Spatio-Temporal Changes of Population Density and Urbanization Pattern in China (2000 – 2010)

Mao Qizhi, Long Ying, Wu Kang

Abstract Population distribution and their temporal variation are a direct proxy of urbanization. This study evaluates the population density variation of China between 2000 and 2010 at the township level by using the data of the fifth and sixth national population censuses. The urbanization patterns of China in 2000 and 2010 are depicted based on the population densities at various levels and the urbanization process of China between 2000 and 2010 is then analyzed through a comparative approach. It also tries to visualize the population density dynamics and urbanization pattern variations of China at the township level.

Keywords population density; urbanization; city cluster; China; population census

1. Introduction

In the last 35 years since the opening-up, China has gone through an accelerated urbanization. As publicized by the government, China's urbanization rate surpassed 50% for the first time in 2011 and further climbed to 53.73% in 2013,① marking its entry into a critical transitional stage. The Third Plenary Session of the 18th CPC Central Committee and the Central Urbanization Work Meeting proposed to take a "human-oriented new urbanization" path in future. Since people are the user and developer of the land, the population distribution and its temporal variation are an intensive embodiment of socio-economic activities (Huang, 2005). In 1935, Chinese geographer Hu Huanyong, based on an investigation on China's population distribution, put forward the famous "Hu Line," which reveals the law of China's population distribution in space (Hu, 1935). As a core element of urbanization, population distribution can directly reflect the basic spatial pattern of urbanization.

Traditional studies on the spatial pattern of population distribution usually concentrate on the population densities at the macro level, which take the province, city, district, or county as a unit (Wang, 1998; Yu, 2012; Ge and Fen, 2009). Some scholars in Geoinformatics also use factors like land classification, infrastructure layout, terrain, surface feature, or nightlight sensing to predict and evaluate population densities (Liu, Yue, et al., 2003; Tian, Chen, et al., 2004; Zhuo, Chen, et al., 2005; Han, Zhang, and Qi, 2007), which utilize an analytical grid to roughly express the fine-scale population densities. In addition, restricted by the statistical caliber, demographic geographers usually use the data of registered population for research purposes, which can hardly reflect the "fluid space" under China's current rapid urbanization (Wu, Fang, et al., 2013).

Since the fifth national population census in 2000, the statistical caliber of China's permanent population has been gradually popularized and standardized, providing a good statistical basis for researches on urbanization's spatial pattern. Based on the population data at the township② level, this paper adopts the tool of GIS spatial analysis to explore the spatio-temporal changes of China's population density and outlines the basic pattern of population distribution, as well as the basic momentum of population flow. Furthermore, on the basis of population density, it brings together relevant researches both from home and abroad to delimit the geographical scope and spatio-temporal variation of China's urbanization, in hope of advancing the judgment for a new urbanization spatial pattern.

2. Characteristics of population density distribution variation

Based on the fifth and the sixth national population census in 2000 and 2010 (National Bureau of Statistics of China, 2002 and 2013) respectively, a national demographic database at the township level was built up, with each entry recording the attribute data like permanent population and local population, as well as detailed addresses. In this research, we use the API of Google Maps to do a spatial match with the addresses and obtain 50,518 township-level units from the 2000 census and 43,536 from the 2010 census;③ then, based on the boundaries of the township-level units in 2012, i.e., 39,007 units covering a total area of 9,525,000 km^2, we compare and match the spots as recorded in the database; and finally, the township-level data of enclosing boundary of the two censuses are integrated.

2.1 Overall population distribution unchanged, highly-populated sub-districts conspicuously increased

Based on the data of permanent population, we calculate the population densities at the township level in 2000 and 2010 and showcase them through classification (see Figs. 1 & 2). In 2000, the average population density of China's 39,007 township-level units reached 873 persons/km^2 and the figure further climbed to 977 persons/km^2 in 2010. Between 2000 and 2010, China's population largely aggregated to the east of the Hu Line as proposed by Hu Huanyong, presenting a multi-centered spatial aggregation pattern, with the Huabei Plain, Yangtze River Delta, Pearl River Delta, Sichuan Basin, and Guanzhong Plain being the major populated regions which had a population density of over 500 persons/km^2. Particularly, the Nanjing-Shanghai-Hangzhou-Ningbo (known as Ning-Hu-Hang-Yong in brief) Z-shape zone as the core region of the Yangtze River Delta, the two wings of the Pearl River Estuary centering on Guangzhou-Foshan-Shenzhen, the regions along the Beijing-Tianjin-Shijiazhuang railway and the Chengdu-Chongqing railway, and the cities along the southeast coastline (e.g., Wenzhou-Taizhou Region, Xiamen-Zhangzhou-Quanzhou Region, and Chaozhou-Shantou Region) reached a population density of over 1,000 persons/km^2.

