International Journal of Environmental Technology and Management

ISSN online: 1741-511X - ISSN print: 1466-2132
https://www.inderscience.com/ijetm

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DOI: 10.1504/IJETM.2022.10048777

Article History:

Received:	22 October 2021
Accepted:	14 February 2022
Published online:	30 November 2022

Study on plant allocation method of landscape architecture based on comprehensive evaluation index method

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Abstract: Aiming at the problems of poor allocation accuracy and low environmental contribution rate in landscape plant allocation methods, a landscape plant allocation method based on comprehensive evaluation index method is proposed in this paper. First, he spatial state of abstract landscape plant configuration is regarded as the spatial sequence of specific configuration points and lines, and the characteristics of different levels of space are constructed. Then, calculate the index weight with the help of analytic hierarchy process to complete the construction of allocation index system. Finally, with the help of the comprehensive evaluation index method, the single category factor index and similar index are determined, the contribution rate of configured plants to the environmental impact is calculated, the landscape plant configuration model is constructed, and the landscape plant configuration is completed. The results show that the configuration accuracy of the proposed method is high.

Keywords: comprehensive evaluation index method; hierarchical features; Markov chain; contribution rate; flexibility.

Reference to this paper should be made as follows: Zhang, A., Huang, D. and Lie, G. (2023) 'Study on plant allocation method of landscape architecture based on comprehensive evaluation index method', *Int. J. Environmental Technology and Management*, Vol. 26, Nos. 1/2, pp.81–93.

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1 Introduction

Plant configuration is the key in landscape architecture design. Plant allocation refers to the allocation of plant species and quantity according to the overall area of garden design and considering environmental benefits in accordance with the principles of artistry, scientificity and aesthetics in garden planning. In the planning of landscape architecture, plants are an important object to reflect the unique beauty of the garden and the key to improve the regional ecological environment and enhance the user experience (Alhaddad, 2018). The presentation of plant communities in landscape architecture is also an important symbol of urban culture (Yu and Han, 2018). In landscape architecture design, due to the differences of plant community characteristics and environment, there are great differences in landscape plant configuration (Zaami et al., 2018). Therefore, how to reasonably allocate landscape plants and improve the quality of urban ecological environment has become a hot issue in the current field.

Chen et al. (2019) proposed a method of configuring plants based on quantitative analysis of colour composition of plant community. Firstly, the configured plant colour frequency is presented, the constituent relationship between plant community and colour is determined, and the plant configuration colour matching is determined according to different seasons, so as to realise the effective configuration of plants. This method considers the plant colour matching, and the effect is good after matching, but the contribution rate of environmental impact considered in this method is less, so it is not suitable for general application. Gu et al. (2020) proposed a study on the impact of green space plant configuration on PM2.5. By analysing the impact of particulate matter in the air on the urban environment, the impact relationship of plant configuration on PM2.5 is determined with the help of envi met simulation method, and then the impact of plant community configuration under

1 tree

2 tree + hedge

3 tree + hedge + shrub

on PM2.5 is analysed, and the plant collocation is completed according to its impact. This method effectively improves the effectiveness of plant configuration according to actual cases, but it does not consider the effectiveness of other configuration spaces, so it has some limitations. Lindenmayer and Sato (2018) proposed and designed a garden plant configuration algorithm based on L-system. Firstly, this method analyses the rationality of three-dimensional typing plants and two-dimensional typing plant configuration in garden configuration, and carries out virtual allocation in VRML environment. Considering the attributes of plant configuration, the type and quantity of plants are determined according to the configured garden area, and the user demand three-dimensional tree is generated to complete plant configuration through three-dimensional tree. The method considers the plant attributes and configuration area, and the configuration is reasonable, but the calculation of the number of configurations is not very detailed, there are some deficiencies, which need to be further improved.

