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THE SPATIAL RELATIONSHIP BETWEEN INTANGIBLE CULTURAL HERITAGE IN XINJIANG AND TRADITIONAL VILLAGE AND ITS INFLUENCING FACTORS

YuXuan Mao[1,2], MingYu Liu[1,2], JinZhi Gu[1,2*]
[1]*School of Resources and Environment, Xinjiang Agricultural University, Urumqi 830052, Xinjiang, China.*
[2]*Xinjiang Key Laboratory of Soil and Plant Ecological Processes, Urumqi 830052, Xinjiang, China.*
[*]*Corresponding Author: JinZhi Gu*

Abstract: This investigation examines the spatial associations and distributional attributes of traditional village settlements and intangible cultural heritage (ICH) across Xinjiang through the application of kernel density estimation, spatial autocorrelation metrics, bivariate spatial correlation analysis, and geodetector modeling techniques. These analytical approaches were employed to characterize spatial differentiation patterns and identify underlying determinants. Kernel density analysis combined with spatial statistical methods revealed the aggregate distributional features of national-level ICH throughout Xinjiang and assessed the impacts of topographic conditions, hydrological accessibility, GDP levels, and population concentration on heritage distribution patterns. Principal findings indicate that: (1) the majority of traditional village settlements and ICH sites concentrate in low-elevation plain and oasis environments, with spatial configurations generally conforming to major mountain system orientations; (2) both traditional villages and ICH exhibit pronounced spatial heterogeneity, with principal concentration zones predominantly clustered in the Changji–Urumqi corridor; (3) topographic elevation demonstrates the strongest explanatory power for ICH spatial distribution, followed by GDP, river network accessibility, and population density, while the interactive effect between elevation and hydrological conditions exhibits the greatest explanatory capacity; (4) for traditional village distribution, GDP and river system accessibility exert comparatively stronger influences, and the combined interaction between GDP and elevation makes the most substantial contribution to spatial differentiation. These results demonstrate that cultural heritage resource configurations in Xinjiang reflect the joint influences of natural environmental parameters and socio-economic development trajectories.
Keywords: Xinjiang; Geodetector; Traditional villages; Intangible cultural heritage; GIS

1 INTRODUCTION

As integral elements of regional historical culture and ethnic memory, intangible cultural heritage (ICH) and traditional villages hold considerable significance for maintaining cultural continuity, fostering social progress, and advancing rural revitalization initiatives [1,2]. The ongoing acceleration of urban expansion and socio-economic restructuring has triggered rapid spatial reconstruction in numerous traditional settlements. Concurrently, the living environments and transmission channels of ICH face mounting pressures from cultural fragmentation and declining inheritance capacity, rendering coordinated preservation and sustainable advancement increasingly imperative [3]. Technological progress in geographic information systems and spatial analytics has facilitated the wider adoption of quantitative methodologies within heritage research domains, drawing growing academic focus toward examining the distributional patterns and underlying drivers that shape the spatial configurations of both ICH and traditional villages [4,5].

Recent investigations concerning ICH and traditional villages have generated notable advancements across theoretical frameworks and practical applications. Domestic scholarship predominantly examines preservation strategies, tourism exploitation, spatial clustering attributes, and rural cultural evolution [6,7]. Overseas scholarship tends to prioritize legislative governance structures, digitized conservation techniques, and metric-based assessment of cultural heritage worth, offering valuable insights for heritage administration and sustainable exploitation [8,9]. Methodological tools such as kernel density estimation, geodetector models, and spatial autocorrelation techniques have gained considerable traction in probing the spatial variability and causal determinants of heritage resource distributions [10]. Yet, the geographical coverage of prior research remains skewed toward eastern and central Chinese territories, leaving arid-zone multi-ethnic areas like Xinjiang relatively underexplored—especially concerning the spatial linkages between ICH and traditional settlements and the interplay between natural environmental and socio-economic driving forces.

In light of these research gaps, the present investigation takes Xinjiang—a characteristic arid-land multi-ethnic territory—as its focal study area. Leveraging DEM topographic datasets, national ICH inventories, traditional village registries, and hydrological network data, this research conducts a systematic examination of the distributional patterns exhibited by ICH and traditional villages. The pivotal determinants governing these patterns are quantitatively discerned through the application of geodetector modeling coupled with spatial statistical techniques. Additionally, this work seeks to deepen theoretical comprehension of cultural spatial differentiation processes within arid environments and furnish evidence-based guidance for safeguarding cultural heritage while promoting the sustainable advancement of traditional villages across Xinjiang.

