Plant landscape planning and design of Nanshan Botanical Garden (China) based on forest ecological garden

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Abstract. In recent years, with the rapid development of human civilization, a variety of environmental problems have emerged. As the most important natural ecological system of terrestrial ecosystems, forest ecosystem plays a significant role in protecting the environment and beautifying cities. The landscape planning and design of botanical gardens is of great significance to the maintenance of the urban forest ecosystem. Taking the Nanshan botanical garden as the research object, this paper analysed the present situation of the garden and carried out the vegetation landscape planning transformation on it from the perspective of landscape ecology. Then, the landscape hierarchy analysis method was used to evaluate the landscape after the transformation, the results of which suggested that the comprehensive evaluation of the garden was the highest when the plant landscape was diversified and the structure level was reasonable, which provided a reference for the optimization of the urban forest ecosystem.

Key words: forest ecological garden, plant landscape, planning and design.

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Introduction

Entering the 21st century, the rapid development of science and technology has brought various environmental problems. How to realize the harmonious development between people and the nature is attracting more and more attention. Therefore, how to ease the contradiction between urban development and forest ecosystem protection has become the main problem of environmental protection. Occupying an important position in the ecosystem, forest ecology plays an important role in the beautification of urban forest ecology and the realization of the sustainable development of cities (Liu & Jinchang, 2012). How to plan urban gardens so that the environmental problems brought by development can be

solved has become an important subject of urban planning. As a new discipline, landscape ecology has a major role in solving this problem and gradually gets the attention of sociologists (Knowlton & Graham, 2010). Masnavi *et al.* (2016) studied the ecological effects of introducing threatening factors to “Nanpa Special Economic Zone” of the mangrove community and its habitat and proposed the use of mangrove community plant landscape planning and design to protect and develop degraded habitats, creating a framework for ecotourism and sustainable development in the region. Wang & Kong (2016) improved the urban hydrogen quality by adjusting the urban landscape planning, so as to improve the living environment of the urban residents. Taking the Nanshan Botanical Garden in

Chongqing city as a research object, this paper analysed the status of its plant landscape, studied its natural and vegetation general situation based on landscape ecology, found its shortcomings and put forward a transformation plan to solve these problems. Then, the ecological landscape of the park was comprehensively evaluated by analytic hierarchy process. The results showed that the best comprehensive assessment appeared when the vegetation type was diverse and the community structure was reasonable. Hence, the suitable landscape design can improve the urban forest ecological garden environment, so as to achieve the purpose of improving the urban environment, which provides a reference for the application of landscape ecology in the prevention and control of urban forest ecological environment pollution.

Overview of forest ecological landscape

Forest ecology

Forest ecosystem is a natural system formed by tree-based biological forest communities and their non-biological environments with self-control capacity and a natural ecological science for the material exchange and energy flow between organisms as well as between organisms and the environment (Pan *et al.*, 2013). Urban forest is the main carrier of forest system in a city, where the forest is not just used to produce trees but to meet the needs of touring and entertainment of people and promote the harmonious coexistence of urban planning and the natural environment. The planning and design of the plant landscape in forest ecological gardens can provide some effective theoretical support for the maintenance of urban development.

Landscape ecology

Landscape ecology is a discipline which studies the spatial structure, interaction, coordination function and dynamic change of the landscape made up of different eco-

systems in a large space range, with ecology and geography as its main body (Žigrai *et al.*, 2015). Taking the landscape within a wide range as the research object, landscape ecology emphasizes the maintenance and development of spatial heterogeneity, the interaction between ecosystems, the conservation and management of large-scale plant communities, the development and utilization of environmental resources, and the impact of human activities on landscape ecology (Turner *et al.*, 2013). Using the landscape ecology to design the botanical garden can effectively optimize its internal structure level, so as to achieve the purpose of beautifying the botanical garden.

Landscape planning of Nanshan Botanical Garden

General situation of Nanshan Botanical Garden

Located at Nanshan Botanical Garden Road 101, Nan'an District, Chongqing City, China, Nanshan Botanical Garden has an elevation of about 420–680.5 m and an actual area of 551 hectares, with 361 hectares of which forest, occupying 65% of the total area. The botanical garden belongs to the subtropical temperate monsoon climate, with very distinctive four seasons, an average annual temperature of 15.8 °C, an average relative humidity of 81% and an average annual sunshine time of 1143.1 hours. As a suburban botanical garden, it provides a place for recreational and entertainment in Chongqing, and has made great contributions to beautifying the city and protecting the urban environment.

