

REVIEW

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Natural world heritage conservation and tourism: a review

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Abstract

The trade-off and synergy between heritage conservation and tourism has become the focus of natural world heritage research. To gain a better understanding of the global researches on natural World Heritage conservation and tourism, we comprehensively reviewed relevant peer-reviewed research literature based on Web of Science (WOS) and China National Knowledge Infrastructure (CNKI). We find that (1) the theoretical research of natural heritage conservation and tourism has gone through a process from emphasizing the protection of heritage value to pursuing the synergy of heritage protection and tourism development; (2) the main research methods include investigation research methods, indirect research methods and experimental research methods; (3) "3S" technology (remote sensing, geographic information system, global positioning system), three-dimensional laser scanning technology, virtual reality (VR) technology, augmented reality (AR) technology, holographic projection technology and other modern technological means are applied to the protection and tourism development of natural properties; (4) the common coordinated development models include ecological science tourism, community participation in tourism, ecological compensation model, world heritage—buffer zone—surrounding areas coordinated protection model and so on. We analyzed the research progresses through (1) the theories proposed in the literature, (2) the main methods applied to address the issues on natural heritage conservation and tourism, (3) the technologies applied in the researches and (4) the coordinated models of heritage conservation and tourism. Furthermore, we put forward the following research prospects: (1) systematically explore the conservation methods and theories based on world heritage criteria; (2) formulate corresponding conservation systems and ecological restoration standards for different types of world heritage; (3) give full play to the complementary advantages of various research methods and reveal the mutual feedback mechanism between tourism and heritage conservation; (4) develop ecological restoration technology based on biodiversity restoration, establish radial ecological corridor, and expand the benign ecological environment of the properties to wider periphery; (5) build ecological compensation development models based on the perspective of heritage tourism and value realization of world heritage.

Keywords Natural world heritage, Ecological tourism, Conservation, Collaborative research, Literature review, Protected area

Introduction

Natural world heritage sites are natural landscapes recognized by the UNESCO World Heritage Committee and inscribed on the World Heritage List, with Outstanding Universal Value (OUV) such as containing aesthetic importance, representing major stages of earth's history, representing significant on-going ecological and biological processes, containing the most important and significant natural habitats for in-situ conservation of biological

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diversity [1]. As the type of protected area with the highest and most representative OUV in the world [2, 3], how to pass on the value of the world heritage through heritage display and solve the livelihood problem of the residents is a problem worthy of study.

For many years after the birth of Convention concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention) in 1972, conservation was the sole goal of World Heritage, but as time passed, World Heritage gradually established its status as an important tourist destination, and UNESCO's policy on World Heritage also no longer limited to conservation, but also sustainable tourism [4]. The purpose of heritage conservation is to preserve their OUV and pass them on intact to the next generation [5]. The ideal goal of heritage tourism is to awaken people's attention and respect for cultural history and natural landscapes through tourism activities [6]. Therefore, heritage tourism is the best way to give full play to the functions of natural World Heritage, which can promote scientific research, social supervision and financial support for heritage conservation, and is also a sustainable way for the social and economic development of natural heritage sites [7]. However, the unreasonable utilization of tourism resources will lead to the imbalance of resource supply and demand [8]. In its World Heritage Outlook report, the International Union for Conservation of Nature (IUCN) pointed out that tourism impact has always been in the top three threats [9–11]. How to coordinate the relationship between World Heritage conservation and tourism development has always been a hot issue of academic and government attention [12, 13].

Currently, international organizations and scholars have carried out a series of fruitful studies, covering the impact of tourism activities on heritage conservation, community residents' perception of heritage tourism, and changes in the landscape pattern. Among them, the community and tourists are the focus of related research. Natural World Heritage sites are often very fragile. To maintain a certain balance between social ecosystems and natural ecosystems, it is important not only to minimize human disturbance, but also to make tourists aware of the need to protect the OUV and to participate in the conservation and promotion of heritage value [14]. The sustainability of community livelihoods is the premise of World Heritage conservation, and ecotourism is an important form of enriching the livelihoods of community residents in heritage sites [15]. Locally-driven responsible and sustainable tourism management in and around World Heritage properties can complement other sources of growth, so as to promote economic diversification between tourism and non-tourism activities. This will strengthen social and economic resilience

in a way that also helps protect the OUV of properties [16]. In addition, some scholars have also paid attention to the impact of tourism activities on the biodiversity [17], water [18], geology and landform [19, 20] of natural World Heritage sites.

