

Spatial Patterns and Heritage Corridor Construction of Red Cultural Heritage in Ganzhou

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How to cite this paper: Zhang, Z.J. (2026) Spatial Patterns and Heritage Corridor Construction of Red Cultural Heritage in Ganzhou. *Open Journal of Applied Sciences*, 16, 3952-3969.

<https://doi.org/10.4236/ojapps.2026.1610219>

Received: September 15, 2026

Accepted: October 23, 2026

Published: October 26, 2026

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Abstract

Red cultural heritage (RCH), a China-specific category of revolutionary heritage, is often spatially dispersed and closely associated with particular historical events. Identifying its spatial clusters and establishing connections among sites at the regional scale are important for shifting from site-by-site conservation toward network-based conservation. This study investigates 134 immovable RCH sites in Ganzhou, Jiangxi Province, China. Average nearest-neighbor analysis, an imbalance index, and kernel density estimation were used to characterize the spatial pattern. Twelve National Key Cultural Relics Protection Units were selected as source sites. A composite resistance surface was constructed from elevation, slope, land use, distance to major roads, and distance to watercourses, with factor weights derived using the entropy weighting method. The minimum cumulative resistance (MCR) model and least-cost paths were then used to identify potential connections, which were organized into primary and secondary corridors according to heritage clustering and network-coverage requirements. The ANN analysis shows significant spatial clustering ($R = 0.652$, $Z = -7.710$, $p < 0.001$), which was independently supported by 999 Monte Carlo simulations under complete spatial randomness within the actual irregular municipal boundary (one-sided $p = 0.001$). KDE, using a data-driven bandwidth of 1.925 km and a 500 m cell size, identifies strongly localized high-density areas, with Ruijin containing the most prominent density peak. Low-resistance areas are concentrated along built-up areas, transport routes, and river valleys, whereas high-resistance areas are mainly located in peripheral mountainous zones. The resulting primary-secondary corridor network is spatially close to the mapped heritage sites: the mean site-to-network distance is approximately 155 m and the maximum is approximately 985 m. The study provides a transferable framework linking cluster identification, source-site selection, resistance modeling, least-cost connectiv-

ity, and corridor hierarchy for the regional conservation of dispersed revolutionary heritage.

Keywords

Red Cultural Heritage, Heritage Corridor, Geographic Information System, Minimum Cumulative Resistance

1. Introduction

Red cultural heritage (RCH) is a China-specific category of revolutionary heritage that materializes the historical experience and associated values of the Chinese revolution. In addition to the general attributes of cultural heritage, RCH carries strong associations with historical events, collective and political memory, and public education [1]-[3]. Existing studies have largely addressed value interpretation, tourism development, public communication, and the conservation of individual sites. Spatially, however, many RCH sites are distributed across administrative boundaries and differ in historical relationships and present-day accessibility. Site-by-site conservation alone therefore cannot fully reveal their regional value or latent network relationships. A broader spatial perspective is needed to identify heritage clusters, hierarchical nodes, and potential connections among dispersed sites.

The heritage corridor provides an important framework for integrating dispersed cultural heritage. International studies initially focused on National Heritage Areas, canals, industrial heritage, and cultural routes, and subsequently expanded to regional cultural landscape conservation, tourism development, and collaborative governance [4]-[7]. Research in China has evolved from conceptual introduction to heritage-value assessment, spatial-structure analysis, and corridor construction [8]-[15]. With the growing use of geographic information systems (GIS) and resistance-based models, topography, land use, road networks, and watercourses have increasingly been incorporated into corridor identification. Minimum cumulative resistance (MCR), cost-distance analysis, and least-cost paths are now widely used to simulate potential spatial connections between heritage nodes [11] [16] [17].

Two gaps remain. First, many existing heritage-corridor studies concern heritage with an inherent linear structure, such as canals, historic trails, and the Great Wall. RCH, by contrast, is often composed of former sites, memorial buildings, and other point-based remains. A robust framework is still needed to identify cores from dispersed sites and then transform them into a hierarchical network. Second, although GIS has increasingly been used to analyze the spatial distribution, resource value, and tourism suitability of RCH [18]-[21], and some studies have begun to apply MCR to red cultural heritage corridors [20], the analytical links among heritage clustering, source-site selection, resistance modeling, path extraction, and

network hierarchy remain underdeveloped.

