Landscape Evaluation of Xinghu National Wetland Park Based on Analytic Hierarchy Process

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Abstract: Wetland parks play an important role in regulating microclimate, providing habitat for flora and fauna, and purifying water resources due to their unique geographical location and ecological environment. Taking Xinghu National Wetland Park in Zhaoqing City as an example, this study comprehensively considers the various impact factors of wetland parks on the city, establishes a value evaluation system for wetland parks, and uses the Analytic Hierarchy Process (AHP), field surveys, and literature research as the main research methods to quantitatively analyze and evaluate the landscape quality of Xinghu National Wetland Park. The research methodology achieves the optimal combination of subjectivity and objectivity, as well as qualitative and quantitative analysis. Based on the research and data analysis, Xinghu National Wetland Park has a good natural ecological environment, with a weight of 72.255% for ecological value, indicating its potential to effectively contribute to ecological value. However, it exhibits relatively less contribution in terms of landscape value (19.858%) and social value (7.887%). This suggests that Xinghu Wetland Park has had a positive impact on the construction of a favorable ecological environment in the city, and efforts should be made to maintain the expression of its ecological value while ensuring the realization of social and landscape values through natural and artificial means.

1. Introduction

Wetland resources possess unique natural attributes[1]. The assessment of wetland ecosystem services and the construction of environmental landscapes are recognized contributors to the sustainable development and well-being of humanity[2]. The importance of preserving wetland resources for present and future livelihoods is widely acknowledged[3]. As a significant ecological strategic resource for sustainable human development, wetlands exhibit remarkable ecological regulation functions and benefits, earning them the title of “the Earth’s kidneys”[4]. Wetland parks, benefiting from their exceptional geographical environments, offer invaluable ecosystem services as transitional zones between land systems, water systems, and interfaces of land and water systems, providing humanity with energy, information, and resources. Efficient management and protection efforts are essential to alleviate the loss of wetland resources and establish clear boundaries through scientific and rational approaches[5].

The Xinghu Wetland Park, located in the old town area of Zhaoqing City, is hailed as the “kidney of the city”. This title recognizes the significant role the wetland park plays in the sustainable development of the city. The park purifies water resources and replenishes groundwater through the planting of various plants, effectively reducing soil erosion within the wetland park. Moreover, during periods of heavy rainfall in the city, the wetland park acts as a reservoir, storing a large amount of rainwater and mitigating urban flood hazards[6]. The Xinghu National Wetland Park provides necessary nutrients for the growth of over six hundred plant species and serves as a habitat for more than two hundred animal species. Its rich biodiversity contributes to its ecological value. This study aims to evaluate the ecological, landscape, and social values of the Xinghu National Wetland Park. By analyzing research data, we will assess the completeness of the wetland park’s ecosystem services, aesthetic functions, and social services. Additionally, this research aims to highlight the overall

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planning and development direction for the future of the wetland park.

The development of the economy and the depletion of natural resources have caused environmental degradation and the depletion, and even exhaustion, of various resources. The degree of human damage to the environment has far exceeded the natural carrying capacity. Today, the immediate priority is to reduce and halt this destruction, protect the natural self-recovery ability, and establish artificial wetlands and protect natural wetlands as important measures to protect the environment and restore ecological resilience. Being crucial environmental resources, wetland parks serve important functions such as adjusting the ecological security of the entire region, maintaining biodiversity, conserving water resources, and regulating the climate[7]. Additionally, they also fulfill the purposes of ecological tourism, leisure, and educational promotion. This study employs the Analytic Hierarchy Process (AHP) to evaluate the value of Xinghu National Wetland Park and utilizes the AHP to calculate the weight of indicators. The Analytic Hierarchy Process (AHP) was initially proposed by Professor T.L. Saaty, an American operations researcher, in the early 1970s to address complex multi-objective decision-making problems[8]. It decomposes the elements related to evaluation into the objective layer, criterion layer, and scheme layer. The highest objective layer represents the evaluation objectives to be achieved or the problems to be solved, with quantified values specified. The decomposed criteria and elements are compared pairwise to determine their relative importance and assign corresponding priority layers. The data is then entered into a computational system to generate the weight values for each element. Data can be obtained through questionnaire surveys and expert consultations. The AHP greatly enhances the orderliness and scientific nature of decision-making by combining qualitative and quantitative analysis methods, ensuring the scientific validity and feasibility of research results[4]. The main objectives of this study are: (1) to evaluate the different value functions of Xinghu National Wetland Park based on the AHP; (2) to provide sustainable development suggestions for Xinghu National Wetland Park through quantitative analysis.

