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Exploring the synergy between Karst World Heritage site's OUV conservation and buffer zone's tourism industry development: a case study of the Libo-Huanjiang Karst

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Abstract

Karst World Heritage Site (KWHS) combines high-grade landscape resources and a fragile ecological environment. As an essential tool for heritage conservation and maintaining local interests, its buffer zone is primarily located in remote villages, a crucial and challenging area for rural revitalization. The conflict between heritage conservation and development is particularly acute at the site. How to deal with the relationship between the heritage site's OUV conservation and the buffer zone's tourism industry development and realize the synergy between the two subsystems? Few studies have focused on it. There is an urgent need to explore the synergistic mechanism of the KWHS's OUV conservation and the buffer zone's tourism industry development. Accordingly, this study takes the Libo-Huanjiang KWHS, one of the 'South China Karst' series of heritage sites, as a case study. The coupling coordination degree model, gray correlation analysis (GCA), and Geographic Information System (GIS) spatial analysis are used. The results show that: (1) There is a synergistic effect between the Libo-Huanjiang KWHS's OUV conservation and its buffer zone's tourism industry development, showing a favorable trend. The mean value of the coupling coordination degree increased from 0.57 in 2015 to 0.63 in 2020, and the overall situation improved from barely coupling coordination state to primary coupling coordination. (2) Influenced by the main driving factors, such as NDVI, landscape dominance, government support for tourism development, tourists' satisfaction, and residents' support, the coupling coordination of the four tourist scenic areas in the study area differed slightly in 2015 and 2020. Yaoshan Ancient Village Scenic Area is the highest in both years, increasing from 0.69 to 0.81, followed by the Mengliu Buyi Scenic Area (0.59), Wanmu Meiyuan Scenic Area is relatively stable with a slight increase, and Lianshanwan Scenic Area (0.45) is the lowest. (3) The four dimensions of ecological resources, policy drivers, economy drivers, and social facilitators work together to create a synergistic mechanism between the KWHS's OUV conservation and the buffer zone's tourism industry development. Future research can promote synergy between the two by formulating a comprehensive plan, encouraging sustainable tourism, establishing a diversified tourism industry, strengthening heritage education and training, enhancing community participation, and reinforcing stakeholder cooperation.

Keywords Natural World Heritage, Buffer zone, Conservation, Tourism, Coupling coordination, Libo-Huanjiang Karst

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Introduction

Natural heritage sites are inscribed on the World Heritage List (WHL) mainly because of their Outstanding Universal Value (OUV) as defined by the United Nations (UN), such as the possession of extraordinary natural landscapes and phenomena, superior geographical location, biological diversity, and complete ecosystems [1]. Natural World Heritage (NWH) conservation refers to the sum of a series of management models applicable to sustainable development, based on the perspective of the human-earth relationship and taking measures to protect values and their integrity and improve heritage conservation and management, taking into account the actual situation of World Heritage Sites (WHSs). Value conservation mainly focuses on the WHSs' OUV and aims to protect the carrier of the OUV and its integrity from the negative impact of peripheral human activities.

World Heritage (WH) faces severe external threats in global economization and urbanization, and there is a tendency to conserve the heritage and the surrounding environment and integrate culture, nature, and the local economy. Therefore, WH conservation is no longer limited to the closed conservation of the heritage site itself but has shown a trend of outward-looking and regional conservation [2]. WH conservation should focus on the core and non-core areas, especially on the periphery of the heritage sites [3]. Heritage conservation research gradually shifts from a 'balance between conservation and development' to a 'conservation for development' paradigm. The changing perception of heritage conservation has contributed to the strengthening of the role of buffer zones, and along with the increasing external threats to heritage in practice, the heritage community has placed buffer zones at the forefront of conservation research and is looking to the establishment of then as the primary method to mitigate external threats, protect and enhance the conservation of WH's OUVs. As a result, WHS's buffer zone theory has been increasingly studied [4–7].

NWH's buffer zone tourism industry development is a sustainable development approach to achieve orderly coordination of the environment, economy, and society through scientific tourism planning, management, and innovation based on the conservation and utilization of NWH resources. The buffer zone's tourism development process should ensure the sustainable use of natural resources and prevent irreversible environmental damage. Firstly, the buffer zone's tourism industry development should be based on the ecological environment protection of the WHS. Second, one of the WH's 5C (Credibility, Conservation, Capacity-Building, Communication, Community) strategies emphasizes the importance of local community residents to WH and its sustainable development [8], community participation should be proper. The development of the buffer zone tourism industry should encourage local communities to participate in it and increase residents' recognition and responsibility sense for NWH conservation [9]. Again, buffer zone tourism development should boost local economic growth, creating more employment opportunities for the community while effectively improving residents' living standards. A tourism-led industrial chain should be formed to explore a practical path for diversified economic development. Finally, relying on the resource advantages and brand effects of WHSs, tourism has become a trendy choice as the primary development industry in buffer zones and significantly impacts local communities' economic activities [10–12]. However, negative phenomena such as population pressure, environmental pollution, and conflicts between residents, tourists, government, and other stakeholders threaten the harmonious development of WH conservation and sustainable tourism, and exploring the interaction between conservation and utilization has become a vital issue in tourism management research in WH's buffer zones [13–16].

The relationship between the Natural World Heritage Sites' (NWHSs) conservation and the buffer zones' tourism industry development is increasingly debated in academic circles, with views differing depending on positions and perspectives. For example, environmentalists argue that WH conservation and tourism development are in complete opposition and may have environmental pollution, population pressure, visual impact, and the wealth gap that threaten WH conservation. To ensure the full implementation of management policies, the development of tourism in buffer zones is not advocated, and their protection in a strict sense is emphasized [17, 18]. Scholars who focus on social development emphasize that development goals are mainly achieved in buffer zones or transition zones near WHSs, and that good buffer zone development patterns can relieve pressure on resource use, drive local economic development, and enhance the conservation and management of WHSs [10, 19, 20]. Nevertheless, socio-ecological conservation advocates are committed to exploring the synergy between WHS's environmental protection and the buffer zone's tourism economic development [21, 22]. Especially for more ecologically fragile areas, they encourage sustainable tourism development to promote synergies between WH conservation and local economic development. However, scholars have paid less attention to the synergy between WHSs' OUV conservation and buffer zones' tourism industry development.

Karst landscapes are widely distributed globally, covering 22 million km^2 and accounting for 10–15% of the

land area [23]. On the one hand, karst areas have created rich NWHSs due to their unique geological and geomorphological evolutionary processes as well as scientific and aesthetic values, making them one of the world's most remarkable landscapes [24–27]. Numerous KWHSs have been inscribed on the WHL due to OUVs that possess overwhelming natural phenomena and are prominent features of the most important stages in the earth's evolutionary history. As of the 42nd World Heritage Congress (WHC), there are 30 KWHSs (including mixed cultural and natural heritage) worldwide, accounting for 14% of the total NWHSs [28] (Fig. 1). On the other hand, karst landscapes are fragile ecosystems with low environmental carrying capacity and resilience coefficients [29, 30], and the problem of rocky desertification caused by unreasonable human activities has become a key factor limiting local economic and social development [31, 32]. Thus, in the particular geographical field of the karst region, how to synergize the conservation of heritage environmental resources and high-quality development has become a fundamental scientific problem that needs to be solved urgently. The KWHSs' OUV is threatened by rocky desertification in the buffer zone, making them 'ecological islands' in the rocky desertification environment, which puts forward higher requirements for the WH's OUV conservation and poses a more significant challenge for the buffer zone to perform the function of WH conservation and drive local development. Most of the KWHSs are located in remote areas, poor mountainous areas, ethnic minority areas, and other economically backward places [25], where the environment is fragile and the level of socioeconomic development is low. High-intensity agricultural activities are the main focus, resulting in sharp conflicts between people and land, leading to the dilemma that 'one side of the land cannot support one side of the people.' It is urgent to explore the coordinated development path between the resource protection of NWHSs, and human development needs. The tourism development based on WH resources is often regarded as the first choice of industry in buffer zones [33, 34], and how to realize the synergy between WH conservation and high-quality development of the tourism industry in the buffer zones has become a realistic demand for KWHSs. Therefore, it is necessary to explore the synergistic mechanism focusing on the WHS's OUV conservation and the buffer zone's tourism industry development, to alleviate further the contradiction between WHS conservation and the high-quality development of the region and to provide a scientific reference for the effective conservation and rational utilization of WHS.