2 MATERIALS AND METHODS

Situated along China's northwestern frontier, Xinjiang encompasses approximately 1.6649 million square kilometers—equivalent to roughly one-sixth of the national territory—establishing it as the country's largest provincial-level administrative division. Occupying a strategically significant position as the principal gateway connecting China with Central, West, and South Asia, it shares international boundaries with eight nations including Russia, Kazakhstan, and Kyrgyzstan, rendering it indispensable to the Belt and Road Initiative framework. As an ethnically diverse territory, Xinjiang has cultivated distinctive cultural traditions and preserved village settlements throughout its extensive history, establishing stable spatial configurations and symbiotic associations with intangible cultural heritage.

Xinjiang presents a distinctive geomorphological configuration commonly characterized as "three mountain ranges framing two basin systems": the Altai Mountains define its northern perimeter, the Kunlun Mountains constitute its southern boundary, while the central Tianshan Mountain chain bisects the region into northern and southern sectors, respectively encompassing the Junggar and Tarim Basins. Its deep continental position, encircled by elevated topography, engenders a temperate continental climate distinguished by pronounced temperature amplitude, abundant solar radiation, minimal precipitation, and pronounced aridity. Mean annual precipitation approximates 150 mm, with substantial regional variation: southern localities experience warmer yet drier conditions, whereas northern areas are comparatively cooler with marginally greater moisture availability.

The territory exhibits remarkable landscape diversity across its extent. The northern zone, subject to Atlantic maritime air mass influence, maintains comparatively humid climatic conditions supporting extensive grassland ecosystems—habitats for ethnic communities such as the Kazakhs, whose pastoral traditions have developed around renowned grassland localities including Nalati. The southern zone is characterized by desert-oasis mosaic patterns, anchored by the Taklamakan Desert (the world's second-largest active dune field). Oasis settlements including Kashgar and Hotan depend upon glacial meltwater irrigation systems, sustaining distinctive oasis agricultural practices.

As a region characterized by ethnic plurality and religious diversity, Xinjiang hosts 56 recognized ethnic communities including Uyghur, Han, Kazakh, and Hui populations. Across successive centuries, individual ethnic groups have generated and perpetuated substantial intangible cultural heritage across musical, choreographic, literary, and artisanal domains. Representative manifestations encompass Uyghur Twelve Muqam traditions and Kazakh Aken oral poetry, exemplifying the distinctive appeal of Xinjiang's multicultural heritage. These abundant natural and human resources furnish valuable empirical materials and expansive analytical scope for interdisciplinary scholarship, carrying substantial academic significance.

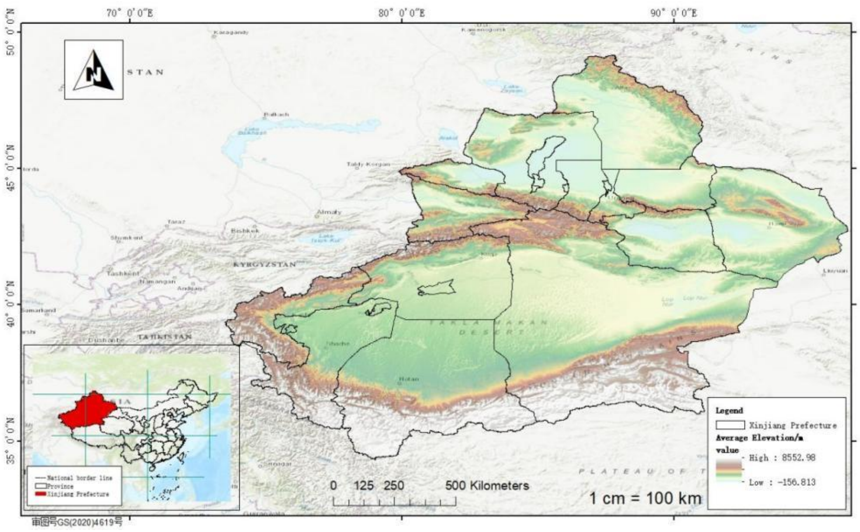

Figure 1 Overview Map of the Study Area.Base map data sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community.
Source: http://bzdt.ch.mnr.gov.cn/