2. Overview of Xinghu National Wetland Park

2.1. Geographical Location

The Xinghu National Wetland Park is situated in Zhaoqing, Guangdong Province, benefiting from its advantageous geographical location, being only 100 kilometers away from Guangzhou. It encompasses the renowned Xinghu Scenic Area, which is further divided into the Qixingyan Scenic Area and the Dinghu Mountain Scenic Area. Serving as a crucial component of the Qixingyan Scenic Area, the Xinghu National Wetland Park contributes to the city of Zhaoqing's recognition as a nationally designated garden city, owing to its exceptional geographical positioning and picturesque environment. Covering an expansive area of 9.35 square kilometers, the Xinghu National Wetland Park boasts 6.78 square kilometers of wetland, characterized by its extensive lake surface, diverse landscape nodes, and abundant biodiversity in terms of flora and fauna.

2.2. Climatic Conditions

The city of Zhaoqing is located south of the Tropic of Cancer and falls within the subtropical monsoon humid climate of southern China. Its primary climatic characteristics include warm temperatures, ample sunshine, and abundant rainfall throughout the four seasons, with an average annual temperature of 22 degrees Celsius (refer to Figure 1) and an average annual precipitation of approximately 1,650 millimeters (refer to Figure 2). Such comfortable temperatures and plentiful water supply facilitate the growth of various plants, while the favorable conditions of light, heat, and water also support the cultivation of diverse crops, making it a major grain-producing region in Guangdong Province. However, the occurrence of extreme weather such as typhoons during certain periods, particularly in July and August, may disrupt normal production and daily life. Additionally, high temperatures during these months present potential risks to human health, and winter's chilly weather can result in frost damage to plants.

