Assessing Changes in Green Space of Suzhou City using Remote-Sensing Images and Landscape Metrics

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***Abstract* — In order to explore the change of Green Space in Suzhou, a central City in China's Yangtze River Delta, and reveal the spatial characteristics, ecological benefits and its impact mechanism, this study extracted a distribution map of the patches of green spaces in Suzhou using Landsat remote-sensing image data from 1998 and 2007, analyzed and assessed the changes in scale and spatial layout of the green spaces using various landscape metrics including CA, PLAND, PD, MPS, LPI, NP, PD, TE, ED, MPI, and LSI. The result indicated that the scale of the green space and the number of the patches in Suzhou decreased significantly, the discrete degree of green space in each area increased in different extent, and the connectivity decreased clearly. More of the small green space patches have disappeared. The green space totally exhibited tendencies of decline and contraction. Green space patches were unevenly distributed in Suzhou. The green space patches in old urban area were founded to be less in quantity, poor in connectivity, and maximal in discrete distance. While the new urban area of Suzhou retained a large number of cultivated land, water and woodland, and there was no distinct rank difference from suburban country. In northern area like Taicang, Changshu and Zhangjiagang districts, the green space increased in scale, and it tended to be large, concentrated and stable in pattern. While in central and southern districts, the green space decreased in different level. Particularly, the green space of Wujiang and Kunshan in the southeast had the highest decrement rate, and the green space patterns turned to be fragmented for getting disturbed by urbanization.**

Keywords - remote-sensing; Landsat; green space; changes; Suzhou; landscape metrics

I. INTRODUCTION

Green spaces are important environmental resources that provide habitats for the subsistence and reproduction of wildlife, so green spaces protection is the main content of environment protection. A healthy green space system also plays a crucial role in promoting sustainable development of city and society. However, human activities and urbanization have had significant impacts on the scale and structure of green spaces, which are considered to undergo further changes as urban construction and development increase. During the process of urbanization, therefore, it is vital to protect and prevent degeneration of green spaces.

Environmental protection is the basis for sustainable urban development in China, green space protection is the main content of the protection. Suzhou is a famous historic city in China, at the same time is one of the important central cities in the Yangtze River Delta. In the process of urbanization, green scales and structures of green space in Suzhou have been greatly affected. The assessment of green space in Suzhou is the basis of environmental protection measures and the concept of sustainable development.

Remote-sensing data have been widely used to monitor green spaces in recent years that have contributed to quantitative analysis of the change of green space. This study analyzed the changes of green space in Suzhou, using Landsat remote-sensing image data, and evaluated the characteristics of the changes from the aspects of size and structure.

II. STATE OF THE ART

China is in the process of rapid urbanization, which have result a profound impact on the environment [1-3]. Since China implemented the Reform and Opening-Up Policy and transform to a market-oriented economy at the end of the 1970s, the factors of economic production and the movement of personnel are active. China's Yangtze River Delta region is densely populated, some of the famous ancient city, such as Suzhou, Nanjing, are important communities, have developed into big cities by the impact of urbanization, and green space resources have changed significantly [4-7].

Landsat remote-sensing data in recent years are applied to the land use, environmental monitoring and green space changes. Kachar and others used Landsat data to analyze and evaluate the Temporal Distribution Changes of the land surface temperature (LST) in Tehran [8]. Bagan and Yamagata used Landsat data to analyze the land use changes in 50 global cities from 1985 to 2010 [9]. Zhu, Tian and Tan used Landsat to monitor and analyze the land use in Xuzhou city of China, and combined with the DEM data for a human settlement environment development index (HSEDI) model [10]. Odindi, Bangamwabo and Mutanga analyzed and evaluated the role of green space in reducing urban heat island effect using the data of Landsat 8 and MODIS Land Surface and Temperature (LST) [11]. Rafiee, Mahiny and Khorasani used the Landsat data for monitoring and analyzing the changes of green space in Mashad, and the results showed that since the beginning of 1987, the urban green space has been significantly reduced, and the local quality of life has been affected [12].

Landscape metrics is one of the evaluation tools of green space pattern and change, and it can be combined with remote-sensing data to analyze the green space. André and Ahern demonstrated how to use the landscape metrics in sustainable landscape planning and explained the meaning of each landscape metrics [13]. Fernandes, Aguiar and Ferreira used the landscape metrics and geostatistical tools to describe and analyze the spatial pattern of waterfront green space, and discussed its relationship with land use (the spatial patterns of riparian vegetation affected by land use.), the results showed that only a combined interpretation of various landscape metrics can consistently describe the spatial patterns of riparian vegetation [14]. Xu used remote-sensing data and green landscape metrics for studying on the green space changes in Nanjing. The results showed that with the development of city, the size of the green space was greatly reduced, the structure of the green space was fragmented, and the distribution of the green space was reduced [15].

These above researches indicate that the Landsat Remote-sensing data combined with landscape metrics is an effective research method to analyze the green space change, and It has a certain significance to apply it to the study of green space in Suzhou, which is the center city of Yangtze River Delta in China.

