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Structural Quality in Waterfront Green Space of Shaoyang City by Scenic Beauty Evaluation†

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Quality of landscape structure in green space of built-up waterfront areas in Shaoyang City were quantitatively assessed on the bases of scenic beauty estimation (SBE) in this paper. Scenic beauty estimation modals were constructed by using polybasic mathematical theory I. The results showed the main factors influencing the quality of forest landscape were green space ratio, canopy coverage, quantity of plant colour, contrast of the colour, composition of plant growth forms and wild-like degree of landscape. The main factors affecting the structure of green space around artificial landscape buildings, building pieces and roads in the county parks were relative trunk height below crow, harmony of landscape, planting pattern of tree, branch and leaf density of trees and style of building. The main factors determining the quality of waterfront landscape more efficiently were space occupied by vegetation, harmony of landscape, planting pattern of trees and vertical stratum structure of vegetation.

Keywords: Shaoyang city, Waterfront green space, Scenic beauty evaluation.

INTRODUCTION

The waterfront green areas derived from the river are the most sensitive regions of the urban environment and culture. With the unique landscape characteristics, the areas are not only the important part of the city ecological environments, but also the most important place for recreation and entertainment. The good waterfront landscapes will meet the demand of people to close the water and upgrade the landscape grade of the whole city.

Nowadays, the city waterfront landscape ecological construction has been paid more and more attention. The ecological construction of the waterfront landscape city mainly includes three aspects: namely, the protection of environmental sensitive areas, ecological green space construction, city appearance and architectural landscape construction. Determination and protection of the environmental sensitive area are not only the basis of city planning and construction, but also the important part of the waterfront ecological security.

Determination of landscape ecological security pattern is proposed by Yu[1], the Chinese scholar. The landscape security pattern (SP) is a way to distinguish and establish the ecological infrastructure. Based on the theory and method of landscape ecology and the relation of landscape process and pattern, this approach determine the landscape pattern which has great importance to the health and safety of these processes through analysis and Simulation of landscape process. The analysis framework of landscape pattern proposed by America scholars Forman in 1995 is the most representative, the specific steps is including: the background analysis, the overall layout, key area identification, ecological planning and spatial planning.

EXPERIMENTAL

Efforts were intensified to construct the waterfront landscape in Shaoyang City and the construction of waterfront areas develop faster. How to satisfy the residents on the build-up waterfront green space; how to further improve the quality of the area; how to make the space construction more scientific. All these are uncertain in currently construction of city waterfront landscape. In recent years, some experts had done some research on the waterfront green belts, such as the research on the urban ecological embankment landscape in the main urban areas[1], evaluation on the waterfront landscape construction and embodiment of history and culture[2,3]. However, they pay little attention to the types of waterfront landscape. Therefore, scenic beauty estimation was used to evaluate different types of green space landscape in waterfront green space of the Shaoyang city. This research provides reference to green structure oriented optimization in waterfront green space construction.

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General situation in the study area: Shaoyang City lies in Chiang-nan hilly region, the transition zone from Chiang-nan hilly region to the Yunnan Guizhou Plateau. Xuefeng mountains are in west, the eastern edge of the Yunnan Guizhou Plateau, while the East and Central of the city is situated in the western Heng shao Hilly Basin. Shaoyang City is located in the subtropical zone. It is a typical central subtropical humid monsoon climate, four distinct seasons, ample sunshine and heat, abundance of rainfall with hot rainy season; the prevailing southerly wind, high temperature and rainy in summer; the widespread northerly wind, low temperature and less rain in winter. Affected by the landform and topography, climate becomes complex and varied obviously in accordance with change attitude and areas. It forms a certain small climate environment and three-dimensional climate effect. The annual average temperature in the city is 16.1-17.1 ºC. July is the hottest month with monthly average temperature 26.6-28.5 ºC and it is the coldest in January with mean monthly air temperature 4.7-5.6 ºC the annual accumulated temperature above or equal to 10 ºC is 5000-5400 ºC and frost free period is 271-309 d. City in the annual sunshine hours is 1350-1670 h with the percentage of sunshine is 31-38 % and total solar radiation is 4131- 4519 Mj/m^2. The annual rainfall is 1000-1300 mm; the rainfall in May is 200-230 mm, at least in December, as 43-53 mm. It is mainly the fertile loess soil in the city.