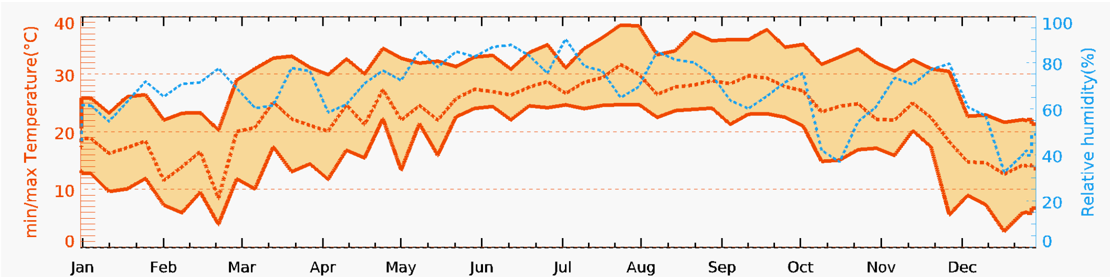

Figure 1 Analysis of temperature in Zhaoqing City

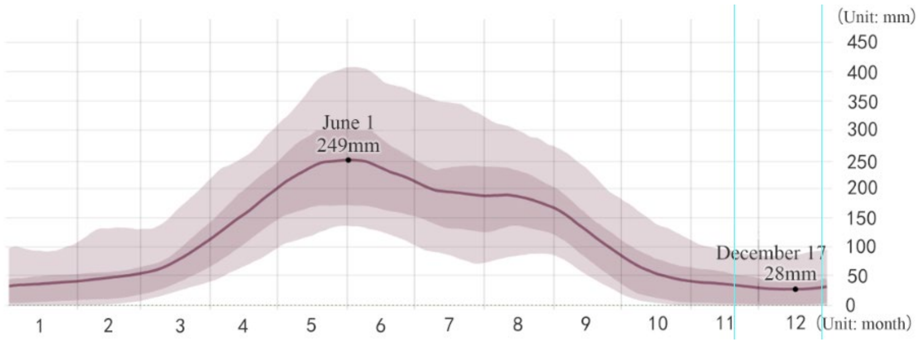

Figure 2 Analysis of precipitation in Zhaoqing City

2.3. Resource Conditions

2.3.1. Plant Resources

Table 1 Table of common plants in Xinghu National Wetland Park

Plant species	Species name and scientific name				
Tall trees	*Prunus persica*	*Salix babylonica L.*	*Ficus concinna Miq.*	*Terminalia arjuna (Roxb. ex DC.) Wight & Arn.*	*Ficus elastica Roxb. ex Hornem.*
Shrubs	*Osmanthus sp.*	*Michelia figo (Lour.) Spreng.*	*Aglaia odorata Lour.*	*Excoecaria cochinchinen sis Lour.*	*Rhododendron pulchrum*
Groundcover s	*Canna indica L.*	*Nephrolepis auriculata (L.) Trimen*	*Esmeralda clarkei Rchb. f.*	*Zoysia tenuifolia Willd. ex Trin.*	*Ophiopogon bodinieri*
Aquatic plants	*Nelumbo nucifera*	*Phragmites communis*	*Taxodium distichum(L.)Rich.*	*Taxodium ascendens*	*Zizania caduciflora*

Due to its perennially humid and mild weather conditions, Xinghu National Wetland Park hosts over 600 plant species, with a plant coverage rate reaching a remarkable 85%. This rich variety includes tall trees, shrubs, groundcovers, and aquatic plants, with a preference for indigenous species that are better adapted to Zhaoqing's local climate and soil environment. Among the commonly seen tall trees are Prunus persica, Salix babylonica, Ficus microcarpa, Terminalia arjuna, Ficus elastic, archontophoenix alexandrae and caryota urens. The overall planting of tall trees focuses largely on palm plants, both conforming to the overall site style and suiting the climate conditions of Guangdong. The commonly seen shrubs include osmanthus fragrans, Michelia figo, Aglaia odorata, Excoecaria cochinchinensis, and Rhododendron pulchrum. A great variety of evergreen shrubs are chosen to set the tone for the wetland park, complemented by colorful foliage shrubs and ornamental flowering shrubs to enhance the plant landscape. As for groundcovers, there are Canna indica, Nephrolepis auriculata, hymenocallis americana, Zoysia tenuifolia, and Ophiopogon bodinieri. These groundcover plants primarily serve the purposes of preventing soil erosion, covering the ground, and adsorbing dust to purify the air. Flowering groundcovers are also carefully selected to increase their ornamental value. Aquatic plants, such as Nelumbo nucifera, Phragmites communis, Taxodium distichum, Taxodium ascendens, and Zizania caduciflora, are classified into emergent plants, floating-leaved plants, and submerged plants based on their growth conditions and environment. These diverse aquatic plants grow in different wetland environments, playing vital roles in purifying water resources, improving the substrate of wetlands, preventing soil erosion, and beautifying the landscape environment (see Table 1).

2.3.2. Water Resources

The wetland, acting as a transitional zone between terrestrial and aquatic ecosystems, plays a crucial role in water source protection and groundwater replenishment[8]. Covering an area of 6.78 square kilometers, which accounts for 72.5% of the entire wetland park, Xinghu National Wetland Park primarily consists of lake wetlands. These include the Central Lake, Bohai Lake, Qinglian Lake, Li Lake, Xiannv Lake, and Dongdiaohong Lake. Each lake area is subject to artificial management to fully harness its ecological benefits. Established in 2004, Xinghu National Wetland Park was previously a semi-artificially developed lake. During the rapid industrialization era, industrial wastewater and domestic sewage were indiscriminately discharged into the lakes, leading to severe degradation of water quality in Xinghu, resulting in eutrophication. Since 2003, the government has invested 50 million in resource integration and protection of Xinghu National Wetland Park. Measures such as pollution interception and dredging have been employed to optimize the water quality of the wetland park. Today, the water quality of Xinghu National Wetland Park meets the standards of class II surface water as specified by the national regulations. To ensure the quality of wetland water resources, enhanced water quality management and monitoring have been implemented, with regular data surveillance facilitating the formulation of effective water purification strategies.

