

**Natural Solutions: Environmental Awareness and Conservation Planning Methods for
Historic Cities under the Impact of Climate Change**
Zhang Bing Zhu Yingying Lan Chun Chen Zhuo

Abstract Climate change and its secondary disasters have become one of the most important factors threatening the safety of cultural heritage. After sorting out the history and current situation of coping with climate change in the field of international and domestic cultural heritage, it is pointed out that the theory and technology of conservation planning for historic cities under the condition of climate change need to break through some major and fundamental problems, to re-cognize and redefine the "environment" of historic cities on the basis of the conventional visual, economic, social, historical and cultural environments, and to improve the conservation planning methods of historic cities, and enhance the climate resilience of historic cities with "natural solutions". It consists of four parts: the first part summarizes the international and domestic discussions on the climate change thesis in the field of cultural heritage, and especially analyzes the situation of coping with climate change in the field of historic city conservation in China; the second part tries to put forward the three levels of historic city environment, i.e., the natural base environment, the human ecological environment and the historic landscape environment. As a whole, the three levels of historic city environment can help us establish a comprehensive view of the environment, and incorporate the factors that need to be considered for sustainable development, such as climate change and ecological service functions, into the conservation planning and scientific research of historic cities; the third part takes Dunhuang as an example to analyze the identification of key environmental factors at different levels and how to enhance the climate of the historic city through the "natural solu " to enhance the climate resilience of the historic city. The fourth part, as a conclusion, advocates the development of conservation planning techniques for historic cities to recognize not only the laws of cultural heritage conservation but also the laws of ecosystems.

Keywords climate change; historic cities; heritage rings

Environment; resilience; natural solutions; territorial spatial planning; natural infrastructural environment; human ecology; historic landscape environment

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Nature-based Solutions: Heritage Setting Cognition and Conservation Planning for Historic Cities in the Context of Climate Change

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Abstract: Climate change and its associated secondary disasters pose significant threats to the authenticity and integrity of cultural heritage. This paper reviews the evolution of international and Chinese responses to climate change within the cul- tural heritage domain. paper reviews the evolution of international and Chinese responses to climate change within the cul- tural heritage domain. It highlights the need to enhance the theory and technology of conservation planning for historic cities in addressing major fundamental issues of climate change. This paper reviews the evolution of international and Chinese responses to climate change within the cul- tural heritage. paper emphasizes the necessity to redefine the central concept of setting beyond conventional physical, economic, social

and cultural dimensions, and - The paper emphasizes the necessity to redefine the central concept of setting beyond conventional physical, economic, social and cultural dimensions, and vocating for improving conservation methodologies and enhancing climate resilience by adopting Nature-based Solutions (NbS). The paper consists of four parts. Firstly, it reviews international and Chinese scholarship on climate change in the field of cultural heritage and critically assesses the state's capacity to address this issue. Firstly, it reviews international and Chinese scholarship on climate change in the field of cultural heritage and critically assesses the state of China's historic city conservation in response to climate change. Secondly, the paper introduces three new concepts --. Secondly, the paper introduces three new concepts --. ba- sic natural setting, human settlement setting, and historic landscape setting -- to de- scribe the historic city setting in three distinct dimensions. This approach fosters a more comprehensive view of heritage setting by incorporating factors of sustainable development, such as climate change and ecology. This approach fosters a more comprehensive view of heritage setting by incorporating factors of sustainable development , such as climate change and ecological services, into the conservation planning and scientific research of historic cities. Thirdly, applying the approach to the case of Dunhuang, the research identifies and analyzes key factors in three di- mensions and explores the potential of utilizing NbS to enhance the conservation of historic cities. utilizing NbS to enhance the climate resil- ience of historic cities. Lastly, the paper concludes that the development of conserva- tion planning techniques for historic cities should be carried out in a manner that is consistent with the principles of the United Nations Framework Convention on Climate Change (UNFCCC). - Lastly, the paper concludes that the development of conserva- tion planning techniques for historic cities should not only involve the understanding of heritage conservation principles but also embrace knowledge of ecosystem laws.

Keywords: climate change; historic city; heritage settings; resilience; Nature-based Solutions (NbS); territorial spatial planning; basic natural setting; human settlement setting; historic landscape setting

The National Outline of Territorial Spatial Planning (2021-2035) issued by the Central Committee of the Communist Party of China and the State Council in October 2022 requires the protection of inherited cultural and natural values and the manifestation of the charm of territorial space, and points out in particular the need to actively respond to air pollution.

Climate change, based on the potential risks of different climatic conditions, different geographic environments, and different types of disasters to the cultural heritage ontology and its environment, to enhance the resilience of the heritage environment, and to avoid the integrity and authenticity of the cultural heritage from being damaged. This paper combs through the international and domestic cultural heritage field to cope with climate change, points out that the theory and technology of historic city conservation planning under the condition of climate change need to break through some major and fundamental issues, and on the basis of conventional visual environment, economic and social historical and cultural environment, to re-cognize and define the "environment" of the historic city, to improve the historic.

1 Response to climate change in the field of cultural heritage

1.1 Main history of the response to climate change in the field of international heritage

Since 2000, the international heritage sector has been focusing on the impacts of climate change on heritage, and a series of studies, policies, and actions have been undertaken to address climate change. Through the protection of heritage of climate change significance, the aim is to address the common global challenges facing humanity^[1].

Climate change was officially introduced into World Heritage work in 2007^[2], the UNESCO World Heritage Centre published Climate Change and World Heritage^[3], Case Studies on Climate Change and World Heritage^[4], and the 16th session of the General Assembly of States Parties to the World Heritage Convention adopted the key strategic document "Policy Paper on the Impacts of Climate Change on World Heritage".^[5-6]

(hereinafter referred to as the "Policy Paper"). As knowledge related to climate change adaptation and mitigation has increased dramatically over the last decade or so, the World Heritage Center has established a project on "Revision of the Policy Document", which has resulted in a revised version of the

Policy Document (hereinafter referred to as the Policy Document).

The Policy Document has been renamed as "Policy Document for World Heritage Climate Action"^[7], which specifies the objectives of action in five areas: climate change risk assessment, climate change adaptation, climate change mitigation, capacity building, and transformational change^[8]. The Policy Document has also been renamed as "Policy Document for World Heritage Climate Action" ().

Climate change has become a high frequency topic in the international heritage sector in recent years, and more and more experts in the field of heritage conservation are realizing that the impacts of climate change on heritage are long-term and difficult to reverse through urgent remedial measures^[2]. According to the third cycle of the World Heritage Asia-Pacific Periodic Reporting for October 2020-July 2021 on site management needs and action plans, coping strategies for disaster risk and climate change are becoming the most prominent and urgent needs^[9-10]. The Fuzhou Declaration adopted by the 44th World Heritage General Assembly in July 2021 focuses on the long term challenges of conservation, such as climate change and rapid urbanization, and calls for an integrated approach to site conservation. The Fuzhou Declaration, adopted at the 44th World Heritage General Assembly in July 2021, focuses on the long-term challenges of heritage conservation, including climate change and rapid urbanization, and calls for an integrated approach to the conservation of sites and the promotion of new relationships between people and nature for the preservation of cultural and natural heritage.^[11] The Global Consortium on Culture, Heritage and Climate Change, organized by UNESCO, ICOMOS and the United Nations Intergovernmental Panel on Climate Change (IPCC), was held in December 2021 (^[12]).

The conference, the highest profile global symposium on climate change and cultural heritage, resulted in the publication of the Global Research and Action Agenda on Culture, Heritage and Climate Change (^[13]), which explores the systemic linkages and interactions between culture, heritage and climate change, as well as solutions based on sustainable development. In general, ICOMOS determines the theme of ICOMOS Day for the following years in advance, but in 2022, when officially launching the annual theme for "4-18 ICOMOS Day", ICOMOS broke with its usual practice and adjusted the annual theme by changing the earlier proposed theme of "Religious heritage" to "Heritage and the environment", and by changing it to "Heritage and the environment". " to "Heritage and Climate", showing the recognition of the urgency of the theme^[14]. At the same time, the United Kingdom, the Netherlands, Ireland, Italy, the United States, Canada and other countries have launched relevant studies^[15-16] to incorporate climate change considerations into World Heritage conservation research, and the management of and actions to address climate change in heritage into the climate governance system. In November 2023, UNESCO convened a conference on Cultural Heritage in the 21st Century in Naples, which released

The "Spirit of Naples" Action Initiative, which advocates for the promotion of the spirit of Naples in all areas of the Organization's work.

