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Assessment and Empirical Research on the Suitability of Eco-Tourism Development in Nature Reserves of China: A Multi-Type Comparative Perspective

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Abstract: The assessment of suitability is the cornerstone for the development of ecotourism in nature reserves. This paper adopts the Delphi method to invite 30 experts to score and screen a series of indicators and then calculates the weight of each indicator through the hierarchical analysis method (AHP) to establish a comprehensive evaluation index system for the suitability of ecotourism development. The AHP method includes four constraints layers (tourism resources, socio-economic environment, ecological conditions, and tourism market), in addition to eleven element layers and thirty-eight indicators. It establishes overarching criteria for evaluating ecotourism suitability. Our research focuses on Dinghushan, Xilin Gol Grassland, Hongze Lake Wetland, and Jiuzhai valley, and the results are as follows: (1) Ecotourism suitability evaluation level is divided into five levels, level I ($0 \leq S < 30$) ecotourism development suitability is the lowest, meaning an area is extremely unsuitable for ecotourism development. Level V ($90 \leq S < 100$) has a very high ecotourism value, meaning an area is highly suitable for ecotourism development. (2) Jiuzhai valley scored the highest ecotourism suitability evaluation score of 87.63, and Xilingol Grassland scored the lowest score of 81.27. However, the composite scores of all the nature reserves were above 80, placing them at Suitability Level IV, and thereby indicating a high suitability for ecotourism development. (3) Divergences in ecotourism suitability emerge among various nature reserve types, with grassland and meadow reserves exhibiting lower suitability levels. Addressing this, a robust management and monitoring system is imperative, alongside intensified efforts in ecological restoration, vegetation protection, community engagement, education, awareness, and increased policy support and tourism capital investment. (4) The results of the expert questionnaire showed that the maximum weight of the indicators affecting the evaluation of the suitability of ecotourism was the satisfaction of tourists (0.120), and the minimum weight was the accommodation facilities (0.002), which illustrated the important role of tourists in the ecotourism development carried out in the nature reserve. (5) Through empirical analysis of numerous cases, the study validates the practicality and effectiveness of the index system and provides scientific guidelines for the suitability of existing nature reserves for further ecotourism development. This contributes to the research theory on the suitability evaluation of ecotourism development and serves as a valuable reference for the future ecotourism development of diverse nature reserves.

Keywords: nature reserves; ecotourism development; suitability assessment

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1. Introduction

The concept of ecotourism was initially introduced by Lascuráin, a consultant to the IUCN in the 1980s, and has gained global acceptance over time. He defined ecotourism as "tourism in which the traveler enters a relatively pristine natural area to learn, appreciate, and enjoy the natural scenery, wildlife, and local culture, both ancient and modern" [1]. Assessing the suitability of ecotourism development is a crucial prerequisite for the effective protection and rational utilization of tourism resources. It provides a scientific foundation for determining the optimal mode and appropriate scale of ecotourism development. *The Guiding Opinions on the Establishment of a Nature Reserve System with National Parks as the Main Body*, officially issued by the General Office of the Central Committee of the Communist Party of China (CPC) and the General Office of the State Council in June 2019, explicitly outlines the creation of a new nature reserve categorization system. This system, with national parks as the focal point, nature reserves as the foundation, and various types of nature parks as supplements, underscores the pivotal role of nature reserves in the evolving protection system [2]. A nature reserve, as defined by law, designates a specific area of land, land waters, or sea areas for the special protection and management of representative natural ecosystems, concentrations of rare and endangered species of wildlife and plants, and significant natural relics [3]. With rich natural and human resources, nature reserves possess noteworthy scientific, educational, historical, cultural, and natural advantages for ecotourism development [4]. They serve as vital spaces for tourists to engage in leisure and recreational activities [5].

Ecotourism is an environmentally friendly, non-resource-consuming natural behavior by tourists based on the concepts of ecological, environmental, and natural resources protection and sustainable development [6]. Eco-tourism not only promotes the development of the economy in the tourist areas, but also meets the demand of tourists to get close to nature [7], and is an effective way for nature reserves to enhance their self-supporting ability and realize sustainable development. According to data from the State Forestry and Grassland Administration, as of 2018, China (excluding Hong Kong, Macao, and Taiwan) boasts a comprehensive network of 2750 nature reserves, including 474 at the state level, covering approximately 1,470,000 square kilometers, equivalent to 14.88% of China's land area. This surpasses the global average, contributing significantly to ecological diversity preservation and ecosystem function restoration [8]. With over 60 years of construction and development, China's nature reserves have evolved into a well-structured network spanning the entire country, featuring a judicious layout and diverse functions. Consequently, there is a compelling need to establish a comprehensive indicator system and employ a scientific evaluation method to assess the suitability of ecotourism development in nature reserves. This initiative will furnish decision-makers with theoretical insights, aiding in the strategic planning and execution of ecotourism development initiatives.

Recognizing the pivotal role that ecotourism plays in the advancement of nature reserves, this study undertakes an assessment of the viability of ecotourism development within each nature reserve, focusing on diverse reserve types. The research aims to achieve the following objectives: (1) Identify pertinent indicators and formulate an evaluation system for assessing the suitability of ecotourism development in nature reserves, (2) Develop an evaluation model categorizing suitability levels for ecotourism development, and (3) Investigate various types of nature reserves to ascertain their suitability for ecotourism development and scrutinize the commonalities and distinctions among different reserve categories.

This study has important applications for determining the suitability of ecotourism development in nature reserves, making a valuable contribution to the broader field of research related to the evaluation of ecotourism development suitability. It enhances our comprehension of the appropriateness of engaging in ecotourism development within nature reserves. Through the assessment of ecotourism suitability in various nature reserve types, this study aids each reserve in clarifying the feasibility of ecotourism development and propelling its sustainable growth. Furthermore, it offers decision-makers the tools to devise scientifically grounded plans for nature reserves, presenting a range of diversified development strategies and optimization measures. This research thus stands as a pivotal resource for guiding informed decision-making and fostering the sustainable evolution of nature reserves.

2. Literature Reviews

Various scholars have conducted extensive research on the evaluation of ecotourism development suitability. From a thematic perspective, evaluation standards have progressively emerged as a focal point in the academic discourse. A predominant focus within existing research has been on the suitability assessment of ecotourism site selection [9]. Notably, Mobaraki et al. [10] and Parvar et al. [11] conducted site selection assessments leveraging GIS and hierarchical analysis method (AHP) methodologies, yielding results that offer valuable insights for managers and decision-makers in the planning and development of ecotourism. Jovanović et al. [12] employed a multi-criteria approach to evaluate areas suitable for ecotourism, enabling a clear distinction between suitable and unsuitable regions for ecotourism development. This methodology provides scientific guidelines for effective ecotourism development in the specified region. Positioned as a relatively recent addition to the realm of land suitability evaluation [13], the focus on ecotourism land suitability evaluations has become central to the broader investigation of ecotourism development suitability [14]. The scrutiny and assessment of ecotourism resources and the environment contribute to establishing a scientific and rational theoretical foundation for ecotourism planning in specific areas, thereby laying the groundwork for the sustainable evolution of ecotourism [15].

