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Spatiotemporal Evolution of Urban Land Uses in Modern Urbanization of China

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Abstract: Taking social statistic data as basic data, this paper extended the meaning of urban land uses, highlighted the meaning of urban land uses in modern urbanization, which includes direct, indirect and induced land uses, quantitatively simulated the indirect and induced land uses by the substitution method of agricultural consumption and urban carbon emission and then, analyzed the spatiotemporal evolution of urban land uses in China during 1952–2005 by spatial analysis tool of Geographic Information System. The results indicate that the area of urban land use in China had been increasing since 1952, showing an inversed pyramid structure, i.e., the direct<the indirect<the induced. Specifically, Chinese urban land use has changed from concentrated distribution in Northwest China to balanced spatial distribution, and the eastern coastal area is under great pressure. Moreover, the northeastern region has moved into the induced dominant stage, while the western region remains at the indirect dominant stage. Finally, it is proposed that in order to guarantee the future demand of urban land use in China, ensuring the induced land use in the eastern region should be taken as a priority goal of Chinese developing policy.
Keywords: urban land use; spatiotemporal evolution of land use; modern urbanization; China

1 Introduction

Modern cities and towns are highly centralized centre of population and social activities. They are the production, accumulation and diffusion centers of human substance and spiritual wealth (Zhou, 1995). Along with the accelerated urbanization in China, urban population increased quickly, the scales of cities and towns extended continuously, and the requirements of various resources increased day by day. Moreover, the industrial production mode has changed the structure of resources use in urbanization. As a result, resource-environmental pressure in urban area increased steadily (Zhang, 2008).

Land is the basic resources for the survival and development of cities and towns. However, in recent years because of its scarcity and non-renewable character, it has become an important restrictive factor for the sustainable development of urbanization. Therefore, how to safeguard the demand of urban land use (ULU) has become a hotspot of research. The existing researches mainly included land use changes in urbanization and its driving forces (John and Richard, 2003; Tan *et al.*, 2005; Mao *et al.*, 2008), urban expansion character and its mechanism (Liu, 2002; Seong-Hoon *et al*., 2008), urban expansion and cultivated land protection (Dae-Sik *et al*., 2003; Wang, 2003; Tan *et al*., 2004), intensive use of urban land (Peng *et al.*, 2008; Wu, 2008), *etc*., but analysis of spatiotemporal evolution on ULU was lack. Moreover, most of the researches were only aimed at urban construction land, which is only the base of cities′ existence. Actually, the total area of ULU is far beyond that scope. Based on the extended meaning of ULU, we explored the spatiotemporal evolution of ULU in China during 1952–2005, so as to put forward scientific base to ensure the future land demand of urbanization.

2 Method and Data Sources

2.1 Meaning of urban land use

2.1.1 Transition of urban functions

As an important part of human civilization, urbanization has a history of thousands of years (Benevolo, 2000). Its

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process could be divided into two basic stages by industrialization, the ancient time and the modern time. In ancient time, due to the restrictions of resources input and productivity level, cities played as the center for settlement and material consumption, except undertaking some simple social work, such as administration, commercial trade and military defense (Gu, 1992; Mumford, 2005; Kotkin, 2006). After coming into the modern urbanization stage, because getting ride off traditional production mode, cities and towns not only inherited traditional functions, but also expanded new functions as central places of social production and environmental pollution greatly. Moreover, the expanded function had changed the dependence character of traditional cities and towns, and has pushed them into the dominant place of social and economic activities in a country or a region (Zhang, 2008).

2.1.2 Meaning of urban land use

We put forward that ULU in modern time is composited of the direct, the indirect, and the induced land uses. The direct land use refers to the land used in the growth or spatial enlargement of cities and towns themselves. The indirect land use refers to the land used in order to satisfy the basic substance consumption of cities and towns. Usually, as the central places of consumption in a country or a region, the daily consumption of cities and towns is of great quantity and of all kinds. When the products are not produced from the built-up area, the indirect land use occurs. And, the most important substance consumption of cities and towns is all kinds of agricultural products, which can not be produced by cities themselves. The induced land use refers to the land used in order to ensure the environment of cities and towns. Usually, it depends on the geographical environment and ecological condition where cities and towns located. For instance, for the sake of relieving the threat of sand storm, Beijing has strengthened capital and technique input in environment government and protection to Zhangjiakou of Hebei Province and Inner Mongolilia, which is a typical case of induced land use in the growth of urbanization.

