Research on Evaluation of Ecological Service Function of Urban Green Space System——Taking Xiamen as an Example

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Abstract: By using the concept of ecological service efficiency index, three first-level indicators and 12 second-level indicators were used to construct the Xiamen urban green space ecological service evaluation model. In order to objectively and scientifically evaluate the ecological service function of urban green space system, a comprehensive evaluation method based on AHP-cloud model is proposed. The example verification shows that the ecological service function of Xiamen urban green space system is between medium and excellent, with certain space for improvement and transformation, and gives specific solutions from the perspective of ecology. The feasibility and effectiveness of AHP-cloud model in the evaluation of urban green space system ecological service function are confirmed, which provides a new research direction for urban green space system ecological service function.

1. Research on the ecological service function of urban green space system

The Urban Green Classification Standard divides urban green space into five parts: park green space, production green space, protective green space, affiliated green space and other green spaces[1]. There are many researches on the ecological service functions of urban green space systems. Li Feng analyzed the status quo of urban ecological infrastructure from the perspective of ecosystem services[2]; Hu Xiaofei conducted a dynamic analysis of the functional value of urban green space system ecological regulation services in Nanchang[3]. Taking Xiamen as an example, this paper uses AHP-cloud model to evaluate the ecological service function of urban green space system.

2. Evaluation of ecological service function of urban green space system based on AHP-cloud model

2.1 Theory of cloud model

1) Cloud definition: Suppose U is a quantitative domain represented by an exact value, C is a qualitative concept on U. If the quantitative value $x \in U$, and x is a random implementation of the qualitative concept C, then the degree of certainty for x to c, which is $\mu(x) \in [0,1]$, is a random number with a tendency to be stable. If $\mu: U \to [0,1]\ \forall x \in U\ x \to \mu(x)$, then the distribution of x on the domain U is called a cloud, and each x is called a cloud drop.

2) Digital features of the cloud and cloud generators. The cloud model is described by three numerical features: Ex (expected value), En (entropy) and He (hyper entropy), as shown in Figure 1.

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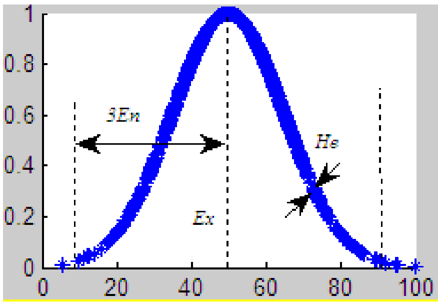

Figure 1 Digital features of cloud model

The cloud generator (CG), that is, the cloud generation algorithm can be divided into two types: forward and reverse cloud generators. The forward cloud generator refers to a forward and direct process. The number of cloud drops is generated by inputting Ex, En, He. The output of any cloud drop will be in the domain of the coordinates and the degree of certainty. The schematic diagram is shown in the figure. 2. The reverse cloud generator is the inverse of the forward cloud generator, as shown in Figure 3.

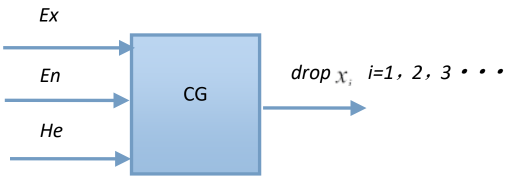

Figure 2 One-dimensional forward cloud generator

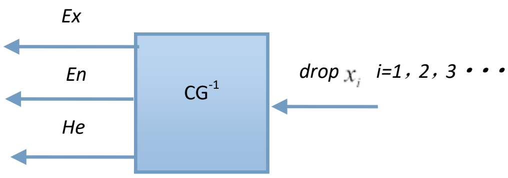

Figure 3 One-dimensional reverse cloud generator

3) Calculation of cloud parameters. The algorithm of the inverse cloud generator[9] is as follows:

Input: n cloud drops x_i ($0 \leqq i \leqq 1$)

Output: 3 digital features of the cloud (*Ex*,*En*,*He*)

4) Synthesized cloud. It refers to the integration of two or more sub-clouds of the same type to generate a higher-level parent cloud.