The body of research on evaluating the suitability of ecotourism development is extensive and diverse, with tourism resources forming the foundational underpinning of tourism development—an indispensable prerequisite for conducting ecotourism. Selemawi et al. conducted a study of Kafta Sheraro National Park, the richest in biodiversity and physical resources, and identified potential ecotourism sites suitable for ecotourism development [16]. The progression of ecotourism activities inevitably impacts tourism destinations [17], making the exploration of the suitability of such activities a valuable reference for ecotourism development. This exploration aids in scientifically classifying the types of ecotourism activities, fostering their healthy development [18]. Eco-products, integral to human survival and development, align with the internationally recognized concept of ecosystem services, underscoring their crucial role in enhancing people's livelihoods and well-being. The judicious development of ecotourism products not only attracts tourists but also influences their attitudes and behaviors [19]. Therefore, the significance of ecological products in shaping the appropriateness of ecotourism development should not be underestimated [20]. The research also encompasses various ecotourism destinations, such as national parks [21], nature reserves [22], and scenic areas [23,24], contributing to a comprehensive understanding of the diverse facets of ecotourism development.

The evolution of research methodology within the field has transitioned from qualitative to a predominantly combined qualitative and quantitative analysis [25]. Among existing scholars, the AHP is frequently employed for research purposes. For instance, Zhong Linsheng et al. [26] exemplified this by applying AHP to evaluate the suitability of ecotourism in the Ussuri River National Forest Park. Utilizing GIS technology, they classified ecotourism areas into three levels—most suitable, moderately suitable, and generally suitable—and provided corresponding development recommendations. Shawky et al. [27] also analyzed the suitability of ecotourism on the island of Masirah, Oman, by combining AHP and GIS, with the evaluation criteria focusing mainly on natural conditions. The integration of AHP with 3S techniques has become a mature approach [28]. Gomal et al. [29], in the context of Gilgit-Baltistan, Pakistan, used GIS, remote sensing, and AHP to formulate a multi-criteria decision analysis (MCDA) model for ecotourism suitability. Yasin et al. [30] similarly applied this method to analyze potential ecotourism sites in The East Hararghe Zone. Jokar et al. [31], exploring ecotourism potential in the Sepidan region of southwestern Iran, introduced an innovative method for assessing suitability, proposing the geometric mean and its calibration method, which outperformed Boolean and multicriteria models. The evaluation index system they established focuses on natural factors and ignores the importance of economic and human factors in the ecotourism development process. Zabihi et al. [32], in Babol, Iran, utilized GIS and F-AHP methods to assess the importance of physical, natural, environmental, and socio-economic factors in determining ecotourism suitability. Nelly et al. [33], employing exploratory survey methodology, empirically analyzed the suitability of mangrove ecosystems, specifically Igboi mangrove forests, for ecotourism development, revealing their high suitability.

In summary, while research on ecotourism suitability is relatively extensive, it is relatively homogenous and often concentrates on specific regions, provinces, or scenic spots, conducting a functional zoning study of ecotourism suitability for a specific region. There is a limited focus on comprehensive studies covering multiple types of nature reserves. Additionally, in the construction of indicator systems, there is a predominant emphasis on selecting indicators related to tourism resources, socio-economic factors, and the ecological environment, with little consideration for the impact of tourists on the suitability of ecotourism development. However, tourists play a key role in the appropriateness of ecotourism development. In addition to protecting the safety of the ecological environment, ecotourism development in nature reserves should focus on the experience and satisfaction of tourists, which is related to the sustainable development of its ecotourism. Therefore, guided by the principles of ecotourism, this paper places significant emphasis on the crucial influence of tourists in determining the suitability of ecotourism development in nature reserves. Aiming at the shortcomings of the existing research index system, this paper scientifically establishes an evaluation index system for the suitability of ecotourism development and selects cases from different nature reserves for research to verify the universality of the evaluation indicator system. This approach aims to mitigate the inherent limitations in tourism development strategies, providing nature reserves with insights for the rational utilization of tourism resources and promoting their healthy and sustainable development.

3. Materials and Methods

3.1. Study Area

Four national nature reserves were initially chosen for empirical analysis, encompassing distinct ecosystem types that are representative of China's major nature reserves: forests, grasslands and meadows, inland wetlands and aquatic ecosystems, and wildlife. Dinghu Mountain National Nature Reserve, situated in Zhaoqing City, Guangdong Province and covering approximately 1133 hectares, falls under the forest ecosystem category. Established in 1956, it is renowned among biologists as a "treasure trove of species" and a "gene repository". Xilingol Grassland National Nature Reserve, the largest grassland-meadow type nature reserve in China, belongs to the grassland and meadow ecosystem type. Located in Xilinhot City, Inner Mongolia Autonomous Region, it spans about 580,000 hectares. Hongze Lake Wetland National Nature Reserve, occupying Sihong County, Jiangsu Province, covers around 49,365 hectares and belongs to the inland wetland and aquatic ecosystem type. It stands as the national nature reserve with the most well-preserved ecosystem in East China. Jiuzhai Valley National Nature Reserve, located in Jiuzhai Valley County, Sichuan Province, encompasses approximately 65,075 hectares and falls under the wildlife ecosystem type. Notably, it is China's inaugural nature reserve, established primarily for the protection of natural scenery. The location of each reserve is shown in Figure 1.

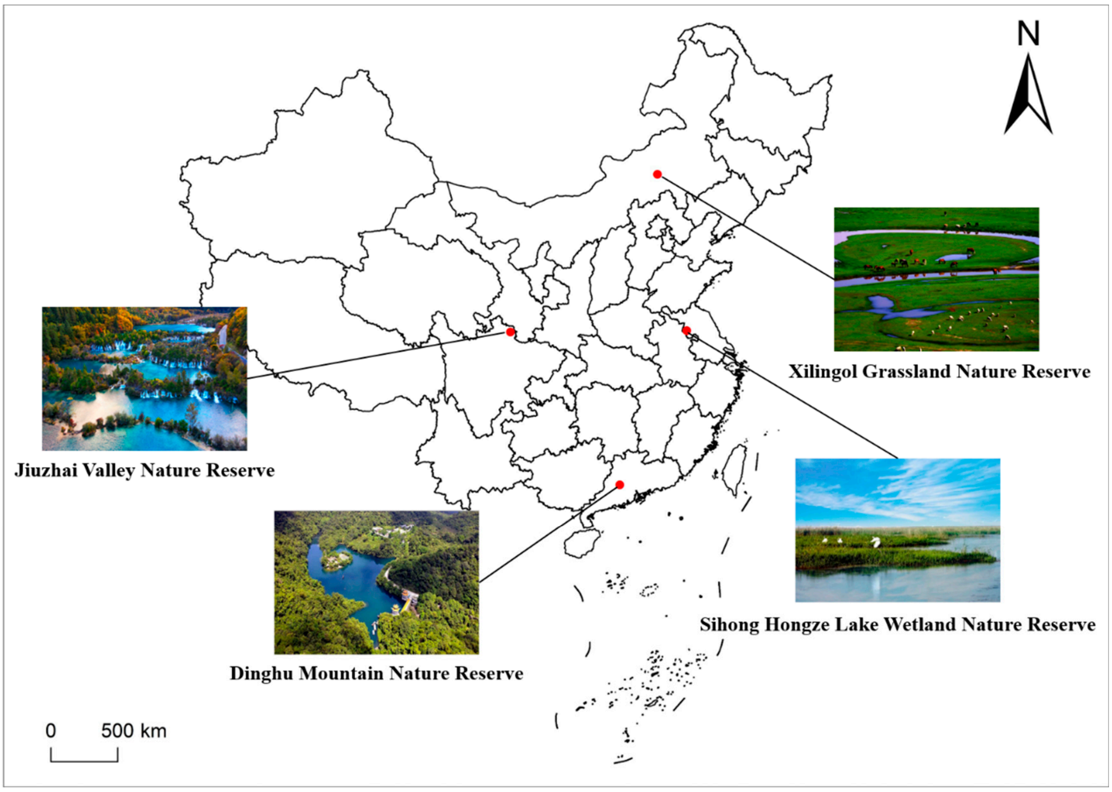

Figure 1. Location distribution of multiple types of nature conservation areas.

