

Article

Spatial Differentiation and Mechanisms of Spatial Mismatch Between Traditional Villages and Intangible Cultural Heritage: Collaborative Conservation Zoning and Strategies in Anhui Province, China

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Abstract

Traditional villages and intangible cultural heritage (ICH) are interrelated components of rural heritage landscapes, linking material spatial carriers with living cultural practices. Yet their spatial matching, mismatch-formation mechanisms, and translation into collaborative conservation zoning remain insufficiently understood. Taking Anhui Province, China, a north–south transitional region, this study examines 836 traditional villages and 685 ICH items at or above the provincial level. We develop a stepwise spatial diagnostic framework that connects clustering identification, positional and quantity–structure mismatch diagnosis, corridor and multi-factor association interpretation, and strategy-oriented conservation zoning. The results show that traditional villages form a strong southern Anhui core (83.01%), whereas the officially attributed locations of listed ICH items are more widely distributed across southern, central, and northern Anhui (43.21%, 26.42%, and 30.36%). The provincial centroid mismatch distance reaches 160.15 km, and prefecture-level cities are classified into ICH-advantaged, traditional-village-advantaged, and relatively matched types. Huangshan further demonstrates that positional proximity does not necessarily imply quantity-structure matching. Mechanism analysis suggests two scale-dependent association patterns: an environmental preservation pattern for traditional villages and a social-transmission and institutional-attribution pattern for listed ICH items. Based on this provincial-scale diagnosis, the study delineates key, secondary, and general conservation zones as strategy-oriented diagnostic zones and proposes differentiated collaborative conservation strategy orientations.

Keywords: traditional villages; intangible cultural heritage; spatial mismatch; collaborative conservation zoning; optimal-parameters-based geographical detector

Academic Editors: Nan Jia, Haimeng Liu, Zhimeng Jiang and Junyu Zhang

Received: 20 June 2026

Revised: 4 July 2026

Accepted: 7 July 2026

Published: 8 July 2026

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1. Introduction

Cultural heritage conservation has increasingly moved beyond the site-oriented protection of individual assets toward holistic and sustainable cultural landscape conservation [1–4]. In this context, the relationship between traditional villages and intangible cultural heritage (ICH) has become an important issue in rural heritage studies. Traditional

villages preserve historical settlement forms, architectural styles, local landscape patterns, production and living practices, and community memory. ICH, by contrast, refers to living cultural expressions transmitted and recreated through the practices of communities, groups, and individuals [4]. From the perspective of rural landscape heritage conservation, rural landscapes are shaped by long-term interactions among natural environments, modes of production, social structures, and cultural values [2]. Cultural landscapes are therefore not isolated heritage sites, but integrated expressions of relationships among people, places, social organizations, and ecosystems [3]. Traditional villages and ICH should thus be understood as interrelated material spatial carriers and living cultural practices within rural heritage landscapes. Their spatial coupling or mismatch reflects not only the distribution of heritage resources, but also the preservation conditions, transmission basis, and collaborative conservation potential of regional cultural resources.

In the Chinese heritage-management context, traditional villages are not simply old rural settlements [5,6]. They refer to rural settlements formed relatively early, possessing rich traditional resources and important historical, cultural, scientific, artistic, social, or economic value, and therefore requiring protection. Official and academic definitions emphasize that traditional villages usually retain relatively complete settlement layouts, vernacular architectural forms, traditional site-selection and spatial organization, local landscape features, tangible and intangible cultural heritage resources, and continuing community life. In this study, “traditional villages” refers specifically to listed traditional villages at or above the provincial level in Anhui Province. The term “traditional” therefore denotes the integrated continuity of historical settlement form, vernacular architecture, rural landscape, production and living practices, and community memory, rather than merely the administrative age or physical size of a village.

This issue also echoes major debates in international heritage theory. UNESCO’s 2003 Convention emphasizes that ICH is not a static cultural object, but a process continuously practiced, expressed, transmitted, and recreated by communities, groups, and individuals [4]. Related studies further argue that ICH safeguarding requires attention to processes, communities, bearers, and transmission conditions rather than only to material objects [7–10]. At the same time, critiques of the authorized heritage discourse (AHD) warn that heritage conservation may marginalize everyday local practices and the production of cultural meanings when it overemphasizes visible and institutionalized material objects [11]. This perspective is directly relevant to the traditional village–ICH mismatch examined in this study. Traditional villages are more readily identified as bounded heritage spaces with tangible forms, while ICH is mobile, practice-based, and bearer-dependent. Examining their spatial relationship can therefore reveal potential disconnections between material heritage carriers and living cultural practices.

International heritage theory and practice also suggest that rural heritage conservation should move beyond visible material spaces or individual cultural resources. It should consider the relationships among material carriers, cultural practices, community participation, local knowledge, and regional governance networks [2,7–10]. In China, rural revitalization, the construction of a culturally strong country, and culture-tourism integration have further increased the need for integrated conservation. Traditional village conservation and ICH safeguarding, however, are often managed through separate institutional systems. This separation may create a gap between material spaces and cultural practices. Some traditional villages lack sustained cultural activities, while some ICH items lack stable local spatial carriers. A spatial coordination perspective can help identify where traditional cultural resources cluster, where mismatch occurs, and where conservation support remains weak. It also supports a shift from single-site protection to integrated conservation, and from static preservation to living transmission.

A substantial body of research has examined the spatial distribution and influencing factors of traditional villages. GIS-based spatial analysis, kernel density estimation, accessibility analysis, geographical detectors, and geographically weighted regression have been used to identify clustering patterns, regional differences, and associated factors. These studies show that traditional villages often exhibit spatial clustering and regional differentiation, shaped jointly by natural geographical environments, historical-cultural foundations, transport accessibility, river-basin patterns, and socio-economic conditions [12–16]. They provide an important basis for understanding traditional villages as material carriers of rural heritage. However, most of this work examines traditional villages as a single heritage category. The question of whether they are spatially matched with living cultural practices such as ICH remains underexplored.

Studies on the spatial distribution of ICH have also expanded in recent years. Scholars have examined its clustering patterns, type structure, influencing factors, and cultural-tourism use. This literature emphasizes that ICH has historical and cultural attributes, while also being closely connected with population activity, transport links, public cultural services, and tourism development. ICH resources often show spatial imbalance and clustering, and their distribution is associated with natural environments, historical-cultural foundations, socio-economic development, population activity, and public cultural services [17–22]. However, most studies relate ICH to cities, tourism, cultural facilities, or regional economic development. Few compare it directly with traditional villages as material spatial carriers of rural heritage.

The rise of collaborative conservation of tangible and intangible heritage has encouraged a heritage-system perspective on traditional villages, cultural landscapes, and ICH. Recent studies have examined spatial association, coupling characteristics, mismatch relationships, and formation mechanisms between traditional villages and ICH at national, river-basin, and provincial scales [23–27]. The geographical detector and its optimal-parameters extension also provide methodological support for identifying spatial stratified heterogeneity and optimizing factor discretization in spatial differentiation analysis [28,29]. However, three limitations remain. First, many studies focus on spatial association or coupling, but pay less attention to the distinction between spatial positional mismatch and quantity-structure mismatch. Second, mismatch identification often remains a general relationship diagnosis. The roles of water systems, roads, cultural facilities, tourism nodes, and population activity in mismatch formation are still not fully examined. Third, existing research rarely translates spatial distribution, mismatch types, and formation mechanisms into collaborative conservation zoning and strategy pathways for specific city types. This gap is especially evident in Anhui Province, a north–south transitional region where the differences among southern, central, and northern Anhui have important implications for conservation zoning.

Anhui Province provides a representative provincial case for analyzing traditional village-ICH mismatch and collaborative conservation strategies. It connects China's eastern coastal areas with the central and western regions and spans the north–south transitional zone. Anhui can therefore be regarded as a macro-scale geographical-cultural transect shaped by natural differentiation, historical-cultural variation, and socio-economic transformation. Southern Anhui is associated with Huizhou culture, lineage systems, Hui-style architecture, and mountainous settlement landscapes, and it contains a major traditional-village core. Central Anhui lies between the Yangtze and Huaihe rivers, with relatively concentrated transport links, urban activities, and public cultural resources. Northern Anhui has a strong foundation of population agglomeration and folk culture. These internal contrasts make Anhui suitable for examining whether material heritage carriers and living cultural practices are spatially matched within the same provincial heritage

system. They also provide a useful basis for exploring collaborative conservation zoning and strategy pathways.

To address these gaps, this study constructs a traditional village-ICH spatial database for Anhui Province, using heritage resources at or above the provincial level. The analysis asks four questions.

- (1) What spatial distribution patterns do traditional villages and ICH present in Anhui Province?
- (2) Do the two heritage types show mismatch in spatial centroids and quantity structures, and what are the direction and intensity of this mismatch?
- (3) How are river systems, backbone road transport, natural environments, socio-economic development, and cultural-tourism conditions spatially associated with their differentiation and mismatch patterns?
- (4) How can spatial distribution, mismatch types, and formation mechanisms be translated into collaborative conservation zoning and strategies for different city types?

Methodologically, this study does not treat kernel density estimation, centroid analysis, SMI, buffer-zone analysis, OPGD, and conservation zoning as isolated tools. Instead, it organizes them into a stepwise diagnostic framework that links spatial pattern identification, positional and quantity-structure mismatch diagnosis, mechanism interpretation, and strategy-oriented zoning. In doing so, the study provides a provincial-scale analytical pathway for the collaborative conservation of traditional villages and ICH.

2. Materials and Methods

2.1. Study Area

Anhui Province is located in eastern China, on the western side of the Yangtze River Delta, and serves as an important transitional region connecting China's eastern coastal areas with the central and western regions (Figure 1a). It extends approximately from 114°54' E to 119°37' E and from 29°41' N to 34°38' N, covering an area of about 140,100 km² and containing 16 prefecture-level cities. Because Anhui spans China's north–south transitional zone, it shows marked internal differences in natural environment, land use, historical culture, and socio-economic development. These characteristics make it a representative region for analyzing the spatial mismatch between traditional villages and intangible cultural heritage.

In terms of regional structure, Anhui Province can be divided into three geographical-cultural regions: northern Anhui, central Anhui, and southern Anhui (Figure 1b). Northern Anhui includes Huaibei, Bozhou, Suzhou, Bengbu, Fuyang, and Huainan. Located north of the Huaihe River and in its adjacent areas, this region is dominated by plains and agricultural production spaces. It is strongly influenced by Central Plains culture and Huaihe River culture and is characterized by population agglomeration and traditional folk activities. Central Anhui includes Hefei, Chuzhou, and Lu'an. Situated between the Yangtze and Huaihe rivers, it forms a transitional zone of north–south physical geography and cultural exchange, with relatively concentrated transport links, urban activities, and public cultural resources. Southern Anhui includes Wuhu, Ma'anshan, Tongling, Anqing, Chizhou, Xuancheng, and Huangshan. This region is dominated by mountains, hills, river valleys, basins, and riverine cultural landscapes, and it has favorable conditions for the preservation of traditional settlements. It also contains rich cultural resources, including Huizhou culture, lineage systems, Hui-style architecture, and traditional crafts. The Huaihe River segment of the Qinling–Huaihe geographical divide crosses northern Anhui, further reinforcing the north–south differences in natural environment and cultural landscape within the province.

From the perspective of natural environment and land-use background, the Yangtze River, Huaihe River, and Xin'an River systems jointly shape the hydrological pattern of Anhui Province. Rivers, lakes, mountains, and hills have long influenced the siting of traditional settlements, agricultural production, and regional cultural exchange. The land use/land cover pattern shows that Anhui is dominated by cropland and forest land. Cropland is widely distributed in northern and central Anhui, whereas forest land accounts for a higher proportion in the mountainous areas of southern Anhui (Figure 1c). This geographical structure, consisting of plain agricultural spaces, the Jianghuai transitional zone, and the mountainous cultural landscapes of southern Anhui, provides contrasting spatial conditions for material heritage carriers and living cultural practices. Mountainous areas in southern Anhui provide favorable conditions for settlement preservation, while plains, transitional corridors, and urban networks create broader spaces for population-based cultural transmission.

Taken together, Anhui Province contains abundant traditional villages and ICH resources and shows significant internal regional differentiation. Taking Anhui as a case helps examine the spatial relationship between material rural heritage carriers and living cultural practices within the same provincial heritage system. It also provides a geographical basis for subsequent spatial mismatch measurement, mismatch-mechanism identification, and collaborative conservation strategy formulation.