Ganzhou, located within the former Central Soviet Area, contains a large number of RCH sites distributed across a mountainous and hilly landscape and multiple county-level administrative units. It therefore provides a useful case for examining network construction for dispersed revolutionary heritage. In the spatial-pattern analysis, all 134 heritage sites are treated equally. For corridor modeling, 12 National Key Cultural Relics Protection Units are selected as source sites on the basis of their statutory protection status, while the remaining sites are used to evaluate network coverage and linkage. This distinction separates the role of a site in spatial-pattern analysis from its role as a model source.

Accordingly, this study addresses three questions: 1) What clustering and spatial differentiation characterize RCH in Ganzhou at the municipal and county levels? 2) How do terrain, land use, roads, and watercourses jointly shape the spatial resistance to heritage connectivity? 3) How can a hierarchical corridor network be constructed from major source sites and least-cost connections while also incorporating dispersed peripheral heritage? The resulting framework integrates spatial-pattern identification, source-site selection, composite resistance assessment, least-cost path extraction, and corridor hierarchy.

2. Materials and Methods

2.1. Study Area

Ganzhou is a prefecture-level city in southern Jiangxi Province, China, with an area of approximately 39,400 km². The landscape is dominated by mountains, hills, and intermontane basins, with pronounced topographic relief and a dense drainage network. Built-up areas and major transport routes are concentrated mainly in basins, river valleys, and relatively gentle terrain, whereas accessibility is lower in the peripheral mountains (see **Figure 1**). This strong internal geographical differentiation provides an appropriate physical context for resistance-surface modeling.

Ganzhou was also a major part of the former Central Soviet Area. During the Agrarian Revolutionary War period, revolutionary activities were particularly concentrated in Ruijin City, Yudu County, Xingguo County, Ningdu County, Huichang County, and surrounding areas, leaving a large number of former revolutionary sites, memorial buildings, and related physical remains. The heritage is concentrated around some historical centers but also widely dispersed across the municipality, making Ganzhou a representative case of a locally clustered yet regionally dispersed heritage system.

2.2. Data Sources and Preprocessing

The RCH dataset was compiled from the first and second batches of immovable revolutionary cultural relics published by the Jiangxi Provincial Department of Culture and Tourism [22] [23]. Following the conceptual definitions of red cultural heritage and red culture in previous research [1] [2], this study retained