3.2. Methods

3.2.1. Basis for the Construction of the Evaluation Indicator System

The construction of the index system for evaluating the suitability of ecotourism development in nature reserves is grounded in several key considerations. First, relevant literature on ecotourism development suitability is meticulously reviewed and summarized, emphasizing indicators with a substantial overlap and a significant impact on ecotourism development [34]. Second, reference was made to relevant national standards to ensure the scientific and representative nature of the indicator system [35–38]. Third, recognizing the unique functions of nature reserves and the need to protect representative natural ecosystems, rare and endangered species of wild fauna and flora, as well as natural relics of special significance, the selection of indicators is guided by the principle of balancing conservation and development. Lastly, through consultations with experts in ecotourism, human geography, and related fields, as well as nature reserve managers and tourists, the construction of the evaluation index system is further refined. This collaborative approach aims to enhance the scientific rigor and standardization of the index system.

3.2.2. Evaluation Index System

Drawing from the aforementioned construction principles, a preliminary screening yielded 101 indicators. The importance of each indicator was then assessed using the Delphi method, involving the participation of 30 experts from prominent institutions such as Ocean University of China, Institute of Geographic Sciences and Resources of the Chinese Academy of Sciences, Central China Normal University, and others. The expert group comprised individuals with expertise in ecotourism, human geography, national parks and nature reserves planning, tourism resources, tourism knowledge mapping, tourism management development and planning, tourism economy, tourism information mining and visualization, and tourism big data. The scoring criteria utilized the Likert Scale Judgment Set, where levels were assigned values of 9, 7, 5, 3, and 1, corresponding to "Most important", "More important", "Generally important", "Less important", and "Unimportant", respectively. The scoring data underwent three rounds of expert questionnaire surveys. After the first round, 68 indicators with a "concentration of opinions" greater than 6.5 were retained. Following adjustments based on expert feedback, the indicators were refined to 57. At the end of the second round, 54 indicators with a "concentration of opinions" greater than 6.5 were identified, and 43 indicators were finalized after adjustments. In the third round, 42 indicators with a "concentration of opinion" greater than 6.5 were selected for further processing. Using SPSS 16.0, the principal component factor analysis method was employed to eliminate factors with weak relationships, retaining effective factors to construct the ecotourism development suitability evaluation index system (Figure 2). The system is organized into 1 target layer, 4 constraint layers, 11 element layers, and 38 indicator layers.

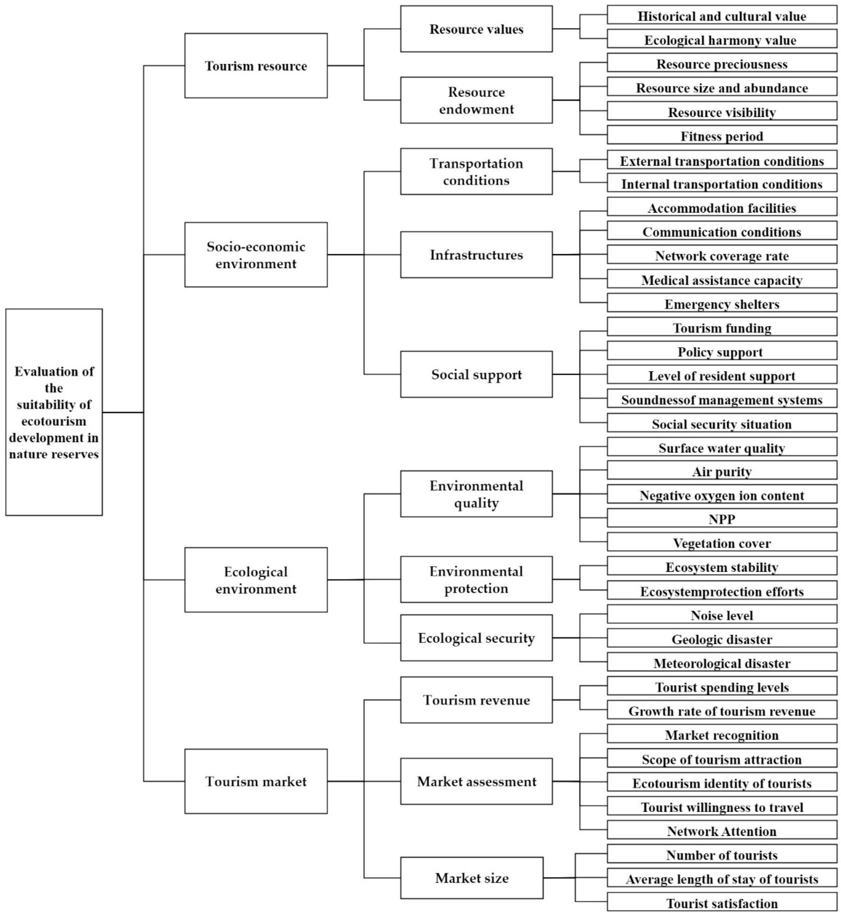

Figure 2. Evaluation index system for suitability of ecotourism development in nature reserves.

3.2.3. Delphi Method

The Delphi method is a technique that involves seeking anonymous input from a panel of experts through a structured questionnaire. This paper employs the Delphi method to solicit expert opinions and scores on the importance of each indicator. The aim is to identify representative indicators for constructing the evaluation index system, using "opinion concentration" and "opinion coordination" as the screening criteria [39,40].

$$F_j = \frac{1}{n}\sum_{i=1}^{n} X_{ij} \quad (1)$$

In Equation (1), F_j represents the arithmetic mean of indicator j (j = 1 to m), which is used to represent the "concentration of opinion" of the experts, X_{ij} represents the score of the *ith* (i = 1 to n) expert on indicator j, with a total of n experts and m indicators. In this paper n = 30, m = 38.

$$S_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(X_{ij} - F_j\right)^2} \tag{2}$$

In Equation (2), S_j denotes the standard deviation of indicator j.

$$C_j = S_j / F_j \tag{3}$$

In Equation (3), C_j represents the coefficient of variation of indicator j, which is used to express the "degree of coordination" of experts' opinions; the smaller the value of C_j, the higher the degree of coordination of experts' opinions.

3.2.4. Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a multi-objective decision analysis method that seamlessly integrates qualitative and quantitative approaches, finding extensive application across various domains [41]. The methodology involves breaking down complex problems, defining evaluation objectives, and identifying key factors. A hierarchical model is then constructed based on the relationships and dependencies among these factors. The process includes comparing the importance of each element at every level according to specific criteria, forming a judgment matrix, and normalizing it to derive the weights for each element. Subsequently, a consistency test is applied to the judgment matrix. The result is considered valid if the Consistency Ratio (*CR*) is less than 0.1 [42]. The consistency test formula is as follows:

$$CR = CI/RI \tag{4}$$

In Equation (4), *CR* is the stochastic consistency ratio, *CI* is the consistency index of the judgment matrix, and *RI* is the average stochastic consistency index.

$$CI = (\lambda_{max} - N)/(N-1) \tag{5}$$

In Equation (5), λ_{max} is the maximum eigenvalue of the judgment matrix and N is the total number of factors within each matrix.

3.2.5. Indicator Data Preprocessing

The data sources and data structures of the indicators in the indicator system are different, so some of the indicators require data pre-processing before scoring.