Topographic information was obtained from the 2024 GEBCO release, stored in raster (.tif) format at 15 arc-second resolution (approximately 500 m), referenced to the GCS_WGS_1984 datum. Traditional village records comprise 53 designated sites in Xinjiang drawn from the first through sixth national nomination rounds, while ICH data encompass 147 state-level entries distributed across five designation cycles. Kernel density estimation serves to measure the concentration intensity of geographical features, offering effective visualization of broad-scale distribution trends. This technique applies greater weights to observations nearer the grid centroid, with influence diminishing as distance increases, as expressed in formulas (1) and (2). Vector datasets were obtained from the Cube Data Society.

$$f(x)=\frac{1}{Nh}\sum_{i=1}^{N}K(\frac{X^i-\overline{X}}{h}) \quad (1)$$

$$k(x)=\frac{1}{\sqrt{2\pi}}\exp(-\frac{X^2}{2}) \quad (2)$$

where: f(x) is the density function; K(x) is the probability density; N denotes the number of samples; h is the bandwidth.
Quantitative spatial relationship models serve to examine the degree of association between paired geographical phenomena across the entire study extent, characterizing both numerical and locational linkages among spatial entities. This approach is employed herein to assess the correspondence between ICH and traditional village distributions. Equation (3):

$$R=\frac{ad-bc}{\sqrt{(a+b)(c+d)(a+c)(b+d)}} \quad (3)$$

Where: a represents sample units containing both traditional villages and ICH; b indicates units with exclusively traditional villages; c denotes units with solely ICH; and d signifies units containing neither traditional villages nor ICH. R values range between [-1, 1], with R>0 denoting positive correlation and R<0 indicating negative correlation.
Significance assessment of the R-value was conducted through chi-squared computation. Equation (4):

$$X^2=\frac{n(ad-bc)^2}{(a+b)(c+d)(a+c)(b+d)} \quad (4)$$

Where: n denotes the aggregate sample unit count. The significance of R is established by comparing the computed chi-squared value against the critical threshold $X\alpha^2$ from the chi-square distribution table.
Bivariate spatial autocorrelation captures the degree of spatial clustering exhibited by two distinct attribute variables, examining whether values of one variable at given locations tend to align with values of the second variable in surrounding areas. This method aims to uncover how paired phenomena interact across local spatial contexts. Herein, it is applied to evaluate the spatial correspondence between nationally designated ICH sites and traditional villages across Xinjiang. Equation (5):

$$I_{ab}^{i}=\frac{X_a^i-\overline{X_a}}{\sigma_a}\sum_{j=1}^{n}W_{ij}*\frac{X_b^j-\overline{X_b}}{\sigma_b} \quad (5)$$

Where: X_a and X_b is the number of ICH sites and traditional villages in each county and city in Xinjiang; $\overline{X}_a$ and $\overline{X_b}$ is the mean value of ICH sites and traditional villages; σ_a and σ_b is the variance of both; and W_{ij} is the spatial weight matrix.
Geodetector constitutes a quantitative approach for dissecting variable relationships within spatial datasets, encompassing four analytical components: factor detection, interaction detection, risk detection, and ecological detection. Relative to conventional modeling techniques, geodetectors impose fewer restrictive assumptions. The present analysis applies factor detection and interaction detection to identify the key driving forces and their synergistic effects governing the spatial patterns of ICH and traditional villages. Equation (6):

$$q=1-\frac{\sum_{K=1}^{L}N_K\,\sigma_K^2}{N\sigma^2} \quad (6)$$

Where: q represents the explanatory capacity of predictor variables regarding ICH or traditional village distributions, with value range [0,1]; L indicates the stratification level of predictor variables; Nk and N denote the unit counts within stratum k and the entire study area respectively; σ^2 and σk^2 represent the variance values for the whole area and stratum k respectively. Five driving variables—topographic elevation, slope gradient, GDP, population density, and distance from major river channels—were selected to investigate the determinants of ICH and traditional village distributions across topographic, hydrological, and socio-economic dimensions. Equation

3 RESULTS

3.1 Spatial Distribution Patterns of Traditional Villages and Intangible Cultural Heritage

3.1.1 Spatial quantitative characteristics of traditional villages and intangible cultural heritage

Xinjiang encompasses 53 recognized traditional villages. The largest shares are found in Bayin'guoleng Mongol Autonomous Prefecture (20.75%), Turpan City (16.98%), and Changji Hui Autonomous Prefecture (18.87%). A second concentration level is observed in Altay, Bortala Mongolian Autonomous Prefecture, and Hotan Region, each contributing 9.43%, 9.43%, and 7.55% respectively. Lower representation occurs in Kashgar, Kizilsu Kirghiz Autonomous Prefecture, Ili Kazakh Autonomous Prefecture, Hami, and Aksu Region, accounting for 3.77%, 3.77%, 3.77%, 3.77%, and 1.89% correspondingly.

