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Assessing construction land potential and its spatial pattern in China

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ABSTRACT

The assessment of construction land potential is a key foundation in the processes of future urbanization, development, and industrialization. Given its background of land resources scarcity, there is a critical need to precisely evaluate land resources in China, especially its construction land potential. This paper determines the thresholds of factors based on references in different fields, defines the arithmetic formulae according to the logical relations of the factors, extracts data from the maps, and calculates the results. This assessment uses GIS spatial analysis techniques, Digital Elevation Models (DEMs), TM remote sensing land use map, administrative maps at the county level, and land use investigation data to derive the spatial pattern of construction land potential of China for 2008. The results show that: (1) construction land potential in China amounts to 283,400 km^2, which accounts for 2.99% of total land area and 0.021 ha/person; and (2) the spatial distribution of supply and demand of construction land potential currently is unbalanced, with areas such as Central China, East China, and metropolitan regions having low potential but high demand, while areas such as the northern part of China having high potential but low demand. It is suggested here that construction land potential could be seen as a key integrative indicator of the land carrying capacity of various regions for future population aggregation, industrialization and urbanization development. The assessment of construction land potential would be significant to diagnosing land resources and making sound development strategies in order to achieve regional sustainable development.

1. Introduction

In the past 30 years, China has experienced tremendous levels of rapid and sustained economic growth and large-scale urbanization. Urbanization now is taking place at an unprecedented rate in China, with rapid economic development and population growth (Liu, Wang, & Long, 2008). The most remarkable growth occurred in coastal areas of East China, especially in those large cities whose urban centers are surrounded by secondary cities and rural townships (Deng & Huang, 2004). As a result of rapid urbanization, China now is experiencing a dramatic loss of arable land (Ding et al., 2007; Gao, Liu, & Chen, 2006; Xu, Wang, & Xiao, 2000), in a country with a vast population and scarce land per capita (Yang & Li, 2000). The national conditions of scarce land area per capita and acute human-land conflict have been exacerbated by the natural environment of vast plateaus, mountains and arid regions and relatively scarce plains, basins and river valleys and the huge population base in China. As such, China's future land use and development must be efficient and intensely managed (Fan & Li, 2009; Li & Guo, 2007). Given these shortages of land resources and rigid farmland conservation policies, it is critical to effectively measure the potential of land resources of its various regions, especially construction land potential and its spatial pattern, as a fundamental principle in the sustainable development of China.

The effects of land use change in rapidly urbanizing areas are well known (Quan, Zhu, & Romkens, 2007; Wu, Su, & Zhang, 2006; Xu, 2001). Urban expansion and spatial restructuring of land use patterns in the Pearl River Delta of South China have been analyzed (Li & Yeh, 2004), and the factors responsible for causing land use changes also have been identified (MacLeod & Moller, 2006; Rasul, Thapa, & Zoebisch, 2004; Tzanopoulos & Vogiatzakis, 2011). GIS-based analysis system, biophysical and system approaches have also been developed for land use management and its simulation (Lee, Huang, & Chan, 2008; Liu et al., 2007). Yeh and Li (1998) developed a sustainable land development model to ensure equity between productivity and efficiency in land use. Liu, Wang, and Long (2010) explored the impact of land use change on the ecoenvironment and sustainable rural development in southern Jiangsu

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Province by elucidating the trend of arable land loss and its spatial pattern.

Previous work on land use change in China, however, has failed to address land use potential and its role in sustainable development. These previous studies limited their focus on the land use changes, even though they have assessed the impact of these changes on the environment. Further, most studies concentrated on land use change in general, or on a specific land use type such as arable land. Few studies have examined the issue of construction land potential and its spatial pattern at a relatively large scale from the perspective of regional sustainable development in China (Fan & Li, 2009).

These tremendous achievements of rapid and sustained economic growth and large-scale urbanization in China have not occurred without detrimental costs to resources and the environment. Most regions with rapid economic growth, especially metropolitan regions, have chaotic industrial layouts and disordered urban spaces (Zhang & Li, 2007). There are additional problems such as inefficiency of land use caused by irrational structure of urban construction, a sharp decline of arable land area caused by large-scale urbanization, and serious environmental pollution caused by dispersive industrial parks distribution (Zhang & Feng, 2007). In 15–20 years, China's economic and urban development will maintain a rapid and sustained growth as before, and the aggregate economic volume will be about 14,000–19,000 billion USD, and the total urban population will reach to 800–900 million (The State Council, 2010). It is important for the Chinese government to formulate a scientific strategy for future development that can effectively address a very large and growing economy and expanding urban population.

The overall aim of this paper is to quantify a measure of the construction land potential of all counties in China and its spatial pattern from a perspective of regional sustainable development, which could be used to address future population agglomeration, industrial organization, and urban development. The specific aims are: (1) to define construction land potential and develop a metric for its quantification; (2) to apply this metric to all counties in China using assembled for 2008; and (3) to discuss the implementation of this metric and its potential use in future expansion of urbanization and industrialization to achieve sustainable development at the regional scale.

2. Research method

2.1. Definition of construction land potential

In the view of the land use classification, the construction land use includes six subclasses which are land for urban construction, independent industrial and mining land, transportation land, rural residential area, land for water facilities, and specially designated land. Construction land potential is defined as the available land area that can be used for future population agglomeration, industrial organization and urban development. The definition of construction land potential consists of quality, quantity, and spatial distribution. The aim of measuring and evaluating construction land potential is to reflect the bearing capacity of land resources for future population agglomeration, industrial, and urban development in different regions. Generally speaking, an area that has high-quality, high-quantity, and continuously distributed construction land potential is suited for population agglomeration, industrial organization and urban development.

2.2. Key factors and parameters

When defining the method to calculate construction land potential, multiple factors are considered and include geological, topographic and geomorphologic conditions, water area distribution, protection zones distribution, and current land use, especially existing construction land and basic farmland. Each of these factors, and the criterion developed, is described below.