2.2 Calculation method

2.2.1 Area of direct land use

In statistic system of cities and towns in China, the built-up area of a city or a town is more close to its physical area. Furthermore, considering modern urbanization is a system, a single city can not exist without contacting with others through various kinds of flow, such as material flow and information flow. And in space the most intuitionistic manifestation of this connection is traffic. Traffic land includes the area of transportation such as railway, highway, pipeline transportation, ports, airports and subsidiary facilities outside the built-up area of cities. Therefore, we used the sum of built-up area and the area of traffic land of cities and towns as the direct land use.

2.2.2 Area of indirect land use

Though the consumption of all kinds of agricultural products in cities and towns can be found in statistic data, the land used to produce them can not be found directly. In this paper, we chose grain, vegetables, edible oil, pork, beef, mutton, poultry and eggs, and fruits as the main consumables, then according to the consumption of all kinds of agricultural products in cities and towns and the productivity of all products in local land, figured out the area of indirect land use. The calculation equation can be expressed as follows:

$$I = \sum C_i P / Pa_i \qquad (i = 1, 2, \ldots, 8) \qquad (1)$$

where I represents the area of indirect land use (km^2); C_i means the average annual consumption of agricultural product i per citizen (kg/(person·yr)); P is the urban population; Pa_i is the productivity of product i in local land (kg/(km^2·yr)) (Zhang, 2007).

2.2.3 Area of induced land use

We used the area of forest land needed to absorb the annual emission of C from cities and towns to represent the induced land use. The calculation formula is as follows:

$$ID = C_e / \alpha \qquad (2)$$

where ID represents the area of induced land use (km^2); C_e is the annual emission of C from cities and towns (t/yr); α is the average density of C in forest land on the earth (38.67 t/ha) (Hu *et al*., 2006).

2.2.4 Total area of urban land use

The total area of ULU can be expressed as follows:

$$TLU = \sum (D, I, ID) \qquad (3)$$

where TLU represents the total area of ULU (km^2).

2.3 Data sources

The data used in the paper were mainly statistic data. In

the calculation of the direct land use, the urbanization data were from *Chinese Statistical Yearbook* (National Bureau of Statistics of China, 1981; 2006), *China City Statistical Yearbook 2005* (National Bureau of Statistics of China, 2006), *The Basic Situation of China's Towns' Statistics* (National Bureau of Statistics of China, 2004), *China Urban Construction Statistics* (Ministry of Construction, 2006), *Annual Report And Statistical Yearbook of China's Urban and Rural Construction* (Composite Account Division Ministry of Housing and Urban-Rural Development, 2007). And the area of traffic land can be acquired from national survey data of land resources and *The Annual National Survey of Land Use Change Since 2000* (Cadastral Management of Ministry of Land and Resources, 2000–2005).

In the calculation of the indirect land use, the data of the urban population, the average annual consumption of agricultural product per citizen and the productivity of each product in local land were from *China Statistical Yearbook* (National Bureau of Statistics of China, 1981; 2006).

And in the calculation of the induced land use, the data of annual emission of C from cities and towns were from the research of Zhang (2008).

3 Results and Analyses

3.1 Temporal evolution of urban land use

3.1.1 Evolution of urban land use area

According to the calculation results (Fig. 1), the total area of ULU in China showed a fluctuating uprising tendency during 1952–2005. In general, it can be divided into three stages.

Initial growth stage (1952–1980). In early modern time, because of traditional functions of cities and towns, i.e., the centre for settlement and consumption, were strong, the ULU was dominated by indirect land use. In 1952, the total area of ULU was 1 250 000 km^2, accounting for 13.0% of the total land area of China. Along with the expansion of industrial construction, modern functions of cities and towns, i.e., the centre for production and pollution, were strengthened. As a result, the total area of ULU increased to 1 474 000 km^2 in 1980, accounting for 15.4% of the total land area of the country .

