Journal of Geographical Sciences 15, 1 (2005) 106–114 ISSN: 1009–637X www.geog.cn

Landscape pattern dynamics of water body in Kaifeng city in the 20th century

CAO Xinxiang[1, 2], *DING Shengyan*[3]
(1. Research Institute of Yellow River Culture and Sustainable Development, Henan University, Kaifeng 475001, China; 2. College of History and Culture, Henan University, Kaifeng 475001, China; 3. College of Environment and Planning, Henan University, Kaifeng 475001, China)

Abstract: Landscape spatial pattern mainly refers to the distribution of patches, which are different in size and shape in space owing to the interaction of various ecological activities. In landscape ecology study, landscape pattern has been one of the key study areas. Water body landscape plays an important role in the development history of a city, but at present city water body landscape in many cities has been destroyed, hence protecting water body in the city is becoming more and more important. In order to protect city water body landscape reasonably, the precondition is to probe the dynamics of water body landscape. Based on historical data and remote sensing data, six indexes including patch number, patch area, landscape dominance index, fractal dimension, patch density and connectivity index etc. were used to analyze landscape pattern dynamics of water body in Kaifeng city since the end of the Qing Dynasty (in the 20th century). The results showed: (1) Since the end of the Qing Dynasty, landscape area of water body in Kaifeng city increased first and then decreased from 1898 to 2002AD; the landscape dominant degree had the same changing tendency with the area. (2) Patch number of water body landscape in Kaifeng city had an increase from 1898 to 2002, but maximum area of patch, minimum area of patch and average area of patch decreased, which resulted in an increase in landscape fragment degree. (3) Connectivity index decreased and fractal dimension increased from 1898 to 2002. The reasons for these changes were the repeated overflows and flooding of the Yellow River and the influence of human activities.

Key words: landscape pattern; water body; dynamics; Kaifeng city; the early 20th century
doi: 10.1360/gs050113

1 Introduction

Landscape pattern is a spatial arrangement and combination form of various landscape elements, which are different in size and shape. It includes the type, number, space distribution and arrangement of landscape element (Wang, 1995; Wu, 2000). Landscape pattern is not only the detailed embodiment of landscape heterogeneity, but also the result of all kinds of ecological processes in different scales (Xiao *et al*., 1997). Landscape pattern determines the distribution, form, constitute of landscape resource, affects the transformation of energy flow, substance cycle and species flow inside landscape, so it has a consanguineous relationship with the abilities of anti-jamming, restoration, stability, and biodiversity of ecosystem, constricting various kinds of ecological processes (Li *et al*., 1999). But the landscape pattern is in the developing and changing process, and the present pattern took shape based on the past landscape flows, including natural, social, economic and various kinds of ecological processes. Therefore through analyzing the landscape pattern changes with time, we can reflect the landscape ecological processes, expound landscape succession mechanism and rules, predict the variation tendency of the future landscape, and realize the sustainable utilization of landscape resource eventually (Zhao, 1993; Wang *et al*., 1996; Chen *et al*., 1996; Fu *et al*., 1995; Ding *et al*., 2003).

At present, the study on landscape pattern mainly focuses on two aspects (Zhang, 2003): (1)

Received: 2004-08-03 **Accepted:** 2004-11-20
Foundation: The Key Project of Henan Province
Author: Cao Xinxiang (1978-), specialized in landscape ecology and tourism ecology. E-mail: caoxx302@163.com

space heterogeneity of landscape pattern, namely for the analyses of landscape indexes and space statistical characters; and (2) time heterogeneity of landscape pattern, namely the dynamics of landscape pattern. Space heterogeneity is an analysis of static state of landscape pattern, a reflection of time heterogeneity and the study base of landscape dynamics. Time heterogeneity is an analysis of dynamic state of landscape pattern. It can better reveal the dynamic law of landscape pattern and forecast the changing trend, so it is of more theoretical and practical significance to the study on the spatial dynamics of landscape pattern.

Water body landscape in the city is the most important green opened-space and a region with densest natural elements and most complicated physical process. It plays an important role in the formation and development of cities (Yu *et al*., 2003). But since the Industrial Revolution, the water body landscape in the city has been in a constant destruction and development state because of people's incorrect consciousness, and how to protect water body landscape in the city has became a necessity of city development and a historical mission. To protect water body landscape in the city, it was necessary to understand reasonably the dynamics of water body landscape patterns in the city and its whys (Cai, 1985). Based on the principles and methods of landscape ecology and historical geography, Erdas and Mapinfo software, adopting system analyses and integration study methods, quantitative and qualitative methods, dynamics and its reasons for the water body landscape patterns in Kaifeng city since the end of the Qing Dynasty was analyzed.