(1) *Geological conditions*: The geological conditions related to construction land include the potential for earthquakes and engineering geology. In general, construction near a geologic fault or fault zone should be avoided, and the fault usually is contiguous to underground water, which could also cause fatal damage to surface buildings (Chen, Du, Zheng, & Lin, 2006). Therefore, there should be a minimum of 300–500 m between new constructions sites and known faults.

(2) *Topographic and geomorphic conditions*: Topographic and geomorphic conditions mainly include elevation, topographic gradient and geomorphic environment. In general, regions with low elevation are more suitable for human occupation than those at high elevation, and the suitability of human residences decreases as elevation increases. There are three obvious hierarchies in China's elevation. From high to low, the first is Qinghai–Tibet Plateau, the second is Neimenggu Plateau, Loess Plateau, Yunnan–Guizhou Plateau, and the arid areas in Northwest China, and the third is the hilly and plain areas in East China (The Committee of Agricultural Regionalization in China, 1981; The editorial board of China's Physical Geography in Chinese Academy of Sciences, 1980, 1982). Based on the geographical meaning of these three hierarchies, we divide the elevation into five classes: above 3000 m, mainly consists of the first hierarchy, and is suitable for animal husbandry, 3000–2000 m, is suitable for crop cultivation, and is the transition area between the first and the second hierarchy, 2000–1000 m, mainly consists of the second hierarchy, 1000–500 m, is used for indentifying the basins and river valleys in the second hierarchy, below 500 m, mainly consists of the plains and low hilly areas of the third hierarchy. Areal percentages of land surfaces at different elevations in China are as follows: above 3000 m 25.9%, 3000–2000 m 7.04%, 2000–1000 m 24.99%, 1000–500 m 16.93%, below 500 m 25.18% (Fig. 1). Topographic gradient also can limit land development. The cost of engineering construction increases as the topographic gradient increases, and steep terrain is apt to cause landslides, mud-rock flows, and other geological phenomena (Xu, Tian, Liu, & Xu, 2005; Yang, 1999). The division of topographic gradient is mainly from regional planning and architecture. Topographic gradient can be classified into five divisions: below 3° (flat), has no soil erosion and is suitable for urban construction, 3–8° (slight slope), is relatively suitable for urban construction, but needs hybrid vertical design based on platforms and flatlands, 8–15° (moderate slope), has moderate but not serious soil erosion, 15–25° (abrupt slope), has relative serious soil erosion, and is difficult to be used for urban construction, above 25° (steep slope), cannot be used for concentrated urban construction land, neither for transportation land and manufacturing plants (Chen et al., 2006; Fan, 2009, 2010). The region with a slope below 8° can be designated as suitable for construction, 8–15° is designated as less suitable, and above 15° is designated as unsuitable. Geomorphic environments include plateau, mountain, hill, plain, basin, etc. In general, it is more difficult and expensive to build on mountainous regions than on flatlands. Moreover, building constructions on mountainous regions produces serious side effect to local ecological environment (Fan, 2009).

(3) *Areas near water*: Water areas include rivers, lakes and reservoirs. Because river banks are vulnerable to flooding, construction land should not be located within 70–100 m from the river bank. As lakes can become polluted by sanitary sewage

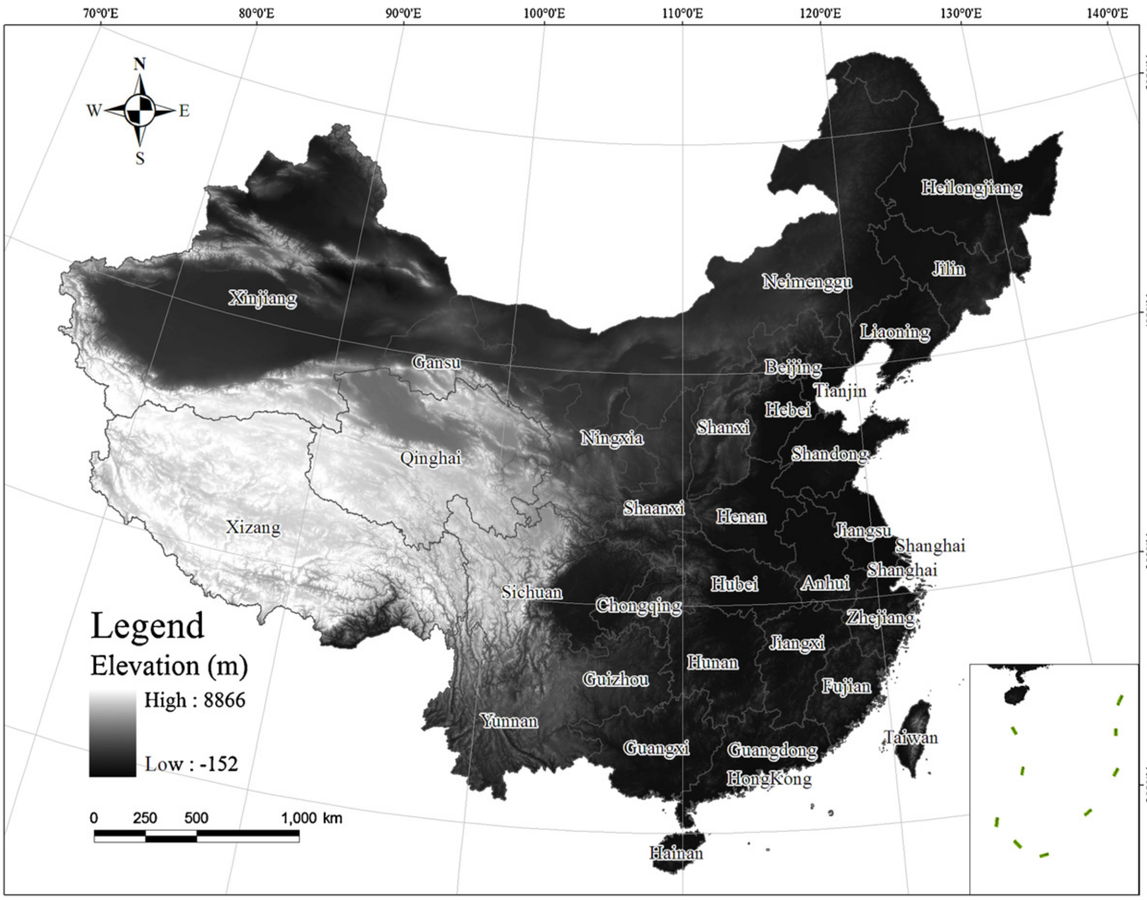

Fig. 1. Digital Elevation Model of China.

