Evaluation on Ecological Service of Urban Green Space System and Estimation on System Carrying Capacity

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Abstract

Urban green space system is an important component of urban natural ecosystem, which has significant function of ecological service. This paper evaluated the green system according to the comprehensive index of ecological service efficiency. Based on analysis of landscape accessibility and combined with the street population density, it estimated the service population of green system and the carrying capacity, which provided effective and technical quantization means for urban sustainable development.

Keywords: urban green space system, ecological service function, landscape accessibility, carrying capacity

1 Introduction

As the carrier of human civilization and social and economic development, city is the area with high-density of population, industries, capital productivities and technologies. It is also the complex ecosystem of society-economy-nature centered on human activities [1]. As the important component, urban green space system is the main contributor of urban ecological service efficiency. With the rapid progress of urbanization in China, urban environmental problems are intensifying, and the cushion and compensation action of green land system to urban ecological environment become obvious day by day. Moreover, our awareness of the importance of green land ecosystem service also unprecedentedly improves. Urban green land system is the green space with function of ecological balance and closely related to human life. Take soil as matrix and vegetation as subject and with characteristics of human disturbance, it is the artificial ecosystem that cooperates with microorganism and animal community. The ecological service efficiency of urban green land refers to that the green land system can provide material products, environmental resources, ecological technology and aesthetic value for maintaining urban human activities and resident physical and psychological health [2].

Concept of urban green land ecological service function has been extensively accepted, which mainly includes climate regulation, environment purification, travel rest, benefits of social culture and biodiversity protection. Researches of ecosystem service of green land mainly center on evaluation of service value, benefits of green land ecology, three-dimensional green of green land. The introduction of landscape accessibility [3,4] has provided important idea for researches of green land ecological service function. The application of evaluation model of landscape accessibility can reflect the fairness level of green land distribution and accessibility level, but the summarization of green land model tends to neglect the some key and detailed parts. Functions like urban green space system purifies environment and relieves heat island can not be fully reflected.

With the rapid growth of urban population and rapid expansion of urban size, the bearing capacity of urban green space system to the constraint of urban development has attracted our attention. How the urban sustainable development coordinates with urban carrying capacity not only relates to the destiny of the city itself, but also relates to whether the surrounding areas can successfully realize sustainable development. We can the significance of studying urban bearing capacity. Therefore, this paper mainly introduced the evaluation methods of urban green space system ecological service and the estimation research of green space system bearing capacity.

2 Evaluation Methods of the Ecological Service of Urban Green Space System

A. ESTABLISHMENT OF THE QUANTIFIED MEASUREMENT INDEX SYSTEM OF ECOLOGICAL SERVICE EFFICIENCY

Based on principles like the accessibility, scientificity and easy quantification of data selection, this paper adopted the evaluation method of DelPh Garden expert consultation, and established the leading index factors and the evaluation system that affect urban green land ecological service. Quantity of sulfur dioxide, absorb heat, transpiration water, water conservation, dust lay and dust fall were selected and measured. These five indexes could be used to represent two most important ecological service efficiencies: improvement of atmospheric environment and regulation of microclimate. The selected indexes were all screened and determined based on the analysis and reference of the existing green land ecological service efficiency evaluation

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index at home and abroad. These ecological service efficiencies mainly generate from the urban ground layer. Under specific conditions of buildings intensive, population concentrated and closed living space, they can contribute greatly to the improvement of urban residents and environmental quality of movement area. By means of looking up the comparative statement of ecological service efficiency ability [5], this paper calculated the ecological service efficiency indexes criteria of sulfur dioxide absorbed by forest land, dust lay and fall and water resources conserved in grassland, as well as the service efficiency criteria of absorb heat and rising water of forest land. The grass land and forest land ecological service efficiency criteria after calculation and arrangement is shown in table 1.

TABLE 1 the annual ecological service efficiency criteria of per hectare greenbelt

type of greenbelt	absorb SO2/ $\left(t \cdot hm^{-2} \cdot a^{-1}\right)$	absorb heat/ $\left(MJ \cdot hm^{-2} \cdot a^{-1}\right)$	rising water / $\left(t \cdot hm^{-2} \cdot a^{-1}\right)$	dust lay and fall/ $\left(t \cdot hm^{-2} \cdot a^{-1}\right)$	conserved water resource/ $\left(t \cdot hm^{-2} \cdot a^{-1}\right)$
grass land	7.92	7.99×104	3.26×104	4.18	38.7
forest land	123.5	1.29×104	5.26×104	10.9	350