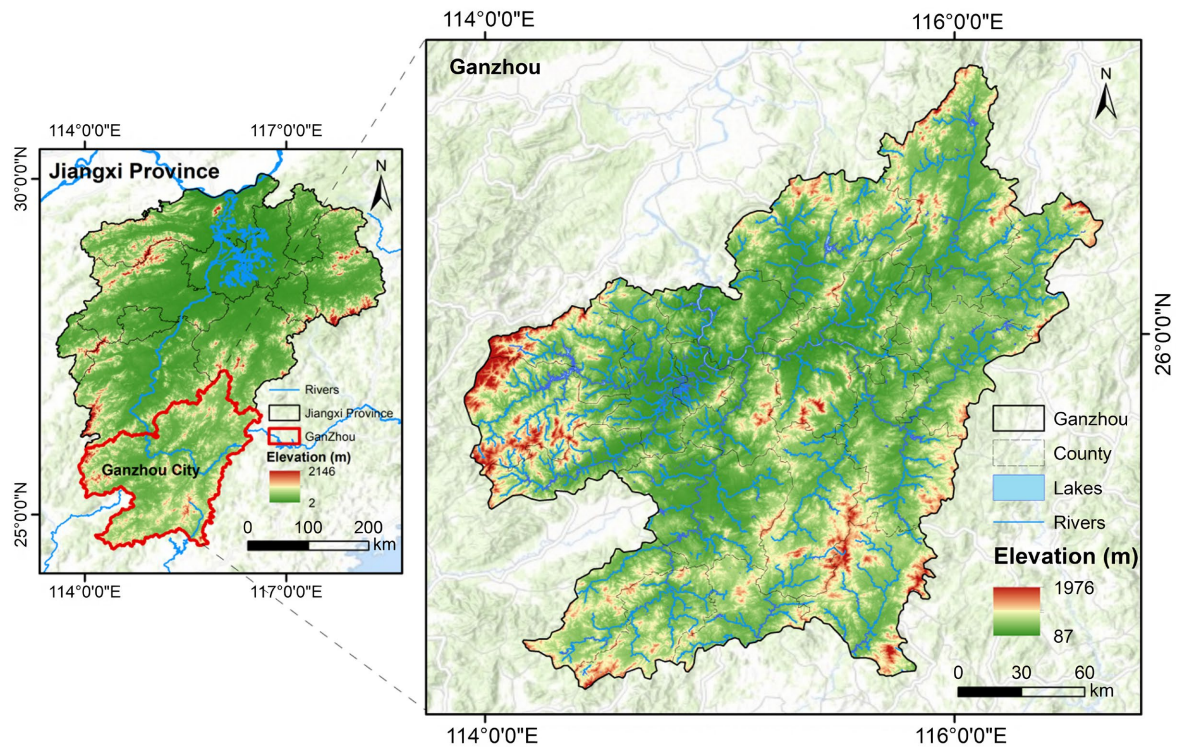


Figure 1. Location of the study area in Ganzhou, Jiangxi Province, China. Note: Administrative boundary data were obtained from Tianditu (Map Approval No. GS(2024)0650). Administrative boundaries were not modified; the same applies to subsequent maps.

immovable physical remains closely associated with revolutionary practices led by the Communist Party of China, major revolutionary events, organizations, and historical figures. To maintain consistency in protection status and data quality and to match the municipal-scale objective of heritage-corridor construction, county-level protected units were excluded from the analytical inventory. The final dataset contains 134 RCH sites, including 12 National Key Cultural Relics Protection Units, 93 provincial-level protected units, and 29 municipal-level protected units. The resulting dataset, therefore, represents national-, provincial-, and municipal-level protected RCH rather than a complete inventory of all red cultural heritage in Ganzhou. Site coordinates were initially obtained through name- and address-based geocoding using the Baidu coordinate-picking service. The returned BD-09 coordinates were converted to WGS84 and subsequently projected to CGCS2000/3-degree Gauss-Krüger CM 114°E (EPSG:4547) for spatial analysis. Coordinate quality control included checks for missing or invalid coordinates, exact coordinate duplicates, locations outside the Ganzhou administrative boundary, and records with ambiguous or incomplete locality information. Suspect duplicate or fallback coordinates were manually reviewed using site names, administrative locations, and publicly available records, and corrected coordinates were recorded where a more specific location could be established. After validation, all 134 retained sites had valid coordinates, no exact coordinate duplicates remained, and all sites fell within or intersected the Ganzhou municipal boundary. A supple-

mentary site register reports the site name, protection level, county-level administrative unit, and final coordinates used in the analysis.

Topographic data were derived from the SRTM 1 Arc-Second Global digital elevation model (DEM) at approximately 30 m spatial resolution [24] [25]. Land-use data were obtained from the China Multi-Period Land Use/Land Cover Remote Sensing Monitoring Dataset (CNLUCC) for 2020 at a spatial resolution of 30 m [26]. Road and watercourse data were obtained from OpenStreetMap (OSM) through Geofabrik [27]. Major roads were selected using the *fclass* attribute (motorway, trunk, primary, secondary, tertiary, and their corresponding link classes). Watercourses included all river features and named stream features. These datasets were used to calculate Euclidean distance to major roads and to watercourses. The administrative boundary of Ganzhou was obtained from Tianditu, the National Platform for Common Geospatial Information Services [28].

All spatial datasets were checked, reprojected, clipped to the study area, and aligned to a common raster grid. The target coordinate reference system was CGCS2000/3-degree Gauss-Krüger CM 114°E (EPSG:4547), and the 30 m DEM was used as the reference raster. Categorical land-use data were resampled using nearest-neighbor resampling, while all rasters were processed using the same extent, cell alignment, and analysis mask. The final resistance-factor dataset comprised elevation, slope, land use, distance to major roads, and distance to watercourses.

