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REVIEW ARTICLE

Natural Beauty and Esthetic Value of Natural World Heritage Sites: a Literature Review and Implications for Karst Geoheritage Sites

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Abstract

In recent years, the esthetic value of natural landscapes has become a research focus in the fields of geography, landscape, and ecology as well as other disciplines. The natural beauty and esthetic value of world heritage (WH) sites have been widely investigated, but there has been no comprehensive review. To fill this gap, this study conducts a systematic literature review based on 110 relevant articles and documents produced since 1989 retrieved from Web of Science and the China Knowledge Resource Integrated (CNKI) database. An analysis of the documents reveals the following results: (1) the number of documents published has increased in a fluctuating manner over the time period, indicating that this field is receiving increasing attention; (2) the main progress and achievements in the research on the natural beauty and esthetic value of natural world heritage (NWH) sites are classified and summarized; and (3) on this basis, 7 key scientific problems to be solved when studying the natural beauty and esthetic value of NWH sites are summarized, and effective research approaches that integrate the specific characteristics of karst WH sites are described.

Keywords Natural world heritage · Natural beauty · Esthetic value · Assessment criterion (vii) · Karst landscape

Introduction

World heritage (WH) is among the priceless and irreplaceable assets attributed to not only each nation but also humanity as a whole (UNESCO 1972). As of June 2021, 194 States Parties had acceded to the Convention Concerning the Protection of the World Cultural and Natural Heritage (hereinafter referred to as "the Convention"). The Convention considers WH sites to have "outstanding universal value" (OUV), that is, cultural and/or natural significance that is so exceptional that it transcends national boundaries and is of common importance for the present and future generations of humanity. Therefore, WH sites deserve special protection (UNESCO 1972). World heritage protection is founded on the existential value of natural and cultural heritage as well as the elements, composition, interpretation, and maintenance of this value (Sun et al. 2019). The World Heritage Committee (WHC) has developed ten criteria and considers a site to have OUV if it meets one or more of the ten criteria (UNESCO and WHC 2019). Criteria vii to x refer to natural heritage. Criterion vii is applicable to a site containing "superlative natural phenomena or areas of exceptional natural beauty and esthetic importance" (UNESCO and WHC 2019). In the WH research realm, "natural beauty" refers to the esthetic value of natural heritage and can describe natural phenomena or regional esthetic quality. The ecosystem service framework adopted by Millennium Ecosystem Assessment considers the esthetic aspect of a landscape (landscape esthetic service) to be a cultural ecosystem service (Millennium Ecosystem Assessment 2005). Compared to other natural resources, natural scenery is more difficult to evaluate in a scientific manner because it depends not only on the nature of the landscape and its profound cultural connotation but also largely on the subjective assessment of the viewer (Yu 1986). Therefore, in the process of defining criteria, subjective and difficult-to-quantify evaluations and other problems often arise.

As of 2021, there were a total of 1154 WH sites globally. On the WH list, 146 properties are inscribed on the basis of criterion vii, of which 26 are karst related.

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Geomorphological heritage and associated geomorphosites are an important part of geoheritage; they are distinguished from other types of geoheritage by their usually high scenic value (Coratza and Hobléa 2018). Williams (2008) considered that when compared to other landscape types and ecosystems, karst has a number of unusual characteristics that must be taken into account when assessing its integrity. For example, karst is unusually complex because it comprises both surface and subterranean features and values and integrates surface and subterranean processes, both biological and physical. Karst ecosystems are fragile due to extreme environmental conditions. Moreover, over thousands of years, the process of dissolution leads to typical karst landscapes with notable surface features, including poljes, dolines, sinkholes, towers, caves and shafts, dry valleys, and underground rivers (Ravbar and Sebela 2015). Due to their special geological structures, karst areas can often form spectacular landforms and exhibit exceptional natural beauty. Since the original purpose of the Convention was to identify, protect, preserve, present, and transfer cultural and natural heritage sites with OUVs to future generations, the study of heritage value is important for guaranteeing heritage protection and management.

This study comprehensively analyzes existing researches on the natural beauty and esthetic value of WH sites that have been published over the past 30 years and classify articles according to their annual distribution, research contents, and document types. It identifies and summarizes 7 key scientific problems when studying the natural beauty and esthetic value of natural world heritage (NWH) sites and offers effective research approaches with particular reference to the characteristics of karst geoheritage sites.

Data Collection

To identify relevant studies, searches were conducted in the China Knowledge Resource Integrated (CNKI) database and Web of Science for articles, theses, and conference publications. In the CNKI database, "topic" was used as the search item, and "WH" was used as the search word for the first search. Among the results of this first search, "natural beauty" and "esthetic value" were used as the search terms for the second search. In Web of Science, "WH" was used as the search term for the first search, and "natural beauty," "esthetic value," and "landscape esthetic" were used as the search terms for the second search. The time range searched was the maximum time range of each database. Moreover, the same search terms were applied to the websites of the International Union for Conservation of Nature (IUCN) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). Finally, the retrieved Chinese and English literature was manually screened according to the research aim of this article.