The remainder of this paper is organized as follows. The third section summarizes the history and geography of Suzhou, and describes the research methods and data sources. In the fourth section, the scale and composition of green space in Suzhou districts were evaluated in 1990 and 2006 respectively. In the fifth section, the changes of landscape metrics were analyzed, and the changes of the scale and space of green space were analyzed. The last section summarizes the paper and gives some conclusions.

TABLE I AREA OF THE STUDY AREA

Study Area	Abbreviation	Area (km^2)	Green space area in 1990(ha)	Green space area in 2006(ha)
Gusu	GS	85.1	1011.50	938.82
Huqiu	HQ	223.36	10574.69	10720.32
Gongyeyuan	GYY	278	10891.9	8955.26
Wuzhong	WZ	742	35822.5	30873.96
Xiangcheng	XC	439	19065.77	15685.88
Wujiang	WJ	1092.90	86975.58	54107.71
Changshu	CS	1094.00	67934.29	69918.65
Kunshan	KS	864.90	49062.71	32310.02
Taicang	TC	620.00	45286.3	45999.83
Zhangjiagang	ZJG	772.40	39148.47	45086.19

III. METHODOLOGY

The study area included the Suzhou, which is located in the middle of the Yangtze River Delta, east of Shanghai, west near Taihu and north of the Yangtze River. The city is China's famous historic city, as well as one of the important cities in Shanghai metropolitan area. Suzhou is dominated by subtropical monsoon climate. The main environmental characteristics of Suzhou are flat terrain, rivers and lakes are densely distributed across the city. The water area accounted for 40% of the total area, and the city is the famous Canal Towns in South of the Yangtze.

Suzhou is an ancient city with 2500 years of history. The city was the capital of Wu in the spring and autumn period. During the Sui and Tang Dynasties, owing to the dug of Beijing-Hangzhou Grand Canal, Suzhou became the Jiangnan Canal waterway hub, the population is growing fast. In the Ming and Qing Dynasties, Suzhou developed into a big developed industrial and commercial city, which occupies an important position in the national urban system, and has become the economic center of the south of the Yangtze River. Especially after the Ming Dynasty, Suzhou has attracted a large number of scholars and officials living in the building of private gardens, Suzhou garden has become an important genre of Chinese garden art. After 1949, with the rapid development of industrial development in Suzhou, the industrialization process accelerated, and industrial planted all over the city, the ancient city of space has also changed a lot, many of the walls were gradually removed. In 2000, the State Council approved the overall planning of Suzhou city (1996-2010), the form of development is the city areas as the main body, and the surrounding suburban areas contrast.

Suzhou covers an area of 8488.42km^2, including urban and suburban districts two parts. As Figure1 showed, Gusu(GS), Huqiu(HQ), Wuzhong(WZ), Xiangcheng(XC), Gongyeyuan(GYY), Wujiang(WJ), a total of six districts are considered urban, while Kunshan(KS), Taicang(TC), Changshu(CS), Zhangjiagang(ZJG) districts are suburban districts. In urban areas, Gusu is a historic district, Huqiu, Gongyeyuan, Xiangcheng, Wuzhong, Wujiang districts are new setting districts after 1990s. This work focused on Suzhou's green space, used Landsat remote-sensing images from 1990 and 2006, extracted distribution map of green spaces in Suzhou, and analyzed the changes in scale and structure of the green spaces using various landscape metrics.

This study used Landsat 5 remote-sensing image dates with seven wavebands and a spatial resolution of 30 m from1990 and 2006 in the Suzhou area, which distributed by Earth observation center of Chinese Academy of Sciences. The original remote-sensing data were processed with image fusion, geometric correction, and image mosaicking using ENVI 5 software, and the Xi’an 85-planar geographic coordinate system was applied. According to Suzhou district map, we extracted the borders of each administrative districts, and saved in the Shape File format. Geometric correction and coordinate transformation were then conducted on these files using the ArcGIS 10.2 software.

In the ENVI software, the satellite images were subsequently cropped based on the previously identified borders to obtain partitioned images of each administrative district. Images were then categorized using the supervised classification method according to land use in each district, in order to extract maps on green space distribution for 1990 and 2006 as Figure 2 showed. Green extraction contains woodland and shrub land, grassland, farmland, then calculated each district's green space area showed in Table 1.

The green space distribution maps were converted to grid format files, and imported into the FRAGSTATS 4.2 software to conduct landscape metrics analysis. Landscape metrics is a very useful tool in the analysis of the pattern and scale of green patches. In recent years, it has applied in evaluation and analysis of green space. Landscape metrics in this study included percent of land (PLAND), mean patch size (MPS), largest patch index (LPI), number of patches (NP), patch density (PD), total edge (TE), edge density (ED), mean proximity index (MPI), mean nearest neighbor distance (MNN), and landscape shape index (LSI). Table 2 shows the use of these landscape metrics in this study. After calculating the landscape metrics of green patches in 1990 and 2006, the research team compared and analyzed these metrics to evaluate the evolution of green space.