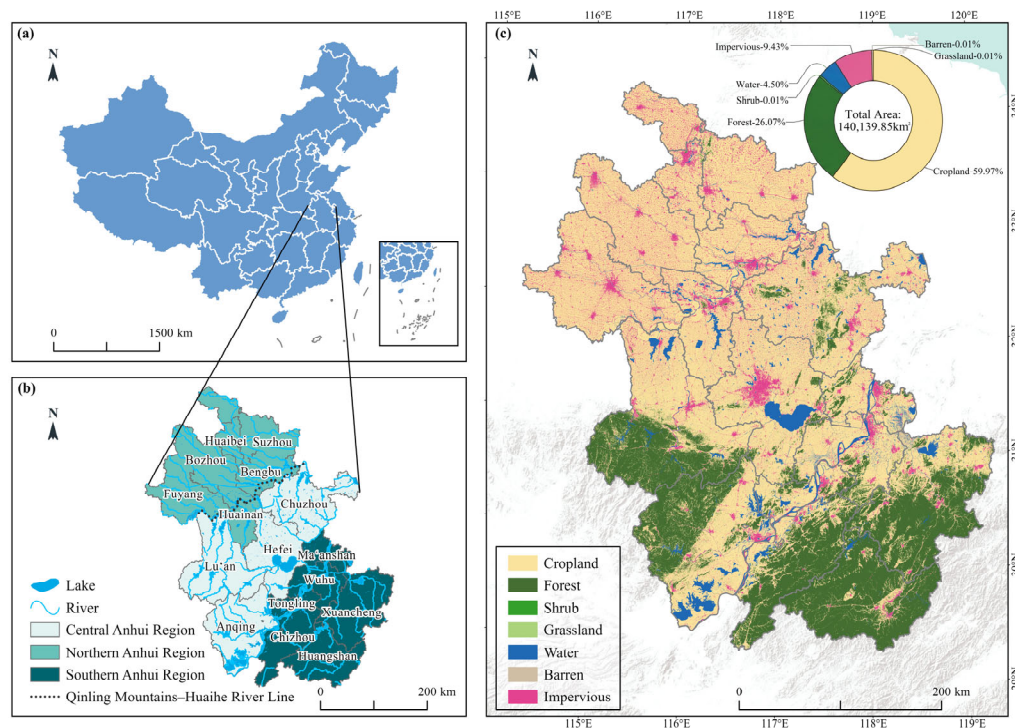


Figure 1. Location and geographical background of the study area (Map Approval No. GS(2019)1822). (a) Location of Anhui Province in China; (b) administrative divisions, major rivers and lakes, the Qinling–Huaihe Line, and the three geographical regions of Anhui Province; (c) land use/land cover pattern of Anhui Province and the proportional composition of major land-use types.

2.2. Data Sources and Preprocessing

This study focuses on traditional villages and intangible cultural heritage items at or above the provincial level in Anhui Province. We first constructed a traditional village–ICH spatial database. Traditional village data were collected from the national list of Chinese traditional villages, the Anhui provincial list of traditional villages, and related tra-

ditional village information platforms [30,31]. After integrating, de-duplicating, and geolocating the national and provincial lists, we obtained 836 traditional villages at or above the provincial level in Anhui Province. ICH data were collected from the China Intangible Cultural Heritage website, the Anhui provincial representative ICH list, and related official materials [32,33]. After sorting, merging, and de-duplicating national and provincial ICH records, we obtained 685 ICH items at or above the provincial level in Anhui Province. The official category information of ICH items was retained and standardized during preprocessing. However, comparable information on village size or morphological type is not consistently available for all listed traditional villages in the official list data; therefore, this study uses list status, administrative location, and prefecture-level aggregation as the main metadata basis for provincial-scale comparison.

Traditional villages have clear spatial-entity attributes and can usually be located relatively accurately using village names and administrative-division information. ICH, by contrast, is characterized by living transmission, mobility, multiple bearers, and multiple practice settings, and its spatial extent is often not equivalent to a single fixed location. To support provincial-scale spatial analysis, this study converted ICH items into point data according to their declared locations, protection units, places of origin, or main places of transmission. These points represent the official spatial attribution of listed ICH items rather than the full spatial extent of everyday ICH practices. For some items, the analytical coordinates may correspond to reporting institutions, cultural centers, museums, schools, associations, or county-level administrative locations, while actual transmission activities may take place in surrounding villages, family workshops, markets, ritual spaces, festivals, or cross-village community networks. Therefore, the mismatch identified in this study should be understood as a list-based spatial-attribution mismatch between listed traditional-village carriers and officially attributed ICH items, not as evidence that ICH practices are absent from rural communities.

Administrative boundaries, river systems, elevation, climate, socio-economic, cultural, and tourism data were obtained from standard map services, fundamental geographic information platforms, DEM products, meteorological data products, statistical yearbooks, statistical bulletins, and government open data [34–38]. Road data were derived from the OpenStreetMap road network [39]. Because OpenStreetMap coverage may be incomplete for minor roads in rural or remote areas, the OSM-based road data were interpreted cautiously in this study. We calculated road network density using the full road vector dataset at the prefecture-level scale and selected road features tagged as highway = motorway and highway = trunk to represent backbone transport corridors in the buffer analysis. Therefore, the road-related results should be understood as indicators of prefecture-level road-network intensity and regional corridor proximity, rather than as a complete assessment of village-level rural accessibility. We processed all spatial datasets in ArcGIS Desktop 10.8.1 and projected them to the CGCS2000 3-degree Gauss–Krüger Zone 40 coordinate system. Elevation-related data were referenced to the 1985 National Height Datum. Projection transformation, spatial correction, topology checking, and attribute joining were then completed [40–42]. Finally, using the 16 prefecture-level cities of Anhui Province as the basic statistical units, we established a spatial database for kernel density estimation, center-of-gravity calculation, mismatch index measurement, buffer-zone analysis, and geographical detector analysis. The data sources, temporal coverage, and preprocessing procedures are summarized in Table 1.

Table 1. Data sources, temporal coverage, and preprocessing information used in this study.

Data Type/Variable	Data Source and Temporal Coverage	Spatial Unit/Preprocessing
Traditional villages	National and Anhui traditional village lists [30,31]; national lists, batches 1–6; latest available Anhui provincial lists; accessed in 2026	Point data; duplicate records removed; names and administrative units standardized; geocoded and manually checked; aggregated to prefecture-level cities
Intangible cultural heritage (ICH) items	China ICH website and Anhui provincial ICH lists [32,33]; national lists, batches 1–5; Anhui provincial lists up to the latest included batch; accessed in 2026	Point data based on declared location, protection unit, place of origin, or main place of transmission; representing the official spatial attribution of listed ICH items rather than the full spatial extent of everyday ICH practices; duplicate records removed; categories and administrative units standardized; aggregated to prefecture-level cities.
Prefecture-level boundaries	Standard map service and national fundamental geographic information data [34,35]; latest available version before analysis	Prefecture-level polygon data; used for spatial aggregation, centroid calculation, and map production
Elevation and slope	DEM data [36]; product version and download date recorded during data processing	Raster data; slope derived from DEM; mean elevation and mean slope calculated for each prefecture-level city
Key river systems and river network density	Provincial WGS84 river-system dataset and national fundamental geographic information data [35]; Anhui river-system data were selected; river features with kind codes 0–3 were used to represent key river systems for provincial-scale corridor analysis	Vector line/polygon data; projected before buffer construction; used to calculate river network density and conduct key-river-system buffer analysis
Temperature and precipitation	Meteorological data products or statistical data [37]; annual or multi-year mean values according to data availability	Raster, station-based, or prefecture-level data; extracted or aggregated to prefecture-level cities
GDP, urbanization, population density, and tourism revenue	Statistical yearbooks, municipal yearbooks, statistical bulletins, and government open data [38]; 2023 statistical data, unless otherwise specified	Prefecture-level statistical data; used as socio-economic explanatory variables
Museums, libraries, cultural centers, and A-level tourist attractions	Statistical yearbooks, bulletins, and government cultural and tourism data [38]; same statistical year or latest available list before analysis	Prefecture-level counts or point data; used to represent public cultural service and tourism-resource conditions
Road network, expressways and trunk roads, and road network density	OpenStreetMap road network data [39]; full road network used for road network density, and road features tagged as highway = motorway and highway = trunk selected to represent backbone transport corridors in the buffer analysis	Vector line data; projected before buffer construction; used to calculate road network density and conduct expressway/trunk-road buffer analysis

2.3. Analytical Framework

This study follows an analytical framework that moves from spatial pattern identification and spatial mismatch measurement to mismatch-formation mechanism analysis and collaborative conservation strategy formulation (Figure 2). The framework treats collaborative conservation zoning as an intermediate spatial diagnostic tool that supports strategy formulation, rather than as an independent step parallel to it.

First, we used kernel density estimation to identify the spatial clustering patterns of traditional villages and ICH items. This step addresses where the two types of heritage

cluster in Anhui Province and whether their hotspot areas overlap. Because kernel density estimation describes clustering patterns but cannot directly evaluate spatial matching, we then combined the center-of-gravity model, spatial mismatch distance, and spatial mismatch index (SMI) to diagnose mismatch. The center-of-gravity model and mismatch distance identify the direction and magnitude of overall spatial displacement between traditional villages and ICH, whereas the SMI compares prefecture-level city shares to distinguish ICH-advantaged, traditional-village-advantaged, and relatively matched areas. Together, these indicators reveal the dual mismatch between traditional villages and ICH in spatial position and quantity structure.

After diagnosing the mismatch pattern, we further examined its formation mechanisms. We used buffer-zone analysis to compare the proximity of traditional villages and ICH items to key river systems, expressways, and trunk roads, thereby assessing whether the two heritage types respond differently to water-system corridors, transport corridors, and cultural transmission channels. We then used the optimal-parameters-based geographical detector to compare the spatial consistency and interactions between the natural environment, socio-economic development, cultural-tourism conditions, and the spatial differentiation of traditional villages and ICH. We do not interpret geographical detector results as strict causal effects. Instead, we use this method to compare the relative explanatory power of different factors and to understand the differentiated spatial association logics of the two heritage types.

Finally, we translated the results of spatial pattern identification, mismatch diagnosis, and mechanism analysis into collaborative conservation strategy formulation. Traditional-village density and ICH density identify the resource agglomeration basis. Spatial mismatch distance and SMI type help determine the degree and direction of mismatch. Buffer-zone analysis and geographical detector results further indicate whether different cities should prioritize environmental preservation, carrier expansion, network linkage, or basic protection. On this basis, we delineated collaborative conservation zones for the 16 prefecture-level cities of Anhui Province. In this framework, conservation zoning functions as a spatial diagnostic basis for strategy formulation: it identifies conservation priorities, resource shortcomings, and strategic directions for different cities, and then supports the proposal of differentiated collaborative conservation strategies.

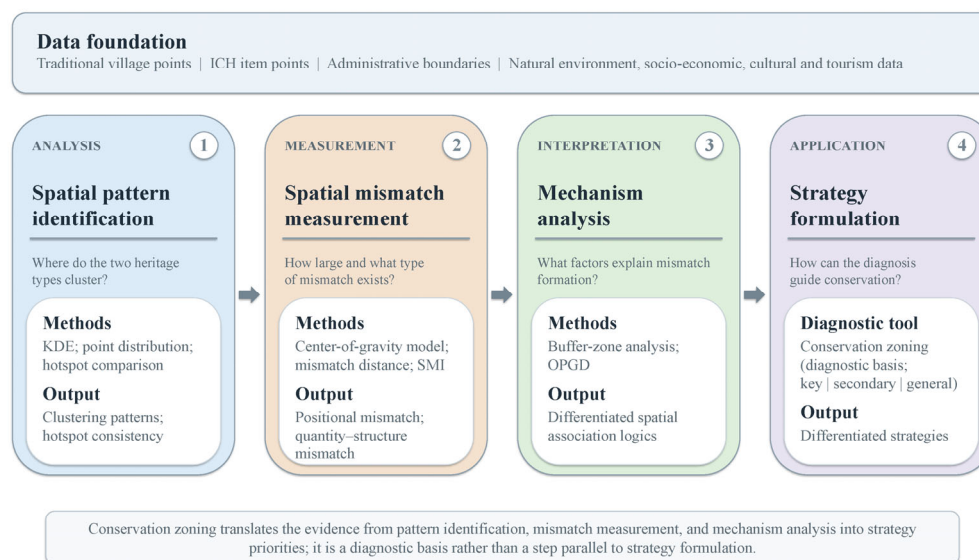


Figure 2. Analytical framework of this study. The analysis proceeds from spatial pattern identification and spatial mismatch measurement to mismatch-formation mechanism analysis and collabora-

tive conservation strategy formulation. Collaborative conservation zoning serves as a spatial diagnostic tool that translates evidence from the first three analytical stages into differentiated conservation strategies.

2.4. Spatial Pattern and Mismatch Measurement

2.4.1. Kernel Density Estimation

We used kernel density estimation (KDE) to transform discrete heritage points into continuous density surfaces and to identify the spatial clustering centers and diffusion trends of traditional villages and ICH items [43–45]. To ensure comparability between the KDE results of the two heritage types, we applied the same search radius to both datasets. Because KDE results are sensitive to bandwidth selection, we conducted a bandwidth sensitivity analysis by comparing six search radii: 30, 60, 90, 120, 150, and 180 km. For both traditional villages and ICH items, smaller bandwidths, especially 30 and 60 km, emphasized scattered local peaks and produced relatively fragmented hotspot patterns. Larger bandwidths, especially 120–180 km, progressively merged adjacent hotspots and over-smoothed regional differences. By comparison, the 90 km bandwidth retained the main provincial-scale hotspot structure while avoiding excessive fragmentation and over-smoothing (Appendix A Figures A1 and A2). Therefore, we used 90 km as the KDE search radius for Figure 3.