The karst region in southern China is one of the specific regions for research on the relationship between KWHS's conservation and the buffer zone's tourism industry development. Its unique environment and ecosystem are high-grade landscape resources and WHSs, and one of the most fragile ecosystems on earth, which urgently needs human protection and inheritance, as

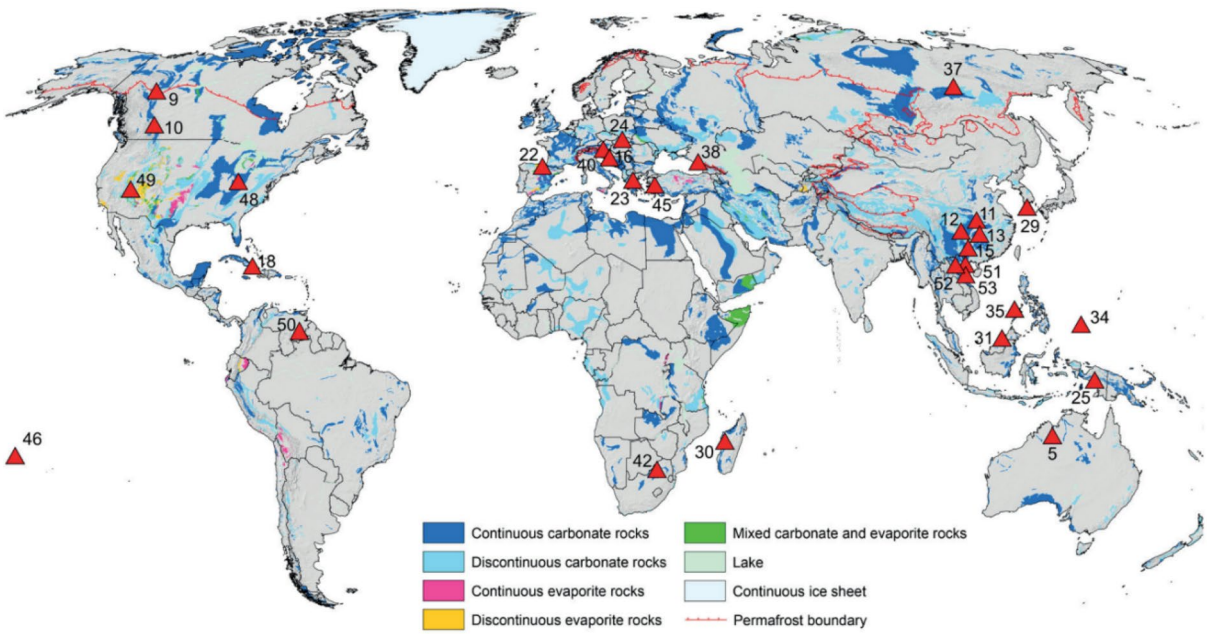

Fig.1 Global Distribution of Karst World Heritage Sites [27, 28]

well as effective governance and development. The buffer zone is mainly distributed in remote villages, which is a crucial and challenging area for rural revitalization, and tourism development is often taken as an industrial choice for this area. There is an urgent need to research the synergy between KWHS's conservation and the buffer zone's tourism industry. The existing studies on NWH tourism mainly focus on tourism impacts, stakeholders, tourism resource management techniques and methods, world heritage values, tourism destination brand image building and marketing, and the impact of WHL on tourism demand [35]. However, OUV, as the focus of WH conservation, few studies have focused on the association between WHS's OUV conservation and the buffer zone's tourism industry development.

Based on the above considerations, this study takes the Libo-Huanjiang Karst of the 'South China Karst' heritage series as the study area. The objective is to explore the synergy between the KWHS's OUV conservation and the buffer zone's tourism industry development by constructing an evaluation indicator system for coupled coordination. The coupled coordination evaluation model is mainly used to analyze the synergistic effect of the two through the coupling coordination state. Furthermore, through the GCA, we analyze the factors affecting the synergy between the two regarding ecological resources, economic drivers, policy drives, and social facilitators. Finally, we reveal the synergistic mechanism and propose the synergy enhancement strategy. The results obtained in this study may provide a scientific basis for the adequate conservation and compatible use of NWH.

Materials and methods

Study area

The Libo-Huanjiang Karst is located at the junction of Libo County, Qiannan Prefecture, Guizhou Province, and Huanjiang County, Hechi City, Guangxi Zhuang Autonomous Region (Fig. 2). The WHSs' scope mainly includes the Maolan National Nature Reserve in Guizhou, the Daqikong and Xiaoqikong scenic areas of the Zhangjiang National Scenic Area, and the Guangxi Mulun National Nature Reserve. Libo-Huanjiang Karst is the only karst zone in the world that is concentrated in distribution, native, relatively stable, and the largest and most complete preserved area on the same latitude of the earth because it satisfies the World Heritage Criterion (vii): contains superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance. (viii): be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features. It was nominated as an NWHS in a bundle with Shilin in Yunnan and Wulong in Chongqing and was inscribed on the WHL by the UN WHC in June 2007. The study area is 84,575 hm^2, including 36,647 hm^2 of heritage sites and 47,928 hm^2 of buffer zones.

It is one of the most representative areas in the transition zone of the Guizhou plateau and Guangxi lowland, and its cone-shaped karst features represent the geological evolution of continental tropical-subtropical cone-shaped karst. The cone-shaped karst features represent the geological evolution of the continental tropics-subtropics. The original forests of the Libo KWHS are well

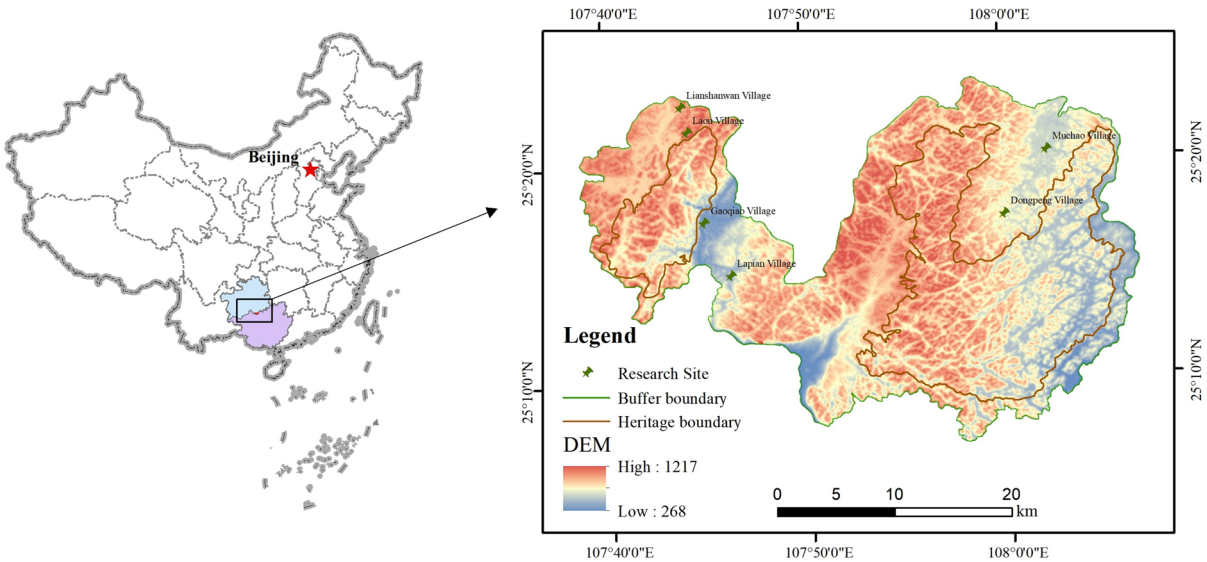

Fig.2 Location of the study area

preserved, but the relatively fragile karst environment has little carrying capacity and is surrounded by rocky desertification, making it a 'green island', which needs to be utilized more carefully. Some areas in the buffer zone have obvious rocky desertification, such as Yaoshan, Jiaoou, and other townships, which poses a more significant challenge to protecting the WHS and developing the buffer zone.

The basic situation of WHS's OUV conservation and buffer zone's tourism industry development of Libo-Huanjiang Karst is as follows.

1. The top-down traditional management model ignores the central role of community residents in WH conservation, and the strengthening of conservation measures in the district leads to differences in policy treatment within and outside the district, which shackles the local economy development and to some extent exacerbates the contradiction between WH conservation and local development needs, and the community's livelihood flexibility, residents' awareness of OUV conservation needs to be enhanced.
2. The tourism industry development in Libo-Huanjiang KWHS started early, but the tourism products are relatively single, the industrial chain is not extended enough, and the industrial synergy effect is not very obvious. The tourism industry development of Libo KWHS has mainly gone through three stages. The first is the initial tourism development stage before its triumphant declaration of NWH in 2007. The development stage of tourism from 2007 to 2015, 2007 became a critical turning point, in which Libo was listed as a member of 'South China Karst' and became the first NWHS in Guizhou, and its tourism development rose to a stage. The third stage was in 2015, after being named a national 5A-level scenic spot, Libo tourism entered the fast development track. With government support, Lapian Village, Gaoqiao Village, and Lianshan Village in the buffer zone (Fig. 2), relying on the geographical location advantage of being close to the WHS and local characteristic tourism resources, have created tourist scenic areas such as Yaoshan Ancient Village, Mengliu Buyi and Lianshanwan (Fig. 3). Residents have expanded their sources of livelihood by participating in the tourism industry development.