Meanwhile, scholars have systematically sorted out and summarized the concept, research methods, authenticity and integrity, heritage management, stakeholders, knowledge systems and development trends of heritage tourism from the theoretical level [21–25]. It is worth noting that the research on tourism and conservation of natural World Heritage is a field in which natural ecosystems and social ecosystems are highly intertwined, involving tourism, aesthetics, geomorphology, ecology, geography and other disciplines. There are research bottlenecks in terms of theory, method, technology, model and so on. The existing articles indicate that the studies on the conservation and tourism of natural World Heritage start from the theoretical perspective, and most of them are macro-heritage studies, rarely distinguishing between cultural heritage and natural heritage. The research methods are mainly based on questionnaire survey and interview with tourists and community residents, lacking the application of experimental monitoring methods. The comprehensive understanding of related research has not been fully formed in the academic circles.

To gain a comprehensive understanding of natural heritage protection and tourism since the World Heritage Convention came into being half a century ago, we reviewed the relevant research progress of theories, methods, technologies and models from the perspective of the systematic chain from theoretical understanding to practical application, and proposed future research directions based on the research progress. The theory about natural World Heritage conservation and tourism is the understanding of objective things and their laws, and the related theory research will help us understand the law of this study field. The generation and development of the methods depends on our theoretical understanding of related researches. Through the analysis of the methods, it will help to promote our theoretical understanding, and also better guide us to use technical means to improve the heritage protection and tourism sustainability in natural sites. Conducting the analysis of related technologies can effectively promote us to adjust the methods of recognizing natural World Heritage conservation and tourism in practice, thus promoting the development of theory. Meanwhile, technology is a practical means to accelerate the promotion of heritage protection and sustainable tourism. The analysis of related models in this study is the summary of different development paths and practical experiences, reflecting the development models of natural sites in different scenarios. It is

expected to provide references for more natural World Heritage sites in the cooperation between heritage protection and tourism.

Materials and methods

The acquisition of journal papers was conducted based on the available databases including Web of Science (WOS) (<https://www.webofscience.com>) and China National Knowledge Infrastructure (CNKI) (<https://www.cnki.net/>). To obtain higher quality and more representative articles, we restricted the databases of paper sources during retrieval. In WOS, Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI) and Emerging Sources Citation Index (ESCI) were taken as the retrieval databases. In CNKI, Science Citation Index (SCI), the Engineering Index (EI), Chinese Social Sciences Citation Index (CSSCI), Chinese Science Citation Database (CSCD) source journals were taken as retrieval databases. Acknowledging that the literature on both heritage conservation and tourism in natural World Heritage sites is sparse and our desire to get a wider review, we also included different synonyms. The search item was “them”. The first search terms was set as “natural heritage”, the second search term was set as “tourism”, and the third terms were set as “conservation” or “protection” or “preservation”. The deadline set for our retrieval was December 31, 2022 (Fig. 1).

Firstly, based on the search conditions above, 610 and 144 articles were found in WOS and CNKI, respectively. Then, we set two inclusion criteria: (1) the research them must include both heritage tourism and conservation; (2) the research object must be natural World Heritage site(s) or mixed site(s). Articles without heritage protection or heritage tourism are discarded. Researches about cultural World Heritage, built heritage, intangible cultural heritage, national parks, geoparks, natural reserves

or other contents without natural World Heritage are also considered irrelevant and excluded. We decide whether an article meets our inclusion criteria by reading the title, abstract, keywords, and even the full text of the article. After screening based on our inclusion criteria and deduplication, 115 and 85 related articles were obtained from WOS and CNKI, respectively. In term of languages, the final obtained articles include Chinese (85 articles), Croatian (1 articles), English (101 articles), Portuguese (2 articles), Russian (1 articles), Spanish (9 articles), Ukrainian (1 articles).

It is worth noting that the number of search results and the final screening results varied greatly, especially in WOS. This may be because when subject is used as the search term in WOS, any one or more of the titles, abstracts, author keywords and keywords plus contain natural, heritage, conservation or protection or preservation and tourism articles will be retrieved. As a result, there are some documents that are not related to the research topic, such as cultural heritage, protected areas, national parks, natural resources, in the search results.

Research progress

Theories

The theoretical research on natural heritage protection and tourism has gone through a process from emphasizing heritage value protection to pursuing synergy between heritage conservation and tourism development.

