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Spatial pattern and influencing factors of land border cultural heritage in China

Shengrui Zhang¹ , Lei Chi¹ , Tongyan Zhang¹ and Hongrun Ju^{2*}

Abstract

This paper provides an analysis of China's land border cultural heritage, aiming to offer guidance for its protection and development. The study compiled a comprehensive database of heritage sites and analyzed their mathematical characteristics based on quantity, type, and quality. The spatial pattern of the cultural heritage was described using kernel density analysis, spatial variability, and spatial correlation, while the driving mechanism was measured based on Geo-Detector model. The findings revealed that the land border areas of China have a total of 1227 cultural heritage, comprising two main types and 18 subtypes. National cultural heritage accounted for 22.74%, with ancient city ruins being the largest type of cultural heritage. The Southwest and Northeast regions of China exhibited high-high clusters and low-low clusters, respectively. Moreover, the study identified history of administrative succession, evolution of historical and cultural, altitude, distance from the city, population density, minority population ratio, urbanization process, and per capita GDP as significant factors impacting the spatial pattern of land border cultural heritage in China. Based on these findings, the study suggests that the government should invest more in border cultural heritage, improve transportation infrastructure in border areas, ensure dynamic inheritance and protection of cultural heritage, and promote the joint development of different types of cultural heritage. The research results will provide data support and decision-making reference for the sustainable development of cultural heritage in land border areas, and can provide a new perspective for the management of cultural heritage in similar areas.

Keywords Cultural heritage, Spatial pattern, Influencing factors, Land border, China

Introduction

Cultural heritage encompasses various aspects such as history, cultural relics, archaeology, literature, art, and folklore. It is generally categorized into two types: material cultural heritage and intangible cultural heritage [1]. Material cultural heritage refers to cultural relics that hold historical, artistic, and scientific value. This includes ancient sites, ancient tombs, buildings, grotto temples, stone carvings, murals, as well as significant historical

sites and representative buildings from both the modern and contemporary eras. It also comprises movable cultural relics like important objects, works of art, documents, manuscripts, books, and materials from different historical periods. The preservation and promotion of material cultural heritage play a vital role in enhancing regional culture and boosting tourism competitiveness [2–4]. On the other hand, intangible cultural heritage pertains to cultural elements that do not possess a tangible form. It encompasses folklore, traditional medicine, traditional dance, traditional music, traditional skills, traditional sports, entertainment and acrobatics, folk art, and traditional art. These diverse forms of intangible cultural heritage exhibit regional, contemporary, and national characteristics [5].

Countries worldwide are actively leveraging their cultural heritage to promote the development of the cultural

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industry and foster the preservation, dissemination, and growth of their cultures. For instance, Ezenagu discovered that both tangible and intangible heritage resources in Nigeria play a crucial role in driving the development of regional culture and tourism, particularly in facilitating the inheritance and advancement of regional culture [6]. In another study, Li focused on the folk song cultural heritage along the Grand Canal of Chinese culture as their research subject. They analyzed its spatial characteristics and influencing factors, which holds immense significance for safeguarding and developing the intangible cultural heritage with regional practical and social relevance. Furthermore, this research contributes to the progress of the Grand Canal cultural belt [7]. Moreover, Stanik et al. developed an index system based on two dimensions—time depth and historical richness—to evaluate Scottish cultural heritage and depict its spatial distribution. This research framework enables a more comprehensive understanding of the diverse values associated with cultural heritage, thereby fostering a stronger bond between people and nature within the region [8].

China boasts the highest number of land neighbors globally, encompassing 22,000 km of land border areas. Among these, 19,000 km are located in ethnic minority regions. As a result of historical cultural exchanges and political interactions among various countries, these border areas are abundant in cultural heritage such as city wall ruins, religious structures, ancient tombs, folklore, and arts. Notably, there is a rich presence of Manchurian culture, fortress and frontier sites along the China-Russia border, grassland culture and nomadic traditions along the China-Mongolia border, as well as Thangka paintings and Tibetan Buddhist culture along the China-India border. China's land border areas are also home to numerous ethnic minority groups. According to the latest census results, over 30 resident ethnic minorities reside in these border areas (comprising 45 prefecture-level cities), with a combined population of 34.56 million. This accounts for 28.8% of China's total ethnic minority population. The cultural traditions of diverse ethnic minorities from different countries have been widely preserved and embraced in these regions, resulting in a unique fusion with mainstream culture. Within this cross-cultural environment, ethnic minorities have retained and developed their traditional customs and cultural practices. China's land border areas, being remote inland and economically less developed, have helped maintain the purity of border culture and heritage. Furthermore, the natural environment, characterized by mountains, grasslands, forests, and rivers, has shaped the way of life, folklore, and traditional knowledge of ethnic minorities residing in the land border areas. It has also facilitated the formation and preservation of intangible cultural heritage. In

addition, the Chinese government has also promulgated a series of policies to promote the protection and development of border cultural heritage. In 2017, the Ministry of Culture and the State Council successively issued the "Guiding Opinions on Strengthening Cultural Construction in Border Areas" and the "13th Five-Year Plan for Revitalizing Border Areas and Enriching People". Relevant documents pointed out that in the future, we should strengthen the protection of cultural heritage and promote the revitalization of traditional crafts in land border areas of China.

In recent years, The Western Development Strategy and One Belt One Road initiatives have gained momentum, making cultural heritage in land border areas crucial for stimulating local economies, improving geopolitical relations, and enhancing international cultural exchanges and cooperation. However, certain challenges arise from the regional natural and social environments, including unbalanced distribution, asynchronous development and protection, and insufficient cross-border cooperation mechanisms and management systems. These challenges hinder the sustainable development of cultural heritage in China's land border areas. To promote the sustainable development of border cultural heritage, it is essential to first understand the background of these resources and describe their spatial pattern. Additionally, revealing the weak points in the protection and development of border cultural heritage and identifying the factors influencing the spatial pattern are critical areas of focus. These topics hold particular significance within the macro context of establishing pilot zones for border culture development and promoting cross-border regional cooperation and sub-regional economic collaboration.

The current focus of cultural heritage research in China has primarily been on economically developed areas. This research has mainly centered around intangible cultural heritage and has been limited in its quantitative analysis. However, there has been a lack of studies on the cultural heritage of ethnic minority areas and areas with less developed economies. Additionally, there has been a notable absence of research on the cultural heritage of China's land border areas. This lack of research and guidance on the development and protection of border cultural heritage poses a challenge to promoting the sustainable development of cultural heritage in these areas. Therefore, it is of great importance and necessity to conduct research on China's land border cultural heritage. In this study, 45 prefecture-level cities located in China's land border areas were examined as the research subjects. The objective was to establish a database of border cultural heritage resources using cultural relics data and field investigation findings. The paper began by describing the mathematical characteristics of border

cultural heritage. It employed research methods such as kernel density, spatial variability, and spatial correlation to quantitatively analyze the spatial pattern of border cultural heritage resources. Next, an index system that affects the spatial pattern of border cultural heritage was constructed based on relevant research outcomes and the current status of border cultural heritage protection and development. By utilizing Geo-detector, the study then performed a quantitative analysis of the influencing factors driving the spatial pattern of different types of cultural heritage from two dimensions: natural environment and social environment. Finally, the paper provided recommendations to address the issues faced in the protection and development of border cultural heritage. The aim was to offer scientific guidance for the preservation and advancement of border cultural heritage in the new era, ultimately promoting its sustainable development (refer to Fig. 1). Overall, this study has made significant contributions to the understanding of cultural heritage protection and development in ethnic minority areas and border regions. The research has provided insights into the spatial patterns and influencing factors of cultural heritage, which can be applied to future studies in this area. Additionally, the study has identified key factors that impact the spatial pattern of cultural heritage in border areas and proposed optimization measures, which can help stakeholders formulate effective strategies for the protection and sustainable development of cultural heritage. Furthermore, the findings of this study can provide valuable insights for policy makers and practitioners in other economically disadvantaged border regions and ethnic minority areas globally.

