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STUDY ON THE COUPLED AND COORDINATED DEVELOPMENT OF TOURISM ECONOMY AND ECOLOGICAL ENVIRONMENT IN CHENGDU CITY, CHINA

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Abstract

The sustained growth of Chengdu's urban tourism economy has brought the relationship between tourism and ecological environment into sharp focus, becoming a key issue in both scholarly research and public policy discourse. In order to promote the positive interaction between the two, this study constructs a set of index system to evaluate the coupled and coordinated development of tourism economy and ecological environment based on the theory of ecological economics, coupled and coordinated theory and sustainable development theory, and based on the actual development background of Chengdu city. This study employed the entropy weighting approach to quantitatively measure the development status of the tourism economy and ecological environment in Chengdu during the period from 2013 to 2022. Subsequently, a coupling coordination model was utilized to examine their interrelationship and the level of coordinated development. The findings indicate that Chengdu's tourism economy and ecological environment have experienced continuous improvement in their comprehensive benefit index over the past decade. This development trajectory can be categorized into three distinct phases: a period of rapid growth, a phase of fluctuation and adjustment, and a stage of relative stability. The observed coupling and coordination levels between the tourism sector and ecological environment demonstrate clear phase characteristics, underscoring the presence of a tightly interwoven and interactive relationship. Specifically, economic indicators such as tourism value-added exert a positive influence on the ecological environment, whereas certain ecological indicators impose constraints on the further enhancement of the coupling and coordination level. These findings offer theoretical support and policy-oriented recommendations for advancing the integrated development of Chengdu's tourism economy and ecological environment.

Keywords: Tourism Economy, Ecological Environment, Coupled and Coordinated Development

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INTRODUCTION

Tourism is one of the most visible and rapidly growing sectors of the global economy and plays a crucial role in boosting national economies (Streimikiene et al., 2021;Manzoor et al., 2019). However, while tourism positively contributes to economic growth, it also significantly pollutes the environment (Koçak et al., 2020). The rapid development of tourism in China has significantly boosted the economy but has also led to environmental pollution and degradation, particularly in some tourist cities (Zeng et al., 2021). In popular tourist cities in China, such as Beijing, Chengdu, and Hangzhou, the operation of large hotels consumes substantial electricity and water resources and generates considerable wastewater and exhaust gases, putting significant pressure on the local environment (Rauf et al., 2021). As the impact of urban tourism on the ecological environment intensifies, exploring the coupling relationship between urban tourism and ecological environmental protection has become a hot topic in academic research. Chengdu, an important tourist city in Southwest China, has experienced increasingly prominent conflicts between rapid tourism industry development and the ecological environment (Wang et al., 2022;Weng et al., 2023). The development of the tourism economy relies on a robust ecological environment, but tourism activities can also consume and even severely damage ecological resources. Once the intrinsic carrying capacity threshold of the ecological environment is breached, the blocking effect on the ecological environment is strengthened, adversely affecting the healthy development of tourism (Pimonenko., 2021;Xu et al., 2022). The concept of “synergistic symbiosis” aptly describes the interrelationship between the tourism economy and the ecological environment(Zhu.,2023). Therefore, it is insufficient to emphasize either tourism economic development or ecological environment protection alone. Instead, it is imperative to study the boundary range of the coupling and coordination between the two and explore the healthy and sustainable growth of Chengdu's tourism economy under the premise of the ecological environment's sustainable development. This will remain a critical concern for the future development of tourism in Chengdu.