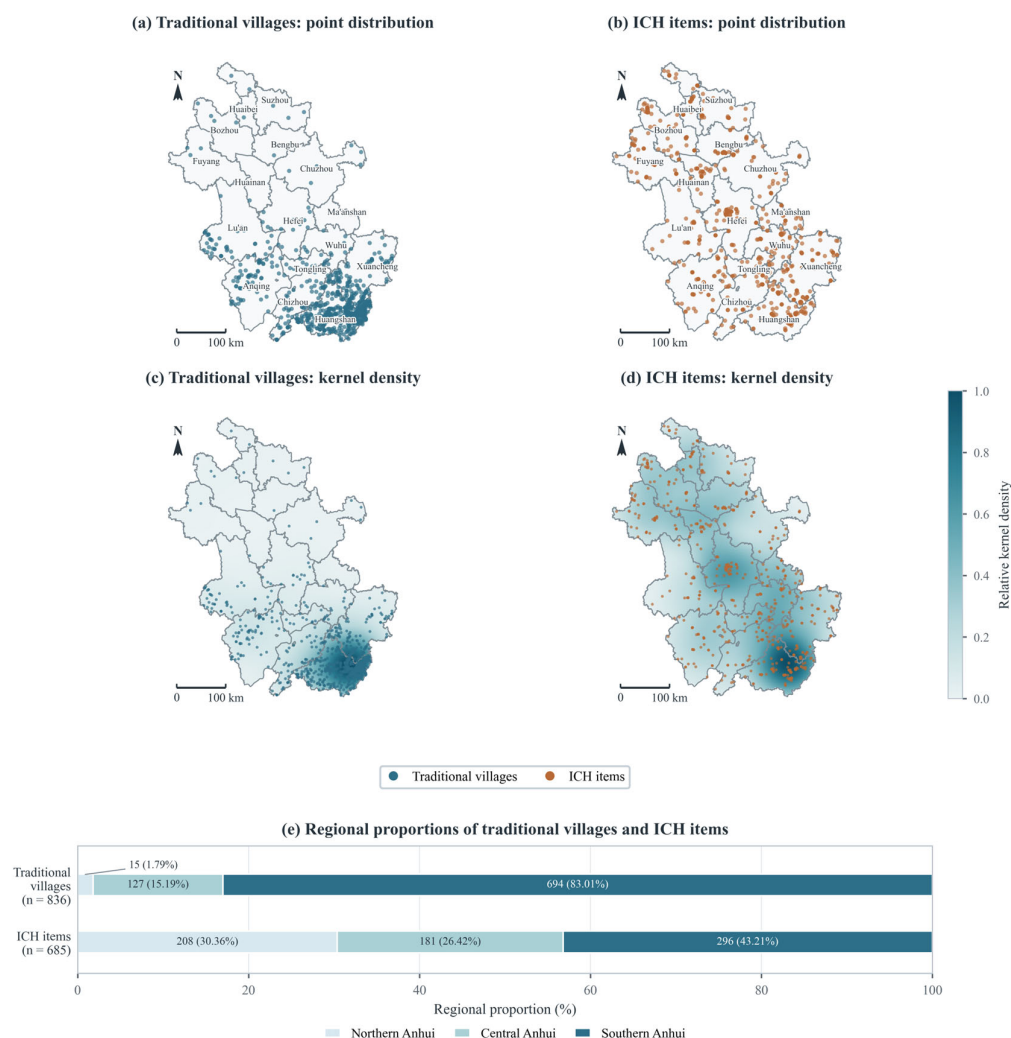


Figure 3. Spatial distribution and kernel density patterns of traditional villages and intangible cultural heritage (ICH) in Anhui Province. (a) Point distribution of traditional villages; (b) point distribution of ICH items; (c) kernel density of traditional villages; (d) kernel density of ICH items; (e) regional proportions of traditional villages and ICH items.

bution of ICH items; (c) kernel density pattern of traditional villages; (d) kernel density pattern of ICH items; (e) regional proportions of traditional villages and ICH items in northern, central, and southern Anhui. Kernel density values were normalized to 0–1 for comparison. Percentages may not sum to 100% because of rounding.

It should be noted that the KDE results were used mainly as a descriptive tool for comparing macro-scale spatial clustering patterns across Anhui Province, rather than for defining micro-scale hotspot boundaries. The subsequent center-of-gravity analysis, spatial mismatch distance, SMI calculation, buffer-zone analysis, and geographical detector analysis were based on heritage point locations or prefecture-level statistical units, rather than on KDE density values. Thus, bandwidth selection affects the visual interpretation of hotspot patterns, but it does not directly determine the mismatch indices or mechanism-analysis results. The kernel density estimation formula is as follows:

$$\hat{f}(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right) \quad (1)$$

where $\hat{f}(x)$ represents the kernel density estimate at location x ; n represents the number of traditional villages or ICH items; h represents the search radius; K represents the kernel function; and $x - x_i$ represents the distance between the estimation location and the i -th point.

2.4.2. Center-of-Gravity Model and Spatial Mismatch Distance

The center-of-gravity model was used to characterize the overall distribution center of geographical elements within a region. Measures of centrality, dispersion, and directionality are important methods for describing the overall spatial distribution of geographical elements and can be used to compare the overall spatial displacement and clustering differences among different sets of heritage elements [46–48]. This study adopted a quantity-weighted center-of-gravity model to calculate the spatial centroids of traditional villages and ICH items at the provincial scale, prefecture-level city scale, and the scale of the three geographical regions of northern, central, and southern Anhui. By comparing the centroid locations of the two heritage types, the overall displacement direction between traditional villages and ICH was revealed. The formula is as follows:

$$X = \frac{\sum_{i=1}^n S_i x_i}{\sum_{i=1}^n S_i}, Y = \frac{\sum_{i=1}^n S_i y_i}{\sum_{i=1}^n S_i} \quad (2)$$

where X and Y represent the spatial centroid coordinates of traditional villages or ICH items; x_i and y_i represent the coordinates of the geometric center of the i -th statistical unit; S_i represents the number of traditional villages or ICH items in the i -th statistical unit; and n represents the number of statistical units included in the calculation. The statistical units differ according to the analysis scale. At the provincial scale and the scale of the three geographical regions of northern, central, and southern Anhui, the statistical units are prefecture-level cities. At the prefecture-level city scale, the statistical units are lower-level administrative units within each prefecture-level city that are used to aggregate the number of traditional villages and ICH items. The resulting centroids mainly reflect the macro-scale spatial distribution trends of traditional villages and ICH items at different scales, rather than the micro-scale activity ranges of individual heritage points.

To further quantify the degree of spatial displacement between the centroid of traditional villages and that of ICH, this study introduces spatial mismatch distance. This indicator calculates the distance between the spatial centroids of the two heritage types and reflects their degree of displacement in the macro-scale spatial pattern [25,46]. A smaller mismatch distance indicates that the centroids of traditional villages and ICH are closer and that their spatial matching degree is higher. A larger mismatch distance indicates a

more obvious spatial displacement and a higher degree of spatial mismatch. The formula is as follows:

$$D = R\sqrt{(X_{ICH}-X_{TV})^2 + (Y_{ICH}-Y_{TV})^2} \quad (3)$$

where D represents the spatial mismatch distance between traditional villages and ICH items; X_{ICH} and Y_{ICH} represent the centroid coordinates of ICH items; X_{TV} and Y_{TV} represent the centroid coordinates of traditional villages; and R is the coefficient used to convert longitude–latitude coordinates into planar distance. If $D = 0$, the two centroids completely overlap; if $D > 0$, the two heritage types show different degrees of spatial mismatch. This study calculated the spatial mismatch distance between traditional villages and ICH at the provincial scale, prefecture-level city scale, and the scale of the three geographical regions of northern, central, and southern Anhui, in order to reveal differences in spatial displacement across scales.

2.4.3. Spatial Mismatch Index

Spatial mismatch distance can reflect the displacement between the centroids of traditional villages and ICH, but it cannot directly reveal whether the quantity structures of the two heritage types are matched across prefecture-level cities. Therefore, this study further introduced the spatial mismatch index (SMI) to measure the direction and intensity of mismatch between traditional villages and ICH in each prefecture-level city from the perspective of differences in their relative shares. It should be noted that this study does not directly transfer the behavioral choice mechanisms of jobs–housing mismatch into heritage research. Instead, it draws on the measurement idea of “differences in the relative shares of different elements within spatial units” from studies of spatial mismatch and spatial separation [49–51]. For traditional villages and ICH, the SMI is mainly used to compare the relative share of the same prefecture-level city in the traditional village system and the ICH system, thereby identifying structurally mismatched areas where the relative share of officially attributed listed ICH items is higher than the relative share of listed traditional villages, or where listed traditional villages are concentrated but officially attributed ICH items are relatively fewer. Similar relative mismatch or spatial relationship measurements have been used in studies of the spatial relationship between traditional villages and ICH. Therefore, this study uses the SMI as a diagnostic tool for provincial-scale collaborative conservation, rather than as a causal mechanism model [24,25,27]. The formula is as follows:

$$SMI_i = \left(\frac{M_i}{M} - \frac{V_i}{V} \right) \times 100 \quad (4)$$

where SMI_i represents the spatial mismatch index of the i -th prefecture-level city; M_i represents the number of ICH items in the i -th prefecture-level city; M represents the total number of ICH items in Anhui Province; V_i represents the number of traditional villages in the i -th prefecture-level city; and V represents the total number of traditional villages in Anhui Province.

According to the sign and absolute value of the SMI, we classified prefecture-level cities into three types: ICH-advantaged, traditional-village-advantaged, and relatively matched. A positive SMI indicates that the share of ICH items in a prefecture-level city is higher than its share of traditional villages, and the city can therefore be regarded as ICH-advantaged. A negative SMI indicates that the share of traditional villages is higher than the share of ICH items, and the city can therefore be regarded as traditional-village-advantaged.

Following a previous study on the spatial mismatch between traditional villages and ICH, we used $|SMI_i| = 1$ as the threshold for distinguishing obvious from non-obvious quantity–structure mismatch [25]. Because the SMI is calculated as the difference between

the relative share of ICH items and the relative share of traditional villages multiplied by 100, one SMI unit corresponds to a one-percentage-point difference between the two provincial shares. Therefore, cities with $|SMI_i| \leq 1$ were regarded as relatively matched areas, indicating that the quantity–structure difference between traditional villages and ICH was not obvious. When $|SMI_i| > 1$, the city was classified as either ICH-advantaged or traditional-village-advantaged according to the sign of the SMI. The absolute value of the SMI was used to assist in judging mismatch intensity: a larger absolute value indicates a more obvious quantity–structure mismatch between traditional villages and ICH in the prefecture-level city. This classification was used as a diagnostic tool for provincial-scale collaborative conservation, rather than as a statistical significance test or a causal classification.

2.5. Mismatch Mechanism Analysis

2.5.1. Buffer Analysis

The river-system data were derived from the Anhui river-system dataset selected from the national fundamental geographic information data [35]. Because this study focuses on provincial-scale corridor relationships rather than micro-scale hydrological environments, we selected river features with kind codes 0–3 to represent key river systems. This selection retains the main rivers and higher-order river corridors that structure Anhui’s regional hydrological and cultural landscape, while reducing the influence of small streams, irrigation ditches, and local water bodies that may reflect micro-scale settlement environments rather than province-wide cultural transmission corridors.

Road data were obtained from OpenStreetMap [39]. OpenStreetMap is a volunteered geographic information dataset, and its completeness for minor rural roads may vary across rural and remote areas. To reduce the influence of this uncertainty, this study did not use the full OpenStreetMap road network to measure local road accessibility in the buffer analysis. Instead, road features tagged as highway = motorway and highway = trunk were selected to represent expressways and major trunk-road corridors. In OpenStreetMap, the highway tag distinguishes roads mainly by function and importance; highway = motorway represents the highest-performance road corridors, whereas highway = trunk represents high-performance or high-importance roads below the motorway level. Therefore, the road-buffer results should be interpreted as proximity to regional backbone transport corridors, not as a complete evaluation of village-level rural road accessibility.

After coordinate harmonization and projection transformation, we constructed four mutually exclusive distance bands from each heritage point to the nearest key river-system or expressway/trunk-road element: 0–2 km, 2–5 km, 5–8 km, and greater than 8 km. These distance bands were set according to the provincial analytical scale, the spatial density of heritage points, and the need to distinguish immediate, near, extended, and outside-corridor relationships while maintaining sufficient sample sizes in each band. These thresholds were used as diagnostic proximity classes for provincial-scale comparison rather than as regulatory buffer standards. The 0–2 km band represents immediate corridor adjacency, the 2–5 km band represents near-corridor proximity, the 5–8 km band represents an extended corridor-proximity zone, and the greater-than-8 km band represents areas outside the main corridor-proximity range. Each heritage point was assigned only to the distance band corresponding to its nearest river-system or road element, thereby avoiding repeated counting. The resulting proportions were used for descriptive comparison of proximity patterns and were not interpreted as strict causal effects.

