# THE COMPARATIVE STUDY ON CONNECTIVITY AND 500 MRSR OF UPGS IN SOUTHERN PROVINCIAL CAPITAL CITIES OF CHINA

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The urban public green system (UPGS) is an important component of the urban ecological system. The relationship between the ecosystem and its social services is a core topic of ecological studies throughout the world. We investigated eight provincial capital cities in southern China to analyze the connectivity and 500 m radius service ratio (500 MRSR) of the public green system based on GIS information from 2010. The connectivity and 500 MRSR were calculated based on the types, amounts, and areas of the green patches. The results indicated that the connectivity was significantly positively correlated with 500 MRSR ($p < 0.01$), while the connectivity and 500 MRSR were significantly negative correlated ($p < 0.01$) with the urban scale. The results also showed that the increase in the amount of patches density, the landscape connectivity and 500 MRSR were accompanied by a progressive decrease in the city scale. Overall, the results suggest that the landscape connectivity and 500 MRSR reflected the ecological structure and the level of function of the public green system, also reflected the degree of coupling between the social services and urban construction in the public green landscape system. This study determined the current state of urban public green spaces from the perspectives of the ecological system and the social services, which are important for facilitating the coordinated development of the urban public green space system.

**Key words:** public green space; landscape connectivity; 500 MRSR; provincial capital; GIS.

**Introduction.** The city public green space (PGS) system refers to city parks, squares and pocket parks etc. have the functions of ecological and social service, but also are important outdoor active places for citizen. So, the PGS patch pattern and changes will influence on ecological safety and living quality of citizen [23]. Meantime, harmonizing the relationship between natural ecosystem and its service, stress, respond and construction of human well-being have become a core topic ecological study in all over the world [40].

With the increasing urbanization, more and more people concentrate upon the large city. Despite awareness of more benefits for human populations such as improved housing arrangements, better employment prospects [10], better access to health and social care, education and cultural activities [25], promoted development of economic capital, labor, goods and services [29], but at the same time, the economic success breeds problems of adjustment [44] and cause a series of social and environmental problems, for example, air and water resource pollution, traffic jam etc..

The system of PGS as an important part of urban ecosystems, play a key role in preserving biodiversity in urban areas. Moreover, green spaces sequester $CO_2$ [31; 32; 27] and produce $O_2$ [15], reduce air pollution [48]; and noise [8] and regulate microclimates, reduce the heat island effect in cities [38]. Also, PGS offer the place for people to recreation, leisure, appreciation and mental restoration [16]. Therefore, the pattern of PGS and its degree of coupling with city areas will directly or indirectly influence human well being, social justice and ecological safety. However, because of the expenditure of city and increase of population density, particularly in large city, there is increasing detraction of environment. To solve these pressing issues, it is necessary to adjust the policy, planning and pattern of PGS to meet social and ecological requires of citizen.

The majority of case studies are from developed nations [34; 42; 18; 4; 6; 2; 14], most of which are highly urbanized and with relatively low population growth rates. On the contrast, developing urban planning agencies frequently struggle to keep up. In such circumstances, if the worth of PGS to local users and communities is not sufficiently acknowledged by planners and managers, urban PGS may be a target for ad hoc development of unsanctioned informal settlements or expropriation for productive purposes such as urban agriculture or infrastructure development (4).

In recent years, many ecologists pay a close attention to fast urbanization and its increasing deteriorative environmental problems in China, and they made a contribution to study on systemic function [35], green space layout structure [51], landscape feature analysis [7; 36, 37], green network construction [19; 20] and green patch connectivity [47; 43; 21; 45; 9; 40; 41, 52] etc.. With the help of GIS information, using the index of connectivity to study the relationship complexity [33], accessibility [13; 11] and interdependency [12] in and between ecological systems have become an important way.