and industrial waste, industrial parks and towns should not be located in the catchment areas of the upper lake (Zhou & Li, 2004). Reservoirs provide for field irrigation, domestic water and process water supply. As such, industrial and urban construction land should not be located in the catchment areas of the upper reservoir, and construction land should not be located within 1.5 km of the reservoir or lake boundary (Fan, 2010).

(4) *Protection zones*: Protection zones include natural parks, scenic zones, forest parks, and geological parks, among others (Chen et al., 2006). Each protection zone has explicit boundaries, so construction land should be kept 1 km away from these zones (Fan, 2010).

(5) *Current land use*: Current land use has an important affect on the quality, quantity and spatial distribution of the construction land potential. Among the current land use types, cultivated land is strictly controlled by the Chinese government, and the conversion from cultivated land to construction land should comply with the policy of "cultivated land requisition–compensation balance." Land policy for forestland and grassland tends to be more flexible, and can be converted to construction land provided the strict process of policy permits is addressed. Most existing construction land types have the potential of increasing effective supply of construction land. The rural settlement land has the biggest potential, which is also the main source of land use intensification in the future.

2.3. Arithmetical formulae

With the key parameters identified, a metric for land construction potential now can be formulated. As this is the first attempt at creating and applying such an index, it is yet unknown how these parameters should be combined, or whether weighting factors should be used. The approach adopted for this study is that all parameters are additive and of equal weight. Based on this, the arithmetic formulae of construction land potential are defined as follow:

$$A_c = A_s - A_e - A_b \quad (1)$$

$$A_s = A_{ge} - A_{wa} - A_{fg} - A_{de} \quad (2)$$

$$A_e = A_{uc} + A_{rs} + A_{im} + A_{tr} + A_{sd} + A_{wf} \quad (3)$$

$$A_b = A_{fs} \times \beta \quad (4)$$

$$A_{cp} = \frac{A_c}{P} \quad (5)$$

where A_c is the construction land potential area, A_s is the suitable construction land area, A_e is the existing construction land area, A_b is the basic farmland area, A_{ge} is the total land area of the regions with groups of specific topographic gradients and elevations, A_{wa} is the area of rivers, lakes and reservoirs, A_{fg} is the area of forestlands and grasslands, A_{de} is the area of deserts, A_{uc} is the area of urban construction land, A_{rs} is the area of rural settlement land, A_{im} is the area of independent industrial and mining land, A_{tr} is the area of transportation land, A_{sd} is the area of specially designated land, A_{wf} is the area of water facilities land, A_{fs} is the area of farmland in the suitable construction region, β ranges from 0.8 to 1, A_{cp} is the construction land potential per capita, and P is the permanent resident population of the region.

In the arithmetical formulae, A_{ge} is the total land area (including all land subclasses) of the regions with groups of specific topographic gradients and elevations. Based on the classification of slope and elevation in Section 2.2, we determine A_{ge} for this study

Table 1
Key factors, parameters, and statement of calculation of construction land potential.

Factors		Parameters and thresholds	Statement of calculation
Geology	Fault	500 m away from the fault	Obtain geologic map for graphic overlay
Topography	Elevation	>3000 m, 3000–2000 m, 2000–1000 m, 1000–500 m, <500 m	Obtain topographic elevation map for graphic overlay
	Slope	<3°, 3–8°, 8–15°, 15–25°, >25°	Obtain topographic gradient map for graphic overlay
Areas near water	River	500 m away from the river bank	Obtain areas from the land use investigation data of
	Lake and reservoir	1.5 km away from the lake and reservoir boundary	Ministry of Land and Resources
Protection zones		1 km away from protection zone boundary	Obtain the actual area from each protection zone
Current land use		Obtain areas of existing land use types	For graphic overlay and data obtainment

using the following rules. Firstly, setting elevation as below 2000 m and slope as below 15°, all geographic units (no matter which land subclasses they are) that meet all the binary criteria and the thresholds of other selected factors in Table 1 are extracted as the first part of A_{ge}. Secondly, setting elevation as between 2000 and 3000 m and slope as below 8°, all geographic units that meet the same requirements of other factors are extracted as the second part of A_{ge}. Thirdly, setting elevation as above 3000 m and slope as below 3°, all geographic units that meet the same requirements are extracted as the third part of A_{ge}. Finally, the values of these three parts are summed up to a value of A_{ge}. All land subclasses including A_{wa}, A_{fg}, A_{de}, A_{uc}, A_{rs}, A_{im}, A_{tr}, A_{sd}, A_{wf}, and A_{fs} are included in A_{ge}.

2.4. Data sources

The TM remote sensing land use map of 2000 is from Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences. Since 1990s, under the support of Chinese Academy of Sciences, Ministry of Land and Resources of China, National Bureau of Statistics of China, and National Natural Science Foundation of China, the Institute of Geographic Sciences and Natural Resources Research, Data Center for Resources and Environmental Sciences, and Institute of Remote Sensing Applications of Chinese Academy of Sciences have been carrying out the remote sensing images interpretation work for over 20 years. Based on a classification system of six land use types including farmland, forestland, grassland, water area, construction land, and unused land, the TM remote sensing images in the same season of 2000 was interpreted and then combined to a land use map for scientific research by Data Center for Resources and Environmental Sciences. The research data for this study is then supplemented by the land use investigation data of Ministry of Land and Resources of China in 2000–2008.