Data sources and methods

This study mainly uses questionnaires, in-depth interviews, and data collection to obtain the required data to evaluate the coupled and coordinated relationship between KWHS's OUV conservation and the buffer zone's tourism industry development. It constructs an evaluation index system suitable for karst areas in combination with the actual local conditions. Firstly, the entropy method is applied to determine the weights of each index, based on which the total scores of the

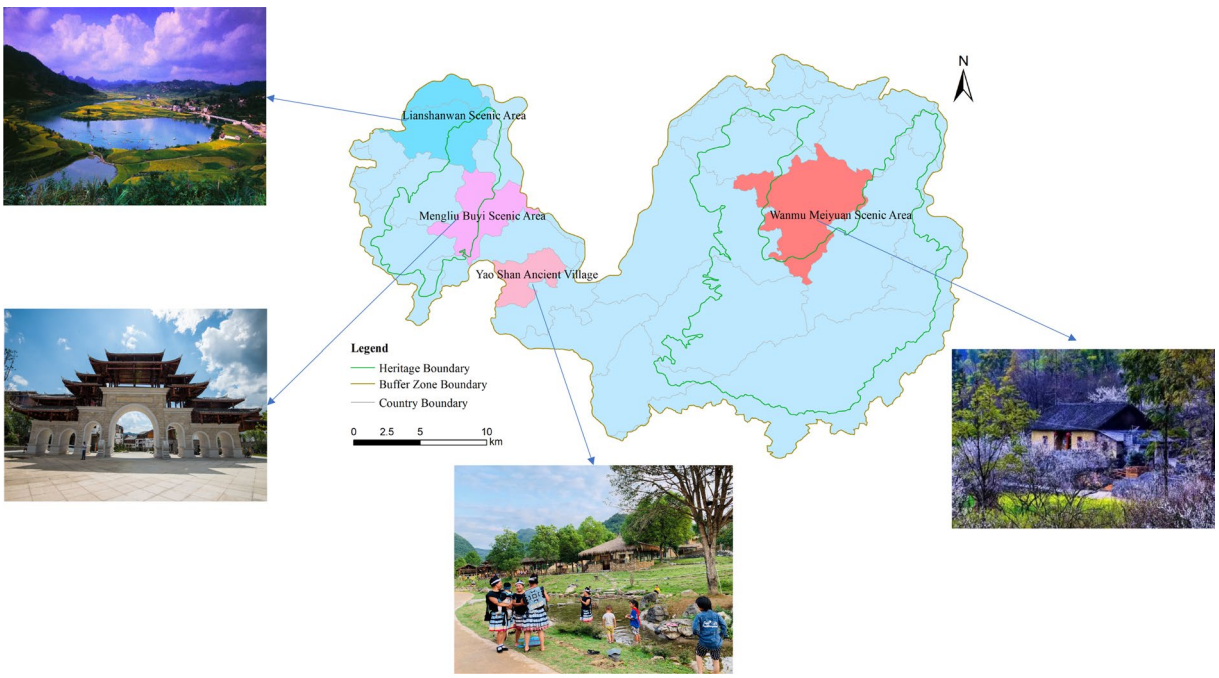

Fig.3 Distribution of tourist scenic area in the study area

two subsystems are calculated in the two years of 2015 and 2020. Secondly, the coupling coordination degree model measures the synergy between the WHS's OUV conservation and the buffer zone's tourism industry development. Finally, GCA is used to identify the main influencing factors affecting synergies between the two.

Data sources

(1) Questionnaires and in-depth interviews

To further ensure the study's authenticity, credibility, and comprehensiveness, our research group visited the study area several times during 2019–2023 to conduct field surveys. Firstly, a questionnaire survey was conducted among the residents involved in tourism operations in the study area. Secondly, in-depth interviews were conducted with some key subjects. The survey sites were mainly concentrated in three townships (Gaoqiao Village, Lapian Village, Laou Village, Lianshan Village, Dongpeng Village, and Muchao Village) within the buffer zone of the Libo-Huanjiang Karst in Yaoshan Township, Xiaoqikong Township, and Liming Shuiguan Township.

(2) Information collection

The evaluation index data are based on 2015 and 2020, remote sensing images from Landsat8 OLI data downloaded from Geospatial Data Cloud (http://www.gscloud.cn/), tourism-related data from Libo County Tourism Industry Transformation and High-Quality Development Plan (2021–2035), Libo County Statistical Yearbook, etc. Other relevant data were obtained from the data collection and interviews conducted by the project team members during the period 2021–2023 at the County Bureau of Culture and Broadcasting, the World Heritage Bureau, and various township governments and village committees, which are under the jurisdiction of the study area.

Constructing the coupling coordination's evaluation index system

(1) KWHS' OUV conservation evaluation index system

Heritage value conservation mainly focuses on OUV and its integrity conservation. The study area's OUV is primarily reflected in geomorphological and aesthetic values, while integrity requires that OUV elements and areas with heritage values maintain regional holistic characteristics [36, 37]. Few studies have been conducted on the definition of WH's OUV characterization elements and the assessment of conservation effects concerning Shi's study on the extraction process of OUV characterization elements and the conservation level of Xinjiang Bogda NWHS [38]. The study divided the OUV and its integrity conservation system into two dimensions: natural ecological elements and landscape aesthetic elements, and constructed a system including 12 measurement indicators, including the KWHS' OUV conservation evaluation index system (Table 1).

At the level of natural ecological elements dimension, environmental factors such as temperature, precipitation, humidity, and normalized difference vegetation index(NDVI) are the fundamental causes of area formation, thus contributing to the formation of OUV environmental components [39, 40], so they are selected as OUV element carriers to observe the conservation effect of heritage values. In addition, two indicators, the degree of rocky desertification and the degree of conservation of geology and geomorphology, were selected to reflect the conservation status of KWHS's geological features value [32, 38].

Table 1 KWHS's OUV conservation evaluation index system and weights

Dimension	No	Indicator items	Indicator definition	Indicator properties	Weight
Natural ecological elements	C1	NDVI	Elements of aesthetic value representation	+	0.0480
	C2	Temperature		+	0.0477
	C3	Precipitation		+	0.0520
	C4	Humidity		+	0.1400
	C5	Degree of rocky desertification (rocky desertification area above potential level)	Degree of protection of geomorphological values	–	0.1386
	C6	Degree of conservation of geology and geomorphology	Degree of disturbance by tourism activities	+	0.0484
Aesthetic elements of the landscape	C7	Degree of landscape fragmentation	Aesthetic value integrity	–	0.0615
	C8	Degree of landscape dominance		+	0.1243
	C9	Degree of landscape separation		–	0.1154
	C10	Degree of landscape degradation		–	0.1301
	C11	The uniqueness of landscape beauty	Aesthetic value characterization elements	+	0.0472
	C12	The richness of landscape beauty	Aesthetic value integrity	+	0.0468

The selection of indicators at the level of landscape aesthetic elements focuses on the representational factors of aesthetic value and its integrity [41]. In terms of landscape aesthetic value characterization elements, the uniqueness of landscape beauty is an aesthetic quality that means the landscape is different or unique from other landscapes in some aspects and is recognizable and attractive [42, 43]. The uniqueness of KWHS landscape beauty is reflected in topographic features, vegetation, fauna, and waters, so the uniqueness of landscape beauty can be used as an indicator of the landscape's aesthetic elements composition [44]. Regarding integrity, there is a relative lack of research on the evaluation index system for the NWHS's integrity conservation, mainly focusing on the evaluation studies of the integrity of cultural heritage landscapes [39, 45, 46]. Studies have been constructed the NWHS's integrity conservation index system, mainly from three dimensions of species integrity, ecological integrity, and landscape integrity to assess the status of NWHS's integrity conservation. Our study refers to the existing research results [37, 38, 47–49], combing with the actual sample area, this section mainly assesses the KWHS's integrity conservation status through landscape integrity and five indicators of landscape fragmentation, landscape dominance, landscape separation, landscape degradation, and the richness of landscape beauty are selected as the basis for evaluating the WHS's integrity conservation status.

(2) Buffer zone's tourism industry development evaluation index system

There are more studies on the evaluation of tourism industry development benefits, drawing on relevant research results [50–54], based on the current situation of tourism industry development in the study area, the evaluation index system of tourism industry development in the buffer zone covering 12 measurement indicators including tourism resources, tourism infrastructure, tourism management and services, tourism benefits, and tourism market potential is constructed in five dimensions (Table 2).