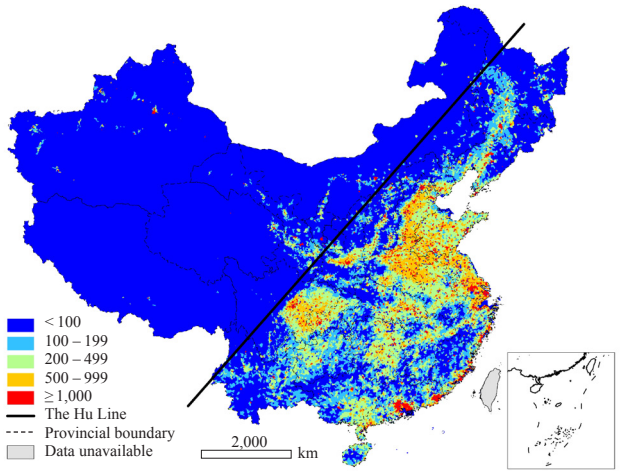

Fig. 1 Population density in 2000 (persons/km^2)

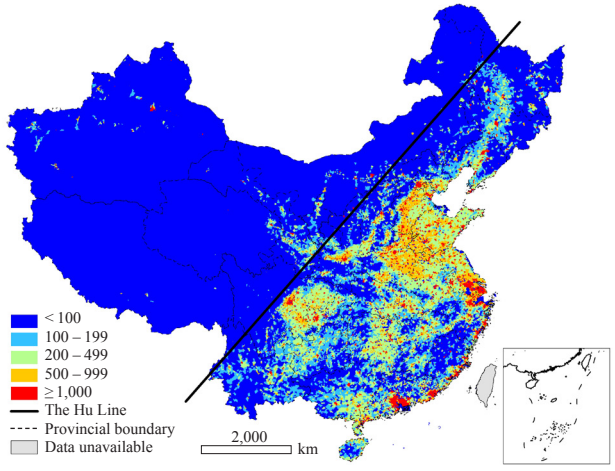

Fig. 2 Population density in 2010 (persons/km^2)

In terms of the frequency distribution of population density (see Fig. 3), more than 14,000 township-level units had a density of less than 100 persons/km^2 in both 2000 and 2010, accounting for about 1/3 of the total quantity and covering above 70% of China's total territory. Over 5,000 had a density between 100 – 200, 200 – 500, 500 – 1000 persons/km^2, whereas quite few had a density of over 1,000 persons/km^2, covering only 2% of China's total territory. Comparing the data of the two years, it may be found that the number of the township-level units with a density of over 2,000 persons/km^2 increased from 1,883 in 2000 to 2,345 in 2010, that of 100 – 1,000 persons/km^2 remained relatively stable, and those of 100 – 200 persons/km^2 and 500 – 1,000 persons/km^2 decreased slightly. The changes of the frequency distribution of population density reflect to some extent the characteristics of China's population flow pattern during one decade.

2.2 Spatial pattern of population flow under "urban-rural dualism" and "core-periphery effects"

The population growth in some typical cities and the outcome of relevant researches on population flow and growth (Caroline et al., 2000) are taken into consideration in this research, based on which the permanent population density variation during the ten years from 2000 to 2010 is classified into six grades: conspicuously decreased ($V \leq 0.75$), slightly decreased ($0.75 < V \leq 0.9$), basically unchanged ($0.9 < V \leq 1.1$), slightly increased ($1.1 < V \leq 1.25$), conspicuously increased ($1.25 < V \leq 1.5$) and significantly increased ($V > 1.5$). Hereby, V refers to the ratio of population density between 2000 and 2010.