In this study, we integrated comparative analysis with PGS patch connectivity and its 500m radius service rate (500MRSR) to quantitatively characterize the PGS pattern of the eight provincial capitals in southern of China. We aimed to address several questions: (1) how do different city PGS change with different population scale? (2) Do have they own relationship among the PGS patch connectivity, patch density and its 500 MRSR? (3) Can PGS system be comparative analysis in different city scale using the index of connectivity and 500 MRSR?

**Study areas.** Research areas include Guangzhou, Wuhan, Chengdu, Hangzhou, Fuzhou, Kunming, Changsha and Guiyang city total eight provincial capital cities, locating at Southern of China, Sichuan basin and the Yunan-Guizhou plateau. Urban population and areas were shown in table 1.

*Table 1*

**Situation of population and area in eight Provincial capitals**

| City | Guangzhou | Wuhan | Chengdu | Hangzhou | Kunming | Changsha | Fuzhou | Guiyang |
|---|---|---|---|---|---|---|---|---|
| City area ($km^2$) | 952 | 500 | 456 | 413 | 275 | 272 | 220 | 162 |
| Population (10,000) | 664.29 | 520.65 | 535.15 | 434.82 | 260.24 | 241.73 | 188.59 | 222.03 |

*Data from the city statistic yearbook of China.

**Material and methods.** In this study, we use satellite remote sensing images of eight capital cities of China of 2010 as the basic research material, and the data of urban area, population is from the Chinese city statistics yearbook 2010.

The index of landscape connectivity is a measure of the continuity among the landscape spatial structure unit. And also is an important parameter of describing the process of landscape ecological and reflect the functions of the landscape.

To capture the data of area of public green patch (PGP), this study use the way of combining the Photoshop and AutoCAD to obtained data. First, our information of interest was PGP in the city districts. For this process we used the Geographical Information System, ArcGIS 9.3. Afterwards all the PGP were identified. Second, we put the image of Photoshop into AutoCAD to obtain the outline of every PGP. And then, we calculate the area of every PGP and distance between PGP [1]. In accordance with the distances of PGP, we use every the shortest one among the distance from the same patch to calculate connectivity. The formula of connectivity is:

$$NC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{a_i \cdot a_j}{1 + nl_{ij}}}{A_L^2}.$$

In formula: n stands for the number of public green patches, and the area of the patch I and j, respectively, represent the number of connections between patch I and j, and AL is the research area. The threshold of connection is less than 500 meters between patches. NC value is between 0 ~ 1.

500 MRSR is one of important indexes in the standard of the national “landscape city” of China which is 500 MRSR > 70%, but it little known in existing literatures. The meanings of the 500 MRSR include two sides: one is its social service function that the citizen can sue the PGS easily in these areas, and another is ecological functions that it can more directly and clearly expresses the spatial pattern of PGS system as a supplement of green patch connectivity and reflect the degree of coupling of PGS system with the area of city.

To gain the information of 500 MRSR, the outline of every PGP was deviated 500 m outwards in AutoCAD, and the area of in new outline as 500m social service area calculated. By means of abandoned the overlap parts of 500m service area between green patch and the parts of beyond boundary, the all area of social service can be calculated with the formula of 500 MRSR:

$$500\ \text{MRSR} = \text{patches social service area/total city area} \times 100\%.$$

**Data calculation and analysis.** SPSS16. O for Windows software packages and Microsoft Office Excel were used in statistical analysis and calculation.

**Results. Urban landscape green space systems.** The basic situations of population, area, feature of PGS patch, connectivity and 500 MRSR in eight provincial capital cities were showed in table 1. The average connectivity is 0.49 in eight cities. The landscape connectivity in Guangzhou, Wuhan, Chengdu, Hangzhou, Kunming five cities is less than 0.5. The Guangzhou city has the minimum connectivity value (0.28), and Guiyang city own the highest value (0.66). The differences among different city scale were obvious.

The average of 500 MRSR was 53.71% in eight cities. The value of 500 MRSR in Guangzhou, Wuhan, Chengdu and Hangzhou city were less than 50%, lower than the national landscape city standard (70%). This situation indicate that pattern of PGS is unreasonable in large city in southern of China. The main reasons conclude dense population (>4 million), small green patch density, unreasonable landscape patch distribution and the poor landscape service function. On the contrary, the cities with small area and population such as Changsha, Fuzhou, and Guiyang are more than 70% 500 MRSR value; conform to the state standard of "landscape city".

