DYNAMICS OF ECOSYSTEM SERVICE VALUES IN RESPONSE TO LANDSCAPE PATTERN CHANGES FROM 1995 TO 2005 IN GUANGZHOU, SOUTHERN CHINA

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Abstract. This study analyzed the landscape pattern changes, the dynamics of the ecosystem service values (ESVs) and the spatial distribution of ESVs from 1995 to 2005 in Guangzhou, which is the capital of Guangdong Province and a regional central city in South China. Remote sensing data and geographic information system techniques, in conjunction with spatial metrics, were used to facilitate the analysis. The forest was the main landscape with a total coverage of 37.36% during the study period. Between 1995 and 2005, the forest and garden became less fragmented while the cultivated land, grassland, water body and built-up area became more fragmented. Such landscape pattern changes have resulted in a significant increase in the overall annual ESVs in Guangzhou of approximately 3.37%. Two important landscape types (forest and water body) were the main contributor to the total ESVs, the proportion of both of which was over 75%. During the period from 1995 to 2005, the ESVs tended to decline from the north and south to the central part in Guangzhou. The average ESVs was more than 15 000 Yuan/ha in the north for the mountainous forest area and 20 000 Yuan/ha in the south for the water body at the Pearl River mouth, but the average ESVs was lower than 5 000 Yuan/ha in the central part of the study area due to low vegetation coverage and widely scattered built-up area for rapid urbanization. So, it is important to protect the key landscape types, such as forest, water body and garden, to avoid fragmentation. Furthermore, this study offers important insights to those in fast-urbanizing regions for achieving more successful landscape to obtain the increasing of ESVs.

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Keywords: *Ecosystem service values (ESVs), spatial distribution, landscape pattern, spatial metrics, Guangzhou*

Introduction

Ecosystem services are the resources and processes supplied by natural ecosystems which benefit humankind directly or indirectly (Daily, 1997; MEA, 2005; Burkhard et al., 2010; de Groot, 2010; Sherrouse et al., 2011). Although the term "ecosystem services" was primarily introduced by Ehrlich and Ehrlich (1981), it didn't attract worldwide attention until the publishing of Daily's book *Nature's Services: Societal Dependence on Natural Ecosystems* (Daily, 1997) and the paper *the value of the world's ecosystem services and natural capital* by Costanza et al. (1997) in *Nature*. The monetary figures of global ecosystem services, which were presented by Costanza et al. (1997), resulted in a high impact on both science and policy making. Especially after the release of the Millennium Ecosystem Assessment (MEA, 2003), which focused on the services(i.e. supporting, provisioning, regulating, and cultural) that ecosystems provide to humans, the literature concerning ecosystem services has increased exponentially (Chazdon, 2008; Fisher et al., 2009) and the concept of ecosystem services has been found increasing attention in environmental science, policy making and practical applications (Daily and Matson, 2008; Fisher et al., 2009; ICSU, UNESCO and UNU, 2008).

To date, the ecosystem service values (ESVs) in various aspects have been studied with different methods. Landscapes, containing many important functions and providing numerous goods and services to society (de Groot, 2006, Gimona et al., 2007; Willemen et al., 2008), play a fundamental role in ESVs and the concept of landscape functions or services, used as synonym to ecosystem services, raised much attention in the field of landscape ecology and landscape planning (Hermann et al., 2011). Accurate assessments of the ecosystem service values is one of the critical endeavors in ecological economics and could help ecological planners (Bryan et al., 2010; Kozak et al., 2011; van der Horst, 2011) by given its capacity to combine ecological processes and economic outcomes (Wainger et al., 2010), and the key aspect of which is to evaluate how ecosystem services respond to specific landscape pattern designs (Jones et al., 2012). Landscape pattern, a major focus of landscape ecology, refers to the spatial structure characters of different landscape combinations, including the diversity and spatial distribution of landscape composition units (Wu, 2007). Monitoring landscape pattern changes provides an indirect approach for characterizing the ecological consequences of human activities (e.g. urbanization) because those changes would influence a variety of ecological processes and functions, such as land quality, biodiversity, vegetation carbon storage and greenhouse gases emission(Su et al., 2012). However, few attempts have been made to jointly analyze changes in landscape pattern and ESVs (Su et al., 2012). So, there is a need for integrating the concepts of landscape pattern and ecosystem services for landscape pattern may affect ESVs in different ways and at different geographical scales (Zhang et al., 2011).