① Vegetation Cover. Vegetation cover is an important parameter for describing ecosystems [43], and this paper uses Normalized Vegetation Index (*NDVI*) data released by the Resource Environment Science and Data Center of the Chinese Academy of Sciences (RESDC) to calculate the vegetation cover ratio (FVC) based on the *NDVI*.

$$FVC = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \tag{6}$$

In Equation (6), $NDVI_{min}$ represents the minimum value of *NDVI* and $NDVI_{max}$ represents the maximum value of *NDVI*.

② Net Primary Productivity (*NPP*). *NPP* is a measure of the net increase in the total amount of organic matter produced by a plant through photosynthesis per unit of time per unit of area, after deducting autotrophic respiration. This indicator not only reflects the value of the energy that plants produce that can be used for growth, development, and reproduction, but also serves as the material basis for the survival and reproduction of other living members of the entire ecosystem, and has an important impact on the stability of the ecosystem [44].

$$NPP_{(x,y,t)} = APAR_{(x,y,t)} \times \varepsilon_{(x,y,t)} \tag{7}$$

In Equation (7), $APAR_{(x,y,z)}$ denotes the light and effective radiation absorbed by the image element at spatial location (x,y) in month t, and $\varepsilon_{(x,y,z)}$ denotes the actual light energy utilization of the image element at spatial location (x,y) in month t.

3.3. Data Source

The indicators within the evaluation index system for assessing the suitability of ecotourism development in nature reserves can be categorized into two groups: qualitative and quantitative. Qualitative indicators are evaluated through methods such as information retrieval, online text analysis, telephone interviews, and reference to pertinent national standards. On the other hand, quantitative indicators are measured using local statistical bulletins, government documents, remote sensing data extraction, information from protected areas, and relevant national standards. The measurement methods draw on information from various sources, including academic contributions by relevant scholars, and are tailored to the specific conditions of nature reserves and the availability of data. The details of these indicator measurements and their respective data sources are outlined in Table 1.

Table 1. Indicator measures and data sources.

Indicators	Measurement Method
Historical and cultural value	GB/T 17775-2003; GB/T 18972-2017; Information Enquiry
Ecological harmony value	GB/T 17775-2003; GB/T 18972-2017; Information Enquiry
Resource preciousness	GB/T 17775-2003; GB/T 18972-2017; Information Enquiry
Resource size and abundance	GB/T 17775-2003; GB/T 18972-2017; Information Enquiry
Resource visibility	GB/T 17775-2003; GB/T 18972-2017; Information Enquiry
Fitness period	GB/T 18972-2017; Provided by nature reserves; Information Enquiry
External transportation conditions	GB/T 17775-2003;
Internal transportation conditions	GB/T 17775-2003; Information Enquiry
Accommodation facilities	GB/T 17775-2003; Provided by nature reserves
Communication conditions	GB/T 17775-2003; Provided by nature reserves
Network coverage rate	GB/T 17775-2003; Provided by nature reserves
Medical assistance capacity	GB/T 17775-2003; Provided by nature reserves
Emergency shelters	GB/T 17775-2003; Provided by nature reserves
Tourism funding	Annual inputs; Provided by nature reserves
Policy support	Information Enquiry; Provided by nature reserves
Level of resident support	Information Enquiry; Provided by nature reserves
Soundness of management systems	GB/T 17775-2003; Information Enquiry
Social security situation	Information Enquiry
Surface water quality	GB/T 3838-2002; Provided by nature reserves
Air purity	GB/T 3095-2012; Air Quality Index (AQI); Information Enquiry
Negative oxygen ion content	QX/T 380-2017; Provided by nature reserves
NPP	QX/T 494-2019; Remote sensing (RS)
Vegetation cover	QX/T 494-2019; Resource and Environment Science and Data Center
Ecosystem stability	GB/T 20416-2006; Information Enquiry
Ecosystem protection efforts	Information Enquiry; Provided by nature reserves
Noise level	GB/T 17775-2003; GB 3096-2008; Provided by nature reserves
Geologic disaster	Provided by nature reserves
Meteorological disaster	Provided by nature reserves
Tourist spending levels	Online text; Information Enquiry
Growth rate of tourism revenue	Information Enquiry
Market recognition	GB/T 17775-2003; Online text; Information Enquiry
Scope of tourism attraction	Online text; Information Enquiry
Ecotourism identity of tourists	Online text; Information Enquiry
Tourist willingness to travel	Online text; Information Enquiry
Network Attention	Baidu index
Number of tourists	GB/T 17775-2003; Information Enquiry
Average length of stay of tourists	Online text; Information Enquiry
Tourist satisfaction	GB/T 17775-2003; Online text; Information Enquiry

4. Results

4.1. Calculation of Evaluation Indicator Weights

Following the established model for evaluating the appropriateness of ecotourism development in nature reserves, the weight of each indicator is determined through the hierarchical analysis method. In this process, experts provide judgments on the relative importance of each indicator. A judgment matrix is constructed for two-by-two comparisons at each level. After calculation, the weights for each index are derived. Importantly, the Consistency Ratio (*CR*) values of the judgment matrices at each level are found to be less than 0.1, satisfying the consistency test. The calculation results for the weights of the evaluation indicators are presented in Table 2.

Table 2. Indicators and weights for evaluating the suitability of ecotourism development.

Target	Constraint/Weights		Element/Weights		Indicator/Weights		Total Weight
Evaluation of the suitability of ecotourism development in nature reserves (A)	Tourism resource (B1)	0.138	Resource values (C1)	0.314	Historical and cultural value (D1)	0.241	0.010
					Ecological harmony value (D2)	0.759	0.033
			Resource endowment (C2)	0.686	Resource preciousness (D3)	0.102	0.010
					Resource size and abundance (D4)	0.160	0.015
					Resource visibility (D5)	0.315	0.030
					Fitness period (D6)	0.424	0.040
	Socio-economic environment (B2)	0.142	Transportation conditions (C3)	0.154	External transportation conditions (D7)	0.482	0.011
					Internal transportation conditions (D8)	0.518	0.011
			Infrastructures (C4)	0.269	Accommodation facilities (D9)	0.063	0.002
					Communication conditions (D10)	0.095	0.004
					Network coverage rate (D11)	0.128	0.005
					Medical assistance capacity (D12)	0.268	0.010
					Emergency shelters (D13)	0.446	0.017
			Social support (C5)	0.577	Tourism funding (D14)	0.112	0.009
					Policy support (D15)	0.175	0.014
					Level of resident support (D16)	0.224	0.018
					Soundness of management systems (D17)	0.147	0.012
					Social security situation (D18)	0.343	0.028
	Ecological environment (B3)	0.330	Environmental quality (C6)	0.212	Surface water quality (D19)	0.078	0.005
					Air purity (D20)	0.166	0.012
					Negative oxygen ion content (D21)	0.166	0.012
					NPP (D22)	0.249	0.017
					Vegetation cover (D23)	0.340	0.024
			Environmental protection (C7)	0.288	Ecosystem stability (D24)	0.270	0.026
					Ecosystem protection efforts (D25)	0.730	0.069
			Ecological security (C8)	0.501	Noise level (D26)	0.107	0.018
					Geologic disaster (D27)	0.337	0.056
					Meteorological disaster (D28)	0.556	0.092
	Tourism market (B4)	0.390	Tourism revenue (C9)	0.152	Tourist spending levels (D29)	0.346	0.021
					Growth rate of tourism revenue (D30)	0.654	0.039
			Market assessment (C10)	0.379	Market recognition (D31)	0.070	0.010
					Scope of tourism attraction (D32)	0.123	0.018
					Ecotourism identity of tourists (D33)	0.149	0.022
					Tourist willingness to travel (D34)	0.385	0.057
					Network Attention (D35)	0.272	0.040
			Market size (C11)	0.469	Number of tourists (D36)	0.131	0.024
					Average length of stay of tourists (D37)	0.214	0.039
					Tourist satisfaction (D38)	0.655	0.120

