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Visual Aesthetic Quality of Qianjiangyuan National Park Landscapes and Its Spatial Pattern Characteristics

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Abstract: This paper conducts a scientific assessment of aesthetic quality to provide intuitive and scientific planning strategies for national park construction. Focusing on Qianjiangyuan National Park, the study used the scenic beauty evaluation (SBE) method to subjectively assess landscape photos from 16 sample sites. Objective eye movement indicators describing visual behavior were also analyzed. A national park landscape visual quality assessment model was derived through multiple linear regressions correlating subjective evaluations with objective indicators. Spatial technologies like ArcGIS were used to analyze the visual quality and its spatial distribution. Key findings include (1) subjective evaluations showed higher SBE scores for wetland landscapes, followed by recreational, village, and forest landscapes, (2) eye movement behavior varied across landscape types, with the forest landscape having the shortest first fixation time and the lowest saccade frequency, while recreational landscapes had the lowest average saccade speed, (3) strong correlations were found between SBE and indicators such as average fixation time and saccade frequency, with fixation duration ratio being the leading factor influencing visual aesthetic quality, and (4) visual aesthetic quality was highest in the north and south areas of the park, with significant differences between sample sites in these regions compared to the central area. Among different functional zones, the ecological protection area had the highest quality, while the Suzhuang management area excelled in aesthetic quality compared to the Hetian management area.

Keywords: landscape aesthetic; visual quality assessment; eye movement experiments

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1. Introduction

National parks not only provide scientific protection for natural ecosystems but also offer opportunities for their rational utilization. Additionally, they offer public spaces for leisure and recreation, facilitating the sustainable development of natural resources [1]. China's ecological civilization emphasizes the rational use of nature based on respect for nature, achieving sustainable development in which humans and nature coexist harmoniously. With the continuous development of China's ecological civilization, national parks have become major sites for ecological environment protection, eco-tourism, natural education, and public awareness campaigns. Consequently, research and planning on the scientific and rational protection and development of national parks have gained increasing emphasis [2–4]. Landscape quality assessment is a crucial component of national park construction, significantly impacting the effective management and conservation of the ecological environment within these parks. Targeted resource management, rational layout planning, and optimization of scenic resource allocation can enhance the efficiency of park utilization, reducing resource wastage and environmental damage [5–8].

The scenic beauty estimation (SBE) method, initially proposed by Daniel et al. [9], employs a rating scale approach. Due to its simplicity, efficiency, and reliability, SBE has been extensively applied in landscape evaluation for both large and small-scale samples [10]. For instance, Robert G. Ribe used the SBE method to establish a general model of beauty perception in boreal hardwood forests [11]. Yang Xinxia et al. utilized the SBE method to assess 30 forest landscape sites in the eastern region of Changbai Mountain [12]. Weng Shufei et al. employed SBE and the analytic hierarchy process (AHP) to evaluate the quality of waterfront plant landscapes in the Lingnan region [13]. Zhang Jianguo et al. established a linear relationship model between scenic beauty and judgment factors using the SBE method in the Xiazhu Lake National Wetland Park [14]. Ray March Syahadat et al. used Kendall's W test, SBE, SD, factor analysis, and MDS to assess the visual quality of the Sibur rice fields and the impact of agritourism-related changes on them [15]. Eye movement experiments objectively reflect individuals' inherent cognitive processes through the recording and analysis of eye movement data [16,17]. These experiments have gradually been integrated into landscape quality evaluation research and applied in various domains, such as tourist landscapes [18], urban greening [19,20], and rural landscapes [21].

Against this backdrop, this paper selects Qianjiangyuan National Park as a case study, focusing on the visual aesthetic aspects of its landscapes. By comparing differences in scenic beauty and eye movement indicators among different landscape types, we constructed a model for evaluating the aesthetic quality of national park landscapes. We also explored the characteristics of spatial patterns of aesthetic quality among different landscape types. The objective is to provide guidance for the planning, management, and development of visual aesthetics in national park landscapes, and enhance the overall visitor experience.

2. Materials and Methods

2.1. Overview of Study Area

Located in Kaihua County, eastern China's Zhejiang Province, Qianjiangyuan National Park is one of the first 10 pilot areas for the national park system in China (Figure 1). It covers a total area of 252.38 square kilometers, integrating the Gutian Mountain National Nature Reserve, Qianjiangyuan National Forest Park, and Qianjiangyuan Provincial Scenic Area, along with the ecological areas between them. The national park spans 4 towns (townships) and 21 administrative villages, with a total population of 9744.

