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Evaluation Indicator System of Low-carbon Landscape in Residential Areas: A Case Study of Garden Plant Landscape

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Abstract Garden plant landscape is one of the main contents of low-carbon landscape design in residential areas. From the basic theory of garden plant landscaping, we put forth five principles and ideas concerning the building of evaluation indicator system of garden plant landscape, to establish the indicator system with ecological quality, recreational function and aesthetic effect as three layers. According to the characteristics of evaluation system, we use qualitative and quantitative integration method, coupled with analytic hierarchy process (AHP) and expert consulting method, to determine the weight of various factors. And we use fuzzy comprehensive evaluation method to test this indicator system, so as to provide a theoretical basis for the research on evaluation indicator system of low-carbon landscape.

Key words Residential areas, Low-carbon landscape, Indicator system, Garden plants

In recent years, green ecological house has increasingly captured universal attention from the real estate sector and the public in China. Each place has some residential projects taking "ecological concept", "green concept" and especially "low-carbon concept" as its selling point[1]. Residents' requirements of living have gradually shifted from the simple pursuit of a comfortable house to the pursuit of high-quality residential outdoor environment, thereby posing new requirements on the outdoor garden landscape quality of the residential area.

Garden plant landscape is the main component of garden landscape in housing area. In addition to landscaping features and ecological benefits, the main thing is the landscape value affecting residents' psychology and vision[2]. In order to better play the role of garden plants and reflect the connotation of low-carbon landscape in residential areas, we try to proceed from the connotation of garden plant landscape, use quantitative and qualitative evaluation indicators, understand the visual needs of people for the plant landscape, and explore the evaluation indicator system of garden plant landscape in residential areas, so as to provide theoretical reference basis for the urban residents to choose garden landscape in residential areas, and enrich garden plant landscape design theory.

1 Principles and ideas for the establishment of evaluation indicator system

1.1 Principles for the establishment of evaluation indicator system The evaluation of garden plant landscape in residential areas is a multi-factor comprehensive indicator system, and these indicators should not only interrelate but also interact with each other. Therefore, around this goal, it is necessary to establish comprehensive, reasonable and feasible evaluation indicator system with clear ideas to evaluate garden plant landscape in residential areas[3].

On the basis of building evaluation indicator system of garden plant landscape, the problem should be based on specific evaluation and we should follow the following principles.

(1) Principle of integrity. Any garden plant landscape problem does not exist in isolation, and the garden plant landscape configuration is the interrelation and interaction within system or between systems. Therefore, the indicators chosen should become a complete indicator system. This system is required to contain all the main aspects that can reflect garden plant landscape, and it should not be overly complex and huge.

(2) Principle of scientificity. The evaluation indicator should be consistent with the objective scientific criteria. On the basis of making full use of the theoretical knowledge of botany, ecology and landscape aesthetics, it is necessary to analyze human physiological characteristics, behavior and psychological needs to establish a scientific evaluation system.

(3) Principle of quantitativeness and qualitativeness. There should be not only qualitative description, but also quantitative analysis to quantify the qualitative indicators as much as possible, to facilitate the use of mathematical model for processing, and ensure objective and rational comprehensive evaluation.

(4) Principle of operability. In the practical operation, it is easy to implement the evaluation system and the evaluation data are easy to be collected, with strong operability.

(5) Principle of participation. Participation is mainly for the residents. As for the evaluation of green space in the past, the indicators were screened and reviewed by experts, and the public participation is very low, or even zero. The residents are users of green space system, so they should be involved in the evaluation of green space system. Especially the indicators concerning social and economic benefits are closely linked to the residents' daily life, so we should increase the participation of the households in these indicators.

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1.2 Ideas for the establishment of evaluation indicator system Ideas for the establishment of evaluation indicator system are shown in Fig. 1.

The specific ideas are as follows: First, according to the study of literature, combined with the views of the experts, build the initial indicator system, then using principal component analysis and cluster analysis, screen the indicators, to form evaluation indicator system, to satisfy the principle of scientificity and rationality.