Taking two clouds, Cloud1 (Ex1, En1, He1) and Cloud2 (Ex2, En2, He2) as examples, the integrated parent cloud model (Ex, En, He) can be obtained. The algorithm is as follows:

$$\begin{cases} Ex = \dfrac{Ex_1 En_1 + Ex_2 En_2}{En1 + En2} \\ En = En_1 + En_2 \\ He = \dfrac{He_1 En_1 + He_2 En_2}{En_1 + En_2} \end{cases} \tag{1}$$

2.2 Establish an indicator system

The ecological service function evaluation of urban green space system is divided into three first-level indicators of carbon sequestration and oxygen release value, purification of environmental value and conservation soil function value, as well as 12 secondary indicators such as green area and connection section, as shown in Figure 4.

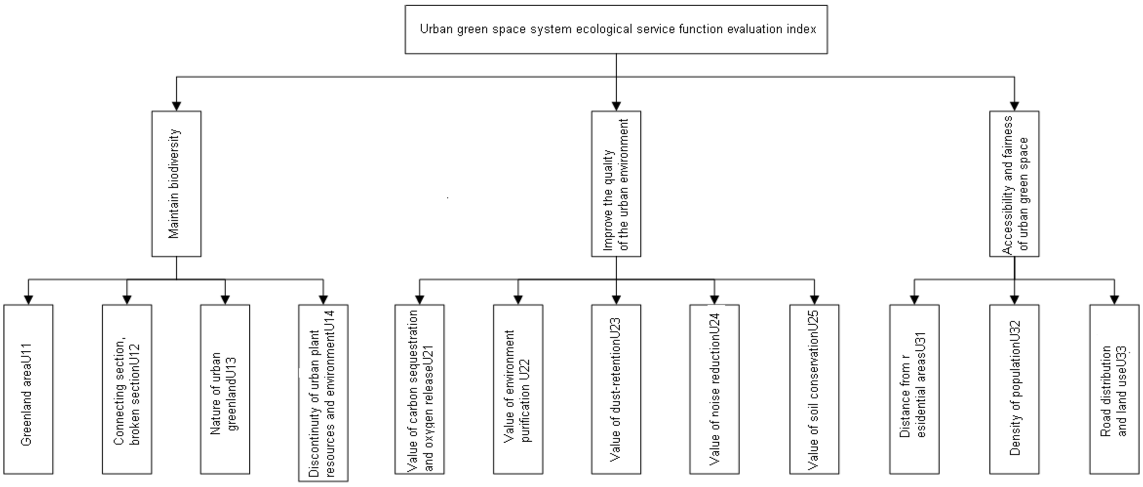

Figure 4 Urban green space system ecological service function evaluation index system

2.3 Establish evaluation index reviews (Cloud ruler)

In this paper, we use the five-layer normal cloud defined by Li Deyi to establish five evaluation levels between [0, 1], which correspond to excellent Cloud (1, 0.1031, 0.013), medium Cloud 0.691, 0.064, 0.008 in the cloud model.), qualified Cloud (0.5, 0.039, 0.005), poor Cloud (0.309, 0.064, 0.008) and very poor Cloud (0, 0.1031, 0.013). The cloud ruler is shown in Figure 5:

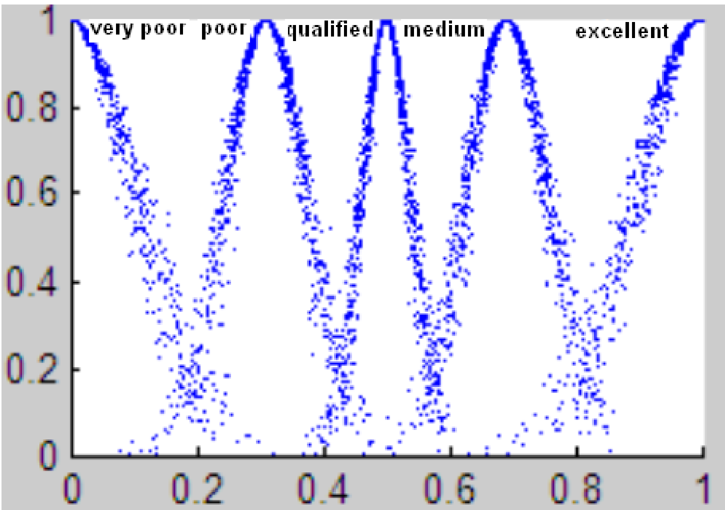

Figure 5 Cloud ruler of opinion rating

2.4 Using analytic hierarchy process to determine index weights

The Analytic Hierarchy Process (AHP) is based on the degree of importance of the indicators, it establishes a judgment matrix and the eigenvectors and eigenvalues are used to determine the index weights.