In order to solve the shortcomings of the above configuration methods, a new plant configuration method is designed in this paper. The abstract configuration space state of landscape plants is regarded as the spatial sequence of specific configuration points and lines, and the characteristics of different levels of space are constructed to complete the configuration space state characteristics; The weight vector of plant allocation is determined by analytic hierarchy process, the weight of allocation index is assigned, and the construction of allocation index system is completed; With the help of the comprehensive evaluation index method, determine the single category factor index and similar index, calculate the comprehensive evaluation index of landscape plant configuration, determine the rationality of configuration, calculate the contribution rate of configured plants to the environmental impact, construct the landscape plant configuration model, and complete the landscape plant configuration with the help of the flexibility of the objective function optimisation model. The technical route of this paper is as follows:

1. The abstract spatial state of landscape plant configuration is regarded as the spatial sequence of specific configuration points and lines, the characteristics of different levels of space are constructed, and the interference of spatial coincidence points is removed with the help of Markov chain to determine the state characteristics of configuration space;
2. The weight vector of plant allocation is determined by analytic hierarchy process, and its consistency is verified. Through the weight calculation of multiple indexes, the weight of allocation indexes is assigned, and the construction of allocation index system is completed;
3. With the help of the comprehensive evaluation index method, determine the single category factor index and similar index, calculate the comprehensive evaluation index of landscape plant configuration, determine the rationality of configuration, calculate the contribution rate of configured plants to the environmental impact, construct the landscape plant configuration model, and complete the landscape plant configuration with the help of the flexibility of the objective function optimisation model.

2 Study on plant allocation method of landscape architecture based on comprehensive evaluation index method

2.1 Determination of spatial state characteristics of landscape plant allocation

In the configuration of landscape plants, the reasonable configuration of plants is affected by their environment and is directly related to the surrounding environment. Therefore, in this paper, firstly, the environment of landscape plant configuration is analysed. The environment of plant collocation mainly refers to the state of its configuration space.

Therefore, firstly, the spatial state characteristics of landscape plant configuration are extracted to determine the spatial state of landscape plant configuration.

In the analysis of landscape plant configuration spatial environment, because the environment is an abstract spatial feature state that can not be determined directly. Therefore, it is necessary to convert this abstract state into the state of the entity. Set the number of point elements to be configured in the landscape plant configuration space as, and determine the sequence of point elements to be configured in the landscape plant configuration space as follows:

$$X_i = \left| x^1(t) - \hat{x}^1(t) \right| \sum_{i=1}^{n} x^1(t) - \hat{x}^1(t) \tag{1}$$

In the formula, X_i represents the sequence of points elements to be configured in the landscape plant configuration space, $x^1(t)$ represents the initial sequence of point elements to be configured in the landscape plant configuration space, $\hat{x}^1(t)$ represents the cumulative sequence points of the point elements to be configured in the landscape plant configuration space.

According to the determined sequence of point elements to be configured in the landscape plant configuration space, the landscape plant configuration space is described as a linear structure, and the linear structure function of the space is constructed, namely:

$$f(x) = \delta \frac{\sum_{i=1}^{n} X_i}{n} \tag{2}$$

In formula, $f(x)$ represents the linear structure function and δ represents the difference angle of linear space.

In the plant configuration space state of landscape garden, in order to make the plant configuration more reasonable, it is necessary to pass the spatial state of landscape garden plant configuration through the analysis of points and lines to form a certain determined space state, and the spatial state characterisation matrix is as follows:

$$Z_i = f(x)_{i \times n} \sum X_i \tag{3}$$

In the formula, Z_i represents the spatial state characterisation matrix of landscape plants.

According to the configuration space state characterisation of landscape plants determined by formula (3), the configuration space and the configuration space hierarchy matrix (Ngo et al., 2020), namely:

$$U = u \begin{bmatrix} 1 & 2 & 1/3 \\ 1/2 & 1 & 1/4 \\ 2 & 3 & 1 \end{bmatrix} \tag{4}$$

In the formula, u represents the spatial characteristic hierarchy ratio of landscape garden plant configuration.

According to the above determined spatial hierarchy of landscape plant configuration, and extracting each hierarchical feature, the spatial state characteristics of landscape plant configuration can be determined, that is:

$$F = R\frac{\frac{X_i}{N}}{Z_i}\sum f(x) \tag{5}$$

In the formula, F represents the spatial state characteristics of the landscape garden plant configuration, and R represents the plant landscape configuration proportion value.

In the above extracted spatial state features of landscape plant configuration, because different configuration points in the space are easy to overlap, resulting in the interference of configuration spatial features, it is necessary to remove such overlapping points in the spatial state, so as to reduce the change of spatial state features of landscape plant configuration, resulting in certain interference of subsequent plant configuration. This paper uses Markov chain to determine the coincidence point of landscape plant configuration space, that is:

$$C_i = v(n-1)q \tag{6}$$

In the formula, v represents the homogeneous point (Farhangi-Abriz and Torabian, 2018) of the space configuration point, n represents all space points, and q represents the value of coincidence.