LITERATURE REVIEW

Scholars have increasingly focused on the dynamic interplay between tourism development and ecological sustainability. For instance, Zhu et al. (2021) incorporated a decoupling analysis model to design a set of integrated indicators evaluating the interdependence between tourism and the environment in the Yangtze River Basin during the period 2000 to 2019. They analysed the spatial and temporal characteristics of tourism economic development and ecological environment pressure using the tourism economic development index, the ecological environment pressure index, and the dynamic change index, exploring

the relationship between the tourism economy and ecological environment. Based on panel data covering 31 Chinese provinces from 2003 to 2017, Lai et al.,(2020) constructed a comprehensive evaluation system integrating indicators related to the ecological environment, economic development, and tourism. They used the entropy method to calculate weights and the coupling coordination model to analyse the coupling and coordination relationship of the three subsystems in the 31 provinces .WANG Zhao-feng, (2019) measured the tourism eco-efficiency of 11 provincial-level regions in the Yangtze River Economic Belt from 2007 to 2016 by adopting the unintended output Super-SBM model. The VAR model was also used to explore the interactive response relationship between tourism eco-efficiency and the level of tourism economic development . J. Wang et al. (2020)focused on the top nine tourist cities in China, using the system dynamics (SD) method to establish a dynamic carrying capacity model and optimize the concept and assessment of the tourism carrying capacity (TCC) .Lee & Chen. (2021) utilized panel data from the top nine tourist cities in China between 1992 and 2016, employing quantile regression methods to explore the effects of economic, tourism, and country risk ratings on the environmental Kuznets curve (EKC) hypothesis. They used the Ecological Footprint (EF) as an indicator of international environmental degradation to explain distributional heterogeneity across countries and possible asymmetric relationships between variables.

This paper constructs an evaluation index system for the coupled and coordinated development of the tourism economy and ecological environment based on the principles of scientific rigor and systematicity. It then analyses the changes and characteristics of Chengdu's tourism economy and ecological environment from 2013 to 2023 using the entropy value method to determine indicator weights. Finally, based on the results of the coupling degree of coordination, this paper proposes targeted sustainable development suggestions for the development of tourism in Chengdu.



Figure 1: The map of Chengdu
Source: Author's own drawing

Construction of the indicator system and methodology

To explore the coupling relationship between the tourism economy and ecological environment in Chengdu, an evaluation index system was established based on specific criteria (Xu et al., 2022b; Niemeijer & de Groot, 2008). Initially, the range method was used to preprocess the data. Then, the weight method and benefit index calculation were introduced in detail, leading to the initial establishment of the coupling coordination system for the tourism economy and ecological environment. The system construction utilized the coupling and coordination development evaluation method. Through this method, the data were preprocessed using the range method, and the weight method and benefit index calculation were applied comprehensively, resulting in the preliminary establishment of the coupling coordination system for Chengdu's tourism economy and ecological environment.

Construction of the indicator system

In constructing the indicator system, each indicator plays an irreplaceable key role, making indicator selection crucial to the system's development (Sdoukopoulos et al., 2019). This study follows six principles—systematicity, typicality, dynamism, scientificity, comparability, and operability—to ensure the reliability and accuracy of the selected indicators.

Range method preprocessed data

Due to the differing values and units of the selected indices, direct calculation is not feasible. Therefore, data preprocessing is necessary, and the range method is used for dimensionless processing to ensure the comparability of the selected indicators.

The standardized formula is shown below. X_{ij} is the value of the ($j=1,2,3\cdots n$) year in the i ($i=1, 2,3\cdots m$) index of ecological environment system, and y_{ij} is the value of the j (x, y positive numbers; m, n natural numbers).

$$\text{Forward indicator: } x_{ij} = \frac{X_{ij}}{K_{max}} \quad (3-1)$$

$$\text{Negative indicator: } x_{ij} = \frac{K_{min}}{X_{ij}} \quad (3-2)$$

X_{ij} is the original data, x_{ij} is the standard value after processing, k_{max} and k_{min} are the maximum and minimum values, respectively. The processing method for tourism economic indicators follows the same approach.

Establishment of indicator weights

The value of the indicator weights is crucial for the accuracy of the research results [18]. Therefore, when assigning weights to indicators, it is essential to ensure objectivity and avoid the influence of subjective factors. In this paper, the entropy value method is used to calculate the weights. The specific steps are as follows:

$$P_{ij} = \frac{x_{ij}}{\sum_{j=1}^n x_{ij}} \quad (3-3)$$

P_{ij} is the share of the value of year j in indicator i for that indicator i , and x_{ij} is the preprocessed data.

$$e_i = -k * \sum_{j=1}^n P_{ij} \log(P_{ij}) \quad (3-4)$$

e_i is the entropy value, $e_i \geq 0$, $k > 0$. Generally, let $k = \frac{1}{\ln m}$ then have $0 \leq e$

$$H_i = \frac{f_i}{\sum_{i=1}^m f_i} \quad (3-5)$$

$f_i = 1 - e_i$, H_i is the weight of each indicator in the system, $0 \leq H_i \leq 1$.

