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The urban land area change in China from 1820 to 1999

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According to the length of city perimeter and the administration systems recorded in the historical literatures of the Qing Dynasty, a set of methods is developed to convert the historical records into the area of urban land use, by which a set of preliminary estimated urban land use data of the 18 provinces during the Emperor Jiaqing (1820AD) in the Qing Dynasty, is achieved. Based on the above achievements, the regional differences of urban land use are analyzed, and the comparison in urban land use between the Qing Dynasty and present (1999) is made.

HE Fanneng, GE Quansheng, ZHENG Jingyun (Inst. of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China) 1 Introduction Since the 1990s, with the development of global change research, more and more attention is paid to the research on land use/cover changes (LUCC) by many international organizations of science. LUCC has been regarded as the major driving force influencing the global change. Both IGBP and IHDP have land use/land cover as their own core project (Huang et al., 1999; Li, 1996). Changes of regional environment even global environment in historical periods are related tightly with land cover change, while land cover change is the inevitable result of the human activities on land use. As one of the major forms of the human activities on land use, the amounts of urban lands used increase rapidly, with the development of the human society, the increase of population, and the continuous advancement of industrialization and urbanization, which has caused amounts of cultivated land, forestland and grassland, were occupied by urban land use. In some regions, urban land use has dominated the land use change (Zhu et al., 2001a, b). In order to reveal the status of urban lands in the Qing Dynasty of China, historical records of the Qing Dynasty are used to estimate area of urban land use of the 18 provinces around the period of Emperor Jiaqing (1820AD) in the Qing Dynasty in this paper. A set of estimated urban land use data in the Qing Dynasty have been obtained. Based on the urban land use data, the regional differences of urban land use are analyzed, and the comparison in urban land use between the Qing Dynasty and present (1999) is made. The research region in this paper includes the 18 provinces in Qing Dynasty, which equals to the 24 provinces, cities and municipalities, except the three provinces in Northeast China, Inner Mongolia, Xinjiang, Qinghai, Tibet and Taiwan, in modern China. 2 Sources of the records The materials used in this paper came from three aspects: (1) Historical materials in the local chronicles of the Qing Dynasty, including the city's perimeter and the total numbers of the cities at the levels of province, district, county in each province, respectively, which were the major source of this paper; (2) The published works by other researchers related to the measurement, estimation and the textual research on the ancient cities; and (3) the urban land use area data of land use survey in 1999. The historical records on the ancient cities were dealt with concisely on following situations. The first is the perimeter of a city with more than one urban section. Some cities were made up more than one urban section, such as inside section and outside section, or old section and new section, or northern section and southern section, main section and son section, paratactic sections and connected sections. For such cities, the city perimeter is united into the length of one urban section whose area is equal to the sum of the all sections. For example, Huai'an City in the Qing Dynasty had three urban sections: the southern one was the old one, the perimeter of which was 11 li (mile of the Qing Dynasty); the northern one was the new one, the perimeter of which was 7.2 li; and the section between the two was named the connected section (Huai'an Mansion 1). To unit the three ones, 15 li was taken as the perimeter of the Huai'an City. The second is the farmland inside the city wall and the urban land use outside the city wall. This occurred in some cities of the Qing Dynasty. In this situation, the area inside the city wall is regarded as the urban land use area considering the area of farmland inside the city balanced the area of the urba

n land outside the city. The third is two counties shared the same city. In some districts south to the Yangtze River of Jiangsu Province, it was often recorded that one city was shared by two or three counties. In this situation, the area of the city was separated into each county in a reasonable proportion. For instance, Kunshan County and Xinyang County of Suzhou District shared the same city, The perimeter of the city was more than 12 li (Suzhou Mansion 1). The perimeter of each county is taken as 8.4 li (70% of the city perimeter). The fourth is the conversion of measurement units. According to the records, li, bu, zhang and so on were often used as the measurement units of the city perimeter in the Qing Dynasty. According to the system of measures and weights in the Qing Dynasty, 360 bu or 1800 chi equals to one li in the Qing Dynasty, and one chi in the Qing Dynasty equals to 32 cm (EBCPG, 1980). In order to be convenient for comparison, all kinds of measurement units were converted into kilometer in this paper.