Literature review

The field of cultural heritage research had its origins in the 1950s. However, during this early period, there were only a few research findings, and the discipline itself lacked clear research themes and a mature system. It was after the promulgation of the Convention on the Protection of the World Cultural and Natural Heritage in 1972 that the academic community began to witness a surge in cultural heritage research, particularly in the Mediterranean region of Europe [9–11]. The research conducted during this time primarily focused on various aspects. This included exploring the concepts and classifications of cultural heritage [12], identifying and developing cultural tourism resources [13], as well as conducting qualitative analyses and evaluations of regional cultural heritage [14]. As the field progressed, scholars also started investigating the relationship between cultural heritage development and local economic growth, cultural inheritance, and protection [15]. However, it became evident that preserving and developing cultural heritage often posed

a paradox, necessitating further research to strike a balance between the two [16]. In their study, Li et al. discovered that issues such as population pressure, economic constraints, and inadequate funding posed threats to the preservation of cultural heritage during the process of local cultural heritage development [17]. To address the risks posed by natural and human factors and to promote the safeguarding and development of cultural heritage, Dhonju et al. proposed an innovative online geographic crowdsourcing system based on web and mobile GIS. The aim of this system was to encourage public participation, raise awareness, instill a sense of ownership in the public towards cultural heritage, and bolster its protection and development [18]. Overall, global research on cultural heritage has demonstrated a trend towards multidisciplinary integration, a focus on sustainable development, advocacy for community participation, and an emphasis on cultural diversity.

Since the twenty-first century, there has been widespread recognition among various institutions, such as the United Nations and UNESCO (the Scientific and Cultural Organization), regarding the significant role that cultural heritage plays in achieving sustainable development. Scholars have conducted extensive research on evaluating the relationship between cultural heritage and sustainable development. In this regard, Bosone et al. conducted a comprehensive study, searching and classifying over 3,500 indicators. They proposed an evaluation index system to assess the factors influencing the sustainable development of cultural heritage from a circular economy perspective [19]. De Medici et al., through analysis and comparison of two cases in Italy—the Ancient Market and the Basilica of Saint Peter the Apostle in Ortigia—described the impacts of heritage protection and restoration projects on natural, cultural, social, environmental, and economic systems [20]. Kim highlighted the importance of intangible cultural heritage in South Korea, emphasizing its unique and indispensable value in representing the cultural authenticity and identity of a community. Furthermore, it was shown to promote sustainable local tourism development [21]. Tadesse conducted a case study in Ethiopia, where it was found that both tangible and intangible cultural heritage played crucial roles in driving culture and were essential for achieving sustainable development of cultural heritage. However, limitations in policies and other factors hindered the realization of expected outcomes [22]. During this stage, qualitative analysis was the primary research method employed, with a focus on intangible cultural heritage [12, 23]. The research covered diverse geographic areas, ranging from entire continents to small villages [24, 25].

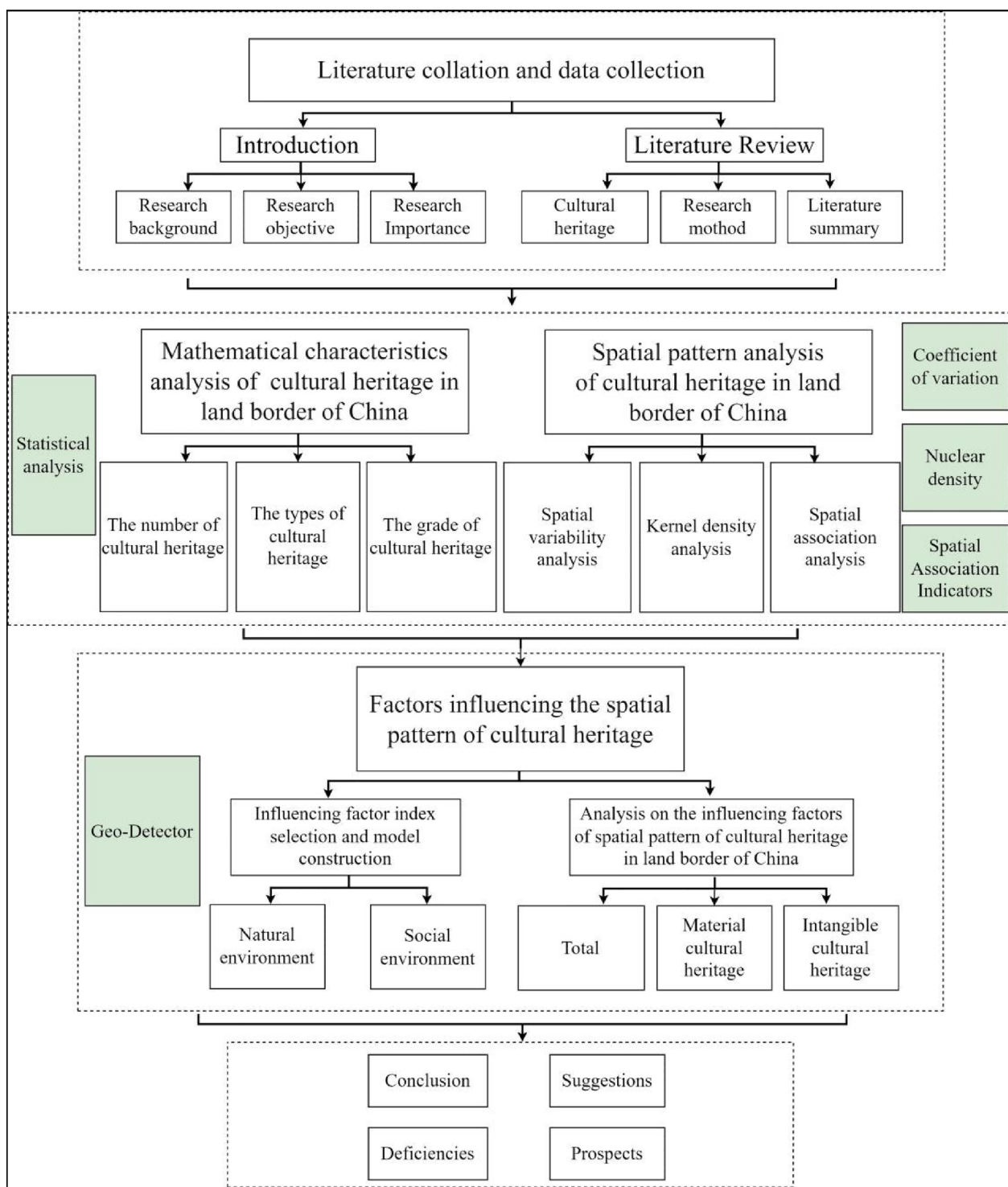


Fig. 1 Research framework and methodology flowchart

In recent years, research on cultural heritage, both domestically and internationally, has primarily focused on spatial quantitative analysis and evaluation, driven

by the development of Geographic Information Systems (GIS) and other geographic information technologies. Traditional qualitative analysis has gradually been

replaced by spatial quantitative research [26–28]. Various research methods have been employed, including kernel density analysis, Geo-Detector, nearest neighbor index, standard deviation ellipse, spatial correlation, Lorentz curve, and imbalance index. Yuan et al., utilizing ArcGIS software, conducted a comprehensive spatial analysis of cultural resources in the Yellow River National Cultural Park. They employed kernel density analysis, imbalance index, standard deviation ellipse, and nearest neighbor index to examine the spatial pattern characteristics of cultural resources. Additionally, the researchers explored the driving factors influencing the spatial pattern using the Geo-Detector [29]. Zhang et al. focused on 891 intangible cultural heritage items in the Yellow River Basin. Through the application of standard deviation ellipse, point pattern analysis, kernel density, spatial correlation, and Geo-Detector, they quantitatively analyzed the spatial and temporal distribution characteristics and influencing factors of intangible cultural heritage in the region. The results indicated a strong spatial dependence of intangible cultural heritage in the Yellow River Basin [30]. Dong et al. utilized GIS tools to conduct spatial analysis of intangible cultural heritage in Guizhou Province. They established a competition matrix for intangible cultural heritage and tourism, identifying the competition status of the two sectors in 2019 [31]. Understanding the spatio-temporal evolution pattern of world cultural heritage is crucial for recognition and protection. Liang et al. examined 869 World Heritage sites as research objects. Using time series modeling, they analyzed the advantages and changes in heritage declarations across different regions and periods. Furthermore, they assessed the impact of heritage strategies on the inclusion of sites in various regions [32]. Additionally, cultural heritage's spatial pattern, protection, and development status are naturally influenced by various factors, including the physical environment (terrain and hydrology) and social factors (population distribution and economic development level) [33]. At this stage, with China's economic and cultural growth, there has been an increasing demand for cultural heritage. Recognizing the importance of protecting and utilizing cultural heritage, the Chinese government has formulated relevant policies and implemented various protective measures. As a result, cultural heritage development and protection efforts are being actively pursued throughout China, particularly in the Yellow River basin, which has become a focal point of cultural heritage research, driving the surge in domestic cultural heritage studies.