Among the 147 national-level ICH entries in Xinjiang, traditional music and craft techniques occupy the foremost tier, comprising 20% and 17.9% of the inventory respectively. Folkloric practices, folk literature, and traditional dance constitute the secondary tier at 15.7%, 13.6%, and 11.4%. The tertiary tier encompasses traditional sports and acrobatic entertainment (6.4%), traditional visual arts (6.4%), traditional medical knowledge (5%), and theatrical performance traditions (3.6%).

Owing to its distinctive geographical position at the intersection of major cultural transmission routes, Xinjiang serves as a critical zone for cross-cultural encounter and synthesis. Diverse ethnic cultures engage in mutual collision, absorption, and blending processes, continuously enriching musical, choreographic, literary, and folk custom traditions while generating characteristically pluralistic cultural expressions.

3.1.2 Characteristics of the spatial distribution of traditional villages and intangible cultural heritage

Traditional village distribution across Xinjiang exhibits a pattern comprising one primary concentration nucleus and three secondary nuclei. The principal nucleus spans the Changji Hui Autonomous Prefecture through Turpan corridor, encompassing 19 villages that collectively represent 35.85% of the regional total. Secondary concentration zones appear in the northwestern, southwestern, and south-central sectors of the territory.

In spatial terms, traditional village concentrations occur in northern Xinjiang along the southern flanks of the Altai Mountains; in central Xinjiang proximate to the Tianshan Mountains on both northern and southern aspects; and in southern Xinjiang along the northern margins of the Kunlun Mountains. The preponderance of villages occupies low-elevation plains associated with mountain drainage systems, with most situated below 1500 m elevation. All Turpan villages and selected Bortala localities occur below 680 m. Higher-elevation areas demonstrate superior preservation outcomes, attributable to reduced external anthropogenic disturbance. Figure 2 presents the distributional pattern of traditional villages across the Xinjiang Uygur Autonomous Region.

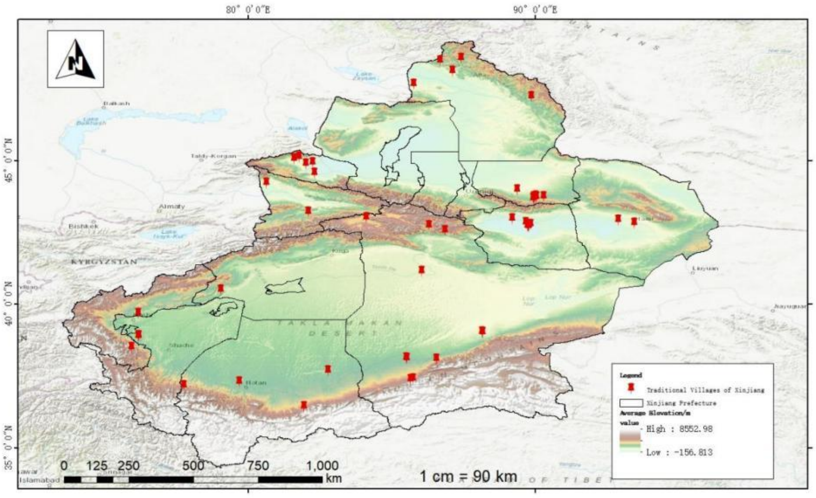

Figure 2 Distribution of Traditional Villages in Xinjiang Uygur Autonomous Region.Base map data sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community.

Source: http://bzdt.ch.mnr.gov.cn/

Across Xinjiang, 147 nationally designated ICH elements demonstrate pronounced proximity to water systems, organizing into two pronounced high-density centers, two moderate sub-density centers, and multiple low-density zones. The principal high-density centers comprise the Urumqi–Changji agglomeration (27 entries, 18.4%) and the Ili Kazakh Prefecture cluster (20 entries, 13.61%). The secondary sub-density centers encompass the Kizilsu–Kashgar area (16 entries, 10.88%) and Bayin'guoleng (10 entries, 6.80%).