The weights of the evaluation indicators calculated from the expert scoring results show that the total weight of tourist satisfaction is 0.120, which has the highest indicator weight, followed by meteorological disasters, ecosystem protection efforts, and tourists' willingness to travel. Tourist satisfaction and tourists' willingness to travel are from the perspective of tourists, which illustrates the important role of tourists in the process of evaluating the suitability of ecotourism development in nature reserves. Meteorological disasters and the strength of ecosystem protection belong to the ecological environment aspect, emphasizing the need to fully consider the ecological environment when developing ecotourism in a nature reserve, which is the basic condition for the suitability of ecotourism development in that nature reserve. The lowest total weight was given to accommodation facilities with an indicator weight of 0.002, followed by communication conditions with an indicator weight of 0.004. This reflects the special characteristics of nature reserves; unlike other ecotourism destinations, infrastructure is not a key aspect to consider when evaluating the suitability of ecotourism development in nature reserves, but it still should not be ignored, and indicators related to the ecological environment and tourists are even more important. The weight of the indicators directly affects the total score of the evaluation of the suitability of ecotourism development in the nature reserve, thus affecting the criteria for judging the suitability of its ecotourism development.

4.2. Indicator Scoring Criteria

Drawing upon existing studies and the grading classifications in relevant evaluation standards [45,46], the evaluation indicators are quantified based on the actual circumstances of the nature reserve to assign scores to each evaluation indicator. The assessment of ecotourism development suitability indicators in nature reserves follows a percentage scoring standard, and four levels of division criteria for evaluation are established (refer to Table 3).

Table 3. Scoring Criteria for Ecotourism Development Suitability Indicators.

Indicators	**Indicator Scoring Criteria**			
	90–100	**80–89**	**60–79**	**0–59**
Historical and cultural value	Worldwide	Nationwide	Governorate	Local
Ecological harmony value	Extremely high	High	General	Relatively low
Resource preciousness	Worldwide rare and endangered	Grade 1 national protected	Grade 2 national protected	Regionally rare and endangered
Resource size and abundance	Huge scale; Extremely rich	Larger scale; Higher richness	Medium scale; Medium rich	Smaller scale; Lower richness
Resource visibility	Worldwide	Nationwide	Governorate	Local
Fitness period (d)	≥300	[250, 300)	[150, 250)	[100, 150)
External transportation conditions	Very convenient	More convenient	Less convenient	Inconvenient
Internal transportation conditions	Very convenient	More convenient	Less convenient	Inconvenient
Accommodation facilities	Fabulous	Better	Ordinary	Worse
Communication conditions	Fabulous	Better	Ordinary	Worse
Network coverage rate	Extremely high	High	General	Relatively low
Medical assistance capacity	Fabulous	Better	Ordinary	Worse
Emergency shelters	Perfect	Relatively perfect	Less perfect	Imperfect
Tourism funding (million/year)	≥50	[40, 50)	[30, 40)	<30
Policy support	Extremely high	High	General	Relatively low
Level of resident support	Extremely supportive	Relatively supportive	Less supportive	Unsupportive
Soundness of management systems	Fabulous	Better	Ordinary	Worse
Social security situation	Fabulous	Better	Ordinary	Worse
Surface water quality	I	II	III	IV, V
Air purity (AQI)	<50	[50, 100)	[100, 150)	[150, 200)
Negative oxygen ion content (PCs/cm^3)	>1200	(500, 1200]	(100, 500]	≤100

Table 3. *Cont.*

Indicators	Indicator Scoring Criteria			
	90–100	**80–89**	**60–79**	**0–59**
NPP((gC/(m^2·a))	≥1000	[600, 1000)	[100, 600)	<100
Vegetation cover (%)	≥95	[90, 95)	[80, 90)	<80
Ecosystem stability	Extremely stable	Relatively stable	Less stable	Precarious
Ecosystem protection efforts	Very strong	Relatively strong	General	Weaker
Noise level (dB)	≤30	(30, 40]	(40, 50]	≥50
Geologic disaster	Very slight	Lighter	General	Greater
Meteorological disaster	Very slight	Lighter	General	Greater
Tourist spending levels	≥300	[200, 300)	[100, 200)	<100
Growth rate of tourism revenue (%)	≥20	[15, 20)	[10, 15)	<10
Market recognition	Extremely high	High	General	Relatively low
Scope of tourism attraction	Worldwide	Nationwide	Governorate	Local
Ecotourism identity of tourists	Strongly approve	More acceptance	Endorsement	Disapprove
Tourist willingness to travel	Extremely high	High	General	Relatively low
Network Attention	Extremely high	High	General	Relatively low
Number of tourists (million persons/year)	≥80	[60, 80)	[30, 60)	<30
Average length of stay of tourists	>7	(3, 7]	(1, 3]	≤1
Tourist satisfaction	Extremely satisfied	More satisfied	Generally satisfied	Unsatisfactory

4.3. Construction of the Evaluation Model

According to the established index system and the weights of each index, the evaluation model of the suitability of ecotourism development in nature reserves is constructed:

$$S = \sum_{h}^{p}\left[\sum_{j}^{m}\left(\sum_{i=1}^{n} I_i G_i\right) E_j\right] R_h \tag{8}$$

Equation (8): S is the total score of ecotourism development appropriateness evaluation, I_i is the indicator score of the ith indicator layer, G_i is the indicator weight of the ith indicator layer (i = 1 to n), E_j is the indicator weight of the jth element layer (j = 1 to m), and R_h is the indicator weight of the hth constraint layer (h = 1 to p). In the model constructed in this paper, n = 38, m = 11, p = 4.

4.4. Classification of Evaluation Ratings

Following the established ecotourism development suitability evaluation model, the scores and weights of each evaluation index are inputted into the model, enabling the derivation of the ecotourism development suitability evaluation score for the nature reserve in question. The score's value range is between 0 and 100, where a higher comprehensive score indicates greater suitability for ecotourism development. Considering the significance and specificity of ecotourism development in nature reserves and referring to the comprehensive grading criteria of other scholars, this paper classifies the evaluation into five grades (refer to Table 4): highly suitable, more suitable, generally suitable, less suitable, and extremely unsuitable. This classification aims to assess the suitability of ecotourism development in nature reserves.

Table 4. Evaluation level of suitability for ecotourism development.

Score	**90 ≤ S < 100**	**80 ≤ S < 90**	**60 ≤ S < 80**	**30 ≤ S < 60**	**0 ≤ S < 30**
Grade Standard	V Highly suitable	IV More suitable	III Generally suitable	II Less suitable	I Unsuitable

5. Discussion

5.1. Results of the Evaluation of Suitability Indicators for Ecotourism Development

5.1.1. Indicator Level Evaluation Results

Relevant data were collected following the ecotourism development suitability evaluation index system and measurement method constructed in the previous section. The quantitative data, gathered in 2022, underwent standardization, and subsequently, the indicators for the suitability of ecotourism development in each nature reserve were evaluated (refer to Figure 3).