Guangzhou, a large central city in South China and China's Southern Gateway to the

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world, have experienced significant economic growth and rapid urbanization since 1980s, which led to a dramatic change in landscape pattern and significantly affected the providing of ecosystem services. Research on urban ecosystem service values is highly demanded (Larondelle and Haase, 2013). In recent years, although many researches on ESVs in Guangzhou have been engaged (Ye et al., 2008; Wang et al., 2009; Ye et al., 2011), little attention has been paid to the ESVs' spatial distribution. The linkages between landscape pattern and ESVs in Guangzhou remain largely unknown. In this paper, we analyzed the landscape pattern changes, the ESVs and its spatial distribution in Guangzhou from 1995 to 2005, using remote sensing and geographic information system techniques in order to provide useful information for policy makers who concern about sustainable development. It aims to: (1) retrieve landscape pattern changes of Guangzhou; (2) evaluate variations of ESVs in response to landscape pattern changes; and (3) analyze the spatial distribution of ESVs during 1995 and 2005.

Materials and methods

Study area

Guangzhou, the capital of Guangdong Province and the biggest city and political, economic, and cultural center of South China, is located in the southeast of Guangdong Province and at the center of the Pearl River Delta. Crossed by the Tropic of Cancer, it is laid between longitude 112°57′ to 114°13′ east and latitude 22°26′ to 23°56′ north, bordering on the South China Sea and adjacent to Hong Kong and Macao (*Fig.1*). The city, covering approximately an area of 7437.14 km^2 and with a population of 1.27×10^7, administrates 10 districts, namely Yuexiu district, Liwan district, Haizhu district, Baiyun district, Tianhe district, Huangpu district, Huadu district, Luogang district, Panyu district and Nansha district, and 2 county-level cities including Zengcheng county and Conghua county(Gong et al., 2009). The topography is higher in the north and lower in the south. The north and northeast are mountainous area and south is an alluvial plain of the Pearl River Delta. Guangzhou has a subtropical monsoon humid climate, which is determined that there is either intense heat in summer or severe cold in winter. The average temperature is 22.8 ℃, the average relative humidity is about 68%, and the annual rainfall at the urban area is over 1,600 mm.

As a regional central city in South China and China's Southern Gateway to the world, Guangzhou has enjoyed economic, political, social and cultural prominence for more than 2000 years. However, the rapid population growth and urban expansion in Guangzhou are now exerting pressure on its natural environment and there are always conflicts among the demands for good natural environment, urbanization, and ecosystem conservation.

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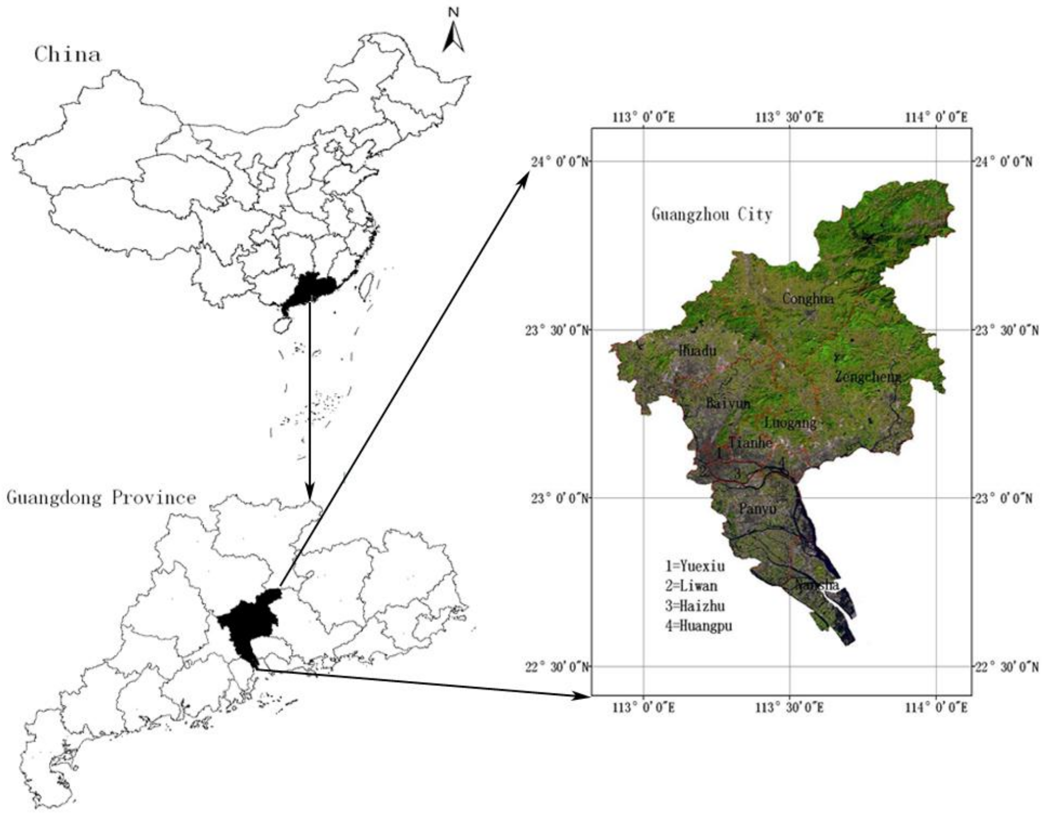