According to the determined coincidence point of landscape plant configuration space configuration, it is deleted to obtain the final spatial state characteristics of landscape plant configuration, that is:

$$H = f(x) + \frac{\sum_{i=1}^{n} b_i}{n} \tag{7}$$

$$H = f(x) + \frac{\sum_{i=1}^{n} b_i}{n} \tag{7}$$

In formula, H represents the removal result of spatial configuration coincidence, and b_i represents the removal coefficient of garden plant space configuration coincidence.

In the determination of the spatial state characteristics of landscape plant configuration, the abstract spatial state of landscape plant configuration is regarded as the spatial sequence of specific configuration points and lines, the spatial state representation matrix is constructed, the characteristics of different levels of landscape plant configuration space are extracted, and the interference of coincidence points in configuration space is removed with the help of Markov chain, The spatial state feature extraction of landscape plant configuration is realised.

2.2 Construction of plant allocation index system in landscape architecture

Based on the basis of the above determined spatial characteristics of landscape plant configuration, in order to realise the reasonable configuration of landscape plants, it is necessary to build the index system of plant configuration according to the configuration spatial characteristics. At present, the most effective method in the index construction of plant configuration is the hierarchical analysis method. Through the qualitative and quantitative study of plant configuration, this method can reasonably set the index system of plant configuration (Macarie et al., 2018). Therefore, this paper constructs the corresponding index system with this method. First, determining that the weight vector of the plant configuration is Q, and the value is tested for consistency, namely:

$$Q = \frac{KCI}{e_i} \tag{8}$$

Among them, K represents the calibration norm, e_i represents the arbitrary consistency index, and CI represents the composite inspection coefficient.

Based on the weight vector and consistency of determined plant configuration, the plant configuration index system is shown in Table 1.

Table 1 Plant configuration index system

Configure target	*Configure the factor*	*Configure criteria*
Configuration rationality	Configure the plant diversity (a_1)	Overall spatial benefits (A_1)
	Plant growth state (a_2)	
	Plant community hierarchy (a_3)	
	Plant color sensory degree (a_4)	Visual benefits (A_2)
	Overall configuration effect of the plant (a_5)	
	morphological change trend after plant configuration (a_6)	

According to the determined plant allocation index system, the weight of the allocated indexes is calculated. The plant configuration index system includes single index and multiple indexes. The weight of these indexes affects the configuration results of beauty such as plant quantity configuration and colour in plant configuration (Yao et al., 2018). Since the effect of plant allocation cannot be directly determined by single index, the weight of allocation index is calculated as multiple indexes in this paper. By determining the weight formula of multiple indexes, the indexes in the plant allocation index system are assigned effective weights. Among them, the calculation formula of multiple index weight is:

$$\omega = 2\sqrt{\frac{a_1 + a_2 + \ldots + a_6}{w_\alpha \left(\frac{A_1}{A_2}\right)}} \tag{9}$$

In the formula, ω represents the weight result value for the multiple indicators, w_α represents the degree of correlation between indicators in a plant configuration.

According to the calculation of various index weights, the indicators in the plant configuration index system are effectively weighted, with the range of [0, 1]. The resulting index weight results are shown in Table 2.

Table 2 Weight assignment of the plant configuration index

Configure target	*Configure the factor weights*	*Configure criteria*
Configuration rationality	a_1 (0.21)	A_1 (0.64)
	a_2 (0.14)	
	a_3 (0.15)	
	a_4 (0.23)	A_2 (0.36)
	a_5 (0.18)	
	a_6 (0.09)	

In the construction of landscape plant configuration index system, determine the right vector of hierarchical analysis, and consistency verification, on this basis, through the weight calculation formula of multiple plant configuration indicators, the indicators in the plant configuration index system for effective weight assignment, complete the landscape plant configuration index system construction, for the subsequent realisation of landscape plant configuration.

2.3 Realisation of the landscape garden plant configuration based on the comprehensive evaluation index method

Comprehensive evaluation index method is an overall evaluation method by effectively evaluating the characteristics and composition index. Therefore, in order to realise the effectiveness of landscape plant configuration, this paper first evaluates the above index method to determine whether the configuration index is reasonable, and reasonably allocate (Carta et al., 2019) for landscape plants.