Raising awareness of the importance of promoting environmental sustainability and addressing the impacts of climate change, and exploring and advancing innovative, community- and culture-based responses to the challenges facing heritage sites, such as disaster risk and loss of biodiversity, this initiative highlights once again the impacts of climate change on heritage conservation, emphasizing actions based on the interconnections between nature and culture.

1.2 The main history of the response to climate change in our heritage sector

China is a sensitive area and a significant impact area of global climate change^[17]. China has always attached great importance to the impacts of climate change on human society, and actively participated in global climate governance. The National Strategy for Adaptation to Climate Change released in 2013 proposes to "strengthen the protection of scenic resources and endangered cultural and natural heritage threatened by climate change"^[18], which is the first time that China has included relevant content on cultural heritage in a strategic document for addressing climate change. This is the first time for China to address the relevant contents of cultural heritage in a strategy document for addressing climate change^[19]. The Fuzhou Declaration issued by the 44th World Heritage General Assembly in 2021 puts forward the idea of conservation and management of world heritage^[2], reflecting the consensus between China and the world in the field of heritage in the context of ecological civilization construction.

The National Strategy for Adaptation to Climate Change issued in 2022 2035, from the perspective of "developing climate-resilient tourism"

Degree, proposes to "identify and assess the potential risks of climate-sensitive tourism resources, and scientifically carry out artificial interventions for the protection of tourism resources such as old and valuable trees, bridges, villages, ancient buildings and ruins and monuments"^[20].

China has issued a number of regulations on cultural relics to deal with extreme weather and disaster response work mechanism, such as the Notice on Doing a Good Job in Protecting Cultural Heritage in Strong Rainfall and Other Disaster Weather by the State Administration of Cultural Heritage in 2008, the Emergency Notice on Establishing a System of Reporting Information on Cultural Relics in Flood Season in 2010, and the Notice on Doing a Good Job in Detecting Dangerous Situations of the Great Wall during the Flood Season and Protecting the Work in 2018, 2021 Opinions on Strengthening the Work of Disaster Prevention and Mitigation for Cultural Relics on Bridges. From these documents, we can see that we are concerned about the damage caused by meteorological disasters to cultural heritage such as ancient buildings and sites, but most of them are based on the starting point of coping with extreme weather and secondary disasters. In fact, these disasters are closely linked to climate change^[21], and the long-term strategy for cultural heritage protection and climate change will be more or less stated in the National Climate Adaptation Strategy report mentioned above.

Scientific research and capacity to address climate change

In terms of construction, in 2012, the State Administration of Cultural Heritage set up the China World Cultural Heritage Monitoring Center^[22] at the China Academy of Cultural Heritage to build a monitoring and early warning system for China's world cultural heritage, in which indicators related to the natural environment and climate change are one of the key concerns of the monitoring work. In addition, in 2020, the Ministry of Science and Technology (MOST) issued a key special project on "Monitoring, Early Warning and Prevention of Major Natural Disasters" (a thematic task on the protection and utilization of cultural heritage), and in 2020, the China Academy of Cultural Heritage (CACH) and others initiated a "Study on the Risk Assessment of Natural Disasters of Immovable Cultural Relics and Emergency Response" (the subject of the aforementioned key special project), and in 2021, the Archaeological Research Center of the State Administration of Cultural Heritage launched the "Preliminary Study on the Impact of Sudden Climate Changes on Archaeological Sites in China", with the aim of striving to enhance the ability to respond to and deal with potential hazards and threats to cultural heritage in the context of climate change^[19, 23]. In 2021, heavy rainfall continued in Henan and Shanxi, and the country was hit by a number of natural disasters. In Shanxi, sustained heavy rainfall brought great damage to ancient buildings, sites, and historical towns, and in drought-stricken Dunhuang, torrential rains led to flooding, posing a great threat to the heritage environment, and these extreme events caused more people in the field of heritage conservation to pay attention to the trend of warming and humidification in China's northern regions, raising the importance of the topic of "climate change". These extreme events have drawn more attention to the trend of warming and humidification in the northern part of China, and have raised awareness of the topic of climate change.

1.3 Status of response to climate change in the field of historic city conservation in China

As an important type of cultural heritage, the issue of conservation planning for historic cities to cope with climate change is the focus of this paper. Undoubtedly, cities with high population density and high economic concentration are particularly affected by climate change^[24]. The current action programs related to urban response to climate change are mainly from urban planning^[25-26], urban infrastructure^[27], urban architecture, ecological patterns, green

The research on climate change in historic cities is still relatively weak.^[17, 24]

Historic cities have their intrinsic composition and conservation management characteristics, and they contain layers of built environments such as historic districts, historic and cultural neighborhoods, and historic buildings. From the perspective of research objects, the research results we have collected focus on the analysis of the impact of climate change on immovable cultural relics such as ancient buildings and sites. From the perspective of protection management, research on climate risk assessment and vulnerability assessment^[28], whole-process management of monitoring and early warning^[23], and application of new technologies such as space information technology^[22, 29] are also often directed to cultural heritage in general, and some of the research involves traditional villages^[30], agricultural cultural heritage^[30-31], and cultural landscapes^[13, 23], while the research on risk assessment, vulnerability assessment, and monitoring and early warning specifically targeting at historical cities is far from enough.

In the literature on measures to cope with climate change, involving different climatic regions such as Henan, Shanxi, Zhejiang, Xinjiang, Gansu, etc.^[29-30, 32-34], the main achievements are: firstly, the preparation of technical guidelines and the formulation of protection strategies based on different climatic and heritage characteristics of zoning classification; secondly, taking into account the emergency response and prevention, carrying out the research on the impacts of long-term climate change on heritage, and perfecting the working system of risk assessment, daily management and inspection, and emergency disposal; Thirdly, to give full play to the role of space information technology in the detection, discovery, monitoring, assessment and management of cultural heritage, and to move cultural heritage from "after" protection to "before" protection, for example, in Dunhuang, to cope with the huge impact of increased rainfall on the Mogao Grottoes in recent years. For example, Dunhuang, in response to the huge impact of increased rainfall on the Mogao caves in recent years, has formed preventive protection against potential climatic hazards in the form of inspecting and reinforcing vulnerable cliffs, strengthening cooperation with meteorological departments, and linking up monitoring and early-warning systems, and has effectively curbed the erosion of wall paintings and colorful sculptures by adopting a sand control project for several decades to cope with extreme sandstorms and dust storms. Although these studies are directly or indirectly related to the protection of historic cities, the overall situation is still in favor of generalized cultural heritage research.

In response to the gas directly targeting historic cities

In the research on climate change, from the materials collected, more research is carried out from the dimension of protection and management measures of historical cities. For example, the study on Yinchuan Historical and Cultural City analyzed the threat of climate change to the historical and cultural values and main protection objects of the city, and put forward climate coping strategies in terms of regional coordination, sectoral coordination, technological exploration, ecological restoration, and industrial adjustment^[35]; Macao has introduced climate coping strategies to deal with climate change, extreme weather (mainly typhoons), and the protection of the Historic Centre of Macao, which is a World Heritage site. For the protection of the Historic Centre of Macao, Macao has introduced targeted strategies to cope with climate change and extreme weather (mainly typhoons and floods), and has clearly defined the following strategies

Measures before, during and after typhoons to systematize the protection of the city when it is threatened and attacked by typhoons^[13, 27]; Gulangyu Island, in the process of being nominated as a World Heritage Site, is studying the establishment of a heritage monitoring and disaster early warning and forecasting system to strengthen management measures^[30].

Historic cities can be regarded as a kind of traditional settlement, and in a broader sense, some research results on traditional settlements to cope with climate change can be paid attention to. For example, the research on Dong village analyzes the traditional cultural foundation and planning methods of settlement construction, and puts forward the path to maintain the balance of human-land relationship in response to climate change^[30]; Honghe Hani terraces have good water storage and regulation functions due to their unique "forest-village-terraces-water system". Due to its unique "forest-village-terraces-water system", the Hani terraces have a good water storage and regulation function, and the Hani terraces still maintain a good production function even though Yunnan Province suffered from a rare five-year drought from 2008 to 2012.^[13, 23] Based on this phenomenon, the principles and measures of planning and management of heritage sites including terraces and villages are deduced from the internal law of better coping with climate change pressure. Principles and measures of planning and management of heritage sites, including terraced rice fields and villages. These researches in the field of traditional settlements coping with climate change are enlightening for recognizing the heritage value of historic cities and dealing with the conservation planning and management of historic cities.