As depicted in Figure 3, the scores for communication conditions, network coverage rate, tourism funding, level of resident support, social security situation, air purity, negative oxygen ion content, noise level, ecotourism identity of tourists, and the number of tourists in the four nature reserves all fall within the range of 90–100 points. This suggests that these nature reserves are highly suitable for ecotourism development due to superior infrastructure, strong social support, a high-quality environment, and a robust tourist base. Dinghu Mountain, Xilingol Grassland, Hongze Lake Wetland, and Jiuzhai Valley Nature Reserve, being national nature reserves, possess exceptional global or national scientific, cultural, and economic values. In addition to the high scores in the aforementioned indexes, these reserves also exhibit scores above 80 points for historical and cultural value, ecological harmony value, resource preciousness, external transportation conditions, medical assistance capacity, policy support, vegetation cover, ecosystem protection efforts, tourists' spending levels, tourists' willingness to travel, and network attention. This indicates a high tourism resource value and endowment, excellent transportation accessibility, strong government support, high ecosystem quality, and positive market evaluation, showcasing natural advantages and social support for ecotourism development. Furthermore, among these reserves, only Jiuzhai Valley attains scores of 90–100 for soundness of the management system, market recognition, and tourist satisfaction. This implies that Jiuzhai Valley places significant emphasis on the crucial role of management in ecotourism development, enhancing management capacity and efficiency to better serve tourists. Higher visitor satisfaction contributes to the further enhancement of market visibility, making Jiuzhai Valley exceptionally well-suited for ecotourism development. Xilingol Grassland, Hongze Lake Wetland, and Jiuzhai Valley exhibit lower scores for the "growth rate of tourism revenue" indicator, attributed to the data being collected in 2022 during the lingering effects of the COVID-19 pandemic. The successive outbreaks of the epidemic globally significantly dampened people's willingness to travel, especially in the period following the loosening of control measures towards the end of 2022, preventing a full recovery of tourism activities and impacting the scores of this particular indicator. Additionally, Xilingol Grassland faces challenges with scores below 60 for indicators such as NPP, surface water quality, fitness period, and meteorological disasters. These factors pose unfavorable conditions for the development of ecotourism in the area. Xilingol Grassland's primary industry is animal husbandry, leading to overgrazing, shrinking pasture areas, and declining pasture quality. Moreover, numerous mineral enterprises within the protected area contribute to extensive degradation of the pasture. Furthermore, being situated in the mid-latitude inland region with a temperate continental semi-arid climate, Xilingol is susceptible to meteorological disasters like droughts and frosts. These not only impact the local residents' livelihoods but also diminish the comfort and satisfaction of visitors during their tours. Consequently, the lower scores for certain indicators in the suitability evaluation of ecotourism development in Xilingol Grassland Nature Reserve adversely affect its overall comprehensive score and rating.

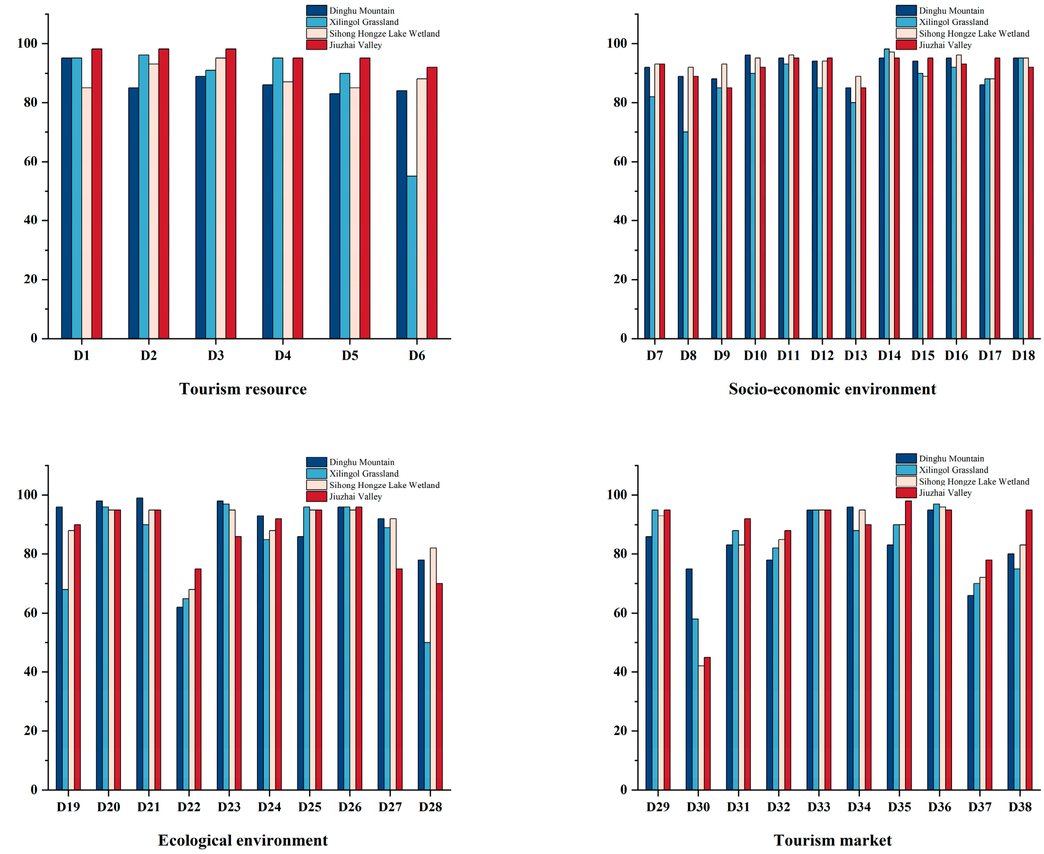

Figure 3. Evaluation of suitability of ecotourism development indicator layer scores.

5.1.2. Element Level Evaluation Results

Scores for element-level indicators were computed based on the weights assigned in Table 1, and differences among the element-level indicators for each type of nature reserve were analyzed. Figure 4 illustrates that Jiuzhai Valley significantly outperforms others in terms of resource values, resource endowment, market assessment, and market size. This can be attributed to its rich history and culture, exceptional ecosystems safeguarding numerous rare species and their habitats, and its recognition as a UNESCO World Heritage Site since 1992. Jiuzhai Valley has earned acclaim as one of the world's premier ecotourism destinations, making it a highly coveted destination for both Chinese and international tourists. The reserve boasts a strong allure and provides an enriching experience for visitors. On the contrary, Xilingol Grassland achieves notably lower scores in resource endowment, transportation conditions, infrastructures, and ecological security. This is attributed to its simpler and more fragile ecosystems, less-developed grassland roads, lower economic development, inadequate infrastructure, and anthropogenic activities that jeopardize ecological security. The tourism industry experienced a severe negative impact from the epidemic, resulting in generally low scores for tourism revenue across all nature reserves. Conversely, scores for social support, environmental quality, and environmental protection were relatively balanced. This indicates that the nature reserves not only possess favorable natural conditions for ecotourism development but also receive robust support from both the government and society.