The theoretical exploration of World Heritage protection started from Operational Guidelines for the Implementation of the World Heritage Convention (Operational Guidelines). It states that cultural properties must meet the conditions of authenticity, and all properties nominated for inscription on the World Heritage List shall satisfy the conditions of integrity [1]. But some scholars believe that the two principles of authenticity

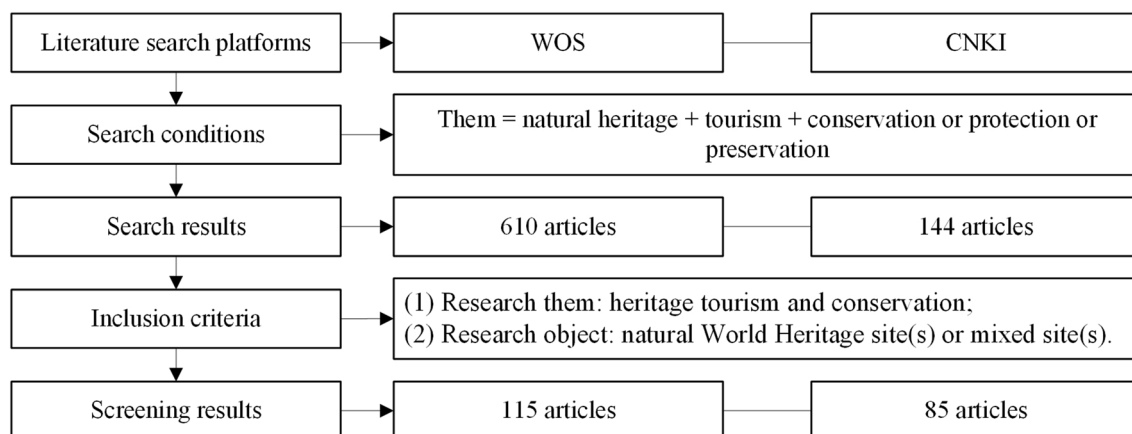


Fig. 1 The process of the literature search and screening

and integrity should not be separated and both natural properties and cultural properties should meet these two principles [26]. Since the number of natural properties is much higher than that of cultural properties, related researches on two principles are mostly focused on cultural properties, while little on natural properties. As an important tool for conservation of properties and then enhance their integrity, as well as create linkages between properties and the wider area that surrounds them [27], buffer zones are also a vital theory to analysis the relationship between heritage protection and sustainable development [28].

With the advancement of researches, scholars have gradually realized that the value display and community development are important ways for the sustainable protection and management of world heritage [29]. Heritage corridor is the product of the joint development and interaction of American greenway movement, scenic road construction and regional heritage conservation concepts [30]. This theory takes into account the balance of linear heritage protection, community economic development and natural ecosystems. It is suitable for linear heritage such as the Silk Road, but not for non-linear heritage. To explore the synergy theory of heritage protection and tourism applicable to a wider range, scholars have carried out research from different perspectives such as natural ecosystems, tourists, and community residents. Moreover, as one of the core theories of tourism geography, tourism man-land relationship theory focuses on the interaction between human tourism activities and geographical environment[31]. It is also an important guiding ideology for the study of sustainable development of natural heritage[32]. Wen [33] proposed to use ecological theory and experience economy theory to stimulate tourists' cognition of heritage value, thereby promoting the coordinated development of protection and tourism in karst world natural heritage sites. In addition, the introduction of symbiosis theory [34], sustainable livelihood framework [35], life cycle assessment theory [36] and other theories have further enriched researches on world heritage conservation and sustainable tourism.

Methods

Based on the data sources, the main research methods used in researches on natural world heritage conservation and tourism can be divided into three categories: investigation research methods, indirect research methods, and experimental research methods. Among them, investigation research methods refer to methods that get data from questionnaires [37], interviews [38], field observations [39] and other similar ways; indirect research methods refer to methods that get data from

websites [40], articles[41, 42], yearbooks [43], institutions [44] and other similar ways; experimental research methods refer to methods that get data through computer experiments such as remote sensing (RS) and geographic information system (GIS) [45], or ground sample monitoring like sample plot [46] and online tracer test [18], or other similar methods. As the most commonly used method for related studies, the first two types of methods are mostly used in humanities research, such as stakeholder attitudes towards heritage conservation and tourism and their influencing factors. The third type of method is mostly used in natural research, such as the impact of heritage tourism on soil, vegetation, and water ecology in heritage sites. Table 1 shows some representative specific methods, data sources, core content and references of these methods.

The vast majority of relevant studies obtain data through questionnaires and interviews with stakeholders such as tourists and residents, as well as in-direct data from websites, reports, institutions and so on. Few scholars obtain data through monitoring experiments or geographic information technology in natural heritage sites. Long-term experimental monitoring research is even more blank. No studies have been found that combined experimental monitoring methods with questionnaire interviews or geographic information technology. This brings great difficulty to the collaborative research and management of natural heritage tourism and protection.