The existing studies on the spatial pattern of cultural heritage and its influencing factors have provided a diverse and rich body of knowledge. However, most of the current research has primarily focused on culturally rich and economically developed cities and urban areas worldwide. In contrast, there is a gap in research regarding the cultural heritage of economically disadvantaged regions, particularly the land border areas of China. Furthermore, existing research has predominantly centered on intangible cultural heritage, lacking a comprehensive understanding of the full range of cultural heritage resources. Regarding research methods, qualitative analysis has been the predominant approach, while quantitative spatial research, especially concerning local spatial correlation characteristics of cultural heritage, remains relatively scarce. China's land border areas are vast and possess abundant cultural heritage resources. However, due to different natural conditions and cultural environments across these regions, the distribution patterns of cultural heritage exhibit variations, leading to imbalances between protection and development. Surprisingly, no research has thus far taken the entirety of China's land border area as the research object, making it difficult to provide systematic and comprehensive guidance for the protection and development of this unique cultural heritage.

In order to address this academic gap, this paper aims to systematically organize border cultural heritage resources based on field research findings and cultural relics data. Additionally, it comprehensively analyzes the spatial patterns of border cultural heritage resources using research methods such as spatial variability, kernel density analysis, and spatial correlation. The Geo-Detector method is employed to identify the driving factors influencing the spatial patterns of cultural heritage resources. Finally, this paper provides corresponding suggestions to address the challenges faced in the protection and development of border cultural heritage, serving as a scientific basis and reference for future endeavors in safeguarding and promoting the rich heritage of China's land border areas.

Methods and data sources

Study area

China boasts a sprawling land border of over 22,000 km, shared with 14 countries: North Korea, Russia, Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, Pakistan, India, Nepal, Bhutan, Myanmar, Laos, and Vietnam. Along this border lie 9 provincial-level administrative regions and 45 prefecture-level administrative regions in China (refer to Fig. 2). Encompassing a total area of 3,713,600 square

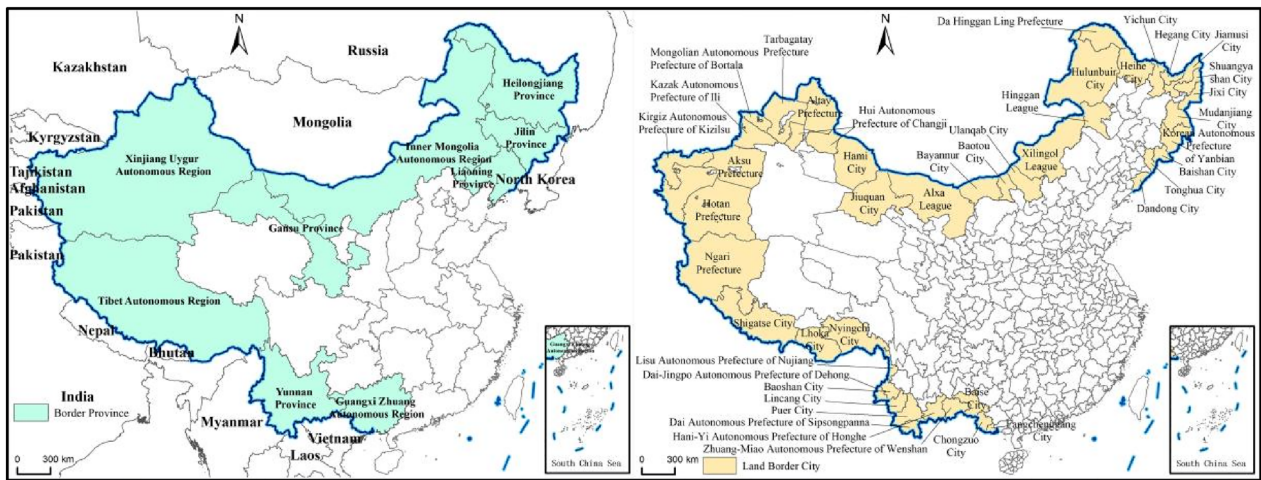


Fig. 2 The spatial divisions at border scale, province scale, and prefectural scale along the land border in China. the land border provinces and neighboring countries of China(left); the land border prefectures (right)

kilometers, these regions possess diverse resources that exhibit distinct regional differences, complementarity, and allure. Visitors can enjoy a wide array of attractions, from leisurely tours along the border to ecological sightseeing, immersing in local folk customs, engaging in archaeological expeditions, and visiting Anti-Japanese War memorials. Notably, certain border cities and prefectures, like the Dai Autonomous Prefecture of Sipsongpanna and Korean Autonomous Prefecture of Yanbian, have gained significant recognition as popular tourist destinations both locally and internationally.

Methods

Kernel density

Kernel density analysis is a non-parametric statistical method used to estimate density in a given dataset. It operates by assigning higher densities to central point elements within a specific bandwidth range, while peripheral density values are lower [34]. This methodology enables the analysis of spatial agglomeration characteristics pertaining to heritage resources. The equation for calculating kernel density is as follows:

$$f(s) = \sum_{i=1}^n \frac{1}{nh^2} K\left(\frac{d_{is}}{h}\right) \tag{1}$$

where $f(s)$ is the kernel density value at s , h represents bandwidth, and n represents the number of heritage resources within the region. d_{is} is the distance from i to s ; K function represents kernel function. The larger $f(s)$ is, the richer heritage resources are, and the density value of resources decreases with the increase of distance (d_{is}).

Spatial variability

The coefficient of variation method was used to calculate the spatial variability of heritage resources in China’s border areas [35]. The formula is as follows:

$$SD = \sqrt{\frac{1}{n} \sum_{i=1}^n (X_i - \bar{X})^2} \tag{2}$$

$$CV = \frac{SD}{\bar{X}} \tag{3}$$

where CV is the coefficient of variation; SD is standard deviation; n represents the number of administrative units; X_i represents the quantity of heritage resources in administrative unit i ($i=1,2,\dots,n$); \bar{X} represents the mean value of heritage resources in each administrative unit. If the coefficient of variation is large, it indicates that the spatial difference of heritage resources in land border areas of China is obvious.

Spatial correlation indicators

- 1. Global indicators of spatial correlation

In this paper, the global Moran’s I index is used to analyze the spatial global association of heritage resources in land border areas of China, so as to obtain the global correlation of different types of heritage resources [36]. The expression is as follows:

$$Global\ Moran's\ I = \frac{n}{\sum_{i=1}^n \sum_{j=1}^n \omega_{ij}} \frac{\sum_{i=1}^n \sum_{j=1}^n \omega_{ij} (X_i - \bar{X})(X_j - \bar{X})}{\sum_{i=1}^n (X_i - \bar{X})^2} \tag{4}$$

where Global Moran's *I* denotes the association coefficient; *n* denotes the number of administrative units at the borderland level; X_i and X_j represent the number of heritage resources of the *i*-th and *j*-th administrative units; \bar{X} represents the mean value; and ω_{ij} represents the spatial weight. The Moran's *I* index value [-1,1], if the result is greater than zero, it indicates that there is a global positive correlation and heritage resources are in a spatial agglomeration state. If it is negative, it indicates the global negative correlation and the spatial difference of heritage resources is large. The closer the result is to 0, it indicates that heritage resources tend to be distributed randomly in space.

2. Local indicators of spatial association (LISA)

The local association can describe the local aggregation state of heritage resources in border areas, which includes four cases in total: H–H Cluster, H–L Outlier, L–H Outlier and L-L Cluster [37]. The expressions are as follows.

$$Local\ Moran's\ I = \frac{X_i - \bar{X}}{S_i^2} \sum_{j=1, j \neq i}^n \omega_{ij} (X_j - \bar{X}) \tag{5}$$

which S_i^2 represents the variance of heritage resources in different administrative units along the border of China, and the rest are consistent with those in Eq. (4). When the value is greater than zero, two cases of high-high cluster or low-low clusters occur. The former indicates that the amount of heritage resources in the administrative unit and surrounding administrative units is both large, while the latter indicates that the amount of heritage resources is both low. When the value is less than zero, two cases of high-low outlier and low-high outlier occur, the former means that the number of heritage resources in the region is large, while the number of surrounding areas is small, and the latter is opposite.