Scenic beauty evaluation is one of strict and reliable method of scenic evaluation to measure landscape beauty with common aesthetic taste of groups[4]. As long as the researcher follow the unified standard and ensure consistent landscape photos, they will get high reliable scenic beauty evaluation result which is from the public evaluation[5].

Difference of aesthetic attitudes which are from different groups or people from diverse culture in statistical way is not significant. The young students' appreciation of the landscape less utilitarian[6] and students of different majors in the same landscape evaluation results have high consistency[7]. The steps of Scenic beauty evaluation method comprise field investigation and landscape photos, photo selection, landscape evaluation, landscape factor decomposition, standardized data processing, model building, *etc*.[7-10] .

Considering that there are great differences in the landscape influence elements of different type of green space in the waterfront areas, five landscape evaluations were carry out in three different type of waterfront green area (the general green areas (58 landscape photos), the artificial green areas around buildings, building pieces and roads (60 landscape photos) and the waterfront plant landscapes (70 landscape photos)). The study was conducted by fifty students majoring in Landscape Architecture in Shaoyang University. The corresponding landscape beauty model was established.

The researcher selected the by-slide method[11] to evaluate landscape and chose the 7 points scenic beauty as the measure standard and the corresponding scores were 3, 2, 1, 0, -1, -2, -3. Beauty model was set up by using multivariate quantitative model of I[7,8]. Three kinds of waterfront green space landscape elements of the decomposition (Tables 1-3).

TABLE-1
COMPONENT OF LANDSCAPE ELEMENTS FOR THE GREEN SPACE

Items	Sub-items				
	1	2	3	4	5
Quantity of colours (x_1)	More than two	Two	Single	–	–
Contrast of colours (x_2)	Less distinct	Distinct	Few	–	–
Spatial structure (x_3)	Less distinct	Horizontal closure	Vertical closure	–	–
Wild of landscape (x_4)	Urbanization	Simple	Indigenous	–	–
Quantity of species (x_5)	1	2	≤	–	–
Growth form (x_6)	Arbor	Arbor-shrub	Arbor-grass	Shrub-grass	Arbor-shrub-grass
Canopy density (x_7)	< 0.4	0.4-0.6	0.6-0.8	≤ 0.8	
Planting pattern (x_8)	Regular	In clumps	Free	–	–
Definition of crown form (x_9)	Few	Less distinct	Distinct	–	–
Noticeable of stems (x_{10})	Few	Noticeable	More noticeable	–	–
Green space ratio (x_{11})	–	–	Quantitative factor	–	–

Green space ratio means the proportion of green area in the visual zone[16].

TABLE-2
COMPONENT OF LANDSCAPE ELEMENTS FOR THE GREEN SPACE AROUND ARTIFICIAL LANDSCAPES OF BUILDINGS, BUILDING PIECES AND ROADS

Items	Sub-items				
	1	2	3	4	5
Wild of landscape (x_1)	Urbanization	Simple	Indigenous	–	–
Spatial structure (x_2)	Open forest	Horizontal closure	Vertical closure	–	–
Quantity of species (x_3)	1	2	≥ 3	–	–
Growth form (x_4)	Arbor	Arbor-shrub	Arbor-grass	Shrub-grass	Arbor-shrub-grass
Planting pattern (x_5)	Isolated	Clump	Free	Regular	
Density of branch and leaf (x_6)	Low	Middle	High	–	–
Harmony of landscape (x_7)	BAD	Middle	Good	–	–
Style of building (x_8)	Modernistic	Simple	Unsophisticated	–	–
Relative under-branch height (x_9)	–	–	Quantitative factor	–	–

When calculating relative under-branch height, average under-branch height is 7 m.