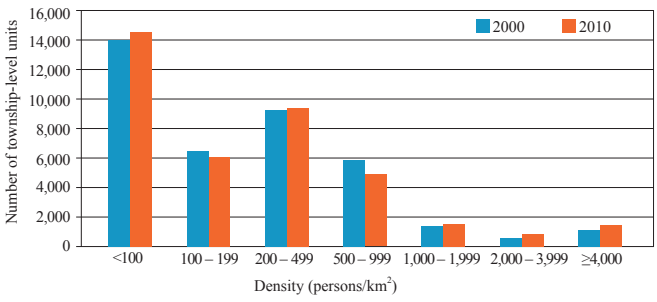

Fig. 3 Frequency distribution of population density during 2000 – 2010

The flow of China's permanent population since 2000 presents two remarkable characteristics (see Fig. 4). Firstly, the middle-east regions with a high population density and a low natural population growth rate witnessed the "urban-rural dualism effects" characterized by a population flow "from rural townships to urban sub-districts," as well as the "core-periphery effects" featured by a population flow "from underdeveloped city cluster peripheries to developed city cluster core areas." The former effects were reflected by the significant population growth in the core cities, like the case in Beijing-Tianjin-Hebei Region and Shandong and Heilongjiang provinces; while the latter effects could be seen in the periphery of the Yangtze River Delta and the Pearl River Delta, like northern Jiangsu, southern Zhejiang, and northern Guangxi and Guangdong, whose permanent population density conspicuously decreased. In comparison, Xinjiang, Yunnan, Inner Mongolia, and Shanxi witnessed a conspicuous population density growth. As minority areas, Xinjiang and Yunnan had a high natural population growth rate and the momentum was further aggravated because of the border development and huge population inflow; while the provinces with rich natural resources, like Inner Mongolia and Shanxi (including southern Sichuan), attracted a large number of labor forces along with the development of mining industries. It is worth noting that two contiguous regions of population outflow were formed in China during this period. One is the Sichuan-Chongqing-Guizhou contiguous region, where, as a major populated region in western China, most township-level units presented a conspicuous momentum of permanent population outflow except the sub-districts in several core cities like Chengdu, Chongqing, and Guiyang. The other is the "southwestern Zhejiang-western Fujian" contiguous region in eastern China, where the population outflow had more complicated influencing factors, such as the hilly topography, relatively low population density, and less developed economy. The local population was apt to flowing into the nearby developed regions, like the Pearl River Delta and the Yangtze River Delta. Certainly, it was also related to the regions' tradition of "going out for business."

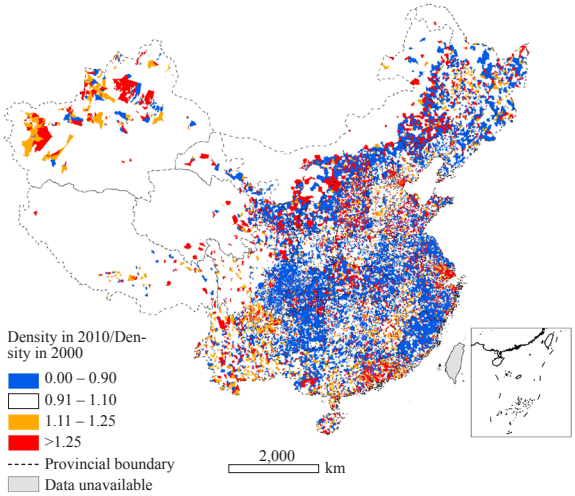

Fig. 4 Population density variation from 2000 to 2010 in China

Table 1 shows that, since 2000, the variation of China's population density has been very conspicuous. Among the over 39,000 township-level units, 17,808 remained unchanged in terms of population density, accounting for less than 50% of the total, while the others witnessed remarkable changes, either increase or decrease, of population density, 22% of which underwent conspicuous changes. 12,840 township-level units saw a decrease of population density, occupying a total area of around 1,734,000 km^2, while 8,359 saw an increased of population density, occupying a total area of around 1,354,000 km^2. No matter in terms of number or area, the township-level units with decreased population density outnumbered those with increased population density. It thus can be said that, since 2000, China's population redistribution has demonstrated to a certain degree a spatial imbalance and further aggregation (see Fig. 4).