The landscape plant configuration index is divided into the single factor index and the index of similar factors. The single-class factor index of the landscape garden plant configuration is:

$$D_i = \frac{1}{m+n} \sum\nolimits_{i,j=1}^{m,n} D_{ij} \tag{10}$$

In the formula, D_i represents single class element index, m and n represent the number of single class elements of landscape plant configuration, and D_{ij} represents single element index of landscape plant configuration.

The similar index calculation formula of landscape garden plant configuration is as follows:

$$PD_i = \frac{1}{n'} \sum\nolimits_{i=1}^{n} D_i \tag{11}$$

In the formula, P represents similar factors and n' represents the number of similar exponents.

Based on the calculation of single factor index and the comprehensive evaluation index of landscape plant configuration (Bell et al., 2018) is:

$$ZD_i = \frac{1}{r} \sum\nolimits_{r=1}^{n} PD_i \tag{12}$$

In the formula, ZD_i represents the comprehensive evaluation index of the landscape plant configuration, and r represents the comprehensive evaluation index factor.

By calculating the comprehensive evaluation index of landscape plant configuration, the rationality (Benatti et al., 2019) of plant configuration is determined. On this basis, build the landscape plant configuration model, complete the research of the method.

In order to realise the effectiveness of landscape garden plant configuration, considering the spatial environment of landscape garden configuration and the plant selection of plant configuration, it is necessary to determine the distance between different plant configurations, and the distance of plant planting constitutes the spatial configuration results of different effects, that is:

$$L = sv_i + ks_\alpha l \tag{13}$$

In the formula, L represents the distance of plant planting in the configuration, sv_i, $s_\alpha l$ represent different plant categories, and l represents the planting space constant values.

After determining the planting distance of plants in the plant configuration of landscape gardens, the impact effect of different plants on the environment is also to be considered. Therefore, the contribution rate of the configured plants to the environment (Chaves et al., 2019) is to be calculated, while improving the configuration effect and the environmental protection, the contribution rate of the configured plants to the environmental impact is:

$$G = \sum_{i=1}^{n} \frac{h_i}{n} \times 100\% \tag{14}$$

Among them, G represents the contribution rate, h_i represents the contribution rate of the plant to the environmental impact, and n represents the number of contribution rate calculation.

On this basis, build the landscape garden plant configuration model, and realise the configuration research, that is:

$$\varphi(x) = \frac{1}{n} \sum_{i=1}^{n} \varepsilon_i + bx \tag{15}$$

In the formula, $\varphi(x)$ represents the configuration model, ε_i represents the configuration effect value, and bx represents the offset value.

The reddest configuration result obtained by the landscape plant configuration model is relatively fixed. If it needs to be changed, the reconfiguration needs and the process is more complicated. Therefore, in order to avoid this problem, this paper improves the configuration flexibility of the above configuration model with the target function and obtains:

$$\vartheta_i = \frac{ax + c}{\varphi(x)} \tag{16}$$

In the formula, ϑ_i represents the objective function and $\frac{ax + c}{\varphi(x)}$ represents the flexibility of the configuration model.

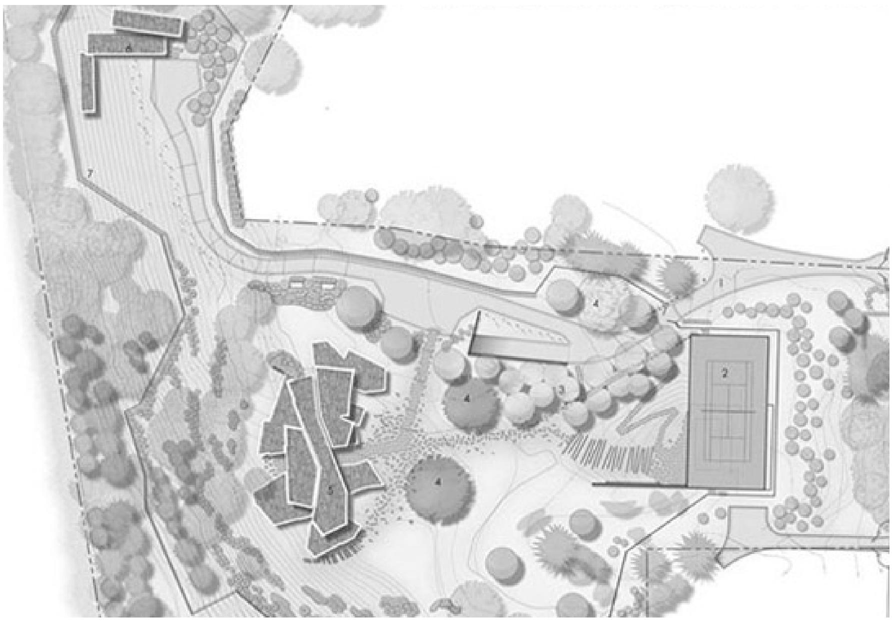
In the configuration of landscape plants, the index of individual elements and the same index, with the basis of the plant configuration, construct the model and optimise the flexibility of the model.