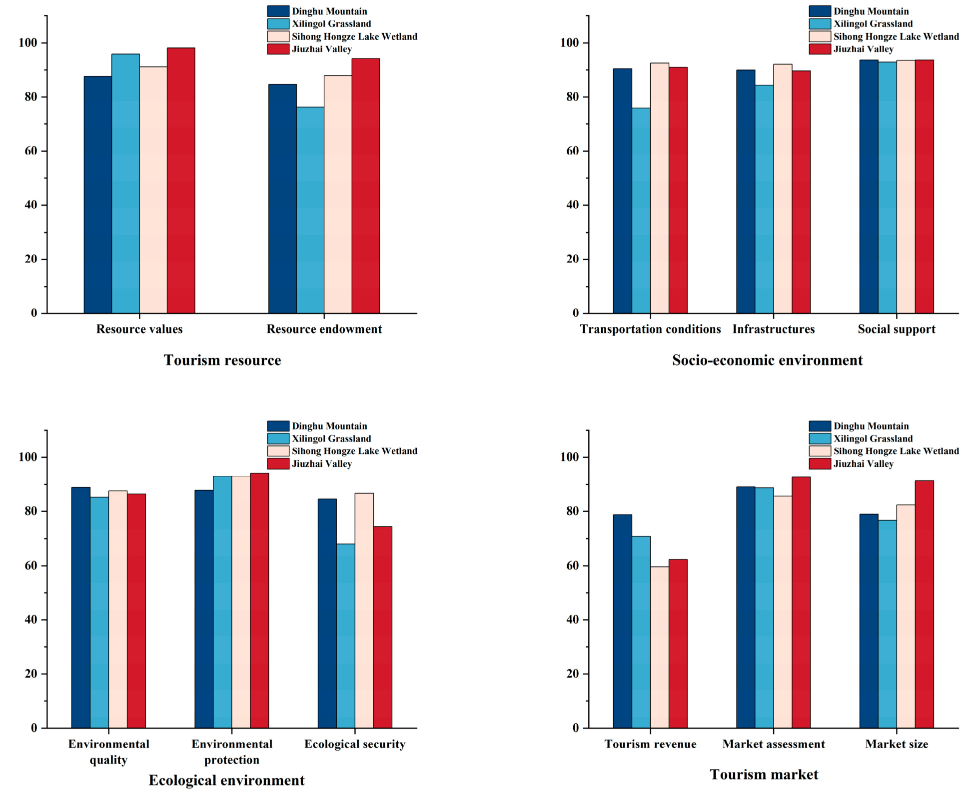

Figure 4. Evaluation of suitability of ecotourism development element layer scores.

5.1.3. Constraint Level Evaluation Results

Figure 5 illustrates the scores and differences in the constraint layer of the suitability evaluation of ecotourism development in each type of nature reserve. Notably, Jiuzhai Valley attains higher scores for tourism resources and the tourism market, while Hongze Lake Wetland excels in the socio-economic and ecological environments. Dinghu Mountain's scores for the indicators fall at an intermediate level, and Xilinguole Grassland records the lowest values across the four indicators. Detailed explanations for these differences have been provided in the preceding analysis of the disparities at the indicator and element levels. Ultimately, the discrepancies in the constraint level contribute to determining the comprehensive scores and grade ratings for evaluating the suitability of ecotourism development in each nature reserve.

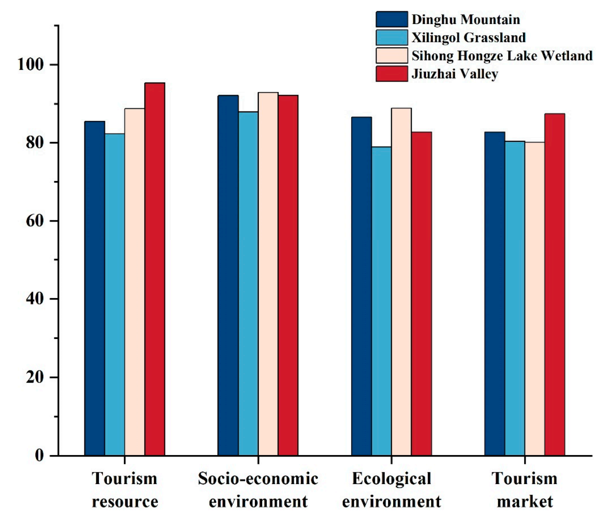

Figure 5. Evaluation of suitability of ecotourism development constraints layer scores.

5.1.4. Indicator Score Interval Ratio

After scoring the indicators for evaluating the suitability of ecotourism development in each nature reserve, the ratio of the score interval for each indicator was calculated to delve further into the results of the evaluation across different types of nature reserves. A high percentage of high-scoring indicators will strongly increase the total score of the evaluation of the suitability of ecotourism development in nature reserves, while low-scoring indicators will lower its total score. The proportion of scores for the indicators shows the high and low total evaluation scores for each nature reserve and the reasons for the roughly equal scores. In Figure 6, Jiuzhai Valley boasts the highest proportion of indicators with scores ranging from 90 to 100, constituting 73.68% of all indicators. Following closely are Hongze Lake Wetland and Xilingol Grassland, with proportions of 57.89% and 52.63%, respectively. Dinghu Mountain, on the other hand, exhibits the lowest proportion of indicators with scores from 90 to 100, standing at only 50%. A substantial number of high-scoring indicators effectively contribute to an enhanced overall score for evaluating the suitability of ecotourism development, providing Jiuzhai Valley with a notable advantage in this regard.

In alignment with the scoring criteria outlined in Table 3, scores between 0 and 59 for indicators are deemed unfavorable for ecotourism development. Low-scoring indicators can negatively affect the overall score for suitability for ecotourism development. Figure 6 illustrates that Xilingol Grassland has the highest proportion of indicators scoring in the range of 0 to 59, comprising 13.16% of all indicators. Xilingol Grassland faces a disadvantageous position due to the high proportion of low-scoring indicators, potentially lowering its comprehensive score and influencing its overall rating. In contrast, Hongze Lake Wetland and Jiuzhai Valley each have a proportion of only 2.63%, while Dinghu Mountain secures scores of 60 or above for all indicators. Despite Dinghu Mountain having the lowest percentage of high-scoring indicators, the absence of low-scoring indicators mitigates any adverse impact on its overall rating. While variations exist among different indicators for each type of nature reserve, the overall results can be improved by leveraging complementary strengths and addressing weaknesses.

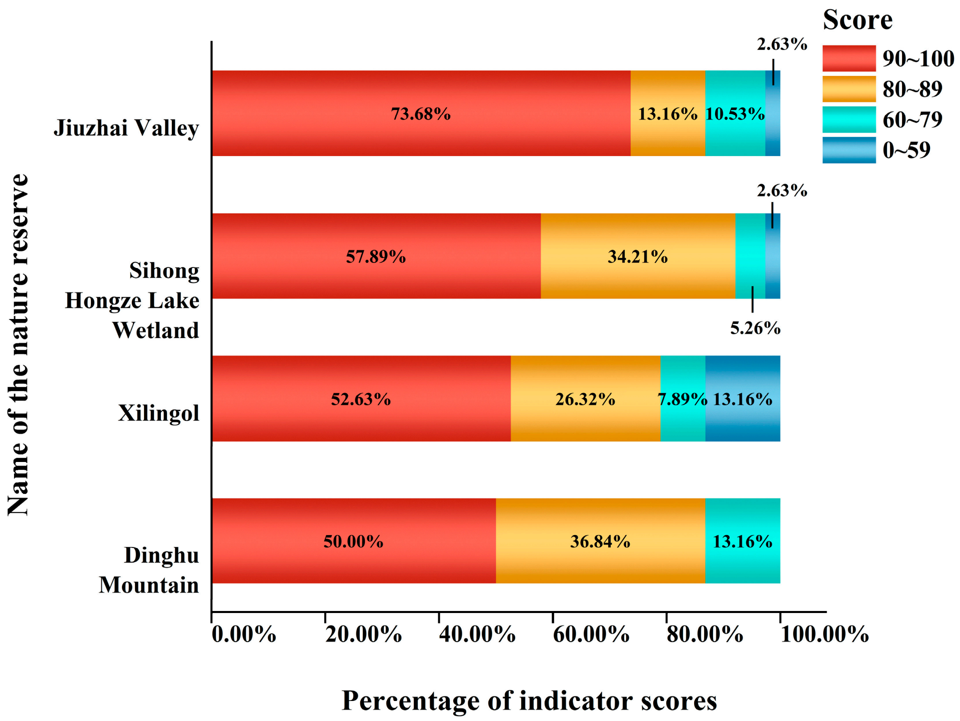

Figure 6. Proportion of indicator scores for each type of nature reserve.