Plant landscape community of Nanshan Botanical Garden

The plant landscape community in the garden belongs to the open forest grassland type plant landscape community, which is mainly composed of a large number of trees and shrubs, with high ornamental values

(Adie *et al.*, 2011). The vegetation types of the garden are: coniferous forest, evergreen broad-leaved forest and coniferous and broad-leaved mixed forest.

Existing problems and countermeasures

Existing problems

- 1) There are few varieties of trees in the garden, which Masson pine accounts for 70.3%. However, dendrolimus, with a strong reproductive capacity, is easy to survive in *Pinus massoniana* Lamb. forest, which is prone to cause pest disasters (Kong *et al.*, 2011). Besides, as the masson pine has weak corrosion resistance capacity and high resin content, it is easy to trigger forest fire (Sun *et al.*, 2010).
- 2) With a subtropical humid climate, Chongqing is rich in plant species. Nevertheless, there is not quite the number of plant species in Nanshan Botanical Garden and its landscape design did not well follow the principle of adjusting measures to local conditions. For example, there are as many as seven kinds of greening vines in Chongqing, but 60% of the ones in the garden are creepers, which shows the lack of diversity in the landscape of the garden.
- 3) With almost artificial afforestation in the garden while original vegetation barely visible, the vegetation species type is simple in the garden. Although they can improve the surrounding environment, large tracts of *P. massoniana* are difficult to attract wildlife to habitat, which is not conducive to the protection of biological diversity, with poor ecological benefits.

Countermeasures

In view of the above problems, we can carry out artificial transformation on Nanshan Botanical Garden and develop a plant landscape planning transformation program to artificially promote the natural evolution of its forest communities. Through the adjustment of tree species and the cultivation of vegetation landscape, the individuality advantages of plants are high-

lighted so as to form a botanical garden mixed scenic area with diverse species and clear structures.

1) Deforestation and rebuilding

In order to change the oneness of tree species, we need to cut down the *P. massoniana* forest and plant other broadleaf trees in gaps to enhance the ornamental values of the woods. To make the overall beauty of the woods not destroyed, each piece of deforestation area is limited to 2-5 hectares. After the completion of the deforestation, the site was cleaned up, with the remaining leaves and weeds on the ground cleared. Afterwards, holes with a size of $0.6 \times 0.4 \times 0.3$ m were dugged up on proper positions on the ground for the cultivation of new tree species.

2) Selection and matching of tree species

In the choice of species, the principle of adjusting measures to local conditions should be followed (Pan *et al.*, 2016). The advantages of Chongqing native tree species should be excavated and the proportion of native tree species and introduced species should be optimized. By selecting the appropriate broadleaf tree species, the forest of the Nanshan Botanical Garden is optimized, the forest features of the various seasons are highlighted, the ecological landscape quality is improved and the touring and sensory effect of visitors are strengthened.

For low altitude areas, key sightseeing districts, both sides of the attraction road and areas within the main range of visibility of visitors, broadleaf species with high ornamental values, such as *Liquidambar formosana* Hance, locust tree and *Liriodendron*, need to be selected. Together with fast growing street trees, courtyard ornamental tree species and *Ficus virens* W.T.Aiton, a seasonal and mixed coniferous and broad-leaved forest is built up.

For higher altitude areas, since they have larger slopes, more adaptable native tree species, such as magnolia and yellow trees, need to be selected. In addition to the

characteristics of good adaptability and high survival rates, these trees have a magnificent silhouette, with wide leaves and thick shadows. As landscaping tree species, they can both resist the wind and purify the air. Besides, deciduous broadleaf species with obvious seasonal characteristics, such as pentagonal maple and acacia trees, are also planted so as to enhance the diversity of species in the park and the stability of stand, improve the park's ecological quality and landscape effects.

For the steep areas with a high altitude, low shrubs or three-dimensional green vines, such as bougainvillea and *Rosa banksiae* W.T.Aiton, are selected, which are adaptable and can well grow under such conditions, with high ornamental values when the flowering season arrives.