2 The formation of water body landscape pattern in Kaifeng city

Kaifeng city is located in the margin of Great Plain in eastern Henan Province and southern part of the alluvium fan of middle and lower reaches of the Yellow River. It backs the Yellow River to the north and connects the Huang-Huai-Hai Plain to the south. Geological structure is situated in the south of North China platform, belonging to North China down-warped basin. Topographically, the surface relief declines from northwest to southeast with a mean altitude ranging between 69 m and 78 m and a gradient of 1/1000 to 1/2000. For a long period of time, the topographic relief near Kaifeng city had less changes and lower altitude because of the cooperative effect of the Yellow River's alluviation and the North China Plain's sedimentation. During the ancient times the average altitude of Kaifeng city was less than 70 m and the gradient to the sea merely 1/8000 with not much difference in altitude change between ancient times and today (Li, 1985). Zhang Yi, born in the Warring States Period, described the topography of Kaifeng city: The topography of Wei State was plain without famous mountains and big rivers (Liu, 1985).

The physiognomy of ancient Kaifeng city was characterized by broad plain mingled with sand dunes, sand hillock and undulating sandlot, which was covered by loose sand layer as a result of flooding and deposition of the Yellow River (Bureau of Houses and Lands, 1998). This kind of landforms led the rivers near Kaifeng city to flow from northwest to southeast into Huaihe River and created a favorable condition for digging man-made canal.

The climate in Kaifeng city belongs to continental monsoonal climate. It is cold in winter and warm in spring; hot in summer and cool in autumn, a clear-cut four seasons. In Kaifeng city, the average sunshine duration is 2267 h, average sunshine percentage is 51, gross annual solar radiation is 114.5 KJ/cm^2, annual mean precipitation is 627.5 mm and annual mean temperature is 16.2 ºC. In ancient times, it was warmer in Kaifeng city and there were flourishing plants and higher temperature. According to historical climate research, the temperature was 3-5 ºC higher than the present day, the annual average rainfall was about 1000 mm and the climate belonged to north sub-tropical one (Zhu, 1972), bringing about sufficient water source for the rivers and lakes near Kaifeng city.

The well-developed drainage system near the ancient city of Kaifeng and crisscrossed rivers and lakes make it known as "the land flooded with water" because of advantageous topography and abundant rainfall. According to historical records, there were 10 rivers near ancient Kaifeng, including the Yellow River, Jihe River and Huaihe River which were called "three ditches among four ones". There were also many lakes near the ancient city including Daye damp, Putian damp, Mengzhu damp and Ying damp (Li, 1956; Li, 1988) (Figure 1). In the Northern Song Dynasty, Kaifeng (Dongjing was called in the Song Dynasty) was very famous for its numerous rivers and lakes, "Bianjing eight sights" were a reflection of the beautiful water body landscape. Among the Bianjing eight sights, there were four describing waterscapes: golden pond and night rain; Zhou bridge and bright moon; sound of Bian water in summer, and smoke from kitchen chimneys willows in Sui bank (Chen, 1982). But Kaifeng was located in the middle and lower reaches of the Yellow River and often suffered overflow and burst of the dikes of the Yellow River, together with the ceaseless changing position of the city and the influence of human activities, water body landscape was seriously damaged, at the same time, much water area came into being in the low-lying depressions. After the founding of the People's Republic of China in 1949 city water body landscape again gained ruins because of some irrational guidelines and policies concerning city construction. At present water area covers 1.69 km^2 in the 13 km^2 of ancient Kaifeng block including Baogong lake, Longting lake, Tieta lake, Yangguang lake and Northwest lake, accounting for 11.2% of the ancient city block area