The majority of nationally designated ICH elements occupy low-elevation plain environments. Across northern Xinjiang, they extend along the southern flanks of the Altai Mountains, oriented parallel to the topographic grain. In central Xinjiang, they follow both aspects of the Tianshan Mountains. Throughout southern Xinjiang, they align with the northern margins of the Kunlun Mountains. In aggregate, Xinjiang's national ICH exhibits a spatial configuration resembling a "W" pattern rotated 90 degrees (Figure 3).

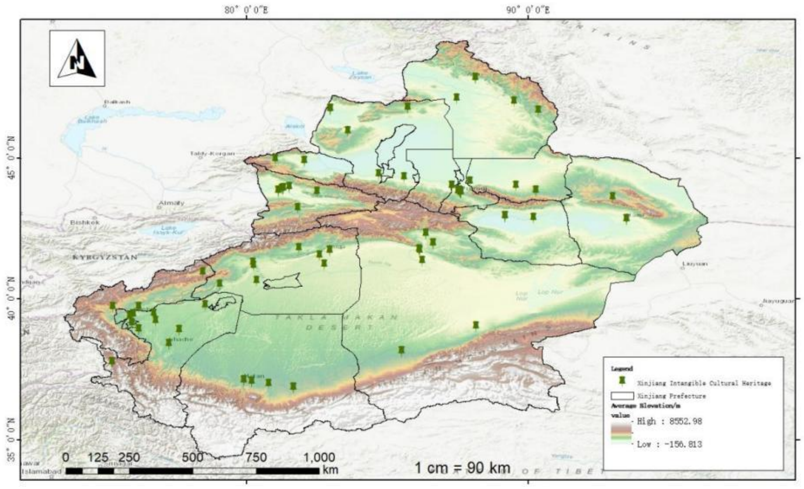

Figure 3 Distribution of National Intangible Cultural Heritage in Xinjiang Uygur Autonomous Region.Base map data sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community.
Source: http://bzdt.ch.mnr.gov.cn/

3.2 The Spatial Relationship between Traditional Villages and Intangible Cultural Heritage in Xinjiang

3.2.1 Quantitative and spatial relationships between traditional villages and intangible cultural heritage in Xinjiang

A marked spatial concordance characterizes the co-distribution of traditional villages and ICH across Xinjiang. Regions exhibiting high-density traditional village concentrations concurrently display elevated ICH densities, notably within the Changji Hui Autonomous Prefecture, Urumqi municipality, Turpan prefecture, and the Ili Kazakh Autonomous Prefecture. Conversely, where traditional villages occur in scattered distributions, ICH manifestations likewise appear dispersed and comparatively scarce, as observed in Kashgar, Hotan, Bayinguoleng Mongol Autonomous Prefecture, and other localities along the southern frontier.Figure 4 illustrates the spatial distribution and sample decomposition study of national intangible cultural heritage and traditional villages in the Xinjiang Uygur Autonomous Region.

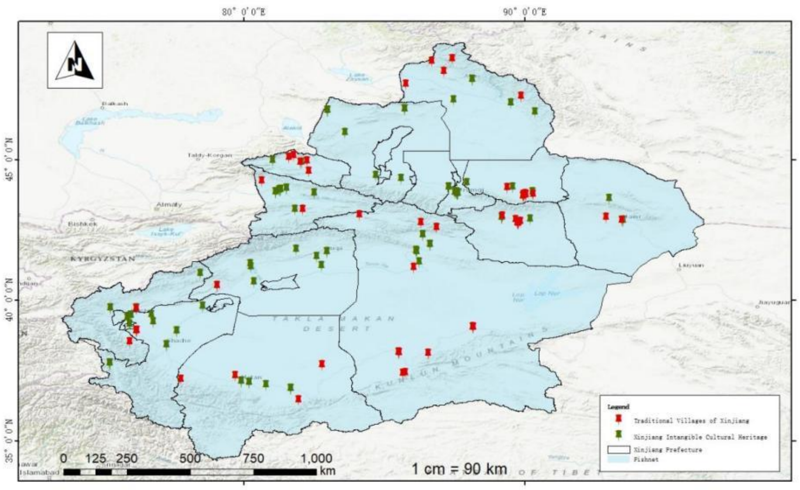

Figure 4 Spatial Distribution and Sample Decomposition of National Intangible Cultural Heritage and Traditional Villages in Xinjiang Uygur Autonomous Region.Base map data sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community.
Source: http://bzdt.ch.mnr.gov.cn/