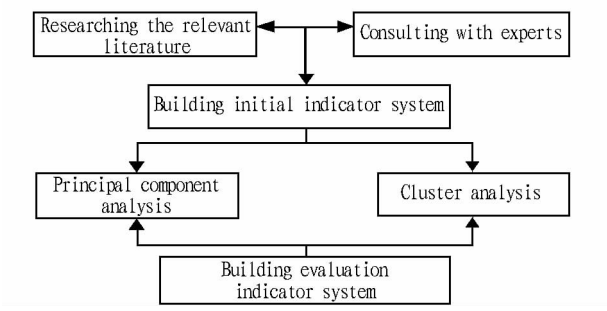

Fig. 1 Ideas for the establishment of evaluation indicator system

2 The path of establishing evaluation indicator system of garden plant landscape

2.1 The structure of evaluation indicator system The evaluation of garden plant landscape in residential areas must reflect the three levels of functionality of garden plant resources: maintaining ecological balance; providing recreation and leisure; reflecting the aesthetic effect (Fig. 2).

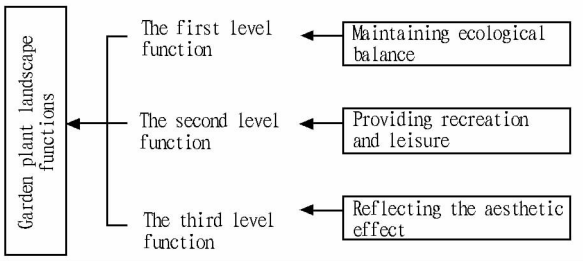

Fig. 2 Garden plant landscape functions

In short, the three levels of functionality are embodied in the three aspects of ecological quality, recreational function, and aesthetic effect[4].

Ecological quality mainly reflects the function of garden plant landscape in the residential community in maintaining the ecological balance of the city and degree of destruction of landscape ecology, which is the material wealth brought for residents in the process of feeling garden plants. Recreational function is to make residents conduct garden plants landscaping to create recreational living space. Aesthetic effect primarily reflects the psychological and physiological aesthetic effects on the residents in the residential area by garden plant landscape.

2.2 Evaluation indicator selection In order to conduct accurate assessment of particular garden plant landscape, the precondition is to choose appropriate indicators from the factors influencing garden plant landscape to establish an objective and indicator system[5].

Based on this, this paper takes the diversity and functionality of garden plant landscape as the basic content and purpose, and chooses the relevant quantitative indicators that can objectively reflect the quality of garden plant landscape. These indicators determine the structure and appearance of plant landscape, richness and spatial and temporal changes, directly affecting the quality of the landscape and its ornamental effect. This constitutes the quantitative indicator part in the indicator system.

At the same time, the ornamental effect of garden plant landscape is also affected by the surrounding environment or other landscape elements, such as the harmony between garden plants and other garden elements. The harmony with the growth environment and coordination with the overall environment constitutes the content of qualitative indicators. The qualitative indicators and quantitative indicators form the overall evaluation indicator system.

From the specific meaning of three levels of functions of garden plant landscape in residential areas, according to the selection principle of evaluation indicators, this paper builds four-level evaluation indicator system of garden plant landscape in residential quarters, in view of the various methods for evaluation of landscape at home and abroad.

The first layer is the objective layer, namely the evaluation objective, the composite index of landscape evaluation. The second layer is the item layer, including three levels of function of garden plant landscape in residential district (ecological quality, recreational function, aesthetic effect). The third layer is the factor layer, namely the factors determining each evaluation criterion. The fourth layer is the indicator layer, namely the specific indicator expression of every evaluation factor. Specific indicators are shown in Table 1.

2.3 Weight determining of evaluation indicator Evaluation indicator weight is a measure of indicator relative to objective. The weight difference tends to affect the rationality of the evaluation results. Therefore, it is critical to take the appropriate method to ensure scientificity and rationality of weight allocation of indicator system.

From the current situation of research on indicator system weight at home and abroad, the determining of weight mainly includes subjective weighting method and objective weighting method. There are many ways to determine the weight, such as Delphi method, AHP method, the principal component analysis method.

According to the characteristics of the evaluation system, this paper uses qualitative and quantitative integration method to determine the weight, namely using AHP (The Analytic Hierarchy Process) method, combined with expert advice, to determine the weight of indicators in item layer, factor layer and indicator layer.

According to AHP method, combined with expert advice, we can get the weight of indicators in the evaluation indicator system, and specific results are shown in Table 1.

2.4 Weight dependence judgment-integration (C.I.) test For the results, we still need the dependence judgment to judge

whether the result is correct, because the comparison is merely the value comparison between two evaluation criteria.

We often use C. I. to solve the problem. The calculation formula of integration is as follows:

C. I. = (average − number of items) / (number of items −1).

Usually C. I. value is "0 to 0. 1", but sometimes it is allowed to reach "0. 15" according to the situation. If the C. I. value exceeds this value, then the comparison table needs to be re-adjusted, to achieve the desired results.