The above results indicated that, with the rapid expansion of large capital city, complex traffic routes and dense buildings blocked the ecological connection in main parts of the city [1], and lead to landscape connectivity and 500 MRSR levels decline. On contrast, because of relatively small area, less population, and better urban PGS system there are good systematic and continuity in Guiyang, Changsha and Fuzhou city (table 2).

*Table 2*

**Situation of city scale and parameters of public greenery patches system**

| No | City | Area ($km^2$) | Population (10 000) | Patch area ($hm^2$) | Patch number | Patch/$km^2$ | Connectivity | 500 MRSR (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | Guangzhou | 952 | 664.29 | 12765.2 | 209 | 0.22 | 0.28 | 13.41 |
| 2 | Wuhan | 500 | 520.65 | 20791.15 | 110 | 0.22 | 0.37 | 41.58 |
| 3 | Chengdu | 456 | 535.15 | 21086.7 | 174 | 0.38 | 0.39 | 46.24 |
| 4 | Hangzhou | 413 | 434.82 | 9422.3 | 156 | 0.37 | 0.5 | 47.36 |
| 5 | Kunming | 275 | 260.24 | 14766.7 | 104 | 0.38 | 0.52 | 53.70 |
| 6 | Changsha | 272 | 241.73 | 20936.8 | 178 | 0.65 | 0.55 | 76.97 |
| 7 | Fuzhou | 220 | 188.59 | 9001.2 | 58 | 0.27 | 0.61 | 77.21 |
| 8 | Guiyang | 162 | 222.03 | 19864.4 | 105 | 0.65 | 0.66 | 73.24 |

**Correlation analysis.** The results of Pearson correlation analysis (table 3) indicated that the connectivity was significantly positively correlated with 500 MRSR ($p < 0.01$), while the connectivity and 500 MRSR were significantly negative correlated ($p < 0.01$) with the urban scale. The results also showed that the increase in the patches density, landscape connectivity, and 500 MRSR were accompanied with the decrease of the city scale. There was no significant correlation happened between the other two factors. With the increase of city scale, PGS system structure and its service function became weakening. And it also showed the coupling relationship between the function of green space system connectivity and 500 MRSR which embody the functions of social service (table 3).

*Table 3*

**Pearson Correlation analysis**

| | Area of city | Population | Area of patch | Number of patch | Patch density | Connectivity | 500 MRSR |
|---|---|---|---|---|---|---|---|
| Area of city | 1 | | | | | | |
| Population | 0.912** | 1 | | | | | |
| Area of patch | –0.136 | 0.057 | 1 | | | | |
| Number of patch | 0.682 | 0.668 | 0.203 | 1 | | | |
| Patch density | –0.609 | –0.594 | 0.467 | 0.062 | 1 | | |
| Connectivity | –0.915** | –0.952** | –0.083 | –0.637 | 0.657 | 1 | |
| 500MRSR | –0.935** | –0.934** | 0.127 | –0.585 | 0.661 | 0.92** | 1 |