2.5. Calculation process

(1) *Maps preparation*: Maps needed for the calculation of construction land potential include digital topographic maps, land use maps, administrative maps at county level, geologic maps, and protection zones maps. Map scale is determined by the size of study area, 1:250,000 at province level and 1:50,000 at county level. Digital raster graphics are obtained from the Digital Elevation Model (DEM). From the digital raster graphics, elevation grading maps are extracted by five classes (3000 m, 3000–2000 m, 2000–1000 m, 1000–500 m, below 500 m), and slope grading maps are extracted by five classes (below 3°, 3–8°, 8–15°, 15–25°, above 25°). Both maps are converted to vector format using ArcGIS spatial analysis techniques. Based on the rivers, lakes and reservoirs location in the land use maps, classification maps of these water areas are extracted according to the distance of 500 m from river bank and 2000 m from lakes and reservoirs boundary. Fault lines are identified from the geologic maps and regions are determined according to the distance of 500 m from these faults. Taking the merged map of various protection zones as a base map, classification maps are extracted according to the distance of 1000 m from the protection zones boundary.

(2) *Maps matching and intersection*: Taking digital topographic maps or land use maps as reference maps, the projections of other maps are transferred. After trimming, all maps are combined into a composite map, which was used for data extraction and spatial analysis.

(3) *Data extraction and spatial analysis*: Based on the composite map, data of each parameter is extracted, and then the construction land potential of each county is calculated according to the formulae given above. The composite map is also the data source of drawing spatial pattern map and carrying out spatial analysis.

3. Results

3.1. Results at province level

Using DEMs and TM remote sensing land use map of 2000, data of three domains are extracted: (1) elevation below 2000 m and slope below 15°; (2) elevation between 2000 and 3000 m and slope below 8°; and (3) elevation above 3000 m and slope below 3°. By setting β (the percentage of basic farmland area in total farmland area) as 0.85, the areas of land use types of each county are extracted and calculated. The extracted data are revised by the land use change characteristics analysis, which is conducted from the land use investigation data of Ministry of Land and Resources of China in 2000–2008. Finally, the construction land potential and construction land potential per capita of each county can be determined. The total area of construction land potential of China amounts to 28,340,000 km^2, which accounts for 2.99% of total land area. The areas of existing construction land and construction land potential of all provinces in China in 2008 are shown as Table 2.

3.2. Quantity and spatial pattern of existing construction land

The existing construction land intensity (the percentage of existing construction land in total land area) of China is 3.45%, which is calculated from the land use investigation data of Ministry of Land and Resources of China in 2008. The values for counties can vary significantly, ranging from 0.0031% to 100%. The main characteristics of spatial pattern of existing construction land intensity are shown in Fig. 2. The values of the east regions are higher than those of the west, the values of the flatlands are higher than those of mountainous regions, and the values of populated areas and developed regions are higher than those sparsely populated and underdeveloped. According to the values classification of existing construction land intensity of counties, only 8.66% have a value over 20% (designated as having the Highest Potential; Table 3), and the total land area of these counties accounts for just 1.72% of China's total land area. The number of county numbers in the regions with the High (10–20%), Middle (5–10%), and Low (2–5%) include 617, 452, and 624 counties, have total land area account for 9.77%, 10.07%, 20.56%, respectively. The region with the lowest land construction

Table 2
Data of construction land potential of all provinces in China in 2008.

Province	Existing construction land			Construction land potential		
	Area (km^2)	Percentage in total land area (%)	Area per capita (ha)	Area (km^2)	Percentage in total land area (%)	Area per capita (ha)
Beijing	3325.57	20.26	0.020	417.79	2.55	0.003
Tianjin	3602.91	31.20	0.025	963.29	8.34	0.007
Hebei	17,569.35	9.37	0.025	12,206.86	6.51	0.017
Shanxi	8652.70	5.52	0.026	8030.69	5.12	0.024
Neimenggu	14,776.51	1.29	0.062	14,320.92	1.25	0.060
Liaoning	13,913.32	9.57	0.032	9922.87	6.82	0.023
Jilin	10,602.01	5.55	0.039	22,304.84	11.69	0.082
Heilongjiang	14,746.93	3.26	0.039	54,272.79	12.00	0.145
Shanghai	2429.08	38.73	0.013	510.35	8.14	0.003
Jiangsu	19,023.57	18.84	0.023	8333.67	8.25	0.010
Zhejiang	10,130.91	9.94	0.021	3698.62	3.63	0.008
Anhui	16,523.51	11.78	0.025	10,010.59	7.14	0.015
Fujian	6311.69	5.19	0.018	3353.23	2.76	0.010
Jiangxi	9400.36	5.62	0.021	6876.88	4.11	0.015
Shandong	24,887.66	16.14	0.026	14,426.19	9.36	0.015
Henan	21,711.00	13.11	0.021	13,613.86	8.22	0.013
Hubei	13,861.53	7.45	0.024	9594.56	5.16	0.016
Hunan	13,736.37	6.47	0.020	9171.89	4.32	0.013
Guangdong	17,768.93	10.02	0.018	5887.78	3.32	0.006
Guangxi	9440.31	4.00	0.019	7018.61	2.97	0.014
Hainan	2958.61	5.88	0.032	1356.11	2.70	0.015
Chongqing	5857.73	7.10	0.018	5017.35	6.08	0.015
Sichuan	15,876.24	3.27	0.017	15,871.54	3.27	0.017
Guizhou	5518.47	3.13	0.014	6964.25	3.95	0.017
Yunnan	7988.32	2.08	0.018	9601.87	2.50	0.022
Tibet	656.59	0.05	0.020	577.88	0.05	0.018
Shaanxi	8092.59	3.93	0.021	8733.58	4.24	0.023
Gansu	9723.84	2.28	0.037	9085.60	2.13	0.035
Qinghai	3162.49	0.46	0.059	902.45	0.13	0.017
Ningxia	2085.89	4.02	0.035	2084.51	4.01	0.035
Xinjiang	12,342.98	0.76	0.061	8237.36	0.51	0.041
China	*326,677.99*	*3.45*	*0.024*	*283,368.77*	*2.99*	*0.021*

Note: Data of Taiwan, Hong Kong and Macao are not included in the table.

potential (<2%) include 470 counties, has 19.85% of all counties in China, and has total land area for 57.89% of China's total land area.