Since 2000, China's natural population growth rate has been annually declining. Its permanent population, as per the sixth national population census in 2010, increased by only 6% compared with that about ten years ago, with an annual growth rate of less than 6‰. Taking that into consideration, the population density variation at the township level reflected the redistribution of mechanical population growth, or the spatial pattern of population flow. Classical demographic theories attribute the redistribution of population density driven by mechanical growth to "pushing force" and "drawing force," which is in essence a projection of industrial restructuring and regional function adjustment onto professional distribution, or economic and industrial factors (Huang, 2005). Amid the accelerated urbanization over the past ten years in China, surplus rural labor forces rushed into big cities for more employment opportunities, resulting in the phenomenon of rural hollowing (Liu, Liu, and Zhai, 2009). This is also reflected on space, that is, the decrease of rural population density and the increase of sub-district population density, under the "urban-rural dualism effects." In the meantime, the regional development gap resulted in a divide in employment opportunities and salaries between the developed core areas and the underdeveloped peripheries of city clusters under the "core-periphery effects." While the population density in the underdeveloped township-level units demonstrated a decreasing momentum, the overall population density of the core areas of city clusters increased. The influence of industrial restructuring was remarkably expressed through the positive correlation between manufacturing industries and population inflow (Yu, 2012a). For instance, in the cities of Shenzhen, Suzhou, Dongguan,

Table 1 Overview of population density variation in China from 2000 to 2010

V=Population density in 2010/Population density in 2000	Total population in 2000 (million)	Total area (1,000 km²)	Number of township-level units
Conspicuously decreased (V≤0.75)	176.5	700	5,232
Slightly decreased (0.75<V≤0.9)	230.4	1,034	7,608
Basically unchanged (0.9<V≤1.1)	431.9	6,437	17,808
Slightly increased (1.1<V≤1.25)	166.4	518	3,059
Conspicuously increased (1.25<V≤1.5)	124.2	342	1,937
Significantly increased (V>1.5)	112.8	494	3,363
Total	1,242.2	9,525	39,007

etc., as the secondary industries were gradually moved out of the city center to the suburban areas, the originally highly populated city centers whose prosperity was strongly supported by manufacturing industry, gradually transferred their population to the townships in the suburban counties or districts. However, the city centers did not see a conspicuous decrease in population density, because the productive service industry represented by finance, real estate, and transportation emerging along with the adjustment of urban functions and the aggregation of tertiary industries in the city centers was becoming an industrial category that drove a new round of net population inflow (Yu, 2012b).

3. Identification of urbanization spatial pattern and its variation characteristics

3.1 Identification of population density and urbanization spatial pattern

For long, due to the lack of statistical definition on township-level units in China (Zhou and Shi, 1995), many concepts concerning the spatial pattern of urbanization, like city, metropolitan area, and city cluster, had to be generalized, which is not conducive to the researches on urbanization spatial pattern. A review on the township definition in statistical term abroad indicates that population density is no wonder the primary element.

In the US, the concept of metropolitan district was firstly proposed in 1910, which referred to a core city of over 100,000 people and its surrounding areas within 10 miles, or even those going contiguously beyond 10 miles from the core city, with a population density of no less than 150 persons/km². In the 1980s, the concept of metropolitan statistical area (MSA) was proposed which was defined mainly in terms of population and commuting. MSA, together with primary MSA (PMSA) and consolidated MSA (CMSA), were all referred to as a metropolitan area.④ It can be seen that, in the US, a metropolitan area is a clear-cut concept designating the combination of a big urban population core and its surrounding area with close socio-economic ties, which is a basic geographical unit employed worldwide for researches on urban statistics and urban studies (Xie, 2008).

In Japan, the population census in 1960 proposed the concept of densely inhabited district (DID), which was defined as an area composed of contiguous basic survey unites with a population density of above 4,000 persons/km² and a total population of above 5,000. The basic survey unit is the smallest unit with regard to which the census data is available.⑤ In the meantime, Japan put forward the concept of metropolitan area which prescribed that the core city should have a population of above 100,000 and the commuting rate from the periphery to the core city should be above 5%; the core city should be a city designated by the central government or a city with a population of above one million, neighbored by cities with a population of above 500,000; the commuting population from the periphery to the core city should account for no less than 15% of the local population; and the freight transportation volume to other metropolises should not exceed 25% of its total freight volume. It can be seen that, in Japan, a metropolitan area is an urban function region centered on a mega-city with comprehensive functions whose radiation effects drive forward the development of the large, medium-sized, and small cities nearby.

In China, Zhou Yixing (1995) proposed to clarify the Chinese definition of various urban areas including urban statistical area, township statistical area, and township-style residential area, among which an urban statistical area should have a population density of 2,000 persons/km², or 1,500 persons/km² for the areas with a high non-agricultural population proportion. Song Xiaodong et al. (2006) once used the data of remote sensing and population census in 2000 to explore the possibility of clarifying the definition of three types of urban and rural areas in Shanghai.