ArcGIS software was employed to partition Xinjiang into grid-based sampling units with cell dimensions of 0.5 degrees in both longitudinal and latitudinal directions. Following sample enumeration, units containing both traditional villages and ICH totaled 10, units with only traditional villages numbered 22, units with only ICH reached 40, and units containing neither category amounted to 596, yielding a=10, b=22, c=40, d=596, and n=671. The spatial relationship index R was subsequently computed. Equation (7):

$$R=\frac{10\times717-22\times40}{\sqrt{(10+22)(40+717)(10+40)(22+717)}}\approx0.661 \qquad (7)$$

The computed R-value exceeding zero confirms the existence of a positive association between intangible cultural heritage and traditional village distributions. Subsequent significance testing of the quantitative spatial relationship index was performed using the chi-squared statistic.

$$X^2=\frac{(10\times717-22\times40)^2\times671}{(10+22)(40+717)(10+40)(22+717)}\approx35.02 \quad (8)$$

Consulting the chi-square distribution with one degree of freedom, the critical value at α=0.05 significance threshold equals 3.841. The computed statistic substantially exceeds this benchmark, confirming that the quantitative spatial association between traditional villages and intangible cultural heritage across Xinjiang achieves statistical significance at the conventional level.

3.2.2 Spatial correlation analysis

Through ArcMap enumeration of ICH sites and traditional village counts within each county-level administrative unit across Xinjiang, bivariate spatial autocorrelation analysis performed in Geoda software identified a positive spatial association between ICH and traditional village distributions (Moran's I = 0.034), with significance p-value exceeding 0.5. Four spatial association categories were distinguished: high–high, high–low, low–high, and low–low, collectively representing 18.63% of the total analytical area, suggesting that regions exhibiting statistically significant spatial correlation constitute a limited proportion. Low–low and high–low clusters predominantly occur in northern Xinjiang, while high–high and low–high clusters concentrate in eastern Xinjiang. Figure 5 presents the LISA cluster analysis of national-level ICH and traditional village distributions across the Xinjiang Uygur Autonomous Region.

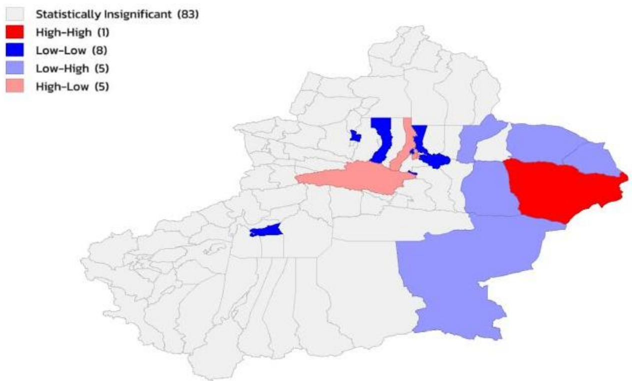

Figure 5 Spatial LISA clustering of national-level intangible cultural heritage and traditional villages in Xinjiang Uygur Autonomous Region

Source: http://bzdt.ch.mnr.gov.cn/

More specifically, the spatial correspondence between ICH and traditional villages in Xinjiang manifests distinctive regional configurations. The high–high cluster centers upon Hami City, a pivotal node along the Silk Road Economic Belt corridor. This locality possesses substantial ICH endowments alongside well-conserved traditional settlements, exemplified by Botan Village, Hami Muqam traditions, and Hami embroidery craftsmanship. These heritage assets cluster within localized areas while maintaining connectivity with surrounding regions, collectively constituting the "East Tianshan Cultural Corridor." The integrated ICH-tourism development approach advanced by regional administrative authorities fosters synergies between heritage exhibition and village-based tourism, attracting capital inflows and skilled human resources. Low–low clusters encompass Manas County and Urumqi municipal districts, where accelerated urbanization has precipitated village demolition or functional transformation, degrading ICH living environments and triggering heritage decline under combined urban expansion and ecological pressures. Low–high clusters extend across Ruoqiang, Shanshan, Yiwu, Barkol, and Qitai counties, where sparse population density, substantial out-migration, and interrupted intergenerational transmission impede ICH continuity. High–low clusters occur in Changji City, Hejing County, and portions of Urumqi, where robust ICH advantages persist primarily because heritage elements have been relocated to urban cultural venues such as the International Grand Bazaar.