2.5 Determine evaluation value

Each expert scores the secondary indicators in the indicator system and gives the lowest and highest scores for each of the secondary indicators. After combining the scores of all the experts, the three digital characteristics of the cloud will be obtained. Use MATLAB software to generate cloud maps to achieve the conversion of qualitative and quantitative indicators. If the cloud image is presented in the form of a fog map, it is necessary to give feedback to the experts, so as to adjust the scores, and generate a satisfactory cloud image after two to four iterations.

$$\begin{cases} Ex = \dfrac{Ex_1 w_1 + Ex_2 w_2 + \cdots + Ex_n w_n}{w_1 + w_2 + \cdots + w_n} \\ En = \dfrac{w_1^2}{w_1^2 + w_2^2 + \cdots + w_n^2} En_1 + \dfrac{w_2^2}{w_1^2 + w_2^2 + \cdots + w_n^2} En_2 + \cdots + \dfrac{w_n^2}{w_1^2 + w_2^2 + \cdots + w_n^2} En_n \\ He = \dfrac{w_1^2}{w_1^2 + w_2^2 + \cdots + w_n^2} He_1 + \dfrac{w_2^2}{w_1^2 + w_2^2 + \cdots + w_n^2} He_2 + \cdots + \dfrac{w_n^2}{w_1^2 + w_2^2 + \cdots + w_n^2} He_n \end{cases} \quad (2)$$

2.6 Comprehensive evaluation

By determining the evaluation, we can get the three-level indicator cloud digital feature, the first-level indicator cloud digital feature is calculated by formula (2), and then the final evaluation result can be obtained.

3. Instance analysis

3.1 Introduction to Xiamen Greenland ecosystem

Xiamen City is located in the hilly area of southeastern Fujian Province. The geographical coordinates are 117.53'-118.25' east longitude and 24.25'--24.54' north latitude. Xiamen is bordered by Zhangzhou and Quanzhou in the west, and faces Taiwan and the Penghu Islands across the sea. The annual average temperature is 21 ° C, the relative humidity is 76%, and the annual average rainfall is about 1100mm. Xiamen belongs to the south subtropical monsoon climate and is characterized by a oceanic climate.

3.2 Determine index weight

The analytic hierarchy process is used to determine the index weights, construct the judgment matrix, and calculate the weight values, as shown in Table 2. The indicator system is shown in Figure 4. The calculation of quantitative indicators is as follows.

3.2.1 Value of carbon sequestration and oxygen release

The formula for calculating the carbon sequestration value of urban Greenland is shown in formula (3):

$$CV = S * Qc * Tc \quad (3)$$

In that, *CV*--- carbon sequestration (ten thousand yuan)

S --- Greenland area in the city (hm^2)

Qc-- the amount of carbon absorbed per unit area of green space, of which 1hm2 of green space absorbs 900 kilograms of carbon dioxide per day, then Qc=328.5t/hm2

Tc -- cost of carbon sequestration

The calculation formula of oxygen release value is shown in formula (4):

$$OV = S * Qo * Po \quad (4)$$

In that, *OV* -- oxygen release value

S-- Greenland area in the city (hm^2)

Qo--the amount of oxygen released by the green area per unit every year, of which the green space in $1hm^2$ releases 600 kg of carbon dioxide per day;

Po – cost of oxygen producing

The value of carbon sequestration and oxygen release of urban green space ecosystem in Xiamen can be obtained from formula (7), (8), as shown in Table 1:

Table1. The value of carbon sequestration and oxygen release of urban green space ecosystem in Xiamen

Year	Urban green space area (hm^2)	carbon sequestration value (ten thousand yuan)	oxygen release value (ten thousand yuan)	Sum (ten thousand yuan)
1999	2713	66970.76	22367.56	89338.32
2001	3194	78844.31	26333.20	105177.51
2009	14304	301995.99	117930.52	419926.51

Note: In 1999 and 2001, the value of carbon sequestration in Xiamen urban green space was calculated at US$150/tC, and the cost of afforestation was 260.90 yuan/tC, of which US$1 was converted into RMB8.28. In 2009, the value of carbon sequestration in Xiamen urban green space was calculated at 150 US dollars/tC, the afforestation cost was 352.93 yuan/tC, and the industrial oxygen production cost was 400 yuan/t, of which 1 US dollar was converted into 6.83 yuan.