2.5.2. Optimal-Parameter-Based Geographical Detector

The geographical detector was used to identify the main explanatory factors associated with the spatial differentiation of traditional villages and ICH, and to measure the relative explanatory power of different factors for spatial distribution differences. Based on the principle of spatial stratified heterogeneity, this method can compare the consistency between the stratification of explanatory variables and the spatial differentiation of dependent variables, and can identify multi-factor interactions [28,52]. In this study, the numbers of traditional villages and ICH items were used as dependent variables, respectively. Twelve explanatory variables were selected from three dimensions: natural environment, socio-economic development, and cultural-tourism conditions. The variable system is shown in Table 2.

Table 2. Variables used in the optimal-parameters-based geographical detector analysis.

Code	Category	Variable Name
Y1	Dependent variable	Number of traditional villages
Y2	Dependent variable	Number of ICH items
X1	Natural environment	Mean elevation
X2	Natural environment	Mean slope
X3	Natural environment	River network density
X4	Natural environment	Mean temperature
X5	Natural environment	Precipitation
X6	Socio-economic development	Per capita GDP
X7	Socio-economic development	Urbanization rate
X8	Socio-economic development	Population density
X9	Socio-economic development	Road network density
X10	Cultural and tourism conditions	Public cultural venues
X11	Cultural and tourism conditions	Tourism revenue
X12	Cultural and tourism conditions	A-level tourist attractions

Because some explanatory variables are continuous, their discretization methods and numbers of strata can influence the q -value results of the geographical detector. To reduce the subjectivity caused by manual classification, this study adopted the optimal-parameters-based geographical detector (OPGD). This method optimizes the discretization process of continuous variables by comparing different combinations of discretization methods and numbers of strata, thereby improving the stability and interpretability of geographical detector results [29]. Specifically, three discretization methods were used: equal interval, natural breaks, and quantile classification.

Considering that this study used only 16 prefecture-level cities as statistical units, the candidate number of strata was limited to 2–4. This setting was adopted to avoid excessive fragmentation of the sample units and unstable q -values caused by over-discretization. Two strata can capture a basic high–low differentiation, three strata can represent a low–medium–high structure, and four strata allow a more refined classification while still maintaining acceptable sample sizes and spatial interpretability. For each explanatory variable, q -values were calculated under different combinations of discretization methods and numbers of strata. Under the premise that each stratum had valid samples and reasonable spatial interpretability, the combination with the highest q -value was selected as the optimal discretization parameter for that variable. The core indicator of the geographical detector is the q -value, which is calculated as follows:

$$q = 1 - \frac{\sum_{h=1}^L N_h \sigma_h^2}{N \sigma^2} \quad (5)$$

where q represents the spatial consistency and relative explanatory power between an explanatory factor and the spatial differentiation of traditional villages or ICH, with a value range of 0–1; L represents the number of strata of the explanatory factor; N_h and σ_h^2 represent the sample size and variance of stratum h , respectively; and N and σ^2 represent the total sample size and overall variance of the study area, respectively. A larger q -value indicates stronger relative explanatory power of the factor for the spatial differentiation of traditional villages or ICH.

It should be noted that this study uses the 16 prefecture-level cities of Anhui Province as statistical units, and the number of sample units is relatively limited. When continuous variables are divided into more classes, especially four classes, some strata may contain relatively few samples, which may lead to inflated q -values. Therefore, this study does not interpret q -values as strict causal effects. Instead, q -values are used as indicators of the consistency between the stratification of explanatory variables and the spatial differentiation of traditional villages or ICH.

Based on single-factor detection, this study further used interaction detection to analyze changes in explanatory power under the joint effects of different factors. Interaction detection compares the q -value after the overlay of two factors with the q -values of each single factor, in order to determine whether the interaction between factors produces enhancement, weakening, or nonlinear enhancement. The purpose of using the OPGD in this study is to compare the relative explanatory power of different factors and their interactions, identify the spatial consistency between natural environment, socio-economic development, cultural-tourism conditions, and the spatial differentiation of traditional villages and ICH, and provide a basis for explaining the formation mechanisms of the spatial mismatch pattern between the two heritage types.

2.6. Conservation Zoning for Strategy Formulation

To translate the spatial distribution, mismatch types, and formation mechanisms of traditional villages and ICH into a strategy-oriented spatial diagnostic framework, this study constructed a multi-indicator overlay method for collaborative conservation zoning. The purpose of this zoning is to identify provincial-scale conservation priorities, resource shortcomings, and possible strategy orientations, rather than to produce statutory conservation plans or directly implementable project schemes. First, using prefecture-level cities as statistical units, traditional-village density and ICH density were derived from the city-level counts of traditional villages and ICH items, respectively, to represent the spatial agglomeration degree of the two types of heritage resources. In this section, “density” refers to the city-level concentration of listed heritage resources, operationalized as the number of traditional villages or ICH items in each prefecture-level city and classified using the natural breaks method, rather than as an area-normalized density per square kilometre. Second, based on the center-of-gravity model, the mismatch distance between the centroids of traditional villages and ICH in each prefecture-level city was calculated to represent the spatial positional displacement between the two heritage types. Third, SMI types were used to identify whether each prefecture-level city was ICH-advantaged, traditional-village-advantaged, or relatively matched, thereby representing the quantity–structure relationship between the two heritage types.

During the zoning process, traditional-village density, ICH density, and spatial mismatch distance were each classified into high, medium, and low levels using the natural breaks method, and assigned scores of 3, 2, and 1, respectively. For SMI types, ICH-advantaged and traditional-village-advantaged cities indicate quantity–structure imbalance and were assigned a score of 3, whereas relatively matched cities indicate small differences in quantity structure and were assigned a score of 0. It should be noted that the SMI-type score was mainly used to identify whether an obvious quantity–structure imbalance

existed, rather than to further distinguish the intensity of mismatch. The four scores were summed to form the collaborative conservation priority score, calculated as follows:

$$P_i = S_{TV,i} + S_{ICH,i} + S_{D,i} + S_{SMI,i} \quad (6)$$

where P_i represents the collaborative conservation priority score of the i -th prefecture-level city; $S_{TV,i}$, $S_{ICH,i}$, $S_{D,i}$, and $S_{SMI,i}$ represent the scores of traditional-village density, ICH density, spatial mismatch distance, and SMI type, respectively. The comprehensive scores were then classified into key conservation zones, secondary conservation zones, and general conservation zones using the natural breaks method.

The zoning results do not replace administrative management units, nor do they represent a ranking of heritage value. They should be understood as a provincial-scale spatial diagnostic and prioritization tool. The scoring system uses comparable spatial indicators, including traditional-village density, ICH density, spatial mismatch distance, and SMI type. Implementation-related factors, such as local fiscal capacity, administrative support, existing safeguarding programs, the endangerment status of specific ICH items, the number and age structure of representative bearers, community willingness, land-use constraints, and county- or township-level planning conditions, were not included in the quantitative scoring because they are project-specific and are not consistently available for all cities. These factors should be used as feasibility filters when the zoning results are translated into local conservation actions.

In addition to the above quantitative indicators, this study further used the three geographical-cultural regions of northern, central, and southern Anhui as regional background factors for conservation zoning. These geographical-cultural regions were not directly included in the quantitative scoring of conservation levels, but were used to interpret and verify the zoning results and to provide a regional basis for subsequent differentiated strategy formulation.

3. Results

For clarity, numerical results in this section follow this rounding convention: counts are reported as integers, percentages and mismatch distances are rounded to two decimal places, SMI values are reported to four decimal places where needed, and OPGD q -values are displayed to two decimal places.

3.1. Spatial Distribution Patterns

Traditional villages and ICH items in Anhui Province both show pronounced clustered distributions, but their clustering centers, diffusion ranges, and regional structures differ substantially (Figure 3). Traditional village points show a high degree of concentration and are mainly clustered in the mountainous and hilly areas of southern Anhui, especially in Huangshan and its surrounding areas, with extensions toward Xuancheng, Chizhou, and Anqing. By contrast, traditional village points are much sparser in northern and central Anhui, with only scattered distributions in Lu'an, northern Anqing, and the hilly areas of the Jianghuai region.

In terms of regional proportions, the concentration of traditional villages in southern Anhui is particularly prominent. Among the 836 traditional villages at or above the provincial level in Anhui Province, 694 are located in southern Anhui, accounting for 83.01%; 127 are located in central Anhui, accounting for 15.19%; and only 15 are located in northern Anhui, accounting for 1.79%. This indicates that the spatial pattern of traditional villages in Anhui Province is strongly concentrated in southern Anhui, which is closely related to the mountainous and hilly environment, Huizhou cultural traditions, historical settlement preservation conditions, and relatively intact rural landscape patterns of the region.

The officially attributed locations of listed ICH items are more dispersed. Among the 685 ICH items at or above the provincial level in Anhui Province, 296 are officially attributed to southern Anhui, accounting for 43.21%; 181 are officially attributed to central Anhui, accounting for 26.42%; and 208 are officially attributed to northern Anhui, accounting for 30.36%. Compared with listed traditional villages, the officially attributed locations of listed ICH items still show a certain degree of clustering in southern Anhui, especially in Huangshan, Xuancheng, Chizhou, and Wuhu, but they are also widely distributed in central and northern Anhui. Cities such as Hefei, Fuyang, Bozhou, Suzhou, Huaibei, and Huainan also show relatively high numbers of officially attributed ICH points. This suggests that the spatial pattern of ICH is not simply anchored in material heritage spaces such as traditional villages. Rather, it may reflect the combined influence of population agglomeration, public cultural services, transport connections, festival and folk activities, local cultural transmission networks, and institutional safeguarding or reporting conditions.

The kernel density results further reinforce these differences. The high-density areas of traditional villages are highly concentrated in southern Anhui, forming a single-center or strong-core clustering pattern centered on Huangshan. In contrast, the kernel density pattern of ICH shows broader multi-regional diffusion, including high-density areas in southern Anhui as well as extensions toward central and northern Anhui. Overall, traditional villages and ICH do not form completely overlapping spatial patterns. Areas with dense listed traditional villages do not necessarily correspond to officially attributed ICH clusters of the same intensity, and areas with higher numbers of officially listed ICH items do not necessarily have corresponding numbers of listed traditional-village carriers. This result should be interpreted as a mismatch between two list-based heritage systems, rather than as a complete representation of all everyday ICH practice spaces. This provides the basis for the subsequent measurement of spatial mismatch.

3.2. Centroid Shift and Mismatch Distance

The spatial centroid results show that traditional villages and ICH items in Anhui Province exhibit a clear spatial displacement at the provincial scale (Figure 4). The centroid of traditional villages is strongly biased toward southern Anhui, whereas the centroid of ICH is relatively biased toward central and northern Anhui. The provincial centroid mismatch distance between the two heritage types is 160.15 km, indicating that traditional villages and ICH are not simply superimposed within Anhui Province, but instead show significant macro-scale spatial differentiation.

Among the three geographical regions, central Anhui has the largest centroid mismatch distance between traditional villages and ICH, reaching 70.22 km. Southern Anhui follows, with a mismatch distance of 50.94 km, while northern Anhui has the smallest distance, at 20.63 km. The large mismatch distance in central Anhui indicates that, as a transitional zone between the Yangtze and Huaihe rivers, the region has more pronounced internal differences in the spatial anchoring conditions of traditional villages and ICH items. In southern Anhui, although both traditional villages and ICH items are relatively abundant, traditional villages are more concentrated in Huangshan and surrounding mountainous villages, whereas ICH items are relatively dispersed across multiple cities and cultural nodes. Therefore, an obvious centroid shift remains. In northern Anhui, the number of traditional villages is small and ICH items are more widely distributed, but the centroid distance between the two is relatively small. This suggests that the two types of resources are relatively close in macro-scale spatial location within this region, although their quantity structures are not necessarily matched.

Mismatch distances at the prefecture-level city scale further reveal intra-city differences. Huainan has the largest mismatch distance, at 57.65 km, followed by Lu'an at 50.74

km and Ma'anshan at 38.28 km, all showing strong intra-city centroid shifts. Bengbu, Chuzhou, Chizhou, Fuyang, Bozhou, and Huaibei show medium-level mismatch distances of 29.81 km, 29.65 km, 29.57 km, 29.00 km, 26.27 km, and 26.02 km, respectively. By contrast, Hefei, Xuancheng, Anqing, Wuhu, and Suzhou have relatively small mismatch distances of 20.67 km, 20.61 km, 20.12 km, 19.77 km, and 18.14 km, respectively. Huangshan and Tongling have the smallest mismatch distances, at 7.84 km and 6.01 km, respectively, indicating that the centroids of traditional villages and ICH within these two cities are relatively close.

Overall, the centroid results indicate a macro-scale positional mismatch between the two list-based heritage systems. The 160.15 km provincial mismatch distance is mainly shaped by the strong southward pull of the Huangshan–southern Anhui traditional-village core, whereas the officially attributed locations of listed ICH items are relatively more dispersed across central and northern Anhui. City-level mismatch distances further show that positional proximity varies across cities and should be interpreted together with the SMI-based quantity–structure mismatch results.