By means of the above searches and the subsequent screening, a total of 110 Chinese and English documents related to the natural beauty and esthetic value of WH research were retrieved: 48 are non-Chinese documents, and 62 are Chinese documents. Moreover, 86 are from periodicals, 11 are master's theses, 8 are doctoral dissertations, 2 are conference papers, 2 are online electronic bulletins, and 1 is a scientific and technological achievement report.

An Overview of Natural Beauty and Esthetic Value Research Associated with WH

Annual Distribution of the Literature

As shown in Fig. 1, the published research on the natural beauty and esthetic value of NWH sites can be traced back to the early 1980s, with a generally increasing research trend. Combined with the development background of WH protection and management measures, the existing research can be divided into three stages, namely, the start-up, slow development, and rapid growth stages (Table 1). The start-up stage occurred from 1989 to 2000, and the annual number of references during this period was no more than 3, indicating that it was indeed the startup period. The slow development stage, from 2001 to 2010, was a stage during which a fluctuating increase in relevant research occurred, indicating a slow growth period. The third phase, from 2011 to 2019, was a period of rapid growth during which the number of annual references was more than 8 and the research content was in-depth.

Content Distribution of References

The references retrieved in the searches were classified and summarized as formation mechanisms of natural landscapes, evaluation of esthetic value and methods, impact assessments, and protection management as well as other types of studies. These reference topics are shown in Fig. 2. Among them, analyses of the causes and structures of landscape documents account for 10% of the total, evaluations of the esthetic importance of landscape documents account for 49%, impact assessments of the possible risks faced by the natural beauty of landscape documents account for 16%, strategies for protection management account for 15%, and other types of documents account for 10%. In particular, many scholars have combined research on landscape formation mechanisms with protection and management practices.

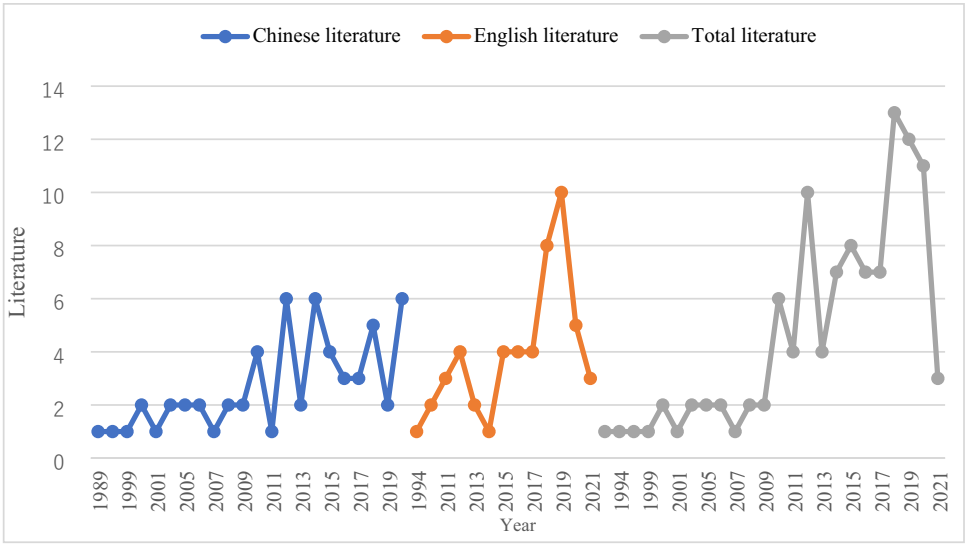

Fig. 1 Annual distribution of literature on the natural beauty and esthetic value of NWH sites

National Distribution of the Literature

The national distribution of the scientific research on the natural beauty and esthetic value of NWH sites is illustrated in Fig. 3. The research areas are dominated by China and Australia, including studies of NWH sites such as Xinjiang Tianshan, the South China Karst (Fig. 4), and the Great Barrier Reef. In general, the distribution of the study areas corresponds to the global distribution of NWH sites, but the distribution is concentrated in a few countries and regions, and the current studies lag behind the NWH declaration process.

Main Progress and Landmark Achievements

In 1750, A.G. Baumgarten published "*Aesthetica*," which mentioned esthetics for the first time. Esthetics has been regarded as an integral part of philosophy (Baumgarten 1987). "Natural beauty" has been among the important research categories associated with esthetics. However, the concept of natural beauty initially lacked an effective definition. "*Contemporary Esthetics and Its Neglect of Natural Beauty*," published by Hepburn in 1966, criticized esthetic studies for overlooking natural beauty (Hepburn and Li 2016). Many environmentalists, such as Allen Carlson and Aldo Leopold, who emphasized that scientific knowledge can strengthen esthetic sensibilities, have appealed for the redefining of the relationship between humans and nature. Moreover, due to the need for environmental protection and the establishment of national parks and nature reserves, evaluative research on natural landscapes has been promoted (Liang and Ding 2002), and research on natural beauty has been widely considered in the fields of geography, ecology, and psychology as well as other disciplines.

In WH studies, "natural beauty" refers to the esthetic value of NWH sites and describes the esthetic quality of natural phenomena or areas (Mitchell et al. 2013). According to the literature retrieval, the published research topics can be divided into the 4 categories presented below.