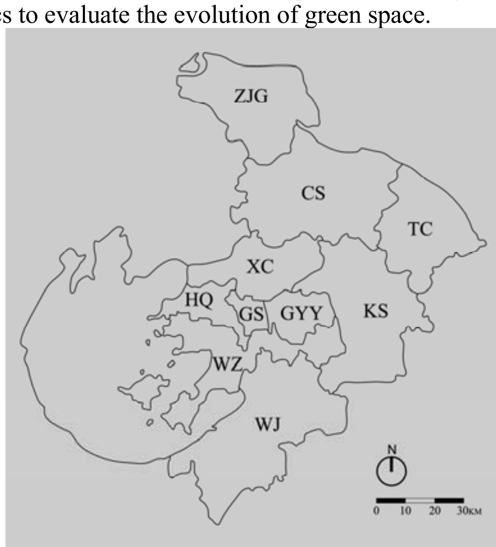

Figure 1. The study area of Suzhou

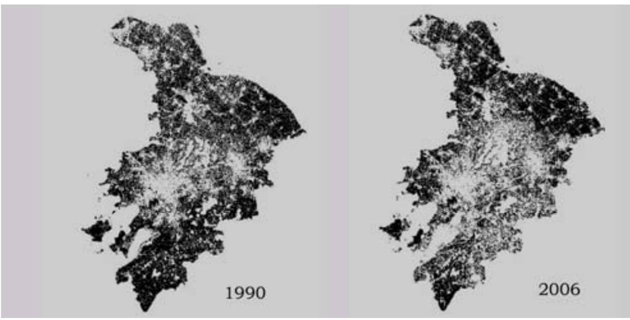

Figure 2. Distribution map of Suzhou green spaces extracted from Landsat

TABLE II PURPOSES OF LANDSCAPE METRICS USED IN THIS STUDY

Metrics	Purpose
percent of land（PLAND）	PLAND refers to the greening rate. A larger PLAND value indicates a higher greening rate.
mean patch size（MPS）	MPS refers to the average area of green space patches. A larger MPS value indicates a greater average area of green space patches.
largest patch index（LPI）	LPI refers to the ratio of floor area of the largest green space patch. A larger MPS value indicates a higher concentration degree of green space.
patch number（NP）	NP refers to the degree of fragmentation. A larger NP value means that more green spaces are fragmented.
patch density（PD）	PD refers to the degree of fragmentation, A larger PD value means that more green spaces are fragmented.
total edge（TE）	TE refers to the shape complexity of a green space patch. A larger TE value indicates a higher degree of shape complexity and more severe disturbance of the patch.
edge density（ED）	ED refers to the shape complexity of a green space patch. A larger ED value indicates a higher degree of shape complexity and more severe disturbance of the patch.
mean proximity index（MPI）	MPI refers to the connectivity of green space patches, which increases with a higher MPI value.
mean nearest neighbor distance（MNN）	MNN refers to the degrees of discretization of green space patches, which increase with a higher MNN value.
landscape shape index（LSI）	LSI refers to the shape complexity of a green space patch. A higher LSI value indicates greater shape complexity and more severe patch disturbance.

IV. RESULT ANALYSIS AND DISCUSSION

(1) Analysis of green spaces in 1990 and 2006

The green space area of each district is shown in table 1. In 1990, Gusu District had the least green space area, and then followed by Huqiu and Gongyeyuan districts, while Wujiang District had the largest green space area. The green space areas of historic districts were significantly less than the new districts and suburb and districts. In 2006, the green scale of Gusu District was still the least, then followed by Gongyeyuan and Huqiu districts. Changshu District has replaced Wujiang District as the largest area of green space.

Figure 3 depicts the PLAND metric of green spaces of the study area, which indicates the ratio of the area of green space to the total area of each administrative district. In 1990, Wujiang ranked first in a PLAND metric of 73%. Taicang District followed with a PLAND metric close to 70%. Gusu District ranked at the bottom with a PLAND metric of 10%. The PLAND value for the remaining districts ranged between30% and 58%. In 2006, Taicang District ranked at the top with a PLAND metric of70%. Then, Changshu and Zhangjiagang districts followed, both with PLAND values of 59%. While Gusu District PLAND still ranked at the bottom with PLAND values of 9%.

Figure 4 shows MPS metric values, which indicates the average area of green space patches. In 1990, the MPS value for Wujiang District was far larger than that for other districts, reaching 62 ha. Taicang District followed with an MPS metric of 38 ha. Gusu District ranked at the bottom with an MPS metric of 1.8 ha. The MPS values for Gongyeyuan and Xiangcheng Districts were 4.7 and 7.7 ha, and the MPS values for other districts were basically between 11 to 18 ha. In 2006, Taicang District ranked first with an MPS metric of 66 ha, Zhangjiagang and Changshu districts followed with MPS metrics of 33 and 31 ha, respectively. Gusu District ranked at the bottom with an MPS of 3 ha.