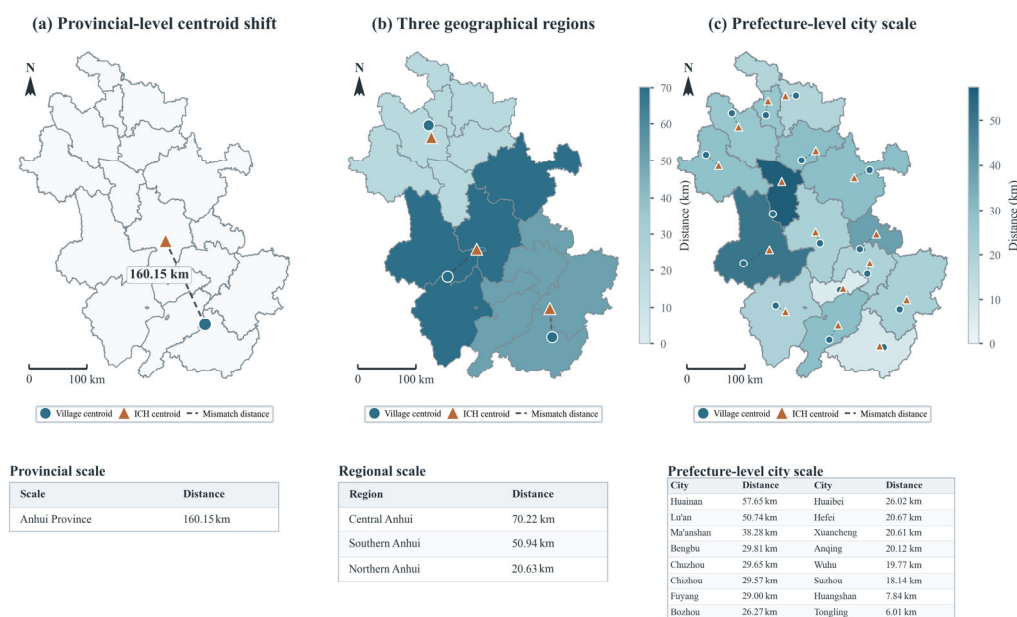


Figure 4. Spatial centroid shift and mismatch distance between traditional villages and ICH items in Anhui Province. (a) Provincial-level centroid shift; (b) mismatch distance among the three geographical regions; (c) mismatch distance at the prefecture-level city scale. Blue circles indicate traditional-village centroids, orange triangles indicate ICH centroids, and dashed lines indicate centroid mismatch distances. In panels (b,c), darker shading indicates larger mismatch distances.

3.3. SMI-Based Mismatch Types

Spatial centroids and mismatch distances can reveal the positional displacement between traditional villages and ICH, but they cannot directly indicate whether the quantitative shares of each prefecture-level city within the two heritage systems are matched. Therefore, this study further uses the SMI to identify quantity–structure mismatch types between traditional villages and ICH across prefecture-level cities (Figure 5).

In terms of SMI ranking, Hefei, Bozhou, Fuyang, and Suzhou show the most obvious ICH-advantaged mismatch, with SMI values of 7.9199, 7.4047, 6.2105, and 5.0953, respectively. This indicates that the relative shares of these cities in the provincial ICH system are higher than their relative shares in the traditional village system. They are therefore characterized by higher shares of officially attributed listed ICH items, but lower shares

of listed traditional-village carriers. Huainan, Ma'anshan, Chuzhou, Wuhu, Bengbu, and Huaibei also show varying degrees of ICH-advantaged mismatch, with SMI values of 3.9680, 3.8220, 3.6619, 3.5545, 3.3840, and 2.5081, respectively. It should be noted that an ICH-advantaged SMI type does not mean that rural communities or traditional villages in these cities lack living ICH practices. The SMI measures the difference between a city's share of officially listed ICH items and its share of listed traditional villages. Therefore, a positive SMI may reflect both the relative abundance of listed ICH items and the institutional attribution of ICH coordinates to county seats, cultural centers, museums, schools, associations, or other safeguarding units. This is particularly relevant for some northern and central Anhui cities, where officially attributed ICH points may be located in urban or county-level institutions, while actual practices may extend into surrounding villages, markets, festivals, family workshops, and community networks.

By contrast, Huangshan shows an exceptionally strong traditional-village-advantaged mismatch, with an SMI value of -42.8988 , far lower than that of other cities. This result is consistent with the high concentration of traditional villages in Huangshan, indicating that Huangshan occupies a very large share of the provincial traditional village system, while its share of ICH items does not reach the same level. Xuancheng and Chizhou also show traditional-village-advantaged mismatch, with SMI values of -3.1801 and -2.0270 , respectively. This suggests that some cities in southern Anhui have abundant traditional village resources, but the relative share of ICH items is not sufficient to fully match their traditional village advantage. This extreme SMI value is particularly important because Huangshan has one of the smallest intra-city mismatch distances. In other words, traditional villages and ICH are spatially close within Huangshan, but their relative shares in the two provincial heritage systems are highly unbalanced. Huangshan therefore represents a typical case in which positional proximity and quantity–structure matching diverge from each other.

In addition, Anqing and Lu'an have SMI values very close to zero, at 0.0817 and -0.4315 , respectively, indicating that their relative shares in the traditional-village system and the ICH system differ only slightly. Tongling also falls within the relatively matched threshold, with an SMI value of 0.9267 , but it is close to the $|SMI| = 1$ boundary. Therefore, this study interprets Tongling as a borderline relatively matched city, rather than as a strongly matched case. These relatively matched cities do not necessarily have equal numbers of traditional villages and ICH items; rather, their relative shares in the two provincial heritage systems are relatively close.

Overall, the SMI results complement the centroid analysis by revealing quantity–structure mismatch. Northern and central Anhui cities are mainly ICH-advantaged, Huangshan, Chizhou, and Xuancheng are traditional-village-advantaged, and Anqing, Lu'an, and Tongling are relatively matched. These results confirm that positional proximity and quantity–structure matching are two separate dimensions of the traditional village–ICH mismatch.

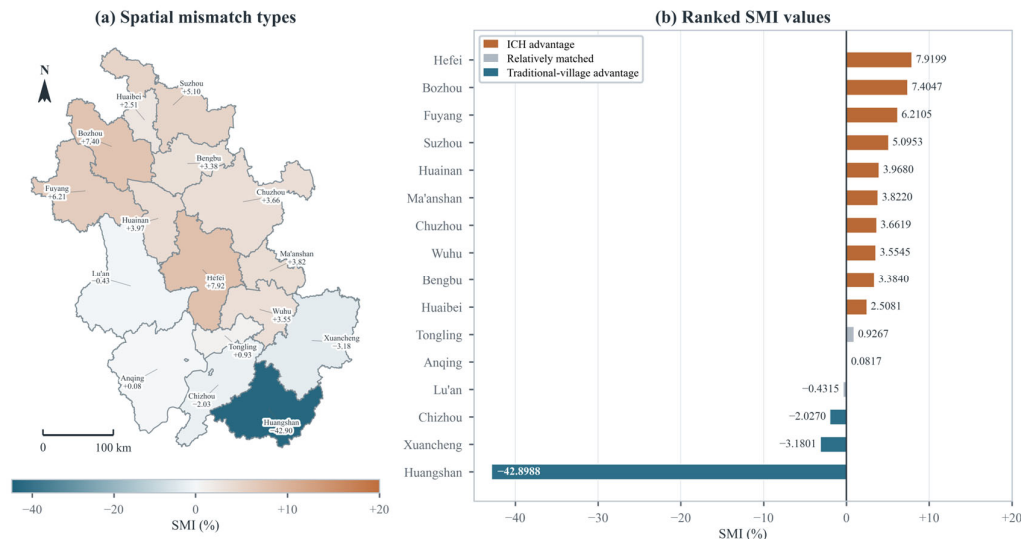


Figure 5. Spatial mismatch index and mismatch types between traditional villages and intangible cultural heritage (ICH) across prefecture-level cities in Anhui Province.

3.4. Mismatch-Formation Mechanisms

After identifying the spatial distribution patterns, centroid mismatch, and quantity–structure mismatch between traditional villages and ICH, this study further analyzes the formation mechanisms of their spatial mismatch from two perspectives: corridor proximity and multi-factor spatial explanation. The first perspective uses buffer-zone analysis of key river systems and expressways/trunk roads to compare the basic spatial proximity between the two heritage types and linear corridors. The second perspective applies the optimal-parameters-based geographical detector (OPGD) to identify explanatory factors and interactions related to natural environment, socio-economic development, and cultural-tourism conditions, thereby further explaining the multi-factor spatial background of mismatch formation.

3.4.1. Buffer-Zone Analysis

The buffer-zone results show clear differences in the proximity of traditional villages and ICH items to key river systems and expressways/trunk roads (Figure 6). For key river-system buffers, 237 traditional villages are located within the 0–2 km zone, accounting for 28.35%; 78 are located within the 2–5 km zone, accounting for 9.33%; 75 are located within the 5–8 km zone, accounting for 8.97%; and 446 are located beyond 8 km, accounting for 53.35%. Overall, 390 traditional villages are distributed within 8 km of key river systems, accounting for 46.65%. This result indicates that traditional villages have a certain spatial proximity relationship with key river systems. However, more than half of the traditional villages are still located more than 8 km away from key river systems, suggesting that the distribution of traditional villages does not simply follow a river-proximity clustering pattern.

By contrast, ICH items show a stronger near-river distribution pattern. Among ICH items, 321 are located within the 0–2 km zone, accounting for 46.86%; 82 are located within the 2–5 km zone, accounting for 11.97%; 37 are located within the 5–8 km zone, accounting for 5.40%; and 245 are located beyond 8 km, accounting for 35.77%. A total of 440 ICH items are located within 8 km of key river systems, accounting for 64.23%. Compared with traditional villages, ICH items have a much higher proportion in the 0–2 km near-distance buffer zone, indicating a stronger spatial proximity relationship with key river systems. This result suggests that, in Anhui Province, rivers may function as natural hydrological

elements as well as corridors of historical transport, commercial exchange, folk activities, festival spaces, and regional cultural transmission.

For expressway and trunk-road buffers, 283 traditional villages are located within the 0–2 km zone, accounting for 33.85%; 198 are located within the 2–5 km zone, accounting for 23.68%; 140 are located within the 5–8 km zone, accounting for 16.75%; and 215 are located beyond 8 km, accounting for 25.72%. Overall, 621 traditional villages are located within 8 km of expressways and trunk roads, accounting for 74.28%. This result indicates a relatively strong spatial proximity relationship between traditional villages and backbone transport corridors. However, approximately one-quarter of traditional villages remain more than 8 km away from backbone roads, reflecting the continued influence of mountainous and hilly environments, historical settlement patterns, and regional development processes on traditional village preservation.

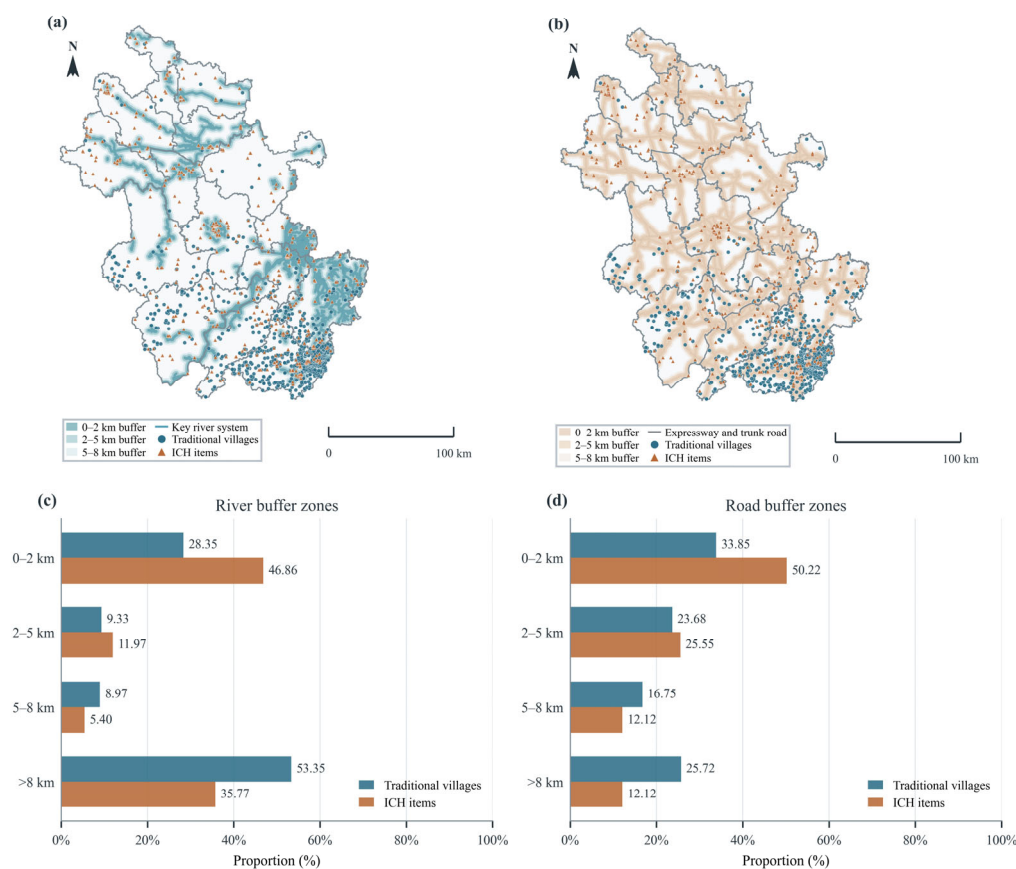


Figure 6. Buffer-zone analysis of heritage points in relation to key river systems and backbone roads in Anhui Province. (a) Buffer zones of key river systems and the distribution of traditional villages and ICH items; (b) buffer zones of expressways and trunk roads and the distribution of traditional villages and ICH items; (c) proportions of traditional villages and ICH items in different river buffer zones; (d) proportions of traditional villages and ICH items in different road buffer zones.