B. CALCULATION AND EVALUATION METHOD OF ECOLOGICAL SERVICE EFFICIENCY

(1)Calculation of the Practical Efficiency Value of Ecological Service

According to urban green land area and green land type, and consult to the ecological service criteria of green land in table 1, the practical efficiency values of various ecological services of green land system under certain condition were respectively calculated. The completed green space system area was denoted by $A_g(hm^2)$ based on its computing unit. Certain ecological service efficiency criterion of grassland within unit area was represented by $E_g(MJ \cdot hm^{-2} \cdot a^{-1}$ or $t \cdot hm^{-2} \cdot a^{-1})$. The forest land area of green space system under certain situation was denoted by $A_f\left(hm^2\right)$. Certain ecological service efficiency criterion of forest land within unit area was represented by $E_f(MJ \cdot hm^{-2} \cdot a^{-1}$ or $t \cdot hm^{-2} \cdot a^{-1})$, and the practical efficiency value X_i (MJ or t) of certain ecological service of green space system under some situation was represented by:

$$X_i = A_g \times E_g + A_f \times E_f \quad (1)$$

(2)Calculation of Sub-index and Comprehensive Index of Ecological Service Efficiency

Full permutation polygon diagram indication can simultaneously reflect the single index and comprehensive index which also can be expressed by geometry perceptual intuition diagram. It needs to be noted that the calculation process of isobar evaluation index adopted in this paper is not just the simple weighting method, thus we can get the objective result. Its basic principle is: suppose there are n indexes (standardized value). The upper limit values of these indexes are considered as the radius to form a centre n-regular polygon. The ligatures of various index values make up a centre n-irregular polygon. The peak of the centre n-irregular polygon is a full permutation of n indexes with end to end.

The following data standardization function is adopted when calculating the sub-index of certain ecological service efficiency:

$$S_i = \frac{(U_i - L_i)(X_i - T_i)}{(U_i + L_i - 2T_i)(U_i + L_i)T_i - 2U_i L_i} \quad (2).$$

In formula, S_i refers to the standard sub-index of certain ecological service efficiency. X_i refers to the practical efficiency value (MJ or t) of ecological service under certain situation. U_i and L_i respectively refer to the maximum and minimum of practical efficiency value of ecological service (MJ or t). T_i refers to the mean of practical efficiency value of ecological service under various situations. A centre n-regular polygon can be drawn with n indexes. Value of n peaks of n-sides polygon is taken when $S_i = 1$, and value of centre point is taken when $S_i = -1$. Segment between centre point and peak is the place where each index locates $[-1, +1]$. The polygon constructed when $S_i = 0$ refers to the critical zone of index. The interior zone of critical zone signifies that the standardized value of each index is under critical value, of negative value. The exterior zone signifies that the standardized value of each value is under the critical value, of positive value.

The sub-index of ecological service efficiency calculated from formula (2) has no non-dimensional value. The comprehensive index of ecological service efficiency is calculated using formula (3). The computational formula of comprehensive index of full permutation polygon is:

$$C = \sum_{i \neq j}^{i,j} (S_i + 1)(S_j + 1) / 2n(n-1) \quad (3)$$

3 Estimation Method of CARRYING Capacity of Urban Green Space System

Indexes like area, proportion, number of plague, density of plague, average plague area, maximum plague index of various green land types are calculated using Fragstats 4.2, so as to reflect the current situation of green land. The computational formula of each index consults to the helpfile of Fragstats 4.2.

The common research methods of landscape accessibility include corridor approach, minimum adjacency method, gravity model method, cost weighted distance method network analysis. This paper analyzed the accessibility of different types of greenbelt using cost weighted distance method. The relative resistance value of various land-use types means to set the landscape resistance value through time cost consumed by certain space distance. Resistance generally means the measurement of relative complexity of man passing through certain spatial picture element. The landscape resistance value of various land-use types are converted to the raster data of 5m×5m.

There are also differences in ecological service function, since the differences of green space area and green quality. This paper partially modified the evaluation method of spatial accessibility, and brought in the evaluation method of ecosystem function level. Given the differences of service area of different green space types, this paper calculated the scope of comprehensive ecosystem function level of urban green space system but not just considered the accessibility of spatial distance of green space system. The service area of different green space types were calculated using cost weighted distance. In this paper, characteristics of 4 types of green space types were considered in grading evaluation. The ecological service function levels from large to small were respectively I, II, III, IV, V. Each green space type was given the corresponding weight. The comprehensive ecological service function level of the green space system was calculated with the following formula (as shown in table 2).

$$R_s = \sum_{i=1}^{i} (R_i \times \gamma_i) \quad (4).$$

In formula (4), R_s stands for the comprehensive ecological service function level of green space system $(R_s = 5,4,3,2,1)$, R_i stands for the comprehensive ecological service function level of green space system $(R_i = 5,4,3,2,1)$ of the i type, and γ_i stands for the weight coefficient of the i type.