The spatial pattern of existing construction land intensity reveals four main characteristics. First, the value subsides from the East China coastal areas through the Central China to the China's Western Region, which is identical to the spatial differentiation of economic development of the three zones. Second, the high value areas are concentrated in developed regions such as Yangtze River delta, Pearl River delta, Bohai Rim region and Shandong Peninsula. Third, border areas of Northeast China, Inner Mongolia and Southeast China and the whole China's Western Region are the primary areas with low existing construction land intensity. Fourth, the values of flatlands are apparently higher than that of mountainous regions. North China Plain, Plain of the middle and lower reaches of Yangtze River, Songnen Plain, Chengdu Plain and Pearl River Delta have the highest values of existing construction land intensity.

The spatial pattern of China's existing construction land intensity has been formed by China's physical geography and long-term regional development policies. The characteristics of China's physical geography determine that East China (especially the flatlands and coastal areas) is the most suitable region for human residences. Industrial and urban development caused by population agglomeration then becomes the primary factor for the high existing construction land intensity. The long-term regional development policies focused on the economic development of East China coastal areas and along Yangtze River areas also contribute to the spatial pattern of existing construction land intensity. Lastly, the clusters of regional economics lead to the concentrating distribution of existing construction land intensity. The high value areas are concentrated remarkably in the developed regions such as Yangtze River delta, Pearl River delta, Bohai Rim region and Shandong Peninsula, while the undeveloped regions have low values such as border areas of Northeast China, Inner Mongolia and Southeast China and the whole China's Western Region.

3.3. Quantity and spatial pattern of construction land potential

Construction land potential reflects the quantity of available land that can be used for construction in the future. According to the average construction land potential value of all counties and the variation trend from one to another, five patterns are divided by above 320 km^2, 320–150 km^2, 150–100 km^2, 100–50 km^2, below 50 km^2, which are named as Most Abundant, Abundant, Middle, Scarce, and Most Scarce Pattern (Fig. 3 and Table 4). The main

Table 3
Data of existing construction land intensity of different patterns in China in 2008.

Pattern	Value range (%)	County numbers	Percentage in all counties (%)	Total area (km^2)	Percentage in China's total area (%)	Average value (%)
Highest	>20	205	8.66	160,313.33	1.72	29.45
High	10–20	617	26.06	912,506.67	9.77	13.74
Middle	5–10	452	19.09	940,726.67	10.07	7.2
Low	2–5	624	26.35	1,920,646.67	20.56	3.12
Lowest	<2	470	19.85	5,407,980.00	57.89	0.49

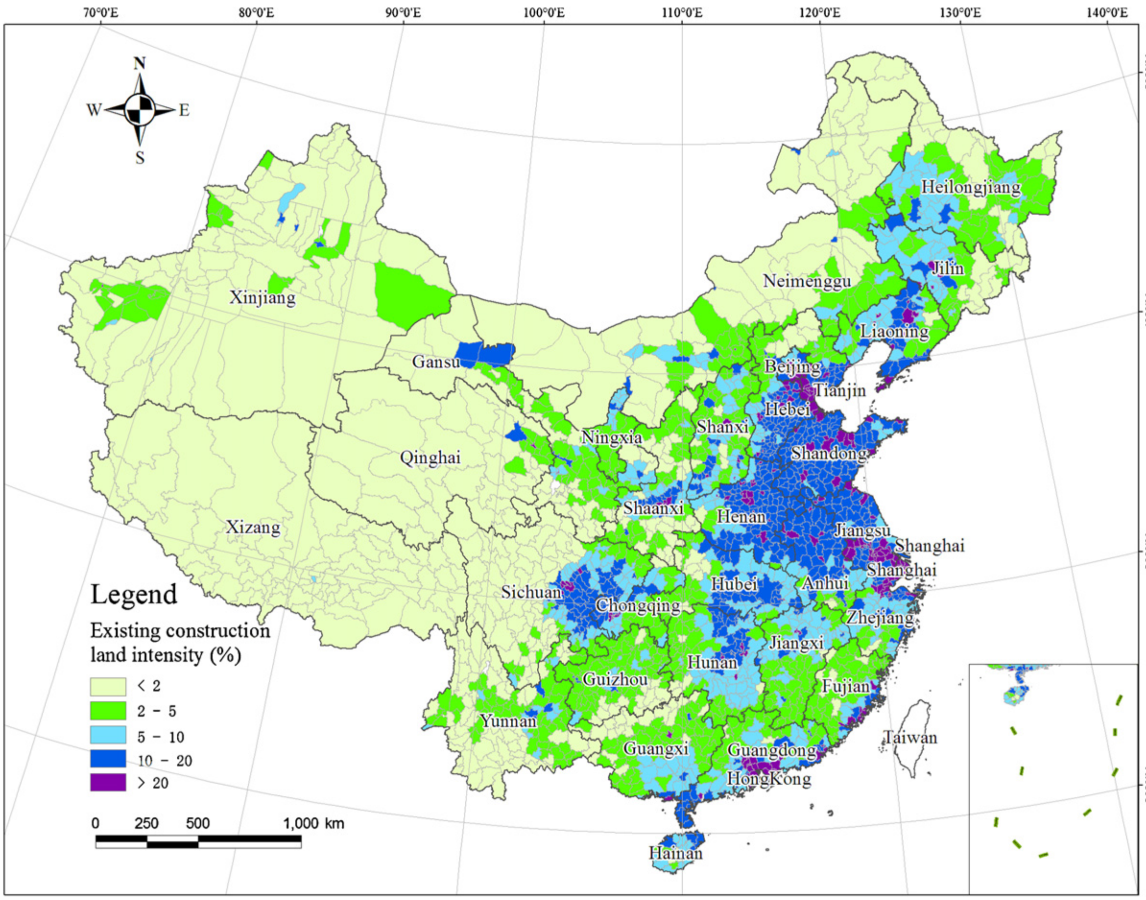

Fig. 2. Spatial pattern of existing construction land intensity in China in 2008.

characteristics of spatial pattern of China's construction land potential show that the values of East are higher than those of the West, the values of North are higher than those of the South, and the values of flatlands are higher than those of the mountainous regions.