** Correlation significant at $p < 0.01$

**The PGS system space structure and its 500 MRSR analysis.** Figure 1—8 demonstrate directly the status of PGS pattern and social service of eight provincial capital cities. Figure 1 shows there are less large patches and less medium-small patches in Guangzhou city. Most large patches are mainly distributed around the central urban area, and medium-small patches are scattered distribution. So, the value of connectivity (0.28) and 500 MRSR (13.41%) is the lowest. Figure 2 shows the PGS system of Wuhan city is similar to Guangzhou, there are more large patches distribute around the city center and a few in other urban areas. The medium-small patches are scattered distribution. And the value of connectivity (0.37) and 500 MRSR (41.58%) are lower. Figure 3 shows there are a ring pattern of PGS system around the center of Chengdu city, and the number of green patch gradually are decreased from the center to suburb. The value of the connectivity (0.29) and 500 MRSR (46.24) present situation of the medium. Figure 4 indicated the pattern of PGS system is characterized by a few large patches of and more medium-small patches in Hangzhou city. The small green patches are scattered distribution. The values of connectivity (0.5) and 500 MRSR (47.36%) are better. Figure 5 demonstrates that the pattern of PGS system is reasonable, but less number of patches. in the peripheral city of Kunming city. The value of (0.52) and 500 MRSR (53.7%) were above the medium level. Figure 6 ~ 8 show the patterns of PGS system in Changsha city, Fuzhou city and Guiyang city. The green patch density, number of patch and uniformity of distribution are more reasonable. The values of connectivity and 500 MRSR are 0.55, 0.61, 0.66 and 76.97%, 77.21%, 76.97% respectively. The pattern of urban green space construction in above three cities are worthy of reference.