Investigation and research methods used in related researches include in-depth interviews and fieldwork, landscape sensitivity assessment, analytic hierarchy process (AHP), Delphi method, structural equation modeling (SEM), travel cost method, contingent valuation method, perception survey, open-ended interviews, principal component analysis (PCA), system dynamics model, what is not there (WINT) analysis and convergent parallel mixed method. The advantages of these methods are: (1) quantitative analysis of each element can enhance the persuasiveness of the analysis results; (2) it is helpful to find potential relationships between different variables through model analysis; (3) access to deep insights and emotional reflections. The disadvantages are: (1) bias in interpretation of results by investigators and respondents; (2) the acquired data is highly subjective, especially in questionnaires and interviews. These methods are suitable for researches on attitudes, willingness and choices of stakeholders, such as local community and visitors.

Indirect research methods used in related researches include SWOT (strengths, weaknesses, opportunities, threats) analysis, carbon footprint, literature review and expert interview, AHP, fuzzy mathematical methods, official evaluations analysis, panel data analysis, propensity score matching, static model of tourism environment

Table 1 Research methods of natural World Heritage conservation and tourism

Categories	Methods	Data sources	Core contents	References
Investigation research methods	In-depth interviews and fieldwork	Questionnaires responses by residents	Residents' value orientation and attitudes toward heritage tourism.	[37, 38]
	Landscape sensitivity assessment	Questionnaires responses by visitors	The impact of tourism on landscape vision.	[47]
	AHP	Questionnaires responses by stakeholders	The coordinated development mechanism of ecotourism.	[48]
	Delphi method	Questionnaires and telephone interviews with experts	Tourism landscape resource evaluation and zoning protection.	[49]
	SEM	Questionnaires responses by visitors	Tourists' environmental attitudes and environmental behavior tendencies.	[50, 51]
		Questionnaires responses by visitors	How Outstanding Universal Value, service quality and place attachment influences tourist intention towards world heritage conservation.	[52]
		Questionnaires responses by residents	The interaction between residents' participation, tourism perception and their environmental protection awareness.	[53]
		Questionnaires responses by visitors	Willingness to pay for tourists' ecological compensation.	[28]
		Questionnaires responses by residents	The value derived by the local community from world heritage.	[54]
	Ethics matrix approach	In-depth interviews, field observations and questionnaires responses by stakeholders	Ethical boundaries of national park management models to achieve multi-value management of natural heritage sites and deal with conflicting stakeholders.	[55]
	Travel cost method, contingent valuation method	Questionnaires responses by visitors	The value of heritage tourism resources.	[56]
	Perception survey	Questionnaires responses by visitors	The impact of tourist's environmental attitude on their environmental behaviors.	[57, 58]
		Questionnaires responses by residents	The factors that influence the perception of residents' responsibility for the world heritage conservation.	[59, 60]
		Questionnaires responses by visitors	The tourists' modal choice motivation and their willingness to accept regulatory measures.	[61]
	Field observations	Interviews to local tour operators and climbers	The impact assessment of outdoor climbing activities on the geological heritage.	[37]
Open-ended interviews	Questionnaires responses by visitors	The pull and push factors in heritage tourism.	[62]	
PCA	Questionnaires responses by residents	The influence of negative political environment on sustainable tourism.	[63]	
System dynamics model	Questionnaires responses by residents and visitors, water quality monitoring	Dynamic prediction of tourism environmental carrying capacity of karst properties.	[64]	
WINT analysis	Questionnaires responses by stakeholders	Local stakeholders' perceptions of sustainable development.	[65]	

Table 1 (continued)

Categories	Methods	Data sources	Core contents	References
Indirect research methods	Convergent parallel mixed method	Questionnaires responses by visitors and in-depth interviews responses by stakeholders	Assess the role of communication in community participation towards sustainable tourism.	[66]
	SWOT analysis	Official websites (provincial institutes, property site, world heritage center)	Sustainable development of natural heritage site.	[40]
	Carbon footprint	Statistical yearbook, tourism enterprises and institutions	Tourism ecological footprint of natural world heritage site.	[43]
	Literature review and expert interview	International articles and scores from experts	The operational mechanism of ecotourism based on the perspective of stakeholders.	[41]
		CNKI, expert's points	Physical fitness tourism resource development and environmental protection innovation in world heritage sites.	[42]
	AHP, fuzzy mathematical methods	Master Plan for the heritage site	Ecological environmental threshold and tourist capacity and its impact on biological diversity.	[17]
	Official evaluations analysis	Advisory body evaluations of nominated sites	How and when issues of sustainability and tourism emerged in the properties as well as how concerns about these issues have changed over time.	[67]
	Panel data analysis	China Entrepreneur Investment Club (CEIC), Official websites of UNESCO world heritage center and Chinese world heritage sites	Tourism effects of world heritage sites and its impact on heritage protection.	[68]
	Propensity score matching	Official websites (national and state institutes, UNESCO world heritage center)	The tourism attractiveness of world heritage sites.	[69]
	Static model of tourism environment capacity	Statistical yearbook, statistical bulletin	The effectiveness of the world heritage on promoting the growth of tourism economy.	[70]
Experimental research methods	Grounded theory	Management agencies and tourism companies of the property	Tourism environmental carrying capacity of natural world heritage site.	[44]
	Literature review	Tourist comment texts from travel social networking sites	The structure of tourism image value perception of karst natural properties.	[71]
	Website analysis	Scopus, Web of Science, Ebsco, Proquest	Different ways of using heritage interpretation as a tool for managing areas of sustainable development.	[24]
	Remote sensing, GIS	Websites of natural properties	How internet content can support the digital identification of nature sites and their branding as tourist destinations.	[72]
	Global static partial equilibrium model	Geospatial data cloud, China meteorological administration, protected planet, National aeronautics and space administration (NASA), National geomatics center of China	The impact of natural disasters on natural heritage site and its tourism.	[45]
		Landsat TM remote sensing image and SPOT remote sensing image	Ecological asset evaluation and ecological compensation of natural heritage site.	[73]