2.3. Methods

2.3.1. Spatial Pattern Analysis and Source-Site Selection

All 134 RCH sites were assigned equal weight in the spatial-pattern analysis. Following previous studies of the spatial differentiation of red resources [29] [30], average nearest-neighbor (ANN) analysis was used to determine whether the overall distribution was clustered, random, or dispersed; an imbalance index was used to characterize differences in heritage counts among county-level administrative units; and kernel density estimation (KDE) was used to identify local concentrations and high-density areas. ANN analysis was conducted for the 134 validated heritage sites using the actual Ganzhou municipal boundary as the study window. Under the null hypothesis of complete spatial randomness (CSR), the expected mean nearest-neighbor distance was calculated from the number of sites and the area of the irregular municipal boundary. Euclidean distances were calculated in CGCS2000/3-degree Gauss-Krüger CM 114°E (EPSG:4547). In addition to the analytical ANN statistic, 999 Monte Carlo CSR simulations were performed within the actual irregular Ganzhou boundary, with the number of points fixed at 134 (random seed = 20260928), to assess whether the observed mean nearest-neighbor distance was unusually small relative to random spatial configurations. KDE was performed in the same projected coordinate system using an unweighted point pattern. The bandwidth was selected using Diggle's mean-square-error cross-validation criterion and was 1925.045 m. A Gaussian kernel, edge correction, a 500 m raster cell size, and the Ganzhou municipal boundary as the analysis mask were

used. To provide a reproducible operational distinction between density levels, KDE values were extracted at the locations of the 134 heritage sites. The 75th and 90th percentiles of these site-level KDE values (0.1201 and 0.2201 sites km^{-2} , respectively) were used as descriptive thresholds. Raster cells with KDE values ≥ 0.2201 sites km^{-2} were classified as primary high-density areas, while cells with values from 0.1201 to <0.2201 sites km^{-2} were classified as secondary high-density areas. These thresholds were used for descriptive spatial classification. The revised ANN, Monte Carlo CSR, and KDE analyses were implemented in R using the *sf*, *spatstat*, and *terra* spatial-analysis packages.

Source sites define the origins from which cumulative resistance is calculated in the MCR model. Drawing on heritage-corridor studies that use important heritage nodes or clusters as sources [11] [31], the 12 National Key Cultural Relics Protection Units were selected as source heritage sites because of their statutory protection level. The remaining 122 provincial- and municipal-level protected sites were treated as non-source heritage sites and considered in supplementary linkage and network optimization. This approach avoids a subjective value-scoring system for all sites while retaining a transparent and verifiable criterion for source selection.

2.3.2. Construction of the Composite Resistance Surface

In this study, “heritage connectivity” is operationally defined as potential spatial accessibility and planning linkage among RCH sites for regional conservation, interpretation, and visitor movement, rather than as evidence of historically documented revolutionary routes between individual sites. Accordingly, the composite resistance surface represents the relative cost of this potential spatial movement and linkage. Based on previous heritage-corridor and least-cost modeling studies [11] [16] [17] [31], five resistance factors were selected to reflect the mountainous terrain, land-use pattern, accessibility, and river-valley structure of Ganzhou: elevation, slope, land use, distance to major roads, and distance to watercourses. Elevation and slope represent terrain-related movement constraints; land use represents the relative resistance associated with different surface types; distance to major roads captures present-day accessibility; and distance to watercourses represents the potential corridor effect of river valleys and adjacent lowland areas. The resulting corridors should therefore be interpreted as potential conservation-and-accessibility linkages rather than reconstructed historical routes. To reduce reliance on subjective expert weighting, the entropy weighting method was used to derive data-driven factor weights [32]. All common valid raster cells were used as evaluation units, and the indicators were directionally standardized and min-max normalized before information entropy and weights were calculated. Entropy weights represent relative information dispersion.

The information entropy and weight of indicator j were calculated as follows:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln p_{ij} \quad (1)$$

$$w_j = \frac{1 - e_j}{\sum_{j=1}^m (1 - e_j)} \quad (2)$$

where e_j is the information entropy of indicator j ; w_j is the weight of indicator j ; p_{ij} is the normalized proportion of evaluation unit i for indicator j ; n is the number of evaluation units; and m is the number of indicators.