5.2. Evaluation Results for Multiple Types of Nature Reserves

The scores for each indicator were input into the model to calculate the ecotourism development suitability score for each nature reserve. The suitability grade for the ecotourism development of each reserve was then assessed, and the evaluation results are presented in Table 5.

Table 5. Evaluation of the suitability of ecotourism development in nature reserves.

Name	Type	Score	Grade	Standard
Dinghu Mountain	Forest ecosystems	85.73	IV	More suitable
Xilingol Grassland	Grassland and meadow ecosystems	81.27	IV	More suitable
Sihong Hongze Lake Wetland	Inland wetlands and aquatic ecosystems	86.87	IV	More suitable
Jiuzhai Valley	Wildlife ecosystems	87.63	IV	More suitable

The results indicate that the ecotourism development suitability scores for each nature reserve are consistently above 80 points, corresponding to a grade of IV, signifying a high level of suitability for ecotourism development. The selected case sites are all national nature reserves boasting rich and diverse ecotourism resources, meticulously preserved ecosystems, and significant historical and cultural values, contributing to a harmonious ecological environment. Many of these reserves hold a 5A-level scenic spot designation, showcasing considerable achievements in tourism development, well-established infrastructure, robust social support, and positive market recognition. Therefore, these reserves exhibit a favorable environment for the development of ecotourism.

Comparisons among nature reserve types reveal that Forest, Inland Wetlands and Waters, and Wildlife reserves generally received higher scores, while Grassland and Meadow reserves scored lower. This discrepancy primarily stems from the distinct characteristics each reserve type exhibits in terms of ecosystem function, stability, and biodiversity. Forests, inland wetlands and waters, and wildlife-type reserves showcase a more diverse range of landscapes, flora, and fauna, contributing to greater ecosystem stability and enhanced ecosystem services. The ecosystem services provided by forest-type reserves are multifaceted, encompassing climate regulation, water conservation, and wind and sand stabilization. Inland wetlands and waters play a crucial role in water purification, flood regulation, and maintenance of water table stability, serving as habitats for numerous rare birds, fish, and plants. Moreover, these reserve types are more manageable for human intervention, fostering easier protection and development, thereby ensuring a more secure ecosystem.

Conversely, grassland and meadow ecosystems exhibit relatively uniform landscapes, simple ecosystem services, and lower biodiversity. The Grasslands and Meadows Nature Reserve primarily comprises expanses of grasslands with few shrubs, lacking natural shade and offering a relatively lower level of comfort. This protected area is predominantly dedicated to animal husbandry, and human activities such as overgrazing, excessive development, and land conversion can lead to ecological issues like pasture degradation, destabilizing the ecosystem. Consequently, its ecotourism suitability evaluation score is lower compared to other nature reserve types. Nevertheless, grassland and meadow nature reserves, exemplified by Xilingol Grassland, still possess unique charm and attraction, holding significant ecotourism value. Implementing effective measures can enhance their suitability for ecotourism development. First, establishing a robust management and monitoring system, coupled with stricter measures against illegal activities, will ensure the effective protection of the ecological environment in the protected areas. Second, avoiding overgrazing and excessive development while prioritizing ecological restoration and vegetation protection is essential. Third, fostering community participation, along with education and awareness campaigns, will elevate the ecological and environmental protection consciousness of local residents, garnering increased support and engagement from the community. Lastly, augmenting policy support and investment in tourism will bolster the development of ecotourism within these nature reserves.

For various types of nature reserves, it is imperative to formulate a scientifically and reasonably tailored development plan that aligns with their suitability and inherent characteristics. Adhering to the principle of balancing protection and development, it is essential to implement appropriate ecotourism activities.

6. Conclusions

Assessing the suitability for ecotourism development serves as a prerequisite and foundational step in implementing ecotourism initiatives within nature reserves. It acts as a crucial reference point for determining the feasibility of ecotourism development in a given nature reserve. The index system and model developed in this paper offer essential criteria for making such determinations, significantly contributing to the research on ecotourism development within nature reserves. The study yielded the following outcomes:

(1) A comprehensive system of indicators for evaluating the suitability of ecotourism development across various types of nature reserves has been successfully formulated. Drawing upon relevant national industry standards, academic research findings, expert opinions, and practical insights from nature reserves, the evaluation index system is designed with consideration for tourist preferences. This system establishes an evaluation model encompassing four constraints (tourism resources, socio-economic environment, ecological environment, and tourism market), eleven elements, and thirty-eight indexes, complete with quantitative standards and weight distribution. The creation of this evaluation index system not only enhances the theoretical framework for assessing the suitability of ecotourism development in nature reserves but also furnishes a scientific foundation and guidance for the implementation of ecotourism initiatives within these reserves.

(2) An empirical study was conducted using four national nature reserves as examples: Dinghu Mountain, Xilingol Grassland, Hongze Lake Wetland, and Jiuzhai Valley. The comprehensive scores for all nature reserves exceeded 80, signifying their high suitability for ecotourism development. This serves as a valuable guide for nature reserves in the phases of pre-development, development, and post-development of ecotourism. By comparing the scores across various types of nature reserves, it is evident that the suitability for ecotourism development varies among different types. Specifically, grassland and meadow nature reserves exhibit lower suitability compared to other types at the same level.

(3) Some reasons were analyzed for this discrepancy and propose effective measures to address the issue. The development of ecotourism in China's nature reserves should be executed with scientific and strategic consideration, aligning with the distinctive characteristics of each reserve type and their respective suitability levels. This approach underscores the adaptability and diversity inherent in the development of ecotourism across China's nature reserves.

The index system developed in this paper for evaluating the suitability of ecotourism development in nature reserves provides valuable guidance for the protection and development of nature reserves and other ecotourism destinations. However, it does have certain limitations:

The evaluation index system presented in this paper primarily emphasizes natural tourism resources, biodiversity, and the ecological environment. It is particularly well-suited for nature reserves grounded in natural ecosystems, landscapes, and wildlife habitats such as forests, wetlands, grasslands, meadows, and wildlife types. However, certain indices may require adjustment to accommodate the characteristics of other nature reserve types, such as deserts, oceans, and geological monuments. The evaluation index system for suitability of ecotourism development in nature reserves constructed in this paper is applicable to ecotourism sites such as nature reserves or nature parks that already exist at present, and it has a certain guiding role in their early development stage and development process, but it is not applicable to undeveloped and purely natural protected areas. For purely natural nature reserves, there may be legal and policy protections that do not allow for ecotourism development, so it is not possible to evaluate their suitability for ecotourism development. Currently, a unified and widely accepted standard for the evaluation index system of ecotourism development suitability in nature reserves is lacking. There is also a limited number of studies that specifically screen and tailor evaluation indices for ecotourism development suitability. Given that establishing a systematic, comprehensive, scientific, and reasonable evaluation index system is a crucial prerequisite for assessing the suitability of ecotourism development in nature reserves, future research in this domain should be further expanded and reinforced.

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