Overall, the field of historic city preservation in China

Research to address climate change still faces challenges. Firstly, starting from the evolutionary relationship between climate conditions and the value of historic cities, although we can explore the traditional experience and traditional wisdom of human beings in adapting to nature, and reveal the distinctive "climate" imprints left behind in the siting of historic cities and the construction of streets and lanes and buildings, etc.^[35], these researches can not substitute for the research on the impact of climate change on the future development of historic cities, and the trend of future impact is still insufficient.

However, these studies cannot replace the studies on the impacts of climate change on the future development of historic cities, and the grasp of future impacts is still insufficient; secondly, in the past period, although research on risk monitoring and early-warning measures for the cultural heritage and the environment under the condition of climate change has been emphasized, there is a lack of multidisciplinary cooperation based on the judgment of research on the mechanism of the changes of the cultural heritage and the environment; thirdly, most of the research results have been focused on the cultural heritage in a wide sense, and the researches focusing on the historic cities are weak. Thirdly, the research results are mostly broadly focused on cultural heritage, and weakly focused on historical cities, although these research methods cannot be said to be irrelevant to historical cities, the overall research on the ontology of historical cities and their heritage environment under climate change is far from being systematized; fourthly, the analysis and research on climate change according to the heritage composition and value characteristics of historical cities has only just begun, and there is no way to talk about systematic empirical research on historical cities located in various ecological base subregions, including climatic factors. This situation means that conservation planning for historic cities is still at a pioneering stage in the field of climate change adaptation and mitigation. In many cases, climate change talk is just talk.

At present, the theory and technology of historic city conservation planning under climate change conditions need to study and break through some major and fundamental issues. The following article tries to make an entry in two aspects: one aspect is about the "environment" of the historic city, and we try to redefine the "environment" of the historic city to solve the problem of the lack of connection between the big environmental problem of climate change and the conventional visual environment (the concept brought by Venice Charter) or even the economic, social and historic-cultural environment (the breakthrough brought by Xi'an Declaration nearly 20 years ago).) or even the economic, social, historical and cultural environment (a breakthrough brought about by the Xi'an Declaration almost 20 years ago); the other aspect is to draw on the new concept of the environment, borrowing cases to illustrate how the climate resilience of historic cities can be enhanced in a naturalistic way, and to make recommendations for improving the planning methods for the preservation of historic cities.

2 Improvement of cognitive methods for historic urban environments

The study of climate change and cultural heritage is essentially a study to reveal the interrelationship between the natural environment and cultural heritage. The study of cultural heritage ontology and its environment affected by climate change is a study of the impact of the "natural environment" on the heritage ontology and its "environment" at a larger scale, and it is necessary to discover and establish the intrinsic relationship between the natural environment, the heritage environment and the heritage ontology, centering on the preservation of heritage values. The "environment" is the same as the "environment". This section will focus on the question of what is the relationship between the natural environment and the heritage environment, which is the same as the "environment", and will attempt to propose a vision for an improved methodology for the perception of the environment in historic cities, bridging the gap between the natural environment and the heritage environment.

2.1 The cognitive journey of the heritage environment

It is well known that the perception of the "context" of cultural heritage has undergone a process of development. 1964 was the first year in which this concept was recognized.

International Charter for the Conservation and Restoration of Monuments and Sites

(The protection of monuments and sites and their surroundings is enshrined in the Venice Charter, which states that "the protection of monuments involves the protection of a setting on a certain scale" and that "monuments cannot be separated from the history they bear witness to and from the environment in which they were created". The 1976 Recommendation concerning the Safeguarding and Contemporary Role of Historic Areas (Nairobi Recommendation) defines "setting" as the natural or man-made context that influences the dynamic and static landscape of a historic area. The 1999 Barra Charter defines "setting" as "the area surrounding a heritage site, which may include the area as far as the eye can see", i.e. the visual area as the setting; the 2005 Hoi An Draft - Asia's Best Conservation Practices continues with this definition and explains that "this includes natural and man-made built-up areas, fixed objects and related activities". By the 2005 Xi'an Declaration

The Words, which collectively and systematically define the setting of the heritage, will be the setting of

ancient buildings, sites and historic areas

(The setting is defined as the immediate and extended environment: in addition to the physical and visual aspects, the setting includes the interrelationships with the natural environment; all past and present human social and spiritual practices, customs, traditions, perceptions or activities, and other forms of intangible cultural heritage that have created and shaped the space of the setting, as well as the cultural, social, and economic climate of the present dynamic development. The Xi'an Declaration extends the protection of cultural heritage to the setting of the heritage and all the historical, social, spiritual, customary, economic and cultural activities contained therein[36], describing the relationship of the heritage setting, as a local environment, to the whole environment and to the wider environmental context[37]. From

More than 40 years have passed since the Venice Charter to the Xi'an Declaration.

The development of the perception of the heritage environment over the years has also witnessed an advancement in the perception of heritage values.

Authenticity and integrity of heritage are key determinants of heritage value and are closely related to the heritage environment. Authenticity is a multidimensional set of key aspects of authenticity given in the Hoi An Draft - Asia's Best Conservation Practices (Table 1), such as place, environmental niches, surroundings, linkages with other projects or sites, changing uses, historical connections, and many other characteristics of authenticity that are highly related to the "environment". The Xi'an Declaration is highly contextualized in terms of completeness. In terms of integrity, the Xi'an Declaration states that "the environment affects or is an integral part of the significance and uniqueness of the heritage", explaining that "the environment" is an important component of heritage integrity, and that if the environment is damaged, the integrity of the heritage will be lost and the value of the heritage will be jeopardized. heritage integrity can be lost and certain features of heritage value can be lost. It was inferred that when we define the meaning and scope of the environment differently, the authenticity and integrity of the heritage will change and the value of the heritage will be assessed differently.

As the impact of climate change on cultural heritage becomes

As a global concern, we need to look not only at the potential impacts on heritage as such, but also to identify those elements of the heritage environment that are sensitive to climate change. This means that, in the same context of the "heritage environment", we need to move not only from the "eyesores" affecting heritage, as advocated in the Xi'an Declaration, to "all historical, social, spiritual, customary, economic and cultural environments", but also to move on to "the environment of the world's heritage". We need to move not only from affecting the heritage "as far as the eye can see" to "all historical, social, spiritual, customary, economic and cultural" environments, as advocated in the Xi'an Declaration, but also to "the natural environment of the site".

The basic spatial unit for adapting and mitigating the impacts of climate change on heritage, because ultimately, historic cities located in different natural environments will require different strategies and technological measures to enhance the climate resilience of historic cities for their preservation.

2.2 Three levels of the historic urban environment

Back to the relationship between climate change and historic cities. If we want to start to change the theoretical and technological status quo of coping with climate change in the field of conservation of historic cities in China, to study the trend of climate change's impact on the future development of historic cities, to probe deeply into the mechanism and process of climate change's impact on historic cities, and to gradually systematize the research in this field, we need not only to carry out a large number of empirical studies with multidisciplinary cooperation, but also to

Tab.1 Dimensions of authenticity

Location & Environment	Form and Design	Uses and Functions	intrinsic property
establishments	spatial planning	use	artistic expression
matrix	devise	user	fig. values (ethical, cultural etc)
“Sense of Place”	material (that sth is made of)	liaison	vigor
localized habitat	arts and crafts	Uses that change from time to time	perceptual influence
Topography and Views	Building technology	spatial arrangement	Religious background
Surroundings	an engineering project	Consequences of use	historical connection
essentials	stratigraphy (geology)	Site-specific uses	Sounds, smells, tastes
Degree of dependence on premises	Links to other projects or heritage sites	historical use	creative process