Figure 5 shows the LPI metric, which represents the ratio of floor area of the largest green space patch in each administrative district. In 1990, the LPI value for Taicang District was significantly larger than other districts, reaching 58%, Wujiang (37%) and Kunshan (23%) districts followed. Gusu District ranked at the bottom, with only 1.5%. In 2006, the LPI values of Taicang District (54%) was still the highest. the LPI values of other districts are less than 17%. Gusu District still ranked at the bottom, with only 1%.

In 1990 and 2006, the total green space area of Suzhou historic districts was less, the green space area in Gusu District was the least, the green space rate was the lowest, and the green space patch scale was the minimum. In the new setting districts, Gongyeyuan District had less green space area, and the green space rate is lower. In 1990, the green space area in Wujiang District was the largest, the green space rate was the highest, and the average patch scale was the highest. In 2006, Taicang District had the largest green space area, and the concentration of green space was also the highest, Changshu District's green space rate is the highest.

The NP metric of green spaces is shown in Figure 6, which indicates the number of green space patches in each district. In 1990 and 2006, the NP in historical district was lower. In 1990, the NP in Changshu District was the highest, Kunshan and Zhangjiagang districts followed. In 2006, the NP in Kunshan District was noticeably larger than other districts, Wujiang and Changshu districts followed.

Figure 7 shows the PD of green spaces, representing the green patch density quantified as the number of green space patches within a 100-ha parcel of land. In 1990, the PD value of Gongyeyuan, Gusu and Xiangcheng districts were the highest, respectively 6.4, 5.5, 5.2. Wujiang District ranked at the bottom, with only 1.2. In 2006, Xiangcheng, Kunshan and Gongyeyuan districts were the highest with the PD values of 3.9, 3.8 and 3.6, respectively. Taicang District ranked at the bottom of all the districts with the PD value of 1.1.

Figure 8 shows the TE metric, which indicates the edge length of green patches. The TE values for suburban areas were significantly larger than those for urban areas, the new setting districts were significantly larger than the historic districts. In terms of this metric, Changshu District ranked first, Gusu District ranked at the bottom. Figure 9 shows the related metric of ED, which represents he edge length of green space patches within a 1-ha land parcel. In 1990, Changshu, Xiangcheng and Zhangjiagang districts ranked first with an average ED of more than 90 m. In 2006, the ED values of Zhangjiagang, Kunshan and Changshu districts were all more than 58 m. The ED value of Gusu was 36 m in 1990 and 26 m in 2006, the lowest among the districts.

Figure 10 shows the MPI metric of green spaces. MPI refers to the connectivity of green space patches, which increases with a higher MPI value. In 1990, Wujiang District ranked first among all the districts, Taicang and wuzhong districts followed. In 2006, The MPI value for Taicang District was the highest, Changshu and Zhangjiagang districts followed. Suzhou District ranked at the bottom, Gongyeyuan District second.

The MNN metric of green spaces is shown in Figure 11. A higher MNN value indicates a higher degree of discretization of green space patches. The overall MNN value of urban areas was clearly larger than that of suburban areas. In 1990, Gusu District had the highest MNN, followed by Huqiu and Wuzhong districts, while Wujiang and Changshu districts had the lowest. In 2007, Gusu District still had the highest MNN, Gongyeyuan and Huqiu districts followed, and Changshu and Wujiang districts ranked at the bottom.

Figure 12 shows the LSI metric of green spaces, which indicates the shape complexity or degree of disturbance. In 1990, Gusu District ranked at the bottom of all the districts, Changshu District ranked first, followed by Zhangjiagang and Kunshan districts. In 2006, Kunshan District ranked first, followed by Wujiang and Changshu districts, and Gusu District still ranked at the bottom.

Overall, the proportion of the green space scale and quantity of historic districts in the whole of Suzhou is small. In 1990, the green space scale and quantity of urban areas were less than those of suburban areas. While in 2006, the green space patches of suburban areas were slightly less than those of urban areas.

The number of green space patches and edge length of green space in Suzhou suburbs were significantly higher than those in urban areas, which was positively correlated with the size of the green space in each district. In addition to the Wujiang District, the degrees of fragmentation and discretization of urban areas were significantly higher than those of suburban areas, the degree of disturbance in the historic districts was lower than the new urban areas and suburban areas. While the connectivity between the green space patches in urban areas was lower than that in suburban areas. The interference of green space in suburban areas was significantly higher than that in urban areas.