3.3 Factors Influencing the Spatial Distribution of Traditional Villages and Intangible Cultural Heritage in Xinjiang

3.3.1 Mainly on the banks of rivers

Riparian buffer zone analysis was performed employing Xinjiang hydrological datasets, establishing concentric distance bands at 1 km, 3 km, 5 km, and 15 km intervals. Enumeration of both ICH sites and traditional settlements falling within each buffer ring was conducted based on geographical positioning.

ICH distribution demonstrates pronounced affinity with river systems, with 10.69%, 26.00%, 38.44%, and 73.21% of entries occurring within 1 km, 3 km, 5 km, and 15 km respectively, exhibiting a monotonic increase with buffer radius. Approximately 73.21% of all ICH elements fall within 15 km of river channels, indicating that heritage sites predominantly concentrate along riparian corridors.

Regarding traditional village settlements, the respective percentages are 47.17%, 66.04%, 73.58%, and 98.11%, demonstrating a consistent increasing trajectory with expanding buffer radius. Over 73.58% of all villages occur within 5 km of river channels, while 98.11% fall within 15 km, indicating that virtually all traditional villages are distributed along or in close proximity to watercourses.

***3.3.2* Impact of physical geography**

Mean population density and GDP values for Xinjiang across the years 2000, 2005, 2010, 2015, and 2020 were compiled and subsequently converted to raster format with reclassification. A fishnet grid was generated for the GDP, population density, and river buffer layers. Through multi-value extraction, kernel density values for traditional villages and ICH, along with GDP, population density, river buffer distances, and topographic elevation values, were extracted to fishnet sampling points. Results were exported to Excel format and analyzed via geodetector to identify the determinants of traditional village and ICH distributions, with outcomes presented below. Table 1 presents univariate detection results for traditional villages, while Table 2 illustrates interactive detection findings.

Table 1 One-way Detection of Traditional Villages

	X1	X2	X3	X4
q statistic	0.091214	0.073531	0.077546	0.086654
p value	0.033091	0.014782	0.236607	0.15943

Table 2 Interactive Detection of Traditional Villages

	X1	**X2**	**X3**	**X4**
X1	0.091214			
X2	0.102163	0.073531		
X3	0.419596	0.195164	0.077546	
X4	0.248862	0.173241	0.273878	0.086654

In this formulation, the response variable Y denotes traditional village kernel density values, while predictor variables X1 through X4 represent GDP, population density, topographic elevation, and river system proximity respectively.
Table 1 reveals that all examined variables exert statistically meaningful influences on traditional village distribution patterns. The explanatory strengths rank as follows: GDP (q=0.091214) exceeds river system proximity (q=0.086654), which surpasses topographic elevation (q=0.077546), with population density showing comparatively weaker explanatory capacity (q=0.073531). Table 2 further demonstrates that the paired interaction between GDP (X1) and elevation (X3) yields the greatest combined effect (0.419596), establishing this factor pair as the most influential interaction. Secondary influential combinations include elevation with river systems, GDP with river systems, population density with elevation, and population density with river systems, whereas the GDP-population density pairing exhibits comparatively modest impact on village spatial patterns. Table 3 and Table 4 present corresponding univariate and interactive detection findings for ICH distribution.

Table 3 One-way Detection Of Intangible Cultural Heritage

	X1	**X2**	**X3**	**X4**
q statistic	0.160183	0.00877	0.477088	0.104664
p value	0.002238	0.399749	0.000	0.043834

Table 4 Interactive Detection of Intangible Cultural Heritage

	X1	**X2**	**X3**	**X4**
X1	0.160183			
X2	0.170301	0.00877		
X3	0.522638	0.51731	0.477088	
X4	0.335657	0.14446	0.653174	0.104664

In this specification, the response variable Y represents ICH kernel density values, with predictor variables X1 through X4 corresponding to GDP, population density, topographic elevation, and river system proximity respectively.
As indicated in Tables 3 and 4, every explanatory variable demonstrates discernible effects on ICH spatial distribution. The factor explanatory powers rank in the following order: elevation (q=0.477088) > GDP (q=0.160183) > river system proximity (q=0.104664) > population density (q=0.00877). Table 4 additionally reveals that the interaction between elevation (X3) and river systems generates the strongest combined effect (0.522638), identifying this pairing as the dominant interactive influence on ICH distribution. Other notable factor combinations comprise GDP with elevation, population density with elevation, and GDP with river systems, while GDP-population density and population density-river system interactions display relatively weaker influences on ICH distributional patterns.