Generally speaking, various countries in the world have their own clarifications on the concepts of different urban entities in view of their specific situations of urban development. Due to a lack of long-term reliable commuting data in China, we could only base this research on the permanent population density as per the two national

population censuses, in order to map China's urbanization spatial patterns under different population density thresholds and to preliminarily analyze its spatio-temporal variation characteristics.

3.2 Identification of urbanization spatial patterns in 2000 and 2010

In order to identify China's urbanization spatial patterns in 2000 and 2010, townships are taken as the basic unit to determine the population density criteria of different levels. This corresponds to the short-term target proposed by Zhou (1995) to clarify the concept of urban statistical area. The first step is to fix a threshold population density for China's urbanization areas. In view that the population density of the over 39,000 township-level units was 873 persons/km^2 in 2000 and 977 persons/km^2 in 2010, it is set to 1,000 persons/km^2 for urbanization areas. The second step is to fix a threshold population density for China's urban statistical areas, which adopts the average population density of 2,000 persons/km^2 according to the idea of Zhou et al. (1995). The last step is to fix a threshold population density for China's highly-populated urbanization areas, in reference to the Japanese concept of "population aggregation area," which takes 4,000 persons/km^2 as population density criteria.

Based on the above population density criteria, three urbanization spatial patterns can be identified in China (see Figs. 5 & 6), among which the highly populated urbanization areas constitute the subset of the urban statistical areas, while the urban statistical areas constitute the subset of the urbanization areas. Specifically speaking, the spatial pattern of the urbanization areas with a population density from 1,000 to 2,000 persons/km^2 remains relatively stable from 2000 to 2010, with their population being mainly distributed in the sub-districts of the large, medium-sized, and small cities, as well as the township-level units nearby. In comparison, the spatial patterns of the urban statistical areas and the highly populated urbanization areas present a remarkable momentum of expansion. For the urban statistical areas, they were mainly the sub-districts of the provincial capitals or other big cities in the Pearl River Delta, the Yangtze River Delta, and the provinces in middle-western China in 2000, like Changchun, Chengdu, Chongqing, Xi'an, Wuhan, and Nanning, while further expanded to the townships nearby the large and medium-sized cities in the eastern coastal area in 2010. For highly populated urbanization areas, they were limited to the sub-districts of some mega-cities or big cities in 2000, like Beijing, Shanghai, Guangzhou, Chongqing, Shenyang, Wuhan, Nanjing, Hangzhou, Xi'an, and Chengdu, in a spatial pattern of discrete dots or patches, while further expanded to the sub-districts of most provincial capitals and large cities, in not only the Yangtze River Delta and the Pearl River Delta, but also the coastal areas like southern Zhejiang, southern Fujian, and Chaozhou-Shantou in southeastern China (see Table 2).

3.3 Development prediction for key urbanization areas based on population density

On Mar. 16, 2014, the *National New Urbanization Plan 2014 – 2020* was promulgated, which reinforced to take "city cluster as the dominant spatial form" of urbanization and proposed to "develop city clusters with high aggregation efficiency, big radiation effects, reasonable system structure, and strong complimentary functions and to make them into important platforms for supporting the national economic growth, facilitating the coordinated regional development, and participating in the international competition and cooperation." As no consensus has