Besides, a team with forestry knowledge should be organised to carry out routine maintenance work on the botanical garden. Through the garden landscape cultivation and maintenance, the landscape design effect can be achieved.

The advantages of the above methods

The deforestation can clean up the dead trees in the forest to prevent them from interfering with the growth of other trees. The cutting down of other species of broad-leaved trees can ensure the unity of the woods and the ornamental purpose. After cutting, the forest density is greatly reduced, which is conducive to tree growth. After the selection and matching of the tree species, the species diversity of the botanical garden and its ornamental value can be greatly improved. Equipped with a forest ranger, the garden landscape is protected.

Analysis of the index weight of landscape planning

Analytic hierarchy process

Analytic hierarchy process (AHP) is a method which uses multi-factor classification to determine the weight of factors

(Ishizaka & Labib, 2011). Combining qualitative analysis and quantitative analysis, it divides complex problems into multiple levels through the collection and analysis of data, identifies the importance of each level to the end result and arranges these levels one by one. Based on the nature of the interaction between these factors, they are recombined to form a multi-level analytic structure model (Saaty, 2014). The analytic hierarchy process can systematically analyse and evaluate the plant landscape after transformation. The method is relatively simple, can easily get the evaluation results, without carrying out complex calculations and reasoning.

Comprehensive evaluation of plant landscape

We use the analytic hierarchy process to evaluate the Nanshan Botanical Garden before and after the planning. The comprehensive evaluation system of AHP is shown in Figure 1.

It can be seen from Figure 1 that forest ecological landscape design can be evaluated by community structure, species diversity index and landscape beauty degree.

Community structure

The community structure before and after the planning is shown in Table 1.

As shown in Table 1, before the landscape planning, Nanshan Botanical Gardens's community structure is relatively simple, which showed an obviously increase after the planning. The mixed broad-leaved forest composed of deciduous broad-leaved forest and evergreen broad-leaved forest made the landscape of the botanical garden more distinct and more ornamental.

Plant diversity index

The diversity index is an indicator that can measure the size of plant species diversity and spatial distribution characteristics. We used the Shannon-Wiener index and the Simpson index to study the diversity index, which uses the uncertainty of the

Note: We use the evaluation index system to quantify the scores from 1 to 5 into very poor, poor, general, good excellent.

Figure 1. Plant landscape comprehensive evaluation system.

information to reflect the individual diversity of plants.

The Shannon-Wiener index formula is as follows:

$$S = -\sum_{a=1}^A P_a \ln P_a \quad (1)$$

$$P_a = N_a / N \quad (2)$$

Where A and N refer to total numbers of individuals of all species and N_a refers to the number of individuals of all the species, $\alpha = 1, 2, 3, \dots$.

Simpson index formula is as follows:

$$H = 1 - \sum [N_a(N_a-1)/N(N-1)] \quad (3)$$

Where N_a refers to the number of individuals of all the species, $\alpha = 1, 2, 3, \dots$.

Table 2 compares the S (Shannon-Wiener index) and H (Simpson index) values of plants.

It can be seen from Table 2 that the diversity of plants is higher after planning, indicating that the diversity of plants after planning is richer.

Landscape beauty degree

The beauty of the landscape is evaluated by the beauty assessment method, which realizes the evaluation and quantification of the beauty degree through the scoring of evaluators on different pictures. The formula is as below:

$$MA_x = 1/(m-1) \sum_{i=2}^m (CP_{xi}) \quad (4)$$

Where MA_x refers to the average A value in picture x , i refers to the evaluation grade, m refers to the total score of the evaluation values, CP_{xi} refers to the frequency of the scores given by the evaluators to be equal to or greater than i and $f(CP_{xi})$ refers to the distribution frequency of the cumulative normal function.

$$SBE_x = (MZ_x - BMMZ) \times 100 \quad (5)$$

Where SBE_x refers to the original value of the beauty assessment method, MA_x refers to the average A value in picture x , $BMMZ$ refers to the baseline value, i.e., the starting point of the beauty assessment method, which is set to be 0 in this study.

Table 1. Plant community structure of Nanshan Botanical Garden (China).