Formation Mechanisms of Natural Landscapes

In the existing research on the natural beauty and esthetic value of WH, scholars have explained the esthetic importance of natural landscapes by analyzing their origins and summarizing their corresponding esthetic characteristics. For example, some researchers have studied the geological and geomorphic, biodiversity, and other conditions of landscapes to determine the origins of natural landscapes (Chen et al. 2004; Deng 2011; Coratza et al. 2016; Xie 2005); some studies have discussed the single and combined forms of natural landscapes (Liu 2017; Zhang 2016) or their spatial distribution characteristics (He 2004). With WH karst sites, some researchers have studied formal beauty characteristics such as the visual images, colors, lines, dynamics, and stasis associated with natural landscapes (Du et al. 2008), while other researchers have examined the processes of landscape formation. For example, since the Cambrian period, the Jiuzhaigou Valley Scenic and Historic Interest Area WH site (Fig. 5) has experienced four main stages of landscape evolution associated with the Jiuzhaigou passive continental margin, fold and thrust orogenics, a continental orogenic block, and the role of Quaternary glaciers (Deng 2011). Moreover, Jon et al. (2021) have analyzed the formation processes, the features of speleothems, and other karst features in Songam Cave, DPR Korea, which indicated that the cave is a geoheritage of high conservation significance because of its geological and esthetical value. Furthermore, Reynard and Giusti (2018) demonstrated that the geysers of

Table 1 Research stages of the natural beauty and esthetic value of NWH sites

Research phase	Main feature	Development background
Start-up period (before 2000)	A few world heritage survey reports, UNESCO meetings, and reports related to natural beauty occurred in this period. Some researchers began to carry out impact evaluations on the value of WH sites, and the research methods prioritized qualitative research	The concept of preserving WH through international efforts was developed in this period. The Convention on the Protection of the World's Cultural and Natural Heritage was successfully signed. The heritage site nomination process was gradually standardized, and European countries, the USA, Australia, and other countries commenced professional research on the preservation of heritage value
Slow development period (2001–2010)	On average, 4 papers were published each year in this period. Some master's and doctoral dissertations began to focus on the esthetic value of WH. Moreover, many basic studies focused on interpreting the OUV standards of WH sites. Meanwhile, some scholars carried out research on the esthetic value of landscapes and impact evaluations of WH sites according to criterion (vii). The research methods changed to quantitative research	With The Budapest Declaration on WH issued by UNESCO, the research on WH was integrated into sustainable development trend research. People's awareness of WH was improved, and research was inclined to explore the scientific value behind the WH criteria
Rapid growth period (2011 to now)	There was a breakthrough in the total amount of literature, with the number of papers published in this period accounting for 69.91% of the overall total. The research contents covered topics from esthetic feature recognition to esthetic evaluations, and the research methods included landscape character assessments (LCAs) and landscape feature evaluations. At the same time, the amount of monitoring and evaluation research increased, especially in the impact assessment literature. The research methods mainly comprised quantitative research	Determining how to identify, protect, and display the value of heritage has become a research hotspot, and scholars from all over the world have begun to explore the direction of heritage research in the context of internationalization. UNESCO has established the "International Natural Heritage Space Technology Center" in China, and research on the esthetic value of heritage has also begun to innovate from analogous methods to exploring new methods, new technologies, and establishing a standard research system

the Iceland rift and Kamchatka Peninsula are examples of natural phenomena showing that beauty is not only static but also lies in the power of the manifestations of internal and external geodynamics.

In addition, some scholars have classified different landscape types based on the classification principles of landscape similarity, difference, and hierarchy, including features such as forests, rivers, mountains, and coasts (Jahani and Rayegani 2020; Mikusiński et al. 2018; Povilanskas et al. 2016; Tenerelli et al. 2017). Among the different types of geosites, geomorphosites are often the most spectacular and popular: waterfalls, canyons, mountain peaks, caves, and erratic boulders constitute visually appealing landscapes that have always aroused great interest and attracted much attention (Goudie 2002) (Figs. 4 and 5). In the existing academic studies, the classification of karst landscapes is based mainly on the distribution of landscape features, geomorphic form, and tourism resource type. For example, Yuan (1994) divided landscape resources in karst areas into mountains, water, and caves based on topography and landscape tourism resources. However, the current classification methods do not cover all types of karst landscapes; some classifications have overlaps, while others apply only to a certain area and are not universally applicable.

Some scholars have classified landscape structures at different levels according to the types of natural landscape elements and the combination of landscape units; this approach has important practical significance for the display of natural landscape characteristics and the unification of esthetic subjects and objects (Yang 2009). The beauty of the natural scenery is essentially a combination of geomorphosites or, more generally, of landforms of different sizes, shapes, origins, and ages (Migoń 2014). The geological and geomorphic conditions of karst have produced diverse landscape types, which exhibit a variety of features at different altitudes and geomorphic conditions (Figs. 4 and 5). For example, there are both horizontal and vertical features. Therefore, it is necessary to carry out research on different landscape structures to reveal the combination of the esthetics of each landscape component or landscape complex in geographical space. Some scholars have studied the relationships between landscape patterns and esthetic characteristics based on the principles of landscape ecology (Jiao et al. 2006; Mirghaed et al. 2020). In current research on the esthetic value of karst heritage sites, research on the esthetic characteristics of landscapes from the perspective of landscape patterns has been lacking. However, landscape patterns can reflect the relationship between landscape ecological benefits and