**Fig. 1.** Gunangzhou city public green system and 500M RSR

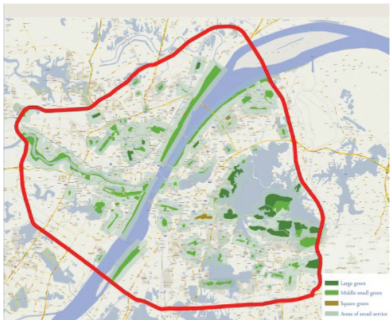

**Fig. 2**. Wuhan city public green system and 500M RSR

**Fig. 3.** Chengdu city public green system and 500M RSR

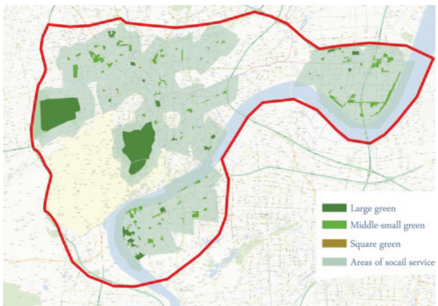


**Fig. 4.** Hangzhou city public green system and 500M RSR

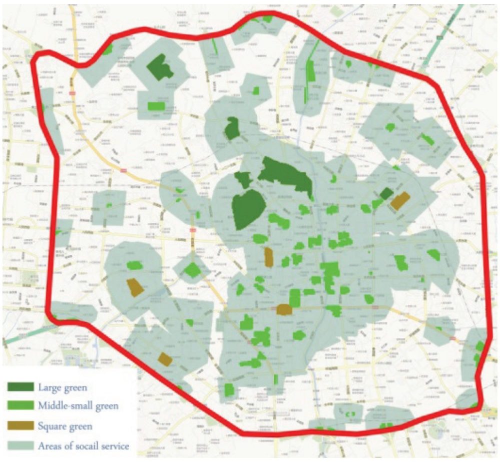


**Fig. 5.** Kunming city public green system and 500M RSR

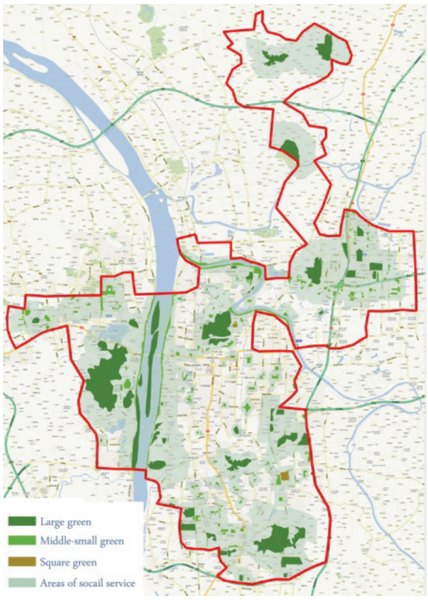


**Fig. 6.** Changsha city public green system and 500 M RSR

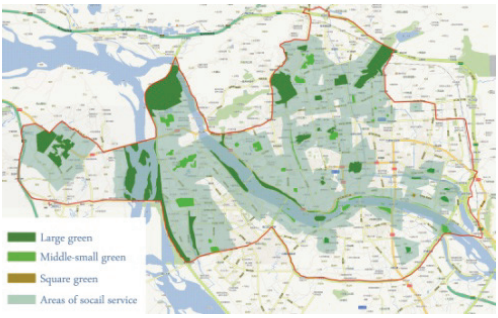


**Fig. 7.** Fuzhou city public green system and 500M RSR

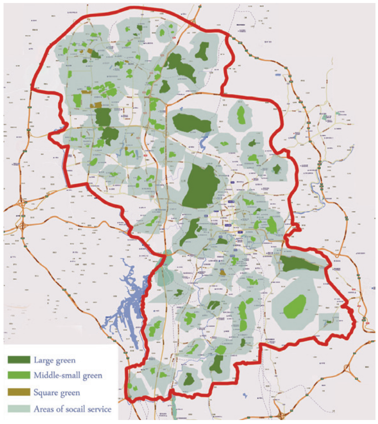


**Fig. 8.** Guiyang city public green system and 500M RSR

**PGS patch density, population, 500 MRSR and connectivity.** To study deeply and directly the relationship among patch density, population, 500 MRSR and connectivity under the gradient of city scales (population), we uses the information from table 2, and obtained figure 9 ~ 10. The result of figure 9 shows that 500 MRSR and patch density increased with the decrease of the scales (population). This finding illustrate that 500 MRSR value not only related to the patch density, also is associated with patch distance and its distribution pattern.

Figure 10 showed that the patch density and connectivity generally present a tendency of positive correlation with the decrease of the scale (population) of the city.