Figure 1. *Sketch map for the location of Guangzhou City, China*

Data acquisition and preprocessing

The basic data used to analyze landscape pattern and dynamics of ecosystem services in this paper were extracted from two cloud-free Landsat Thematic Mapper (TM) images taken on December 30, 1995 and October 22, 2005, respectively, and the World Wide Reference System (WRS) = 122/04385. The resolution of the images was 30 m. Although these satellite images were pre-geo-referenced, they could not be compared directly because the coordinate reference system and resolution used in each image was not consistent. To reduce potential position errors between the two data sets, we used a three-step image preparation procedure. Firstly, we identified the X and Y coordinates of pairs of points that represent prominent features on both the TM image in 1995 and the 1:250,000 topographic map of Guangzhou in 1985, compiled by Guangdong Province Municipal Institute of Surveying and Mapping. Secondly, we used the same topographic map as the geo-referenced standard together with the geo-referencing and Re-sampling modules of IDRISIs Release 2 software (Clark Labs, 2001; Li et al.,2011) to resample the 1995 TM data set into a Universal Transverse Mercator (UTM) coordinate system with original longitude 117ºE, original latitude 0ºN, WGS84 (World Geodetic System-1984) geodetic datum and WGS84 ellipsoid. Finally, using the same procedure as in the second step and the geo-rectified 2005 TM data as the master dataset, the 2005 TM image was resampled and rectified. Average Root Mean Square (RMS) error of less than 0.5 pixel in step 2 and 3 was achieved for all the images and the pixel size was kept as 30×30m grid.

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Classification of landscape types

The landscape types used in this study were extracted from the two TM images in 1995 and 2005. In order to describe and represent the actual physical landscape of Guangzhou more profitably, the landscape was classified into six classes, namely cultivated land, garden, forest, grassland, built-up area and water body. The cultivated land class includes areas utilized for agricultural activities, particularly for the growing of grain crops, generally refers to paddy fields and dry land. The garden class includes areas utilized for the growing of cash crops such as fruit, vegetable, tea and flower, etc. The forest class includes thickly forested area, riparian forested area and shrub forested area, which are mostly protected areas and parks. The grassland class includes high, middle and low coverage plain grassland. The built-up class includes urban, residential, industrial, mining and institutional areas, traffic land (roads, the airport) and other concrete structures. The water body class includes rivers, channels, lakes and beaches.

Landscape pattern analysis

There are a growing number of literatures that discuss the landscape metrics for ecological process and landscape fragmentation analysis (e.g., Ribeiro et al., 2009; Solon, 2009; Su et al., 2012; Thapa and Murayama, 2009; Zhang et al., 2011) in recent years. Spatial metrics at the landscape level provide more general information, whereas class level metrics provide more specific information about landscape development patterns, variations at the local level, spatial patterns and the distribution of land-use classes (Estoque and Murayama, 2013). So, in this study, based on landscape maps established by the above steps, we selected six indices for class/landscape level landscape metrics to monitor the changes in the landscape patterns of Guangzhou (*Table 1*). The eight-neighbor rule was used to derive the patch number and all the indices were calculated using Fragstats3.3.

Ecosystem service values assessment

Ecosystem services and their values have been studied since the 1970th, but the Earth's ecosystem service values are difficult to assess accurately because of the lack of a corresponding theory systems and methods (Huang et al., 2009). Costanza et al. (1997) classified the global biosphere into 17 types of service functions and then estimated their ecosystem service values, which made the principles and methods of assessing ecosystem service values clearer in a scientific sense. The result of Costanza et al. (1997) has also attracted the Chinese ecological researchers’ attention over the years. However, it is unsuitable to directly adopt this method, which is intended for a global scale to a specific region for some ecosystem services may be less valued or even ignored (Du et al.,2008; Lin et al.,2013). Based on actual conditions in China and through the survey of 700 Chinese ecologists, Xie et al. (2008) extracted the ecosystem service values (ESVs) coefficients, which are the values per unit area of various ecosystem services in China to facilitate its practical application.