Geo-detector

This paper provided a comprehensive analysis of the factors impacting the spatial distribution of heritage resources in border regions. It proposed an index system that considers both natural and social environmental factors influencing their distribution. Moreover, the study

employed the Geo-Detector's factor detector to assess the explanatory power of various factors on the spatial distribution of different types of heritage resources [38], as measured by *q* value. The formula used for this calculation is given below:

$$q = 1 - \frac{\sum_{h=1}^L \sigma_h^2 N_h}{N \sigma^2} \tag{6}$$

where *N* and σ^2 respectively represent the variance of the number of units and *Y* in the study area. The population *Y* consists of *L* layers (*h*=1, 2... *L*). *q* represents the explanatory ability of each influence factor to *Y*, and its value is strictly within [0,1]. The larger the value of *q*, the stronger the explanatory ability of independent variable *X* to dependent variable *Y*, and vice versa.

Data source

The data presented in this manuscript on land border heritage resources in China was collected from various sources, including the third National Cultural Heritage Survey and the first to fifth batches of the National Intangible Cultural Heritage List. Furthermore, academic literature and relevant data were consulted to supplement the analysis. The database was constructed by collecting primary data through field investigations, poi point collection, and other methods. In total, 1227 heritage resources were gathered during the field trip between June and September 2021, covering 21 prefectural cities such as Dandong City, Hami City, Honghe Prefecture, and Sipsongpanna Prefecture. The spatial coordinates of the border heritage resources were obtained using the Baidu coordinate picker, converted into WGS_1984 coordinates, and imported into ArcGIS for correction. Finally, the spatial point data was acquired.

This study utilized various data sources to examine the spatial pattern and influencing factors of land border heritage resources in China. Vector data of provincial and municipal administrative boundaries and government residences were obtained from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences. Additionally, vector data of main traffic roads and river systems were sourced from the 1:250,000 basic geographic database. The study area's DEM raster data was acquired from the geospatial data cloud. Furthermore, relevant statistics such as population density, urbanization rate, number of ethnic minority

populations, and gross national product of each city were retrieved from the 2021 Statistical Yearbook of each city. The national key cultural protection units were obtained through the National Cultural Heritage Administration, and the number of administrative division changes was obtained through Local Chronicles and Baidu, and the religious activities and sacrificial sites were obtained from the official tourism websites of various cities. These data sources were used to examine the factors that influence the spatial pattern of land border heritage resources in China.

Results

Mathematical characteristics analysis of cultural heritage in land border of China

In this study, a database of 1227 land border cultural heritage in China was constructed. The categorization of cultural heritage into two main types, namely material cultural heritage and intangible cultural heritage, was based on relevant standards and literature [39, 40]. Furthermore, the 18 subtypes were identified based on their mobility and substantiality.

The results of this study demonstrated a clear variability in the quantity of different types of resources, as refer to Table 1. Notably, the number of intangible cultural heritage was significantly higher, accounting for

709 resources and representing 57.79% of the total. Conversely, material cultural heritage was relatively scarce, comprising only 42.22% of the total.

In terms of the subtypes, the most abundant resources were ancient city sites of material cultural heritage, with a total of 217 resources, accounting for 17.69% of the overall inventory. Other subtypes identified included ancient houses and sites, traditional medicine, traditional dance, city wall ruins, traditional music, traditional skills, traditional sports, entertainment and acrobatics, Quyi, folk literature, beacon tower sites, traditional fine arts, traditional drama, ancient town sites, folklore, movable cultural remains, ancient kiln sites, and canal sites. Notably, ancient town sites, canal sites, ancient kiln sites, traditional fine arts, traditional drama, and movable cultural remains exhibited relatively small numbers, comprising less than 2% of the total inventory.

Regarding the grade of heritage resources, there were 279 national, 391 provincial and municipal, and 498 district and county resources, representing 22.74%, 31.87%, and 40.59% of the total resources, respectively, based on relevant classification standards. Moreover, 59 heritage resources were yet to be classified. Among the national cultural heritage, folklore resources were the most abundant, with 47 resources, while canal sites were the least represented. At the provincial and municipal and district and county levels, ancient city ruins were

Table 1 Quantity and type of cultural heritage in land border of China

Main types			Subtypes		
Types	Number	Proportion (%)	Types	Number	Proportion (%)
Material cultural heritage	518	42.22	Ancient city sites	217	17.69
			City wall ruins	74	6.03
			Beacon tower sites	25	2.04
			Ancient houses and sites	143	11.65
			Ancient town sites	20	1.63
			Canal sites	9	0.73
			Ancient kiln sites	13	1.06
			Movable cultural remains	17	1.39
			Intangible cultural heritage	709	57.78
			Traditional fine arts	23	1.87
			Traditional sports, entertainment and acrobatics	36	2.93
			Traditional dance	95	7.74
			Traditional theatre	22	1.79
			Traditional medicine	137	11.17
			Traditional music	62	5.05
			Folklore	204	16.63
			Folk literature	49	3.99
			Quyi	33	2.69
Sum	1227	100.00	18	1227	100.00

the most common subtypes, with 115 and 91 resources, respectively.

In the land border areas of China, various types of cultural heritage were broadly distributed, among which ancient city sites had the largest number and were present in most cities. Baishan City had the highest number of individual resources, with 26 ancient city cultural heritage sites. Folklore were mainly distributed in Baise City, Hani-Yi Autonomous Prefecture of Honghe, and Korean Autonomous Prefecture of Yanbian, with 19, 18, and 11 sites, respectively. Heritage resources of ancient houses and sites were mainly concentrated in Honghe Prefecture, Jixi City, and Mudanjiang City, with 16, 13, and 10 sites, respectively. Traditional medicine was mostly found in Baishan City, Tonghua City, and Yanbian Prefecture, accounting for 9.49%, 8.03%, and 7.30% of the total, respectively. Among the subtypes with less than 100 individual units, traditional dance heritage resources were primarily distributed in Yanbian Prefecture and Lincang City. City wall ruins were mainly located in Dandong City and Jiuquan City, while traditional music heritages

were mainly found in Kazak Autonomous Prefecture of Ili and Hulunbuir City. In addition, cultural heritage of traditional skills, traditional fine arts, traditional sports, entertainment and acrobatics, traditional drama, folklore literature, Quyi, movable cultural remains, and other types were relatively small and evenly distributed among various cities. The number of canal heritages was the least, mainly found in Puer City (refer to Fig. 3).

Spatial pattern analysis of cultural heritage in land border of China

Spatial variability analysis

The distribution of cultural heritage sites along China’s land borders showed significant variability, as demonstrated by an overall coefficient of variation of 51.98%. Two prefecture-level administrative units emerged with the highest number of heritage resources—the Korean Autonomous Prefecture of Yanbian and Hani-Yi Autonomous Prefecture of Honghe. These two units accounted for around 5.22% and 5.05% of the total, with 64 and 62 resources, respectively. Conversely, Hegang City