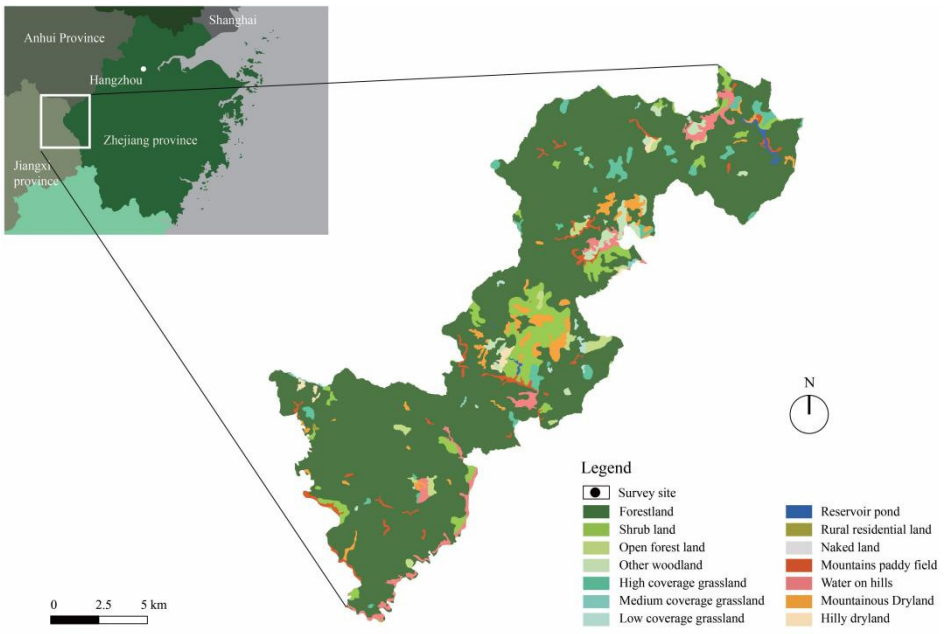

Figure 1. Geographical location of Qianjiangyuan National Park [22].

Qianjiangyuan National Park features five types of vegetation, including mid-subtropical evergreen broad-leaved forests, evergreen deciduous broad-leaved mixed forests, coniferous broad-leaved mixed forests, coniferous forests, and subalpine wetlands. It boasts globally pristine and well-preserved low-altitude subtropical evergreen broad-leaved forests and serves as the primary habitat for many key protected wildlife species. Based on the characteristics of the park's conservation targets and the needs of residents and social development, it is divided into four functional zones: core protection area, ecological conservation area, recreational display area, and traditional utilization area. Differentiated management strategies are implemented according to these zones. The core protection area safeguards the original ecosystems and restricts human activities; the ecological conservation area aims to restore and maintain ecosystems, limiting development; the recreational display area provides tourism and educational opportunities under the premise of ecological protection; and the traditional use area allows for sustainable traditional activities, promoting community development.

To date, there has been no comprehensive assessment of the visual aesthetic quality of Qianjiangyuan National Park. To fill this research gap, this study establishes a national park landscape visual quality assessment model through multiple linear regressions, integrating subjective and objective evaluation data. This model aims to explore the key factors affecting the visual aesthetic quality of different landscape types in Qianjiangyuan National Park, as well as the correlation between subjective perception and objective eye-tracking indexes. This research is of great theoretical and practical significance for enhancing visitor experiences, increasing scenic area attractiveness, conserving the natural environment, and supporting planning and design.

2.2. Sample Materials

All photos were taken between 8:00 a.m. and 10:00 a.m. on sunny days. The shooting locations were selected based on landscapes commonly mentioned or deeply impressed by local villagers and external tourists. This strategy ensured the representativeness of the samples while maximizing the consistency of objective conditions such as sunlight, light, and weather. After pre-selection, the photos were uniformly sized, and after consultation with experts, the 16 most representative photos were selected. The samples were divided into four categories: forest, wetland, village, and recreational, with four samples for each category. To eliminate primacy effects, three photos were selected as warm-up photos for the experiment from the remaining photos. The order of sample images was randomized, and blank controls were set between sample images to ensure relatively consistent eye fixation positions when viewing different images.

2.3. Respondents

The subjects met the criteria of "normal vision, uncorrected visual acuity or corrected visual acuity above 1.0". A total of 96 undergraduate and graduate students from various regions were recruited, and 64 valid data were collected. Among them, there were 25 male subjects and 39 female subjects, accounting for 39% and 61%, respectively. The subjects' academic backgrounds included arts majors, forestry majors, and others (such as business administration, finance, and Chinese language and literature), accounting for 30%, 40%, and 30%, respectively. They came from various cities across China, as shown in Table 1. Overall, the sample representativeness was relatively high.

Table 1. Basic information of subjects.

Item	Group	No. of Subjects	Percentage (%)
Gender	Male	25	39%
	Female	39	61%

Table 1. *Cont.*

Item	Group	No. of Subjects	Percentage (%)
Education	Bachelor's degree	26	41%
	Master's degree	34	53%
	Doctoral degree	4	6%
Native place	Eastern region	29	45%
	Central region	11	17%
	Western region	24	38%
Major	Arts majors	19	30%
	Forestry majors	26	40%
	Other majors	19	30%

2.4. Methodology

2.4.1. SBE Method

To objectively assess the aesthetic quality of landscapes in Qianjiangyuan National Park, this study employed the SBE method for evaluation [5,11,12]. This evaluation method has been widely used in the field of forest aesthetic evaluation. By providing on-site pictures to subjects and having them rate each landscape according to criteria, different landscapes are assigned corresponding SBE scores, which measure the visual aesthetic quality of different landscapes [23,24]. Tailored to the needs of this study, the steps for evaluating the visual aesthetic quality of landscapes in Qianjiangyuan National Park are as follows: (1) Selection of representative landscapes; (2) Establishment of evaluation criteria to measure subjects' aesthetic attitudes; (3) Calculation of SBE values for sample landscapes; (4) Interpolation analysis of SBE values for sample landscapes to generate a spatial distribution map of the visual aesthetic quality of landscapes in Qianjiangyuan National Park.