According to the scientific and representative principles of indicator selection, combined with the unique geographical environment of KWHS, tourism resources include not only natural ecological resources but also consider cultural festivals and events of ethnic minorities as well as intangible cultural heritage [55]. Road mileage, number of agritainment/hotels/B&Bs, and number of beds are critical indicators to measure the tourism infrastructure's level [56, 57], so they are included in the index system. Tourism management and services mainly focus on the quality improvement of tourism employees and government policy support [58, 59]. Tourism benefits are mainly considered through social and economic benefits [60, 61]. In addition, tourism market potential broadly refers to a destination's potential to attract tourists [62, 63], a significant reference value for formulating tourism development strategies, expanding tourism markets, and attracting investment. Given that the life cycle of the tourist destinations in the study area is all in the development stage, the future direction needs to consider the tourism market potential as a measure.

Table 2 Buffer zone's tourism industry development evaluation index system and weights

Dimension	No	Indicator items	Unit	Indicator definition	Indicator properties	Weight
Tourism resources	T1	Number of tourism resources	Individual	Resource abundance and attractiveness of tourist destinations	+	0.024
	T2	Number of national/provincial/county-level intangible cultural heritage	Events		+	0.134
	T3	Number of tourism festivals and events held	Times		+	0.054
Tourism infrastructure	T4	Road mileage	Km	Accessibility of tourist places	+	0.018
	T5	Number of agritainment/hotels/B & Bs	Families	Tourism reception scale and carrying capacity	+	0.093
	T6	Number of beds	Pieces		+	0.184
Tourism management and services	T7	Number of training for tourism employees	Times	Degree of specialization in tourism services	+	0.056
Tourism benefits	T8	Number of tourism employees	People	Tourism social benefits	+	0.104
	T9	Total tourist arrivals	Million people	Tourism economic benefits	+	0.165
	T10	Total tourism income	Billion yuan		+	0.132
Tourism market potential	T11	Average number of days tourists stay	Days	The attractiveness of tourist places	+	0.020
	T12	Tourist awareness of World Heritage Sites	%	Visitors perception of heritage value	+	0.017

Methods

(1) Entropy method

The entropy method is a multi-objective decision analysis means mainly used to evaluate and rank multiple solutions with different attributes. It is based on the information entropy theory, which normalizes the attribute values of each solution, thus eliminating the dimensional and unit differences between different attributes, and then evaluates and ranks each solution comprehensively by calculating entropy values and weights. The entropy method has the advantages of simple calculation, easy operation, and eliminating dimensional and unit differences. This study mainly uses the method to calculate the evaluation indicators' weights of the coupling coordination degree of WHS's OUV conservation and buffer zone's tourism industry development and the comprehensive index of the two subsystems [64]. The specific steps are as follows.

Due to the different units of measurement of each index data, data standardization is carried out by the extreme value method to achieve comparability of each dimensional index data.

$$\text{Positive indicators}: X'_{ij} = \frac{X_{ij} - min(X_{ij})}{max(X_{ij}) - min(X_{ij})} + 0.01$$

$$\text{Negative indicators}: X'_{ij} = \frac{max(X_{ij}) - X_{ij}}{max(X_{ij}) - min(X_{ij})} + 0.01$$

Where X_{ij} denotes the value of the j_{th} evaluation index of the i_{th} tourist scenic area, $\min(X_{ij})$ denotes the minimum value of the j_{th} evaluation index of each tourist scenic area in the study area, and $\max(X_{ij})$ denotes the maximum value of the j_{th} evaluation index in each tourist scenic area.

The indicators' weights of WHS's OUV conservation and buffer zone's tourism industry development are determined by the entropy method, in which the average value is taken for discrete data, and the specific calculation process is as follows.

First, the weight of the j_{th} indicator of the i_{th} scenic area is calculated:

$$Y_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}$$

Then, the entropy value of the j_{th} indicator is calculated as follows:

$$e_i = -k \sum_{i=1}^{m} Y_{ij} ln Y_{ij}$$

Next, the weights of each indicator are calculated:

$$W_j = \frac{1 - e_j}{\sum_{i=1}^{n} 1 - e_j}$$

Finally, the composite index of the i_{th} scenic area is calculated:

$$U_i = \sum_{j=1}^{m} W_j \times X_{ij}$$

where Y_{ij} is the weight of the j_{th} indicator of the i_{th} scenic area, X_{ij} is the value of the j_{th} indicator of the i_{th} scenic area, n represents the number of scenic areas, e_i is the entropy value, ln is the natural logarithm, $k = 1/\ln m$, m represents the sample size, W_j is the indicator weight, and U_i is the comprehensive index. WHS's OUV conservation and buffer zone's tourism industry weights are determined based on the above steps of calculating indicator weights.

(2) Coupling coordination degree model

The coupling coordination degree model is a multi-objective decision analysis method for assessing and analyzing the coupling relationship and coordination degree between multiple factors to achieve coordinated and balanced development of objectives. The model is mainly based on the basic theories and methods of system theory and cybernetics. It represents the interaction and influence between different factors as a mathematical model. Through calculation and optimization, the optimal degree of coordination and equilibrium are obtained [65, 66]. The following are the main calculation steps of the couping coordination degree model.

The coupling formula is used to analyze the interaction of the elements between the two systems of WHS's OUV conservation and buffer zone's tourism industry development, and the coupling degree between the two systems is obtained, namely:

$$C = \left[\frac{A^* B}{\left(\frac{A+B}{2} \right)^2} \right] \frac{1}{2}$$

A represents the total score of WHS's OUV conservation system, and B represents the total score of the buffer zone's tourism industry development system. The coupling degree C takes values between 0 and 1. C = 1 indicates the best coupling degree of the two systems, and the two have reached a positive interactive development. C = 0 indicates the opposite result, the worst coupling degree of the two systems, and the two develop separately without any relationship.

It is difficult to judge the overall relationship between the two systems through the coupling degree alone, and in order to reflect the degree of interaction and

collaboration, it is then necessary to further resolve the coupling coordination degree, namely:

$$D = (C \times T)^{\frac{1}{2}}$$

$$T = \alpha A + \beta B$$

where D denotes the coordination degree of the two systems, α denotes the weight value of the WHS's OUV conservation, and β represents the weight value of the buffer zone's tourism industry development. This study considers that the importance of WH conservation and tourism industry development are equal, so both α and β take the value of 0.5. T is the coupling coordination degree of the two systems, and it ∈ [0–1]. The larger the value, the better the coupling coordination state of the system. The coupling coordination degree level is classified by drawing on relevant studies [67] to provide a basis for coupling coordination state evaluation (Table 3).

(3) Gray correlation analysis

The GCA is a quantitative model that indicates the magnitude of the correlation between 2 series and can reflect the relative changes between factors during the system development [69, 70]. If the two factors change in the same trend, it implies a high correlation between them and vice versa. This method measures the degree of correlation or proximity mainly based on the change dynamics between the parent data column and each sub-data column. Compared with the traditional mathematical statistical analysis methods such as regression analysis, analysis of variance (ANOVA), and principal component analysis, the GCA method is equally applicable to the sample size and the presence or absence of patterns in the samples. It is less computationally intensive and prone to the discrepancy between quantitative analysis results, which makes up for the shortcomings caused by using mathematical-statistical methods for systematic analysis [71]. This study mainly applies this method to identify the main influencing factors of the coupling coordination degree of WHS's OUV conservation and buffer zone's tourism industry development.

The steps of GCA are as follows.

Step 1: Select the reference sequence $X_i = (x_i1, x_i2, x_i3, x_i4, x_i5, x_i6, x_i7 \ldots\ldots)$
Compare the sequence $X_j = (x_j1, x_j2, x_j3, x_j4, x_j5, x_j6, x_j7 \ldots\ldots)$, $j = 1,2,3\ldots,n$.
Step 2: Apply the initial value method to dimensionless the parent and child series to obtain $X'_i = X_i / x_i1 = (x'_i1, x'_i2, \ldots, x'_in)$, $i = 0,1,2,\ldots,m$. $X'_j = X_j / x_j 1 = (x'_j 1, x'_j 2, \ldots, x'_j n)$, $j = 1,2,3\ldots,n$.
Step 3: Find the sequence of maximum and minimum differences. The difference sequence is: $\triangle ij(k) = |x'_i(k) - x'_j(k)|, k = 1,2,\ldots,n$.
The maximum difference is: $M = Max_i Max_k \triangle ij(k)$.
The minimum difference is: $m = Min_i Min_k \triangle ij(k)$.
Step 4: Calculate the correlation coefficients. $r(x_i(k), x_j(k)) = (m + \S M) / (\triangle ij(k) + \S M), \S \in (0, 1), k = 1,2,\ldots,n$, $j = 0,1,2,\ldots,m$. Where § is the resolution factor, often taken as § = 0.5
Step 5: Find the correlation degree. $r(x_i, x_j) = \sum r(x_i(k), x_j(k))$, $j = 0, 1, 2, \ldots, m$.
Step 6: Analyze the results. If $r(x_i, x_j) > r(x_i, x_k) > r(x_i, x_l) > \ldots > r(x_i, x_z)$, it means x_j is better than x_k, x_k is better than x_l, and so on for the rest. Denote $x_j > x_k > \ldots > x_z$, where $x_j > x_k$ indicates that the gray correlation of factor x_j to the reference sequence x_i is greater than x_k. The greater the correlation, the stronger the closeness between the group of factors and the parent factor.