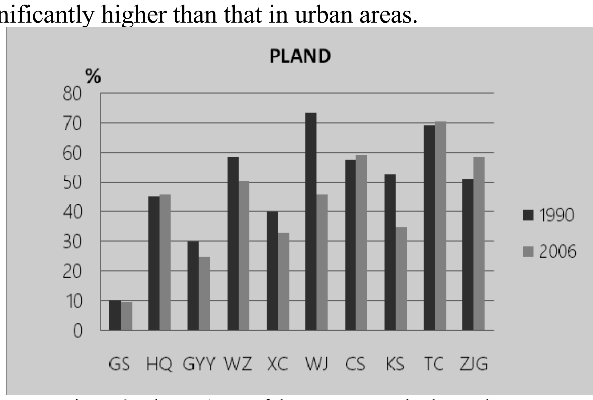

Figure 3. The PLAND of the green space in the study area

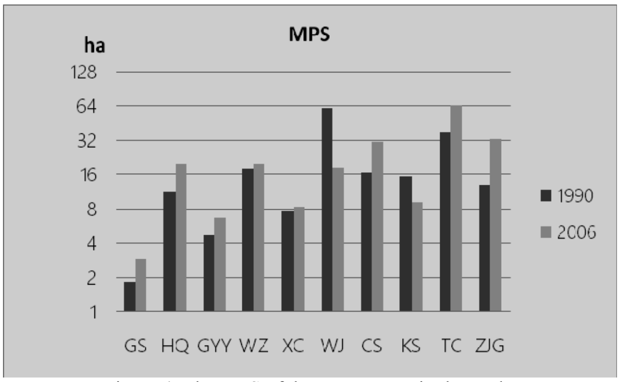

Figure 4. The MPS of the green space in the study area

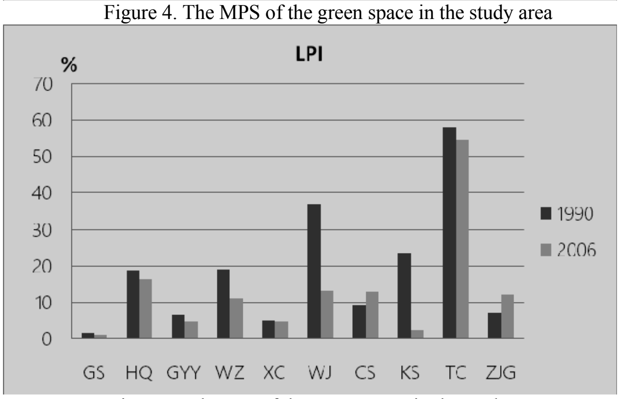

Figure 5. The LPI of the green space in the study area

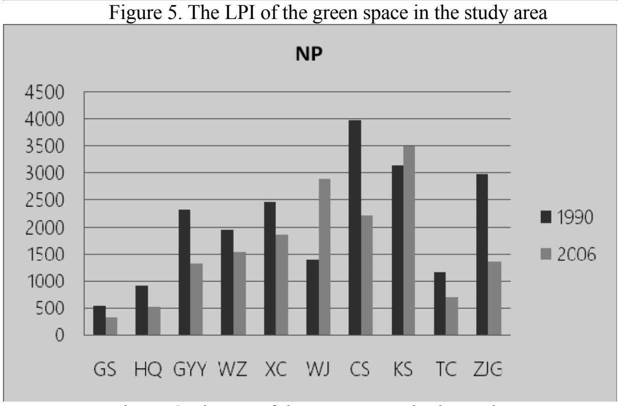

Figure 6. The NP of the green space in the study area

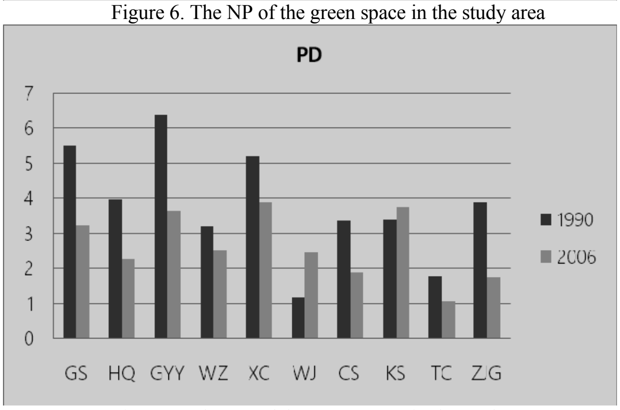

Figure 7. The PD of the green space in the study area

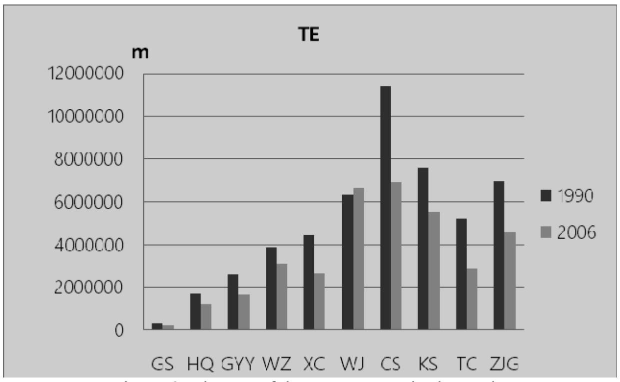

Figure 8. The TE of the green space in the study area

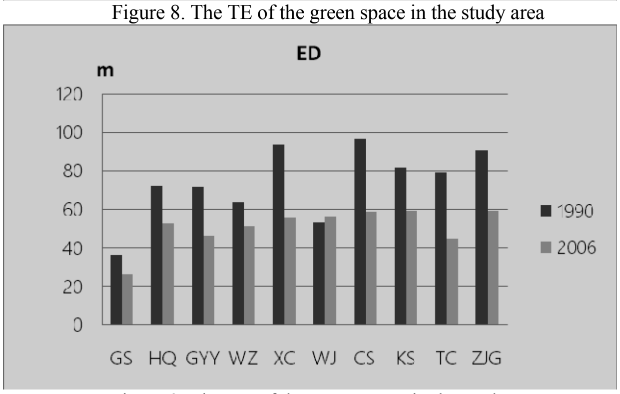

Figure 9. The ED of the green space in the study area

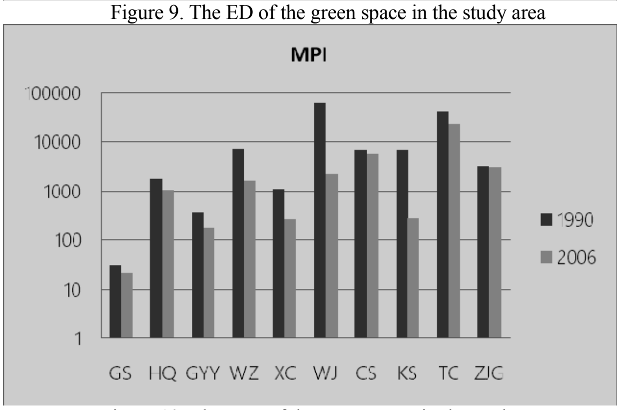

Figure 10. The MPI of the green space in the study area

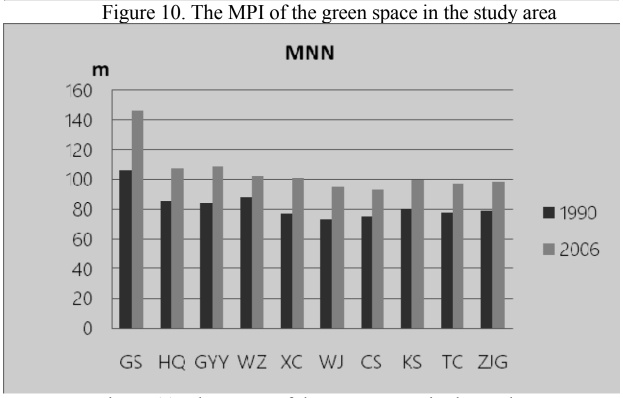

Figure 11. The MNN of the green space in the study area

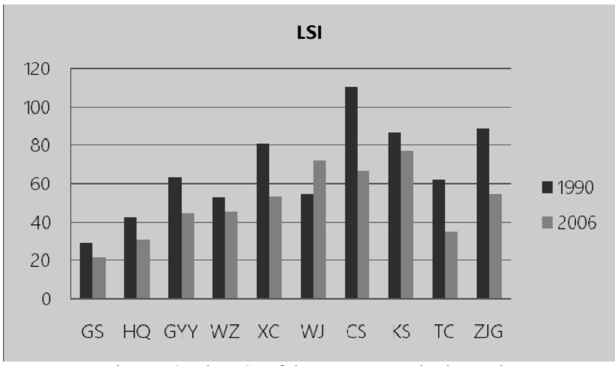

Figure 12. The LSI of the green space in the study area

(2) Changes in green space between 1990 and 2006

Compared to 2006, the total area of green space in Suzhou decreased by 51177ha by 1990, and the decrease rate was 14%. Among these districts, the green space areas of Huqiu, Kunshan, Taicang, Zhangjiagang districts have increased. This increase was greatest in Zhangjiagang District at 5937.7ha, an increase of about 15%. the other three districts increased by no more than 3%. The area of green space decrease was greatest in Kunshan and Wujiang districts. The green space area of Wujiang District reduced 32867ha, and Kunshan reduced 16752ha, the rate of decline was 38%, 34%. The decrease rate of Gongyeyuan, Wuzhong, Xiangcheng districts were between 14% to 18%. The change of PLAND was consistent with the change of area.

From the change in MPS, in addition to Kunshan and Wujiang districts, decreased by 70% and 41%respectively, the MPS of other districts were all increased. The largest growth of MPS was Zhangjiagang District with a rate of 154%, followed by Changshu (84%), Huqiu (78%) and Taicang (70%).

From the LPI metric, the rates increased for Changshu and Zhangjiagang districts by 75% and 38%, respectively. Other districts had different degrees of decline. The LPI values for Kunshan District had the greatest decreases by 90%, followed by Wujiang, decreased by 64%. The LPI value for Taicang District was the lowest, decreased by 5%.