The proximity of ICH items to expressways and trunk roads is even more pronounced. Among ICH items, 344 are located within the 0–2 km zone, accounting for 50.22%; 175 are located within the 2–5 km zone, accounting for 25.55%; 83 are located within the 5–8 km zone, accounting for 12.12%; and 83 are located beyond 8 km, accounting for 12.12%. Overall, 602 ICH items are located within 8 km of expressways and trunk

roads, accounting for 87.88%. Compared with traditional villages, ICH items have a higher proportion in the 0–2 km near-distance buffer zone and a lower proportion beyond 8 km. This indicates that ICH items have stronger spatial proximity to backbone transport corridors and may reflect their relationship with transport-based transmission networks.

3.4.2. OPGD Results

Building on the buffer-zone analysis, the OPGD was further used to examine the spatial consistency between natural environmental, socioeconomic, and cultural-tourism conditions and the spatial differentiation of the two heritage types. Traditional villages and ICH items exhibit different q -value profiles (Figure 7).

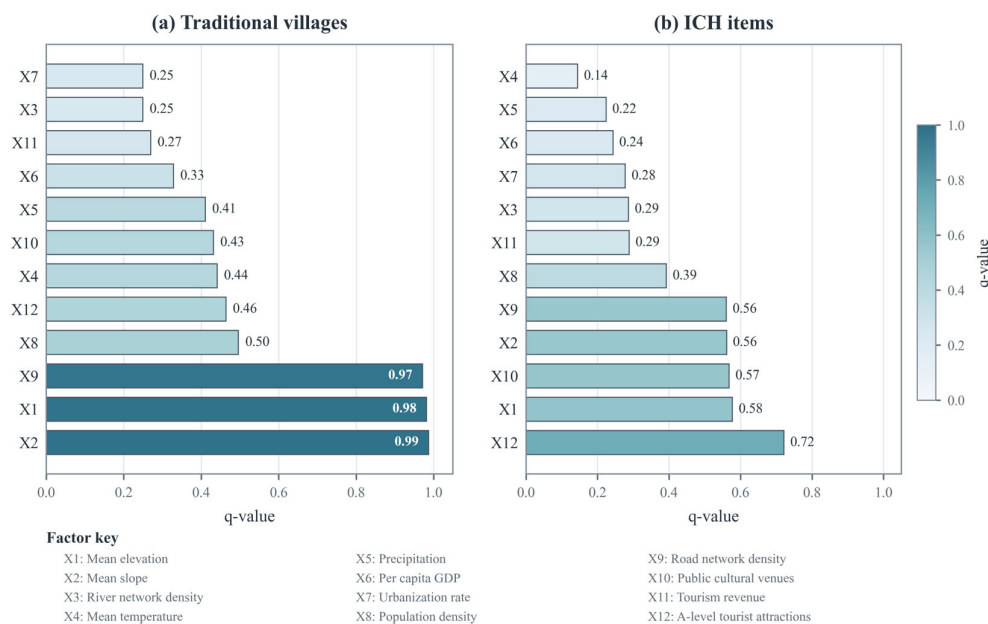


Figure 7. q -values of explanatory factors calculated using the optimal-parameters-based geographical detector for traditional villages and intangible cultural heritage (ICH) in Anhui Province. (a) q -values for traditional villages; (b) q -values for ICH items. The q -values are rounded to two decimal places for visualization. They indicate the spatial stratified consistency between explanatory factors and the distribution of heritage items under the current analytical scale and discretization scheme, and should not be interpreted as causal effects.

For traditional villages, mean slope, mean elevation, and road network density form the top-ranked group, with all q -values exceeding 0.97. These near-unity values should be interpreted cautiously. Given the small sample of 16 prefecture-level cities and the optimized discretization procedure, they may partly reflect artifacts associated with small stratum sizes and very low within-stratum variance. They therefore do not indicate that these factors almost completely determine the distribution of traditional villages, nor should the small numerical differences among them be interpreted as a precise or generally applicable ranking. Rather, they indicate a very high degree of spatial consistency under the current prefecture-level analytical scale and the selected discretization schemes.

The high spatial consistency of this group may also be related to the marked concentration of traditional villages in Huangshan and other southern Anhui cities, where mountainous terrain, Huizhou cultural landscapes, and favorable conditions for historical-settlement preservation overlap spatially. Population density, the number of A-level tourist attractions, mean temperature, and the number of public cultural venues form a second

group, with q -values ranging from approximately 0.43 to 0.50. River network density, per capita GDP, urbanization rate, tourism revenue, and precipitation rank lower, indicating comparatively weaker single-factor spatial consistency with the prefecture-level distribution of traditional villages.

Road network density represents city-wide road-network intensity at the prefecture-level scale, whereas the expressway/trunk-road buffer analysis measures the nearest-distance relationship between individual heritage points and backbone transport corridors. The two indicators therefore capture different dimensions of transport conditions. Consequently, the high relative ranking of road network density for traditional villages is not inconsistent with the higher proportion of ICH items located within the near-distance buffers of backbone roads.

For ICH items, the number of A-level tourist attractions ranks first, with a q -value above 0.70. Mean elevation, the number of public cultural venues, mean slope, and road network density form a second high-ranking group, with q -values concentrated between approximately 0.56 and 0.58. Population density occupies an intermediate position, whereas tourism revenue, river network density, and urbanization rate have q -values of approximately 0.28–0.29. Per capita GDP, precipitation, and mean temperature show comparatively weak single-factor spatial consistency.

Relative to the traditional-village factor profile, ICH items show stronger spatial consistency with A-level tourist attractions and public cultural venues. Together with the buffer-zone results, which reveal stronger proximity of ICH items to key river systems and backbone transport corridors, this pattern is consistent with the interpretation that ICH, as a set of living cultural practices, is closely connected with tourism nodes, public cultural spaces, and wider cultural transmission networks.

The interaction detector results further show that the joint stratification of factor pairs generally corresponds more closely with the spatial differentiation of both heritage types than the stratification of individual factors, mainly in the forms of bivariate enhancement and nonlinear enhancement (Figure 8). For traditional villages, high- q interaction combinations mostly involve geomorphological conditions, transport conditions, and cultural-tourism resources. These combinations are consistent with the spatial co-occurrence of mountainous environments, historical-settlement preservation, transport connections, and tourism-resource conditions. For ICH items, high- q interaction combinations more frequently involve public cultural venues, tourism nodes, population activity, and transport networks. These patterns are consistent with the combined roles of historical-cultural foundations, modern public cultural services, and social transmission networks. Because interaction detection identifies enhancement in statistical spatial consistency rather than causal interaction effects, these results should also be interpreted within the prefecture-level analytical scale and the adopted discretization schemes.

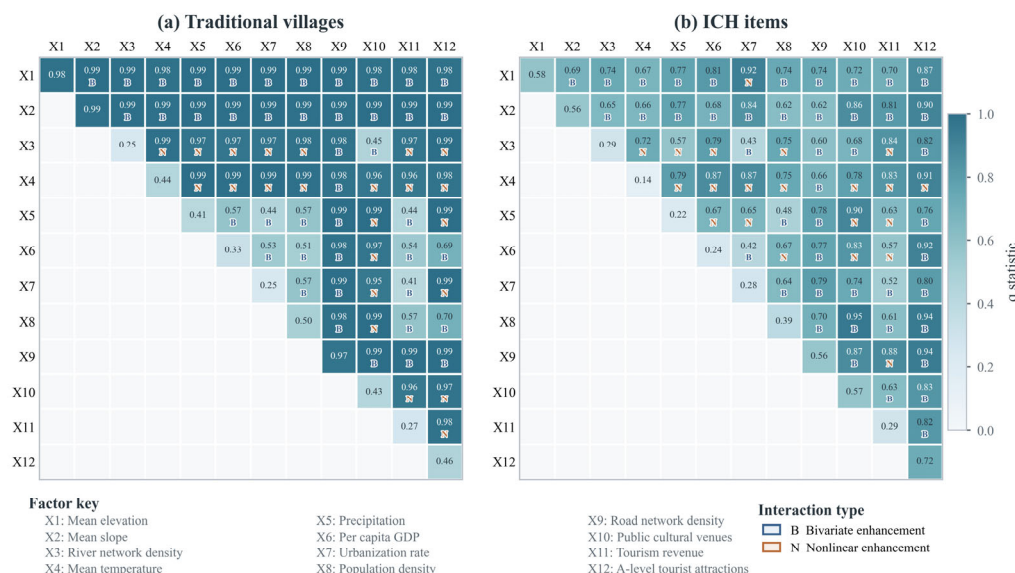


Figure 8. Interaction detector results based on optimal discretization parameters for traditional villages and intangible cultural heritage (ICH) in Anhui Province. **(a)** Interaction detector results for traditional villages. **(b)** Interaction detector results for ICH items. The q -statistic values in the cells are rounded to two decimal places. B indicates bivariate enhancement and N indicates nonlinear enhancement; the interaction types indicate enhancement in spatial stratified consistency after factor overlay, rather than causal interaction effects.

Overall, the combined buffer-zone and OPGD results support two differentiated and scale-dependent spatial association patterns at the prefecture-level city scale. Traditional villages show stronger spatial consistency with geomorphological conditions and the regional cultural-landscape structure of the Huangshan–southern Anhui traditional-village core, corresponding to an environmental preservation pattern. The officially attributed locations of listed ICH items, by contrast, show stronger proximity or spatial consistency with river corridors, backbone transport connections, tourism nodes, public cultural venues, and cultural transmission networks, corresponding to a social-transmission and institutional-attribution pattern at the prefecture-level scale. These patterns summarize the observed spatial associations under the current data, analytical scale, and discretization settings and should not be interpreted as strict causal mechanisms or city-independent general laws. Nevertheless, they provide an interpretive basis for understanding the spatial mismatch between traditional villages and ICH and for identifying subsequent collaborative conservation zones and differentiated strategy orientations.

3.5. Conservation Zoning and Strategy Orientation

To transform spatial patterns, mismatch types, and formation mechanisms into strategy-oriented diagnostic zones, this study identified collaborative conservation zones for the 16 prefecture-level cities of Anhui Province based on traditional-village density, ICH density, spatial mismatch distance, and SMI type (Figure 9). These four indicators served as the direct scoring variables: traditional-village density and ICH density represent the resource agglomeration basis of material heritage carriers and living cultural practices, respectively; spatial mismatch distance reflects centroid displacement; and SMI type identifies the quantity–structure relationship between the two heritage systems. The mechanism-analysis results in Section 3.4 were not assigned independent scores, in order to avoid double counting, but were used to interpret the zoning results and refine strategy orientations. Specifically, the environmental preservation logic of traditional villages and

the social transmission logic of ICH support four strategy directions: environmental preservation and embedded transmission, carrier expansion, network linkage and functional supplementation, and basic protection and dynamic monitoring. After overlaying the three geographical-cultural regions of northern, central, and southern Anhui, the zoning results capture differences in resource density and mismatch intensity, together with the north–south natural-cultural gradient and regional governance needs within Anhui Province.

It should be emphasized that the zoning results are not final implementation plans for individual cities. Rather, they provide a provincial-scale spatial diagnosis of where collaborative conservation pressure, resource imbalance, and strategic priority may be more prominent. In practice, the proposed strategy orientations need to be further adjusted through local fiscal assessment, administrative coordination, ICH endangerment evaluation, bearer-network investigation, community consultation, county-level planning, and site-specific feasibility assessment.