Fluctuating change stage (1980–2000). Since China initiated the economic reform and opening up policy in the late 1970s, the population and economy of cities and towns increased fast, and the direct land use expanded constantly. At the same time, with the development of agricultural technology, the output benefit of agriculture was gradually improved, thus resulted in the decrease of indirect land use. And the induced land use kept on the rise because of the strengthening of production and pollution functions of cities and towns. The joint effects of the three components of ULU resulted in the fluctuating changes of it. In 2000, the total area of ULU was 1 348 000 km^2, accounting for 14.0% of the total land area of the country, dropped a little compared with that in 1980.

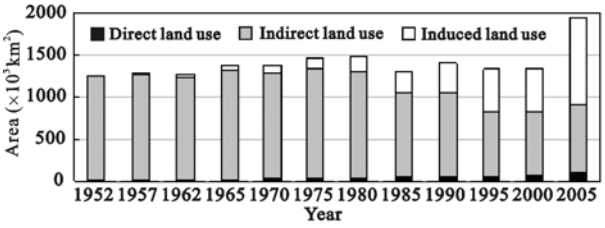


Fig. 1 Evolution of area of urban land use in China during 1952–2005

Fast development stage (2000–2005). Since 2000, the induced land use showed strong tendency of increase, which resulted in the fast growth of ULU. In 2005, the total area of ULU in China was 1 950 000 km^2, accounting for 20.3% of the total land area of the country.

3.1.2 Evolution of urban land use structure

Through calculating the percent of each component of ULU during 1952–2005, we concluded that the evolution of ULU structure could be divided into two stages.

Initial development stage (1952–1980). In this stage the indirect land use was the main part of ULU to meet with the cities′ consumption accumulation function. However, the proportion of it to the total ULU decreased from 98.0% in 1952 to 85.0% in 1980.

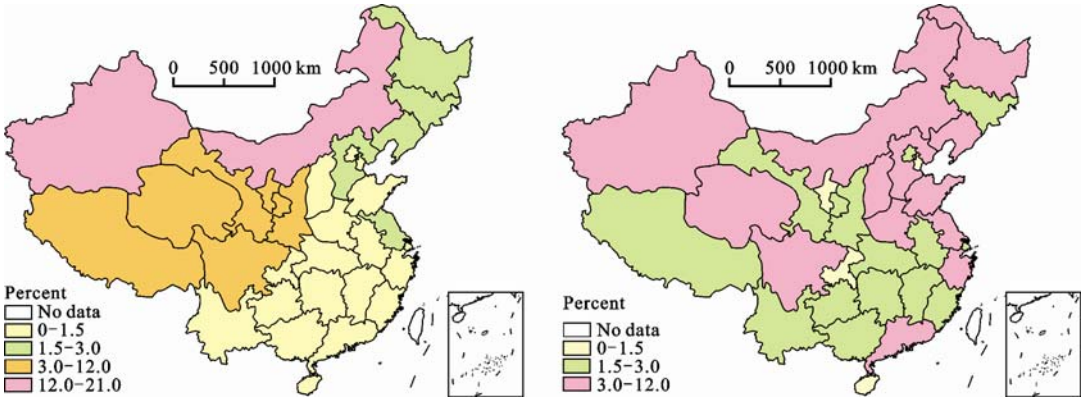
Fast development stage (1980–2005). In this stage, the induced and indirect land uses took up the main part of the total area of ULU. The percent of induced land use raised from 11.9% to 54.0%, the percent of indirect land use reduced from 86.2% to 40.9%, and the percent of direct land use increased from 2.0% to 5.2%. The portion of induced land use exceeded the indirect land use, and became the most important part of the total ULU. Thus the inversed pyramid structure of ULU, i.e. the direct<the indirect<the induced, had formed.