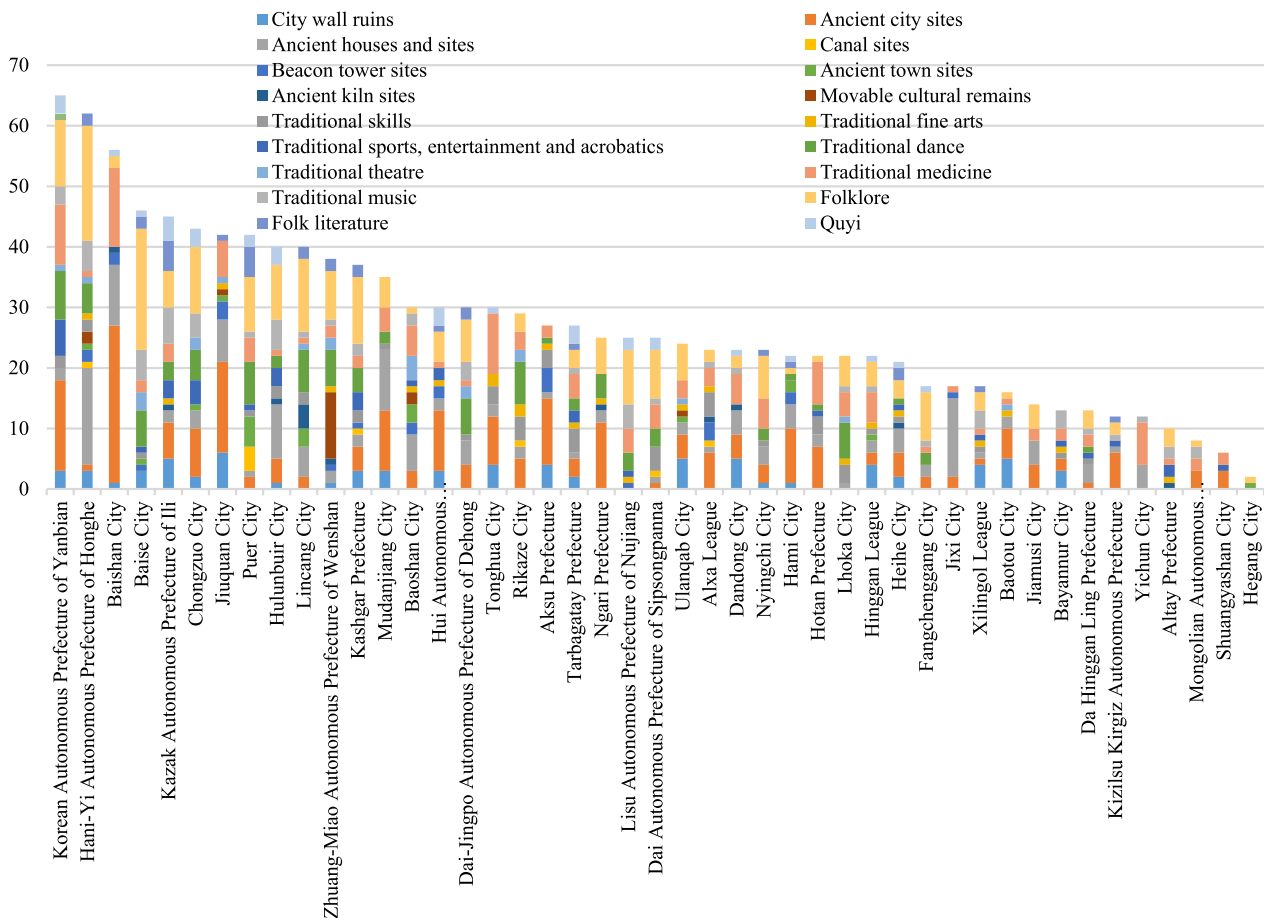


Fig. 3 The quantity and structure of cultural heritage of prefectural administrative units in land border of China

Table 2 Coefficient of variation and Moran's *I* index of cultural heritage resources

Indicators	Total	Material cultural heritage	Intangible cultural heritage
CV (%)	51.98	71.84	66.09
Moran <i>I</i> 's	0.3991**	0.1622*	0.4170**

* indicates significant at the level of 0.1

** indicates significant at the level of 0.01

displayed the lowest number of cultural heritage (refer to Fig. 3). The material cultural heritage and intangible cultural heritage exhibited variation coefficients of 71.84% and 66.09%, respectively (refer to Table 2), underscoring the significant spatial disparities between these two types of resources.

Most of the material cultural heritage was concentrated in Baishan City, Jiuquan City, and Hani-Yi Autonomous

Prefecture of Honghe, accounting for 19.11% of all such resources. Located at the center of the fabled Silk Road, Jiuquan City played a crucial role in facilitating cultural exchanges between the East and West over the ages, and its diverse cultural heritage has been impeccably preserved.

In contrast, intangible cultural heritage was mainly distributed across Baise City, Korean Autonomous Prefecture of Yanbian, and Hani-Yi Autonomous Prefecture of Honghe, accounting for 17.07% of all such resources. These regions have acted as incubators of ethnic minorities, promoting the constant exchange and integration of diverse cultures that have led to a multitude of human customs and traditional festivals.

Kernel density analysis

Upon analyzing the kernel density, it was evident that China's land border cultural heritage exhibits a multi-core agglomeration distribution (refer to Fig. 4). As a whole, the border cultural heritage have formed two

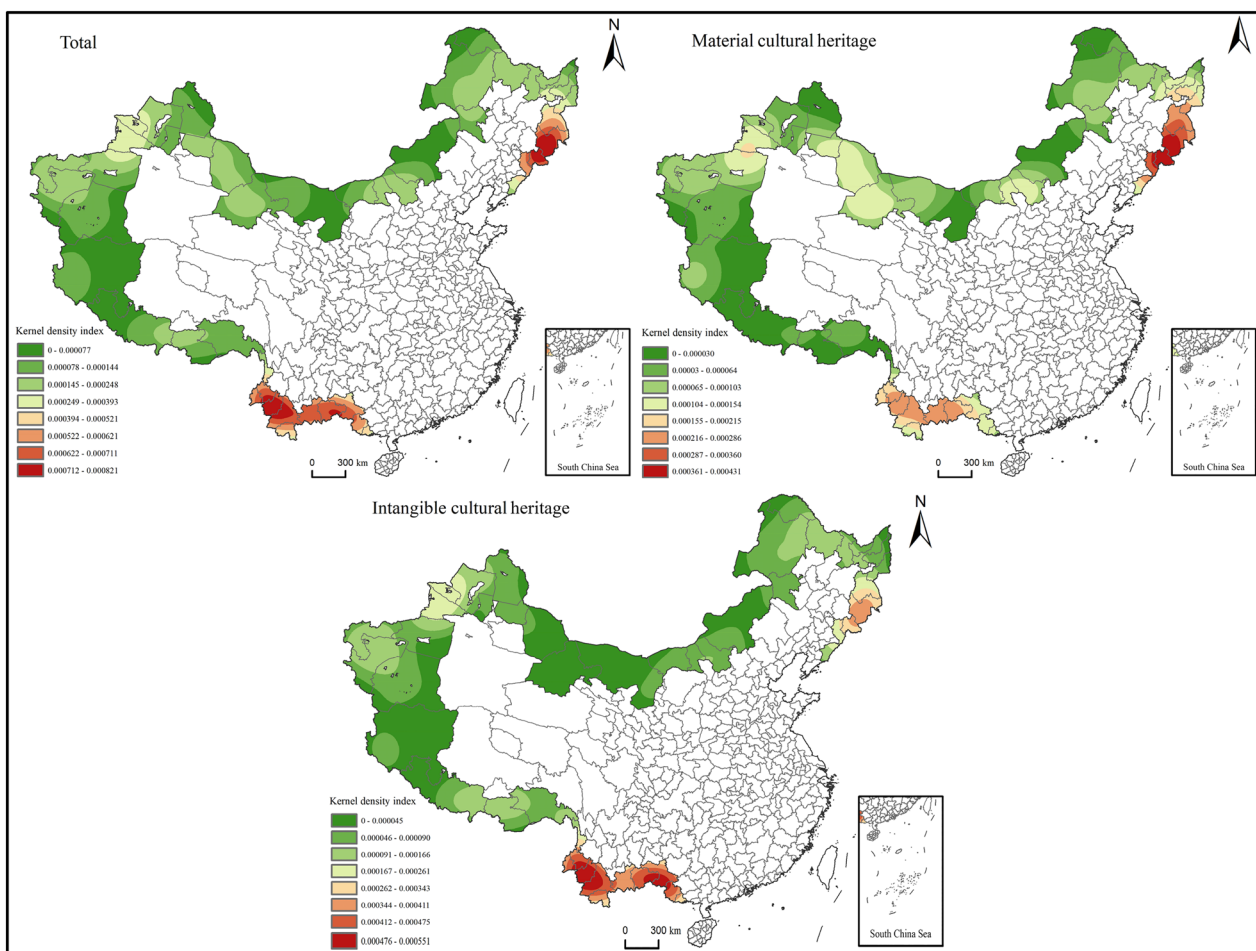


Fig. 4 Kernel density distribution of different types of cultural heritage resources in land border of China

primary core areas, one secondary core area, and several tertiary core areas. Lincang City and Korean Autonomous Prefecture of Yanbian were the two primary core areas, respectively. These locations possessed inherent advantages due to their natural conditions and cultural environment, and their heritages are endowed with relatively high resources.

The secondary core areas were primarily located in Hani-Yi Autonomous Prefecture of Honghe and Zhuang-Miao Autonomous Prefecture of Wenshan. The dominant resources in these areas were ancient city sites, folklore, traditional dances, and movable cultural remains.

The third-level core area of border cultural heritage radiated outwards from the center to the periphery of Kazak Autonomous Prefecture of Ili, Baotou City, Hulunbuir City, and Jiuquan City. The cultural heritage in this region primarily consisted of intangible cultural heritage, with diverse types and high abundance, particularly traditional music, traditional medicine, and folklore (refer to Fig. 4).