2.3.3. Animal Resources

Birds are an indispensable part of wetlands, as they promote processes such as material cycling, energy flow, and information transmission, thereby maintaining the stability and health of wetland ecosystems[9]. Wetlands also serve as important foraging and resting habitats for waterbirds, migratory birds, and other organisms[10]. The superior wetland ecological environment of Xinghu National Wetland Park provides necessary conditions for the growth and reproduction of animals. With over 250 species of wild birds, including the nationally protected red-crowned crane, as well as nightjars, egrets, cormorants, and woodpeckers, the park boasts diverse avian populations. To promote harmony between humans and nature and enhance human understanding of the natural world, Xinghu National Wetland Park has designated birdwatching sites where visitors can observe a variety of cherished bird species found within the wetland park. In order to provide a habitat for the "wetland deity" - the red-crowned crane, a Red-crowned Crane Ecological Park has been established, primarily focusing on breeding red-crowned cranes. The park also houses other wetland birds such as flamingos and white-naped cranes. It features observation platforms, boardwalks, and birdwatching activities, allowing people to gain a close understanding of the habitat and behaviors of wetland birds. Xinghu National Wetland Park has become the largest bird conservation and education base in Guangdong.

The wetland park is home to a variety of amphibians and reptiles, including the notable Fujian Kuhl's creek frog, Microhyla pulchra, Hylarana guentheri, and tiger frog among the amphibians, as well as cobras, kraits, and mock vipers among the reptiles. The conservation of these wetland creatures plays a crucial role in promoting the sustainable development of the wetland[11].

3. Research Methods and Calculation

The AHP decomposes elements related to decision-making into the objective layer, indicator layer, and scheme layer, constructing an evaluation system (as shown in Figure 3) to calculate the weights of each criterion. The ultimate evaluation data for the wetland park is represented by the objective layer (O), which breaks down the final evaluation objective into different components. By establishing quantitative values (as shown in Table 2), pairwise comparisons are made between elements, and their importance is assessed to construct a judgment matrix. Finally, the corresponding weights for each element are calculated (as shown in Table 3)[12]. Through the establishment of a structural model, the evaluation results are computed and analyzed (with data that pass the consistency test deemed as logically valid evaluation results) (as shown in Figure 4).

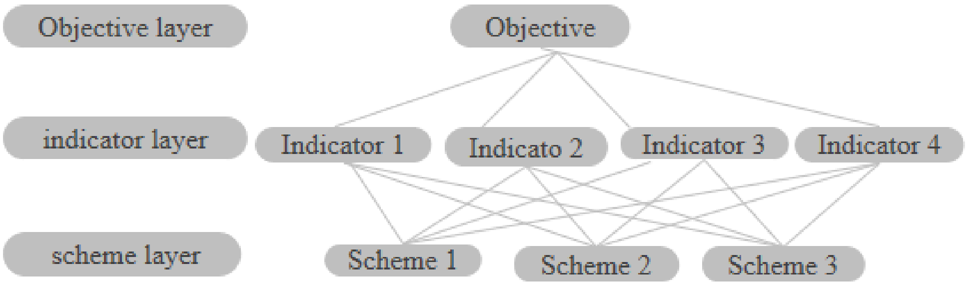

Figure 3 Construction of evaluation system

Table 2 Establishing the quantized values

The factor i compared to factor j	Quantitative value
Equally important	1
Slightly more important	3
Moderately more important	5
Strongly more important	7
Extremely more important	9

Table 3 Construction of the judgment matrix

Z	Indicator 1	Indicator 2	Indicator 3	Indicator 4
Indicator 1	1			
Indicator 2		1		
Indicator 3			1	
Indicator 4				1