Results

The comprehensive development index

Table 4 and Figs. 4, 5 show that the comprehensive development index of WHS's OUV conservation and buffer zone's tourism development subsystems in the Libo-Huanjiang KWHS are increasing in 2015 and 2020. In 2015, the comprehensive index of the WHS's OUV conservation was ranked as follows: Yao Shan ancient village > Wanmu Meiyuan scenic area > Lianshanwan scenic area. That year, the Mengliu Buyi scenic area was not yet open for operation, so the comprehensive index was not

Table 3 Classification criteria of coupling coordination [67, 68]

D-value interval	Coupling coordination state	D-value interval	Coupling coordination state
0 < D ≤ 0.1	Extreme disorder	0.5 < D ≤ 0.6	Barely coupled coordination
0.1 < D ≤ 0.2	Severe disorder	0.6 < D ≤ 0.7	Primary coupling coordination
0.2 < D ≤ 0.3	Moderate disorder	0.7 < D ≤ 0.8	Intermediate coupling coordination
0.3 < D ≤ 0.4	Mild disorder	0.8 < D ≤ 0.9	Good coupling coordination
0.4 < D ≤ 0.5	Impending disorder	0.9 < D ≤ 1.0	Quality coupling coordination

Table 4 Coupling coordination between KWHS's OUV conservation and buffer zone's tourism industry development

Year	Scenic area	U1	U2	C	T	D
2015	Lianshanwan	0.224	0.175	0.992	0.200	0.445
	Mengliu Buyi	0.000	0.000	0.000	0.000	0.000
	Yao Shan Ancient Village	0.551	0.421	0.991	0.486	0.694
	Wanmu Meiyuan	0.433	0.256	0.966	0.345	0.577
2020	Lianshanwan	0.224	0.380	0.966	0.302	0.540
	Mengliu Buyi	0.243	0.496	0.940	0.370	0.589
	Yao Shan Ancient Village	0.627	0.687	0.999	0.657	0.810
	Wanmu Meiyuan	0.459	0.282	0.971	0.370	0.600

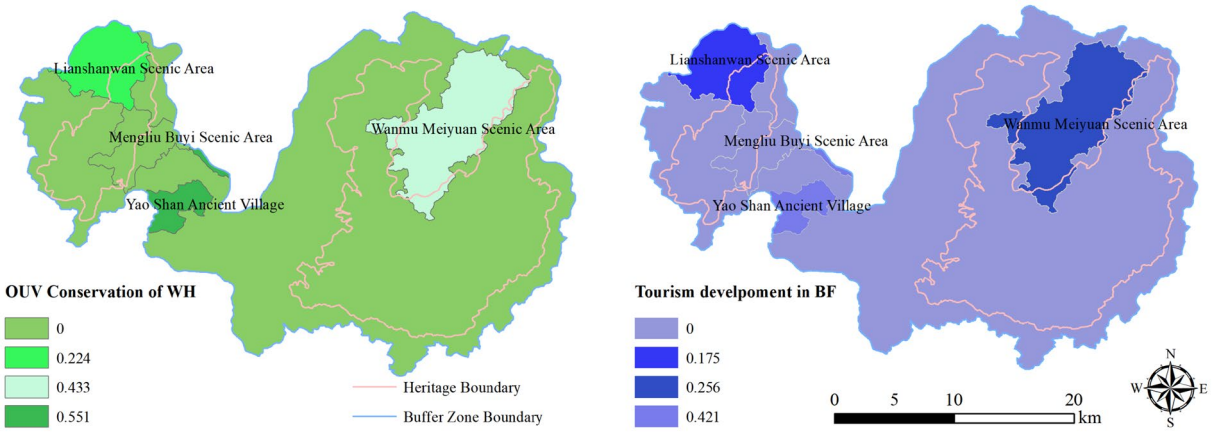

Fig.4 KWHS's OUV conservation and buffer zone's tourism industry comprehensive development index 2015

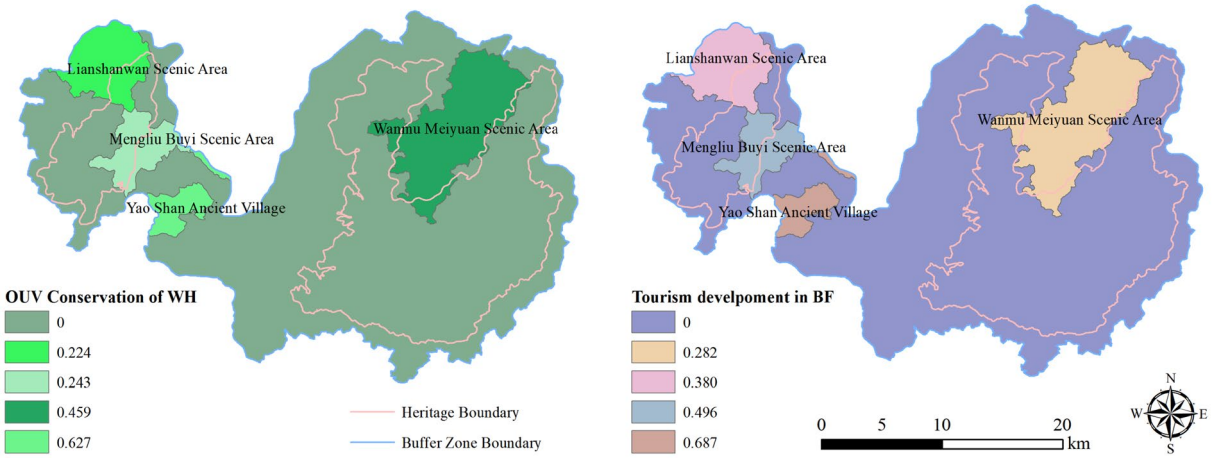

Fig.5 KWHS's OUV conservation and buffer zone's tourism industry comprehensive development index in 2020

calculated. Regarding the buffer's zone tourism industry development index, Yao Shan ancient village > Wanmu Meiyuan scenic area > Lianshanwan scenic area. In 2020, the comprehensive ranking of WHS's OUV conservation was: Yao Shan ancient village > Wanmu Meiyuan scenic area > Mengliu Buyi scenic area > Lianshanwan scenic area

(Fig. 6). As far as the buffer zone's tourism industry development index, Yao Shan ancient village > Mengliu Buyi scenic area > Lianshanwan scenic area > Wanmu Meiyuan scenic area.

The coupling coordination degree

The mean value of the coupling coordination degree in the study area increased from 0.572 in 2015 to 0.635 in 2020 and changed from a barely coupled coordination state to primary coupling coordination (Fig. 7). Compared with 2015, the coupling coordination degree of WHS's OUV conservation and buffer zone's tourism industry development in 2020 is rising. In 2015, the coupling coordination degree of the three scenic areas in the Libo-Huanjiang KWHS was, in order of magnitude, Yao Shan Ancient Village > Wanmu Meiyuan > Lian shanwan. In 2020, the development of the emerging scenic area Mengliu Buyi exceeded that of Lian shanwan, Yao Shan Ancient Village > Wanmu Meiyuan > Mengliu Buyi > Lianshanwan (Fig. 8). Mengliu Buyi scenic area has the most

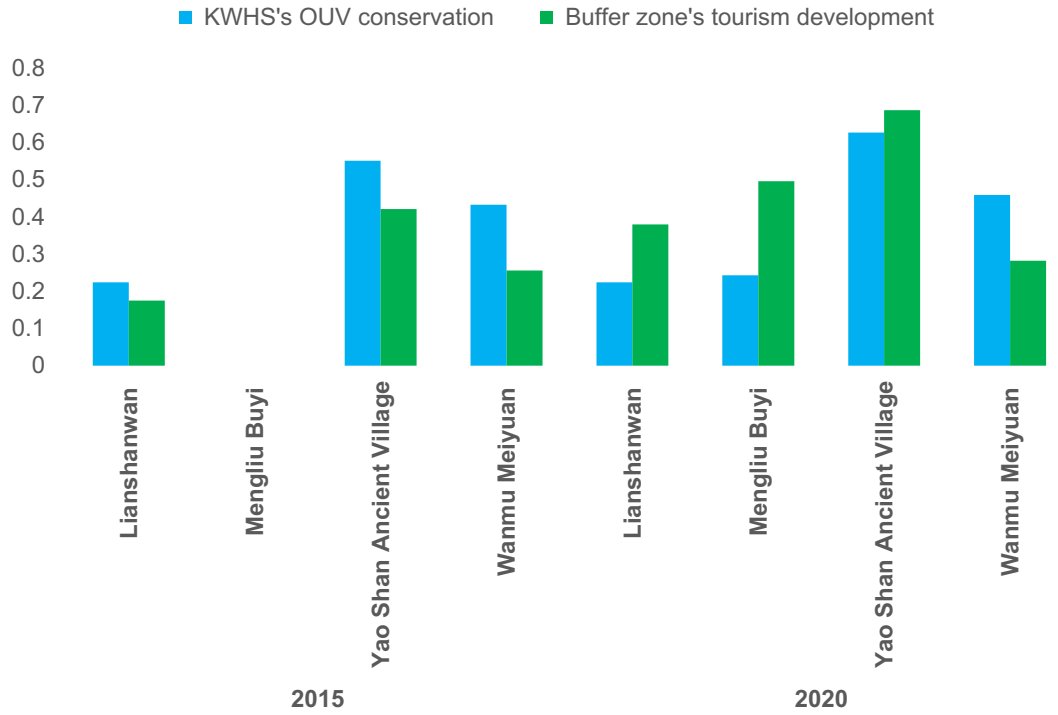

Fig.6 Trends in the comprehensive development index of the two subsystems of WHS's OUV conservation and buffer zone's tourism development