Calculation of benefit indices

Let $x_1, x_2, \dots, x_i, x_n$ are n indicators describing the economic characteristics of tourism, $y_1, y_2, \dots, y_j, y_m$ are m indicators describing the ecological environment (x_i, y_j are positive numbers; n, m are natural numbers), Here x_i, y_j take the dimensionless values:

$$f_{(y)} = \sum_{j=1}^m b_j y_j \quad (3-6)$$

$$f_{(x)} = \sum_{i=1}^n a_i x_i$$

In formula (3-6), $f_{(x)}, f_{(y)}$ are tourism economic benefit index and ecological environment benefit index, respectively. a_i, b_j represent the weight of the selected indicator.

Coupling evaluation model of tourism economy and ecological environment

Coupling coordination degree model

The tourism economy and ecological environment are constantly changing, and the coupling and coordination relationship between them is also dynamic. As mentioned earlier, the coupling degree model is a static analysis model, and its measurement accuracy for dynamic coupling relationships is insufficient. Therefore, according to the theory of coupling coordination degree, this paper introduces the coupling coordination degree model to accurately assess the state of dynamic interaction and coordination between the two.

The specific calculation steps are as follows:

$$C = \left[\frac{f_{(x)} \times f_{(y)}}{|(f_{(x)} + f_{(y)}) \div 2|^2} \right]^k \quad (3-7)$$

k is the correction index ($k=2$); C is the coupling degree (coordination degree) ($0 < C < 1$), the greater the C value, the higher the coupling degree. This paper divides the coordination degree of the two systems into five categories, as shown in Table1.

Table1: Coupling coordination degree classification

Coupling coordination degree	Class	Coupling coordination degree	Class
0-0.09	Hyperdysregulation	0.5-0.59	Forced coordination
0.1-0.19	Severe disorder.	0.6-0.69	Primary coordination
0.2-0.29	Moderate dysregulation	0.7-0.79	Moderate coordination
0.3-0.39	Mild disorder	0.8-0.89	Good coordination
0.4-0.49	Borderline disorder	0.9-1	Quality coordination

Source: Deng et al., (2022)

Construction of evaluation method for coupled and coordinated development

The coupling degree alone cannot fully reflect the level of coordination between the tourism economy and the ecological environment. Therefore, the coupling coordination degree (D value) is introduced as a comprehensive index. By establishing a coupling coordination development model, we can more accurately analyse the relationship between these two systems:

$$D = \sqrt{C * T} \quad (3-8)$$

$$T = \alpha f_{(x)} + \beta f_{(y)} \quad (3-9)$$

D is the coupling coordination degree (coordination development degree); T is the comprehensive evaluation index; α 、 β are undetermined coefficients and $\alpha + \beta = 1$. A large number of literatures show that most scholars believe that tourism economy and ecological environment are equally important, so $\alpha = \beta = 0.5$.

Based on Table 2.1, according to the contrast relationship between the benefit index $f(x)$ and $f(y)$, each category can be divided into three basic types: tourism economy lagging, tourism economy synchronizing with ecological environment, and ecological environment lagging. Based on this, the paper makes a quantitative evaluation of the coordinated development of tourism economy and ecological environment.

Table 2: Coordinated development type of tourism economy and ecological environment based on benefit index

Contrast between $f(x)$ and $f(y)$	Type
$F(x) > f(y)$	Tourism economy lags behind
$F(x) = f(y)$	Tourism economy and ecological environment synchronous type
$f(x) < f(y)$	Ecological environment lag type

Source: Deng et al., (2022)

An empirical analysis on the construction of coupling coordination model between tourism economy and ecological environment in Chengdu

The Chengdu Municipal government initially achieved commendable results in environmental protection. However, over the past five years, there has been a continuous increase in tourism waste discharge. If this upward trend is not promptly addressed, it could severely impact the ecological environment of Chengdu in the future.