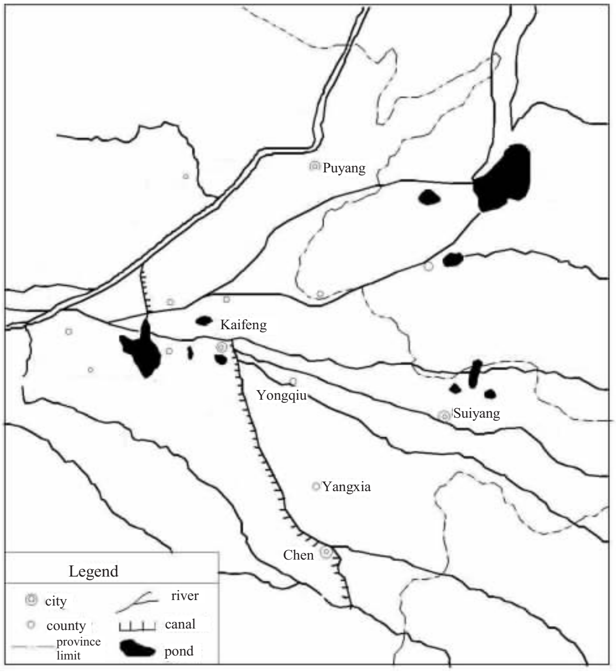

Figure 1 The location of Kaifeng and water body near ancient lower reach of the Yellow River

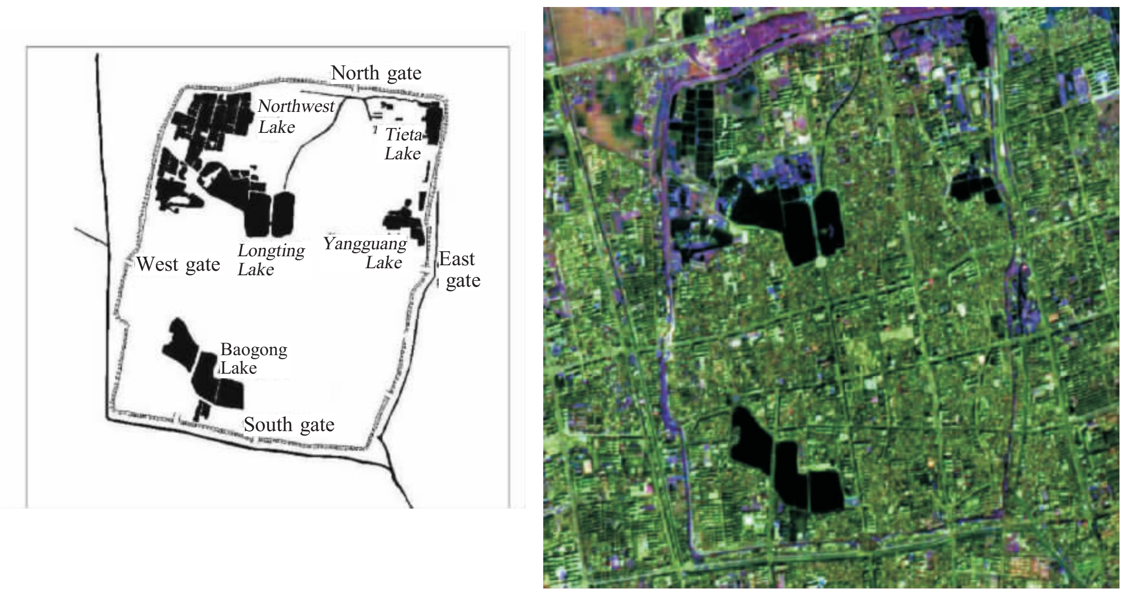

Figure 2 Water body distribution in modern Kaifeng city

(Figure 2). In addition, there are 112 waterways in Kaifeng city, including 32 ones with a drainage area of over 100 km^2 each, such as the Yellow River, Wohe river, Huiji river, Jialu river and 47 inlet channels. Thus it is of very representativeness taking Kaifeng as a research object.

3 Materials and methods

3.1 Data sources

The data of this paper derived from below: (1) the atlases of Kaifeng city in 1898, 1914, 1919, 1948, 1988 and 2002 from Kaifeng City Construction Bureau and the College of Planning and Designing; (2) TM image on March 11, 1988 and ETM image on March 29 (124/036) provided by the ground satellite station of remote sensing of CAS; and (3) data on the landscape changes of water body in Kaifeng city from field investigations and some historical data such as Kaifeng land annals, Kaifeng city history and Kaifeng city construction annals from the departments concerned in Kaifeng city.