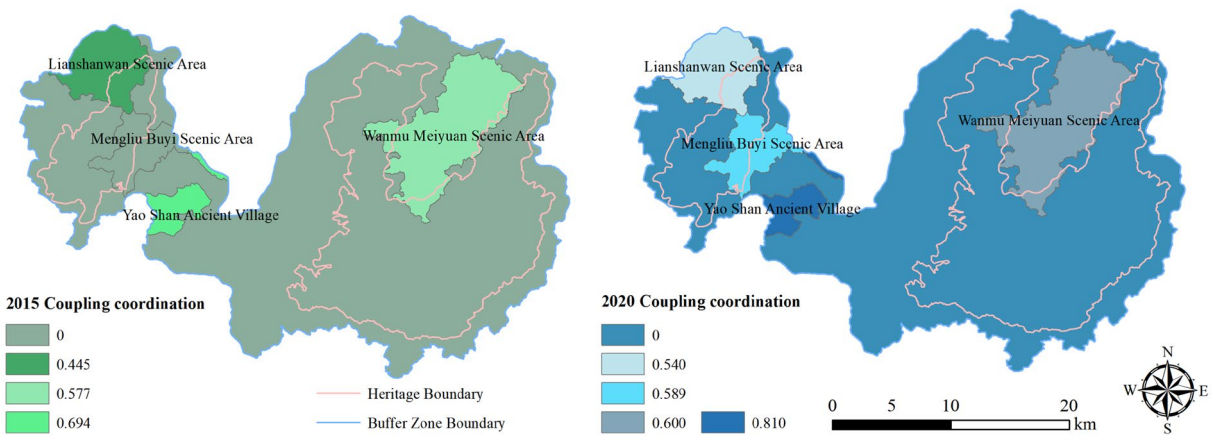

Fig.7 Coupling coordination between WHS's OUV conservation and buffer zone's tourism development in 2015 and 2020

significant growth in coupling coordination. Yao Shan Ancient Village maintains the highest level and has changed from the primary coupling coordination state to the excellent one. The coupling coordination degree of the Wanmu Meiyuan scenic area is relatively stable, and Lianshanwan scenic area rises from a state of impending disorder to barely coupled coordination. After Mengliu Buyi scenic area was completed and opened in 2016, the tourism accommodation and catering industry gradually developed, and the coupling coordination degree was 0.589 in 2020, which was barely coupled.

Main influencing factors of coupling coordination

Many factors influence the coupling coordination degree of WHS conservation and tourism development. Given the accessibility and representativeness of indicator data, referring to the relevant research results [53, 68, 72], combined with the actual situation of the study area, the NDVI (X1), the rocky desertification area(X2), the degree of landscape dominance(X3), the number of government documents supporting tourism development(X4), the number of agritainment/hotels/B&Bs(X5), the residents' support(X6), the tourists' satisfaction(X7), the educational level of the tourism practitioners(X8), the total tourism income(X9), and the total tourism arrivals(X10) are selected as the independent variables in the following aspects: ecological resources, policy drivers, social facilitators, and economy drivers.

The correlations of each influencing factor with the coupling coordination degree of Libo-Huanjiang KWHS conservation and tourism development ranged from [0.4 to 0.7] (Table 5), with a minimum value of 0.463 and the maximum value of 0.673. It indicates that the interaction strength between each factor and the coupling coordination degree was enormous and had a high degree of correlation. From the average values of the correlation degrees of the influencing factors in the four-dimensional layers, the economic drivers significantly influence the coupling coordination degree of the two systems, followed by ecological resources, policy drivers, and social facilitators. As the correlation values, the magnitude of the correlation between each indicator and the coupling coordination degree is in the following order: the NDVI (0.673), the degree of landscape dominance (0.621), the total tourism income (0.620), the total tourism arrivals (0.588), the number of government documents supporting tourism development (0.579), the residents' support (0.544), the rocky desertification area (0.512), the number of agritainment/hotels/B&Bs (0.507), the tourists' satisfaction (0.498), and the educational level of the tourism practitioners (0.463).

Discussion and conclusion

Discussion

Synergistic Mechanism of KWHS's OUV Conservation and Buffer Zone's Tourism Industry Development

Consistent with the results of existing studies [68, 73, 74], the coupling coordination degree between KWHS's OUV conservation and the buffer zone's tourism industry development is mainly influenced by the combined effect of the four factors: social facilitators, policy drivers, economic drivers, and ecological resource factors (Fig. 9). The difference lies in the unique geographical environment of karst, and its fragile environmental substrate

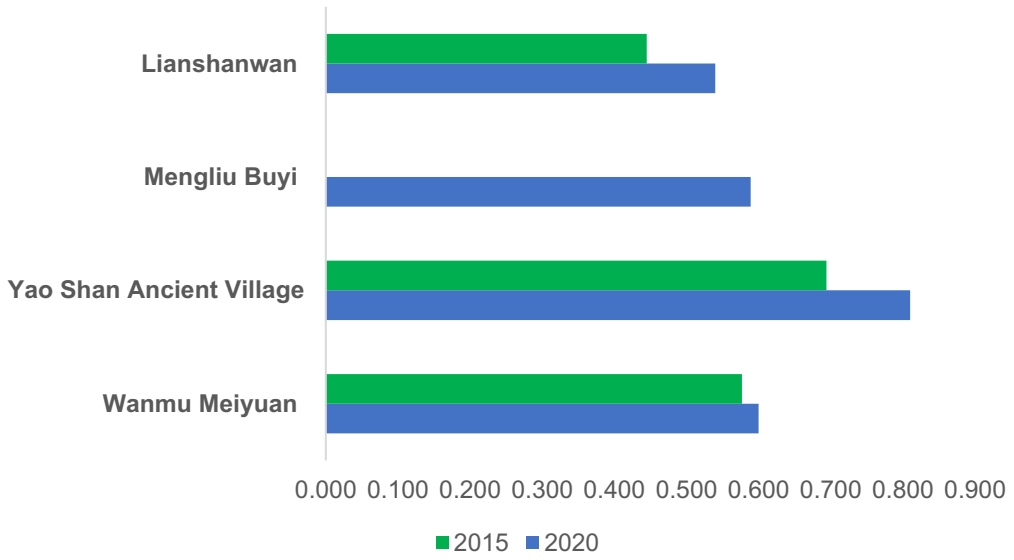

Fig.8 Trends in the coupling coordination degree of the two subsystems of KWHS's OUV conservation and buffer zone's tourism development

Table 5 Influencing factors of coupling coordination of Libo-Huanjiang KWHS's OUV conservation and buffer zone's tourism development

Influencing factors	Evaluation indicators	Gray correlation	Mean value	Order
Ecological resource	NDVI	0.673	0.602	2
	Rocky desertification area	0.512		
	Degree of landscape dominance	0.621		
Policy drivers	Number of government documents supporting tourism development	0.579	0.543	3
	Number of agritainment/hotels/B&Bs	0.507		
Social facilitators	Residents' support	0.544	0.502	4
	Tourists' satisfaction	0.498		
	Educational level of the tourism practitioners	0.463		
Economic drivers	Total tourism income	0.620	0.612	1
	Total tourism arrivals	0.604		

and the rocky desertification degree is a significant factor. The particular geomorphic type of karst areas, with more severe soil erosion and rocky desertification [75], seriously challenge WH conservation and tourism industry development. While the increase of rocky desertification areas intensifies the human-land conflict, it also adversely affects the integrity and aesthetic value of karst landscapes, reducing the attractiveness of tourism resources and limiting the future development potential of regional tourism. Taking into full consideration the negative impact of the rocky desertification phenomenon on the KWHS's OUV conservation and tourism industry