3.2.2 Value of environment purification

The value of environment purification includes the absorption of SO_2、NO_X, dust retention and noise reduction. This paper adopts the market value method for calculation.

1) The value of SO_2 absorption

The formula to calculate the value of SO_2 absorption is as follows:

$$SV = S * Qs * F\mathrm{t} \quad (5)$$

In that, SV -- the value of SO_2 absorption (then thousand yuan);

S -- greenland area in the city (hm^2)

Qs -- the ability of urban green space to absorb SO_2 per unit area, taking 88.65kg/ hm^2

Ft -- Cut the cost of SO_2, take 600 yuan / ton

Substituting the above data into formula (3), the value of SO_2 absorbed by green space in Xiamen City in 1999, 2001 and 2009 was 144,300 yuan, 169,900 yuan and 760,800 yuan respectively.

2) The value of NO_X absorption

The formula to calculate the value of NO_X absorption is as follows:

$$NOV = S * Qs * F\mathrm{t} \quad (6)$$

Among them, NOV —— the value of absorbing NOX (ten thousand yuan);

S —— total area of urban green space (hm2);

Qs——the ability of urban green space to absorb NOX per unit area, taking 0.38t/hm2;

Ft - the cost of purifying NOX, take 600 yuan / ton.

Substituting the above data into formula (7), the value of absorbing NOX in Xiamen City in 1999, 2001 and 2009 was 618,600 yuan, 728,200 yuan and 3,261,300 yuan respectively.

3.2.3 Dust retention value

The formula for calculating the value of dust retention is shown in equation (11):

$$DV = S * Qs * F\mathrm{t} \quad (7)$$

Among them, DV - the value of absorption of dust (10,000 yuan);

S —— total area of urban green space (hm2);

Qs——the ability of urban green space to absorb NOX per unit area, taking 10.11t/hm2;

Ft - the cost of industrial dust reduction, take 170 yuan / ton.

Substituting the above data into formula (11), the value of NOX absorbed by Xiamen green space in 1999, 2001 and 2009 was 4,662,800 yuan, 5,489,500 yuan and 2,548.4 million yuan respectively.

3.2.4 Attenuating the value of noise

The formula for weakening the noise is as shown in equation (8):

$$NV = S * F * C * 15\% \quad (8)$$

Among them, NV - weakening the value of noise (ten thousand yuan);

S —— total area of urban green space (hm2);

F—— China's average afforestation cost, taking 240 yuan/m3;

C—— the amount of mature forest area per unit, take 80m3/hm2.

Substituting the above data into formula (12), the value of absorbing NOX in Xiamen City in 1999, 2001 and 2009 was 7.814 million yuan, 91.99 million yuan and 4,210,700 yuan respectively.

3.3 Determine the indicator cloud

The ecological service function of Xiamen urban green space system is evaluated. Ten experts score the second-level indicators separately, and the highest score is given. The two sub-clouds are calculated by the cloud parameter calculation formula and calculated according to formula (1). The parent cloud is calculated by the formula (2) to obtain the first-level indicator cloud, as shown in Table 2.

Table 2. Cloud model digital feature table for each indicator

Overall performance	Primary indicator	Indicator cloud model digital features (Ex, En, He)	weigt	secondary indicators	cloud model digital features (Ex, En, He)	weight
Evaluation of Ecological Service Function of Urban Green Space System U	Maintains biodiversity U1	(0.716,0.095,0.022)	0.54	Green area U11	(0.824,0.088,0.012)	0.10
				Connecting section, broken section U12	(0.783,0.089,0.025)	0.46
				The natural attribute of urban green space U13	(0.529,0.149,0.014)	0.16
				Urban plant Resource habitat discontinuity U14	(0.659,0.094,0.014)	0.28
	Improve urban environmental quality U2	(0.788,0.066,0.015)	0.30	carbon sequestration value U21	(0.708,0.079,0.015)	0.12
				Absorption of SO2 and NOX U22	(0.808,0.056,0.018)	0.35
				Dust retention value U23	(0.823,0.072,0.012)	0.35
				Attenuate the noise value U24	(0.680,0.072,0.012)	0.06
				Conservation soil function value U25	(0.766,0.071,0.014)	0.12
	Accessibility and fairness of urban green space U3	(0.762,0.081,0.013)	0.16	Distance from residential area U31	(0.688,0.075,0.011)	0.16
				Population density U32	(0.686,0.082,0.016)	0.30
				Road distribution and land use U33	(0.826,0.082,0.012)	0.54