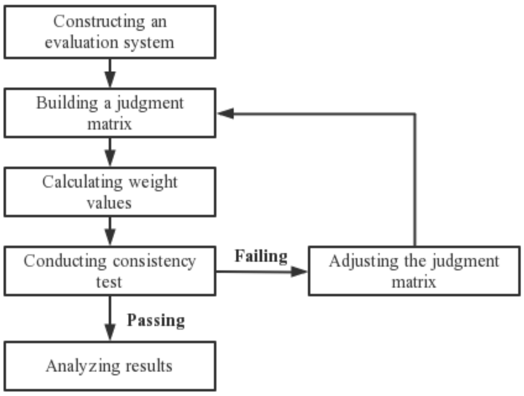

Figure 4 Application process of AHP

3.1. Constructing the Evaluation System Model

By referring to the scholars' use of the AHP for evaluating the landscape ecological quality of wetland parks[13], combined with the actual situation of Xinghu National Wetland Park in Zhaoqing City, a questionnaire survey method was employed to collect evaluation data from 13 relevant professionals. The evaluation of wetland parks' value not only includes the assessment of ecological value, but also measures the landscape value and social value that wetland parks bring to the city. For example, the aesthetics of plants and water bodies in the wetland park have an impact on the landscape value. Based on the principles of representativeness and systematicness, the wetland park evaluation system was divided into three aspects and ten evaluation factors for qualitative and quantitative analysis (as shown in Table 4). To facilitate data collection and determine the comprehensive evaluation values, a rating method was adopted for each evaluation indicator, with five levels: equally important, slightly more important, moderately more important, strongly more important, and extremely more important (as shown in Table 5), which were quantified using a proportional scale of 1-9[14]. A pairwise comparison matrix A = (αij)m×n was constructed, where αij＞0, αji= 1/αij and αii= 1. Then, the influencing weights of each indicator were calculated.

Table 4 Landscape comprehensive evaluation system model

Objective layer	Criterion layer Indicator layer	
Landscape evaluation of Xinghu National Wetland Park in Zhaoqing	Landscape value B_1	Plant aesthetics C_1
		Waterscape aestheticsC_2
		Public sculpture C_3
		Park color C_4
	Social value B_2	vity space C_5
		Interactive facilities C_6
		popular science C_7
	Ecological B_3 value	Habitat value C_8
		Plant ecological value C_9
		Climatic value C_{10}

Table 5 Quantized values of the judgment matrix

The factor i compared to factor j	Quantitative values
Equally important	1
Slightly more important	3
Moderately more important	5
Strongly more important	7
Extremely more important	9

3.2. The Determination of the Weight of the Criteria Layer and the Results of Consistency Test

The evaluation process divides the criterion layer into three components, namely, landscape value, social value, and ecological value. Through the collection, organization, and square root method calculation of relevant data, the weights of landscape value (B_1), social value (B_2), and ecological value (B_3) were determined as 19.858%, 7.887%, and 72.255% respectively (as shown in Table 6). A consistency test was conducted to determine the weights of each indicator. The weighting values were tested using SPSSPRO, and the calculation results showed a maximum eigenvalue of 3.102 and an RI value of 0.525. Hence, the consistency ratio (CR) calculated as CI/RI was 0.097, which is less than 0.1, indicating passing the consistency test (as shown in Table 7).

Table 6 Weight value and ranking of criteria layer

Items	Eigenvector	Weight value(%)	Ranking	The largest eigenvalue	CI value
Landscape value B_1	0.885	19.858	2	3.102	0.051
Social value B_2	0.351	7.887	3		
Ecological value B_3	3.218	72.255	1		

Table 7 Consistency test results of criteria layer

The largest eigenvalue	CI value	RI value	CR value	Result of consistency test
3.102	0.051	0.525	0.097	Pass

3.3. The Determination of the Weight of the Indicator Layer and the Results of Consistency Test

The indicator layer consists of ten elements, and through calculations, the weights of plant aesthetics (C_1) were determined as 3.303%, water feature aesthetics (C_2) as 4.946%, public sculpture

(C_3) as 1.804%, park color (C_4) as 2.162%, activity space (C_5) as 4.055%, interactive facilities (C_6) as 3.595%, education of popular science (C_7) as 8.189%, habitat value (C_8) as 21.431%, plant ecological value (C_9) as 20.57%, and climate value (C_{10}) as 29.944% respectively (as shown in Table 8). The calculations of the AHP resulted in a maximum eigenvalue of 10.879 and an RI value of 1.486. Therefore, the consistency ratio (CR) calculated as CI/RI was 0.066, which is less than 0.1, indicating passing the consistency test (as shown in Table 9).