Resistance classes were defined with reference to heritage-corridor research [31] and adjusted to the regional characteristics of southern Jiangxi, where settlements are concentrated in low hills, basins, river valleys, and areas close to roads and rivers [33]. Each factor was assigned resistance scores of 1, 3, 5, 7, and 9 from low to high resistance. The reclassified factors were combined using the entropy weights to produce the composite resistance surface. Classification thresholds, resistance scores, and weights are listed in **Table 1**.

Table 1. Resistance factors, classification criteria, resistance scores, and entropy weights.

Resistance factor	Classification criteria	Resistance score	Entropy weight
Elevation (m)	<200; 200 - 400; 400 - 600; 600 - 800; >800	1; 3; 5; 7; 9	0.157
Slope (°)	<5; 5 - 10; 10 - 15; 15 - 25; >25	1; 3; 5; 7; 9	0.185
Land use	Built-up land; cultivated land; grassland and bare land; water bodies; forest land	1; 3; 5; 7; 9	0.077
Distance to major roads (km)	<0.5; 0.5 - 1; 1 - 2; 2 - 5; >5	1; 3; 5; 7; 9	0.330
Distance to watercourses (km)	<0.5; 0.5 - 1; 1 - 2; 2 - 5; >5	1; 3; 5; 7; 9	0.251

Note: Built-up land includes urban land, rural settlements, and industrial/transportation construction land; cultivated land includes paddy fields and dry cropland; water bodies include rivers/canals, lakes, reservoirs/ponds, and shoals; forest land includes closed forest, shrubland, sparse forest, and other forest land.

2.3.3. MCR Model and Corridor Extraction

The minimum cumulative resistance (MCR) model was used to identify potential spatial connections within the heritage network. The model integrates source location, spatial distance, and resistance values to calculate cumulative cost across a heterogeneous landscape and identifies paths with relatively low cumulative resistance. It has been widely applied to landscape connectivity and heritage-corridor identification [11] [16] [17] [31]. The model is expressed as:

A concise factor-weight sensitivity analysis was conducted by replacing the entropy weights with equal weights (0.20 for each of the five resistance factors), while keeping the 12 source sites, resistance classes, raster resolution, and least-cost path procedure unchanged. Least-cost paths for all 66 unique source-site pairs were generated under both scenarios. Spatial persistence was evaluated by resistance-surface correlation and by the proportion of equal-weight paths located within 500 m and 1000 m of the corresponding baseline paths; these distances were used only

as comparison tolerances.

$$\text{MCR} = f_{\min} \sum (D_{ij} \times R_i) \quad (3)$$

where MCR is the minimum cumulative resistance from a source site to a target cell; D_{ij} is the spatial distance between source site j and spatial unit i ; R_i is the resistance value of spatial unit i ; and $f_{\min}$ denotes selection of the minimum cumulative resistance.

The 12 national-level protected sites were treated as the principal source nodes for identifying the backbone structure of the corridor network, and the composite resistance surface served as the cost surface. Least-cost connections were generated and subsequently integrated with the remaining non-source heritage sites during supplementary linkage and network optimization. Candidate paths were evaluated according to the original network-optimization criteria, with preference given to shorter paths, lower cumulative resistance, connections incorporating a larger number of heritage sites, and routes spatially associated with major roads and river valleys. Highly overlapping or functionally redundant paths were removed during network optimization. No fixed Euclidean-distance threshold was imposed for retaining candidate paths. Paths providing cross-county backbone connections among major source nodes and important heritage concentrations were classified as primary corridors, whereas supplementary branches improving linkage to dispersed non-source heritage sites were classified as secondary corridors.

3. Spatial Patterns of Red Cultural Heritage

3.1. Overall Clustering and County-Level Disparities

ANN analysis of the 134 validated RCH sites yielded an observed mean nearest-neighbor distance of 5592.06 m, compared with an expected distance of 8578.97 m under CSR within the 39448.94 km² Ganzhou municipal boundary. The nearest-neighbor ratio was $R = 0.652$ ($Z = -7.710$, two-sided analytical $p < 0.001$), indicating significant spatial clustering. This result was independently supported by 999 Monte Carlo CSR simulations within the actual irregular municipal boundary: the simulated mean nearest-neighbor distance was 9084.44 m, with a 95% simulation envelope of 8233.13 - 9931.03 m, whereas the observed value was 5592.06 m (one-sided Monte Carlo $p = 0.001$). The heritage sites are therefore significantly more clustered than expected under spatial randomness.