TABLE-3
COMPONENT OF LANDSCAPE ELEMENTS FOR THE WATERFRONT LANDSCAPE

Items	1	2	3
Pattern waterfront plant (x_1)	Qpen vegetation belt	Open woodland	Closed forest
Spatial structure (x_2)	Open forest	Horizontal closure	Vertical closure
Laminated structure (x_3)	Single layer	Double layers	More than two layers
Ornamental type (x_4)	Flower ornamentals	Foliage plants	Gainly plants
Spatial structure of plants (x_5)	Straight line	Curves	Polyline
Spatial occupancy of vegetation (x_6)	≥ 2/3	1/3~2/4	< 1/3
Planting pattern (x_7)	Isolated planting	Lincer planting	Patch planting
(x_8)	Pinnacle or cylindrical	Spherical or ovoid	Platform

RESULTS AND DISCUSSION

Forest landscape model: The general green landscape model was conducted by using Polybasic Mathematical Theory I which compiled by Yang *et al.*[12]. Firstly, operating 15 selected projects; according to the calculation results t test for the partial correlation coefficient is conducted. The items with little differences and small partial correlation coefficients will be deleting and then continue to operate the rest project. A total 6 operation will be done in the same way and finally 6 landscape elements can be selected, such as quantity of plant colour (x_1), colour contrast (x_2), wild-like degree of landscape (x_4), composition of plant growth forms (x_6), canopy coverage (X_7) and green space ratio (X_{11}). The model can be set up with six landscape elements which are the dominant factors to affect scenic beauty of forest landscape in waterfront green space. The specific models are as follows:

$Y = -0.333 + 0.805\ x_{1\text{-}1} + 0.369\ x_{1\text{-}2} - 0.668\ x_{2\text{-}1} - 0.661\ x_{2\text{-}2} + 0.289\ x_{4\text{-}2} - 0.432\ x_{7\text{-}1} - 0.485\ x_{7\text{-}2} + 0.434\ x_{7\text{-}3} - 0.377\ x_{6\text{-}1} - 0.510\ x_{6\text{-}2} - 0.233\ x_{6\text{-}3} - 0.176\ x_{6\text{-}4} + 1.584\ x_{11}$ ($R^2 = 0.806$).

$F = 8.904^{**} > F_{0.01}14, 30 = 2.742$; $t = 10.991^{**} > t_{0.01}29 = 2.756$, the results of linear equations F test and regression coefficients T test are as follows: F = 8.904** > F0.01 (14, 30) = 2.742; t = 10.991** > t0.01(29) = 2.756. This model can be used as the predictive model of forest landscape beauty of waterfront green areas in Shaoyang City.

From the contribution ratio of various landscape elements in the model (Table-4). The green space ratio has great contribution to the scenic beauty of forest landscape in the waterfront green space, up to 27.5 %, the contribution rate of other landscape elements from high to low are canopy density, plant colour quantity, plant colour contrast, composition of plant growth forms wild-like degree of landscape.

Models of artificial landscape around buildings, building pieces and roads: After 5 calculations, some landscape elements have been selected, such as planting pattern of tree, branch and leaf density of trees, harmony of landscape and style of building. These elements are the main factors which affecting the harmony between forests and surroundings in suburb garden to model. The concrete models are as follows:

$Y = -0.103 + 0.390\ x_{5\text{-}1} + 0.341\ x_{5\text{-}2} + 0.482\ x_{5\text{-}3} 0.344\ x_{6\text{-}1} 0.171\ x_{6\text{-}2} 0.676\ x_{7\text{-}1} 0.467\ x_{7\text{-}2} 0.285\ x_{8\text{-}1} 0.239\ x_{8\text{-}2} + 0.699\ x_9$ ($R^2 = 0.774$)

$F = 13.044 > F0.01(10, 38) = 2.828$; $t = 11.270 > t0.01(37) = 2.715$, the results of linear equations F test and regression coefficients T test are as follows: F = 13.044 > F0.01(10, 38) = 2.828; t = 11.270 > t0.01(37) = 2.715 this model can be regarded as the predictive model of scenic beauty in forest landscape and artificial landscape around buildings, building pieces and roads in Shaoyang City.