Among the primary types of cultural heritage, material cultural heritage exhibited a widespread distribution, with high-density core areas primarily located in Baishan City, the Korean Autonomous Prefecture of Yanbian, Tonghua City, and Mudanjiang City in Northeast China. These regions boasted an abundance of cultural heritage such as ancient city sites and city wall ruins, with core density values far exceeding those of other areas, reaching up to 0.000431. Northeast China was identified as a significant historical and cultural birthplace of China, with numerous cultural heritage sites, including the Great Wall, imperial tombs of the Qing Dynasty, and buildings from the Guanto Warlord period.

The sub-high-density core area was mainly distributed across the Yunnan and Guangxi, extending from the Dai-Jingpo Autonomous Prefecture of Dehong to Baise City, encompassing the Hani-Yi Autonomous Prefecture of Honghe, Zhuang-Miao Autonomous Prefecture of Wenshan, Dai Autonomous Prefecture of Sipsongpanna, Puer City, and Lincang City. This region displayed general irregular dot and zonal distribution, with kernel density between 0.000155 and 0.00215. The low-density core area exhibited a relatively random distribution (refer to Fig. 4).

The distribution of intangible cultural heritage was scattered throughout the country, but the core areas and sub-core areas were particularly prominent. As the number of intangible cultural heritage accounted for a relatively high proportion of China's land border, its spatial pattern was comparable to that of heritage resources overall. The intangible cultural heritage resources radiated outwards in space, with the Yunguang region, Northeast China, and Yili Prefecture of Xinjiang acting

as the core, with the core density of the center reaching 0.000551.

The primary high-density core area was comprised of Wenshan Prefecture, Honghe Prefecture, and Sipsongpanna Prefecture. The sub-high-density core areas were mainly distributed in the Korean Autonomous Prefecture of Yanbian, Baishan City, and Mudanjiang City in northeast China, with core density values ranging from 0.000344 to 0.000441 (refer to Fig. 4).

Spatial correlation analysis

In relation to spatial distribution, we computed the Moran's *I* index for three categories: total heritage resources, material cultural heritage, and intangible cultural heritage. The resulting figures were 0.3991, 0.1622, and 0.4170, respectively. It was worth noting that both overall heritage resources and intangible cultural heritage had a significant global Moran's *I* index at the 0.01 level. Similarly, the global Moran's *I* index for material cultural heritage was significant at the 0.1 level. These observations indicated that the types of heritage resources mentioned above were clustered and distributed in space (refer to Table 2).

In terms of local distribution, high-high clusters of total cultural heritage were primarily identified in Yunnan Province, Guangxi Zhuang Autonomous Region, and Jilin Province. Notably, Wenshan Prefecture, Honghe Prefecture, Baise City, and Tonghua City showed significant agglomeration characteristics at a level of 0.01. In contrast, the results indicated that the low-low clusters of land border cultural heritage were predominantly located in the northeastern region of China, specifically in Heilongjiang Province. This pattern was observed in six cities: Heihe City, Hegang City, Jixi City, Shuangyashan City, Yichun City, and Jiamusi City, with a significant level of 0.01. On the other hand, the low-high outliers were found in Dandong City, Sipsongpanna Prefecture, and Fangchenggang City. Notably, Chongzuo City and Hulunbuir City displayed an overall high-low outlier pattern for heritage resources in the local space (refer to Fig. 5).

The spatial distribution of different types of cultural heritage varied significantly. Material cultural heritage showed high-high clusters in the northeast and northwest regions, with Hami City, Dandong City, Tonghua City, and Yanbian Prefecture clustered at a level of 0.01. The formation of a high-density core area of material cultural heritage in Northeast China can be attributed to historical and modern military wars, as well as early human activities. In contrast, low-low clusters were mainly located in Nyingchi City and Heihe City, while Baise City and Baoshan City were the low-high and high-low outliers, respectively (refer to Fig. 5).

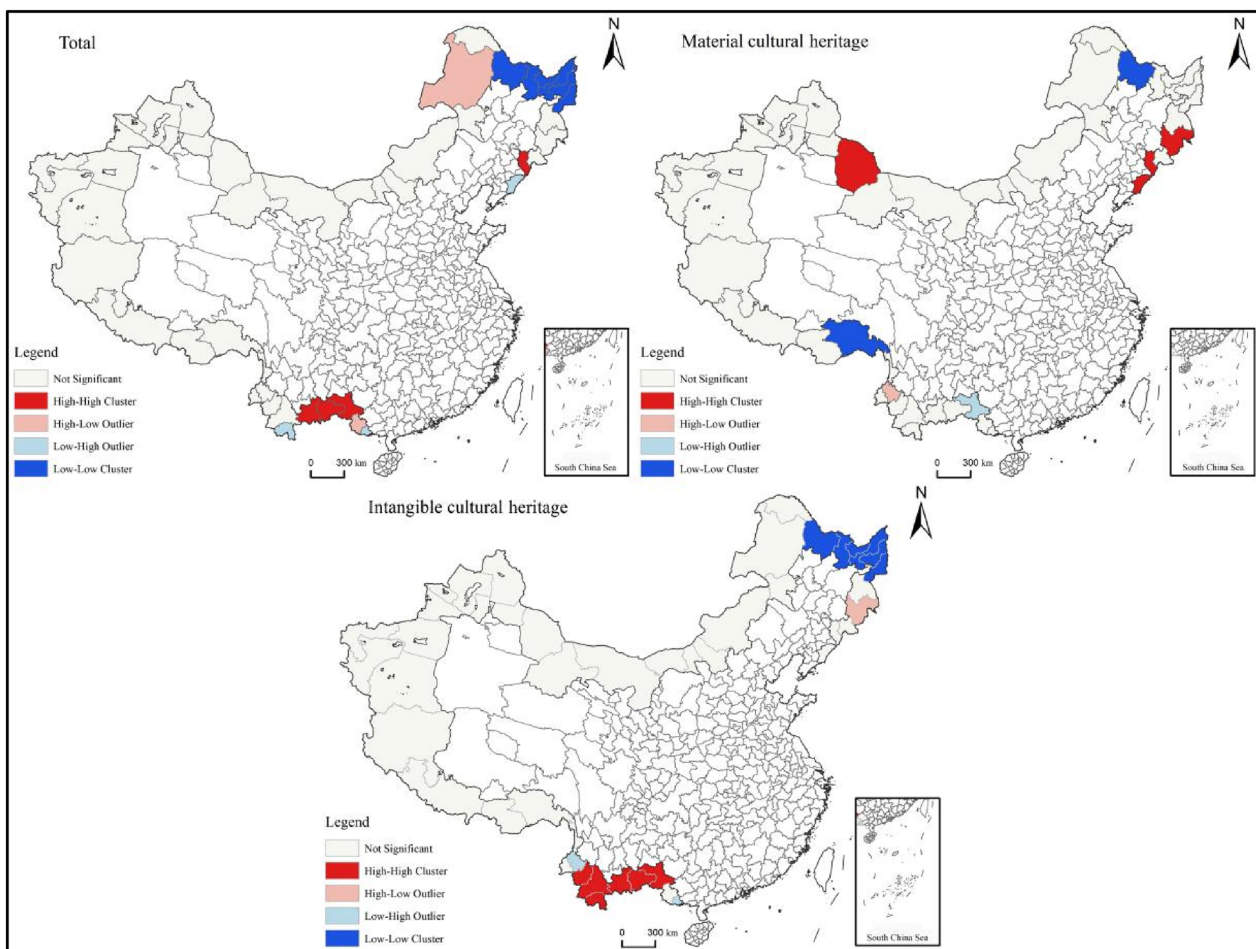


Fig. 5 Local spatial correlation of different types of cultural heritage resources in land border of China

For intangible cultural heritage, the distribution pattern demonstrated significant local spatial agglomeration, with high-high clusters mostly located in the southwest border areas of China. Lincang City, Baise City, Puer City, Sipsongpanna Prefecture, Honghe Prefecture, and Wenshan Prefecture exhibited a clustering distribution pattern at a level of 0.01. Conversely, the low-low clusters phenomenon of intangible cultural heritage was mainly observed in Heilongjiang Province in northeast China, with six prefectural administrative units, including Heihe City, Hegang City, Jixi City, Shuangyashan City, Yichun City, and Jiamusi City, showing agglomeration distribution characteristics at a significant level of 0.01. The low-high outliers areas included Baoshan City and Fangchenggang City, while the Korean Autonomous Prefecture of Yanbian was the only high-low outlier area (refer to Fig. 5).

Our findings indicated that China's land border cultural heritage was mainly concentrated in regions with

advantageous geographical locations, rich historical and cultural heritage, frequent military conflicts, diverse ethnic cultures, and strong religious roots. The southwest region exhibited the highest concentration of such resources, followed by the northeast region, while the northwest region had the lowest concentration. Additionally, the northwest border region held significant potential for future development in this regard.