At the county level, Ruijin City, Ningdu County, and Xingguo County account for 22.39%, 11.94%, and 11.19% of all sites, respectively, representing 45.52% of the total. The imbalance index is 0.595, indicating an uneven distribution among county-level administrative units. Overall, heritage resources are concentrated in the central-northern and eastern parts of Ganzhou, while parts of the south and west contain relatively fewer sites.

The analytical ANN, boundary-constrained Monte Carlo simulations, and county-level results jointly reveal two complementary characteristics: significant municipi-

pal-scale clustering and marked disparities among county-level administrative units. The former indicates strong spatial proximity among heritage sites, whereas the latter reflects differences among areas in the density of historical events, surviving remains, and concentrations of protected resources. These patterns provide the basis for identifying local density concentrations and subsequent corridor connection targets.

3.2. Kernel Density Structure and High-Density Areas

The KDE surface shows a strongly localized pattern of heritage concentration rather than a small number of broad, continuous clusters (see **Figure 2**). Using the site-level KDE distribution as a reproducible descriptive rule, the 75th percentile ($0.1201 \text{ sites km}^{-2}$) and 90th percentile ($0.2201 \text{ sites km}^{-2}$) distinguish secondary and primary high-density levels, respectively. Of the 134 heritage sites, 100 occur below the 75th-percentile density level, 19 occur within the secondary high-density range, and 15 occur at or above the primary high-density threshold. Ruijin contains the most prominent high-density concentration on the KDE surface. The threshold classes describe density intensity. Spatially, the KDE surface is characterized by localized peaks separated by extensive low-density areas. This pattern indicates that RCH in Ganzhou combines a limited number of strong local concentrations with a much broader distribution of isolated or small-group heritage sites. The localized character of the KDE surface is consistent with the relatively small, data-driven bandwidth of 1.925 km and reinforces the need for a corridor framework that can connect dispersed sites without treating all locations as a continuous high-density belt.