Preliminary construction of the indicator system

Because coupling development involves a complex, dynamic system, the situation of the entire system cannot be adequately measured using just a few simple indicators. Therefore, it is essential to comprehensively consider multiple perspectives when constructing an indicator system that reflects the overall development level(Xing et al., 2019).

Based on the complexity of the entire system and following the principles of index selection, this paper relies on authoritative statistical data publicly released by sources such as the "Chengdu Statistical Yearbook (2013-2023)", "Chengdu Tourism Yearbook (2013-2023)", and "Chengdu Water Resources Bulletin (2012-2022)", among other government statistical departments. Reflecting the specific characteristics and actual situation of Chengdu City, a four-level progressive structure is initially constructed, comprising one target layer, two system layers, six factor layers, and sixteen index layers, utilizing high-frequency indicators.

Table 3: Evaluation index system for coupling tourism economy and ecosystem in Chengdu city, China

Target level	System level	Factor layer	Indicator layer
Coupled evaluation of tourism economy and ecosystem	Ecological environment	Ecological conditions	Per capita water resources （X1）
			Forest coverage rate (X2)
		Environmental protection	Green area of parks (X3)
			Area covered by greener (X4)
			Industrial solid waste utilization rate (X5)
		Environmental pressure	Total industrial wastewater discharge （X6）
			Total sulfur dioxide emissions （X7）
			Total industrial solid waste emissions (X8)
	Tourism economy	Tourism industry	Number of star-rated hotels (Y1)
			Cumulative number of people received during the National Day Golden Week (Y2)
		Tourism scale	Domestic tourist arrivals (Y3)
			Inbound tourist arrivals (Y4)
Total tourist arrivals (Y5)			
Tourism efficiency		Foreign exchange earnings from international tourism (Y6)	
		Gross tourism receipts (Y7)	
		Gross tourism receipts as a share of GDP (Y8)	

Source: "Chengdu Statistical Yearbook (2013-2023)", "Chengdu Tourism Yearbook (2013-2023)", and "Chengdu Water Resources Bulletin (2012-2022)",

This section discusses the outcomes derived from the surface pressure measurement study. The effects of angle of attack, Reynolds number, and leading-edge bluntness are examined in subsequent subsections.

The weights of each index layer in the two systems were calculated using a specific formula. It was found that the tourism economic foundation and ecological environment pressure exert the highest weights in their respective subsystems, signifying their significant impact on the overall index system. An analysis of the tables reveals that sulfur dioxide emissions dominate the ecological environment system in terms of weight proportion, while the forest coverage rate exhibits the lowest weight. In contrast, inbound tourist numbers hold the highest weight in the tourism economy system, while the number of star-rated hotels shows the smallest weight.

Although the weights vary across indices, the differences are not substantial, suggesting that each index plays a similarly crucial role in the overall system and requires comprehensive consideration. Notably, total industrial wastewater discharge, sulfur dioxide discharge, and industrial solid waste discharge are identified as reverse indicators among the indicators, while the remaining 13 indicators are positive indicators.

Data processing and inspection

Results of entropy weighting of the index system

In this study, the entropy method was employed for weight assignment of indicators. Initially, the data underwent preprocessing using formulas (3-1) and (3-2) based on the range method to standardize the values, considering the information content of each index's actual values. Subsequently, the statistical software Stata 15.0 was utilized to process the values of each index in Chengdu. This process yielded the final weights, which were then analysed to provide comprehensive insights into the coupling and coordination development of the tourism economy and ecological environment in Chengdu. As shown in Table 4

Table 4: Evaluation index system and weight of coordinated development of tourism economy and ecological environment in Chengdu, China