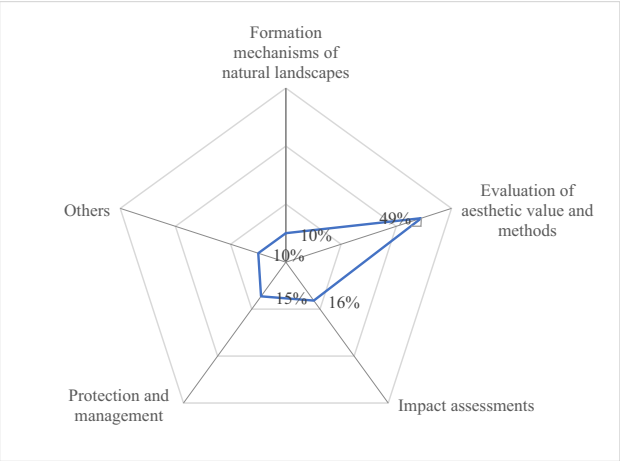

Fig. 2 Distribution of research contents in studies on the natural beauty and esthetic value of NWH sites

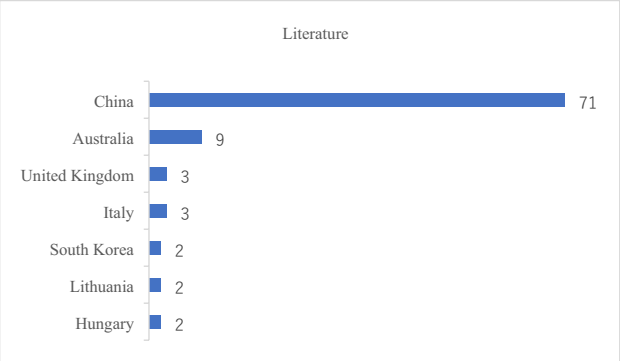

Fig. 3 Regional distribution of research on the natural beauty and esthetic value of NWH sites

esthetic benefits, which is helpful for the in-depth study of the esthetic quality of karst landscapes.

This breadth of research fully demonstrates that the natural beauty and esthetic value of NWH sites comprise an interdisciplinary topic involving landscape architecture, tourism esthetics, geology, ecology, and other disciplines and explains the existence of a wealth of scientific knowledge of the representation of landscape esthetics.

OUV criteria are regularly revised by the WHC to reflect the evolution of the NWH site concept itself. Scholars have gradually formed a complete and comprehensive understanding of the OUV of NWH sites when studying their evolution (Shi 2008). For example, Migoń (2018) suggested that OUV is understood as being of broader relevance and that claims of uniqueness and distinctiveness should not be too narrowly focused. Some studies have argued that the evolution of criterion vii reflects the evolution of esthetics theory. There has been a transformation from perceptual evaluation

Fig. 4 South China Karst WH site. Diverse landscape types in South China Karst WH site. **a** Spectacular tower karst and fenglin riverine landscapes; **b** subtropical fengcong karst in dolomite and deep gorges; **c** cave; and **d** stone forests (source: https://whc.unesco.org/en/list/1248)

methods to scientific and quantitative evaluation methods because the definition of beauty according to criterion vii is shaped by the esthetics of the eighteenth and nineteenth

Fig. 5 Jiuzhaigou Valley Scenic and Historic Interest Area WH site. Spectacular waterfalls and colorful lakes add to the visual appeal of the landscape. **a** The lake is blue and purple; **b** waterfalls surrounded by plants (source: https://whc.unesco.org/en/list/637)

centuries and the scientific and quantitative esthetics from the twentieth century to the present (Zhao and Xu 2020). Other researchers have proposed suggestions to improve the objectivity and operability of criterion vii (Bi and Han 2018; Xu et al. 2018). In addition, some scholars have studied the esthetic systems of different countries and proposed new esthetic identification frameworks based on different cultural backgrounds (Xu et al. 2016).

Evaluation of Esthetic Value and Methods

When faced with the key issue of how to determine whether a natural landscape has the esthetic value of WH, some scholars have explored and employed a variety of esthetic evaluation methods. Among these methods, most scholars (Jon et al. 2020; Zhong 2014) have used the global frameworks approach recommended by UNESCO to evaluate the esthetic value of natural scenery. This method requires comparisons and analyses of the same or similar heritage sites to indicate their esthetic value and importance. The IUCN (2007) suggested that the nomination documents of the "South China Karst," accompanied by a comprehensive global comparative analysis developed through extensive dialog within the international karst community, provide an exemplary standard for other nominations. The documents also include a volume that can be regarded as a reference statement for karst areas in relation to the WH list. However, such methods rely not on measurable indicators but rather on qualitative descriptions of the attributes of natural beauty.