From the contribution rate of various landscape elements in the model (Table-5), one can see the relative trunk height below crow has great contribution to the scenic beauty of artificial landscape in the waterfront areas, up to 28.1 %, the contribution rate of other landscape elements from high to low is harmony of landscape, planting pattern of tree, branch and leaf density of trees and style of building.

Waterfront landscape model: After 6 operations, some landscape elements such as vertical stratum structure of vegetation (X_3), space occupied by vegetation (X_6), planting pattern of trees (X_7) and harmony of landscape (X_9) and *etc.* have been choose as the important factor to model. These factors have great influence on the harmony of forest and surroundings in the waterfront green areas. The specific models are as following: $Y = 1.481 - 0.35x_{3\text{-}1} 0.254x_{3\text{-}2} 0.711\ x_{6\text{-}1} 0.194\ x_{6\text{-}2} + 0.530\ x_{7\text{-}1} + 0.251\ x_{7\text{-}2} + 0.127\ x_{7\text{-}3} 0.694\ x_{9\text{-}1} 0.382_{9\text{-}2}$ ($R^2 = 0.694$)

TABLE-4
COMPONENT VALUES OF ITEMS IN LANDSCAPES ESTIMATION MODEL OF THE FOREST

Items	Sub-items	Coefficient	Score	Percentage (%)	Items	Sub-items	Coefficient	Score	Percentage (%)
X_1	1	0.805	0.805	14.0	X_6	1	-0.377	0.510	8.8
	2	0.369				2	-0.510		
	3	0				3	-0.233		
X_2	1	-0.668	0.668	11.6		4	-0.176		
	2	-0.611				5	0		
	3	0			X_7	1	-0.432	0.919	15.9
X_4	1	0.3	0.300	5.2		2	-0.485		
	2	0.289				3	0.434		
	3	0				4	0		
X_{11}		1.584	1.584	27.5	–	–	–	–	–

TABLE-5
COMPONENT VALUES OF ITEMS IN LANDSCAPES ESTIMATION MODEL OF THE GREEN SPACE AROUND ARTIFICIAL LANDSCAPES OF BUILDINGS, BUILDING PIECES AND ROADS

Items	Sub-items	Coefficient	Score	Percentage (%)	Items	Sub-items	Coefficient	Score	Percentage (%)
X_5	1	0.390	0.482	19.4	X_7	1	-0.676	0.676	27.2
	2	0.341				2	-0.467		
	3	0.482				3	0		
	4	0			X_8	1	-0.285	0.285	11.5
X_6	1	-0.344	0.344	13.8		2	-0.239		
	2	-0.171				3	0		
	3	0			X_9		0.699	0.699	28.1

F = 11.085 > F0.01(9, 44) = 2.840; t=9.873 > F0.01(43) = 2.695, the results of linear equations F test and regression coefficients T test are as follows: F = 11.085 > F0.01(9, 44) = 2.840; t = 9.873 > F0.01(43) = 2.695. This model can be regarded as the predictive model of scenic beauty in the waterfront landscapes in Shaoyang City.

From the contribution ratio of various landscape elements in the model (Table-6), we can obtain the information about space occupied by vegetation has great contribution to the scenic beauty of the waterfront green space, up to 31.3 % and it indicate that the planting the waterfront plant is not the wide the better. The contribution rate of other landscape elements from high to low is harmony of landscape, planting pattern of trees and vertical stratum structure of vegetation.

Quality of forest landscape in waterfront green space: This study results show that the green ratio has observable influence on the scenic beauty of the forest landscape in the waterfront green space. Firstly, the green space meets the psychological needs of people return to nature. Secondly, the environment with high green ratio can enhance the eye visuognosis persistence, help to eliminate the visual fatigue and promote the pulse and blood pressure recovery and stability[13]; in addition, the stand with high green ratio can avoid the negative effects that the surface exposed to the visual beauty. With the canopy density increase, scenic beauty of the forest landscape increases and then decreases. The canopy density is an index to reflect the stand density. The maximum of canopy density is 0.6-0.8.