System level	Element level	Index level	Indicator plus or minus	Weight
Ecological environment	Ecological condition	X1	+	0.12299
		X2	+	0.12192
	Environmental protection	X3	+	0.12357
		X4	+	0.12360
		X5	+	0.12212
	Environment stress	X6	-	0.12216
		X7	-	0.14077
		X8	-	0.12287
Tourist economy	Tourist industry	Y1	+	0.12086
		Y2	+	0.12991
	Tourism size	Y3	+	0.12117
		Y4	+	0.13432
		Y5	+	0.12133
	Tourism efficiency	Y6	+	0.12646
		Y7	+	0.12360
		Y8	+	0.12235

Source: "Chengdu Statistical Yearbook (2013-2023)"&Author's Calculation

This section discusses the results obtained from the surface pressure measurement study. The effects of angle of attack, Reynolds number and leading edge bluntness are discussed in the next sub section.

The weights of each index layer in the two systems are calculated by the formula, and it is found that the tourism economic foundation and ecological environment pressure are the most weighted in their respective subsystems,

which have a greater impact on the whole index system. It can be seen from the table that, from the perspective of weight proportion, sulfur dioxide emissions in the ecological environment system are the largest, and forest coverage rate is the lowest; In the tourism economy system, the number of inbound tourists is the largest and the number of star-rated hotels is the smallest. Although the weights of each index are different, the difference between them is not significant, indicating that the importance of each index to the system is similar, and comprehensive consideration is needed. Among the indicators, three indicators of total industrial wastewater discharge, sulfur dioxide discharge and industrial solid waste discharge are reverse indicators, and the remaining 13 indicators are positive indicators.

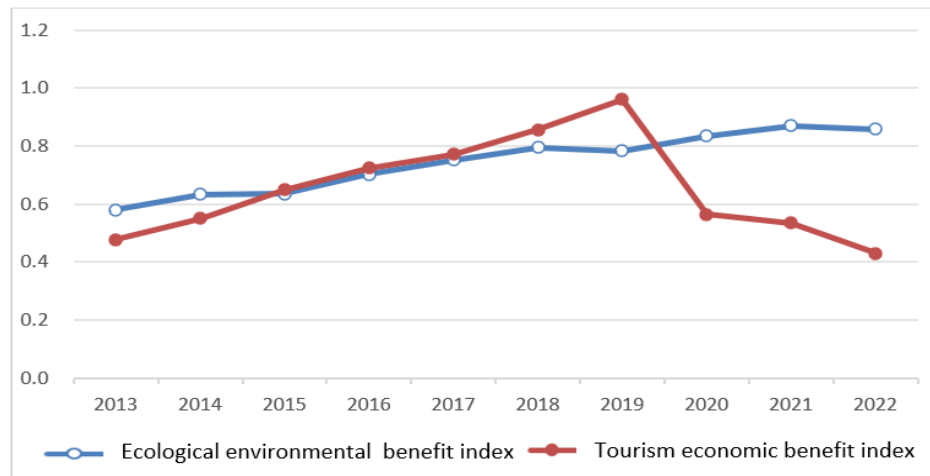


Figure 2: Change chart of tourism economic benefit and eco-environmental benefit index in Chengdu from 2013 to 2022

Source: "Chengdu Tourism Yearbook (2013-2022)", & Author's Calculation (2024)

As depicted in the figure2, the tourism economic benefit index exhibited a steady increase from 2013 to 2019, rising from 0.4779 to its peak at 0.9607. This trend reflects the robust development of Chengdu's tourism economy over the past seven years. However, following the onset of the COVID-19 pandemic in 2020, there was a sharp decline, and by 2022, the index had even dropped below the level recorded ten years earlier.

Conversely, the ecological and environmental benefit index showed a generally upward trend with fluctuations, experiencing only slight declines in 2015, 2019, and 2022. The increase in the ecological and environmental benefit index over the past decade indicates continuous positive development in

Chengdu's ecological environment from the end of the "Twelfth Five-Year Plan" to the early stages of the "Fourteenth Five-Year Plan".