Notably, the "preparing WH nominations" resource manual suggests that "measurable scenic indicators should be used wherever possible" (UNESCO 2012). In view of this suggestion, other researchers have evaluated landscape esthetics based on psychophysical theory and have heavily applied the principles of the scenic beauty estimation (SBE) method and the semantic differential (SD) method. For example, some authors have used the SBE method to show pictures of different landscapes to test subjects and allow them to score the images to obtain the esthetic value of the corresponding landscapes (Zheng et al. 2012), revealing the contribution of different landscape factors to their esthetic value (Di et al. 2010). In addition, some scholars have used the SD method to obtain quantitative data on participants' psychological feelings through a speech scale. Furthermore, these two methods are often combined in comprehensive analyses (Xu and Li 2014; Zhao 2019). Psychological theory is widely applied in quality evaluations and preference research of visual landscapes, enabling the application of statistical analyses and to improve the robustness of the results (Qi et al. 2013). Of course, the combination of these two methods can also be helpful for the study of karst heritage sites in the future.

At the same time, some scholars have carried out empirical research on the esthetic preferences of different groups, thus diversifying the evaluative perspectives of landscape esthetics. Some scholars have regarded heritage sites as international tourism destinations and conducted investigations and studies on the needs, expectations, and satisfaction levels of visitors (Le et al. 2019; Oladeji et al. 2012; Povilanskas et al. 2016). For example, it has been confirmed that visitors are indeed capable of visually distinguishing different coastal landscapes and habitats that occur in the succession from shifting dunes to mature forests (Povilanskas et al.2016). In addition, some researchers have conducted questionnaire interviews with WH experts, administrators, and other stakeholders (Cetinkaya 2021; Pike et al. 2015). For example, Zhang et al. (2020) designed and implemented an analytical framework based on the public participatory geographic information system (PPGIS) method to explore similarities and differences in local stakeholders' recognition of preferences and social values for ecosystem services in a typical karst basin. However, there have been no studies on esthetic preferences in karst WH sites. In general, landscape

preferences refer to the comprehensive perceptions of landscapes generated by observers (Qi et al. 2013). Different stakeholders have very different landscape preferences (Tang et al. 2018). Landscape preference is influenced by observers' different cultural backgrounds, ages, genders, occupations, and other factors (Van den Berg and Koole 2005; Strumse 1996; Yu 1995).

In terms of research techniques, spatial analysis methods such as remote sensing (RS) and geographic information systems (GIS) are increasingly used to evaluate the esthetic value of natural landscapes. Some scholars (Mirghaed et al. 2020; Qiu 2013) have introduced GIS spatial analysis technology and landscape pattern indices to the visual quality evaluations of landscapes, extending abstract visual evaluations to the quantitative level. Moreover, Massimo et al. (2014) used GIS methods to detect and define landscape units and their endowments, such as natural, ecological, historical, cultural, and urban resources, in space. Ha and Yang (2019) used the NWH criteria, ecological environment, and viewing experience as established indicators; nine metrics were applied as corresponding layers to map and give a final spatial evaluation based on ArcGIS overlay analysis. These new techniques can compensate for the temporal and spatial limitations of traditional evaluation methods, in which landscapes are analyzed only by photos and text data, and allow esthetic value evaluations to be more organized and richer in information. "3S" technology, including RS, GIS, and global positioning systems (GPS), is frequently used in monitoring and evaluation in research on karst WH sites. For example, Duan et al. (2013) used RS images, GIS, and ecosystem service value models to quantify the protection of Yunnan Shilin karst sites and to analyze the changes in ecosystem service value of these sites and in their surrounding buffer zone.

Impact Assessments

Impact assessments are indispensable for evaluating and protecting WH sites. Any construction projects conducted in WH sites or their buffer zones that may potentially impact their heritage value must be disclosed to the WHC using a protection and management status report (UNESCO and WHC 2019) to ensure that the OUV of these WH sites is effectively protected.

Some scholars have carried out visual impact assessment studies to identify possible problems in the development of projects surrounding heritage sites. For example, Xiao et al. (2020) adopted horizon analysis methods to evaluate the impact of a glass bridge on the value of the Wulingyuan WH site and demonstrated that it had no negative impact on the OUV of the site. Moreover, using natural cognition theory and ecological esthetics theory, some scholars have revealed the role of disturbance regimes on landscape esthetics. For example, Liu (2009) discussed the forms and dynamic changes in the esthetic quality of Kanas forest landscapes in the Altai Mountains, Xinjiang, based on the dynamic spatiotemporal responses of the tree species structures in the landscapes to natural fire disturbances. Furthermore, a study of phototrophic microorganisms from two caves in Serbia (Podped and Stopia) revealed that although the ecological parameters inside the cave did not show significant variation, they should be monitored because of the potential influence on the development of the lampenflora community that has a negative esthetic impact on cave formations (Nikolic et al. 2020).

In addition, some scholars have conducted exploratory analyses on the factors that may influence OUV by developing early-warning mechanisms. For example, Wang et al. (2016) have utilized the reports published by the WHC, proposed intensity of threat indices, and analyzed the space–time change in threats and threat intensity. Other scholars have developed monitoring and evaluation models based on the essential attributes of heritage to evaluate the sustainable development statuses of karst WH sites and to determine the importance of each index according to the corresponding threat intensity and index weight (Liu 2018; Zhang 2017).