3 Estimation of the urban land area in 1820s

In the abundant Chinese historical records, even the records in the Qing Dynasty, there was no record on the urban land use area, but on the length of the city perimeter. In this paper, the urban land use area of the city is estimated according to the city perimeter.

3.1 Number of the cities in different administration levels

At the beginning of the Qing Dynasty, the local administration at first level, succeeded that of the Ming Dynasty, was divided into 15 provinces. At the beginning of Emperor Kangxi, Jiangnan Province was divided into Jiangsu Province and Anhui Province, Shaanxi province was divided into Shaanxi Province and Gansu Province, Huguang Province was divided into Hunan Province and Hubei Province. So there were 18 provinces in total (Gu and Shi, 1938). The second level local administration under the province was district (Fu in Chinese), and the third level local administration under the district was a county. Generally speaking, cities in ancient China were the location of local government at different levels, which also reflected the economic level of the region. The size of the city corresponded to the level of the local government (Han, 1995). According to the administration system of the Qing Dynasty, the cities and towns in the Qing Dynasty could be divided into provincial, district, and county levels respectively. Since the 18 provinces were established at the beginning of Emperor Kangxi, it was relatively stable. At district and county levels, the number changed a few. During the 80 years from the late Emperor Jiaqing (1820AD) to the late Emperor Guangxu (1908AD), only 19 districts and 12 counties were added (Zhao, 1955; Geographical Record, History of the Qing Dynasty, 1975). In this paper, the late Emperor Jiaqing (1820AD) was selected as standard time to count the number and to calculate the perimeter of the cities at different levels. Based on the data basically from the Unification Topography Reedited in the Emperor Jiaqing, as well as the records from History of the Qing Dynasty and Table on Geographical Evolution in the Qing Dynasty, numbers of districts and counties in each province are counted respectively (Table 1). Table 1 shows that there were totally 276 districts and 1,475 counties in the 18 provinces at the Emperor Jiaqing of the Qing Dynasty.

3.2 The averaged city perimeter at the district and county levels

The estimation of the urban land use area is mainly based on the city wall perimeter recorded in the historical literatures. The averaged city wall perimeters (Table 2) came from the related records on the cities the Unification Topography Reedited in the Emperor Jiaqing and some local logs. City perimeters of 18 cities at the provincial level (including the capital city), 205 cities at the district level, and 1,020 towns at the county level in the 18 provinces were counted. By which the averaged city perimeters at the province, district and county levels were worked out respectively. Table 2 shows that: 1) the perimeter of the provincial level city is generally longer than that of the district level, and that of the district level is obviously longer than that of the county level. 2) the difference among the city perimeters of the provincial level is more obvious. The cities such as Jiangning (Nanjing) and Shuntian (Beijing) were the largest, whose perimeter was 33.5 km and 32.8 km, respectively. It was 6.5 times that of the smallest ones such as Guiyang, Yunnan and Anqing (5.2 km). 3) In most provinces, the averaged perimeter of the cities at the district level, was 5 to 10 li, about 7.2.2%; and only 5 longer than 10 li, which were the provinces of Zhili, Jiangsu, Shandong, Zhejiang and Fujian. 4) the difference among the averaged city perimeter at the county level was comparatively small. In most provinces, the perimeter was 4 to 6 li (72.2%), and the rest 5 were all shorter than 4 li in the provinces of Hunan, Guangdong, Guangxi, Yunnan and Guizhou.

3.3 Estimation of the urban land use area

Estimation of the urban land use area is based on the conversion from the perimeter to the built-up area of the city. The following are the calculation methods. Most of the cities in the Qing Dynasty were approximately in the shapes of rectangle, square, circle or ellipse, although exceptions existed. Thus the area of the city may be calculated by the geometrical formula for area according its shape. In order to reduce the error in the course of calculation as possible as we could, the area of the 18 provincial capital cities are calculated one by one in terms of their shapes. For example, the shape of Kaifeng was approximately square, so the area of the city is calculated by $S = C^2 \cdot L^2 / 64$ (where S is area, whose units are km²; L is perimeter, whose unit is li of Qing Dynasty; and C is the converting coefficient from li of the Qing Dynasty to km². The followings are the same) with the result 8.29 km². In the same way, the area of Xi'an was 12.1 km², which was only 5.2% d