Generally, the service radius of City Park, Community Park and roadside green space are respectively 800, 500 and 200m. However, in terms of the development of ecological service function, the service radius of park green land can be more than 1000m. This paper set the service radius of park green land in service area of Ⅰ and Ⅱ level as 500m, and the service radius of other types as within 200m. The service radius of park green land in service area of Ⅲ was set as 1000m, and other types as within 500m. In terms of ecological service function, the service area of Ⅰ and Ⅱ level can enjoy area of convenient service, while that of Ⅲ level is the place where the ecological service function can effectively develop. The ecological service functions of higher than V level can not effectively develop.

TABLE 2 evaluation standard of ecological service function level of urban green space system

level	park green land	productive plantation area	preen buffer	attached green space	evaluation
Ⅰ	0-200	0-100	0-50	0-100	5
Ⅱ	200-500	100-200	50-100	100-200	4
Ⅲ	500-1000	200-500	100-200	200-500	3
Ⅳ	1000-2000	500-1000	200-500	500-1000	2
Ⅴ	>2000	>1000	>500	>1000	1
weight	0.40	0.15	0.20	0.25	–

Relationships between population density and green area in urban community can reflect the level of urban ecological environment. Overlay the register service area of ecological service function and block population density, and adopt spatial analysis to calculate the service population of urban green space. The appropriate population density is calculated with green space area per capita as standard. Compare the service population of green space system and proper population, so as to analyze whether it has exceeded the carrying capacity threshold of green space system [7].

4 Discussion

Based on the evaluation of green space accessibility, this paper considered the ecological service function difference of different types of green space. What the traditional green space accessibility generally considered is the recreation function of urban park green space, thus the ecological service function difference of different greenbelt qualities are easy to be neglected. However, the ecological service function of greenbelt system is more important to the sustainable development of urban ecosystem. Greenbelt like greenbelt of residential quarter, road green space which is close to urban landscape and environment also should be taken into consideration. The landscape accessibility model is the quantified expression to function and range of greenbelt system service, which is of high generalization in the quantification model of greenbelt system. Take the ecological service function difference of different green space types into consideration, and then the accuracy of the quantitative evaluation of green space system can be enhanced. This paper brought in the evaluation method of ecological service functional level which provided new idea for the evaluation of green land system landscape accessibility.

This paper integrated the advantages of spatial distance accessibility and ecological service function. Compared with the accessibility evaluation of cost consumption, it extruded the effect of green land ecological service function, improved the accuracy of greenbelt system in aspect of quantified model. Compared with method of relief area, it modified the service area of greenbelt ecological service function using cost weighted distance [8]. From the evaluation result, it also conforms to the greenbelt layout and the characteristics of different greenbelt service functions. It is more of ecological significance than the previous greenbelt accessibility evaluation. The quantitative evaluation of ecological resources like urban greenbelt and urban forest is a complex problem, and the construction of representative, complete and operable index system needs much consideration [9]. Greenbelt service function also affects by many complex factors, like residential willingness and greenbelt attraction. There are still many places need to be completed of landscape accessibility evaluation model of urban greenbelt.

Researches about the carrying capacity of urban greenbelt mainly center on calculating the population carrying capacity based on greenbelt area standard per capita and carbon and oxygen balance method. Based on the landscape accessibility evaluation model, and combined with the block population density distribution, this paper put forward the estimation method of carrying capacity of greenbelt system. The service range of urban green land is divided into different levels, which effectively reflect the spatial arrangement characteristics of greenbelt ecological service function. It is the improvement of stage division only on spatial distance. Calculation of greenbelt system carrying capacity within service range of different levels can judge size of carrying capacity of regional green space and its distribution pattern, which overcame the disadvantages of only evaluating the regional carrying capacity and provided quantitative basis for greenbelt system, urban function area and planning and layout of population size.

With the rapid development of urban construction and social economy, population density in street will inevitably increase, which come up with higher requirement to urban greenbelt construction. The quantitative evaluation of greenbelt carrying capacity is a complex problem, thus it is necessary to put forward the comprehensive assessment model of urban green space integrating various aspects of ecological system service function. Green space carrying capacity is also influenced by many factors like seeds of trees, plant furnishing, green quality, etc. The community configuration of urban green space and the health condition of trees are contents cannot be neglected in evaluating greenbelt carrying capacity. Development of 3S technology in information extraction of vegetation will promote researches of urban green space ecological system. It can provide more data support for the green space ecological service function evaluation and carrying capacity estimation, and provide effective technical quantitative means for urban sustainable development.

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