Assuming that the aesthetic perception and judgment of all subjects towards sample landscapes follow a normal distribution, before calculating the average Z-score of each tested sample landscape, a pre-selected group of judgment populations was computed as the "baseline" average Z-score for sample landscapes in Qianjiangyuan National Park, aiming to adjust the starting point of SBE measurement. The Z-score calculated for each tested landscape sample was subtracted from the average Z-score of the "baseline" and then multiplied by 100 to obtain the original SBE value (denoted as SBE in the formula) of the tested landscape sample [5]. The calculation formula is as follows:

$$Z_{M,i} = \frac{1}{m-1} \sum_{k=2}^{m} f(CP_{i.k})$$

where $Z_{M,i}$ is the average Z-score of sample landscape i; $CP_{i.k}$ is the cumulative frequency ratio of the average value given by subjects to sample landscape i at level k or higher; $f(CP_{i.k})$ is the frequency of the cumulative distribution function of the normal distribution; m is the total number of evaluation levels; k is the evaluation level.

$$S_{BE,i} = (Z_{M,i} - Z_{bmm}) \times 100$$

where $S_{BE,i}$ is the original SBE value of sample landscape i; $Z_{M,i}$ is the average Z-score of sample landscape i; Z_{bmm} is the average Z-score of the baseline sample landscape.

As the original SBE values of different groups of subjects may be measured using different starting points or measurement scales, they were standardized by dividing them with the standard deviation of the Z-scores of the baseline group. The standardization eliminated measurement scale differences caused by perceptual differences among different subjects. The formula for calculation is as follows:

$$S^{*}_{BE,i} = \frac{S_{BE,i}}{Z_{bsdm}}$$

According to the above calculation method, the SBE scores of subjects for different landscapes in Qianjiangyuan National Park were computed, and after standardization, the visual aesthetic quality assessment values of Qianjiangyuan National Park landscapes were obtained.

2.4.2. Questionnaire Design

The semantic differential (SD) method was used to define subjects' acceptance of SBE for sample landscapes. The SD method, proposed by Osgood et al., employs verbal scales for perceptual measurement to obtain quantified data on subjects' aesthetic perception of landscapes. It is a common method in psychological research [25]. Following the principles of the SD method, this study set the left-hand adjectives as "ugly" and the right-hand adjectives as "beautiful". Using a Likert 5-point scale (−2, −1, 0, 1, 2), each score represented the subject's perceptual tendency. A score of 2 indicated a stronger inclination towards the right-hand adjective and vice versa (Table 2). Subjects were instructed to judge individual samples at a speed of 8–10 s per sample and record their evaluation results on the questionnaire.

Table 2. SBE assessment based on the SD method.

Evaluation Indicator	Score and Adjective	Description
SBE value	−2 −1 0 1 2 Ugly Beautiful	Whether this landscape appears ugly or beautiful

2.4.3. Eye Tracking Test

The eye tracking test used the Tobii Pro X3-120 screen-based eye tracker (sampling rate of 120 Hz) and two ThinkPad X1 laptops (LCD screen resolution of 1920 × 1080).

The experimental process was as follows: (1) Subjects were guided to sit approximately 60 cm in front of the eye tracker screen with both eyes facing the center of the display, and the experimenter explained the purpose, process, and requirements of the entire experiment to the subjects. (2) Prior to the formal test, eye calibration was performed to adjust the subjects' sitting posture and ensure relative stability. (3) After calibration, 3 warm-up pictures were played to subjects without their knowledge, followed by random presentation of 105 experimental pictures. Meanwhile, the eye tracker began tracking eye movement data until the presentation was completed.

2.4.4. Model Construction

The eye movement indicators selected are specifically defined, as shown in Table 3.

Table 3. Explanation of eye movement indicators.

Eye Movement Indicator	Indicator Definition	Basic Interpretation
Average fixation time (ms)	The average duration of all fixations within a certain period, reflecting the average time subjects spend in different areas.	A long average fixation time may indicate that subjects tend to observe and analyze the details of the landscape more thoroughly.
First fixation time (ms)	The duration of the first fixation on an area, reflecting the duration of subjects' attention to initial visual stimuli.	A short first fixation time may indicate that subjects are able to quickly identify and capture visual stimuli in the landscape, perceiving the overall layout of the landscape.

Table 3. *Cont.*

Eye Movement Indicator	Indicator Definition	Basic Interpretation
Average saccade speed (°/s)	The rapid movement of the eyes between different points, reflecting the average speed of subjects' rapid eye movements.	A fast average saccade speed may indicate that subjects shift attention more quickly within the landscape and conduct more visual information searches.
Average saccade amplitude (°)	The average distance the eyes move during saccades, reflecting the average distance the eyes move between two different points.	A large average saccade amplitude may indicate that subjects tend to conduct larger scanning movements within the landscape, focusing on broader areas rather than local details.
Fixation duration ratio (%)	The proportion of fixation time to total observation time, reflecting the distribution of subjects' observations at different points.	A high fixation duration ratio may suggest that key areas of the landscape are more attractive to subjects.
Saccade frequency (count/s)	The average number of saccades per minute, reflecting the frequency and speed of subjects' saccades during observation.	A high saccade frequency may indicate that subjects have active visual search behavior in the landscape, requiring more advanced information exploration of the landscape environment.