Table 1 (continued)

Categories	Methods	Data sources	Core contents	References
	Landscape pattern index	Geospatial data cloud	Spatiotemporal changes of the landscape pattern and diving factors in natural heritage site.	[74]
	High-resolution online tracer test	On-line monitoring	Influences of tourism activities on hydrochemistry of karst ground water.	[18, 75, 76]
	Investigation method of sample plot	Ground sample survey	Effects of tourism disturbance on the plant diversity of typical karst forest.	[46, 77]

capacity, grounded theory, literature review and website analysis. The advantages of these methods are: (1) simple and easy to operate; (2) easy to obtain the required data; (3) low research cost. But the data of these methods often face problems of poor data correlation, poor timeliness and low reliability. These methods are suitable for theoretical analysis researches and researches with low requirements on data timeliness and resolution.

Experimental study methods used in related researches mainly include two categories: geographic information technology and experimental monitoring. Specifically, these methods contain remote sensing, GIS, global static partial equilibrium model, landscape pattern index, high-resolution online tracer test, and investigation method of sample plot. Geographic information technology can quickly obtain spatiotemporal data of large-scale study areas, which is suitable for monitoring and research of natural heritage sites. But it needs to be combined with ground monitoring survey data to increase the precision of its analysis results. The results obtained by the ground monitoring method are the most objective and accurate among all methods, but usually require higher professional knowledge of operators, and are time-consuming and costly.

Technologies

Compared with cultural World Heritage sites, natural properties are often more difficult to display and manage, with large area and complex natural and man-made influencing factors. The introduction of 3S technology (remote sensing, geography information systems, global positioning systems), 3D laser scanning technology, virtual reality (VR) technology, augmented reality (AR) technology, holographic projection technology, computer digital technology and other modern technical means is conducive to the digital construction, post-disaster landscape restoration and ecological restoration, and efficient manage of natural World Heritage sites.

Spatial information technology with 3S technology as the core has become the main technical means of current resource and environmental investigation and analysis [78]. The conservation and tourism researches on aesthetic value (criterion vii) and geological and landform value (criterion viii) conservation and tourism of natural World Heritage sites mostly use this technology. Zhou et al. [79] revealed the relationship between the tourism development process and the landscape pattern of the natural property based on multi-period remote sensing images. Xiao et al. [80] carried out an evaluation of the impact of tourism project construction on the aesthetic value of heritage landscapes based on GIS perspective analysis. Furthermore, remote sensing images are also widely used to measure and interpret the changes of the

geological hazards area and the scale of disaster [81], as well as vegetation' reconstruction [82, 83]. The use of 3S technology can effectively monitor the changes in the ecological environment, and is an important technical means for the conservation of natural properties. Researches using this method are relatively mature, but most of them focuses on the ecological change of a single property and the impacts analysis of infrastructure construction, urbanization and other human activities. There are few coupling studies on tourism and heritage ecological changes, and the horizontal comparative study between heritage sites is still blank.

3D laser scanning technology has the characteristics of fast scanning speed, strong initiative, high precision and low cost, which provides a new technical means for cave measurement [84]. Zhou et al. [85] discussed the morphological characteristics and control factors of Miao Chamber, which was included on the World Heritage Tentative List of China in 2019, based on terrestrial laser. Using 3D laser scanning technology to carry out cave measurement and imaging, mapping and analysis can effectively promote the popularization of the scientific value of cave heritage sites and the improvement of tourism quality.