3.2 Spatial evolution of urban land use

3.2.1 Evolution of urban land use area

We calculated the total area of ULU of 31 provinces (regions or municipality) (the induced land use of Tibetan Autonomous region was ignored, and the area of ULU in Hong Kong, Taiwan and Macao were not calculated for lack of data) in 1952 and 2005, and then calculated the percent of ULU area in each province to China′s total ULU area in 1952 and 2005 to show the spatial evolution of ULU (Fig. 2).

The differences between the eastern and the western regions in 1952 and 2005 were obvious (Fig. 2). In 1952, the ULU centralized in the western region, including Xinjiang, Inner Mongolia, Gansu, Shaanxi, Ningxia, Sichuan, Tibet and Qinghai, which amounted to 76% of the China′s total. On the contrary, the provinces in the eastern and middle regions had a smaller area of ULU.



(a) 1952 (b) 2005

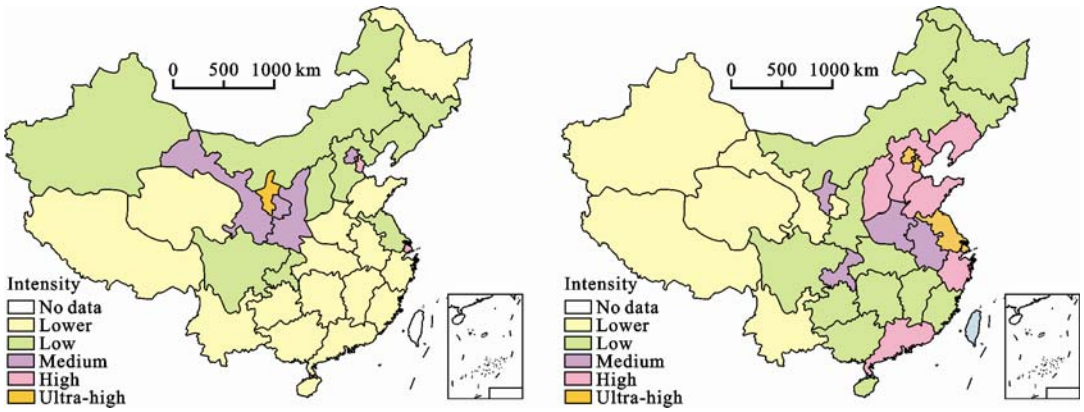
Fig. 2 Percent of urban land use area of each province to China′s total in 1952 and 2005

In 2005, with rapid urbanization, the percent of ULU in the western region including Inner Mongolia, Xinjiang, Gansu, Ningxia, Shaanxi and Tibet reduced, while the percent of ULU in the eastern and middle regions increased. Spatial distribution of ULU showed the character of equilibrium, while the difference between the north and the south is relatively more significant.

In a word, the spatial distribution of ULU in China changed from concentrated one in the northwestern region to balanced one, the center of gravity moved eastwards, and spatial differences changed from east-west difference to north-south difference during 1952–2005.

3.2.2 Evolution of urban land use intensity

We used the percent of the total area of ULU to total land area of each province to represent the ULU intensity. The intensity was divided into ultra-high intensity, high intensity, medium intensity, low intensity and lower intensity corresponding to the percents of >100%, 50%–100%, 30%–50%, 10%–30% and <10%. And the ULU intensity maps of 1952 and 2005 were formed (Fig. 3).



(a) 1952 (b) 2005

Fig. 3 Urban land use intensity of each province in 1952 and 2005

In 1952, the ULU intensity in the north was obviously higher than that in the south. Provinces with ultra-high intensity included Shanghai and Ningxia, which can be ascribed to the small area of itself; provinces with high intensity included Tianjin only; provinces with medium intensity included Beijing, Shaanxi and Gansu; provinces with low intensity included Jiangsu, Liaoning, Inner Mongolia, Xinjiang, Sichuan, Hebei, Jilin and Shanxi; and all the other provinces belonged to lower intensity.