Effects of plant colour to stand reflect on two aspects: the quantity of colour and colour contrast (Table-4). The colour quantity is richer, the higher the contrast the greater the scenic beauty of stand. Because the rich colour can create a strong, relaxed, happy atmosphere[14]. High contrast colour combinations can produce a strong visual impact, but the big area single colour forest scenery often let people feel dull, inflexible, lack of vigor. Therefore, partial adjustment of the existing green area should be carried out step by step. The different colour plants should be increase to expand the plant colour diversity and the landscape heterogeneity[11-13].

The effects of different plant growth forms to the forest landscape beauty are grass and shrub type > shrub grass type > arbor grass type > arbor > shrub type. Grass and shrub type, shrub grass and arbor grass landscape beauty is relatively high, because the herbaceous plants increase the vegetation cover and the green ratio and herbaceous plants are mostly in the wild state with a relatively strong local flavor. Forest landscape beauty depends on interaction of the landscape elements, but not the simple superposition of single factor or multiple elements.

Structure of green space around artificial landscape buildings, building pieces and roads: The contribution ratio of relative trunk height below crow and branch and leaf of tree to the landscape beauty model of green space around artificial landscape are, respectively 28.1 and 13.8 % (Table-5). As a result, reasonable selection of tree species is one of the key problems to optimize the structure of green space around artificial landscape buildings, building pieces and roads because the green areas around artificial areas have the recreational function, need to have better accessibility and shade effect, especially the both sides of the road greening.

The contribution ratio of the harmony of landscape to scenic beauty model of green space around artificial landscape buildings, building pieces and roads is 27.2 %, slightly less than that of the relative height under branch (Table-5). Coordination of buildings and greening mainly reflect on two aspects: the building materials and relative building volume of buildings, building pieces and roads. Therefore, the building form, mainly in antique style, should be moderate and coordinate with wild-like landscape of waterfront green belt. In order to blend the buildings into the landscape, the building should add the beauty to the nature landscape and not let the building dominate[15,16].

Quality of waterfront landscape: The contribution rate of the plant space occupancy to the waterfront landscape beauty

TABLE-6
COEFFICIENT VALUE OF ITEMS IN LANDSCAPES ESTIMATION MODEL OF THE WATERFRONT LANDSCAPE

Items	Sub-items	Coefficient	Score	Percentage (%)	Items	Sub-items	Coefficient	Score	Percentage (%)
X_3	1	-0.351	0.351	15.4	X_7	1	0.53	0.53	23.2
	2	-0.254				2	0.251		
	3	0				3	0.127		
X_6	1	-0.711	0.711	31.1		4	0		
	2	-0.194			X_9	1	-0.694	0.694	30.3
	3	0				2	-0.382		
–	–	–	–	–		3	0		

model is as high as 31.1 %. Therefore in dealing the waterfront landscape, reasonable application of plants plays a vital role to the landscape effects. As with the green space of artificial landscape, the relative volume of the water and plant should be thought over in the waterfront landscape. When we come to the different plant space occupancy, waterfront landscape beauty from big to small are: < 1/3, 1/3, 2/3, ≤ 2/3.

The planting pattern of trees is good with solitary planting and linear planting, not to plant in a plot, because the plot planting trees rarely lead to the dynamic forest top line and the overall landscape will lack spirituality. The combination design of irregular dot and line planting can enrich the level change of embankment. The differences of the tree size and canopy shape can be full used to form a beautiful varied forest top line and to create an ups and downs landscape sequence.

The scenic beauty of multilayer structure green space is higher that of monolayer and double layer from the landscape beauty model (Table-6). We should pay more attention to the arrangement of plant vertical structure and make full use of the growth characteristics of plants to build sufficient space layer landscapes. We can also plant more native plants to enrich the vertical space variation and form the natural and wild-like waterfront landscape.

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