Since the basic purpose of the Convention is to protect the integrity of heritage values, outstanding landscapes are the core embodiment of the esthetic value of natural world heritage. Some scholars (Han et al. 2011) used three indices, a visual index of outstanding landscape, a harmony index of the artificial landscape, and a disturbance index of damaged landscape, to measure the impact of landscape integrity and established an environmental impact assessment model for the integrity of world heritage.

The above studies have provided some new methods for the evaluation of impacts on the landscape esthetics of karst geoheritage sites. At present, most of the studies on impact assessment focus mainly on a few karst WH sites. Thus, it is necessary to systematically explore the influencing factors of karst geoheritage sites.

Protection and Management

There is no doubt that protecting and maintaining OUV are the most essential goal of WH inscription. At the same time, while heritage tourism has undergone dramatic growth, WH sites have experienced more negative forms of development. These sites becoming "urbanized, commercialized, and artificial," among other problems, because of the negative forms of development (Chen and Liu 2012).

In recent years, on the one hand, the features of landscape, landscape formation mechanisms, and conservation measures have been systematically considered in a value-based conservation framework (Deng 2011; Xu

et al. 2016). On the other hand, models for the protection and sustainable development of NWH sites have been established. Based on the principle of "priority in protection, scientific development, and sustainable use," Xiong et al. (2012) established a heritage protection concept in accordance with the "core zone for protection, buffer zone for integration of management and development, and upper catchment zone for the combination of prevention and management" while considering protective measures against construction, development, and infrastructure construction. The protection model was formed to realize the protection and sustainable development of WH sites.

Other scholars have identified multiple heritage value systems from the perspective of systems theory and protected the value of heritage in a "live" way. Zhang (2021) identified the multiple values of Hani terraces, Yunnan, from the perspective of heritage, brought the composition system and heritage elements of the terraces into the scope of protection, and improved the overall protection of heritage elements with community residents at the core. This includes the heritage tourism industry with community participation as an important component of heritage utilization and promotes the sustainable development of heritage. In the same way, on a global scale, Hamilton-Smith (2007) underlined that out of the approximately 50 karst sites inscribed on the WH list, many are included on the basis of their non-karst values: natural beauty (esthetic quality), biodiversity values, and/or the development of important cultural traditions. There is no doubt that it is important to pay attention to the multiple value systems of karst WH sites, which are equally important for OUV protection and inheritance.

Over time, WH sites have gradually become established as important tourist destinations, and UNESCO's policy on WH sites is no longer limited to protection only and now also includes sustainable tourism (Lyck 2015). Zhang and Bao (2004) suggested that tourism activities in WH sites are inevitable, so WH sites should be studied in the context of tourism activities and the protection of OUV through sustainable tourism. This approach is beneficial to constructing a coordinated development model of WH protection and tourism and promoting the display of OUV. Moreover, scholars have explored ways to show the value of geoheritage. For example, Columbu et al. (2021) demonstrated the value of stalagmites from an educational point of view. It aimed to boost awareness of the scientific importance of karst and cave geosites, promoting their conservation and the valorisation of the cave material studied. It demonstrated that the utility of stalagmites, and all speleothems by extension, extends beyond scientific research, especially in terms of educational and tourist resources.

Key Scientific Issues to Be Solved and Implications for Karst Geoheritage Sites

Often only visual quality is considered when conducting multisensory natural esthetics research. According to Daniel (2001), research on traditional "landscape quality" evaluations would actually be better termed as that on "visual esthetic quality" because it relies on the examination and analysis of only the visual characteristics of the target region and seldom involves sounds or smells. Today, the landscape esthetic definition focuses on the sensory responses of humans to interactions with a particular landscape. People's natural experiences cannot be fully expressed through only a single esthetic approach. Tuan (1977) suggested that not only a visual image can become a symbol of the corresponding region but the smell can also be recognized as a regional characteristic. In recent years, soundscapes have also arisen as a research topic in protected natural areas (Deng et al. 2020; Wang and Zhao 2019). Furthermore, some scholars have begun to consider the influence of sound, smell, and other factors on landscape quality (Kaplan et al. 2006; Xu and Zhou 2020). Karst processes have produced a variety of landscape forms, especially karst natural landscapes such as waterfalls and caves. However, how to measure effectively the scientific value and esthetic characteristics of karst landscapes and how to multi-dimensionally explore people's esthetic preferences need further discussion. Therefore, performing more comprehensive examinations of esthetic value through multisensory evaluations should be a focus of future research.

In view of the abstract problems associated with describing the value characteristics of natural beauty, mapping is necessary through new technologies and methods such as 3S (RS, GIS, and GPS) and 3D methods. Map-based modeling can be applied to evaluate a landscape continuously in space and on different scales and in different regions (Martin et al. 2016; Sahraoui et al. 2016). With the continuous development and maturity of 3S and 3D technologies, complex analyses based on regional data have become possible, facilitating more accurate and objective evaluations (Hernández et al. 2004). In addition, the application of 3S, 3D, and other spatial technologies can provide timely heritage monitoring information and improve the heritage protection efficiency and level. It is worth mentioning that Le et al. (2019) provided evidence that eye tracking can be used to measure the relative perceived beauty of natural images by reflecting the attention paid to images perceived as attractive. Furthermore, some researchers have used geotagged photos and the fields of view of each photo location to identify the corresponding information of the photographed sites (Yoshimura and Hiura 2017). But in the existing research on karst landscapes, 3S technology is mostly used to monitor

vegetation coverage and the transformation of landscape patterns, and research on landscape esthetics remains at the traditional data analysis and photo-scoring stage. In general, the key attributes can be explained intuitively through mapping. Moreover, new technologies and methods can broaden the channels through which preference data can be collected and have broad application prospects.