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Table1. *Indices of class-level landscape metrics*

Indices	level	Descriptions	Units
NP	Class/landscape	Number of patches of the corresponding patch type or land-use class	None
PD	Class/landscape	Equal to the number of patches of a specific land-use class per unit	Number/100ha
LPI	Class/landscape	Area of the largest patch of the corresponding land-use class divided by the total landscape area and multiplied by 100	%
MPA	Class/landscape	Total area occupied by a particular land-use class divided by the NP	ha
LSI	Class/landscape	Equal to the total length of edge (or perimeter) of the corresponding land-use class divided by the minimum length of class edge (or perimeter) possible for a maximally aggregated class, which is achieved when the class is maximally clumped into a single, compact patch	None
IJI	Class/landscape	Measures the extent to which a focal patch type or land-use class is juxtaposed with all other classes. It is based on patch adjacencies	%

Source: Estoque & Murayama, 2013
Note: NP-number of patches; PD-patch density; LPI-largest patch index; MPA-mean patch area; LSI- landscape shape index; IJI-interspersion and juxtaposition index.

Considering about the real-world situation of Guangzhou, this paper referred to the ESVs coefficient of Xie et al. (2008) and revised some coefficients. For the cultivated land, which is mainly paddy fields and almost two crops planting in Guangzhou, the ESVs coefficient of cultivated land is 2 times greater than the ESVs coefficient of Xie et al. (2008). The ESVs coefficient of forest and grassland is 1.45 times greater than the ESVs coefficient of Xie et al. (2008) for the evergreen broad-leaved forest in Guangzhou and the ESVs coefficient of garden is the average of forest and grassland (Ye and Dong, 2010; Ye et al., 2011). So, the ESVs coefficient per unit area of each landscape class in Guangzhou is assigned (*Table 2*). The ESVs of different land use and the ESVs of Guangzhou for each of the two time periods (i.e., 1995 and 2005) were determined using Eq. (1), (2) and (3).

$$ESV_k = \sum_f A_k \times VC_{kf} \qquad \text{(Eq.1)}$$

$$ESV_f = \sum_k A_k \times VC_{kf} \qquad \text{(Eq.2)}$$

$$ESV = \sum_k \sum_f A_k \times VC_{kf} \qquad \text{(Eq.3)}$$

where ESV_k, ESV_f, and ESV refer to the ecosystem service value of landscape type k, the value of the function type f, and the total ecosystem service value, respectively. A_k denotes the area of landscape type 'k'. VC_k is the value coefficient (Yuan$\cdot$ha$^{-1}\cdot$a^{-1}), which refers to the service value per unit area of function type 'k' on landscape type 'f' (Kreuter et al., 2001).

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Table 2. *Ecosystem service value of unit area of different land use in Guangzhou (Yuan·ha^{-1}·a^{-1})*

First class	Ecosystem services types	Forest	Grassland	Cultivated land	Water body	Garden	Built-up
Supply	Food production	214.89	280.01	898.20	238.02	247.45	Not available
	Raw material	1 940.56	234.44	350.30	157.19	1 087.50	Not available
Regulation	Gas regulation	2 813.16	976.79	646.70	229.04	1 894.98	Not available
	Climate regulation	2 650.37	1 015.87	871.26	925.15	1 833.12	Not available
	Water supply	2 663.39	989.81	691.62	8 429.61	1 826.60	Not available
	Waste treatment	1 120.05	859.57	1 248.50	6 669.14	989.81	Not available
Support	Soil formation and retention	2 617.80	1 458.67	1 320.36	184.13	2 038.24	Not available
	Biodiversity protection	2 936.89	1 217.74	916.16	1 540.41	2 077.31	Not available
Culture	Recreation and culture	1 354.49	566.54	152.70	1 994.00	960.52	Not available
	Total	18 311.60	7 599.45	7 095.78	20 366.69	12 955.53	Not available

Results

Changes in landscape area

From the composition of landscape in 1995, the forest, with a total coverage of 37.36%, was the most extensive distribution area. The next was the cultivated land, built-up area, water body, grassland and garden, which accounted for 18.37%, 16.73%, 11.48%, 9.01% and 7.05% of the total area, respectively. In 2005, forest was still the biggest, which accounted for 38.23%. Built-up area, cultivated land, water body garden and grassland accounted for 17.60%, 16.63%, 14.17%, 8.39% and 4.98% of the total area respectively.

From *Table 3*, we can also see that the area of grassland and cultivated land decreased during the last decade, while areas of forest, garden, water body, and built-up area increased. Water body and garden increased fastest with a rising rate of 23.40% and 19.05% respectively, the primary cause of which is that the grassland and cultivated lands had low economic profits and were artificially transformed into garden and water body. The built-up area increased by 5.18%, which reflected the needs of economic development, population growth and urbanization in Guangzhou, and the forest increased by 2.33%.