Through technical means such as VR, AR and holographic projection technology, tourism products and tourism experiences can be extended to the field of virtual tourism [86], and the interactive experience of heritage tourism can be enhanced. In addition, the application of computer digitization technology has further promoted the efficient management of heritage tourism. Shilin Karst strengthens the informatization of geological heritage conservation and tourism management through the construction of smart platforms such as video surveillance, call center system, and GIS system [87]. Chen [88] built the tourism management system of the natural World Heritage site based on ASP.NET, WWW information service site technology, Browser/Server model, and SQL database system. Digital construction and smart tourism under the premise of protecting heritage value are the general trend of heritage tourism development and an effective management model.

Models

Based on different research perspectives, scholars have proposed the ecological popular science tourism development model, the community participation tourism model, the ecological compensation model, the World Heritage-buffer zone-peripheral area coordinated protection model and other collaborative model of natural World Heritage conservation and tourism.

Wen [33] constructed an ecological popular science tourism development model based on the landscape

Table 2 The World Heritage-buffer zone-peripheral area coordinated protection model [93]

Regions	The sustainable development models
World Heritage	Biodiversity-based land consolidation model, ethnic minority traditional protection model, green ecological industry model, poverty reduction construction model
Buffer zone	Ecological restoration and returning farmland to forest model, ecological restoration shelter forest project model, ecological restoration timber forest development model, ecological restoration economic fruit forest development model, rural low-carbon energy development model, eco-tourism development model
The peripheral areas	Environmental pollution control model, soil and water conservation management model, rocky desertification comprehensive management model

spatial structure and morphological characteristics of the natural World Heritage site from the perspective of tourists. This model not only emphasizes the realization and acquisition of ecological popular science tourism, but also focuses on the management of various elements of the tourism, so as to facilitate its continuous development, rather than being limited to the existing ecological popular science tourism activities. But the specific implementation paths of this model still need further study.

Yang [89] proposed the natural heritage protection model of “feeding farmers through travel” from the perspective of the community. This type of model can effectively improve the income, conservation willingness, sense of belonging and education level of community residents, and is applicable to all World Heritage sites. However, in practice, this model often has problems such as lack of participation in decision-making, economic benefit distribution that is out of sync with the economic development of heritage sites, and the lack of effective guarantees for economic participation [90].

To solve these problems, Duan and Li [73] proposed to use the ecological compensation model to coordinate the protection of heritage values and the protection of indigenous interests. Their research method is to use the global static partial equilibrium model of Costanza et al. [91] to obtain landscape change information by interpreting remote sensing images, and to assess the ecological assets and depletion of natural ecosystems. On this basis, Fu [92] proposed a multi-ecological compensation mechanism for karst natural heritage sites by combining interviews with community residents and questionnaires on tourists, taking into account the interests of all stakeholders.

The conservation of World Heritage is inextricably linked to its buffer zone and wider peripheral areas, especially in karst-type natural World Heritage Sites. Due to the special above-ground-underground dual structure and complex hydrological system of the karst areas, the coordination and protection of the buffer zone and its surrounding areas is crucial to the sustainable development of the karst sites. Xiong et al. [93] constructed the World Heritage-buffer zone-peripheral area coordinated

protection model (Table 2). This model organically combines World Heritage conservation, the prevention and control of rocky desertification with the development of surrounding communities, and promotes the sustainable development of natural World Heritage sites in karst areas.

Future research directions

Systematically explore the conservation methods and theories based on world heritage criteria

Aiming at the problem of fragmented analysis and problem-oriented research in the studies of World Heritage conservation, it is an urgent need to systematically explore heritage conservation methods and theories based on World Heritage criteria. The World Heritage Budapest Declaration adopted by the World Heritage Committee in 2002 pointed out that an appropriate and reasonable balance should be sought between heritage conservation, sustainability and development [94]. Scholars’ understanding of World Heritage conservation and tourism has gone through three stages: conflict theory, reconciliation theory and synergy theory [95]. However, due to the huge disparity in the number of cultural heritage sites and natural heritage sites, scholars’ research on heritage conservation mostly focuses on cultural heritage, and less on natural heritage. Most of the related studies are fragmented analysis or problem-oriented research, or regard natural properties just as a special study area like other protected areas, with little characteristics of the World Heritage. The systematic theories and methods for heritage conservation has not yet formed. With the increasing number of world heritage sites and the trend of human and natural life community, researches on the theories and methods based on World Heritage criteria and classified conservation of heritage values are imminent.