The Most Abundant Pattern includes 109 counties, which are mainly concentrated in the Heilongjiang, Jilin, Liaoning and Inner Mongolia provinces of Northeast China. There also are some counties scattered in Shanxi, Gansu, Hubei, Anhui and Shandong provinces. The Abundant Pattern includes 359 counties, which are mainly concentrated in surrounding areas of the Most Abundant Pattern in Northeast China, Hubei–Henan–Anhui–Jiangsu–Shandong region, Bashang District of Hebei, Central part of Inner Mongolia, North Shanxi, contiguous areas of Gansu and Ningxia, and South Mount Tianshan. There also are some counties scattered in Yunnan, Guangxi, Hunan and Jiangxi provinces. The Middle Pattern includes 420 counties, which are widely distributed among provinces and relatively concentrated in the surrounding areas of the Abundant Pattern. The Scarce Pattern includes 744 counties, which are relatively concentrated in the Yunnan–Guizhou Plateau, the South mountainous region, both sides of Taihang Mountains, surrounding areas of Changbai Mountain and perimeter zones of metropolises in East China. There also are some counties scattered in Hexi Corridor of Gansu and Xinjiang provinces. The Most Scarce Pattern includes 748 counties, which are concentrated in Qinghai–Tibet Plateau and arid region of Northwest China. There also are some counties scattered in the surrounding areas of the Pattern Scarce in South and East China. Besides, special attention should be directed at that most core areas of metropolises belong to the Most Scarce Pattern and their values of construction land potential are almost zero.

3.4. *Quantity and spatial pattern of construction land potential per capita*

The construction land potential per capita of China is 0.021 ha/person. Significant differences exist among counties, with the highest value of 2.60 ha/person and the lowest value of 0. According to the average value and the variation trend of all

Table 4
Data of construction land potential of different patterns in China in 2008.

Pattern	Value range (km^2)	County numbers	Area of pattern		Average area (km^2/county)
			Area (km^2)	Percentage in total (%)	
Most Abundant	>320	109	84,758.91	29.91	777.60
Abundant	320–150	359	74,558.70	26.31	207.68
Middle	150–100	420	51,364.38	18.13	122.30
Scarce	100–50	744	53,868.71	19.01	72.40
Most Scarce	<50	748	18,818.06	6.64	25.16
Total	2380	283,368.80	100	119.06	

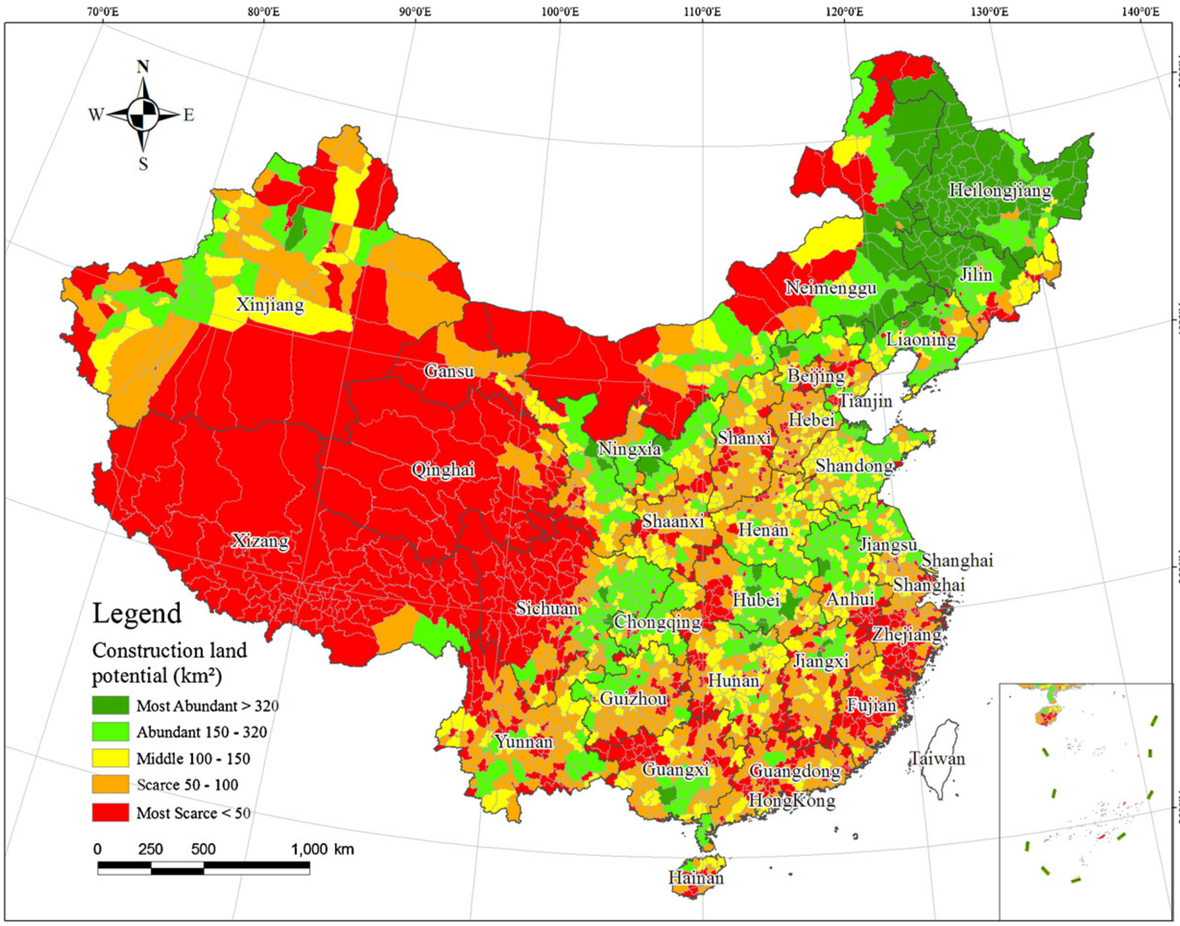

Fig. 3. Spatial pattern of construction land potential in China in 2008.