3.4 comprehensive evaluation

The final evaluation cloud of the ecological service function of the urban green space system in Xiamen can be calculated as (0.745, 0.088, 0.020), as shown in Figure 5. By comparing the final evaluation cloud with the cloud scale, it can be concluded that the ecological service function level of the urban green space system in Xiamen is between medium and excellent levels and moderately biased. Figure 6 shows the comparison between the first-level indicator evaluation cloud map and the final evaluation cloud map. It shows that the urban green space accessibility level is good for maintaining good biodiversity, and the urban environmental quality level is higher. It shows that Xiamen's urban green space system ecological service function is between medium and excellent, with certain room for improvement, and effective measures are needed to further improve the ecological service function of Xiamen urban green space system.

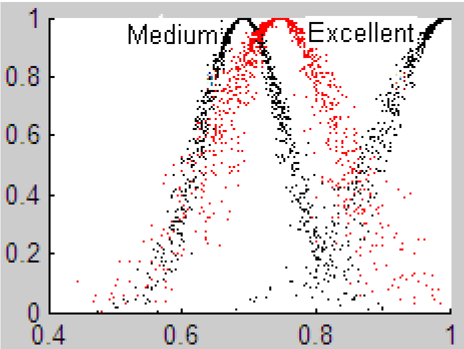

Figure 5 Final evaluation cloud and cloud scale comparison chart

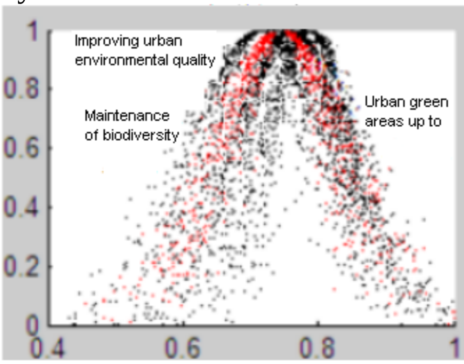

Figure 6 First-level indicator evaluation cloud map and final evaluation cloud

4. Countermeasures for improving the ecological service function of Xiamen green space system

4.1 Simultaneously improve the area and quality of urban green space

The physical reform of the urban green space system needs to be carried out from a global perspective. Based on the ecological principles, the geological characteristics of Xiamen and the landscape form should be combined to formulate a reasonable Xiamen green space system plan. By effectively configuring the types of greening, training green plants with high cost performance, adaptability and local characteristics, plants with good drought resistance and easy cultivation and cultivation are selected.

4.2 Optimize the urban green space structure

When selecting the species of trees, we should establish a scientific ecosystem based on the principle of optimizing the urban green space structure, and configure a greening model with arbor as the mainstay, supplemented by flowers and grass and arbor. In addition, the community characteristics of plants should be fully considered. When planning urban green space planning, the tree species in the street trees and the roads should be selected to have the characteristics of absorbing waste, dust-retaining value and reducing the noise value, such as broad-leaved trees. .

4.3 Strengthen the management of the green space system

In order to effectively guarantee the ecological service function of the urban green space system, the management of the green space system should be strengthened. During the conservation period, the impact on the ecosystem should be fully taken into account, such as fertilizers, pesticides and irrigation methods. Ecological fertilizers and pesticides should be selected as much as possible to select the best irrigation method. In addition, management and maintenance efforts should be intensified for proper fertilization, pruning and irrigation.

5. Conclusion

Based on the example application and analysis of the urban green space system ecological service function evaluation method based on AHP-cloud model, the applicability and rationality of this method in evaluating the urban green space system ecological service function is verified. AHP-Cloud Model uses the maximum and minimum scores to convert quantitative indicators and qualitative indicators when evaluating the ecological function of urban green space system, which effectively reduces the impact of individual experts' subjective tendencies on the evaluation results.

The cloud model is used to evaluate the ecological service function of the urban green space system, and the operability is strong. The final result uses the cloud image to judge the level of the ecological service function of the urban green space system, which is more visual and convincing.

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