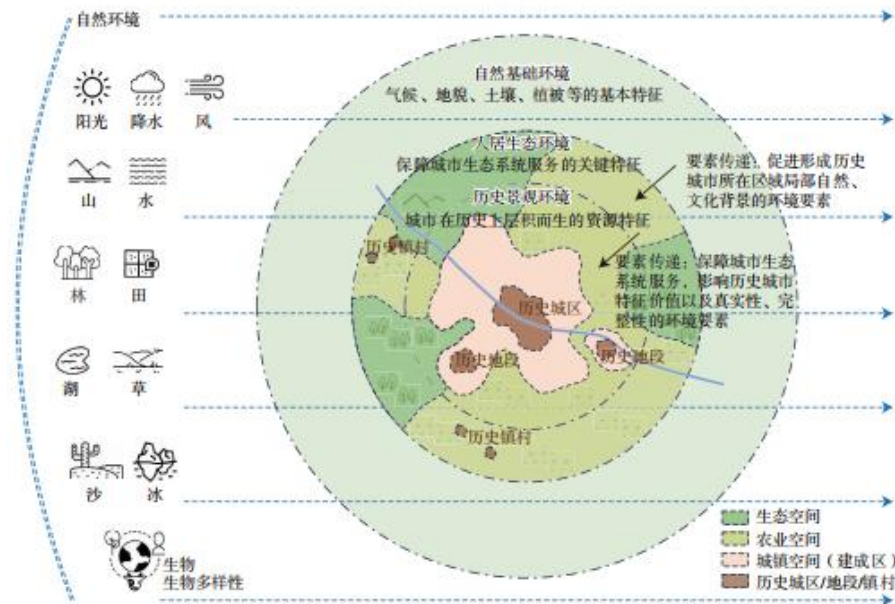


Fig.1 The cognitive framework for heritage settings of a historic city

Source: Hoi An Draft - Asia's Best Conservation Practices. 2005

and also needs to be actively practiced in the field of conservation planning. However, as pointed out above, between global climate change and historic cities, it is necessary to add the level and dimension of "environment" on the basis of visual environment, economic, social, cultural and historical environment. In this paper, we propose three levels of the environment of historic cities, i.e.: natural base environment, human ecological environment and historic landscape environment (Fig. 1), and try to This paper proposes three levels of historic city environment, namely: natural basic environment, human ecological environment, and historic landscape environment (Figure 1), and tries to build a bridge of value recognition and pave a path of protection action between the protection of cultural heritage of historic cities and the natural process of global climate change.

2.2.1 Natural infrastructure

The first level is the natural basic environment in which the historic city is located, which clarifies the basic characteristics of the ecological endowment, ecological mechanism and land use of the region where the historic city is located. The natural basic environment is the foundation of the historical city from its formation receptors of the impacts of climate change, but also to take the right steps to Figure 1 Historic Urban Environment Cognitive Framework

It is a basic natural environment on which the city is based. Compared to the history of human city-building, natural environmental conditions such as climate, landforms, soil and vegetation are relatively stable and slow to change. Under the influence of global climate change, in order to adapt to or mitigate the impacts of climate change, historical cities should first formulate measures from the natural base environment in which they are located. For example, for the same heavy rainfall, a historic city located in the arid northwestern region and a historic city located in the coastal region will take different measures to solve the problem of alleviating the pressure of heavy rainfall on the historic city. Another example is that in order to maintain and improve the ecological environment of a historic city, the methods of water system management and improvement of vegetation conditions will be different depending on the natural geographic conditions that the historic city possesses. With the promotion of historic cities towards a high-quality development path that is safe and resilient, ecologically livable, and green and low-carbon, the natural base environment of historic cities needs to be included in the context of the recognition of the heritage environment.

For natural base environments, it is possible to utilize

China's first "China Land Ecological Basis Zoning

(Trial)"[38] results (released in May 2023 by the Ministry of Natural Resources). As stated in this document, "China's terrestrial ecological base zoning is an important fundamental work based on natural and anthropogenic elements" and "provides a technical basic framework and reference for zoning classification to scientifically carry out ecological restoration and ecological monitoring, evaluation and early warning, etc." The zoning is based on the natural geographic pattern. The zoning is based on the natural geographic pattern, drawing on the results of China's eco-geographic zoning, offshore eco-zoning, climate zoning, vegetation zoning, and eco-functional zoning, and analyzing multi-type, multi-temporal, and high-precision natural resources data, such as the Third National Land Survey, eco-geological surveys, groundwater resources surveys, geographic national conditions monitoring, high-resolution remote sensing imagery, and digital three-dimensional modeling. The spatial and temporal data of natural resources, such as high-resolution remote sensing images, digital three-dimensional models, etc., are used to comprehensively determine the zoning, and the ecosystems of the national land area (excluding Hong Kong, Macao, and Taiwan) are divided into 6 first-level ecological zones, 47 second-level ecological zones, and 233 third-level ecological zones at different regional scales.[38] (The spatial distribution of the third-level ecological zones can be referred to the Ecological Basis Partitioning Map of China's Land Area published by the Ministry of Natural Resources in 2023.) Although the six counties of ancient Huizhou have outstanding commonalities in history and culture, they are divided into three levels of eco-regions from the perspective of natural base zoning (Fig. 2). The natural environment of the historic city can be divided into three levels of ecological zones, so as to obtain a comprehensive understanding and positioning of the climate, landforms, soil, vegetation, geology, hydrology and other conditions, which is conducive to the conservation and utilization of the historic city and the surrounding historic towns and villages to comply with the overall laws of evolution of the natural environment on a large scale.

2.2.2 Habitat ecosystem

The second level is the ecological function of the historical city and the neighboring towns and villages constitutes the ecological ecological environment which is closely connected, in this relatively complete urban and rural functional territorial unit, the life, production and ecological functions are closely connected, the exchange of material, energy and information is frequent, there are the ecological service functions such as water conservation, soil and water conservation, windbreaks and sand fixing and biodiversity etc., which maintain the basic ecological stability of the historical city and the survival and development of the urban and rural residents through the internal role of support, regulation and supply etc.. regulating), supplying and other intrinsic functions to maintain the basic ecological stability of the historical city and the survival and development of urban and rural residents, constituting a unique spatial pattern of ecological space, agricultural space, and urban space integrated with each other.

Habitat Ecology research focuses on identifying

Key features and associated environmental elements that safeguard urban ecosystem services. The "patch - corridor - matrix" model of landscape ecology[39] may help to provide us with a "spatial language" to describe this functional-territorial unit, which can be plant communities, lakes, grasslands,

farmlands, urban and rural settlements, etc. Corridors can be windbreaks. "The patches can be plant communities, lakes, grasslands, farmlands, towns and villages, etc., the corridors can be windbreaks, rivers, canyons, roads, cultural exchange corridors, etc., and the substrates can be mountainous substrates, water network substrates, forested substrates, grassland substrates, farmland substrates, etc. This functional-territorial unit articulates the natural base environment outwardly, connecting with the mountain, water, forest, field, lake, grass and sand system of the large region, and inwardly, connecting with the historical urban area and other built-up areas of the historical city, especially penetrating into the interior of the historical city through the blue-green open space inside the city, which enables the large natural ecological area to be connected with the city's urban and rural settlement system, the centralized construction area of the city, the historical urban area inside the city, the community unit, and the cultural exchange corridor, and so on. This makes the large natural ecological zone, together with the urban and rural settlement system, the centralized construction area of the town, the historical urban area, the community units and the buildings inside the town, form a natural ecology-social ecology organic and unified whole. This scale of the environment, as Mr. Wu Liangyong[40] said, is the city's overall natural environment and ecological environment, is the settlement to produce and play a function of the foundation, human settlements.