Discussion

Influencing factor index selection and model construction

The relationship between the origin, development and protection of cultural heritage is deeply intertwined with the natural environment, social and economic environment, historical and cultural environment of a region. The spatial distribution of cultural heritage is the result of various factors that contribute to their formation. Utilizing previous research [29, 30, 41] and expert opinion, this study has developed an index system that incorporates the influences impacting the spatial pattern of heritage

Table 3 Index system of influencing factors of spatial pattern of cultural heritage resources in China's land border areas

Evaluation indicators	Detection factors	Explanation of indicators
Natural environment	X ₁ Altitude (m)	The altitude of the heritage resources (m)
	X ₂ Slope	The slope of the heritage resources (°)
	X ₃ Water system distribution	Distance from a water system (m)
Social environment	X ₄ Traffic accessibility	Distance from a line of transportation (m)
	X ₅ Distance from major cities	Distance from a main administrative unit (m)
	X ₆ Population density	Population density (people/km ²)
	X ₇ Per capita GDP	Regional per capita GDP (dollars)
	X ₈ Urbanization process	Urbanization rate (%)
	X ₉ Minority population ratio	The proportion of ethnic minorities in the total population of the region (%)
Historical and cultural environment	X ₁₀ History of administrative succession	Number of regional administrative division changes (times)
	X ₁₁ Evolution of historical and cultural	Number of national key cultural protection units (pcs)
	X ₁₂ Evolution of religious belief	Number of places for religious and sacrificial activities (pcs)

resources in China's land border areas. The index system consisted of three dimensions: natural environment, social and economic environment and historical and cultural environment. Each dimension was represented by distinct indicators that allow for a comprehensive examination of the factors influencing the spatial pattern of different types of heritage resources (refer to Table 3).

Altitude (X₁) is a critical factor that affects the regional climate, hydrology, geomorphology, and habitability. As a result, it influences the origin and development of heritage resources, particularly material cultural heritage. Slope (X₂) also plays a significant role in population habitation and building construction. Plains or basins with a lower slope are optimal for living, while mountainous areas with steeper slopes are unsuitable for construction and habitation [40]. Additionally, water system distribution (X₃) is closely linked to human activities. To determine their influence, this study calculated the nearest distance between heritage resources and water systems [42]. Traffic accessibility (X₄) within a region is directly impacted by the convenience of transportation, which can significantly affect the development and construction of heritage resources [43]. The closer a region is to major cities (X₅), the more frequent early human activities were, generating more heritage resources. Population density and Minority population ratio (X₆, X₉) have contributed to the creation of numerous heritage resources with unique folklore [39]. Therefore, the number of regional populations, especially ethnic minority populations, is a crucial factor affecting the spatial structure of heritage resources. The Urbanization process (X₈) can lead to the demolition or reconstruction of historical and cultural heritage and traditional buildings, ultimately changing the spatial distribution of these resources [33]. Finally, per capita GDP (X₇) can represent the consumption power of a region, as high-income groups have a correspondingly

high demand for resources [44]. This demand can attract more investors and developers to the region, ultimately affecting the spatial pattern of heritage resources. Finally, it is difficult to obtain pure historical data, and historical sites themselves are the witnesses of historical development. This paper focused on entities that can reflect historical evolution for statistics. The number of regional administrative division changes (X₁₀) can represent the succession characteristics of administrative divisions, which can affect the spatial pattern of cultural heritage, especially material cultural heritage such as ancient city sites and beacon tower war relics. The number of national key cultural protection units (X₁₁) and the Number of places for religious and sacrificial activities (X₁₂) can reflect the historical characteristics of regional history, culture and religious belief evolution, and can better reflect the social history and historical succession in China's land border areas, so as to have an impact on the spatial differentiation of cultural heritage.

Analysis on the influencing factors of spatial pattern of cultural heritage in land border of China

The study has revealed that various detection factors have varying explanatory power on the spatial pattern of land border heritage resources in China (refer to Table 4). Moreover, each type of cultural heritage has different leading driving factors. The natural environment, including altitude, slope, and water system distribution, had some impact on the spatial distribution of cultural heritage. However, the influence was not significant. On the other hand, social and economic environment, historical and cultural environment had a more substantial impact on their spatial distribution. The distance from major cities was the primary driving factor for spatial differentiation of total cultural heritage, while history of

Table 4 Exploration results of spatial pattern factors of cultural heritage resources in land border of China (q value)

Evaluation indicators	Detection factors	Total	MCH	ICH
Natural environment	X ₁ Altitude (m)	0.1269	0.2679	0.0854
	X ₂ Slope	0.1176	0.0759	0.1219
	X ₃ Water system distribution	0.0403	0.0552	0.0485
Social and economic environment	X ₄ Traffic accessibility	0.0635	0.0737	0.0764
	X ₅ Distance from major cities	0.2859	0.1922	0.2663
	X ₆ Population density	0.2076	0.2960	0.2783
	X ₇ Per capita GDP	0.2409	0.1489	0.3418
	X ₈ Urbanization process	0.2296	0.1591	0.2224
	X ₉ Minority population ratio	0.1858	0.1868	0.3764
Historical and cultural environment	X ₁₀ History of administrative succession	0.1954	0.3077	0.1813
	X ₁₁ Evolution of historical and cultural	0.2749	0.3061	0.2565
	X ₁₂ Evolution of religious belief	0.1356	0.1488	0.2414

MCH Material cultural heritage; ICH Intangible cultural heritage

administrative succession was the primary driving factor for material cultural heritage. Lastly, the minority population ratio was the dominant driving factor for intangible cultural heritage.

1. Total

Various factors influenced the spatial pattern of land border cultural heritage in China, with the distance from major cities being the dominant driving factor. This factor can explain almost 29% of the spatial differentiation level significantly at 0.01, indicating that cultural heritage was heavily reliant on urban areas. The closer these resources were to the city center, the higher the density of heritage resources. Cities serve as a starting point for regional development and possess rich historical and cultural heritage, traditional architecture, and other resources that attract tourists. As a result, they have become high-density core areas of heritage resources. The number of national key cultural protection units plays a significant role in reflecting the characteristics of regional historical and cultural evolution. These units often represent important milestones in the development and preservation of a region's cultural heritage. They embody the rich history and cultural identity of a place, showcasing the traditions, customs, and achievements of the past. Moreover, part of the material cultural heritage itself is constituted by the cultural relics protection units. These units are designated for the conservation and protection of specific cultural artifacts, buildings, or sites of historical significance. The presence of these protection units not only safeguards the cultural relics but also contributes to the

spatial agglomeration of cultural heritage. Population density was another crucial factor that determines the spatial pattern of border cultural heritage. Regions with high population density usually have a more substantial concentration of historical and cultural development, leading to the creation of numerous cultural heritage such as historical buildings, cultural sites, traditional skills, and folk culture. This indicated that cultural heritage also exhibits characteristics of population dependence. Per capita GDP was a significant factor that explains 24.09% of the spatial differentiation of heritage resources, reflecting the consumption power level of a region. This can significantly influence the development and utilization of cultural heritage. For instance, Baishan City has high per capita GDP and rich heritage resources, accounting for 4.56% of the total. History of administrative succession, ethnic minority population ratio and urbanization process were also key factors affecting the spatial pattern of border heritage resources. The urbanization process necessitated a considerable amount of land, resulting in the demolition or reconstruction of many historical cultural heritage and traditional buildings. This not only changed the spatial distribution of these resources but also concentrated cultural heritage previously dispersed in rural areas in cities. In contrast, evolution of religious belief, altitude, slope, water system, and traffic had low q values, indicating their limited ability to explain the spatial differentiation of land border cultural heritage. Overall, the spatial pattern of border cultural heritage in China exhibited clear characteristics of city dependence, cultural dependence, population dependence, and economic orientation.