counties, five patterns can be identified: above 0.133 ha/person named Most Abundant, 0.133–0.053 ha/person named Abundant, 0.053–0.020 ha/person named Middle, 0.020–0.007 ha/person named Scarce, and below 0.007 ha/person named Most Scarce (Fig. 4 and Table 5).

The Most Abundant pattern includes 63 counties, which are mainly concentrated in Northeast China, northern part of North China, contiguous areas of Shanxi–Gansu–Ningxia, North Xinjiang and Southeast Tibet. The Abundant pattern includes 172 counties, which are mainly concentrated in surrounding areas of the Most Abundant pattern in Northeast China, northern part of North China, Shanxi–Gansu–Ningxia region, North Xinjiang, and Southeast Tibet. There are also some counties scattered in Qinghai, Shandong, Jiangxi and Yunnan province. The Middle pattern includes 721 counties, which are widely distributed among provinces and relatively concentrated in Central China. The Scarce pattern includes 1110 counties, which are relatively concentrated in East China coastal areas and Henan–Anhui–Hubei–Hunan–Jiangxi region. The Most Scarce pattern includes 314 counties, which are concentrated in Qinghai–Tibet Plateau and most core areas of metropolises. Besides, there are some counties scattered in Inner Mongolia and Xinjiang autonomous regions.

In general, the main characteristics of spatial pattern of China's construction land potential per capita shows that the values of counties in North China are higher than those of counties in South China, and the values of sparsely populated regions are higher than those of densely populated regions. The high value areas of construction land potential per capita are concentrated in Northeast China, northern part of North China, Northwest China, and the middle reaches of the Yellow River, while the low value areas are aggregated in the Qinghai–Tibet Plateau and the densely populated areas of Central and Eastern China.

The spatial pattern of construction land potential per capita also has been formed by the characteristics of physical geography, regional development history, population aggregation processes, and economic developments in the long term. The deficiency of construction land potential per capita in the Qinghai–Tibet Plateau is the result of the highland climate of local geographical environment. Because of very high altitude, few data are extracted from the composite map, and only a small amount of construction land

Table 5
Data of construction land potential per capita of different patterns in China in 2008.

Pattern	Value range (ha/person)	County numbers	Percentage in all counties (%)	Average area (ha/person)
Most Abundant	>0.133	63	2.65	0.353
Abundant	0.133–0.053	172	7.23	0.081
Middle	0.053–0.020	721	30.29	0.029
Scarce	0.020–0.007	1110	46.64	0.013
Most Scarce	<0.007	314	13.19	0.003
Total	2380	100.00	0.021	