The existing research on esthetic value has ignored the esthetic preferences of local communities/minority groups; their opinions should be integrated into decision-making discussions to deepen the awareness of the heritage protection perspectives of local residents. Landscape is not only an objective arrangement of natural and anthropic elements but also a social construction resulting from the perception of the Earth by human society. The recognition of the geoheritage value of a place is the result of a social process (Reynard and Giusti 2018). Local community esthetics are rarely considered when defining values, but communities need to take responsibility for conservation management. In recent years, the role of traditional communities has been increasingly recognized in the WH system. The IUCN encourages local community participation in the identification and protection of WH sites (Charles 2021) and provides a basis for community participation in esthetic evaluations. Moreover, Hieu et al. (2018) linked livelihood quality with the conservation of geomorphological resources and found that local people were unaware of natural landscape values, likely because they did not directly benefit from them. It is worth noting that in extreme cases, human impact has led to an induced ecological desert, the process being called "rocky desertification" (Williams 2008). Others have confirmed that the increasing population in karst mountain areas interrupts the fragile balance maintained against the background of the low carrying capacity and low productivity of the landforms, resulting in land degradation (Li et al. 2017). This balance is crucial for the protection of karst landscapes in which community residents fully recognize the multidimensional value of the landscape and earn sustainable livelihoods from it. The inclusion of multiple stakeholder values into assessments of karst environments and landscapes is both an emerging and necessary focus (Chazal et al. 2008). Therefore, paying attention to the values of community residents is important for enhancing residents' awareness of karst WH sites.

Based on the existing global comparison framework that forms part of the WH nomination process, the "comparative method" should be refined to construct a more specific comparison framework for landscapes of the same type. Esthetic evaluations are conducted by combining the effects of the biophysical characteristics and human perceptions and cognition of landscapes (Kaplan et al. 2006; Tveit et al. 2006). Differences in identity, cognition, and viewing purposes and inconsistencies in tourist routes all lead to different evaluation results being obtained for the same landscape. For this reason, most evaluators' descriptions of natural beauty may be biased by their own emotions. In addition, different natural, social, and cultural backgrounds may lead to differences in the understanding of the standards by state parties (Hazen 2007). The above factors cause esthetic evaluations to be more subjective than other value standards. Moreover, although there are several available methods for the assessment and inventory of geomorphosites, when it comes to the comparative study of genetically similar landforms, one can note the need for further studies and analyses (Cocean and Cocean 2016). The main feature of karst environments is the duality of the surficial and underground spaces. Because the landscape is complex and diverse, it is necessary to further refine the feature lists created for the same type of landscape and provide more detailed and objective descriptions of the single and combined landscape forms, as well as their importance in similar landscapes.

In view of the problem that the esthetic value evaluation method is not comprehensive enough, it is necessary to establish a comprehensive evaluation model that combines the attributes, structures, and levels of the natural landscape of WH sites. Several factors should be considered when designing this new model. First, heritage value is considered using a "value system" composed of "background value, direct application value, and indirect derivative value"; this system is both hierarchical and spatial (Chen and Liu 2012). In addition, the UNESCO (2011) advocates the necessity of using quantitative methods to explain superlative characteristics as much as possible. Moreover, the IUCN recommends the further development of qualitative research methods and further research on suitable methods and principles based on the existing methods for esthetic value recognition that have been utilized in various countries worldwide. For example, Ha and Yang (2019) established a universal system combining subjectivity and objectivity with expert and public opinions. In this system, the NWH site criteria, ecological environment, and viewing experience were used as established indicators. Furthermore, the Bayinbuluk area of Tianshan Mountain in Xinjiang was used as a case study to verify the rationality of the model. It is worth noting that Pike et al. (2015) used the Chichester Outstanding Natural Scenic Area in the UK and the Pacific Rim National Park in Canada as examples to explore the application of Q methodology in the identification of cultural ecosystem services in marine reserves. They argued that Q methodology provides a highly appropriate way of examining unmeasurable values by being able to convert qualitative, subjective data into quantitative information. In general, the evaluation of the natural beauty of karst landscapes is a complex systematic project with a large spatial scale and many influencing factors. Current karst landscape esthetic evaluations are faced with the problems of there being only a single method,

evaluation subject and evaluation type. It is necessary to establish a comprehensive and distinctive karst landscape comprehensive evaluation system, especially combining humanistic methods.