In 2005, the ULU of Shanghai, Tianjin, Beijing and Jiangsu belonged to ultra-high intensity. Among them Shanghai even reached 760%, which meant that its urbanization could not only depend on the local land. Guangdong, Hebei, Shanxi, Zhejiang, Liaoning and Shandong belonged to high intensity, and this could be attributed to their higher urbanization level since a long time ago especially after the reform and opening up and the smaller areas of themselves. Among them, the ULU intensity of Shandong and Liaoning was higher than 80%, which meant that the potential of urban land exploitation in these areas were weak. Henan, Anhui, Chongqing and Ningxia were of medium intensity, just the same as their urbanization level. Most provinces in the central China belonged to low intensity, and provinces in the west including Tibet, Xinjiang, Yunnan, Qinghai and Gansu belonged to lower intensity. This could be attributed to the weakness of their resources and environment basis, the inland location, the slow growth of urbanization and relatively larger area of themselves. As a result, they had a strong potential of land exploitation for urbanization.

In general, the ULU intensity in the eastern coastal provinces obviously enhanced, while the western provinces dropped during 1952–2005. And it had changed from the north higher than the south to the east higher than the west, and the eastern coastal area is under great pressure now.

3.2.3 Evolution of urban land use structure

According to the percent of the area of each component of ULU to total urban land area in each province, the ULU structure was classified into three types, i.e., the indirect dominant type with only the percent of indirect land use exceeding 40%, the induced dominant type with only the percent of induced land use exceeding 40%, and the relatively equilibrium type with both the percents of indirect and induced land uses exceeding 40%.

According to foregoing analysis, the urbanization progress of China could be divided into two stages by the year of 1980, so that we chose the ULU structure data of 1952, 1980 and 2005 to show the temporal changing character of ULU structure (Table 1).

In 1952, all the provinces belonged to the indirect dominant type with the percent of indirect land use more than 90%. After 30 years of large-scale industrial development, the initial differentiation of ULU structure of the provinces appeared. Beijing, Shanghai, Tianjin and Liaoning became to the relatively equilibrium type in 1980. After the reform and opening up in the 1970s, with the fast development of economy and increase of energy consumption, the induced land use increased significantly. As a result, the evolution of ULU structure of the provinces quickened, and the growth of type of ULU structure matured. As can be seen from Fig. 4, in 2005, the induced dominant type came into being, and mainly centralized in the northeast and northern China, including 13 provinces. Another 13 provinces distributed in the southeast belonged to the relatively equilibrium type, and the other 5 provinces, i.e. Inner Mongolia, Xinjiang, Qinghai, Tibet and Sichuan remained at indirect dominant type.

In a word, the ULU structure of the provinces gradually developed from indirect dominant to induced dominant, and it evolved from the northeast to the southeast then to the middle and the west.

4 Conclusions

Modern cities and towns become central places of human activities not only for settlement and consumption but also for production and pollution. Along with functions extended, the ULU become more complicated. And in modern time, the ULU can be divided into three parts, i.e., the direct, the indirect and the induced land uses.

First, with cities and towns′ status in a country or a region′s wealth accumulating rising constantly, the ULU is on the rise. The total area of ULU in China in 2005 was up to 1 950 000 km^2, corresponding to 20.3% of the total area of the country.

Second, the ULU of a country or a region embodies not only at the increase of the total area, but also at the structure change, especially in the fast development stage

Table 1 Urban land use structure of each province in China from 1952 to 2005 (%)