To scientifically explain the relationship between objective physical indicators of eye movement and subjective evaluations, this study introduces statistical tools for further analysis. The attempt was to construct a scenic beauty quality assessment model based on multiple linear regressions, combining the objective psychophysical indicators of eye movement with subjective scenic beauty evaluations. To enhance the accuracy of the regression model, all 16 scenic beauty materials were used as samples for statistical analysis. When the dependent variable y of subjective evaluation results (I = 1, 2,. . . . . m) is multiple, the multiple linear regression equation between y and xi is as follows:

$$y = \alpha + \beta_1 x_1 + \cdots\cdots \beta_m + \varepsilon$$

where α, β_1, and β_m are the linear regression coefficients; ε is the random error. It was assumed that ε follows a normal distribution N(0,σ2).

3. Results

3.1. Subjective Evaluation of Visual Aesthetic Quality of National Park Landscapes

The SBE scores for the four landscape types are shown in Figure 2. The use of the SBE method can directly reflect people's subjective aesthetic evaluations of the landscape with a high degree of intuitiveness and reliability. It can be observed that wetland landscape received the highest scores, while forest landscape received the lowest scores. This reflects both the inherent characteristics of the landscapes and the subjective aesthetic judgments of the evaluators.

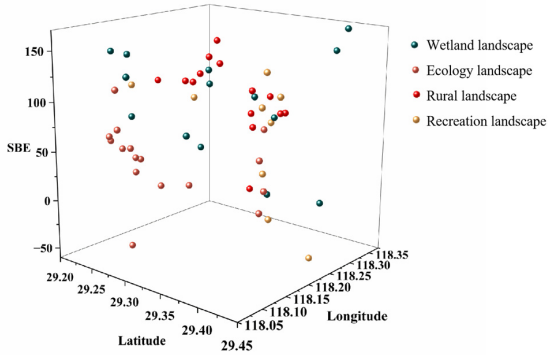

Figure 2. SBE scores of various sample sites in Qianjiangyuan National Park.

3.2. Objective Evaluation of Visual Aesthetic Quality of National Park Landscapes

A single-factor analysis of variance was conducted on the eye-tracking data of the four landscape types, and the results are shown in Table 4. It can be observed that there were no significant differences ($p > 0.05$) in the four indicators of first fixation time, average saccade speed, average saccade amplitude, and saccade frequency among the sample sites, while average fixation time and fixation duration ratio were horizontally significant ($p = 0.044$ and 0.045, respectively). Forested landscapes and recreational landscapes have greater differences in eye movement characteristics than the other 2 groups of landscape types. Forest landscapes had the shortest first fixation time, the lowest saccade frequency, and the largest average saccade amplitude, indicating that forest landscapes could more quickly attract the attention of the subjects due to their distinctive features. Recreational landscapes featured the lowest average saccade speed and average saccade amplitude, suggesting that the information present in recreational landscapes was the most attractive to the subjects, and the scenes were relatively peaceful.

Table 4. Analysis of differences in eye movement indicators for different types of forest landscapes in Qianjiangyuan National Park.

Eye Movement Indicators	Average Fixation Time (ms)	First Fixation Time (ms)	Average Saccade Speed (°/s)	Average Saccade Amplitude (°)	Fixation Duration Ratio	Saccade Frequency (count/s)
Overall difference	0.044 *	0.133	0.28	0.359	0.045 *	0.114
Difference between landscape types						
Recreational landscape	156.10 ± 13.73	138.37 ± 15.75	104.83 ± 19.82	2.42 ± 0.40	0.23 ± 0.04	0.42 ± 0.12
Wetland landscape	187.16 ± 20.41	186.75 ± 41.01	99.21 ± 7.38	2.18 ± 0.54	0.28 ± 0.01	0.59 ± 0.14
Forest landscape	183.46 ± 16.14	182.36 ± 16.47	93.48 ± 4.96	2.00 ± 0.25	0.24 ± 0.03	0.56 ± 0.05
Village landscape	169.13 ± 3.85	164.07 ± 34.81	84.73 ± 18.60	1.80 ± 0.65	0.27 ± 0.02	0.59 ± 0.07

* $p < 0.05$.

During the visual behavior visualization analysis, a typical sample was selected from each of the four landscape groups as a case study, and a comparison was made of their eye movement heatmaps and fixation path trajectories, as shown in Figure 3. The visual analysis of eye movement data enables a more intuitive demonstration of the characteristics and differences between different landscape types in terms of attracting attention. From the distribution in eye movement heatmaps, it was found that fixations on forest landscapes were more concentrated around the center of the image, as well as within the forests and the sky. The visual range was relatively wide, with no concentration on specific elements. Fixations on wetland landscapes were guided by the wetlands and water bodies in the images and were relatively concentrated in these areas. Fixations on village landscapes were the most dispersed, influenced by various factors such as buildings, trees, and rivers. Fixations on recreational landscapes were obviously concentrated on artificial landscapes, such as stone monuments and bridges, which acted as visual guides. From the fixation path trajectories, it was observed that fixations on forest landscapes were initially close to the boundaries of the images and then moved left, right, up, and down along the boundaries. The fixation paths for wetland landscapes displayed a back-and-forth pattern along the water bodies. The fixation paths for village landscapes varied depending on their composition but could mainly be categorized as natural landscape–village–natural landscape. The fixation paths for recreational landscape mainly traversed between artificial landscapes, occasionally lingering around textual elements.