Path analysis to improve the coupling and coordinated development of Chengdu's tourism economy and ecological environment

Coupling analysis of high quality development of tourism economy and ecological environment in Chengdu

The relationship among the three comprehensive development indicators in the research evaluation index system is shown in Figure2 below:

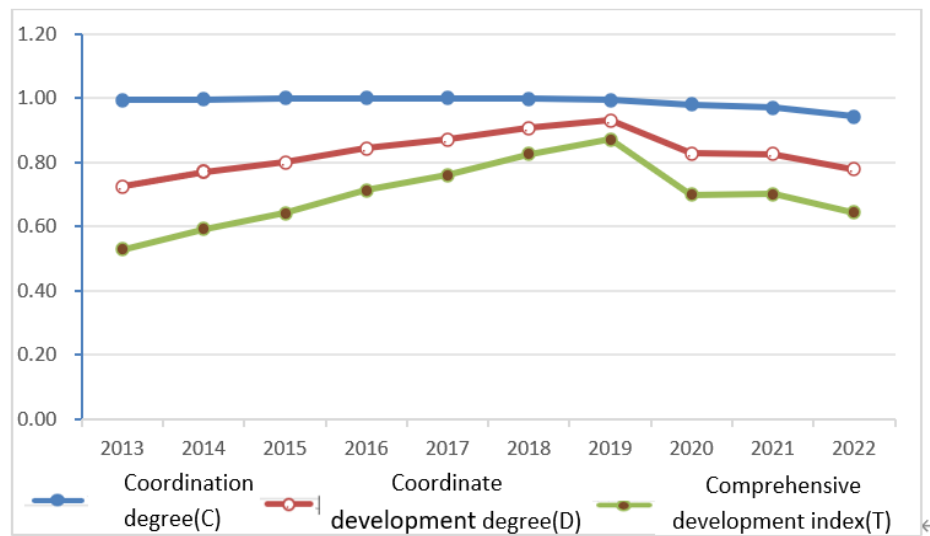


Figure 3: Indicators of coordinated development of tourism economy and ecological environment in Chengdu from 2013 to 2022

Source: "Chengdu Tourism Yearbook (2013-2022)", & Author's Calculation (2024)

According to Figure 3, the coordination degree between the two systems exhibited a gradual decline from 2013 to 2022. Initially, the coordination development degree and the comprehensive development index of both systems showed a slow and balanced increase from 2013 to 2019, with the comprehensive development index increasing more rapidly. However, from 2020 to 2022, there was a downturn in both the coordinated development degree and the comprehensive development index, with the rate of decline slowing down or halting.

Based on the above observations and discrimination criteria, the types of coordinated development between the tourism economy and ecological environment in Chengdu from 2013 to 2022 can be categorized as follows:

Table 5: Coordinated development types of tourism economy and ecological environment in Chengdu from 2013 to 2022

Year	Coordinated development degree(D)	Contrast between $f(x)$ and $f(y)$	Coordinated development type
2013	0.7256	$f(x) > f(y)$	Moderate coordinated development type Tourism economy lag type
2014	0.7684	$f(x) > f(y)$	Moderate coordinated development type Tourism economy lag type
2015	0.8017	$f(x) < f(y)$	Good coordinated development type Ecological environment lag type
2016	0.8443	$f(x) < f(y)$	Good coordinated development type Ecological environment lag type
2017	0.8726	$f(x) < f(y)$	Good coordinated development type Ecological environment lag type
2018	0.9085	$f(x) < f(y)$	High-quality coordinated development type Ecological environment lag type
2019	0.9312	$f(x) < f(y)$	High-quality coordinated development type Ecological environment lag type
2020	0.8284	$f(x) > f(y)$	Good coordinated development type Tourism economy lag type
2021	0.8259	$f(x) > f(y)$	Good coordinated development type Tourism economy lag type
2022	0.7789	$f(x) > f(y)$	Moderate coordinated development type Tourism economy lag type

Source: "Chengdu Tourism Yearbook (2013-2022)", & Author's Calculation (2024)

From the table5, it is evident that the dynamics of the relationship between the benefit indexes of the two systems can be characterized as follows: $f(x) > f(y)$ from 2013 to 2014. During this period, the tourism economy in Chengdu was relatively underdeveloped and urgently required rapid growth. $f(x) < f(y)$ from 2015 to 2019, indicating that the ecological environment development in Chengdu lagged behind during this phase, necessitating a focus on environmental protection in development planning. From 2020 to 2022, the COVID-19 pandemic significantly impacted the tourism economy, resulting in $f(x) > f(y)$, highlighting a severe setback in tourism economic development.