2.2.3 Historic landscape setting

The third level is the historic landscape setting of the historic city, which encompasses the natural, man-made and human resources within the city, i.e. the natural features of the historic city on a relatively small scale such as topography and hydrology, the historic and contemporary built environment, the infrastructure above and below ground, the land-use patterns and spatial arrangements, the sensory and visual connections, and the structural elements of the city, as well as the practices and values of the society and culture, the economy, and the intangible aspects of heritage related to diversity and identity. processes, and intangible aspects of heritage related to diversity and identity[41] . Environments at this scale are characterized by "historically layered resources". It is clear that the historic landscape environment is to be transcended

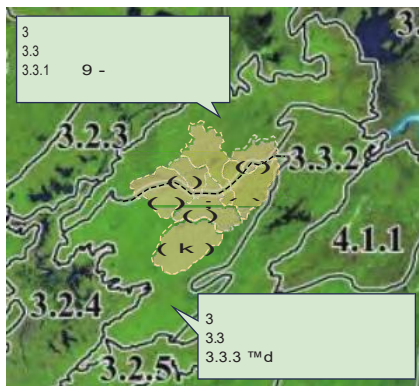


Fig.2 Overlapping of Huizhou cultural ecological reserve with level 3 ecological zones of China's territorial ecological base zones

The more we usually refer to the city site environment and its interdependent mountains and rivers in the study of historic cities^[42] . We broadly adopt the imagery of historic urban landscapes in the UNESCO Recommendation on Historic Urban Landscapes, which includes not only the material part of the landscape environment, i.e., the visual landscape that is visually recognizable and psychologically perceptible, but also the immaterial part of the landscape, such as the activities of city dwellers that have historical value.

In the context of studying the impacts of climate change on historic cities, it may be more or less difficult to explain the interrelationships between climate change and historic cities when the scale of the environment is limited to the "setting of the city site and its interdependent mountains and rivers". Although the literal scale of "city site environment" can be large or small, in practice this term points to

the environmental characteristics of the location where the city site is situated. For example, we may say that a certain historical city is located at the confluence of two rivers, with convenient transportation and a concentration of merchants and traders, and has become the "Little Shanghai" of this region. " and so on, focusing on the development of urban functions of the resource environment conditions, and "with its interdependent mountains and rivers form and scenery" belongs to the "cultural-environmental", is the city site around with the growth of settlements, the It is the result of the people who were born and grew up around the city site transforming the nature and enjoying the landscape, "that place is his home and memory storage place, and also the source of livelihood"^[43] . "Mountains and rivers are larger in spatial scale and richer in dimensions than the environment of a city site, which is the environment perceived in production and life. Today, in the historical context of building an ecological civilization system, research on the conservation and use of historic cities must pay attention to the ecological functions of historic cities and the possible impacts of climate change, which is linked to the natural base environment and the ecological environment of human settlements in which historic cities are located.

Introducing nature into the perception of the environment of the historic city is a change of concept; at the same time, we adopt the concept of the historic landscape environment in order to break through the narrow understanding of the visual environment, and to incorporate the economic, social and cultural elements of the environment beyond the environment within visual reach. Undoubtedly, as a whole, the three levels of historic urban environment can help us to establish a comprehensive dimension of understanding, and incorporate the factors that need to be considered for sustainable development, such as climate change and ecological service function, into our research on historic cities, which not only tries to open up a new topic for the study of the relationship between climate change and historic cities, but also opens up a new space. In the next section, based on the proposed path to improve the environmental cognition of historic cities, this paper tries to make a rough study on how to enhance climate resilience in the practice of historic city conservation planning.

3 A "natural solution" to enhance climate resilience in historic cities: the case of Dunhuang
"Nature-based Solutions (NbS), often translated as "nature-based solutions", is defined by the IUCN as "actions that address societal challenges and provide benefits for human well-being and biodiversity through the conservation, sustainable management and restoration of natural or improved ecosystems". NbS, often translated as "nature-based solutions", is defined by the IUCN as "actions to address societal challenges through the conservation, sustainable management and restoration of natural or modified ecosystems in order to respond effectively and adaptively to societal challenges and to bring benefits to human well-being and biodiversity"^[44-45] , i.e., the use of ecosystems and the services they provide to address societal challenges facing society such as climate change, food security, water security, disaster risk, social and economic development. In the early 21st century, NbS was proposed by the World Conservation Union (IUCN) and the World Bank to address environmental challenges such as climate change, diminishing environmental resilience, and ecosystem decline through sustainable and cost-effective ecological restoration measures^[46-47] . The "nature solution" is inspired by the laws of nature and utilizes or emulates the natural forces of ecosystems and their services to adapt to and mitigate the risks and challenges posed by climate change. For historic cities, the force of climate change alters the environmental conditions for the development of historic cities, the historical and cultural remains may be damaged, the environment on which the remains depend may be altered, and the damage to the authenticity and integrity of the historic city means the damage to its historical and cultural value. Therefore, the conservation planning of historic cities under climate change should sustainably manage the changes that are occurring and will continue to occur, so that the resilience of historic cities can be improved. Controlling and guiding land use and spatial patterns around historic cities is a means of management, but the environmental change behind the
The key to planning.

The discussion in this section takes Dunhuang in Gansu as an example. Dunhuang is located at the western end of the Hexi Corridor in Gansu Province, and is a county-level city in Gansu Province, administered by Jiuquan City, with a total area of 26,700 km² and a resident population of 185,000 people. The cultural heritage mainly includes Mogao Grottoes, Hangquanjiu Ruins, Yumen Pass Ruins and other world cultural heritages, Dunhuang National Historical and Cultural City (including historical

and cultural neighborhoods) and intangible cultural heritages, etc.; the natural heritage mainly includes the Yadan National Geopark, Yueya Springs, Mingsha Mountain, Wolvu Pools, Dunhuang West Lake, Dunhuang East Lake, Nanshuanyuan Wetland, etc.: it can be said that there are rich and diversified natural and cultural heritage resources distributed in this arid land of the Northwest. It can be said that on this arid land in Northwest China, there are abundant natural and cultural heritage resources.

3.1 Identification of Key Environmental Elements at Multiple Scales in Historic Cities

Culture is a product of adaptation to the natural environment, and culture in turn influences the natural environment[48] . As an ecosystem, the city has the basic functions of material circulation, energy flow and information transfer[49] . The overall study of the natural environment, human ecological environment and historical landscape environment of the historical city requires attention to the key elements of the material cycle, energy flow and information transfer, and the understanding of the process of their transfer helps to reveal the process of the interaction between different levels and scales of the environment, and helps to understand the uniqueness of the formation and evolution of the historical city as an organic unity of the natural and social ecosystems. It helps to understand the uniqueness and creativity of the formation and evolution of the historic city as an organic unity of natural ecology and social ecology, and helps to understand the characteristics and connotations of the heritage value of the historic city.

3.1.1 Key environmental elements in the natural base environment Dunhuang is located in the westernmost part of the Hexi Corridor, Gansu, The border of Qinghai and Xinjiang provinces (regions). According to China's Land Ecological Base Zoning (Trial), Tun

Tab.2 The ecological base zone where Dunhuang is located

Class I ecoregion	Secondary ecoregion	Basic characteristics of the secondary ecoregion to which it belongs	ecological zone III
6 Northwest Ecoregion	6.2 Allah Shan-Hesi corridor	It has an arid climate in the middle temperate zone, with an average annual precipitation of 40-360 mm, and the landforms are dominated by hilly and Gobi landscapes. The soil is mainly gray desert soil and wind sandy soil, and the parent material of soil formation is loose One of the. The wetlands and grasslands The desert-like mosaic is an important barrier to It is an important barrier to prevent wind and fix supply function	6.2.1 Northern Alxa Gobi Desert Ecoregion
			6.2.2 Low mountain grassland ecoregion in
			6.2.3 Ulan Buh Desert Desert Ecoregion
			6.2.4 Tengger Desert Desert Ecoregion
			6.2.5 Badanjilin Desert Ecoregion
			6.2.6 Yaburaj Hills Central Mountain
			6.2.7 Shiyang River Plain agro-
			6.2.8 Farmland and grassland ecoregion of the
			6.2.9 Lower and Middle Black River Plain
			6.2.10 Shule River Plain Grassland

Dunhuang belongs to the Northwest Ecological Region in the first-level ecological zone, the Alashan-Hexi Corridor Ecological Zone in the second-level ecological zone, and the Shule River Plain Grassland Ecological Zone in the third-level ecological zone. According to the principles of similarity within ecological regions, inter-regional divergence and maintaining the relative integrity and continuity of natural geographic units, the region where Dunhuang is located presents the natural basal characteristics of "wetlands and grasslands distributed along the river are mosaic in patches in the desert". See Table 2. Specific analysis, the desert Gobi oasis basin area in central Dunhuang is mainly to realize wind and sand control, stabilize the oasis, and conserve the ecosystems of forests, grasses, wetlands, rivers, etc., and is also an important area for coordinating the integrated development of urban and rural construction, agricultural production, ecological protection, cultural protection, tourism, etc., of which the oasis is the key to maintaining the stability of the ecology of Dunhuang and the key to sustainable development. The two ecological corridors dominated by the Shule River and the Danghe River are rich in wetlands, forests, grasses and biodiversity resources along the river, and are the lifeline of Dunhuang's sustainable ecosystem development. Therefore, "arid, desert, oasis, river" is the key environmental element in the first level of the natural base environment to promote the formation of

the local natural and cultural background of the area where the historic city of Dunhuang is located, reflecting the ecological function and spatial structure of the historic city of Dunhuang and the symbiosis of the environment.