3.2 Data processing

Based on relevant historical records and data from field investigations we found the city wall and the patterns of main streets in Kaifeng city have remained unchanged since the reign of Emperor Guangxu in the Qing Dynasty (Cao *et al.*, 2003). For example, compared with the map of Xiangfu County in the 24th year of Emperor Guangxu (1898), the maps of Kaifeng government office in the 3rd year of the Republic of China (1914), the map of Kaifeng streets and blocks in the eighth of the Republic of China (1919) and the map of Kaifeng city in 1948 with the ward map of Kaifeng city in 2003, the patterns of the main streets and the city wall kept unchanged, and the position of the city wall did not displace since the Ming and Qing dynasties. What is more, its perimeter and length were measured in 1999 (Liu, 2003), so the scale of the maps in 1898, 1914, 1919 and 1948 could be measured. According to the scale, with the help of AutoCAD software, the perimeter and area of the water body landscape could be calculated. Since the 1990s, the protection of water body landscape has been launched, so the area of water body in Kaifeng city has less changes. In order to calculate conveniently, we chose the remote sensing images of 1988 and 2002 as the study object after the 1980s. The remote sensing images were analyzed with the help of Erdas and ArcGIS software and we referred to the planning maps of Kaifeng city in 1998 during the course of calculation.

3.3 Landscape indexes applied in the paper

Landscape index including highly condensed landscape pattern information is a kind of simply quantitative index reflected the structure makeup and space deploy of landscape (O'Neil, 1988; Turner, 1990; Li *et al.*, 1992). Applying landscape index can show quantitative changes of water body landscape pattern. Patch number and mean patch area; fractal dimension; type area and total area; fragment index; landscape connectivity index, maximum patch area and minimum patch area etc. were chosen in this paper.

(1) Patch Number (NP): $EN = n_i$, $NP = N$, including the total number of patches of all landscapes and the number of some single types.

(2) Patch Area (CA): $CA = \sum_{j=1}^{n} a_{ij} \left(\frac{1}{10000}\right)$, CA is the most basic space characteristics of landscape patterns, and the foundation of other space characteristics indexes that is to be calculated. The size of the patch not only influences the distribution of the nutrition and energy within the landscape components, but also influences species forming and diversity in the landscape.

(3) Patch Density (PD): $PD = 10^6 N/A$. PD can reflect the fragment degree of landscape and heterogeneity. For example, the bigger PD is, the bigger the fragment degree and heterogeneity are.

(4) Mean Patch Fractal Dimension (P): $P = kA^{Fd/2}$, namely, $F_d = 2\ln(p/k)\ln(A)$. The complexity degree of patch shape can be measured by P. P is between 1.0 and 2.0. When p is 1.0, it represents a square patch which is most simple and 2.0 does a circle one which is most complex.

(5) Landscape Dominance Index (P_i): $P_i = \sum_{i=1}^{n} a_{ij}/A \times 100$. P_i can be used for measuring the departure degree between landscape diversity and maximum landscape diversity or describing the degree that the landscape is dominated by several main landscape types. In this paper, landscape percentage is used to present landscape dominance degree and its value is between 0 and 100. When P_i is 0, it shows the proportion of each type of landscape in landscape is equal. When P_i is 100, it shows landscape is not heterogeneity, namely landscape is made up of a kind of landscape.

(6) Landscape Connectivity Index (r): $r = L/L_{max} = L/3(V - 2)$. Landscape Connectivity Index is a relation of space structure between landscape element which can be represented from the patch shape, patch area, distance between the same patch and the corridor is be or not. In this paper, corridor network connectivity index is used to represent Landscape Connectivity Index and it was defined as follows: the proportion between corridor number and maximum corridor number can be connected in a network.

In the above formulation, n_i represents the number of patches, a_{ij} represents the area of the j pieces of patch in the i type, A represents the whole area of landscape, P_i represents the circumference of the patch, N represents the total number of patches, L represents the number of corridors and V represents the number of nodes.

4 Results and analyses

4.1 The change and whys of landscape area of water body in Kaifeng city

Based on the disposal data, landscape area of water body in Kaifeng city increased from 190.3 ha to 480 ha between 1898 and 1966 and then decreased to 169.6 ha from 1966 to 2002, which was 35% of the figure in 1966. The landscape dominant degree had the same change tendency with the area increasing from 14.6% to 36.9% between 1898 and 1966 and decreasing to 13.05% in 2002 (Table 1). According to relevant historical data (the group of Kaifeng city construction annals, 1989), there were 480 ha of pits, ponds and washes in Kaifeng city in 1966 including those in front of the Kaifeng No.1 Middle School, Henan University etc. But after 1966, many pits, ponds and washes were filled and imbedded because of blurry cognition then and there, which led to a rapid drop of water body landscape area. According to statistics, there were 190.9 ha of rivers and lakes, taking up 35% of that of 1966 including 128 ha of Longting lake, 8.4 ha of Tieta Lake and 42.4 ha of Baogong lake etc. (Figure 3).