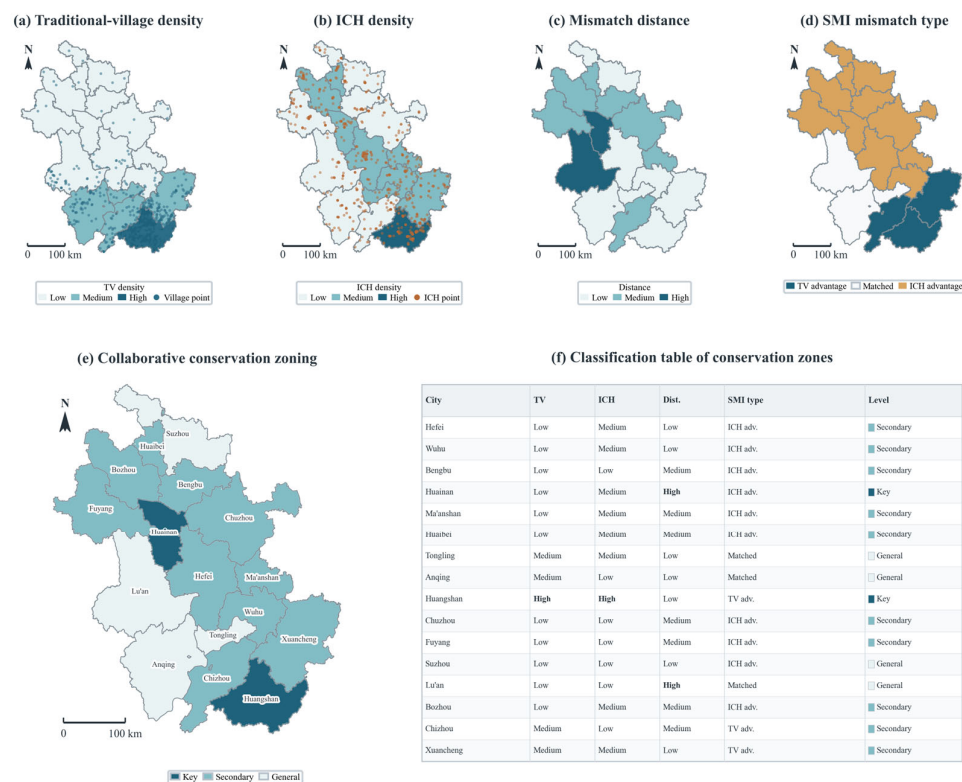


Figure 9. Collaborative conservation zoning based on traditional-village density, ICH density, mismatch distance, and SMI type. (a) Traditional-village density; (b) ICH density; (c) mismatch distance; (d) SMI mismatch type; (e) collaborative conservation zoning; (f) classification table of conservation zones.

In terms of traditional-village density, Huangshan is classified as a high-density area, while Tongling, Anqing, Chizhou, and Xuancheng are classified as medium-density areas. The remaining cities have relatively low traditional-village density. This indicates that the spatial carriers of traditional villages in Anhui Province are mainly concentrated in southern Anhui and some cities along the Yangtze River. In terms of ICH density, Huangshan is also classified as a high-density area, while Hefei, Wuhu, Huainan, Ma'anshan, Huaibei, Tongling, Bozhou, and Xuancheng are classified as medium-density areas. This indicates

that ICH resources are not completely attached to high-density traditional village areas, but are distributed to varying degrees across northern, central, and southern Anhui. In terms of spatial mismatch distance, Huainan and Lu'an are classified as high-mismatch-distance cities; Bengbu, Ma'anshan, Huaibei, Chuzhou, Fuyang, Bozhou, and Chizhou are classified as medium-mismatch-distance cities; and Hefei, Wuhu, Tongling, Anqing, Huangshan, Suzhou, and Xuancheng have relatively low mismatch distances. In combination with SMI types, Hefei, Wuhu, Bengbu, Huainan, Ma'anshan, Huaibei, Chuzhou, Fuyang, Suzhou, and Bozhou are classified as ICH-advantaged; Huangshan, Chizhou, and Xuancheng are classified as traditional-village-advantaged; and Tongling, Anqing, and Lu'an are classified as relatively matched.

Based on these indicators, this study divides the collaborative conservation of traditional villages and ICH in Anhui Province into key conservation zones, secondary conservation zones, and general conservation zones. It should be emphasized that these three types of zones do not represent a hierarchy of heritage value. Instead, they reflect conservation priorities formed according to differences in resource density, mismatch degree, and governance needs. Key conservation zones emphasize resource integration and targeted intervention; secondary conservation zones emphasize network linkage and functional supplementation; and general conservation zones emphasize basic protection and dynamic monitoring.

First, at the strategy-orientation level, key conservation zones may prioritize “targeted intervention and key integration”. Huangshan and Huainan represent two different key-zone pathways. Huangshan combines high traditional-village and ICH density with low positional mismatch, but its strongly negative SMI indicates that listed traditional villages still dominate the provincial quantity structure. Its strategy orientation is therefore embedded transmission: Huizhou craftsmanship, opera, rituals, food culture, and festival activities can be integrated into ancestral halls, ancient dwellings, streets, and village public spaces. Huainan, by contrast, has low traditional-village density, medium ICH density, high mismatch distance, and an ICH-advantaged type. Its strategy orientation is carrier expansion and spatial reconnection: the Huaihe cultural corridor, cultural centers, museums, township cultural stations, community spaces, ordinary villages, historical districts, and traditional markets can serve as supplementary carriers for ICH display, education, and transmission.

Second, secondary conservation zones may emphasize “network linkage and functional supplementation”. These zones include Hefei, Wuhu, Bengbu, Ma'anshan, Huaibei, Chuzhou, Fuyang, Bozhou, Chizhou, and Xuancheng. These cities are not the areas with the highest concentration of heritage resources or the most prominent mismatch, but they have strong coordination value in terms of resource foundation, mismatch distance, SMI type, and regional linkage potential. Therefore, secondary conservation zones should not adopt strong single-site intervention. Instead, they should enhance the spatial connections between traditional villages and ICH through functional supplementation and network linkage.

Third, general conservation zones may emphasize “basic protection and dynamic monitoring”. These zones include Tongling, Anqing, Suzhou, and Lu'an. Their priority is not large-scale intervention, but resource inventory, transmission recording, community participation, and continuous monitoring. Tongling and Anqing may maintain existing relatively matched resource patterns and moderately embed ICH activities into traditional village spaces. Suzhou may strengthen grassroots ICH surveys and township-level transmission spaces. Lu'an, despite being relatively matched in quantity structure, should pay attention to intra-city spatial connection because of its high mismatch distance, especially through Dabie Mountain culture, educational tourism, and community development.

Overall, the three zoning types should be understood as differentiated diagnostic priorities rather than implementation plans. Key zones emphasize targeted integration, secondary zones emphasize network linkage, and general zones emphasize baseline protection and monitoring. The zoning translates mismatch diagnosis into strategy orientations, but local application still requires feasibility assessment and adaptive adjustment.

4. Discussion

4.1. Theoretical Implications

In recent years, research on the relationship between traditional villages and ICH has gradually shifted from the parallel protection of separate resources to the analysis of spatial relationships and collaborative conservation. Existing studies at national, river-basin, and provincial scales have shown that traditional villages and ICH are not simply superimposed, but instead present varying degrees of spatial association, spatial differentiation, and mismatch [24–27,53]. Building on these studies, this study contributes by distinguishing positional mismatch from quantity–structure mismatch. This distinction shows that spatial proximity does not necessarily mean structural matching, and that collaborative conservation should examine the relationships among listed spatial carriers, living cultural practices, and governance mechanisms rather than only the coexistence of two heritage categories.

Taken together, the spatial distribution, centroid shift, SMI results, buffer-zone analysis, and OPGD results suggest that the spatial mismatch between traditional villages and ICH can be interpreted through two differentiated spatial association patterns. Traditional villages tend to align with an environmental preservation pattern. Their distribution is highly associated with terrain, geomorphology, historical settlement patterns, and spatial preservation conditions, especially in the mountainous and hilly areas of southern Anhui and the Huizhou cultural region. Complex terrain, relatively stable settlement patterns, and deep historical-cultural accumulation provide an important spatial basis for traditional village preservation. ICH, by contrast, shows a transmission-oriented pattern. Its distribution is associated with historical-cultural foundations, population activity, transport connections, cultural venues, tourism nodes, and public cultural service networks. Buffer-zone results show that ICH items have higher proportions near key river systems and expressways/trunk roads than traditional villages. The geographical detector results also indicate stronger spatial consistency between ICH and cultural venues, tourism nodes, and population activity. These findings suggest that the continuity of ICH requires community interaction, festival activities, public spaces, display platforms, and transmission networks.

This comparison should be interpreted within a clear analytical boundary. The “environmental preservation logic” and “social transmission logic” proposed here are not intended to be strict causal laws derived from the OPGD results alone. They are scale-dependent interpretive patterns supported jointly by the spatial distribution, centroid shift, SMI types, buffer-zone results, and OPGD results. In particular, the very high q -values for traditional villages are partly associated with the use of prefecture-level city counts as dependent variables and with the strong concentration of traditional villages in Huangshan and the broader southern Anhui region. Huangshan therefore plays a structurally influential role in the provincial mismatch pattern: it pulls the traditional-village centroid southward, produces an extremely negative SMI value, and magnifies the spatial consistency between traditional villages and mountainous Huizhou cultural landscapes. Rather than treating Huangshan simply as a statistical outlier, this study interprets it as a key case that reveals how a highly concentrated material heritage core can reshape province-wide mismatch patterns.

The interaction detector results further indicate that multi-factor coupling is an important spatial explanatory mechanism for the formation of traditional village-ICH mismatch. For both traditional villages and ICH, the q -values of two-factor interactions are higher than those of the corresponding single factors, mainly showing bivariate enhancement and nonlinear enhancement. For traditional villages, high-explanatory-power combinations mostly involve terrain, climate, transport, and cultural-tourism resources, indicating that their spatial pattern is grounded in natural environment and historical preservation conditions, but is not completely determined by natural factors alone. For ICH, high-explanatory-power combinations more often involve population density, cultural venues, tourist attractions, and transport networks, suggesting that its spatial pattern is more closely associated with social activity and cultural transmission networks. Compared with studies that only identify a single dominant factor, this study places greater emphasis on the explanatory role of multi-factor interactions in the spatial mismatch between traditional villages and ICH.

From the perspective of international heritage theory, the “environmental preservation logic–social transmission logic” proposed in this study can also be placed in dialogue with UNESCO’s 2003 Convention for the Safeguarding of the Intangible Cultural Heritage and the ICOMOS–IFLA Principles Concerning Rural Landscapes as Heritage. The UNESCO 2003 Convention emphasizes that ICH is not an isolated cultural item, but a living cultural expression transmitted and recreated through the continuous practices of communities, groups, and individuals [4]. The ICOMOS–IFLA rural landscape principles emphasize that rural landscapes are the result of long-term interactions among natural environments, land use, social structures, modes of production, and cultural meanings [2]. Therefore, although the Anhui case has the specificity of a Chinese provincial context and the Huizhou–Jianghuai–Huaihe cultural gradient, the mismatch it reveals between “material heritage spaces” and “living cultural practice spaces” can also provide a comparative perspective for other regions with clear geographical-cultural gradients and diverse heritage resources. Furthermore, studies on community participation, value negotiation, and creative transmission in ICH safeguarding also show that the core of ICH safeguarding is not the preservation of fixed objects, but the continuous production of bearers, social relations, and practice settings [54,55].

The findings of this study can also be further explained through the lens of authorized heritage discourse (AHD) [9]. Traditional villages have relatively clear spatial boundaries, material forms, and visible landscapes, making them easier to incorporate into institutionalized conservation systems such as list-based designation, spatial control, architectural restoration, and tourism display. ICH, however, is characterized by mobility, practice-based transmission, and multiple bearers. Its actual transmission spaces are often embedded in festivals, market exchange, family workshops, community rituals, and everyday life, and are therefore difficult to fully capture through a single location or administrative boundary. Accordingly, the spatial mismatch between traditional villages and ICH arises from the combined effects of natural environmental and socio-economic factors, as well as from differences between material heritage spaces and living cultural practices in identification methods, conservation objects, and governance tools. If heritage governance relies excessively on visible material boundaries and list-based heritage objects, it may reinforce the protection of traditional villages as “heritage spaces to be viewed”, while relatively weakening the community-based and everyday nature of ICH as “cultural practices to be participated in”.

This theoretical understanding also provides a basis for the collaborative conservation zoning identified later in this study, which is based on traditional-village density, ICH density, spatial mismatch distance, and SMI type. It also supports the proposal of

differentiated strategies, including embedded transmission, carrier expansion, network linkage, basic protection, and dynamic monitoring.

4.2. Practical Implications and Strategy Dialogue

The collaborative conservation zoning and strategy pathways proposed in this study need to be understood in relation to existing research on traditional village conservation, ICH safeguarding, and rural landscape heritage management. Existing national-scale research on the relationship between traditional villages and ICH has pointed out that systematic spatial mismatch exists between the two, and that conservation strategies should shift from single-resource management toward cultural-space reconstruction, dynamic protection networks, and regionally differentiated governance [24]. Related studies at river-basin and provincial scales have also emphasized that the collaborative conservation of traditional villages and ICH should formulate differentiated pathways by integrating natural environments, transport networks, cultural venues, population activity, and regional cultural foundations [25–27,53]. Compared with these studies, this study goes beyond macro-level governance suggestions at national or river-basin scales. It overlays traditional-village density, ICH density, centroid mismatch distance, and SMI type at the scale of 16 prefecture-level cities to form key conservation zones, secondary conservation zones, and general conservation zones. This enhances the spatial specificity and operational applicability of the proposed strategies.