ifferent from the measured data. As for the estimation of the area at district and county levels in each province, variety of the shapes of individual cities is neglected. The average city perimeter is used to calculate the areas of square ($S = C^2 \cdot L^2 / 64$) and circularity ($S = C^2 \cdot L^2 / 16\pi$) respectively. The average of the calculated areas of square and circularity plus the number of the cities at the level is the urban land use area in a province at district or county levels. Theoretically, the total area obtained by the average area calculated from the average city perimeter plus the number of cities should be smaller than that by accumulating the city area one by one. The differences between the area estimated from the average city perimeter and the area calculated by accumulating the city area one by one are compared in the provinces of Zhejiang and Shandong at a district level. It is found that the area estimated from the average city perimeter is 14.7% and 17.8% smaller in the two provinces. Similarly, the area estimated at the county level in the Hubei Province is 13.2% smaller than that calculated one by one. Therefore, 16% and 14% are used to adjust the urban land use area estimated by the average city perimeter at the district and county level in each province respectively (Table 3). The results showed that the total urban land use area of the 18 provinces in the Emperor Jiaqing in Qing Dynasty was 1,987.44 km², only 0.05% of the total area. In the urban land use area, the land occupied by provincial capital city was 242.92 km², 12.2% of the total urban land use area; and the cities at district and county levels occupied 687.61 km² and 1,056.91 km², or 34.6% and 53.2% of the total area, respectively. In the 18 provinces, the urban land use area of Zhili Province was the largest, 316.34 km²; while the area of Guangxi Province was the smallest and only had 27.92 km². There were six provinces whose urban land use area was 100 to 200 km², namely Shanxi, Shandong, Henan, Jiangsu, Zhejiang and Sichuan; eight provinces whose areas were 50 to 100 km², namely Anhui, Gansu, Shaanxi, Jiangxi, Hubei, Hunan, Fujian and Guangdong; and three were below 50 km², namely Guangxi, Yunnan and Guizhou in Southwest China.

4 Regional differences of urban land use in the Qing Dynasty

The total amount of urban land use in a region depends on the size of city and number of cities which are different obviously due to differences of natural conditions, social economy and status of politics and military affairs. In order to reveal the regional differences of urban land use in the 18 provinces in Qing Dynasty, four indexes are selected, i.e., the total urban land use area, city size (the average city perimeter at a district level), density of cities, and percentage of urban land use area in the total area of the province (Table 4). It is showed that there were obvious regional differences of urban land use among the 18 provinces in the Emperor Jiaqing of the Qing Dynasty. The main characteristics are as follows: First, all of the four indexes indicated that, generally speaking, urban land use area in northern China was larger than that in southern China, and that in eastern China was larger than that in western China. The total urban land use area was more than 100 km² in the six provinces in northern China (Zhili, Shanxi, Shaanxi, Shandong, Henan and Gansu) except that of Gansu. The urban land use area in Zhili reached 316.34 km². While in the 12 provinces in southern China, most of the urban land use area was less than 100 km². The percentage of the urban land use area in the total area was generally more than the national average 0.049% in northern China, while in much of southern China it was less than the national average. The percentage of the urban land use area in the total area was more than 0.035% in the 12 provinces in eastern China's Shanxi, Henan, Hubei, Hunan, Guangdong and those east to them); while that in western China (Gansu, Shaanxi, Sichuan, Guizhou, Yunnan and Guangxi) was less than 0.03%. As far as the city density is concerned, it was mostly higher than 5 cities/104 km² in northern China, and mostly 3-5 cities/104 km² in southern China; it was 4 to 7 cities/104 km² in eastern China, while less than 4 cities/104 km² except Guizhou Province in western China. In the aspect of city size, the average city perimeter was more than 8 li in the six provincial capital cities in northern China; while in the 12 provinces in southern China, only 5 of whose perimeter was over 8 li, and those of the remaining 7 were all below 8 li. Second, all of the four indexes in the provinces of Zhili in North China, Shaanxi in Northwest China, Sichuan in Southwest China, Jiangsu and Zhejiang south to the Yangtse River were much larger than the others, which embodied their position as the regional center of politics, economy and culture. Third, all of the four indexes in the three provinces in Southwest China (Yunnan, Guizhou and Guangxi) were less than those of others obviously. City systems in the three provinces developed slowest in the Qing Dynasty. Urban land use area was only 30-40 km² in the three provinces. The city perimeter at the district level was only more than 5 li. And the percentage of urban land use area in the total area was 0.009%, 0.003% and 0.012%, respectively.