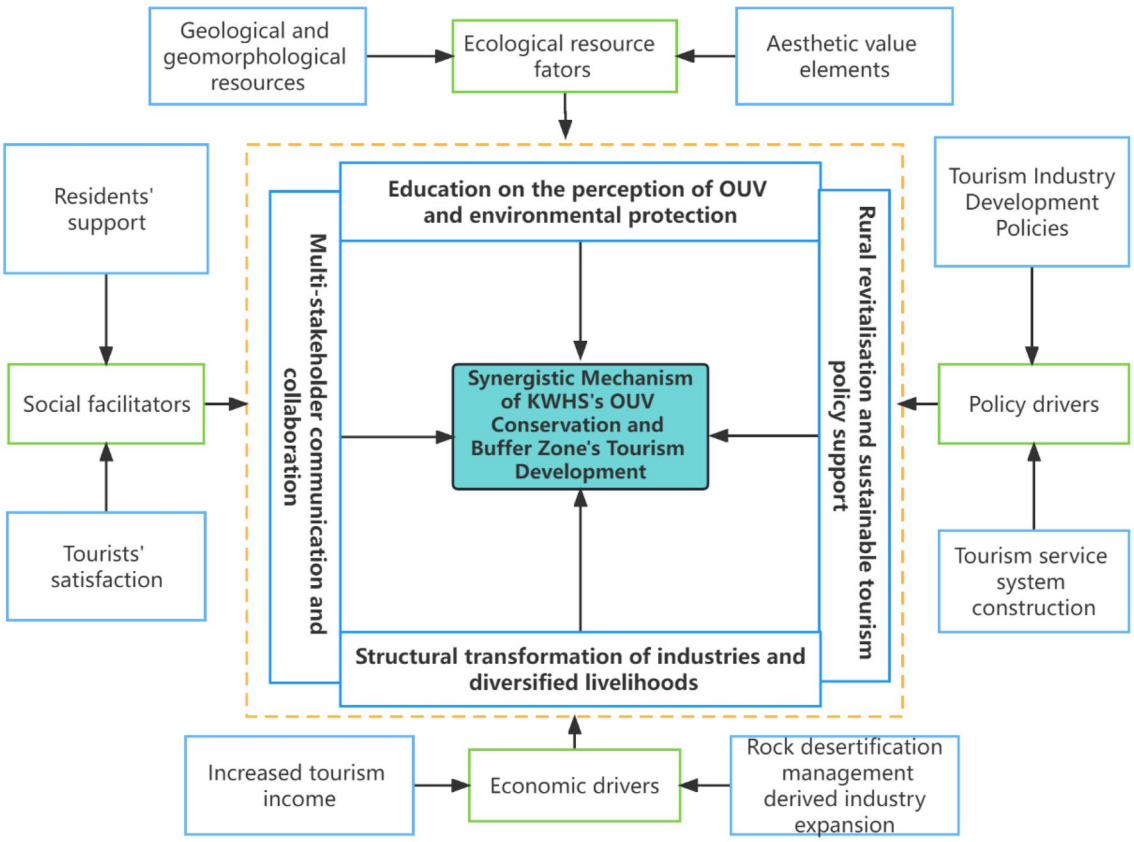

Fig.9 Synergistic mechanism of KWHS's OUV conservation and buffer zone's tourism industry development

development, taking adequate measures to reduce the rocky desertification area and mitigate the degree of it is an inevitable choice to realize the synergy between WH conservation and tourism development. This study focuses on the above four levels of major influencing factors, the actual WH conservation situation, and the four tourism scenic areas development in Libo-Huanjiang KWHS combined to analyze the causes of the differences in the coupling coordination of KWHS's OUV conservation and buffer zone's tourism industry development.

Regarding the policy drivers, policy support plays a vital role in the synergistic mechanism of KWHS's OUV conservation and buffer zone's tourism industry development. In rural revitalization and sustainable tourism development strategies, the Chinese government promotes the synergy between KWHS's OUV conservation and buffer zone's tourism industry development by formulating conservation policies and management measures, providing financial support to implement tourism industry development policies, and constructing a tourism service system. Due to the fragile ecological background caused by rocky desertification, the Yao Shan Ancient Village was profoundly impoverished before poverty eradication. With the promotion of poverty eradication and rural strategy, it received more policy support. The benefits of tourism poverty alleviation are apparent with the cooperation of multiple stakeholders, such as the government, local communities, and tourism enterprises. The livelihoods source is expanded, further promoting community participation and thus enhancing the effectiveness of WH conservation and management. As a result, WH conservation and tourism development are well coupled and coordinated, ranking relatively high among scenic areas and showing a positive trend. Under the existing policy and management system, the ecological conservation effect of the integrated heritage management system needs to be further explored in the future [76].

Economic drivers are essential in the synergistic mechanism of KWHS's OUV conservation and buffer zone's tourism industry development. Expanding industries derived from KWHS's rocky desertification management and increasing tourism income are key. Broadening their livelihood channels is vital for the rural residents living in the KWHSs to protect and promote sustainable development. By improving income sources and broadening livelihood channels, rural residents can reduce the livelihood pressure caused by KWHS conservation restrictions and reduce the possibility of relying on undesirable environmental practices such as traditional farming and tree cutting. Through expanding farmers' livelihood channels, more rural residents can be attracted to participate in the conservation and tourism development of KWHSs. Increasing their participation and responsibility sense for environmental protection can help farmers change their traditional production methods, which are overly dependent on natural resources, and adopt more environmentally friendly and sustainable agricultural production methods to promote ecological conservation and reduce damage to karst landscapes. Thus, by fostering income growth and livelihood diversification for rural residents, the sustainable development and ecological conservation of the KWHSs can be promoted, achieving multiple wins for the economy, society, and the environment, promoting the value of ecosystem services of KWHS [77]. Most residents of the Mengliu Buyi scenic area have moved out from the core heritage area, and the government has been supporting the residents to move out for business and employment. Because the town is newly built, its cultural background and attractiveness need to be improved, and its resource endowment is not as high as the Yao Shan Ancient Village's. Accordingly,the coupling coordination between heritage conservation and tourism industry development is not as high as that of other scenic areas. However, residents participate in tourism development through the hospitality industries development, such as specialty restaurants, B&B, and farmhouses. Improving economic income promotes local heritage conservation responsibility and community participation, and the economic drive plays a prominent role.

Regarding social facilitators, the residents' support and the tourists' satisfaction are essential drivers for achieving synergy between KWHS conservation and tourism development. As important stakeholders in WH conservation and tourism development, residents can promote community involvement and enhance the vitality of WH conservation when they have a supportive attitude. Tourists' satisfaction is one of the crucial indicators for successful tourism industry development, and it is directly related to the tourism services quality. Tourism services such as environment, transportation, and accommodation in scenic areas directly impact tourists' satisfaction, so the synergy of KWHS's OUV conservation and buffer zone's tourism industry development requires simultaneous environmental protection and tourism service system construction. Multi-stakeholder cooperation can also promote KWHS's tourism development. For example, the government can provide financial and policy support to guide enterprises that can invest in building tourism facilities, residents can provide services such as accommodation and tour guides, and tourists can enjoy the beautiful scenery and rich cultural experiences.

As ecological resource factors, geological and geomorphological resources and aesthetic value elements are the main constituents. Behind these valuable resources, OUV perceptions and environmental responsibility and behavior are crucial in driving the synergistic mechanism

of KWHS's OUV conservation and buffer zone's tourism industry development. Firstly, OUV conservation perception can help people recognize the uniqueness, fragility, and importance of karst landscapes, thus raising awareness of environmental protection and avoiding damage to heritage due to human activities. Secondly, heritage value perception can stimulate local communities to participate in WH conservation and tourism development, so they can recognize their regional characteristics and cultural values, thus forming a sense of shared responsibility and identity for KWHS. In addition, it is indispensable to strengthen the ecological resource protection and management techniques of KWHSs, such as remote sensing monitoring of the impacts of human tourism activities on NDVI and carbon emissions, taking into account existing research [78–80].

Strategies for synergistic enhancement of future KWHS's OUV conservation and buffer zone's tourism industry development

The synergy between the two subsystems of WHS' OUV conservation and buffer zone's tourism development reflects the symbiotic relationship between WH conservation and tourism industry development. It is a critical path to achieving sustainable tourism development. However, although the coupling coordination between WH conservation and tourism industry development has been continuously improved and enhanced, the best coupling coordination state between the two subsystems of Libo-Huanjiang KWHS is only the primary coupling coordination, and there is still much room for improvement compared to the quality coupling coordination state. Achieving the synergy between WH conservation and tourism industry development is a long-term and complex process. The experiences and practices among different regions show that more comprehensive and scientific policies and measures must be formulated. The balance and coordination between the WHS's OUV conservation and buffer zone's tourism development need to be further promoted to strengthen the overall planning and management of WH conservation and tourism industry development to enhance the coupling coordination degree.