Because of repeated overflows and deluges of the Yellow River since the Northern Song Dynasty, many low-lying areas in Kaifeng city changed into lakes by seeper which resulted in an

Table 1 Landscape indexes of water body landscape pattern from 1898 to 2002

Year	Total area	Patch number	Average area	Max area	Min area	Connectivity	Fractal dimension	Patch density	Dominance degree
1898	190.31	4	47.58	163.5	2.56	0.40	1.134	2.1	14.6
1914	224.90	22	10.22	58.43	0.34	0.36	1.146	9.7	17.3
1919	282.41	33	8.56	66.37	0.18	0.32	1.234	11.6	21.7
1966	480.00			128.0					36.9
1971	201.56	21	9.60	41.99	0.90	0.32	1.162	10.4	15.5
1988	196.91	43	4.58	42.40	0.16	0.30	1.213	21.8	15.1
1998	171.99	76	2.26	44.99	0.09	0.24	1.209	44.1	13.2
2002	169.65	84	1.95	36.00	0.01	0.28	1.201	49.54	13.05

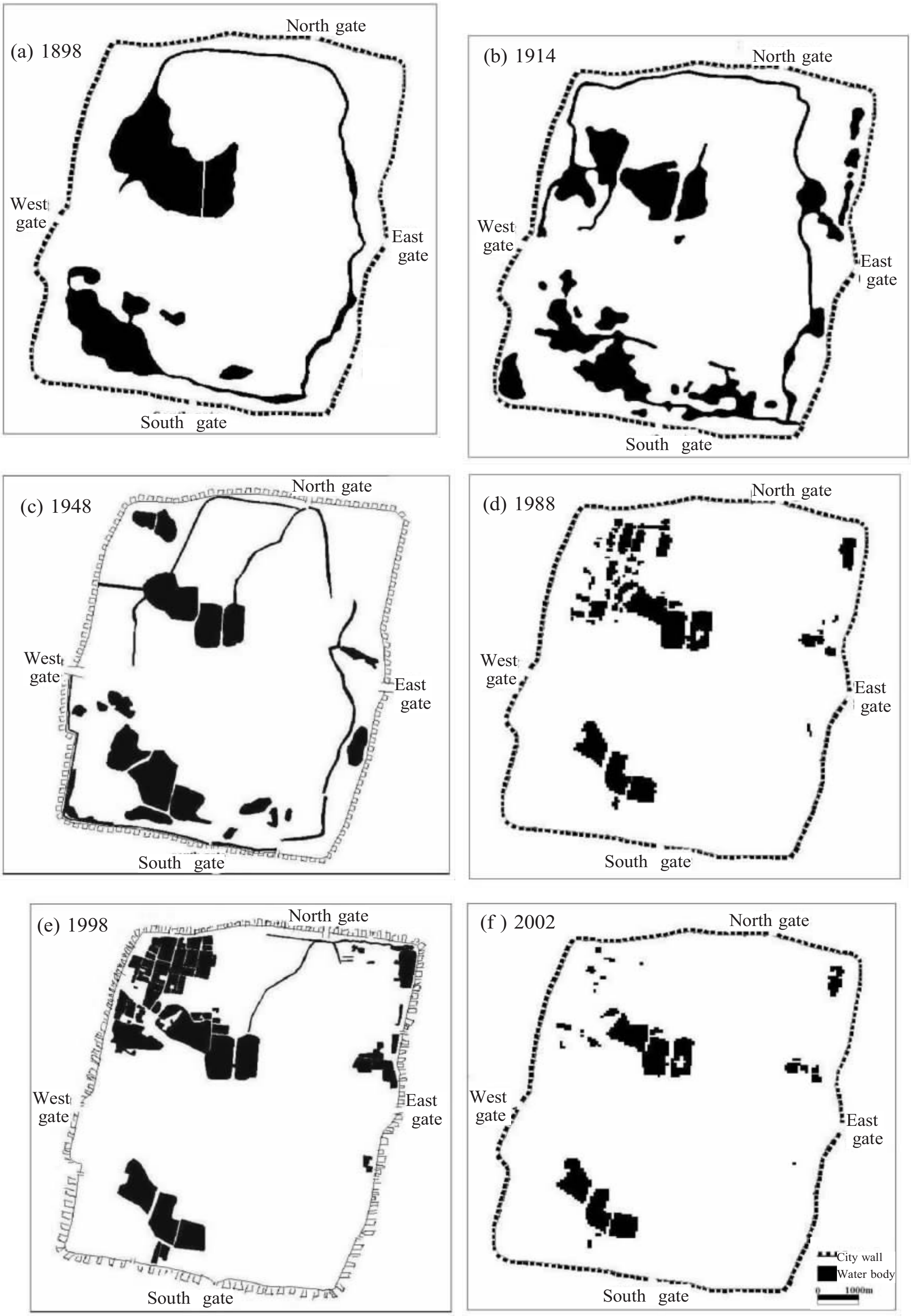

Figure 3 Distribution of water area in Kaifeng since 1898

increase of water body area in the city block in Kaifeng city. According to statistics, there were 338 times of overflows during the period from the burst in Jingdong Zhao of Kaifeng County in the Jin Dynasty (AD 1180) to the burst in Rong village of Weishi County in the 33rd year of the Republic of China (AD 1944), once averaged over two years, if the burst outside Kaifeng city was considered, there would be many times of disasters in Kaifeng city. Kaifeng city was flooded four times and surrounded by flood 15 times. All these exerted great impact to the formation and development of Kaifeng city, and also to the evolution of landscape pattern of water body of the city.

When new China came into existence in 1949, Kaifeng was a scene of devastation everywhere and full-scale construction was under way. In order to adapt to the needs for economic construction, a series of policies for urban development of Kaifeng were formulated, including: city planning in 1956 included the scheme of pushing aside city wall and filling and leveling up puddle and billabong in order to add inhabitation area; in 1958, Kaifeng city set up many small and medium-sized factories according to the guidelines of constructing Kaifeng city into an integrated city of machinery, chemistry, textile, food and instrument and built 86 factories including large, small and medium-sized ones. The guidelines played an accelerating role in the industrial development and Kaifeng city took on a new look. However, in the process of economic development, many water areas were filled up in order to build houses and factories, which resulted in a decrease of water body area and affected prevention or control of flood and drainage of waterlogged fields.