Province	1952			1980			2005		
	Direct	Indirect	Induced	Direct	Indirect	Induced	Direct	Indirect	Induced
Beijing	2.84	92.46	4.69	1.77	47.21	51.03	5.89	35.92	58.19
Tianjin	1.92	93.93	4.15	2.28	57.27	40.45	3.91	26.08	70.00
Hebei	3.74	95.61	0.65	5.32	83.51	11.17	4.20	21.59	74.21
Shanxi	2.66	96.12	1.22	3.42	79.61	16.97	2.45	21.54	76.01
Inner Mongolia	0.50	99.49	0.01	0.97	97.33	1.70	3.02	61.05	35.93
Shandong	5.32	93.98	0.70	4.35	60.50	35.14	5.62	17.79	76.59
Liaoning	2.75	90.11	7.14	2.36	53.77	43.87	3.32	23.00	73.68
Jilin	2.22	95.03	2.75	2.37	73.81	23.81	5.70	26.93	67.38
Heilongjiang	2.88	94.37	2.75	2.63	70.94	26.43	5.71	38.45	55.85
Shanghai	0.94	91.00	8.06	1.42	50.67	47.91	3.53	20.15	76.32
Jiangsu	2.82	96.91	0.27	5.23	63.15	31.62	5.89	24.33	69.78
Zhejiang	4.61	94.97	0.42	4.99	71.55	23.46	6.39	26.79	66.82
Anhui	4.43	94.74	0.83	7.29	75.49	17.22	9.24	46.01	44.75
Fujian	5.19	94.06	0.75	7.28	66.17	26.55	7.25	50.44	42.32
Jiangxi	7.31	92.66	0.03	7.83	85.97	6.20	9.45	41.73	48.82
Henan	5.99	93.51	0.50	6.29	76.58	17.13	7.27	29.88	62.85
Hubei	3.50	95.90	0.60	5.16	43.79	20.05	8.45	33.43	58.12
Hunan	3.39	96.34	0.27	5.01	78.32	16.67	8.35	40.40	51.25
Guangdong	5.81	93.38	0.80	5.65	55.59	38.75	7.68	41.96	50.36
Guangxi	5.11	94.86	0.03	7.64	80.67	11.68	8.77	60.81	30.42
Hainan	–	–	–	–	–	–	9.53	60.35	30.12
Chongqing	–	–	–	–	–	–	5.94	48.36	45.70
Sichuan	1.02	98.66	0.32	1.95	87.96	10.09	6.62	62.18	31.20
Guizhou	1.71	98.14	0.15	3.03	92.30	4.67	6.47	41.61	51.92
Yunnan	2.11	97.77	0.11	3.64	89.43	6.93	7.57	49.55	42.88
Tibet	0.17	99.83	–	0.42	99.58	–	3.08	96.92	–
Shaanxi	0.43	99.49	0.08	0.91	95.69	3.40	3.98	45.83	50.19
Gansu	0.24	99.33	0.43	0.49	96.45	3.06	3.38	55.90	40.72
Qinghai	0.32	99.66	0.01	0.55	97.89	1.56	1.11	92.64	6.25
Ningxia	0.09	99.91	0	0.26	98.61	1.14	3.72	42.14	54.14
Xinjiang	0.15	99.75	0.10	0.27	98.21	1.51	2.13	68.07	29.81

Note: – presents no datum

Fig. 4 Type of urban land use structure of each province in China in 2005

of urbanization, the induced ULU exceeds the indirect ULU and becomes a most important part of the total ULU. The inversed pyramid structure, i.e., the direct<the indirect<the induced of ULU in China now has formed. The pressure and challenge of ULU in China now is more manifest at the direct land use because Chinese urbanization is at the fast development stage. However, as the process of urbanization matured, it will be more transferred to the induced. Therefore, only the induced land use is ensured, can urbanization develop healthily and sustainably.

Third, as ULU centralized to the induced land use, the spatial distribution of the total ULU of China was becoming equilibrium, the center of gravity of ULU

moved eastwards, and the eastern coastal area is under great pressure. What′s more, in the aspect of ULU structure, the northeast of China has come to the type of induced dominant, the west region remains in indirect dominant type, and the southeast belongs to the relatively equilibrium type. Therefore, we should ensure ULU in the eastern region first, especially the induced land use.

References

Benevolo L, 2000. *A History of World Cities*. Beijing: Science Press. (in Chinese)

Cadastral Management of Ministry of Land and Resources, 2001–2005. *Annual National Survey of Land Use Change*. Beijing: Chinese Earth Press. (in Chinese)

Composite Account Division Ministry of Housing and Urban-rural Development, 2007. *Annual Report and Statistical Yearbook of China's Urban and Rural Construction*. Beijing: China Building Industry Press. (in Chinese)

Dae-Sik Kim, Kei Mizuno, Shintaro Kobayashi, 2003. Analysis of urbanization characteristics causing farmland loss in a rapid growth area using GIS and RS. *Paddy and Water Environment*, 1: 189–199.