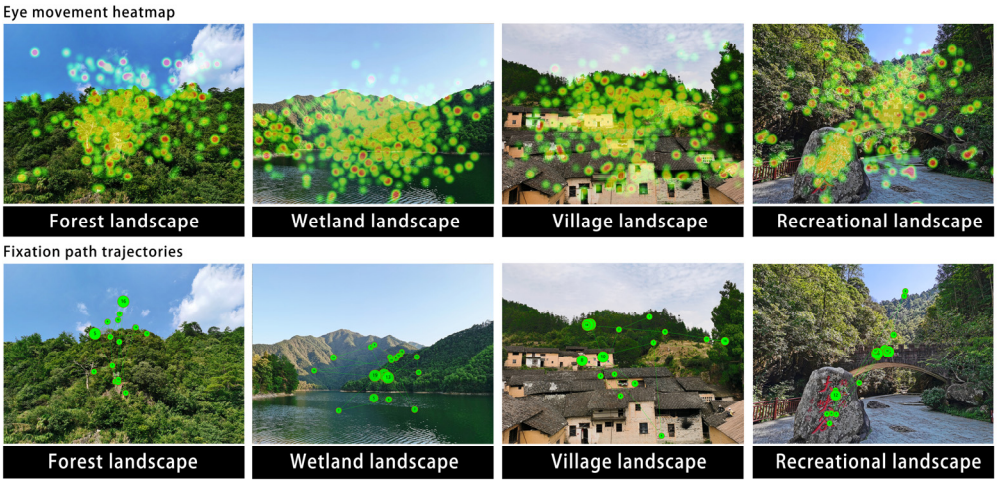

Figure 3. Visual representation of eye movement data for different landscape types.

3.3. Construction of the National Park Landscape Visual Aesthetic Quality Model

3.3.1. Univariate Linear Regression Analysis

Univariate linear regression analysis was conducted on eye movement indicators such as average fixation time, first fixation time, average saccade speed, average saccade amplitude, fixation duration ratio, and saccade frequency. The use of univariate linear regression analyses was designed to initially explore the relationship between individual eye movement metrics and SBE scores in order to find out which eye movement metrics had a significant effect on subjective aesthetic ratings. The results are shown in Figure 4.

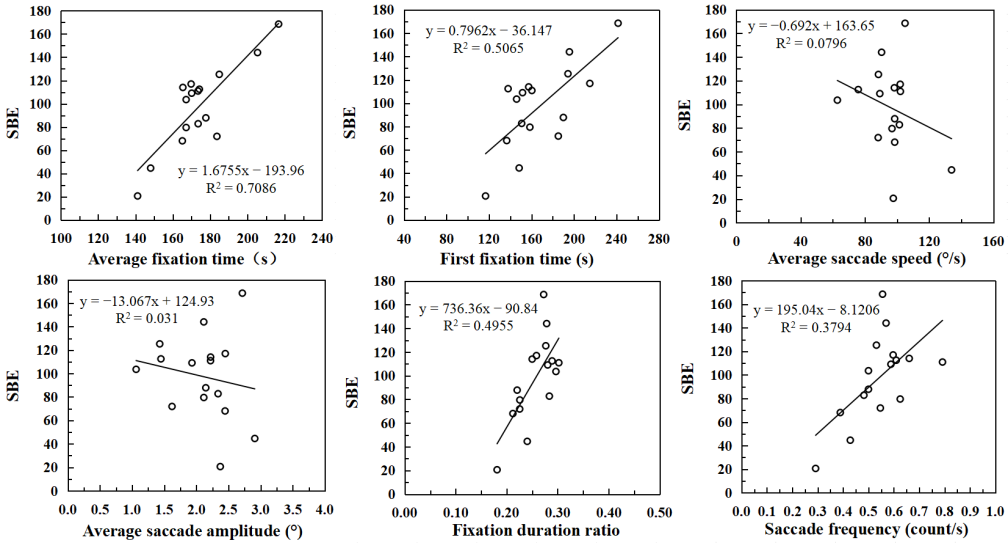

Figure 4. Correlation between SBE and eye movement indicators.

As observed from Figure 3, the majority of data points for average fixation time, first fixation time, fixation duration ratio, and saccade frequency were distributed near the regression line, indicating a strong linear correlation with SBE. The correlations were all positive. However, the remaining two indicators, average saccade speed, and average saccade amplitude, did not show significant correlations with SBE, suggesting that univariate linear regression analysis alone is insufficient to analyze the relationship between SBE and eye movement indicators. Therefore, multivariate regression analysis is also needed to construct the model.

3.3.2. Multivariate Regression

To ensure the accuracy of the model, a significance test was first conducted on eye movement indicators and SBE values, as shown in Table 5. From the results, it can be seen that the F-value of the ratio of between-group variance to within-group variance in the model was 17.209, with a significance level of $p < 0.05$. Therefore, the linear relationship between SBE values and eye movement indicators must be significant, which enables the establishment of a multivariate regression model. A multiple regression model was used in order to combine the effects of multiple eye movement metrics to construct a model that more accurately predicts SBE scores.