3.1.2 Key Environmental Elements in Habitat Ecosystems The factors that have contributed to the evolution of the Dunhuang ecosystem are primarily from the

Natural and social aspects: in the context of climate change, the originally arid climatic conditions are facing a warming and humidifying trend, and the increase in average temperature has a certain impact on the growth of vegetation; population growth, increase in arable land, technological advances, tourism activities and other social factors have increased the demand for water resources, crowding out the use of ecological water, which is the main reason for the degradation of vegetation and the shrinkage of the natural ecosystem.

Grasping and adapting to the laws of nature is the key to good conservation.

Source: Organized by the author based on the "Ecological Base Zoning of China's Land Area (Trial)". This is due to^[50]. Changes in the natural ecosystem are closely related to the environment in which Dunhuang's heritage exists, and the deterioration of the ecosystem due to water scarcity, declining groundwater levels, increasing land sand, flooding and dust storms has seriously threatened the survival of the cultural heritage and natural landscapes. Mogao Grottoes due to sand attack, statues and murals disease is becoming more and more serious, and may even cause the collapse of the cliff body; affected by the continuous decline in groundwater levels, the crescent moon spring is facing the risk of depletion; mingsha mountain south foothill sand mountain to spring side advance, the crescent moon spring is also faced with the danger of being buried^[51]. Therefore, within the urban and rural functional territorial units of Dunhuang, "wind, sand and water", which are highly relevant to heritage security, have become key environmental elements in the second level of the human ecological environment to maintain ecosystem services and influence the heritage value of Dunhuang, especially in recent years, when the extreme precipitation caused by climate "warming and humidification" has caused the whole area to suffer from the effects of the "warming and humidification" of the climate. The extreme precipitation brought about by climate "warming and humidification" has created many uncertainties in the spatial and temporal distribution of water resources throughout the region, and the risk of flooding has increased.^[52] It also constitutes an unprecedented pressure on the regional flood control and urban flood prevention of the historic city.

3.1.3 Key environmental elements in the historic landscape setting

Relevant studies at the level of historical landscape environment usually have a more skillful organization of the material space elements such as the outline of the city wall, spatial layout, historical axes, street texture, important spatial nodes, and important sight corridors that characterize the traditional pattern of the historical urban area. The Dunhuang Historical and Cultural City Protection Plan (2013-2030) states that the natural landscape and humanistic elements of the city's environment should be protected. The key elements of the spatial form management of the Dunhuang Historic City include "mountain landscape, high points, contour lines, the water body and shoreline of the Danghe River, and the heights, volumes, styles, and colors of the buildings around the county and county towns" (Fig. 3), which are also mainly based on the visually cognizable and psychologically perceptible form environment, and all of which are in line with the requirements of the national norms of the Protection Plan for Famous Historic and Cultural Cities. It is also in line with the requirements of the national norms^[42]. However, the key environmental elements in the historic landscape environment need to be examined in the context of the natural base environment and human ecological environment, from the requirements of heritage authenticity and integrity, and through long-term environmental monitoring to examine the weak points under the influence of climate change, so as to find the correlation between the key environmental elements at different scales. For example, the conditions of the subsurface, such as the height and volume of buildings in the urban area of Dunhuang City, have an impact on the wind direction and force, and indirectly affect the speed and direction of movement of the sand hills in the southern foothills of the Mingsha Mountains. Such monitoring may be readily available, or it may be yet to be carried out, but its essence is to establish a deeper understanding of the nature-heritage relationship in question, and to provide a scientific basis for applying the forces of nature and utilizing ecosystems and their services to address some of the specific challenges of historic city conservation.

3.2 " Natural Solutions" for Enhancing Climate Resilience in Historic Cities

3.2.1 Impacts of climate change and urbanization on heritage properties and their environment

(1) Extreme weather flooding threatens World Heritage Mogao Grottoes

The Mogao Grottoes site selection due to water, one of the necessary conditions for the construction of caves is water, near the Daquan River site selection for the excavation of the grottoes of the craftsmen to provide the necessary living water, but also for future generations to protect the Mogao Grottoes put forward a higher flood control requirements. Due to the very limited conditions of rainwater interception and storage in the Daquan River basin, surface runoff converges rapidly, and short-term heavy rainfall often poses a flooding threat to the Mogao Grottoes. 2011 June 16, the occurrence of the mega-flood, destroyed the Mogao Grottoes Cultural Heritage Protection Zone according to the standard of one in a hundred years of the set of levees, the floodwaters over the riverbanks into the Mogao Grottoes Grand Paikou and the surrounding green space, and into the Mogao Grottoes in the northern area of the grottoes of the lowlands in front of the cave; June 4, 2012 On June 4, 2012, another major flood occurred, and floodwaters from the Daquan River spread over the flood control levee in front of the Mogao Grottoes and the bridge across the river, causing some of the ground floor caves to enter the water and depositing a large amount of sediment in front of the grottoes.

(2) Falling groundwater levels jeopardize Luna Springs

continue to exist

The Dunhuang oasis plain consists of the Danghe flood plain, alluvial plain and lakeshore plain, with thick aquifers, and is a groundwater-rich accumulation zone. For the further development of the region, the local area has been exploiting groundwater in large quantities since the 1970s, and the over-exploitation of groundwater is serious, with the over-exploited area basically covering all the cultivated land, gardens, and forests in the rural and agricultural areas of the Danghe River Irrigation District in Dunhuang City, and the recharge of groundwater is insufficient, leading to the ecological degradation of native vegetation around the Lunya Spring and even the entire oasis due to the lack of water and the aggravation of desertification, which is generated by the siphoning of groundwater. The water level of the Lunar Spring, which was created by the siphoning of groundwater, has been declining and was once facing exhaustion.

(3) The wind ring on which Mingsha Mountain depends for its stabilization and recovery

The situation is affected

The size of the Mingsha Mountain is comparable to that of a sandbar oasis, with a sand source from the Kumtag Desert, and the stability of its morphology is highly dependent on the stability of the regional wind environment formed by the enclosure of the Three Dangerous Mountains, the Black Stone Peak, and the oasis to the north. Normally, the effects of moderate anthropogenic activities on the morphology of the sandhills can be recovered by nighttime wind effects. However, excessive urban construction can affect the natural action of wind and have an impact on the stability of the sandhill morphology. Statistically, during the 15 years from 1995 to 2010, the ridges of the east and south mountains of the Mingsha Mountain moved 8-10 m toward the Lunar Spring, and the area between the north and south mountains shrank by about 7%. In the wind environment affects the stabilization of the morphology of the sandy mountains, the urban construction of the



Fig. 3 Schematic representation of Dunhuang historical city and surrounding landscape environment
 Fig.3 Dunhuang historic city and its surroundings Source: Beijing Tsinghua Tongheng Planning and Design Institute Co. Dunhuang Historic and Cultural City Protection Plan (2013-2030) ,^② 2015

The combined effects also threaten to bury the Moon Springs in yellow sand.

3.2.2 Seeking "natural solutions" based on environments at different scales.

According to the Global Standard for Nature-Based Solutions (2021) published by the IUCN[53], the guidelines for good NbS planning and design are to plan and design well at different environmental scales (Guideline 2), with three key indicators: firstly, it should recognize and respond to the interactions between economic, social and ecological systems; secondly, it should be complementary to other relevant measures and bring together synergies across different sectors; thirdly, it should incorporate risk identification and risk management in areas outside the intervention site; and thirdly, it should incorporate risk identification and risk management in areas outside the intervention site. Thirdly, risk identification and risk management in areas beyond the intervention site should be incorporated.