Gu Chaolin, 1992. *Urban System in China-History, Present and Prospect Situation*. Beijing: The Commercial Press. (in Chinese)

Hu Huifeng, Wang Zhiheng, Liu Guohua, 2006. Vegetation carbon storage of major shrub lands in China. *Jouranl of Plant Ecology*, 30(4): 539–544. (in Chinese)

Jiang Jianjun, Zhou Jie, Wu Hongan *et al*., 2005. Land cover changes in the rural-urban interaction of Xi′an region using langsat Tm/ETM data. *Journal of Geographical Sciences*, 15(4): 423–430. DOI: 10.1007/BF02892149

John E Hasse, Richard G Lathrop, 2003. Land resource impact indicators of urban sprawl. *Applied Geography*, 23: 159–175.

Kotkin Joel, 2006. *The City*: *A Global History.* Beijing: Society Science Document Publishing House. (in Chinese)

Liu Shenghe, 2002. Spatial patterns and dynamic mechanisms of urban land use growth. *Progress in Geography*, 21(1): 43–50. (in Chinese)

Mao Jiangxing, Li Zhigang, Yan Xiaopei *et al*., 2008. Human dimensions of land use change in the context of rapid urbanization in Shenzhen. *Resources Science*, 30(6): 939–948. (in Chinese)

Ministry of Construction, 2006. *China Urban Construction Statistics*. Beijing: China Building Industry Press. (in Chinese)

Mumford Lewis, 2005. *The City in History.* Beijing: China Architecture & Building Press. (in Chinese)

National Bureau of Satistics of China, 2004. *Basic Stuation of China's Towns' Satistics*. Beijing: China Statistics Press. (in Chinese)

National Bureau of Satistics of China, 2006. *China City Statistical Yearbook 2005*. Beijing: China Statistics Press. (in Chinese)

National Bureau of Statistics of China, 1981, 2006. *Chinese Statistical Yearbook*. Beijing: China Statistics Press. (in Chinese)

Peng Jianchao, Xu Chunpeng, Wu Qun *et al*., 2008. Regional disparities of urban land intensive utilization degree in the Yangtze delta. *China Population, Resources and Environment*, 18(2): 103–109. (in Chinese)

Seong-Hoon Cho, Neelam Poudyal, Dayton M Lambert, 2008. Estimating spatially varying effects of urban growth boundaries on land development and land value. *Land Use Policy*, 25: 320–329.

Tan Minghong, Li Xiubin, Lu Changhe, 2004. Expansion of construction land of big cities in China since 1990 and its occupancy of cultivated land. *Science in China* (*Ser. D*), 34(12): 1157–1165. (in Chinese)

Tan Minghong, Li Xiubin, Xie Hui *et al*., 2005. Urban land expansion and arable land loss in China—A case study of Beijing-Tianjin-Hebei region. *Land Use Policy*, 22: 187–196.

Wang Qun, 2003. Sustainable land use of urbanization. *China Land Science*, 17(2): 47–51. (in Chinese)

Wu Li, 2008. The evaluation on the efficiency of urban land intensive utilization in Zhejiang Province. *Guangdong Land Science*, 7(1): 10–13. (in Chinese)

Zhang Lei, 2007. *The Energy Eco-system: A Strategic Study on Energy Resource Exploitation in West China.* Beijing: Science Press. (in Chinese)

Zhang Lei, 2008. Reconsider development of modern urbanization. *China Population, Resources and Environment*, 18(1): 26–33. (in Chinese)

Zhang Lei, Zhang Shumin, 2008. Land resources and urbanization. *Resources Science*, 30(4): 578–584. (in Chinese)

Zhou Yixing, 1995. *Urban Geography*. Beijing: The Commercial Press. (in Chinese)