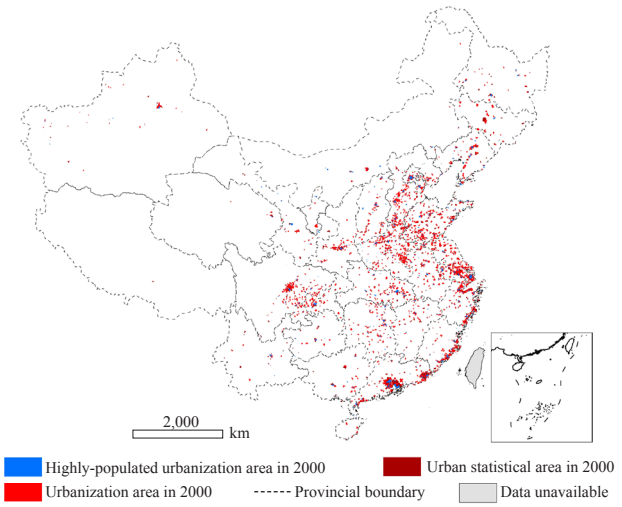

Fig. 5 Urbanization pattern of China in 2000

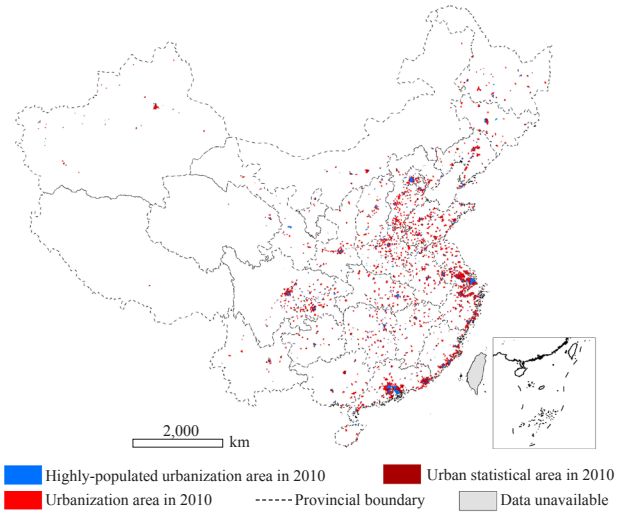

Fig. 6 Urbanization pattern of China in 2010

been reached on the quantity and distribution of city clusters in China, we hereby try to predict the development of the key urbanization areas based on the three threshold population densities mentioned above, with reference to the 21 key urbanization areas within the 18 key development regions and three optimized development regions defined by the *National Main Functional Area Plan* issued in 2010 (see Fig. 7).[6]

Overall, among China's three world-level city clusters, as proposed for priority development by the National New Urbanization Plan, the Yangtze River Delta and the Pearl River Delta have a relatively higher urbanization level where the urbanization areas become contiguous and the highly-populated urbanization units are evenly distributed in space. In the Beijing-Tianjin-Hebei Region, the population density distribution presents a ring-shaped declining trend around the two mega-cities of Beijing and Tianjin and the urbanization areas are not contiguous yet, with a pattern of discrete dots in the area beyond the metropolitan areas of Beijing and Tianjin which is much smaller than the surface of the "2+8" municipalities that composed of the Beijing-Tianjin-Hebei metropolitan region (Fan et al., 2008). Among the other 18 key urbanization areas for priority development, Shandong Peninsula and Liaodong Peninsula in eastern China, Central Plains Economic Region and Chengdu-Chongqing region in middle-western China possess a higher population density and a more contiguous urbanization layout, with a greater potentiality to be developed into city clusters.

Table 2 Overview of urbanization patterns in China

Urbanization zoning	Year	Total population (million)	Total area (km^2)	Number of township-level units
Urbanization area (above 1,000 persons/km^2)	2010	516.2	186,976	3,949
	2000	375.8	147,071	3,361
Urban statistical area (above 2,000 persons/km^2)	2010	360.6	71,974	2,346
	2000	247.2	49,771	1,883
Highly-populated urbanization area (above 4,000 persons/km^2)	2010	230.9	25,300	1,494
	2000	158.7	17,152	1,209