Changes of landscape pattern at the class level

The results showed that the forest and garden became less fragmented, as shown by the overall decrease in the number of patches (NP), patch density (PD) and landscape shape index (LSI) and the increase in mean patch of area (MPA), largest patch index (LPI). The increase in interspersion and juxtaposition index (IJI) suggests that the forest has become more contiguous while the decrease in IJI showed that the garden has become less contiguous.

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Table 3. *Total area of each landscape change in 1995 and 2005*

Landscape	1995		2005		2005-1995	
	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)	Changing area (ha)	Changing rate (%)
Forest	277841.09	37.36	284323.54	38.23	6482.45	2.33
Grassland	67037.46	9.01	37041.09	4.98	-29996.40	-44.75
Cultivated land	136620.08	18.37	123715.27	16.63	-12904.80	-9.45
Garden	52401.38	7.05	62383.99	8.39	9982.61	19.05
Water body	85391.97	11.48	105377.93	14.17	19985.96	23.40
Built-up area	124421.9	16.73	130872.06	17.60	6450.16	5.18
Total	743713.88	100	743713.88	100	-	-

The grassland, water body and built-up area were all more fragment in 2005 than that in 1995, as shown by the overall increase in NP and PD, as well as the reduction in MPA, LPI, LSI and IJI. The reduction in MPA, LPI, LSI and IJI indicated a result of continuous losses of grassland, water body and built-up.

The cultivated land was more fragmented in 2005 than that in 1995, as shown by an overall decrease in NP, PD, MPA, LSI and IJI. The decrease of NP and PD revealed a continuous loss of fragmented cultivated patches. The decrease in LIS indicated the formation of more regular shapes at the edges of cropland, whereas the overall decrease in IJI showed that the cultivated land patches were not contiguous (*Table 4*).

Table 4. *Comparison of class-level landscape metrics in 1995 and 2005*

landscape	NP		PD(No./100ha)		MPA(ha)		LPI(%)		LSI		IJI(%)	
	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005
Forest	540	466	0.07	0.06	514.52	610.14	15.05	23.07	44.54	18.75	87.10	88.78
Grassland	1825	1897	0.25	0.26	36.73	19.53	0.37	0.16	49.54	15.78	70.99	64.73
Cultivated land	1381	1351	0.19	0.18	98.93	91.57	0.49	3.58	81.62	28.48	87.41	81.91
Garden	760	548	0.10	0.07	68.95	113.84	0.48	1.26	54.37	21.66	87.57	85.60
Water body	1537	2470	0.21	0.33	55.56	42.66	7.89	5.65	76.91	26.85	82.66	78.67
Built-up	2078	2166	0.28	0.29	59.88	60.42	0.27	0.08	77.05	21.19	91.80	90.34

Note: NP-number of patches; PD-patch density; LPI-largest patch index; MPA-mean patch area; LSI- landscape shape index; IJI-interspersion and juxtaposition index.

Changes in ecosystem service values

The total annual ESVs of Guangzhou was 8984.63 million Yuan in 1995 and 9320.18 million Yuan in 2005 (*Table 5*), which showed an increasing trend in the total ESVs. Although the reduction of grassland and cultivated land area lead to reduce 319.53 million Yuan and the changing rate was -44.75% and -9.45%, the value of garden, water body and forest increased 655.08 million Yuan and the changing rate was 19.05%, 23.41% and 2.33%, respectively, which made up the loss value caused by grassland and cultivated land. The total ESVs of Guangzhou maintained sustaining growth of 335.55 million Yuan from 1995 to 2005 and the increasing rate was 3.73%.

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Forest and water body were the two main ESVs contributors in the study area. ESVs from both were over 75% of the total ESVs. The area of forest accounted for 37.36% in 1995 and 38.23% in 2005, instead, it generated 56.63% of the total ESVs in 1995 and 55.86% in 2005. Meanwhile, the area of water body accounted for 11.48% in 1995 and 14.17% in 2005, it generated 19.36% of the total ESVs in 1995 and 23.03% in 2005. Contribution rate from the cultivated land ranked in third, accounted for 10.79% in 1995 and 9.42% in 2005. Grassland contribution rate was smallest, accounted for 5.67% in 1995 and 3.02% in 2005.