Formulate corresponding conservation systems and ecological restoration standards for different types of properties

Aiming at the problem of unclear objects of heritage protection and restoration degree of World Heritage,

the protection systems and ecological restoration standards of different World Heritage types need to be discussed. Since the birth of World Heritage Convention in 1972, World Heritage has a history of fifty years. However, what exactly are the World Heritage site to protect, how to protect them, and to what extent to restore the damage that has occurred, how to restore? These problems still plague scholars and heritage managers in actual researches and conservation management practices. UNESCO World Heritage Center and scholars agree that the core element of World Heritage is OUV, which includes three aspects: satisfying World Heritage criteria, authenticity/integrity, and protection and management. We must protect the carrier that embodies the OUV of World Heritage sites. But what elements are contained in each World Heritage criterion or the OUV carrier of each type of World Heritage has become a broad issue that has not been discussed. Scholars tend to study the protection of things that can be seen and felt in the short term, such as water quality, vegetation coverage and vegetation types, species diversity, protection of buildings and rock paintings, post-earthquake recovery, cave microorganisms and so on. Little attention has been paid to things whose changes can only be perceived over a long period of geological history, such as the preservation of landform values. In addition, the extent to which OUV should be protected and restored after being destroyed are also unclear, which hinders the researches on heritage conservation and the effectiveness of practice in solving practical problems.

Give full play to the complementary advantages of various research methods and reveal the mutual feedback mechanism between tourism and heritage conservation

The main research methods used in related researches are investigation research methods, indirect research methods, and experimental study methods. Related researches mostly use the first two types of methods. The vast majority of relevant studies obtain data through questionnaires and interviews with stakeholders such as tourists and residents. However, natural World Heritage sites are protected areas dominated by natural ecosystems, and the importance of experimental study methods, such as experimental monitoring and geographic information technology, in the mutual feedback research on heritage value conservation and tourism cannot be ignored. While these methods are rarely used in current research. Long-term series of experimental monitoring studies or studies that combine these types of methods are even more blank. Each kind of method has its own advantages and disadvantages. In future researches, the three kinds of methods should be combined, together with the heritage database constructed by long-term

experimental monitoring, to deeply analyze the mutual feedback mechanism between heritage conservation and tourism.

Develop ecological restoration technology based on biodiversity restoration

In response to the problem of land degradation around the natural properties, ecological corridors need to be built through species diversity restoration to expand the benign outward influence of heritage ecology. There are many land degradation phenomena around natural World Heritage sites. On the one hand, due to the requirements for protection and management attributes when applying for the title of World Heritage, areas with better natural environment are often included in the scope of World Heritage when the boundary is delimited. While the buffer zone and its surrounding ecological environment are poor or disturbed by human activities. On the other hand, due to the requirements of the World Heritage Convention on the protection and management, environmental protection in World Heritage sites is generally given great attention, while the ecological environment of the buffer zone is often neglected, weakening the buffering effect of the buffer zones. Unreasonable tourism activities, infrastructure construction and urbanization in the buffer zones have accelerated the pace of land degradation. Vegetation is the most basic part of a terrestrial ecosystem, and all other organisms depend on it [96]. Species diversity is the manifestation of biodiversity at the species level, which can represent the structural complexity of biological communities, and reflects the structure type, organization level, development stage, degree of stability and habitat level of the community [97, 98]. It is one of the key contents for future research to develop a series of ecological restoration technologies based on biodiversity restoration. It can be realized by building the radial ecological corridor connecting the World Heritage sites, buffer zones and their periphery, and driving the restoration of species diversity through vegetation restoration, so as to expand the benign ecological environment of the properties to wider periphery.

Build ecological compensation development models based on the perspective of heritage tourism and value realization of world heritage

Most of the World Heritage sites are important tourist attractions due to their high-grade tourism resources and outstanding scientific value. However, how to achieve these outstanding values has not yet been answered. In addition, stakeholders have different impacts on the ecological environment due to different ways of participating in tourism. Different travel models and behaviors of tourists, and different ways of providing tourism-related

services (such as homestays, picking, hiking, rafting) will have different contribution values to the ecological degradation of tourist destinations. Ecological compensation can enhance the conservation awareness and protection behavior of tourism stakeholders, thereby promoting ecological protection and ecological restoration. As one of the effective ways to balance social benefits, economic benefits and environmental benefits, it has been widely valued by scholars and managers since it was proposed [99]. In the past, scholars have studied the ecological compensation mechanism, impact factors, and compensation methods of forest resources, wetland resources, grassland resources and so on. Some scholars paid attention to ecological compensation from the perspective of community residents and farmers' livelihoods. However, few attentions have been paid to targeted ecological compensation studies in natural World Heritage sites [100, 101]. Thus, aiming at the problem of ecological degradation caused by the unbalanced distribution of benefits from tourism and unclear paths to realize the heritage values, researches on ecological compensation mechanism based on tourism perspective and value realization path of World Heritage are needed.

Conclusions

This literature review summarized the research progress of natural world heritage conservation and tourism from the perspectives of theory, method, technology and model, and proposed future research directions.