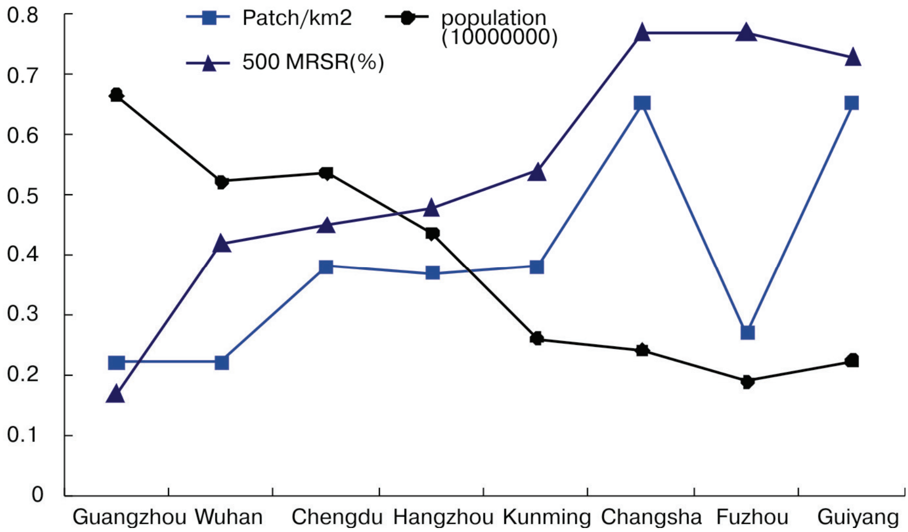


**Fig. 9.** Tendency analysis between numbers of pitches/km$^2$ and 500 MRSR

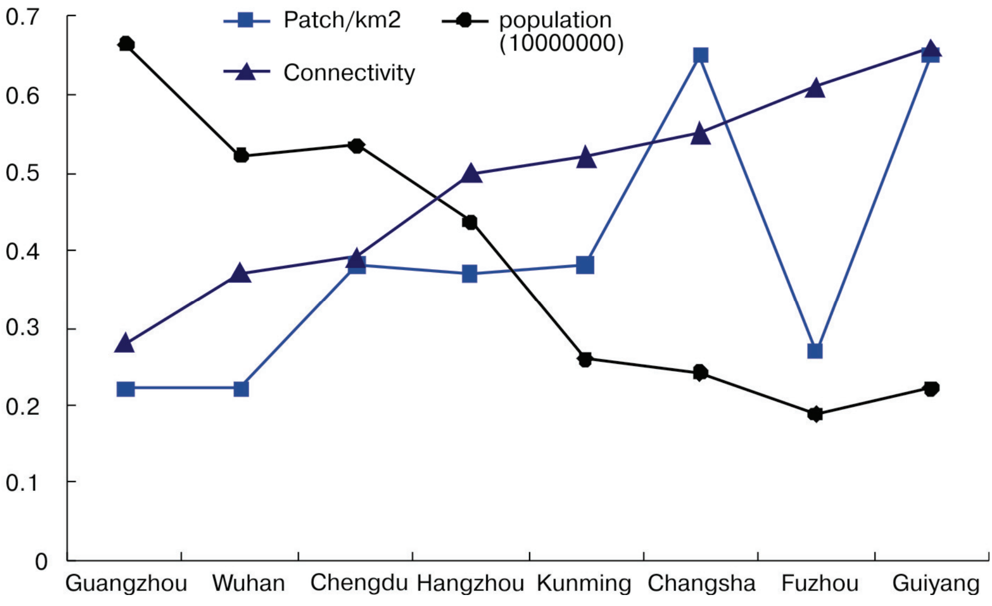


**Fig. 10.** Tendency analysis between numbers of pitches/km$^2$ and connectivity

**Discussion and conclusions. General PGS patterns in the eight capital city.** Our study has demonstrated that the change and spatial pattern of PGS in different city can be quantified using a combination of landscape metrics and comparative analysis. The results from our study can adequately address the research questions we defined earlier in Section 1: (1) how do different city PGS change with different population scale? (2) Do have they own relationship among the PGS patch connectivity, patch density and its 500 MRSR? (3) Can PGS system be comparative analysis in different city scale using the index of connectivity and 500 MRSR? While the answer to these questions is generally affirmative, more details are discussed below. The scales (population) of city exhibited distinctive, but not necessarily unique, spatial signatures that were dependent on specific landscape metrics. For example, for patch density, patch size coefficient of variation, and patch connectivity index displayed different patterns along the gradient of scale (population) of city. The relationship between patch connectivity and 500 MRSR indicated clearly positive correlation. Therefore, different PGS patch pattern may indeed show distinctive "spatial signatures" as scale based "landscape pattern" which may be used to compare urban developmental patterns between cities and dynamics over time [46]. It was clear, though not surprising, from this study that the degree of human impact on the urban landscape depended on the scales of different city.

**Importance of quantifying spatial patterns of PGS and 500 MRSR.** To understand the ecological and social consequences of PGS, it is necessary to quantify the spatial patterns of PGS. First, PGS systems are spatially extended systems in which physical, ecological, and socioeconomic processes create, maintain, or destroy spatial patterns. and at the same time spatial patterns facilitate, inhibit, or neutralize these processes. The changes in PGS pattern in different city as revealed by our analysis may have important ecological implications. For example, the elimination of large green patches, increased habitat fragmentation, and substantially high patch density of human land use types may significantly affect the biogeochemical cycling and biota of this area [3; 28]. In particular, combining comparative analysis with landscape metrics, as illustrated here, can help to identify quantitatively and characterize the social service and complex spatial pattern of PGS, which can subsequently be related to ecological and socioeconomic processes [26].

Landscape connectivity was put forward by Merriam in1984 for the first time. The connectivity was described the characteristics of landscape structure and the interactions between species movement behavior. Since then, Forman, Schreiber, Taylor put forward more definitions complement, but all of them believed that landscape connectivity is a measure of the continuity among the landscape spatial structure unit and a parameter describing the process of landscape ecological and reflect the functions of the landscape [21]. In this study, landscape patch connectivity is defined as the urban PGS system excluding the corridor green space, forest participation and other green space without any landscape facility. So, the results may be different with others study of urban green space system. Our results supported the hypotheses that, with increasing urbanization, patch density increases while patch size and landscape connectivity decrease [50].