Table 5. *Changes in ecosystem service values from 1995 to 2005 (10^6 Yuan/year)*

Landscape	Ecosystem service values				Changes	
	1995	Percent (%)	2005	Percent (%)	2005-1995	Changing rate (%)
Forest	5087.72	56.63	5206.42	55.86	118.70	2.33
Grassland	509.45	5.67	281.49	3.02	-227.96	-44.75
Cultivated land	969.43	10.79	877.86	9.42	-91.57	-9.45
Garden	678.89	7.56	808.22	8.67	129.33	19.05
Water body	1 739.15	19.36	2 146.20	23.03	407.05	23.41
Total	8 984.63	100	9320.18	100	335.56	3.73

The ESVs provided by single ecosystem function were calculated by the Eq. (1) and Eq. (3). The contribution of single ecosystem function by forest was mainly focused on the gas regulation, climate regulation, water supply, soil formation and retention, and biodiversity protection, each of which increased from 1995 to 2005 (*Fig. 2A*). The single service function of grassland and cultivated land was mainly the soil formation and retention and biodiversity protection. All the service functions provided by grassland and cultivated land decreased for their area reduced from 1995 to 2005 (*Fig. 2B and Fig. 2C*). The principal service functions of garden were raw material, gas regulation, climate regulation, soil formation and retention, and biodiversity protection, which all increased more from 1995 to 2005 (*Fig. 2D*). For the water body, the water supply and waste treatment were the most extensive distributors (*Fig. 2E*).

As seen from *Table 6*, the value of the individual ecosystem service functions in Guangzhou did not change the basic structure. The contribution order of the every ecosystem function value to the total value was followed by Water supply > Biodiversity protection > Waste treatment > Soil formation and retention > Climate regulation > Gas regulation > Raw material > Recreation and culture > Food production. The value of water supply was the largest category in Guangzhou and the principal reason is the location of Guangzhou at the center of the Pearl River Delta, where the water courses are densely and have many rivers and lakes. However, the value of food production was the smallest category because of the reduction of cultivated land for the rapid development of urbanization in Guangzhou, which leads to the land-use change from cultivated land to built-up area(Gong et al., 2009).

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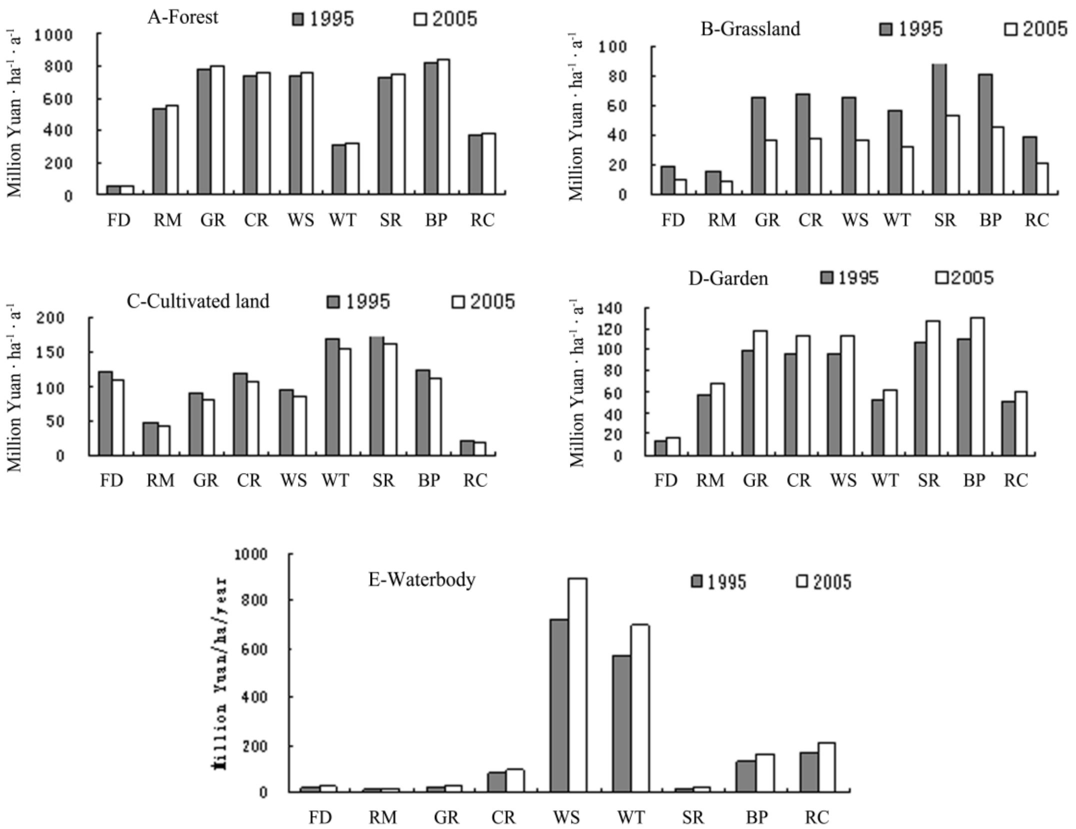

FD: food; RM: raw material; GR: gas regulation; CR: climate regulation; WS: water supply; WT: waste treatment; SR: soil formation and retention; BP: biodiversity protection; RC: recreation and culture