2. Material cultural heritage

The spatial distribution of material cultural heritage in China was influenced by various factors. Among these, the influence of the history of administrative succession was the most significant, which can explain the spatial differentiation of border material cultural heritage at the level of 30.77%. The changes of administrative divisions were mainly caused by war invasions and changes of dynasties. The Chinese nation has a history of more than 5000 years, with frequent changes of dynasties, so there are more beacon towers, ancient city walls, war relics and other material cultural heritage in areas with more changes in administrative divisions. Secondly, the evolution of historical and cultural can most affect the spatial differentiation level of border material cultural heritage. The greater the number of national key cultural protection units, indicated that the region has a long and rich history and diverse culture, laying a historical and cultural foundation for the development and protection of material cultural heritage. Population density also had a significant effect, accounting for 29.60% of the spatial differentiation at a significant level of 0.01. Regions with high population densities tend to have more historical buildings and cultural heritage sites, such as ancient city sites, city wall ruins, temples, palaces, and ancient towns. Altitude was another crucial factor, with steep terrain generally characterized by difficult transportation, harsh natural environments, and low livability, making it challenging to protect and preserve cultural heritage. Statistics indicated that areas with an altitude between 0 and 1000 m account for 50.77% of the total material cultural heritage resources, while those above 2000 m only account for less than 10%. Distance from the main city and minority population ratio also played a role in the spatial layout of cultural heritage sites, with areas closer to cities and with higher minority populations having a greater presence of material cultural heritage. Per capita GDP, urbanization, transportation accessibility, and natural environmental factors like slope and water system distribution had a relatively weak relationship with the spatial distribution of cultural heritage resources. It was evident that the distribution of material cultural heritage in border areas showed a trend of historical deposits. The stronger the history of administrative evolution and cultural evolution, the more likely it was to cause the phenomenon of spatial agglomeration of material cultural heritage.

3. Intangible cultural heritage

The explanatory power of the various influencing factors on intangible cultural heritage resources can be ranked in a particular order. The factors that had the most significant impact were the proportion of ethnic minority population, per capita GDP, and population density. These three factors interacted with each other to affect regional economic conditions, the frequency of human activities, and the process of urbanization, which ultimately influenced the development of the regional economy. As a result, areas with a higher proportion of ethnic minorities tended to have more intangible cultural heritage, including traditional skills, music and dance, folk literature, and folklore. In addition, the evolution of historical and cultural and the evolution of religious belief also showed significant impact on the spatial pattern of intangible cultural heritage. The key cultural protection units represent the tangible aspects of this cultural heritage, such as historical sites, architectural structures, and artifacts. These sites are not only important for the local communities to carry out their cultural customs and religious activities but also serve as symbols of their collective identity and pride. Moreover, these sites play a crucial role in the preservation and transmission of intangible cultural heritage. Folklore, traditional skills, myths, legends, and other intangible cultural practices are passed down from generation to generation through oral traditions, performances, and rituals, many of which are associated with these cultural protection units and religious worship sites. The concentration of intangible cultural heritage in ethnic minority areas such as Honghe Prefecture, Yanbian Prefecture, and Yili Prefecture is not surprising, considering the rich and diverse cultural landscapes in these regions. The presence of numerous ethnic minority groups in close proximity fosters cultural exchange and the blending of different traditions, resulting in a vibrant and concentrated intangible cultural heritage. These areas often become hotspots for cultural heritage tourism and research, attracting both domestic and international visitors interested in experiencing and learning about these unique cultural practices. Other factors such as distance to major cities, urbanization process, slope, altitude, traffic accessibility, and water system distribution also played a role in the spatial pattern of intangible cultural heritage. However, their explanatory abilities were found to be less than that of the dominant factor, which was the proportion of ethnic minority population. This

suggested that while natural factors such as altitude, slope, and water system still played a role, they were not significant enough to determine or significantly affect the spatial pattern of intangible cultural heritage. In conclusion, social and historical environmental factors such as the proportion of ethnic minority population, per capita GDP, and urbanization process had a more substantial impact on the spatial distribution of intangible cultural heritage, while natural factors such as altitude, slope, and water system had a weaker effect. Understanding these factors can help preserve and inherit the intangible cultural heritage of different regions.

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Conclusions

To summarize, this study has shown that cultural heritage resources in China's land border areas were concentrated in specific regions. The spatial pattern of distribution was influenced by natural and social factors. Natural factors like topography and climate had a significant impact on cultural heritage distribution, while social factors such as population density and economic development levels also played an essential role. These findings were crucial for policymaking and planning decisions related to the development of these resources, providing valuable insights into the factors that shaped their distribution in China's land border areas.

1. The study findings revealed that China's land border areas were home to a vast number of cultural heritage, consisting of 2 main types and 18 subtypes with

a total of 1227 sites. Intangible cultural heritage made up the majority, with 709 sites, while ancient city sites were the most extensive subtype, with 217 objects. In terms of distribution, there were 279 national heritage resources, 391 provincial and municipal heritage resources, and 498 district and county cultural heritage. Notably, the Korean Autonomous Prefecture of Yanbian had the highest number of heritage resources among prefecture-level administrative regions, whereas Hegang City had the least.

2. The study highlighted that land border cultural heritage in China were distributed in multiple cores. Our analysis revealed the presence of two first-level core areas, one second-level core area, and several third-level core areas, indicating discernible spatial variability and association among different types of cultural heritage. We found that there was a significant spatial agglomeration of total cultural heritage, material cultural heritage, and intangible cultural heritage. Moreover, we observed high-high and low-low clusters for Southwest and Northeast China border cultural heritage, respectively.
3. The spatial distribution of land border heritage resources in China was influenced by a range of natural environment, social and economic environment and historical and cultural environment. Among these factors, altitude, distance from major cities, population density, proportion of minority population, urbanization process, per capita GDP, history of administrative succession, evolution of historical and cultural and evolution of religious belief had a significant impact on the distribution of heritage resources. Specifically, distance from major cities, population density, minority population ratio, history of administrative succession and evolution of historical and cultural had strong explanatory power on the spatial pattern of cultural heritage, whereas altitude, slope, and water system distribution had weak explanatory power.

This manuscript proposed recommendations for optimizing, protecting, developing, and utilizing cultural heritage in China's land border areas from the perspective of sustainable development. Firstly, these areas were predominantly inhabited by ethnic minorities with rich and unique cultures. However, underdeveloped economies and poor infrastructure constructions limited the sustainable development of cultural heritage in these regions. The government should increase investment in cultural heritage, improve the utilization efficiency and economic benefits of heritage resources, and ensure a balanced state of development and protection of sites. This will enable the achievement of a virtuous cycle of

development of border cultural heritage. Secondly, the government should strengthen transport infrastructure construction in border areas and explore cultural exchanges and cooperation with neighboring countries and regions to open cross-border tourism routes gradually. The government should also strengthen the protection and restoration of cultural heritage to maintain their originality and integrity. Additionally, the inheritance and protection of intangible cultural heritage must be promoted to ensure dynamic inheritance and protection of cultural heritage. Finally, the government should promote combination development between different types of cultural heritage. For example, regions such as the Dai Autonomous Prefecture of Sipsongpanna and Korean Autonomous Prefecture of Yanbian can integrate a variety of heritage resources and develop a new heritage tourism model that integrates folk cultural heritage and archaeological exploration tourism. These recommendations provided concrete steps towards promoting the sustainable development of cultural heritage in China's land border areas. By adopting a comprehensive approach to infrastructure development, cultural exchange, and heritage preservation, policymakers can unlock the potential of these cultural treasures while ensuring their long-term sustainability.

As a result of limited availability of relevant data and field research time constraints, there remains a significant need to supplement the database of cultural heritage at the border that has been constructed in this paper. Additionally, the index system of influencing factors also requires further refinement. Subsequent research can make use of a variety of road data and more comprehensive water system data for a deeper analysis, resulting in increased scientific rigor of the relevant analysis. At the same time, future studies should focus on the impact of changes in China's diplomatic relations with neighboring countries on the sustainable use of cultural heritage in border areas. In addition, it is worth studying how to measure the applicability of the current development strategy to the sustainable development of cultural heritage in border areas and determine the degree of exploitation of such cultural heritage. In addition to the previous points, it is important for future studies to focus on examining the sustainability of land border cultural heritage development. As globalization continues to blur cultural boundaries, it is crucial to understand how land border areas can effectively preserve and promote their unique cultural heritage. Overall, focusing on the sustainability of land border cultural heritage development and conducting quantitative research will contribute to the preservation and promotion of cultural heritage in these regions. It will also help in formulating evidence-based

policies and strategies for the long-term sustainability of cultural heritage.

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Author contributions

HJ and SZ briefly introduced the background and reviewed all the published papers. SZ, LC and HJ collected relevant data and made tables for explanation. SZ and HJ analyze the spatial pattern of land border heritage resources in China. SZ, LC and TZ summarized the factors affecting the spatial distribution of land border heritage resources in China and proposed suggestions for the protection and development of the heritage resources. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

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Not applicable.

Consent for publication

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Competing interests

The authors declare that they have no competing interests.

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