Location	Period	Plant formation	Vegetation type	Community type
Low altitude areas	Before planning	Camphor forest	Evergreen broad – leaved forest	Camphor
	After planning	Camphor forest	Mixed coniferous broad – leaved forest	Camphor + <i>Liquidambar formosana</i> + <i>Ficus virens</i>
Higher altitude areas	Before planning	<i>Pinus massoniana</i> forest	Evergreen broad – leaved forest	Masson pine + camphor
	After planning	<i>P. massoniana</i> forest	Mixed coniferous broad – leaved forest	Masson pine + camphor + wide magnolia + pentagonal maple
Steep areas with a high altitude	Before planning	Creepers	Deciduous broad – leaved forest	Creepers + <i>Cynodon</i>
	After planning	<i>Rosa banksiae</i> + creepers	Deciduous broad – leaved forest	Creepers + <i>Cynodon</i> + <i>R. banksiae</i> + <i>Bougainvillea</i>

Table 2. Variety values of plant collocation before and after planning. S – Shannon-Wiener index, H – Simpson index.

Location	Period	Community type	Vegetation type	S	H
Low altitude areas	Before planning	Camphor	Evergreen broad – leaved forest	0	0
	After planning	Cinnamon – <i>Liquidambar formosana</i> – <i>Ficus microcarpa</i>	Mixed coniferous broad – leaved forest	1.2514	0.7452
Higher altitude areas	Before planning	Masson pine – camphor	Evergreen coniferous broad – leaved forest	0.4298	0.2765
	After planning	Masson pine – camphor – wide magnolia – pentagonal maple	Mixed coniferous broad – leaved forest	1.5826	0.9844
Steep areas with a high altitude	Before planning	Creepers	Deciduous broad – leaved forest	0.4351	0.3956
	After planning	<i>Parthenocissus</i> – <i>Cynodon</i> – <i>Rosa banksiae</i> – <i>Bougainvillea</i>	Deciduous broad – leaved forest	1.1352	0.8534

In this paper, questionnaire survey was conducted on the distribution of garden plants before and after the planning. The aesthetic evaluation score is shown in the Table 3.

From Table 3 we can see that Nanshan Botanical Garden landscape beauty increased significantly after the landscape planning. To sum up, we evaluated the landscape of Nanshan Botanical Garden. The evaluation results are shown in Table 4.

As can be seen from the table, after the landscape planning, the comprehensive evaluation on the garden is higher, plant species are richer and more hierarchical and the matching of plant species is more reasonable, which brings sensual promotion for visitors.

Conclusions

In the increasingly developed society today, we need to pay more attention to the harmony between man and the nature. The existence of urban forest ecological garden can be a good coordination for the natural and human development. X. H. Zhang (2010) mentioned that urban forest is the vitality of urban infrastructure, its ecological benefits are irreplaceable and the construction of urban forest is essential to the urban ecological environment construction. Salvati *et al.* (2017) found that using the “spread model” to shape the degree edge landscape can be a good protection of forest resources. In this paper, the plant community species of Nanshan Botanical Garden were analysed by landscape ecology and landscape planning was performed. In addition, a comprehensive evaluation of the botanical garden before and after landscape planning was carried out by using AHP. The results showed that the best comprehensive assessment appeared when the plant species were diverse, the landscape beauty was natural and the structure levels of the community were reasonable, which provided a reference for the application of landscape ecology in the improvement of urban forest ecological landscape.

Table 3. Scores of ecological landscape of each location. MA – the average A value in picture, SEB – the original value of scenic beauty assessment method.

Location	Period	MA value	SEB value
Low altitude areas	Before planning	-0.0049	-0.49
	After planning	0.4212	42.12
Higher altitude areas	Before planning	-0.0846	-89.46
	After planning	0.2984	29.84
Steep areas with a high altitude	Before planning	0.1624	16.24
	After planning	0.5352	53.52

Table 4. Landscape comprehensive evaluation of Nanshan Botanical Garden (China).

Type	Specific indexes	Score before planning	Score after planning
Community structure	Advantage index	2	3
	Proportion of native plants	1	3
	Landscape level	2	4
	Landscape integrity	3	3
Plant diversity index	Landscape diversity index	2	3
	Species diversity index	1	3
Landscape beauty degree	Color harmony degree	2	4
	Species purity degree	4	3
	Species seasonal index	2	4
	Canopy density	2	3
Total score		21	33

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