Figure 2. *The changes of ecosystem service values of the five landscape classes in Guangzhou in 1995 and 2005*

Table 6. *Ecosystem service values of each service type in 1995 and 2005 (10^6 Yuan·a^{-1})*

First class	Ecosystem service types	1995			2005		
		ESVs	%	Rank	ESVs	%	Rank
Supply	Food production	234.48	2.61	9	223.11	2.39	9
	Raw material	673.15	7.49	7	688.18	7.38	8
Regulation	Gas regulation	1054.30	11.73	6	1058.39	11.36	6
	Climate regulation	1098.57	12.23	5	1110.83	11.92	4
	Water supply	1716.38	19.10	1	1881.74	20.19	1
	Waste treatment	1160.75	12.92	3	1269.28	13.62	3
Support	Soil formation and retention	1128.04	12.56	4	1108.24	11.89	5
	Biodiversity protection	1263.18	14.06	2	1285.39	13.79	2
Culture	Recreation and culture	655.78	7.30	8	695.03	7.46	7
	Total	8984.63	100.0	–	9320.19	100.0	–

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Spatial distribution of Ecosystem service values

ESVs of Guangzhou decreased from the north and south to the central part in 1995 and 2005 respectively (*Fig.3*). ESVs in the north were higher mainly due to the higher vegetation coverage. The average ESVs was more than 15 000 Yuan/ha in the north, where the mountainous area is known as the ecological shelters of Guangzhou. Moreover, ESVs in the south were highest mainly due to the Pear River's estuary. The average ESVs were more than 20 000 Yuan/ha in the south for water body, which could provide many kinds of aquatic ecosystem services such as water storage, water supply, aquatic product, tourism, flood control, water purification, hydro-power, transportation and sand transport, etc. On the contrary, the average ESVs was lower than 5 000 Yuan/ha in the central part of Guangzhou mainly due to the widely scattered of built-up area for rapid urbanization, where is the city center of Guangzhou, including the Districts of Yuexiu, Liwan, Tianhe, Haizhu, Huangpu, Luogang and Baiyun.

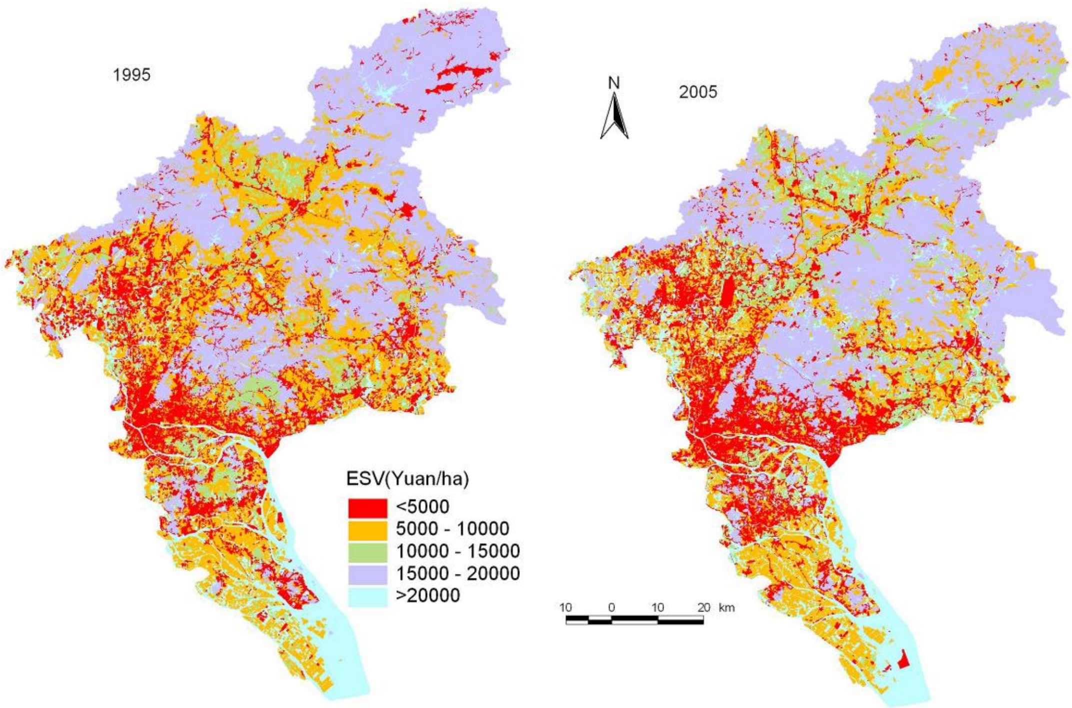

Figure 3. *Distribution of the ecosystem service values in Guangzhou in 1995 and 2005*