In the 1970s and the 1980s, considering the importance of water body landscape in the urban development, especially in the cities of North China, the then municipal government of Kaifeng put forward three countermeasures to protect and exploit city water body landscape: (1) The lakes, pits and depression which need to be protected should be properly refitted and could not be arbitrarily filled in order to store and drain water and beautify environment. (2) The lakes, pits and depression which need not to be protected would be arranged and utilized by municipal government in a planned way through warping by water diversion of the Yellow River. (3) The small ponds and depressions which need not to be protected are transferred to units that need land and can use them freely. All these measures can help to slow down decrease of water body area. In recent years, the municipal government of Kaifeng has taken actions to protect and manage urban water body landscape in order to bring into play the characteristics of water city in North China and promote the development of tourism, which made water body area reduce by inches, but with rapid urbanization process, the area of water landscape is still decreasing.

4.2 The change of fragment degree of patches and whys

The fragment of landscape can be reflected by some indexes, such as patch number, mean patch area, the maximum and minimum areas of patch etc. (Fu *et al*., 2001). From Table 1 we can find patch number of water body increases, the maximum and minimum areas of patch decreased, but the increase of patch density indicates the fragment degree of landscape increases. According to historical records, before 1949, water body was distributed almost in connections in Kaifeng city with large patches but less patch number. But after 1949, many water bodies were destroyed with constant increase of human activities and urban development, especially in recent years, in order to add the number of fishing ponds, the Northwest Lake was reconstructed ceaselessly which resulted in the increase of the patch number.

4.3 The change of landscape connectivity and whys

The continuity of water body landscape pattern is very important for adjusting city climate, shaping city landscape and conserving city biodiversity. Merely in the sense of ecology, the continuity of a water body landscape can reduce habitat isolation; increase open space and the connectivity between habitat patches; ensure the integrity and continuity of physical ecologic process; reduce the resistance of survival, moving and distribution of city biology and provide more habitats and bigger survival space; increase the chance of gene change between organisms which had an advantage to protect city biodiversity, so the integrity of water body landscape pattern was paid much attention to the construction of city ecology. At present, many city water bodies were destroyed, which results in city water environmental deterioration and the destruction of integrality. The landscape connectivity of water body in Kaifeng city has been continually declining since 1898; only in recent years an increasing trend has occurred (Table 1 and Figure 3).