Table 5. Analysis of variance results.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance
Model	6	18,469.681	3078.280	17.209	0.000
Error	9	1609.846	178.872		
Total	15	20,079.527			

With subjective SBE values as the dependent variable and various elements of eye movement indicators as independent variables, linear regression analysis was performed to establish a multivariate regression model. The parameters of the regression model are shown in Table 6.

Table 6. Parameters of the multivariate linear regression model.

	Item	Estimate	Standard Error	T Ratio	P > |t|
	Intercept	−141.994	59.734	−2.377	0.041
x1	Average fixation time	0.522	0.397	1.315	0.221
x2	First fixation time	0.399	0.206	1.942	0.084
x3	Average saccade speed	−1.233	0.594	−2.075	0.068
x4	Average saccade amplitude	31.577	17.404	1.814	0.103
x5	Fixation duration ratio	407.158	143.655	2.834	0.020
x6	Saccade frequency	53.733	39.378	1.365	0.206

Based on the data in Table 6, the predictive expression of the aesthetic quality model of the Qianjiangyuan National Park landscape is derived as follows:

$$y = -141.994 + 0.552x1 + 0.399x2 - 1.233x3 + 31.577x4 + 407.158x5 + 53.733x6$$

The R-squared value of the regression accuracy was 0.61, and the root mean square error was 0.44, indicating consistency between the established predictive model and actual values. From the coefficients in the predictive expression, it was observed that the coefficient of x5, fixation duration ratio, was the largest. As indicated by univariate linear regression analysis, the value of x5 had a strong linear correlation with SBE values. Hence, it is inferred that the fixation duration ratio plays a dominant role in SBE and is positively correlated with it.

Comparing the predicted values of SBE with the actual values (Figure 5), it can be observed that the majority of data points were within the 95% confidence band, and all data points fell within the 95% prediction band, indicating consistency between the predicted effect and actual data. This means a multivariate regression model for the aesthetic quality of national park landscapes has been successfully established. This model effectively bridges subjective and objective evaluations, providing a new scientific method for evaluating the aesthetic quality of national park landscapes.

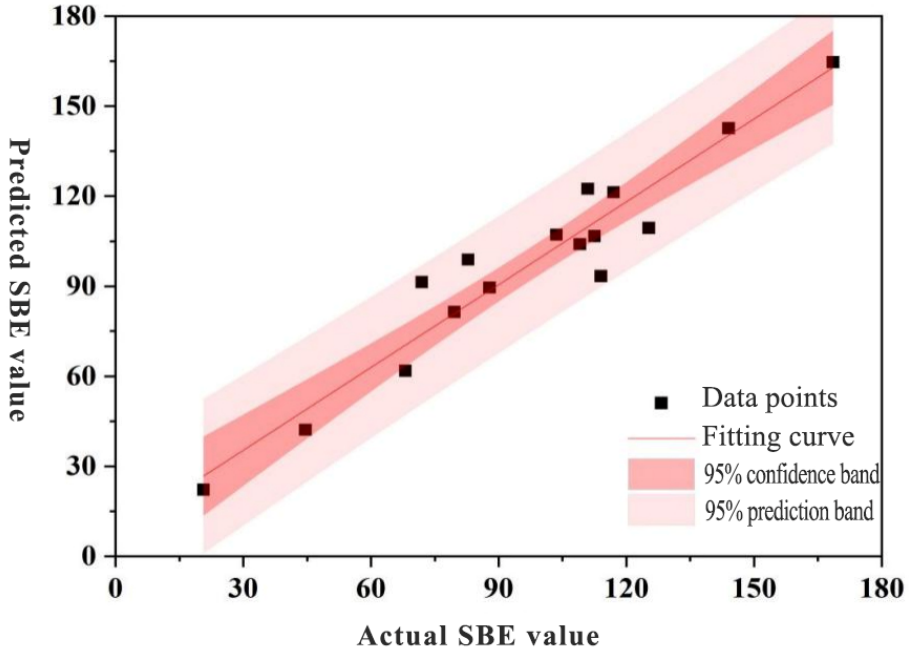

Figure 5. Effectiveness of the predictive model.

3.4. Spatial Pattern Characteristics of Visual Aesthetic Quality of National Park Landscapes

Based on the national park landscape aesthetic quality model established above, the geographical locations of the samples were combined to calculate the spatial distribution of the overall landscape visual aesthetic quality of Qianjiangyuan National Park (Figure 6). From the overall distribution map, it can be seen that the areas with the highest visual aesthetic quality in Qianjiangyuan National Park were located in the north and south, followed by the central region. Comparing the box plots of landscape visual aesthetic quality in different geographical locations, as shown in Figure 7, it can be seen that the median and mean SBE scores in the central region were the highest. The variance in the northern region was smaller, but there are two outliers that should be considered in the study. In the southern region, the largest difference and highest variance in upper and lower limits of scores among all regions were observed, and the scores were relatively scattered among different sample sites.