Discussions

The concept of ecosystem services from landscapes is rapidly gaining momentum as a language to communicate values and benefits to scientists. Landscape ecology has an enormous contribution to make to this field (Iverson et al., 2014) and responses of ecosystem services to landscape pattern changes are widely discussed(Estoque and

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Murayama, 2013; Su et al., 2012; Zhang et al., 2011). ESVs are the benefits that human derive from ecosystem (Millennium Ecosystem Assessment, 2005). Evaluating ESVs in an economical way may draw sufficient public attention on one hand and build a green GDP accounting system and ecological compensation mechanism on the other hand (Feng et al., 2012). Landscape development changed the biogeochemical cycling, ecosystem structure, and ecosystem service values. The consequences have become the main difficulty of global sustainable development and the vital focus of public attention. Thus, evaluating its variations due to the landscape change is of profound significance. Our study indicated that the economic value of services of the landscape in Guangzhou is huge, which is 8984.63 million Yuan in 1995 and 9320.19 million Yuan in 2005. It cannot be imagined that the local people are able to make such huge quantity of investment per year.

Understanding the spatial distribution of the ecosystem service value is as important as the value itself, especially when the ecosystems are being faced with dramatic changes. Our study showed that remote sensing from satellites may be the only economically feasible way to regularly gather information with high spatial, spectral and temporal resolution over large areas (Seidl et al., 2000; Kreuter et al., 2001). And the satellite data are useful and inexpensive for analyzing changes in the value of ecosystem services and the spatial distribution at the local level for most available landscape data are based upon geopolitical boundaries and regional planning maps, neither of which relate well to the spatial arrangement changing landscape patterns (Zhao et al., 2004). Some studies on the relation between land use changes and the ecosystem service value indicate that it can only analyze the temporal change of the ecosystem service value for statistical data while the spatial distribution couldn’t be analyzed (Ye et al., 2008; Wang et al., 2009). So, our study also indicated that this comprehensive approach is feasible to study spatial distribution dynamics of ecosystem service values in response to landscape pattern change.

It is clearly shown that ecosystem services contribute substantially to human welfare on our Earth. In the decision-making process, we should give adequate weight to natural capital stock that produces these services and build up the mechanisms of economic compensation for the people who conserve ecosystem services (Li et al., 2011). In our study, forest lands in the north mountainous area, which is known as the ecological shelters and was called the “North Lung” of Guangzhou, provide huge ecosystem services (e.g., raw material, gas regulation, climate regulation, water supply, biodiversity protection, recreation) while the economic development is lag behind the southern area of Guangzhou. So, some economic compensation should be given to the north area. Furthermore, we should also pay specific attention to conserve this natural capital stock and find ways for its sustainable use. As natural capital and ecosystem services become more stressed and more limited in the future, we must determine how to use and protect them. The analyzing of ESVs is just a useful starting point.

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Conclusions

Guangzhou City, a large central city in South China and China's Southern Gateway to the world, has enjoyed economic, political and social prominence for more than 2000 years, well known for its favorably subtropic climate and attractive natural landscape. This study has attempted to analyze the landscape pattern changes and the dynamics of the ESVs, which offer important insights to those in fast-urbanizing regions for achieving more successful landscape.

In this paper, not only the landscape pattern but also the spatiotemporal changes of ecosystem service values were analyzed in Guangzhou City from 1995 to 2005. The results showed that the forest and garden became less fragmented with the overall decrease in the number of patches (NP), patch density (PD) and landscape shape index (LSI) and the increase in mean patch of area (MPA), largest patch index (LPI). But the cultivated land, grassland, water body and built-up area became more fragmented for the overall increase in NP and PD, as well as the reduction in MPA, LPI, LSI and IJI. The total ESVs maintained sustaining growth of 335.55 million Yuan from 1995 to 2005 and the increasing rate was 3.73%. Two important landscape types (forest and water body) contribute to the majority of ESVs, which accounted for over 75% of the total ESVs. The ESVs tended to decline from the north and south to the central part of Guangzhou. The average ESVs was more than 15 000 Yuan/ha in the north and 20 000 Yuan/ha in the South in Guangzhou, but it was less than 5 000 Yuan/ha in the central part of the area due to low vegetation coverage and the widely scattered of built-up area for rapid urbanization.

Zhang et al.(2011) analyzed the relationships between spatio-temporal variation of ESVs and landscape pattern indices, the result of which indicated that ESVs tend to increase with the growth of patch area and decrease with the development of patch fragmentation and shrinking of patch sizes. So, in order to maintain the increase of ESVs in Guangzhou, it is high time to protect the landscape types such as forest, garden and water body and to increase patch size to avoid fragmentation.

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