Table 1 The evaluation indicator system of garden plant landscape in residential areas and the weight allocation

Objective layer	Item layer	Factor layer	Indicator layer
The evaluation indicator system of garden plant landscape in residential areas	Ecological quality (0.540)	Diversity (0.667)	Plant species richness(0.133); color plant richness(0.059); plant form richness (0.071); aquatic plant richness (0.095); flowering plant richness (0.042); total garden plants(0.369); type of plant in garden(0.231)
		Stability (0.333)	Plant growing conditions(0.427); stability of plant community(0.234); the ratio between the area of arbor and shrub (0.164); ground cover rate (0.108); vertical greening rate(0.067)
	Recreational function (0.297)	Wholeness(0.154)	The overall plant landscape (0.489); feeling of main plant landscape (0.168); coordination of main plant landscape (0.186); visual sense of plant landscape(0.157)
		Functionality (0.443)	Noise and dust control(0.246); shade effect(0.162); affinity of aquatic plant (0.107); canopy density of plant communities (0.062); utilization rate of public green space(0.423)
		Basic value(0.403)	Green space rate(0.139); greening coverage rate(0.197); per capita green space area(0.332); per capita public green space area(0.332)
	Aesthetic effect (0.163)	Artistic quality (0.196)	Matching between plants and the environment (0.540); matching between plants(0.297); cultivation hierarchy of plants(0.163)
		The ornamental effect (0.493)	Beauty of plants(0.410); plant modeling situation(0.061); plant garden art (0.225); proportion between evergreen and deciduous trees(0.137); share of flowering plant area(0.157)
		Color (0.311)	Seasonal change of plants(0.540); plant color matching(0.297); application of color-leafed plants(0.163)

3 Case verification

During this study, we assess the converted data, using the indicator system established and field survey of garden plant landscape in several residential districts. Based on fuzzy comprehensive evaluation method[6] and a comprehensive range of domestic and international index grouping methods, we evaluate the garden plant landscape in the residential areas surveyed, and determine the judgement set standard of objective layer (Table 2).

Table 2 Evaluation and judgement criteria of garden plant landscape in the residential district

Comprehensive assessment value	4 – 5	3 – 4	2 – 3	1 – 2	<1
Evaluation and judgement criteria	Very good	Good	Comparatively good	Average	Poor

Through the application of quantitative and qualitative data, finally the evaluation results are derived, using fuzzy comprehensive evaluation model. The specific results are shown in Table 3.

Table 3 Overall evaluation form of garden plant landscape in 8 residential areas

Indicators	Dashuying	Dianchi Kangcheng	Donghua	Gaoxiao	Qianshuiwan	Yueyatang	Wenquan Huayuan	Yuntianhua
Ecological quality	Average	Good	Average	Comparatively good	Good	Comparatively good	Average	Good
Recreational function	Poor	Good	Average	Average	Good	Average	Poor	Good
Aesthetic effect	Average	Very good	Comparatively good	Good	Very good	Comparatively good	Average	Very good
Comprehensive evaluation	Average	Good	Comparatively good	Comparatively good	Good	Comparatively good	Average	Good

The comprehensive evaluation results of garden plant landscape in the residential districts show that the comprehensive evaluation result of three residential districts (Dianchi Kangcheng, Qianshuiwan, Yuntianhua) is good; the comprehensive evaluation result of three residential districts (Gaoxiao, Donghua, Yueyatang) is comparatively good; the comprehensive evaluation result of two residential districts (Dashuying, Wenquan Huayuan) is average level.

Through the cases, we verify that the evaluation system of garden plant landscape in residential areas established is scientific and effective.

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4 Conclusions

This paper initially establishes the evaluation indicator system of garden plant landscape in residential areas, and analyzes the indicators in criteria layer, using analytic hierarchy process and cluster analysis, in order to lay foundation for the scientific evaluation of garden plant landscape in residential areas. In specific use, it is necessary to select and complement the indicators proposed in this paper, according to the specific circumstances of residential areas in different cities.

At the same time, there are many indicators for evaluation of garden plant landscape in residential areas, but some indicators are still difficult to be quantified at present. When determining the evaluation indicator system, there are also some human propensities factors influencing the weight. Therefore, how to scientifically select evaluation factors and determine the scale of importance needs to be further researched when conducting mutual comparison between various elements.

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