Before 1949, water body in Kaifeng was uninterrupted (this could be shown in Table 1). But after 1949, many river corridors and lake patches were filled because of large scale economic construction and the limitation of people's consciousness, for example, Huiji River was filled up in the late 1970s and the early 1980s, which led to a decrease of continuity of water body landscape pattern. Since the 1990s, the target of building Kaifeng city into an excellent tourism city and a garden city has been initiated. Accordingly, as essential tourism resources in the city's economic construction, has been attached much importance, many rivers, lakes and gardens such as Qingmingshanghe garden, Jinming pond and west Shuncheng river were further opened or excavated, the plan of renewing the water system was implemented (Figure 4), which has improved the continuity of water body landscape pattern.

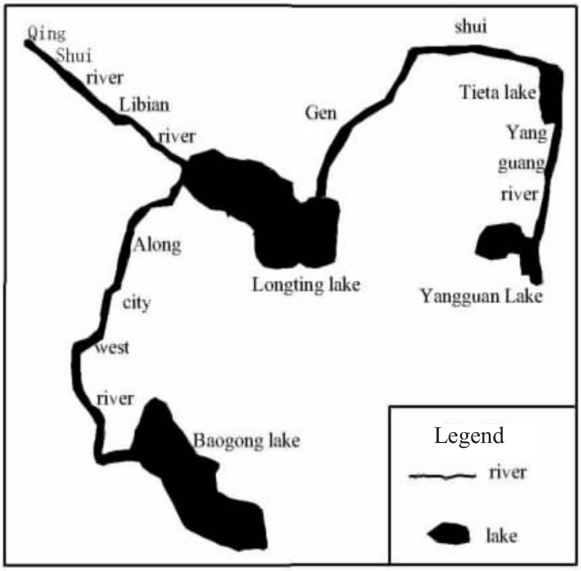

Figure 4 Recovery planning of water system in Kaifeng city

4.4 The change of fractal dimension and whys

Fractal dimension serves as a good indicator of the changes of landscape spatial patterns. The value of fractal dimension reflects the abnormity and fragment degree of patch or landscape. Commonly, the more abnormal or fragmentized of patch or landscape is, the bigger the fractal dimension is, and vice versa. The change of fractal dimension can reflect the space change of patch in time dimension. As showed in Table 1, the fractal dimension of water body landscape in Kaifeng city from 1898 to 2002 increased gradually, but decreased in recent years. Because of the importance of water body landscape to the development of the city, water body landscape was protected and renovated, which resulted in a decrease of fractal dimension.

5 Conclusions and discussion

Based on the principles and methods of historical geography and landscape ecology, the dynamics of water body landscape were analyzed in Kaifeng city from the turn of the 20th century. The objective of research is to reveal the mechanism and law of water dynamics and put forward some references for realizing sustainable utilization of water body landscape resources. The research results are as follows: (1) Since the end of the Qing Dynasty, landscape area of water body in Kaifeng city had increased and then decreased from 1898 to 2002; the landscape dominant degree had the same changing tendency with the area. (2) Patch numbers of water body landscape in Kaifeng city increased from 1898 to 2002, but the maximum area, minimum area and average area of the patches decreased, which resulted in an increase in landscape fragment degree. (3) Connectivity index decreased and fractal dimension increased from 1898 to 2002. The reasons for these changes were the repeated overflows and flooding of the Yellow River and human activities. (4) The factors affecting the dynamics of water body landscape pattern in Kaifeng city included physical ones and man-made one. But before the founding of the

People's Republic of China in 1949, the influences of the Yellow River took the lead and after 1949 human activities dominated.

Based on historical data and TM images, with the help of GIS and landscape indexes the analyses for dynamics of water body landscape pattern was attempted by breaking through the traditional research methods of historical geography and putting forward some theories thereunder and research methods for the study of the dynamics of city water body landscape. But there still exist many differences between drawing precision in historical period and different rate of TM images, and how to integrate them would be a key to the studies on water body landscape pattern dynamics. Besides, the deformity of historical data and qualitative study methods would need to be paid much attention to the dredging up and retrieving data and doing quantitative study.