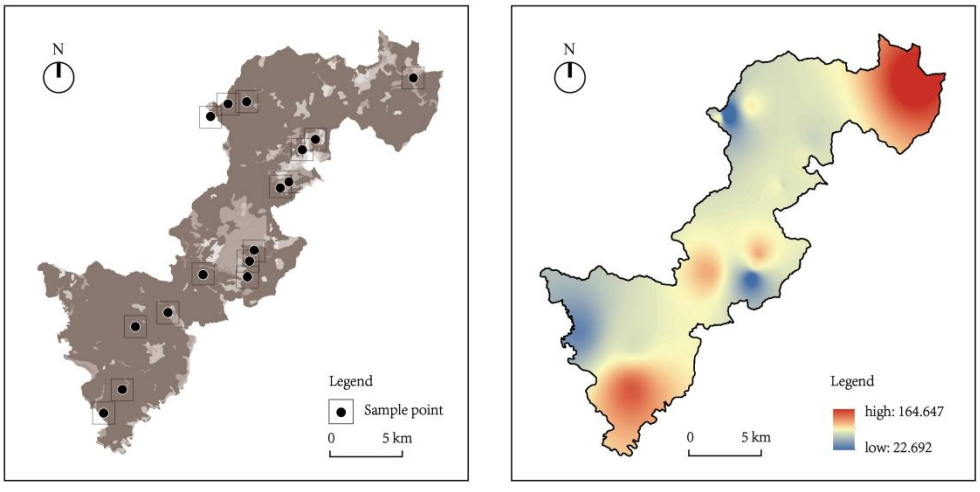

Figure 6. Spatial Distribution of Landscape Visual Aesthetic Quality in Qianjiangyuan National Park.

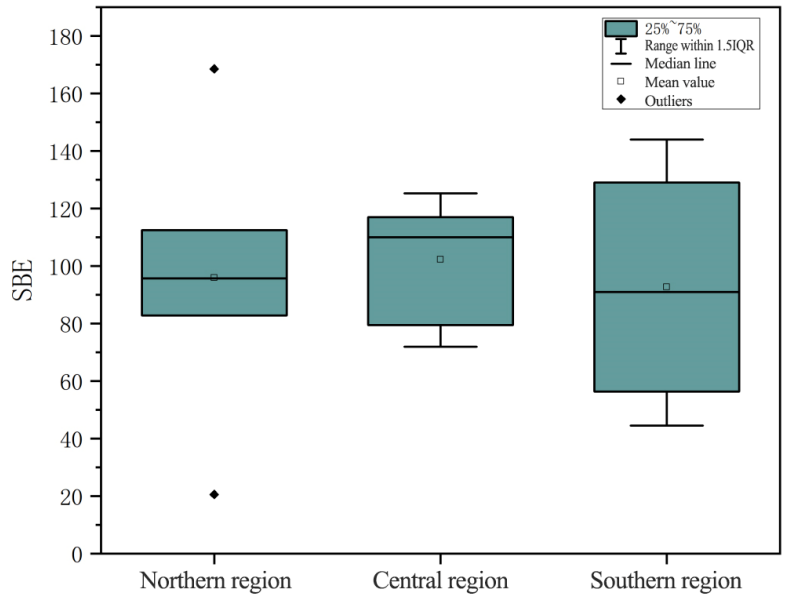

Figure 7. Comparison of landscape visual aesthetic quality in different geographic locations.

After analyzing and comparing the overall spatial distribution map with the functional zoning of the national park, the overall differences among various functional zones are as follows: ecological protection area (105.55) > traditional utilization area (97.26) > core protection area (91.05) > recreational display area (88.97). This may be because, although the recreational landscape has the highest SBE scenic beauty scores among the samples, its area is relatively small, and other landscape types are also distributed in the recreational display area. Therefore, its performance in the overall distribution of aesthetic quality is not as prominent as that of the ecological protection area. Furthermore, the overall spatial distribution map was compared with the administrative management areas set by the National Park Management Bureau. The comparison reveals that the overall differences among various administrative management areas were as follows: Suzhuang management area (108.7) > Qixi management area (101.31) > Changhong management area (95.47) > Hetian management area (87.91). There was a significant gap in scores between the Hetian management area and other management areas.

Combining the above analysis and overall evaluation, it can be seen that the areas with high landscape visual aesthetic quality in Qianjiangyuan National Park are mainly concentrated in areas with abundant natural resources and well-developed recreational functions, and most of these areas belong to the southern and central regions. This is mainly because the southern region is where the Gutian Mountain National Nature Reserve is located, featuring beautiful ecological natural landscapes and rich species diversity. Meanwhile, the central region has many recreational development-oriented communities, relatively complete recreational facilities, and a vibrant social economy. This study systematically analyzed the aesthetic quality of national park landscapes by integrating SBE subjective evaluations, eye movement data, and multiple regression models, revealing the intrinsic associations between different evaluation methods and providing a comprehensive perspective for future landscape aesthetics research.

4. Discussion

This study comprehensively assessed the landscape aesthetic quality of Qianjiangyuan National Park through a combination of subjective and objective methods and constructed a national park landscape aesthetic quality assessment model. Using this model, the aesthetic quality and spatial pattern characteristics of different landscapes were discussed, and a comprehensive and objective evaluation was conducted for the aesthetic features of Qianjiangyuan National Park. This research helps to guide the subsequent planning,

construction, and management operations of national parks, promoting their ecological conservation and sustainable development.