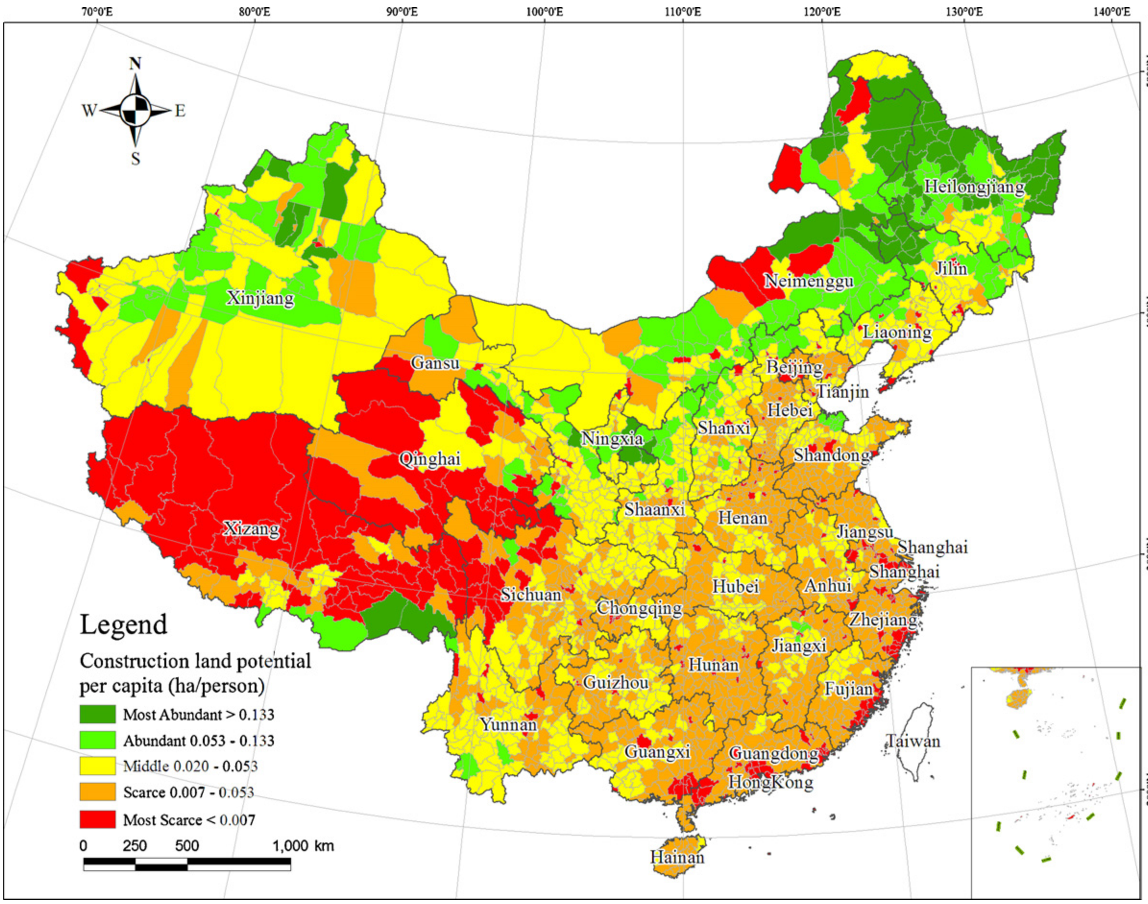

Fig. 4. Spatial pattern of construction land potential per capita in China in 2008.

potential is identified. Despite the sparse population in this region, the construction land potential per capita is still very low. The abundance of construction land potential per capita in Northeast China, northern part of North China, Northwest China is the result of sparse population and short-term development history. During the Qing dynasty (before 1911), the northeast region belonged to restricted area of the Manchu royalty and people of other nations cannot enter this area. In the late Qing dynasty, it was a focus area which Russia and Japan wanted to seize. During 1931–1945, this region was occupied by Japan and governed by Manchu puppet regime. The large-scale immigration and economic development did not start until 1949. While the deficiency of construction land potential per capita in most southeast regions of Hu's line is the result of the advantageous natural conditions, long-term development history, dense population and high-level urbanization and industrialization. Due to the rapid and sustained economic growth and large-scale urbanization in Southeast China, a lot of available land has been converted to construction land for obtaining economic benefits. Because of dense population, the values of construction land potential per capita in this region are relatively low for future development.

4. Discussion

4.1. The use of land construction potential in china

Construction land potential could be seen as a key integrative indicator of the land carrying capacity of various regions for future population aggregation, industrialization and urbanization development. Due to the significance of land carrying capacity in the processes of future urbanization, development, and industrialization, the assessment of construction land potential would be significant to diagnosing land resources, making sound development strategies, and achieving regional sustainable development. In most cases, a wise strategic plan for regional sustainable development is based upon the precise assessment of elements including land resources, water resources, economic base, transport infrastructure, ecoenvironment, etc. The assessment of construction land potential is one of the most essential foundations for a wise strategic plan in order to achieve regional sustainable development.

For China, a country that now is experiencing rapid economic growth and has a vast population and scarce land per capita, the assessment of construction land potential is of great importance to efficient and intense management of land resources. In fact, construction land potential has been chosen as an important indicator in the processes of developing the National Major Function Zoning of China, sponsored by the National Development and Reform Committee of China. Construction land potential proves to be an expressive indicator at national and provincial levels because it is able to reveal the spatial pattern of land carrying capacity of counties in the nation or a specific province. Without doubt, it is also useful for a subregion when an additional sophistication is employed in the method of calculation.

4.2. Future considerations

Construction land potential is essential to reflecting land carrying capacity of different regions for future population aggregation, industrialization and urbanization development. However, it is hard to quantitatively describe all the contents by a single index such as construction land potential or construction land potential per capita due to its complexity and multiple involved factors. Therefore, some issues could be further considered when applying the indicator for practical purposes.

The contents of construction land potential consist of quantity, quality, and concentration ratio. Here, the quantity factor was assessed by the standard of geologic, topographic, geomorphologic and climate conditions. It is very difficult to combine quantity and concentration ratio into an integrative index. A measurable expression of integrative index is realized by the use of a single index. Construction land potential per capita and construction land potential are such integrative indices. One former focuses on the status of construction land potential from the perspective of human–land relationship, which means that the higher the value, then the more abundant the construction land potential. The latter reflects the concentration ratio in a certain region by the total amount of construction land potential, which means that the higher the value, then the more concentrated the construction land potential of the region.

In general, regions suitable for future population aggregation, industrialization and urbanization developments should have historical foundations and considerable proportion of existing construction land in land use structure. In order to assess spatial pattern of existing construction land of different regions, it is necessary to establish auxiliary indices such as existing construction land intensity.

The construction land potential can be further subdivided and classified based on the source of the land. Construction land potential usually comes from three domains. The first is the part that can be used for construction in unused lands, which could be designated as the remaining construction land potential. The second is from the intensification of the inefficient part in existing construction land and the promotion of land carrying capacity for population, industries and towns, which could be designated as exploitable construction land potential. The third is based on the conversion from forestland, grassland, and farmland to construction land, which could be named as adjustable construction land potential. In short, these issues pertaining to selection of key indicator, establishment of auxiliary indices, and subdivision of the source of construction land potential should be included in future assessments to improve upon the methodology.

5. Conclusions

In this study, a methodology was developed and applied to calculate the construction land potential and analyze its spatial pattern in China. The area of construction land potential of China in 2008 amounts to 283,400 km^2, which accounts for 2.99% of total land area. The value of construction land potential per capita of China is 0.021 ha/person. The main characteristics of spatial pattern manifest that: the high value areas are concentrated in Northeast China, northern part of North China, Northwest China and the middle reaches of the Yellow River, while the low value areas are aggregated in the Qinghai–Tibet Plateau and densely populated areas of Central and Eastern China.

Construction land potential proves to be an expressive indicator to reveal the land carrying capacity of different regions for future population aggregation, industrialization and urbanization development. The assessment of construction land potential of China in 2008 reveals a clear picture of land carrying capacity at regional scale. This is, without doubt, essential to making sound regional development strategies in order to achieve sustainable regional development in China. It is concluded that the assessment of construction land potential plays an important role in promoting effective urban and industrial expansion. The methodology could be improved by some additional parameters when it is applied for future assessments both here in China and elsewhere.

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