From the perspective of domestic research on the spatial distribution of ICH, existing studies have often proposed conservation and utilization recommendations based on the clustering patterns, socio-economic conditions, historical-cultural foundations, and culture–tourism integration potential of ICH resources. For example, Zhang et al. [56] analyzed the spatial distribution and influencing factors of ICH resources at the national scale, emphasizing that ICH distribution is closely related to economic development, historical-cultural resources, and social factors, and arguing that such findings should support ICH safeguarding, culture–tourism integration, and regional sustainable development. Xu et al. [57], taking Anhui Province as a case, constructed a tourism potential matrix based on the matching relationship between ICH tourism resources and historical-cultural city resources, in order to identify the cultural-tourism transformation capacity of different cities. Compared with these studies, the strategies proposed in this study do not take tourism potential or ICH resource abundance as the only basis. Instead, they further incorporate traditional villages as material spatial carriers of rural heritage, focusing on whether ICH resources have spatial carriers, whether traditional village spaces contain living cultural content, and whether the two are mismatched within cities. Therefore, the conservation zoning proposed in this study places greater emphasis on the collaborative relationship between traditional villages and ICH, rather than on the development potential of a single type of cultural resource.

International cases further support this logic. Bali's Subak system shows that living heritage depends on the linkage among material landscapes, irrigation networks, community cooperation, and ritual practices [58]. Noto's Satoyama and Satoumi demonstrates the importance of integrating agriculture, local knowledge, festivals, and community co-management [59]. Cinque Terre shows that traditional settlement conservation may weaken when landscape maintenance and community participation are separated from everyday practices [60]. These cases collectively support the strategies of network linkage, basic monitoring, and embedded transmission proposed in this study.

Therefore, the strategies proposed in this study both correspond to and supplement existing domestic and international research. On the one hand, this study continues the basic ideas of traditional village revitalization, ICH transmission, community participation, culture–tourism integration, and regionally differentiated conservation. On the other

hand, its contribution lies in placing the two types of heritage within a unified spatial diagnostic framework. By jointly using traditional-village density, ICH density, centroid mismatch distance, and SMI type as zoning indicators, and by using mismatch-formation mechanisms as interpretive evidence for strategy orientation, this study identifies conservation priority areas and translates strategies into specific city types. Compared with macro-level policy recommendations or single-site heritage experiences, this approach is more helpful for identifying differentiated issues, such as “listed traditional-village concentration but insufficient ICH embedding”, “higher shares of officially attributed listed ICH items but insufficient listed traditional-village carriers”, and “medium-level resource foundations but strong potential for network linkage”. Nevertheless, the zoning and strategy orientations proposed in this study remain based on provincial-scale spatial diagnosis. Their practical implementation requires further refinement through county-level planning, local fiscal capacity assessment, administrative resource evaluation, interdepartmental coordination, existing safeguarding programs, the endangerment status of specific ICH items, the number and age structure of representative bearers, community willingness and participation, land-use constraints, and site-specific feasibility assessment. Therefore, the zoning results should be used as a decision-support reference for collaborative conservation, rather than as directly executable conservation plans.

4.3. Limitations and Future Research

This study still has several limitations. First, converting ICH into point data is a necessary prerequisite for provincial-scale spatial analysis, but it may also introduce spatial-attribution bias. Unlike traditional villages, which have relatively fixed locations and clearer spatial entity attributes, ICH practices are often transmitted through mobile, multi-sited, and bearer-based networks. In official list data, however, some ICH items are spatially attributed to declared locations, protection units, cultural centers, museums, associations, schools, or county-level administrative locations. As a result, some ICH points may represent institutional safeguarding locations rather than all actual practice sites. This may overestimate the concentration of ICH in cities or county seats with stronger reporting and cultural-service capacity, while underestimating dispersed rural practices, family workshops, market networks, festival routes, and cross-village transmission spaces. Therefore, the ICH-advantaged, traditional-village-advantaged, and relatively matched types identified in this study should be interpreted as relationships between listed traditional-village carriers and officially attributed listed ICH items, rather than as a complete representation of the relationship between all rural settlements and all living ICH practices. Future research could further distinguish place-anchored and mobile ICH types by combining official list data with project descriptions, protection-unit information, bearer interviews, community mapping, and field surveys.

Second, this study uses prefecture-level cities as the basic statistical units for the geographical detector, resulting in a limited number of samples. Although the OPGD can reduce the influence of subjective classification, a small sample size and optimal stratification may lead to relatively high q -values for some variables. Future research could reconstruct sample units at county, township, or village scales to examine whether the ranking of dominant factors and interaction relationships remains stable. It could also limit the number of discretization classes for continuous variables and compare the results with those of the OPGD to improve the robustness of mechanism interpretation.

Third, the collaborative conservation zoning proposed in this study is based mainly on provincial-scale spatial indicators, including traditional-village density, ICH density, spatial mismatch distance, and SMI type. It does not incorporate all implementation constraints, such as local fiscal capacity, administrative staffing, existing project funding, ICH endangerment levels, the number and age structure of bearers, community participation,

land-use control, and county- or township-level planning arrangements. Therefore, the key, secondary, and general conservation zones should be interpreted as spatial diagnostic priorities rather than directly implementable planning schemes. Future research could integrate spatial diagnosis with project-level heritage assessment, bearer surveys, community consultation, and local fiscal and governance data to improve the feasibility of collaborative conservation planning.

Fourth, this study mainly identifies the spatial mismatch between traditional villages and ICH at the provincial scale, but it does not deeply examine bearers, activity processes, and local cultural practices within specific communities. Future research could combine field surveys, oral interviews, activity trajectory data, and multi-period list data to further reveal the dynamic relationship between traditional village spaces and ICH practices.

5. Conclusions

Taking 836 traditional villages and 685 ICH items at or above the provincial level in Anhui Province as research objects, this study constructs a stepwise spatial diagnostic framework to analyze the spatial distribution, mismatch characteristics, and spatial explanatory factors of traditional villages and ICH. The results show that both heritage types present clustered distributions, but their clustering centers and regional structures differ markedly. Traditional villages form a pronounced southern Anhui core, whereas the officially attributed locations of listed ICH items are more widely distributed across southern, central, and northern Anhui.

The mismatch between the two systems is reflected in both centroid displacement and quantity–structure difference. The 160.15 km provincial mismatch distance indicates macro-scale positional separation, while SMI types reveal ICH-advantaged, traditional-village-advantaged, and relatively matched cities. Huangshan shows that positional proximity does not necessarily imply quantity–structure matching.

Mechanistic analysis suggests differentiated association patterns. Traditional villages are more closely related to terrain, settlement preservation, and regional cultural landscape conditions, whereas the officially attributed locations of listed ICH items are more closely associated with cultural venues, tourism nodes, population activity, transport connections, transmission networks, and institutional attribution conditions. These patterns are scale-dependent associations rather than causal laws.

Based on traditional-village density, ICH density, mismatch distance, and SMI type, the study delineates key, secondary, and general conservation zones as provincial-scale diagnostic references. The corresponding strategy orientations—targeted integration, network linkage, and basic monitoring—should be further adjusted according to local fiscal capacity, administrative resources, ICH endangerment status, bearer networks, community participation, and implementation feasibility.

Author Contributions: W.W.: Conceptualization, Methodology, Software, Formal analysis, Data curation, Visualization, Writing—original draft, Writing—review and editing. X.Z.: Conceptualization, Methodology, Supervision, Project administration, Funding acquisition, Validation, Writing—review and editing. Y.H.: Methodology, Software, Formal analysis, Writing—original draft, Writing—review and editing. C.F.: Investigation, Data curation, Formal analysis, Writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Social Science Fund of China, grant number 22BSH085, and the Scientific Research Project of Hefei University of Technology, grant number W2023JSFW0290.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

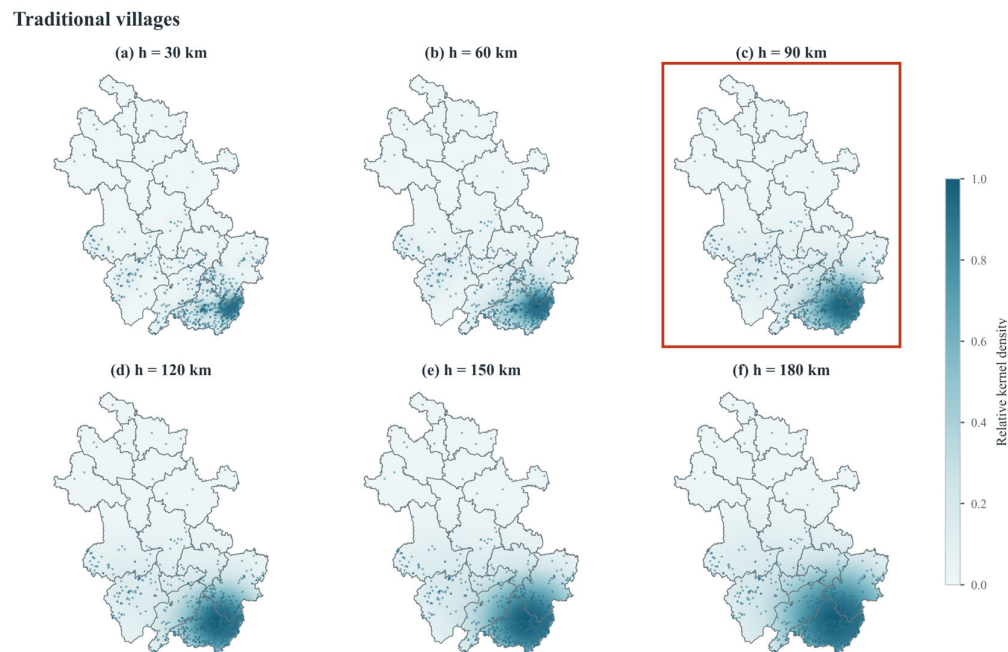


Figure A1. Bandwidth sensitivity analysis of KDE for traditional villages. Panels (a–f) show KDE results using search radii of 30, 60, 90, 120, 150, and 180 km, respectively. Bandwidths below 90 km emphasize scattered local clusters, whereas bandwidths above 90 km progressively merge the southern hotspot into a broad smoothed surface. The red frame marks the selected bandwidth used in Figure 3 ($h = 90$ km). Kernel density values were normalized to 0–1 for comparison. Dots indicate traditional-village point locations used for KDE.

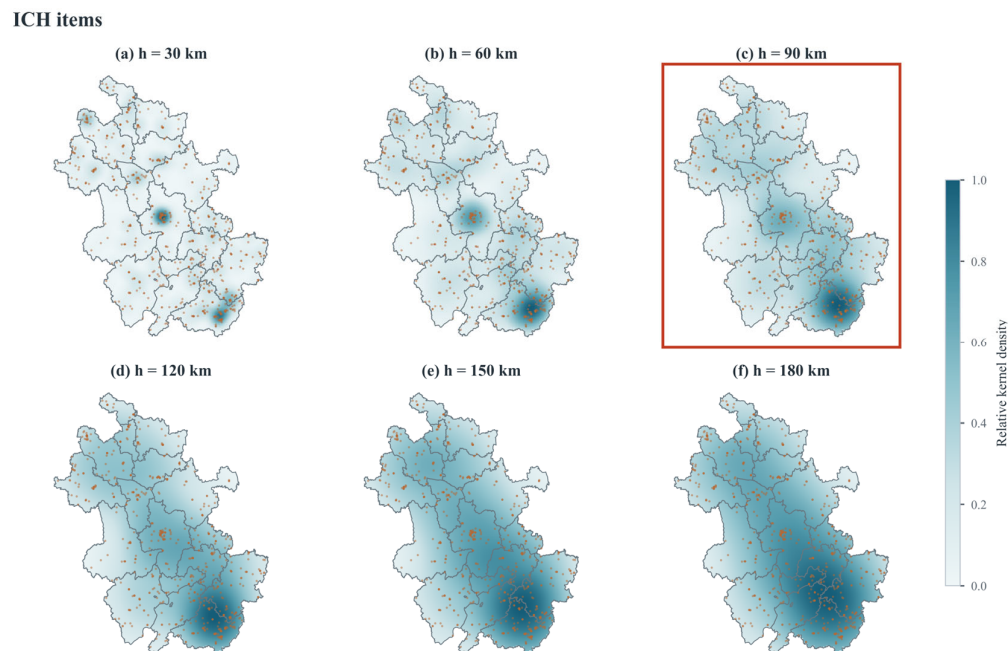


Figure A2. Bandwidth sensitivity analysis of KDE for ICH items. Panels (a–f) show KDE results using search radii of 30, 60, 90, 120, 150, and 180 km, respectively. Bandwidths below 90 km produce fragmented local peaks, whereas bandwidths above 90 km over-smooth the multi-center distribution of ICH items. The red frame marks the selected bandwidth used in Figure 3 ($h = 90$ km). Kernel density values were normalized to 0–1 for comparison. Dots indicate ICH item point locations used for KDE.

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