From the changes in the NP metric, Wujiang increased by 110%, Kunshan increased by 11%, the rest of districts declined. The NPs of Wuzhong, Xiangcheng districts decreased by 20%, the NP values of Gusu, Huqiu, Gongyeyuan, Changshu, Taicang districts decreased by 40%, the NP of Zhangjiagang decreased by 55%. The NP value of Urban green NP overall decreased by 11%, and the suburbs decreased by 31%. The changes in PD for the districts were basically consistent with the results for NP.

From 1990 to 2006, except to Wujiang District increased in TE of5%, The TE values of other administrative districts were all decreased. The TE values of Urban areas decreased by19%, The TE values of suburban areas decreased by 36%. Taicang District had the highest increase in TE of44%, followed by Xiangcheng with the decrease of 40%. Among the districts, the maximum reduction of TE was Changshu with a decrease of 4460253 m, accounting for 30% of the total reduction. The change in ED was basically consistent with that in TE.

In 2006, the MPI values of all districts decreased to varying degrees. The MPI of Wujiang and Kunshan districts were decreased by 96%, The MPI of Wuzhong, Xiangcheng districts were decreased by78% and 75%, the MPI of Zhangjiagang District was decreased by1%, and other districts decreased from 32% to 50%. On the other hand, the MNN values of all districts somewhat increased. Gusu District had the highest increase in MNN of 38%, followed by Xiangcheng District with 30%. The increase in MNN of Wuzhong District ranked at the bottom at only 16%.

From LSI changes, in addition to The LSI of green space patches in Wujiang District decreased by 32%, The LSI of other districts were all decreased. The LSI of Taicang decreased by 43%, The LSI of Changshu, Zhangjiagang and Xiangcheng districts, respectively, decreased by 40%, 39% and 34%, The LSI for all other districts increased between 10% and 30%. These changes in MPI, MNN and LSI showed that the connectivity between Suzhou green space patches decreased significantly, and the degree of discretization and fragmentation increased. The interference of green space in Wujiang District has increased significantly.

V. Conclusion

Gusu District is a historic city, with flat terrain, dense road network, and big density of construction. Of all districts, Gusu has the lowest green space area and green space rate. The green space in this district is mainly distributed in the residential area, the degree of discretization is the highest, and the connectivity of green patches is lowest. By the historic districts renewal, parking space and road areas increased, from 1990 to 2006, the area of green space decreased by 7%, the number of patches decreased by 41%, the main disappearance were small green patches, and MPS increased by 58%. There are Humble Administrator's Garden and other classical gardens in this district, green area is larger, and received good preservation. Affected by the increase in building density, road network, and the influence of road widening, the degree of discretization of green patches significantly increased, the connectivity of green patches further decreased, and patch shape tended to be regular and smooth.

The eastern part of Huqiu District is a national high-tech industrial park, central and Western of Huqiu are Jilong hill, Nanyang hill, Mantou mountain and a part of farmland with high green space rate. Among them, Dayangshan national Forest Park is the largest piece of green space. Compared to 1990, the green space rate has not changed basically in 2006. In the central and western of Huqiu, hilly land and the cultivated land maintained a good overall. However, due to the construction of high tech Industrial Park, the small green patches in the east of the district have disappeared, and the degree of discretization has increased. Network construction leads to the connectivity of green patches decreased obviously, and the form of green space tended to be smooth.

Gongyeyuan District is a new development area of the city in 1990s, it has flat terrain and has Jinji Lake, Dushu Lake and other large lakes in there. From 1990 to 2006, the green space area decreased by 18%, the number of patches decreased by 43%, the area of the largest green patch decreased by 27%. In 2006, green space mainly included central cultivated land and the southern lakeside green space, the West and the East of Gongyeyuan had big density of construction. The degree of discretization has increased and morphological complexity of the patches decreased significantly. This district was obviously influenced by the urbanization, and the green space was shrinking constantly.

The eastern part of Wuzhong District is the plain, is the urbanization development area. The western part near Taihu has low mountains and hills. In1990, it showed high connectivity of green space. While in 2006, green space area decreased by 14%, the number of green patches decreased by 21%, and the largest green patch area decreased by 43%, which indicates that the green space is in a declining stage. Green patch edge length reduction rate (19%) and the rate of patches decreases were near, the degree of disturbance decreased, but the degree of discretization has increased and the connectivity of green patches decreased significantly.

Xiangcheng District is located in the northern suburbs of Suzhou, with its west side adjacent to Taihu, the region has Cao lake, Yangcheng lake. From 1990 to 2006, the green space area was reduced by 18%, the number of patches decreased by 25%, and the largest green patch area decreased by 14%. The green space in the area mainly existed in the eastern and western flat regions near the lake. Due to cutting by highway transit, road network, the connectivity of green space was greatly reduced, the discrete degree of green space was further intensified, green patches tended to be smooth, and green space showed an overall decline trend.