5 Comparison with modern urban land use

As one of the major forms of land use by the human activities, the urban land use increases rapidly in recent decades with the increases of population and the continuous achievement of industrialization and urbanization. In some regions, urban land use even dominates the land use/cover changes induced a great amount of forestland and grassland disappeared. In order to understand the character of such a changing process in China, comparison of the urban land use in the Qing Dynasty with modern urban land use is made (Figures 1, 2 and 3). Figure 1 showed the city density above county level in the Emperor Jiaqing of the Qing Dynasty and in modern times. It indicates that t

he city density of all the provinces except Guizhou increased in a small extent. The 18 provinces in the Emperor Jiaqing included 1,751 districts and counties altogether, while in the same regions in 1999 belonged to 24 provinces have 2,486 cities at the same level (NBS, 1999). The total number of cities only increased by 0.46 times. The city density increased from 4.31 cities/104 km² in the Qing Dynasty to 6.29 cities/104 km² nowadays, only increased by 2 cities/104 km². The city density of Zhili (including Beijing, Tianjin and Hebei of today) and Anhui Province increased 1.43 and 1.08 times of that in Qing Dynasty, respectively. Zhejiang and Shanxi only increased 0.03 times. Most provinces increased 0.3-0.6 times. The urban land use area and its percentage in the total area increased greatly. The urban land use area in the Qing Dynasty was 1,987.44 km², 0.05% of the total land area; while that in 1999 increased to 14,116 km² (after National Survey Office on Land Resource, Gathering Table of Surveying Data on National Land Use, 1999) and was 0.36% of the total area. That is the area had increased by more than 6 times in recent 200 years. The increase of the urban land use area was more than 9.0 times in the 5 provinces of Guangdong, Hubei, Guangxi, Hunan and Shandong, by 14.78, 13.30, 11.43, 9.58 and 9.47 times, respectively. In Zhejiang, Fujian and Shaanxi, the increase was less than 3.0 times, by 1.85, 2.33 and 2.75 times, respectively. In the remaining provinces, the increase was 3-7 times (Figure 2). The increase in the percentage of the urban land use area in the total area was the same. That is the provinces increasing more than 9.0 times are Guangdong (16.14), Hubei (12.96), Guangxi (10.87) and Hunan (10.16); and less than 3.0 were the five provinces of Zhejiang (1.63), Fujian (2.14), Shaanxi (2.46), Guizhou (2.65) and Shanxi (2.97); and the remaining provinces increased 4 and 9 times (Figure 3).

6 Conclusions and discussion

(1) It is reasonable to estimate the urban land use area in historical periods based on the data of the administration system, amount of cities and the city perimeter recorded in the historical literatures. The results can reflect the urban land use to some extent in the history. (2) According to the estimated results, the total urban land use area of the 18 provinces in the Emperor Jiaqing in the Qing Dynasty was 1,987.44 km², only 0.05% of the total area. The urban land use area in Zhili Province and Jiangsu Province was bigger, which was 316.34 km² and 185.77 km², or 0.097% and 0.188% of the provincial area, respectively. The urban land use area in Guangxi Province and Guizhou Province was smaller, which was only 27.92 km² and 32.78 km², 0.012% and 0.033% of the provincial area, respectively. (3) There were obvious regional differences in spatial distribution of the urban land use area among the 18 provinces in the Qing Dynasty. The characteristics were that, that in northern China was more than that in southern China, that in the east was more than that in the west, and that in southwestern China was the smallest. In addition, as the regional center of politics, economy and culture, all of the four indexes in the provinces of Zhili, Shaanxi, Sichuan, Jiangsu and Zhejiang were larger than the others. (4) Compared with the modern urban land use data, it is realized that the increase of the urban land use area was mainly by the enlargement of the city size. With the enlargement of the cities, amounts of forestland, grassland and cultivated land were occupied by the urban land use. In the past 200 years, the city density only increased by 0.42 times, while the total area of urban land use enlarged by more than 6 times. The percentage of the urban land use area in the total area reached 0.36% nowadays from 0.05% in 1820s.

关键词: urban land use; area estimation; Qing Dynasty; China