Table 8 Weight value and ranking of indicator layer

Items	Eigenvector	Weight value (%)	Ranking	The largest eigenvalue	CI value
Plant aesthetics C1	0.523	3.303	8	10.879	0.098
Waterscape aesthetics C2	0.784	4.946	5		
Public sculpture C3	0.286	1.804	10		
Park color C4	0.343	2.162	9		
Activity space C5	0.642	4.055	6		
Interactive facilities C6	0.57	3.595	7		
Education of popular science C7	1.297	8.189	4		
Habitat value C8	3.395	21.431	2		
Plant ecological value C9	3.259	20.57	3		
Climatic value C10	4.744	29.944	1		

Table 9 Consistency test results of indicator layer

The largest eigenvalue	CI value	RI value	CR value	Result of consistency test
10.879	0.098	1.486	0.066	Pass

4. Conclusions and Discussion

4.1. Conclusions

From an overall perspective, the wetland park has a significantly high ecological value, with a weight of 72.255%, surpassing both its landscape value and social value. This demonstrates that the wetland park effectively embodies its ecological value, providing a space for the growth and reproduction of flora and fauna, air purification, environmental beautification, and microclimate regulation. The landscape value within the wetland park accounts for 19.852%, lower than its ecological value but higher than its social value. It effectively meets the needs of urban residents or tourists to appreciate the scenery and get close to nature. The proportion of social value is 7.887%, indicating a lesser emphasis on providing interactive facilities and educational outreach within the wetland park.

4.2. Discussion

Wetlands are multifunctional landscapes that bridge the gap between terrestrial and aquatic ecosystems[15]. They are the most biologically diverse ecological landscapes on Earth and one of the most important living environments for humans[16]. Wetland parks serve as crucial regulation spaces within cities. In addition to their effective filtration capabilities and abundant biodiversity, wetlands can be directly utilized by humans, consistently providing valuable ecological benefits[17]. This study comprehensively compares and evaluates various indicators of the ecological environment in wetland parks using the AHP, resulting in the final assessment data. This not only facilitates the effective utilization of Xinghu Wetland Park’s significant and unique ecological value but also promotes the provision of leisurely and nature-immersive landscape spaces for people.

Based on the evaluation weight values and rankings of the ecological value, landscape value, and social value of the wetland park, this article provides four important development suggestions for the later construction and maintenance of the wetland park:

(1) Ensure the realization of the ecological value of the wetland park. Xinghu Wetland Park's ecological value is mainly reflected in enhancing animal and plant diversity, purifying air, and improving urban heat island effect. The final evaluation weight also demonstrates the good ecological environment of the wetland. The key is to stabilize and maximize the ecological value of the wetland park.

(2) Enhance the landscape value of the wetland park. The aesthetic appeal of the wetland park's landscape space can greatly influence its popularity. Aesthetically pleasing water features, abundant greenery, and harmonious park colors can bring joy and relaxation to visitors. It is necessary to leverage the advantages of the wetland park's unique geographic conditions and optimize the park environment.

(3) Actively promote the realization of social value. The wetland park should not only fulfill its wetland functions but also provide park value. Improvements should be made to the activity and leisure spaces as well as the observation spaces within the wetland park. The addition of interactive facilities can cater to the needs of different audiences. Additionally, the wetland park should showcase its unique educational and scientific outreach functions.

(4) Ensure the coordinated development of landscape and ecological harmony in the wetland park. The wetland park is a complex ecological system due to its special geographic location, which determines its complexity and vulnerability[18]. The development of a high-quality wetland park requires the harmonious realization of ecological value, landscape value, and social value, fostering their mutual reinforcement and guaranteeing the sound ecological development of the wetland park.

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