Wujiang District is located in the south of Suzhou urban areas and has many rivers and lakes, the ancient town of Tongli and many other historic towns and villages distributed in there. The green space resources of Wujiang mainly include cultivated land and plains forest land. In 1990, the rate of green space was 73%, and the green space area was largest in the city. In 2006, affected by the spread of the northern built-up areas and villages, the rate of green space dropped to 46% substantially, the number of green patches increased by 1.09 times, and the average patch area decreased by 70%. The scale of green space had a trend of miniaturization and fragmentation. Due to cutting by traffics and roads, the connectivity of green patches significantly decreased, and the degree of dispersion and the degree of disturbance of patch shape had increased significantly.

Changshu District is located in the north of Suzhou and north of the Yangtze River, the district has Yu mountain, Shang Lake, and most of the territory are plain. In 1990, the green space area of Changshu just followed that of Wujiang. In 2006, green space area increased by 3%, and becoming the largest green space area of all districts. Over the same period, the number of green patches decreased by 44%, the average patch area increased by 84%, and the largest green patch area increased by 38%. The dispersion degree of green patches increased, the complexity of patch shape and the degree of disturbance decreased significantly, and the connectivity also decreased. This indicates that in the process of urbanization, the protection and construction of farmland, the lakeside green space, and mountain forest were suitable. The green space tended to be large, central and centralized, and the core green space had outward tendency.

Kunshan District is the most economically developed administrative area, with its east side adjacent to Shanghai. The territory of the area has flat terrain with many lakes and ponds in South and North-West. Compared to 1990, the eastern part of Kunshan border on Shanghai, where the urban construction area was spreading in 2006. The green space area decreased by 34%, the number of numbers decreased by 44%, and the largest green patch area decreased by 90%. The degree of discretization of patches increased, the connectivity and shape complexity decreased, the overall green space showed obvious atrophy and decline trend.

Taicang District is located in the north-east of Suzhou, north of the Yangtze River, and has flat terrain. The eastern plains along the river, and west of Taicang is low-lying polder. From 1990 to 2006, the green space area was essentially flat, the number of green patches decreased by 40%, the largest green patch area was slightly smaller, which showed that mainly disappearance are the small green patches, and large green patches were more stable. Residential construction and urbanization spread, led the increase of the degree of connectivity, and the obviously decrease of patch connectivity. A large number of small green patches disappeared, reducing the degree of disturbance on the edge of the green space, and the overall shape of the green space is stable.

Zhangjiagang District is located in the north end part of Suzhou, north of the Yangtze River, with terrain is flat. The construction area is mainly concentrated in the south-west and along the Yangtze river port area. From 1990 to 2006, the green space area increased by 15%, green patch number decreased by 55%, and the largest green patch area increased by 75%, the average patch area increased by 1.54 times, which indicated that disappeared mainly were small green spaces, large green spaces expanded further. The degree of discretization of patches increased, the degree of morphological complexity and the degree of disturbance are further reduced, and the green space tended to be large, concentrated, and the edge tended to be smooth.

Compared the green space metrics in 1990 and 2006, it can be found, that the scale and quantity of urban green space in Suzhou have significantly decreased, degree of discretization has increased to varying degrees in each distract, connectivity decreased significantly, small green patches disappeared more. In addition to Changshu and Zhangjiagang districts, the area of the largest green patch of the district had varying degrees of reduction; the overall green space had trends of decline and shrinking.

The green patches were unevenly distributed. The green space patches of historic urban areas had small number and scales, poor connectivity, and discrete distances, only some of the historic garden preserved patches of green space. A new urban area retained a lot of land, water and forest, and the green space metrics of suburban areas showed no significant difference in grades. In the northern part of Taicang, Changshu and Zhangjiagang districts, the scale of green space increased, the green space had the tendency of large scale and centralization, and the pattern of green space was more stable. The green space of central and southern districts had different levels of decrease. Especially in the south-east of Wujiang and Kunshan districts, the decrease rate of green space was the highest, the form of green space was strongly disturbed by the urbanization, and showed obviously fragmentation pattern.

Due to the construction of the historic urban areas was already saturated, new urban areas and suburban areas are the main area of urbanization in the future, especially Kunshan District which's eastern border with Shanghai has the most urbanization pressure. Suzhou has a favorable ecological base, we must pay attention to the changes of green space, in advance to do a good job in the protection of green space planning. In the process of urbanization, the scope of ecological protection should be defined, and the trend of green space decline should be stopped. At the same time, strengthen the construction of ecological green road, and improve the connectivity of green space. For the northern suburban areas, we should control the scope of construction, protect the core green space, and increase the small green space. For Wujiang and Kunshan districts, the ecological red line should be delineated, to control the spread of villages and towns. For the historic districts, ways should be taken to wall greening, roof greening and other types of green, see the seam inserted green. For other new urban areas and suburban areas, we should set the country Forest Park as far as possible, combined with water, woodland hills and lakes. Only in the process of urbanization, effectively curb the sharp reduction of green patches and fragmentation trend, can we promote the environmental protection and sustainable development of Suzhou.

ACKNOWLEDGMENT

The study was supported by the fund of Nanjing Forestry University (No. G2014019)

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