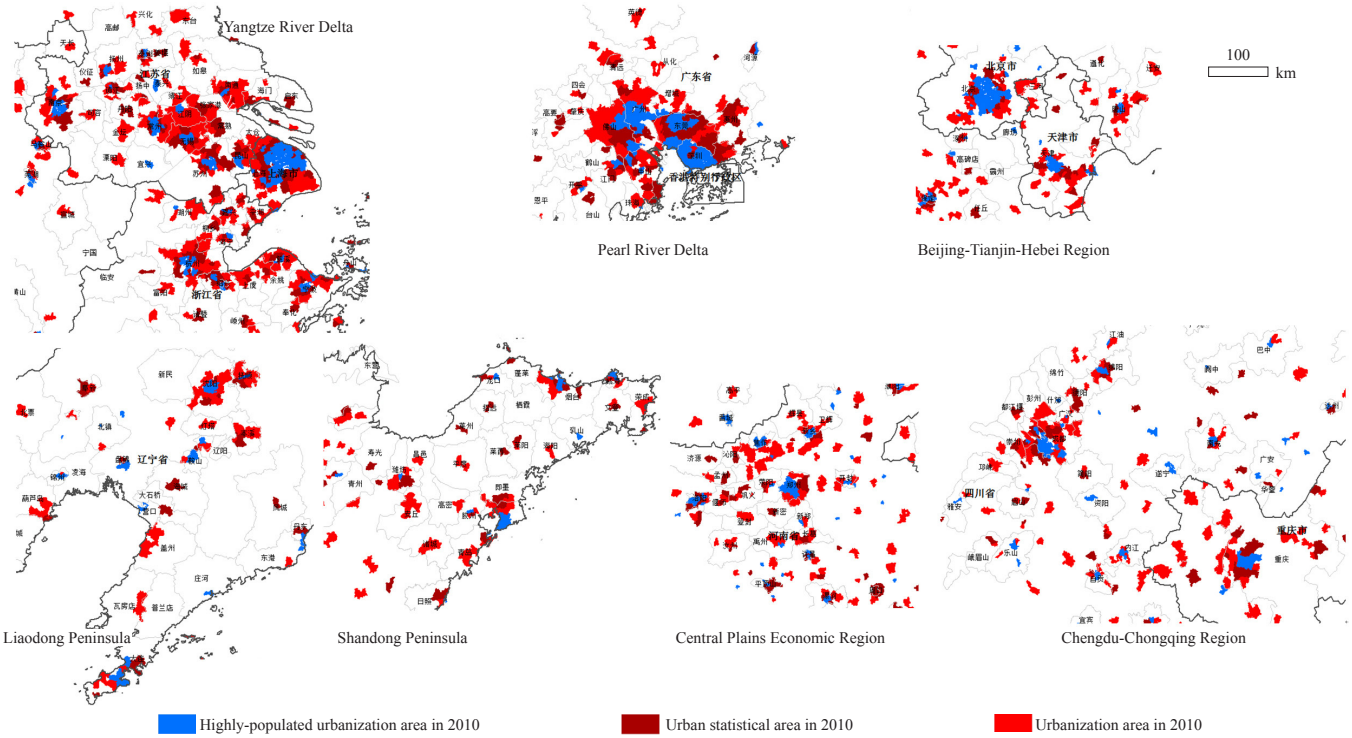

Fig. 7 Key urbanization areas in China with preferable conditions and potentialities

4. Conclusions and implications

By analyzing the demographic data at the township level from the perspective of population density, this paper identifies the spatio-temporal variation of China's population density and urbanization spatial pattern between 2000 to 2010. It puts forward the thresholds for the urbanization areas, urban statistical areas, and highly-populated urbanization areas in China, which are 1,000, 2,000, and 4,000 persons/km^2 respectively, and maps the spatial pattern of urbanization accordingly. A comparison of the urbanization patterns in 2000 and 2010 shows that both the urban statistical areas and heavily-populated urbanization areas presented a momentum of conspicuous expansion. When evaluating the development status of China's key urbanization areas from the perspectives of population density, it can be found that the Yangtze River Delta and the Pearl River Delta possess better development conditions among the three city clusters in eastern China and Shandong Peninsula and Liaodong Peninsula on the eastern coast, Central Plains Economic Region and Chengdu-Chongqing region in middle-western China have more potentials for further development. As for the other 10 – 20 key urbanization areas which are currently under discussions, the cultivation of market forces and the guidance of national planning are more necessary for orderly development to be important growth poles facilitating balanced spatial development in future. C

Translated by Zhang Qingfei
Proofread by Liu Jian

From *City Planning Review*, 2015, 39 (2), pp. 38 – 43.

Notes:

① Source: Statistical Bulletin of National Socio-Economic Development of P. R. China in 2013 publicized on Feb. 24, 2014.

② Township is used in this article as a generic term embracing all township-level administrative units, including town, township, and jiedao (subdistrict).

③ As the boundaries of the basic statistical units adopted by the two national population censuses are slightly different from those of the township-level units, for example, a development zone is not an administrative unit but might be a census unit, the number of statistic units might slightly deviate from the number of township-level units recorded by the Civil Affairs Departments.

④ Source: <http://www.whitehouse.gov/sites/default/files/omb/bulletins/2013/b13-01.pdf>.

⑤ Source: <http://www.stat.go.jp/english/data/nenkan/1431-02e.htm>.

⑥ The overlapping borders are the borders of the cities, excluding the counties under their jurisdiction.

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