The index of the 500 MRSR reflects both social service function that the citizen can sue the PGS easily in these areas, and ecological functions that it can more directly and clearly expresses the spatial pattern of PGS system as a supplement of green patch connectivity as well as reflect the degree of coupling of PGS system with the area of city. The results in this study, the value of 500 MRSR are less than 50% in Guangzhou, Wuhan, Chengdu and Hangzhou city, and it was similar to Li's [22] research results of Harbin city park green space service. This situation indicated there were many problems in the urban PGS system construction, especially in the large provincial capital cities, PGS systemic constructions were serious lag in urbanization process in recent years due to the rapid expansion.

Research results show that the construction of urban green space system should not only consider the number of green patches and their size, but also pay attention to the distribution pattern of patch system. Namely it is necessary conditions to improve the urban PGS ecosystem service rate: a uniform distribution in the appropriate number of patches and the moderate distance (less than 600 meters distance). And the area and the size shape of patch decide the amount of biological species diversity which is important for the stability of the whole urban green space system.

With the acceleration of urbanization and the increasing of construction land demand, more and more serious contradictions happened among the various land use. And more and more ecological land were invaded and led to the decline in land ecosystem service function [49; 39]. The reasons for above results are included the urban greening policies, rapid urbanization and the growing environmental requirements of residents [23]. There are many dense buildings in center of city in the southern of China. The public green spaces were serious segmented and led to green patches more scattered. In contrast, the above problems were solved by considering of urban functions and services as well as the urban space layout in some of the second-line city [45].

**Difficulties and challenges of the study.** First, to capture the data from satellite map, it is necessary to intercept maps of eight cities, identify the range of PGS and to calculate the areas and distances of every public green patch. So, there are needs very much work to do. Second, some information from satellite map are not clear and can't be use and need to check in the network and site inspection. These works supported by the data set group of "the report on the development of China's city" green book. Finally, because above reasons, this study only research the patterns of eight cities to reflect the situation and changes of PGS system in different city scales, and lack of conformation of repeated trails.

This study was only a first step towards understanding the structure and functioning of the PGS of city. The extension of this study to understanding the mechanisms involved in urban landscape eco-system pattern formation necessitates a more comprehensive framework that explicitly incorporates geographical, ecological, social service, and political considerations.

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# СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ СВЯЗИ И КОЭФФИЦИЕНТА ОБСЛУЖИВАНИЯ СИСТЕМЫ ГОРОДСКОГО ОЗЕЛЕНЕНИЯ АДМИНИСТРАТИВНЫХ ЦЕНТРОВ ПРОВИНЦИЙ ЮГА КИТАЯ

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Городские зеленые системы (UPGS) являются важным компонентом городской экологической системы. Отношения между экосистемой и социальными услугами — это основной признак экологических исследований во всем мире. Мы исследовали восемь провинциальных столиц в Южном Китае и проанализировали коэффициент обслуживания (500 MRSR) общественной зеленой системы на расстоянии 500 м на основе ГИС-информации в 2010 г. Связь между зелеными зонами и областью их обслуживания 500 MRSR была рассчитана в зависимости от вида и площади зон зеленых участков. В целом, полученные результаты позволяют предположить, что обеспеченность зелеными зонами 500-метровой доступности (500 MRSR) отражает экологическую структуру и уровень функционирования общественной зеленой системы, также отражает степень связи социальных служб и городской застройки с общественной зеленой ландшафтной системой. В этом исследовании определяется текущее состояние городских общественных зеленых зон с точки зрения экологической системы и социальных услуг, которые имеют важное значение для содействия скоординированному развитию системы городских общественных зеленых насаждений.

**Ключевые слова:** общественные зеленые пространства, ландшафт-связь, 500 MRSR, столицы провинции, ГИС.