Our findings indicate that the UNESCO World Heritage Center and IUCN are the main force of the theory research, and put forward important theories such as authenticity, integrity, buffer zone, and sustainable tourism of heritage sites. Scholars have also introduced heritage corridor theory, ecological theory, experience economy theory, actor network theory, symmetry theory, sustainable livelihood framework, life cycle assessment theory, carbon footprint and so on into related researches from the perspective of social science. In future researches, we should pay more attention to the particularity of world heritage, and focus on theoretical and methodological research based on different world heritage value standards.

We also found that the vast majority of current research uses social science research methods, especially questionnaires and in-depth interviews. In addition, mathematical modeling methods are also common methods in related research. Only a few scholars use experimental monitoring or geographic information technology methods to carry out research from the perspective of natural science. No studies have been found that combine these types of methods. In future research, attention should be

paid to the combination of long-term experimental monitoring data of natural heritage sites with social science and geographic information technology to build a natural heritage monitoring database to promote in-depth research and scientific management of natural heritage.

In terms of technology, scholars have used modern technical means including 3S technology, 3D laser scanning technology, virtual reality technology, augmented reality technology, holographic projection technology, and computer digital technology to promote the digital construction, smart tourism and post-disaster landscape restoration and ecological restoration in heritage sites. In future researches, ecological restoration technologies based on biodiversity restoration should also be paid attention to. And radial ecological corridors should be constructed to connect properties, buffer zones and their periphery, so as to expand the benign ecological environment of the natural properties to the buffer zones and wider peripheral areas.

Regarding the coordinated model of natural world heritage conservation and tourism, scholars have proposed models such as ecological popular science tourism development, community participation in heritage tourism, ecological compensation, and coordinated protection of property, buffer zone and peripheral areas. The core starting points are stakeholders' participation in heritage tourism, distribution of heritage tourism income and heritage zoning.

Furthermore, we put forward the following research prospects: (1) systematically explore the conservation methods and theories based on world heritage criteria; (2) formulate corresponding conservation systems and ecological restoration standards for different types of world heritage; (3) give full play to the complementary advantages of various research methods and reveal the mutual feedback mechanism between tourism and heritage conservation; (4) develop ecological restoration technology based on biodiversity restoration, establish radial ecological corridor, and expand the benign ecological environment of the properties to wider periphery; (5) build ecological compensation development models based on the perspective of heritage tourism and value realization of world heritage.

However, this study still has some limitations. Firstly, the research theme of world natural heritage protection and tourism involves the interdisciplinary integration of ecology, environmental science, tourism and other disciplines. Although we used some synonyms to cover more publications in this field, the retrieval results may still be incomplete due to the complexity and limitations of literature database and search methods. The search results of related articles in this study are subject

to uncertainty but have little influence on the exploration of research progress and future research directions of natural World Heritage conservation and tourism in terms of the overall direction of research development. Monographs, newspapers, patents, technical reports and other types of literature, as well as articles in other literature databases may further clarify our findings. Finally, there is a certain degree of subjectivity in articles inclusion and subject analysis.

Abbreviations

WOS	Web of Science
CNKI	China National Knowledge Infrastructure
UNESCO	United Nations Educational, Scientific and Cultural Organization
OUV	Outstanding Universal Value
IUCN	International Union for Conservation of Nature
SCI-EXPANDED	Science Citation Index Expanded
SSCI	Social Sciences Citation Index
ESCI	Emerging Sources Citation Index
SCI	Science Citation Index
EI	The Engineering Index
CSSCI	Chinese Social Sciences Citation Index
CSCD	Chinese Science Citation Database
RS	Remote Sensing
GIS	Geographic Information System
AHP	Analytic hierarchy process
SEM	Structural equation modelling
PCA	Principal component analysis
WINT	What is not there
SWOT	Strengths, weaknesses, opportunities, threats
CEIC	China Entrepreneur Investment Club
NASA	National aeronautics and space administration
3S	Remote sensing, geography information systems, global positioning systems
3D	Three Dimensions
VR	Virtual reality
AR	Augmented reality

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Author contributions

All authors are contributed to the manuscript. Conceptualization, ZZ and XK; methodology, ZZ; validation, ZZ; formal analysis, ZZ; data curation, ZZ; writing—original draft preparation, ZZ; writing—review and editing, ZZ, XK and HD; visualization, ZZ and HD; project administration, XK; funding acquisition, XK. All authors have read and agreed to the published version of the manuscript.

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Availability of data and materials

The data presented in this study are openly available in [China National Knowledge Infrastructure (CNKI)] at [<https://www.cnki.net/>] and Web of Science (WOS) at [<https://www.webofscience.com>].

Declarations

Competing interests

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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