(1) Policy drivers

Formulate a comprehensive plan

The government should formulate a comprehensive plan covering NWHS conservation, tourism development, and community development to establish coordinated development goals and objectives for the WH conservation and tourism industry development. The program should fully consider the ecological base characteristics of the WHS, the development needs of community residents, and the actual conservation requirements, consider the impact and demand of tourism in conjunction with the scale of human activities resulting from tourism development, and promote the organic integration of WH conservation and tourism development with the sustainable development goal.

Strengthen regulation and enforcement

The government can focus on strengthening the regulation and enforcement of tourism, establishing a sound regulatory mechanism and enforcement system for tourism development, preventing unreasonable development and irreversible damage to the fragile ecological environment of WHSs, and protecting the NWHSs in a top-down manner. At the same time, we should strengthen education and guidance for tourists in different ways to promote civilized tourism and enhance tourists' WH conservation awareness.

(2) Ecological resources factors

Encourage sustainable tourism

Sustainable tourism is an effective path to protect NWHSs and promote healthy tourism development. Based on the actual human and natural environment of the community's natural resource vulnerability and lagging economic development, the government can combine the rules and regulations of the UN Sustainable Development Goals. It supports the tourism industry in taking the lead in adopting various green measures by adhering to the green development concept to realize the development path shift of community economic and tourism development with low-carbon tourism and eco-tourism.

Strengthen advocacy training

The lack of OUV understanding may give rise to conservation and management problems and disconnection between tourism products and heritage values. Therefore, to make more stakeholders understand the scientific and aesthetic values inherent in KWHSs, on-site public welfare training classes with various forms and contents can be carried out within the WHSs' territory with the theme of heritage conservation and scientific management and through the state of knowledge to the countryside and in-depth grassroots. We can disseminate the KWHSs' value to the grassroots and rural communities through knowledge dissemination. Training and publicity are practical means to enhance the awareness of different stakeholders about the WHSs' OUV and its conservation and management, as well as to improve the understanding of management and services at the grassroots level and in the communities. Also, it is necessary to strengthen the stakeholders' sense of ownership, transform the heritage conservation function originally

belonging to the government into an issue of concern to every stakeholder group and every KWHS resident, and put themselves into the WH conservation activities.

(3) Economic drivers

Establish a diversified tourism industry

Local governments and communities should take advantage of tourism development opportunities to extend tourism forms and economic drive by exogenous stimulation of tourism, including different aspects of tourism services, cultural experiences, agricultural tourism, eco-tourism, etc. To reduce dependence on a single tourism project, extend the employment types and livelihood channels for community residents, and increase the tourism industry's resilience and the residents' dependence degree. At the same time, they are relying on the community's minority culture and heterogeneous natural resources through the integration of cultural tourism and agricultural tourism. Moreover, other forms of local conditions to develop practical off-season tourism development measures to reduce the seasonal pressure on tourism and promote the stable tourism development.

Improve the ecological compensation mechanism

Based on the background of the ecological vulnerability of the regional karst system, establishing and improving ecological compensation mechanisms in the buffer zone is a blatant promotion for protecting NWHSs and tourism development. Specifically, firstly, the economic compensation for the buffer zone can prompt local governments and enterprises to take measures to protect the ecological environment and ensure the ecosystem balance in the KWHSs. Secondly, the reward and punishment system of the ecological compensation mechanism can encourage KWHSs to implement green tourism development and improve the environmental friendliness of tourism. Thirdly, the secondary transfer of compensation funds can help improve residents' living conditions and help achieve economic and ecological benefits in the community. Finally, an effective ecological compensation mechanism can increase the importance of environmental protection by local governments, enterprises, and residents for promoting the WHSs' sustainable development.

Innovative tourism products and services

Relying on the scientific values of karst topography and the evolution of the karst, we will focus on the excavation of traditional culture and intangible cultural heritage of ethnic minorities. It is developing tourism products and derivative services that match the humanities characteristics and natural environment of the KWHSs, meeting the differentiated tourists' recreation perceptions in the process of tourism, and increasing the community income through tourism products. Derivative services will help to achieve the goal of promoting the development of WH conservation through tourism. The purpose of developing KWHS conservation is to promote tourism.

(4) Social facilitators

Strengthening WH education and training

Strengthening education and training for the NWH conservation and enhancing people's conservation awareness and skills will help improve the quality and effectiveness of conservation efforts. In addition, tourism industry practitioners should improve their service quality and attention to sustainable development by receiving professional training.

Enhance community participation

Community residents can be regarded as the human subjects of WHSs. Community management mode is encouraged to change from top-down management to horizontal governance so that the residents can form a deep bond with the NWHSs conservation in tourism development through community participation and gain tangible benefits through the stakeholders' role. Along with the enhancement of local attachment and cultural self-awareness, it is conducive for community members to actively participate in conservation, management, and promotion activities, contributing to the WNHSs conservation and tourism development.

Strengthening stakeholder collaboration

Stakeholders are generally regarded as a social facilitator. In KWHS conservation and tourism development, realizing different goals requires stakeholders' joint efforts and collaboration. First, stakeholder collaboration can enable resource sharing and efficient implementation of conservation and development projects. Second, in the planning and decision-making process, the practical cooperation of different stakeholders can ensure the balance of other points of interest while formulating both feasible and long-term tourism development strategies. Third, an effective collaboration mechanism can promote the stakeholder's participation in the monitoring and evaluation process of tourism development projects so that problems can be identified and measures can be taken through regular evaluation and adjustment to ensure the sustainable tourism development in the buffer zone of the KWHS. Fourth, the communication and cooperation among stakeholders can provide valuable feedback for tourism projects, which helps to improve and perfect WH conservation projects and tourism development, thus ensuring that the tourism industry in the KWHS's buffer zone always respects and protects the natural environment and OUV in the development process.

Conclusion

The study takes Libo-Huanjiang KWHS and its buffer zone as the research object. It constructs a coupling coordination evaluation index system for KWHS' OUV conservation and buffer zone's tourism industry development. Firstly, it determines the weights of each indicator by the entropy method and measures the comprehensive development level of the two subsystems. Secondly, it evaluates the synergistic state of KWHS's OUV conservation and buffer zone's tourism industry development with the help of coupling coordination degree model. Finally, the GCA method is used to determine the main factors affecting the synergy of the two, and the main driving mechanisms and enhancement strategies are summarized and refined.

1. The comprehensive development index of the two subsystems of Libo-Huanjiang KWHS's OUV conservation and buffer zone's tourism development is on an increasing trend in 2015 and 2020, reflecting that while the study area is concerned with WH conservation, it also focuses on promoting local socioeconomic development through tourism development to feed WH conservation better.
2. Synergy exists between WHS's OUV conservation and buffer zone's tourism industry development in the study area and is moving towards greater harmonization. The integration degree of WH conservation and tourism industry is improved to a certain extent in five years. The KWHS's OUV conservation and buffer zone's tourism development toward better coupling coordination state. The mean value of coupling coordination in the Libo-Huanjiang KWHS increased from 0.572 in 2015 to 0.635 in 2020. It overall changed from a state of barely coupled coordination to primary coupling coordination, where Yao Shan Ancient Village (0.810) > Wanmu Meiyuan (0.600) > Mengliu Buyi (0.589) > Lianshanwan (0.540). Attempts to define elements of heritage value characterization, focusing on the linkage between OUV conservation and the tourism industry to explore the synergistic mechanism, enrich the current research on the conservation path of heritage tourism sites' OUV, which is conducive to exploring the way of WH conservation and tourism development that is aligned with both OUV and local reality.
3. Factors at four-dimensional levels of ecological resource, policy diver, economic diver, and social facilitator are crucial in coordinating the two systems of KWHS's OUV conservation and buffer zone's tourism industry development. The main driving factors are NDVI, landscape dominance, government support for tourism development, tourists' satisfaction, and residents' support. Economic drivers are more vital in Libo-Huanjiang KWHS than policy factors. Different scenic areas in the buffer zone are influenced by various policy drivers, thus leading to differences and changes in the coupling coordination degree. The future improvement of the WH conservation coordination and tourism development needs to focus on developing comprehensive planning, strengthening regulation and enforcement, encouraging sustainable tourism, establishing diversified tourism industries, enhancing WH education and training, improving community participation, and maintaining stakeholder collaboration to carry out localized WH conservation efforts.

Abbreviations

WHL	World Heritage list
OUV	Outstanding Universal value
WH	World Heritage
WHS	World Heritage site
NWH	Natural World Heritage
NWHS	Natural World Heritage site
KWHS	Karst World Heritage site
WHC	World Heritage Committee
UN	United Nations
NDVI	Normalized difference vegetation index
B&B	Bed and breakfast
GIS	Geographic information system
GCA	Gray correlation analysis
ANOVA	Analysis of variance

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Author contributions

JZ and KNX developed the concept of this work. JZ wrote the manuscript, KNX and ZJL reviewed the whole text and made comments and suggestions to improve it. LXH, NZ, XYG and DC were involved in collecting data and producing some of the images. All authors read and approved the final manuscript.

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Availability of data and materials

Data will be made available on request.

Declarations

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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