First of all, in the case of Dunhuang, considering that in the arid northwestern region, the landform type is dominated by hilly and Gobi landscapes, the soil is dominated by gray desert soils and wind-sand soils, and the soil-forming matrices are dominated by the loose accumulation type, which is one of the birthplaces of sandstorms and dust storms in the northern part of China, in order to solve the security of a series of cultural heritages in Dunhuang, it is necessary to intervene within the area of these heritages or even a larger area of the surrounding region, which is based on the principle of Interaction between different levels of the environment. Based on Dunhuang's "arid, desert, oasis, river" natural base environmental characteristics, reduce disturbances, eliminate threats, and maintain the stability and longevity of the habitat ecosystem. Adopting the natural recovery path, in the western part of the city area, the protection of biodiversity is the main focus, while taking into account the sandy land management and windbreaks, curbing the eastward invasion of the Kumtag Desert, and protecting the sites of Yangguan Pass and Yumen Pass; in the southeastern part of the city area, focusing on the key areas of Mingsha Mountain-Moonacre Springs, the Mogao Grottoes, and the Hanging Springs, the establishment of the sand obstruction zone, Gobi protection zone, protective forests, and the Gobi protection zone, according to the different geomorphological features and surface composition of the material. Gobi protection area, protective forest belt construction area, natural vegetation sealing protection area and other different ecological functions of the restoration area, so that the wind and sand disasters that jeopardize the heritage have been effectively controlled to a certain extent.

(Figure 4), creating environmental conditions for the protection of Dunhuang on a larger scale than the heritage site. It is easy to take for granted that the establishment of the Sand Barrier Zone, the Gobi Protected Area, and the Protected Forest Belt is a series of engineering measures, but in fact it is an economic and social activity led by the government, with the participation of the state-owned forest farms, enterprises, and the community that has lasted for several decades, and embodies the interrelationships among people, the economy, and ecosystems that tend to lead to a benign cycle. This is the first key indicator of the "natural solution".

Groundwater table decline and survival of Luna Springs and flooding

The water threat is actually a problem brought about by changes in the regional water ecology and water system. This issue was studied in the Dunhuang City Land Space Master Plan (2021-2035), based on the whole region, the whole element, multi-systems, composite technology system to promote the return of water ecology to a state of relative balance, so as to solve the protection of the "point" of the Moon Springs. Four measures are formulated with the goal of improving the overall water environment: one is for groundwater, the other is for water quality.



Figure 4 Dunhuang Mogao Grottoes Protection and Utilization Project - Wind and Sand Protection

Project

Fig.4 Dunhuang Mogao Grottoes conservation and utilization project: wind and sand protection project

Source: China Academy of Planning (Beijing) Planning and Design Co. Dunhuang City Territorial Spatial Master Plan (2021-2035) Project Team^③, 2020-2023

The third key indicator of a "natural solution" is the inclusion of risk identification and risk management in areas outside the intervention site. This is based on a full understanding of the overall ecological relationship between the Mingsha Mountain, the Moon Spring and the city of Dunhuang. The Mingsha Mountains and the Moon Springs are capable of long

The problem of falling levels is not limited to localized water transfers,

"Headache cure headache foot pain cure foot", but in the regional scale system to carry out ecological governance and restoration of mountains, water, forests, fields, lakes, grasses and sands, ecological vegetation restoration of the Shule River and the Party River along the line, to maximize the creation of natural restoration of the conditions, to achieve the effective rebound of the water level of the Lunar Spring and the collection of a variety of governance efficacy. Secondly, we will continue to optimize the water use structure, starting from optimizing the planting structure and improving agricultural water conservation technology, improving agricultural water use efficiency, reducing agricultural irrigation water use, enhancing the proportion of ecological water use, and promoting the rebound of the oasis' groundwater level. Thirdly, for the flood prevention of Mogao Grottoes, we do not simply choose to build flood prevention facilities around Mogao Grottoes (raising the flood prevention standard of the urban section of the Danghe River to one in 50 years, and that of the Mogao Grottoes section of the Dazhuan River to one in 300 years), but rather, in combination with the regional flood prevention, we will increase the storage capacity and the area of stagnant floodplain through ecological restoration of the entire area and upstream and downstream water conservancy projects in Dunhuang, so as to effectively increase the overall response to sudden floods in the surrounding areas of the heritage site. Regional overall response to sudden flood storage capacity, the Mogao Grottoes flood risk to a minimum. Fourth, in the oasis water-saving agriculture effectively back to the groundwater on the basis, assisted by engineering water recharge, the use of party river along the Gobi construction "twelve even lake" and water basin project, increase the amount of catchment water seepage, and targeted water recharge on the moon spring (Figure 5). From these problem-solving paths, synergistic cooperation between multiple sectors is a basic guarantee, and reflects the fact that the "natural solution" is not simply all-natural, but rather, depending on the specific circumstances and scenarios, promotes complementary natural restoration measures and other types of projects, which can include engineering projects, information technology projects, and the necessary financial measures (Figure 5).

The fundamental reason for the coexistence of the period is that the sandy mountain and the big and small spring bay surrounding the crescent moon spring are either subjected to two groups of sand-carrying winds with comparable sand-carrying capacity but opposite sand-carrying winds or subjected to three groups of sand-carrying winds with offsetting sand-carrying winds, which realizes the dynamic equilibrium of the sand and wind transport. Since Dunhuang's tourism industry entered a rapid development stage in the 1990s, along with the growth of tourists at Mingsha Mountain and the expansion of the city's construction scale, academics and planning practitioners have gradually carried out relevant research on the deformation of the mountain during the daytime due to tourists' trampling, and the recovery of the wind at night. According to the current consensus, the key to maintain the stability of the location and shape of the Mingsha Mountain is to minimize the impact of urban construction and even irrational afforestation on the native wind environment of the Mingsha Mountain. Dunhuang City Territorial Spatial Master Plan (2021-2035) puts forward three core initiatives to protect the regional native wind environment and synergistically protect the ancient wonders of the "Sand and Spring Symbiosis": one is to adopt the relevant experts' recommendation to take the center point of the south bank of the Moonacre Spring as the origin, and to have a 12 km isometric circle, The first is to adopt the relevant experts recommend to take the center point of the south bank of the crescent spring as the origin, by 12 km isometric circle, 40 ° azimuth line and 80 ° azimuth line composed of the northeast wind mouth fan area are assigned as the mingsha mountain - crescent moon spring protection zone, the region is strictly prohibited new arable land, vegetation and buildings, and gradually transform

the existing vegetation and buildings, in order to reduce the vegetation and buildings of the wind block, and at the same time to avoid the man-made reclamation of arable land and lead to enter the scenic area of the sand and dust material increased, in order to reduce the topography to wind The second is to take the initiative to optimize the urban spatial structure and morphology through the delimitation of urban development boundaries, and to pre-control the northward ventilation corridor (Figure 6). (Fig. 7); Thirdly, the height of buildings in the main urban area should be controlled, the height limit of urban construction should be set scientifically, and the height of oasis vegetation should be controlled.

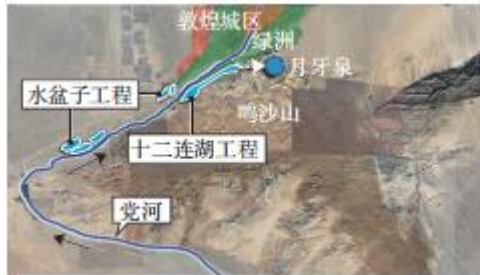


Figure 5 Schematic diagram of the ecological water replenishment project in the upper reaches of the Dang River

Fig.5 Upper Dang River ecological water replenishment project

Source: China Academy of Planning (Beijing) Planning and Design Co. Dunhuang spatial master plan (2021-2035) phase results^③, 2020-2023

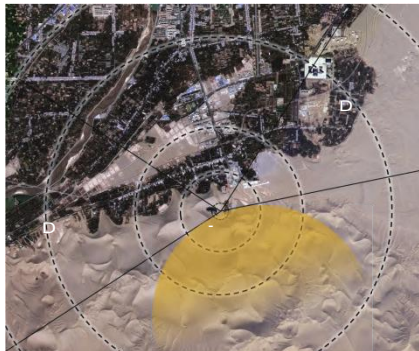


Fig. 6 Schematic of wind environment around Mingsha Mountain-Moonhope Spring

Fig.6 Wind environment around Mingsha Mountain-Yueya Spring

Source: China Academy of Planning (Beijing) Planning and Design Co. Dunhuang spatial master plan (2021-2035) phase results^③, 2020-2023