Considering that esthetic value is a part of the overall value of the environment, we should pay attention to the relationship between esthetic value and other ecological values and need to systematically carry out impact evaluation for esthetic value. The evaluation of the impact of a project at an WH site before the construction of the project has become a heritage protection requirement within the international community (IUCN 2020). In addition, other scholars have suggested that there is an "esthetic-ecological" conflict in current landscape assessment practices. Many natural landscapes with important ecological value are not considered beautiful under the traditional esthetic concept and thus do not garner the same level of public interest or support as do more charismatic species, so the former cannot be properly protected, resulting in ecological damage (Stewart and Johnson 2018). Cayla et al. (2012) observed that the scientific importance of geomorphological sites is often hidden by a "mask of the picturesque," which has two consequences: sites with low esthetic value tend to become "invisible," and thus, to escape conservation efforts (they are not retained in geoheritage inventories) and for emblematic and highly visual sites, only landscape interest is taken into account at the expense of their scientific value. Moreover, Pasquale (2021) estimated the impact of air pollution on WH sites and showed that air pollution accelerated the degradation processes of WH sites and reduced their esthetic value. He et al. (2021) linked physical-environmental properties to human perceptions of landscapes and conducted related research on the multiple impacts of human disturbances and climate change on karst landscape WH sites. Human production and living activities have been identified as the main causes of landscape changes, followed by natural disasters and climate change. Karst landforms are fragile, as manifested in their low resistance to external disturbances and poor stability (Xiong and Chi 2015). However, most of the existing studies of karst WH sites have focused on assessing these impacts on a single heritage site construction project. In future research, scholars should consider new influencing factors, such as climate change, and systematically carry out impact evaluation research to provide scientific bases for preventative protection and risk prevention and to design decision-making systems for heritage sites.

Considering the depth of WH protection research, it is also necessary to explore esthetic value-oriented heritage protection research to develop a targeted and innovative protection management system.

The core element of WH is "highlighting universal value," which has been widely recognized by UNESCO and relevant scholars. Its connotation includes three aspects: satisfying the WH criteria, authenticity/integrity, and protection management. In protected areas, the identification of the different aspects of geoheritage site values is part of a holistic concept of protection, education, and sustainable development (Szepesi et al. 2016). However, there is no quantitative or accurate description of natural characteristics corresponding to value either in world heritage criteria or the OUV of each type of WH site (Xu et al. 2016). When studying heritage protection, a protection scheme should be formulated in combination with the value of the features of landscape contained in the standards met by the specific type of WH. Additionally, the Convention stipulates that state parties have five responsibilities regarding WH, including the identification, protection, preservation, exhibition, and inheritance of WH by future generations. Therefore, the significance and connotation of creating WH sites are not limited to the scope of protection. There is no doubt that WH research is not only focused on protection but is also motivated by sharing WH with all of humanity so that people can learn about and share the value of WH sites together (Xiao et al. 2020). More importantly, Carlson and Lintott (2008) expounded that paying attention to natural beauty can be an important motivator for environmental protection. At present, most countries or regions in the world display mainly the natural beauty of heritage sites to the public through tourism, and, thus, it is necessary to further explore diversified and sustainable methods of displaying these sites. Karst WH sites are known for having some of the most beautiful landscapes in the world and are among the most fragile ecosystems on Earth. Therefore, the construction of an integrated "protection and sharing" management system can effectively realize the protection and sustainable development of karst geoheritage sites.

Conclusion and Future Research

In this study, we performed a systematic literature review by analyzing 110 articles retrieved from Web of Science, the CNKI database, and the websites of UNESCO and IUCN. The main conclusions are as follows: (1) The number of documents published has risen in a fluctuating manner since 1989, indicating that this field is receiving an increasing amount of attention. In addition, the research on natural beauty and esthetic value at NWH sites has been conducted mainly in China and Australia; (2) the main progress and achievements in studies on the natural beauty and esthetic value of NWH have been in four areas: formation mechanisms of natural landscapes, evaluation of esthetic value and methods, impact assessments, and protection management. Among the studies, the research on evaluation of esthetic value is most common, and (3) this paper identified 7 key scientific problems to be solved in future research on the

natural beauty and esthetic value of NWH sites and offers effective research approaches that integrate the characteristics of karst geoheritage sites.

The future directions of natural beauty and esthetic value at karst geoheritage sites can be developed based on the following aspects: how to perform more comprehensive examinations of esthetic value through multisensory evaluations; how to strengthen the application of 3S (RS, GIS, and GPS), 3D, and other new technologies and methods and broaden the collection of landscape esthetic preference data; how to help communities find sustainable livelihoods from landscape values, integrate their perspectives into evaluation and decision-making discussions, and strengthen their protection willingness; how to refine the "comparative method" scheme based on the existing global comparison framework and construct a more specific comparison framework among landscapes of the same type; how to establish a comprehensive evaluation model that combines the attributes, structures, and levels of karst geoheritage sites; how to systematically carry out the impact evaluation for esthetic value; and how to explore esthetic value-oriented heritage protection research to develop a targeted and innovative protection management system. In the future, the comprehensive characteristics of this research field will become more obvious. A more comprehensive approach will be essential in developing this research field. Moreover, it is necessary to obtain not only relevant information from the literature but also the latest policy information from institutions such as the IUCN and UNESCO.

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Declarations

Conflict of Interest The authors declare no competing interests.

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