One of the key findings of the study is the significant difference in SCE (Scenic Beauty Estimation) scores among different landscape types. Wetland landscape boasts the highest SCE score (121.89), while forest landscape faced the lowest score (60.59). This indicates that within the sample area, wetland landscape possesses more prominent visual aesthetic qualities, while forest landscape has relatively low visual aesthetic qualities. This result is consistent with Ronghua Wang's study in the judgment of naturalness and aesthetic preference of landscapes, where human preference judgment of landscape aesthetics is not exactly in the same order of naturalness, and human beings prefer grassland landscapes with prairies, scattered trees, and watercourses [26]. According to Mathias Hofmann's study, lay people prefer man-made landscapes, and green areas that are too natural tend to give the impression of being cluttered and undeveloped [27].

Analyzing eye movement metrics between different landscape types enables the identification of characteristic patterns in natural landscape observation [28]. In addition to the visual quality of photographs, tourists' preferences significantly influence the visual attractiveness of landscapes [29]. Different landscape types differ in eye movement indicators. Significant horizontal significance can be observed in the average fixation time and fixation duration ratio. Specifically, forest landscape has the shortest first fixation time, the lowest saccade frequency, and the largest average saccade amplitude, attracting subjects' attention rapidly. Conversely, the recreational landscape has the lowest average saccade speed and average saccade amplitude, indicating that the information present in this landscape holds the strongest attraction for subjects.

A number of studies have been proposed to model the aesthetic quality of landscapes [30–32]. In this study, through univariate linear regression and multiple regression analyses, a model describing the relationship between landscape aesthetic quality and eye movement indicators was established. It was found that average fixation time, first fixation time, fixation duration ratio, and saccade frequency have strong linear correlations with SBE scores. Among them, the fixation duration ratio is the leading factor affecting landscape aesthetic quality and has a positive correlation with the quality. This model provides a scientific explanation for the connection between objective physiological indicators of eye movements and subjective evaluations.

By calculating the overall landscape aesthetic quality of Qianjiangyuan National Park, it was found that areas with the highest visual aesthetic quality are mainly located in the northern and southern regions, followed by the central region. Comparing various functional zones, it was observed that landscape aesthetic quality is highest in the ecological protection area (105.55), followed by the traditional utilization area (97.26), core protection area (91.05), and recreational display area (88.97). Locations with high landscape aesthetic quality are mainly concentrated in areas with rich natural resources of wetlands and well-developed recreational functions. Checking against the administrative management areas delineated by the National Park Administration, it was found that the Suzhuang management area features the highest landscape aesthetic quality, while the Hetian management area shows relatively poorer landscape aesthetic quality compared to other management areas. The final evaluation results are consistent with the results of Xiao Lianlian's research on the scenic beauty assessment of Qianjiangyuan National Park, which also suggests that SBE assessments are influenced by ancient villages, water bodies, and animal habitats. A comparison reveals that areas with high SBE values are mainly distributed in ecological conservation areas with less obvious land use conflicts or in areas advantageous for recreational use [33,34]. However, our research findings differ from the results of landscape visual aesthetic quality evaluation of functional areas and administrative management areas of Qianjiangyuan National Park by Peng Wang, which may be due to differences in sample selection [35].

5. Conclusions

This study conducted a comprehensive evaluation of the landscape aesthetic quality of Qianjiangyuan National Park, integrating subjective and objective assessments, and constructed an evaluation model. The key findings indicate that wetland landscapes have the highest aesthetic quality scores (121.89), while forest landscapes have the lowest (60.59), suggesting that wetlands are visually more appealing within the study area compared to forests. Significant differences exist in eye-tracking metrics across landscape types, with forest landscapes quickly attracting attention but not holding it as effectively as recreational landscapes, which have the most attractive information. The model shows a strong linear correlation between eye-tracking metrics and SBE aesthetic scores, with the fixation duration ratio having the greatest positive impact on landscape aesthetic quality, providing a scientific explanation for the connection between objective and subjective evaluations. The highest visual aesthetic quality in Qianjiangyuan National Park is found in the southern and central regions, particularly in areas with rich wetland resources and well-developed recreational facilities. The Ecological Protection Zone has the highest aesthetic quality among functional zones, while the Suzhou Management Zone has the highest aesthetic quality among administrative management zones.

However, the sample size and geographic scope of the study may limit the generalizability of the findings to other regions. The reliance on eye-tracking metrics, while objective, may not capture the full range of factors contributing to landscape aesthetic quality, and differences in individual preferences and cultural background were not deeply explored, which could influence aesthetic evaluations.

The methodology and conclusions of this study can provide a framework for other national parks and forested landscapes to assess the quality of landscape aesthetics in different contexts. Combining subjective and objective assessments can provide a balanced and holistic understanding of landscape aesthetics, contributing to effective management and planning of protected areas globally.

Future research should expand the study to include a larger and more diverse sample of landscapes and participants to enhance the generalizability of the findings. Investigating the influence of cultural and individual differences on landscape aesthetic evaluations is necessary to develop more inclusive and representative assessment models. Additionally, exploring additional objective metrics, such as physiological responses, to complement eye-tracking data can provide a more holistic evaluation of landscape aesthetics. Assessing the long-term impact of landscape aesthetic quality on visitor satisfaction and ecological conservation outcomes will also inform sustainable management practices.

These conclusions offer valuable insights for the effective planning and management of Qianjiangyuan National Park and other similar protected areas, ensuring the enhancement of their aesthetic value while promoting ecological sustainability.

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