References

Bureau of Houses and Lands, 1998. Land Annals of Kaifeng City. Zhengzhou: Zhongzhou Ancient Books Publishing House, 32. (in Chinese)

Cai Fan, 1985. Ancient Canal of Beijing City and City Water Supply. Beijing: Beijing Press, 1. (in Chinese)

Cao Xinxiang, 2003. The tourism exploitation thinking of ancient city wall of Kaifeng city. *Modern City Research*, (5): 74-76. (in Chinese)

Chen Daiguang, 1982. Kaifeng in the Northern Song Dynasty. *Geographical Knowledge*, (2): 6-8. (in Chinese)

Chen Lixiang, Fu Bojie, 1996. Influences of human activities on landscape structure in the loess area. *Acta Ecologica Sinica*, 16(4): 337-344. (in Chinese)

Ding Shengyan, Cao Xinxiang, 2004. Landscape pattern dynamics of water body in Kaifeng city since the end of the Qing Dynasty. *Acta Geographica Sinica*, 59(6): 956-963. (in Chinese)

Ding Shengyan, Qian Lexiang, Cao Xinxiang *et al.*, 2003. Forest landscape patterns dynamics and analysis of its driving forces in Luoning County, Henan Province. *Acta Geographica Sinica*, 52(3): 552-559. (in Chinese)

Fu Bojie, 1995. The spatial pattern analysis of agricultural landscape in the loess area. *Acta Ecologica Sinica*, 15 (2): 113-119. (in Chinese)

Fu Bojie, Chen Lixiang, Ma Keming *et al.*, 2001. The Principles and Application of Landscape Ecology. Beijing: Science Press. (in Chinese)

Li Changfu, 1956. Historical Geography of Kaifeng City. Beijing: The Commercial Press. (in Chinese)

Li Habin, Wu Yegang, 1992. Quantity Methods of Landscape. Beijing: China Science and Technology Press, 209-233. (in Chinese)

Li Runtian, 1988. Influences of Yellow River on the historical development of Kaifeng City. *Historical Geography*, (6): 45-56. (in Chinese)

Li Xiaowen, Xiao Duning, 1999. Landscape ecology and biodiversity conservation. *Acta Ecologica Sinica*, 19(3): 399-407. (in Chinese)

Liu Shun'an, 2003. The City Wall of Kaifeng City. Beijing: Yanshan Press. (in Chinese)

Liu Xiang, 1985. Zhanguo Plan. Shanghai: Shanghai Classics Publishing House. (in Chinese)

O'Neil R V, Krummel J R, 1988. Indices of landscape pattern. *Landscape Ecology*, (1): 153-162.

Turner M G, 1990. Spatial and temporal analysis of landscape patterns. *Landscape Ecology*, (4): 21-30.

The Group of Kaifeng City Construction Annals, 1989. Annals of Kaifeng City Construction. Zhengzhou: Surveying and Mapping Press. (in Chinese)

Wang Xianli, Hu Yuanman, 1996. Analysis of wetland landscape changes in Liaohe Delta. *Scientia Geographica Sinica*, 16(3): 260-265. (in Chinese)

Wang Yanglin, 1995. Pattern and Process: The Theory Frontier of Landscape. Beijing: China Science and Technology Press, 437-441. (in Chinese)

Wu Jianguo, 2000. Landscape Ecology: Pattern, Process, Scale and Hierarchy. Beijing: Higher Education Press. (in Chinese)

Xiao Duning, Li Xiuzhen, 1997. Spatial ecology and landscape heterogeneity. *Acta Ecologica Sinica*, 17 (5): 453-461. (in Chinese)

Yu Kongjian, Li Dihua, 2003. Dredge and beauty of city waterways and waterfront. *Modern City Research*, (5): 29-32. (in Chinese)

Zhao Yi, 1993. Landscape pattern changes and influences on environment of Dongling area in Shenyang City. *Metropolitan and Planning* (Taiwan), 20(1): 75-87. (in Chinese)

Zhang Qiuju, 2003. Several problems of landscape patterns dynamics. *Scientia Geographica Sinica*, 23(3): 264-270. (in Chinese)

Zhu Kezhen, 1972. Climate changes of about 5000 years in China. *Acta Archaeologica Sinica*, (1): 65-71. (in Chinese)