2011, Vol. 6, No. 8, e23777.
- [10] Schneider, A. and Mertes, C.M., Expansion and growth in Chinese cities, 1978–2010, *Environmental Research Letters*, 2014, Vol. 9, No. 2, pp. 1-11.
- [11] Su, J., Wei, Q., and Guo, H., The mechanism and adjustment of urban sprawl of Guangzhou, *Acta Geographica Sinica*, 2005, Vol. 60, No. 4, pp. 626.
- [12] Wang, W.W., Jin, J.W., Xiao, Z., and Shi, T., Urban expansion and its driving forces based on remote sensed data and GIS: A case study of Hangzhou city from 1991 to 2008, *Geographical Research*, 2009, Vol. 28, No. 3, pp. 685-695.
- [13] Xu, C., Liu, M., Zhang, C., An, S., Yu, W., and Chen, J.M., The spatiotemporal dynamics of rapid urban growth in the Nanjing metropolitan region of China, *Landscape Ecology*, 2007, Vol. 22, No. 6, pp. 925-937.
- [14] Xie, Y., Fang, C., Lin, G.C., Gong, H., and Qiao, B., Tempo-spatial patterns of land use changes and urban development in globalizing China: A study of Beijing, *Sensors*, 2007, Vol. 7, No. 11, pp. 2881-2906.
- [15] Yang, Y., Feng, Z., Zhao, Y., and You, Z., Coordination between urban land expansion and population growth in China, *Geographical Research*, 2013, Vol. 32, No. 9, pp. 1668-1678.
- [16] Zhou, B.X., Dai, T.Q., and Liang, J.S., Simulation of urban spatial structure in Beijing based on Lowry model, *Acta Geographica Sinica*, 2013, Vol. 68, No. 4, pp. 491-505.
- [17] Zhou, C. and Ye, C., Features and causes of urban spatial growth in Chinese metropolises, *Acta Geographica Sinica*, 2013, Vol. 68, No. 6, pp. 728-738.

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