4 CONCLUSIONS

The present research systematically explores the distributional attributes, spatial coupling patterns, and underlying determinants of both intangible cultural heritage and traditional village settlements in Xinjiang, employing kernel density estimation, bivariate spatial autocorrelation metrics, and geodetector modeling techniques. Findings indicate that ICH and traditional villages demonstrate non-uniform spatial distributions, with pronounced concentration clusters situated in the Changji–Urumqi–Turpan corridor and the Ili prefecture, predominantly occupying low-elevation alluvial plains and riparian corridors. Statistically significant positive spatial association characterizes their co-distribution, exemplified by high–high concentration clusters in Hami that constitute the East Tianshan Cultural Corridor, alongside low–low clusters in northern Xinjiang indicative of heritage resource degradation associated with urbanization pressures. Geodetector analysis identifies topographic elevation as the primary driver of ICH distribution, whereas GDP and hydrological accessibility emerge as chief determinants of traditional village patterns, with interactive effects between variable pairs markedly amplifying explanatory capacity.

These outcomes furnish actionable guidance for cultural heritage preservation and sustainable development initiatives across Xinjiang. Tailored intervention measures may be developed according to spatial coupling classification, encompassing intensified safeguarding efforts in high–high association zones, amelioration of urbanization-induced pressures in low–low areas, and advancement of integrated ICH-tourism development frameworks to harmonize inheritance objectives with economic growth. Prospective investigations might assimilate multi-source observational data to enable dynamic tracking of heritage resource evolution, incorporate supplementary biophysical and anthropogenic variables to elucidate more nuanced driver mechanisms, and refine cultural ecological resilience modeling specific to arid-zone contexts for wider geographical applicability, thereby advancing sustainable heritage continuity and development in multi-ethnic arid regions.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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REFERENCES

[1] BHou Y, Kenderdine S, Picca D, et al. Digitizing Intangible Cultural Heritage Embodied. ACM Journal on Computing and Cultural Heritage, 2022, 15(3): 55.

[2] Selmanović E, Rizvic S, Harvey C, et al. Improving Accessibility to Intangible Cultural Heritage Preservation Using Virtual Reality. ACM Journal on Computing and Cultural Heritage, 2020, 13(2): 13.

[3] Vondolia GK, Kusi AM, King SR, et al. Valuing Intangible Cultural Heritage in Developing Countries. Valuing Cultural Capital in the Smart Cities Era, 2022, 14:4484.

[4] Barliana MS, Ilhamdaniah, Adhi N, et al. Contemporary urban design in Denpasar based on Balinese local culture and architecture. City and Built Environment, 2025, 3: 2.

[5] Hasim IS, Widiastuti I, Faisal B, et al. The birth and demise of a village within the vernacular community of Baduy in Banten, Indonesia. Frontiers of Architectural Research, 2025, 14: 127-144.

[6] Feizizadeh B, Fathi S, Ghasmeizad Gonbad Z, et al. A Multiple Geospatial Approach for Intangible Cultural Heritage Tourism Potentiality Mapping in Iran. Tourism, Culture, and Heritage, 2023, 15: 16659.

[7] Heather PM, Paul DA, Joshua BB. Can Social Vulnerability Indices Predict County Trauma Fatality Rates?. Journal of Trauma and Acute Care Surgery, 2021.

[8] Lv Jing, Chai Yu, Hu Xin. Synergistic development of intangible cultural heritage and tourism industry: Empirical experiences from Jilin, China. PLoS ONE, 2025, 20(5): e0313421.

[9] Cai Xiang, Sun Ming. On the Evolution and Influencing Factors of the Resilience Spatial and Temporal Pattern of China's Tourism Industry. Journal of Sichuan Tourism University, 2024: 87-95.

[10] Wang Yu, Fan Zhe, Xu Li, et al. Response and influencing factors of habitat quality and land use change in the Tarim River Basin. Arid Zone Research, 2024, 41(6): 2132-2142.