3 Experimental analysis

3.1 Experimental environment design

To verify the effectiveness of the configuration method, experimental choose a garden in the suburbs of northern China, the landscape garden area covers an area of about 200 square metres, the area belongs to the subtropical monsoon climate, spring, summer, autumn and winter seasonal is more obvious, the configuration of the plant in the need to consider the four seasons temperature, the spring, summer and autumn plant growth is better, but after winter plants need winter, planting plant need to pay attention to reasonable collocation. This experiment selected an area of about 50 square metres in the garden for plant configuration. The experimental area is shown in Figure 1.

Figure 1 Map of the experimental area



In the sample configuration area, a total of six plants were selected for collocation. Through matching the effect of these six plants, the configuration plant details are shown in Table 3.

Table 3 Sample configuration plant details

Plant name	*Quantity*
North China larch	10
Deodar	15
Dawn redwood	20
Platycladus orientalis	15
Savin	15
Casuarina	15

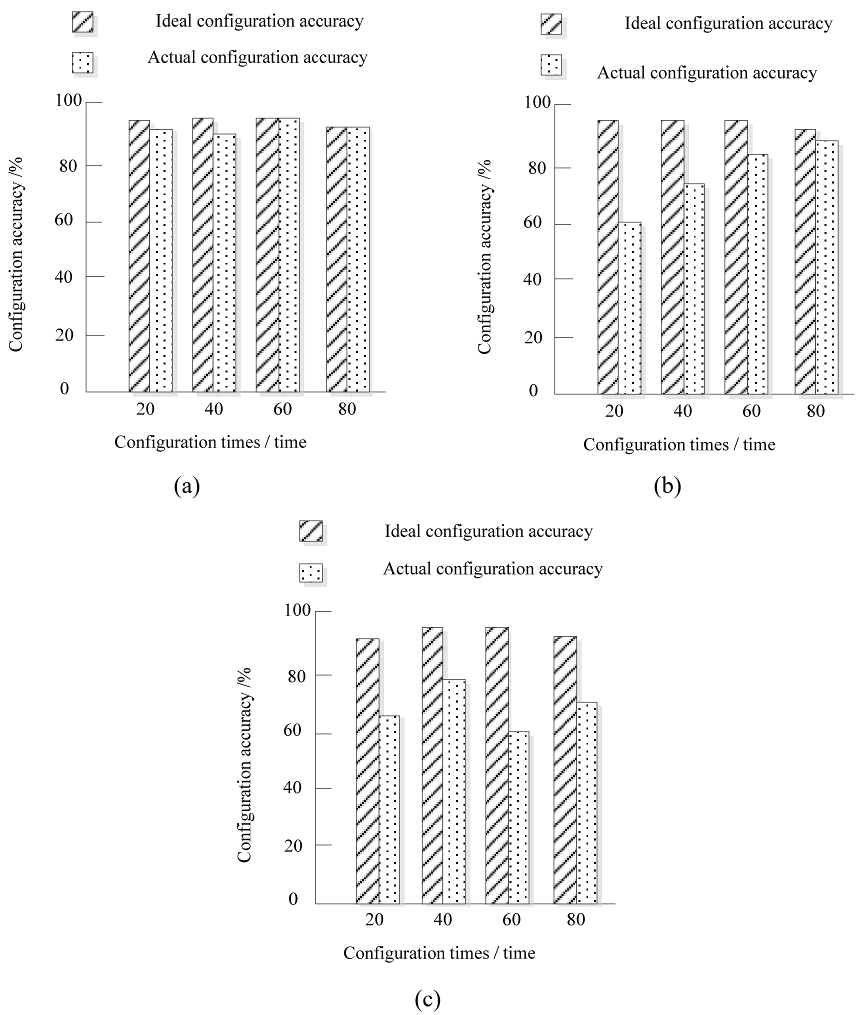
3.2 Experimental index setting

According to the setting of the above configuration plants, the plants in the above landscape area are configured through the configuration method in this paper, the configuration method in Gu et al. (2020) and the configuration method in Lindenmayer and Sato (2018). The rationality of plant allocation and the contribution rate to the environment were taken as the experimental indexes. The contribution rate of the environment is calculated by formula (14), and the calculation formula of configuration accuracy is:

$$R = \frac{t_i}{N} \times 100\% \tag{17}$$

In the formula, t_i represents the accuracy value of the actual configuration and N represents the number of actual configurations.

Figure 2 Accuracy analysis of landscape plant configuration, (a) configuration method in this paper (b) Gu et al. (2020) (c) Lindenmayer and Sato (2018)



3.3 Analysis of experimental results

3.3.1 Rational analysis of plant configuration in landscape garden

The rationality of plant configuration is experimentally analysed based on the number of plants and the adaptability of spatial characteristics. The rationality of plant allocation is the key to measure the effectiveness of the value allocation method. Therefore, the experiment configures the plants in the above landscape areas through the allocation method in this paper, the allocation method in Gu et al. (2020) and the allocation method in Lindenmayer and Sato (2018), and analyses the accuracy of the allocation. The results are shown in Figure 2.

By analysing the experimental results in Figure 2, it can be seen that the accuracy of landscape plant configuration in the sample area is different by using the three methods. Among them, the accuracy of the configuration method in this paper is more than 90%, and is relatively consistent with the ideal value. The accuracy of the configuration method in Gu et al. (2020) and Lindenmayer and Sato (2018) is lower than the ideal value and lower than the accuracy of the configuration method in this paper; This is due to the analysis of the characteristics of the configuration space before the spatial configuration, which can adjust measures to local conditions, improve the effectiveness of the method and improve the accuracy of plant configuration.

3.3.2 Analysis on the contribution rate of landscape garden plant configuration to the environment

The plant configuration of landscape garden is ultimately to improve the quality of the ecological environment, so the configuration method, the Gu et al. (2020) configuration method and the Lindenmayer and Sato (2018) configuration method are [0, 1], and the higher the value represents the better performance. The results are shown in Table 4.

Table 4 Analysis of the contribution rate of landscape garden plant allocation to the environment

Iterations/times	*Method of this paper*	*Gu et al. (2020)*	*Lindenmayer and Sato (2018)*
20	0.91	0.89	0.81
40	0.91	0.91	0.81
60	0.90	0.90	0.86
80	0.90	0.84	0.85
100	0.92	0.89	0.82

The calculation results in Table 4 can be seen that the contribution rate of the garden to the environment after the three methods are good, which are within the consistent range. However, the contribution rate of this method is slightly higher than the other two methods, due to calculating the comprehensive evaluation index of landscape plant configuration, determining the allocation rationality, calculating the contribution rate of configuration plant impact on the environment, constructing the landscape plant configuration model, fully taking into account the impact of the environment, and verifying the effectiveness of this method.

4 Conclusions

In order to improve the ecological environment, a landscape plant allocation method based on comprehensive evaluation index method is proposed in this paper. The abstract spatial state of landscape plant configuration is regarded as the spatial sequence of specific configuration points and lines, the characteristics of different levels of space are constructed, and the interference of spatial coincidence points is removed with the help of Markov chain; The weight vector of plant allocation is determined by analytic hierarchy process, and its consistency is verified. Through the weight calculation of multiple indexes, the weight of allocation indexes is assigned, and the construction of allocation index system is completed; With the help of the comprehensive evaluation index method, determine the single category factor index and similar index, calculate the comprehensive evaluation index of landscape plant configuration, determine the rationality of configuration, calculate the contribution rate of configured plants to the environmental impact, construct the landscape plant configuration model, and complete the landscape plant configuration with the help of the flexibility of the objective function optimisation model. This method has the following advantages:

1 the accuracy of plant configuration in this method is 90%, which has a certain configuration effect

2 the contribution rate of the configuration method in this paper to the environment after configuration is more than 0.9.

Acknowledgements

This work was supported by the 2022 Quality Project of Guangdong Ecological Engineering Vocational College.

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