The sand hill morphology and location can be stabilized by coordinating the height of the vegetation and avoiding the weakening of the wind speed in the north direction (Fig. 8). Maintaining the symbiotic relationship between the Mingsha Mountain and the Moon Spring can only be realized through scientific planning interventions on land use practices in areas other than the problematic site, such as reclaiming farmland, reforestation, and the external spatial patterns of the buildings, etc., and in order to do so, the key to finding a "natural solution" also lies in the understanding and mastery of the environment of Dunhuang at all levels of the environment. The key to finding the "natural solution" also lies in recognizing and mastering the laws of nature at all levels of Dunhuang's environment. The former long-term scientific



Fig.7 Reserving ventilation corridor through the de- lineation of urban growth boundaries
Source: China Academy of Planning (Beijing) Planning and Design Co. Dunhuang spatial master plan (2021-2035) phase results^③ , 2020-2023

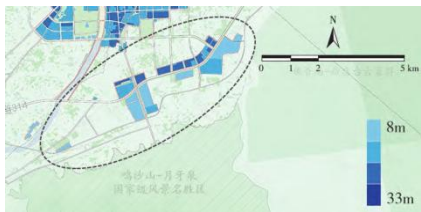


Fig. 8 Building height control in Dunhuang central city adjacent to Mingsha Mountain area
Fig.8 Building height control in Dunhuang urban area adjacent to Mingsha Mountain

Source: China Academy of Planning (Beijing) Planning and Design Co. Dunhuang spatial master plan (2021-2035) phase results^③ , 2020-2023

The accumulation of observations has enabled future generations to identify where the risks lie in the Mingsha Mountains and the Lunar Springs, and to realize effective management of the risks through the means of spatial planning.

3.3 Heritage impact assessment based on three environmental levels (HIA): further considerations

The identification of key environmental elements for the natural base environment, human ecological environment and historical landscape environment of historic cities is based on research results and established experience on the natural environment and cultural heritage of historic cities. In order to formulate a good program to cope with climate change in the conservation planning of historic cities, this technical link is at the initial stage of planning preparation, and it can be said that the identification work should be basically completed in the investigation stage. However, it is obvious that most of the basic information for identifying key environmental elements is the current situation, the present, not the future. Therefore, we envision that improving the technology of conservation planning for historic cities under the condition of climate change requires the establishment of a forward-looking, predictive, and relatively rigorous analytical link, which leads to this paper's proposal of a heritage impact assessment under the condition of climate change based on the three levels of the heritage environment. This part of the reflection belongs to the technical logic of the setup

thought, and there are no actual cases to back it up. In order to find To find the path to adapt to and mitigate the impact of climate change in the conservation and development of historic cities, we firstly stratify the heritage environment of historic cities, and identify key environmental elements from each level of heritage environment, and reveal the mechanism of interaction of key environmental elements in different levels of environment, but what will happen in the future? We believe that heritage impact assessment under the influence of climate change should focus on the three spatial levels of natural base environment, human ecological environment, and historic landscape environment as a whole, and judge the impact of future natural and artificial interventions under climate change on the authenticity and integrity of historic cities as well as on their historical and cultural values as a whole.

For impact assessments at the level of the natural base environment.

National and regional climate and meteorological data and research results can support the analysis and assessment of future trends in the natural base environment, for example, based on the precipitation, temperature and other observation data covering the whole country and lasting for several decades, the trend of the impact of climate change on the ecological base of the terrestrial area in which the historical city is located can be finely estimated and depicted; for the assessment of the impact of the human habitat ecological environment level, on the one hand, we have to see which factors at this spatial level will be significantly affected by climate change. For the impact assessment of the habitat ecological environment level, on the one hand, it is necessary to see which factors at this spatial level are significantly affected by climate change, and on the other hand, it is also necessary to look at the impacts of various economic and social activities planned for the urban and rural functional territorial units on the ecological service functions such as water conservation, soil and water conservation, windbreak and sand fixation and biodiversity, etc., so as to predict the trend of the changes of the ecological service functions in the future, which will greatly enhance the strategic value of the conservation planning for the historic cities in dealing with climate change. For the impact assessment at the level of historic landscape environment, more attention can be paid to the development and protection construction projects that have been specified or proposed in the relevant plans, and the spatial impacts of the major projects on the historic landscape environment can be assessed, which may include some construction activities or some tourist and leisure activities with concentrated population. Impact assessment at different spatial levels will have different effects: heritage impact assessment based on the natural base environment can help to grasp the changes of the ecosystem background conditions in which the historic city is located, and to clarify the laws of nature that must be complied with when there is nature to support or imitate nature; heritage impact assessment based on the ecological environment of human settlements can help to better formulate preventive protection measures in the conservation planning, and through the overall arrangement of the ecological function relationship between living and production in the urban and rural functional and territorial units, it can also help to improve the living and production conditions of the historic city. The impact assessment of heritage based on the historic landscape environment helps to better formulate preventive conservation measures in conservation planning through the holistic arrangement of ecological function relationships in urban and rural functional territorial units to ensure that ecosystem functions are stabilized or that changes are contained within the scope of natural recovery; the impact assessment of heritage based on the historic landscape environment helps to better formulate preventive and salvage conservation measures in conservation planning for the heritage itself and its environment. It should be emphasized that impact assessment based on the three levels of the heritage environment is not a simple split. Rather, it is necessary to make an overall analysis and judgment, so that the heritage impact assessment work can be more systematic and comprehensive, and grasp the impacts of climate change on historic cities more comprehensively around the historical and cultural values and characteristics of historic cities, so that the natural environment and cultural heritage can be truly integrated, and the next ecosystem protection and restoration measures can provide a more accurate and efficient focus point.

4 Conclusion: Improvements in the planning methodology for the conservation of historic cities Adapting to and mitigating the impacts of climate change on historic cities and enhancing their climate resilience are new issues. The relationship between the natural environment and cultural heritage needs to be re-examined. Looking back at the history of conservation of historic cities, conservation planning started from the conservation of cultural relics, and step by step we realized that "all" of the historic city could be the object of conservation. This process of realization started from the buildings, the historic lots, the historic urban area to the environment of the city site and the surrounding landscape, from the inside to the outside. The pressure brought by climate change may force us to re-recognize the environment of the historic city, from the natural base environment to the human ecological environment to the historic landscape environment, from the outside to the inside, bringing our awareness of cultural heritage preservation to a new level.

Conservation planning techniques for historic cities will also change, i.e., part of the problems to be addressed by planning belong to the natural environment and ecosystems, the best means of adapting to and mitigating climate change is to let nature do the work, nature is the least costly way for humans and ecosystems of the planet to adapt to climate change, and ecosystems and their services are to be

utilized to help historic cities to gain a greater resilience to disaster risk Resilience. Finding the "natural solution" to the problems posed by climate change, the way out lies in multidisciplinary cooperation, long-term scientific observation and understanding of the laws of nature. The development of conservation planning techniques for historic cities should not only recognize the laws of cultural heritage conservation, but also the laws of ecosystems. Looking back to the beginning of the reform and opening up, the planning predecessors placed the planning of scenic spots and historic cities in the same research organization, which has the deep meaning of integrating nature and culture, so that we can still be inspired by it when we face the new challenges of climate change today.

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I would like to express my deep appreciation!

marginal notes

① Policy Document on Climate Action for World Heritage (new Policy Document) Revised for discussion at the 44th session of the World Heritage General Assembly in July 2021 (The final version of the Policy Document on Climate Action for World Heritage (2023) was considered and adopted at the 24th session of the General Assembly of States Parties to the World Heritage Convention in November 2023 (Resolution 24 GA 8). The final version of the Policy Document on Climate Action for World Heritage (2023) was adopted by the General Assembly of States Parties to the World Heritage Convention at its 24th session in November 2023 (Resolution 24 GA 8).

② "Dunhuang Famous Historical and Cultural City Protection Plan (2013-2030)" was prepared by Beijing Tsinghua Tongheng Planning and Design Institute有限公司 and approved in 2015.

③ The "Dunhuang City Territorial Spatial Master Plan (2021-2035)" was prepared from 2020 to 2023 by the China Academy of Planning and Design (Beijing) Company.bibliography

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