In terms of the coordinated development degree, Chengdu's tourism economy and ecological environment achieved a high level over the past decade, showing an initial increase followed by a subsequent decrease in the coordinated development degree. Starting from 2019, the coupling coordination degree steadily improved for seven years, reaching a peak D value of 0.9312 in 2019, indicating a high-quality coordination level favoring ecological environment development. However, in the subsequent two years, there was a rapid decline,

reflecting a regression to moderate coordinated development with tourism economic lag tendencies, characterized by a D value of 0.7256 in 2014, the lowest observed during this period.

Improvement suggestions based on coupling coordination degree

This illustrates that during the "Twelfth Five-Year Plan" and "Thirteenth Five-Year Plan" periods, the coordinated development situation remained stable and showed improvement. However, from the end of the "Thirteenth Five-Year Plan" to the early stages of the "Fourteenth Five-Year Plan", the novel coronavirus epidemic dealt repeated severe blows to the tourism industry. As a result, the development of the tourism economy lagged behind, necessitating policy support for recovery and future development.

CONCLUSION

This study establishes an evaluation index system for Chengdu's urban tourism economy and ecological environment, focusing on their developmental trajectories. Initially, data undergoes preprocessing using the range method, followed by entropy weight calculation to determine the significance of each index. Subsequently, a coupled coordination model assesses the system's coordinated development level, delineating yearly development types. The findings reveal the following insights:

From 2013 to 2019, Chengdu's tourism economic benefit index exhibited robust growth, soaring from 0.4779 in 2013 to 0.9607 in 2019. Concurrently, the ecological and environmental benefit index displayed a fluctuating upward trend, climbing from 0.5800 to 0.7829. Despite strides in ecological protection, a notable disparity between the two indices persisted, emphasizing the ongoing need for ecological conservation.

The pivotal year of 2020 marked a downturn as Chengdu's tourism economic benefit index plummeted sharply from 0.9607 in 2020 to 0.4290 in 2022. This decline underscored significant obstacles to the tourism sector's development. In contrast, the ecological and environmental benefit index continued a slower growth trajectory, reaching 0.8581 in 2022. This slower pace suggests a stall in ecological progress, with the ecological index surpassing that of tourism economy, necessitating future efforts to bolster tourism recovery while advancing ecological resilience.

During 2013-2019, the coordination degree between the two systems remained consistently high, fluctuating marginally above 0.99. However, from 2020 onwards, this coordination declined, hitting a low of 0.9428 in 2022. This decline primarily resulted from the rapid downturn in Chengdu's tourism economic benefit index due to the novel coronavirus pandemic, compounded by stagnation in the growth of the ecological and environmental benefit index.

The period from 2013 to 2019 witnessed significant improvements in both the coordinated development degree and comprehensive development index, peaking at 0.8718 and 0.9312, respectively. This period highlighted optimized coupled and coordinated development, characterized by high-quality ecological environment lag-type coordination.

Conversely, during 2020-2022, the coordinated development degree declined to 0.7789 by 2022, while the comprehensive development index dropped to 0.6436. Chengdu transitioned to medium coordinated development, indicating deteriorating coupling and coordinated development between tourism economy and ecological environment. Urgent measures are imperative to rejuvenate tourism sector growth and advance ecological restoration, underscoring the need for enhanced coordination between these sectors. This analysis underscores the dynamic interplay and evolving challenges facing Chengdu's tourism economy and ecological environment. Strategic interventions are crucial to navigate current setbacks and guide Chengdu towards sustainable and balanced development in the future.

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