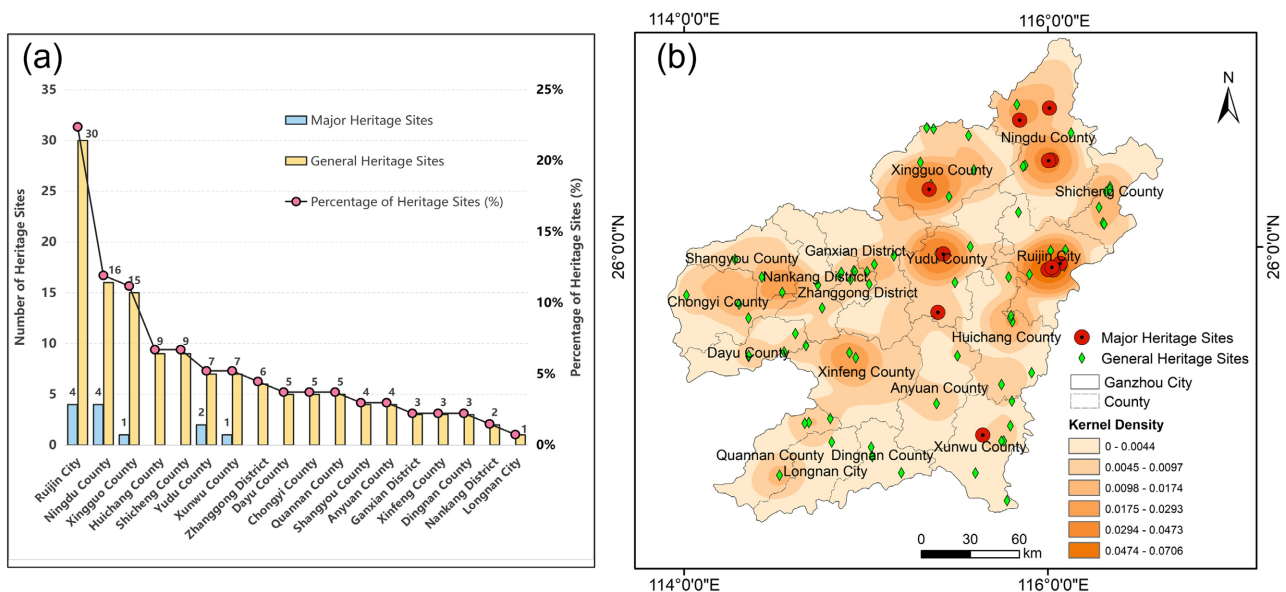


Figure 2. Spatial distribution and kernel density of red cultural heritage in Ganzhou: (a) Number and percentage of heritage sites by county-level administrative unit; (b) Kernel density of red cultural heritage sites (bandwidth = 1.925 km; cell size = 500 m).

Taken together, the ANN, county-level, and KDE results indicate significant

overall clustering but substantial local heterogeneity. The density thresholds provide reproducible information on the relative intensity of local concentrations, while the wide distribution of non-source sites requires the corridor network to provide both backbone connectivity and supplementary linkage.

4. Heritage Corridor Construction and Network Configuration

4.1. Characteristics of the Composite Resistance Surface

Reclassification and weighted overlay of the five resistance factors produced the composite resistance surface. The entropy weights for distance to major roads, distance to watercourses, slope, elevation, and land use were 0.330, 0.251, 0.185, 0.157, and 0.077, respectively. The relatively high information weights of road and watercourse distance indicate greater spatial variability in these two factors across the study area; slope and elevation show intermediate information contributions, while land use shows the lowest. These weights should be interpreted as measures of information dispersion rather than direct causal importance.

The resistance surface exhibits a clear terrain-accessibility gradient. Low-resistance areas are concentrated along built-up areas, major transport routes, river valleys, and watercourses, forming several continuous low-resistance belts in central and eastern Ganzhou. High-resistance areas are concentrated in high-elevation, steep, and peripheral mountainous zones. Consequently, low-resistance space has a pronounced linear continuity, whereas high-resistance mountain patches create barriers that divert potential paths.

The composite surface, therefore, integrates both natural terrain constraints and present-day accessibility into a common cost space. Potential connections among heritage nodes are not simple straight lines; instead, they follow continuous areas of relatively low cumulative resistance and avoid high-cost terrain where possible.

4.2. Least-Cost Path Extraction and Corridor Optimization

Using the 12 principal source sites, cumulative-cost and least-cost connections were evaluated across the composite resistance surface and then integrated with supplementary links to non-source heritage sites. Because an unrestricted set of potential connections would generate substantial path redundancy, network optimization considered path length, cumulative resistance, the number of heritage sites linked, and spatial association with major roads and river valleys. Highly overlapping or functionally redundant paths were removed, retaining backbone connections and supplementary peripheral branches. No fixed Euclidean-distance threshold was used to select or retain the modeled paths.

Primary corridors provide cross-county backbone connectivity among major source nodes and important heritage concentrations, whereas secondary corridors supplement the backbone by improving linkage to dispersed non-source heritage sites. A post hoc spatial diagnostic of the existing primary-secondary corridor prod-

ucts showed that the combined network was closely associated with the 134 mapped heritage sites: the median site-to-network distance was effectively 0 m, the mean distance was approximately 155 m, and the maximum distance was approximately 985 m. For descriptive reference, 122 of 134 sites (91.0%) were located within 500 m of the combined network, and all 134 sites were within 1 km. These distances are reported as post hoc proximity measures and were not used as corridor-construction or path-retention thresholds.

The factor-weight sensitivity analysis showed that the main spatial pattern remained stable under equal weighting. The equal-weight resistance surface was strongly correlated with the baseline surface ($r = 0.973$). At the network level, 86.02% of the equal-weight LCP network lay within 500 m of the baseline network and 93.07% lay within 1000 m. Across the 66 source-site pairs, median path overlap was 86.44% at 500 m and 96.89% at 1000 m, indicating persistence of the broad corridor configuration with some local route displacement.

Corridor optimization prioritized routes with relatively low cumulative resistance that connected important nodes or linked multiple heritage sites. Where conditions were similar, shorter routes and those close to major roads were preferred, while river-valley context was also considered in network integration. The final network should nevertheless be interpreted as a regional-scale pattern of potential conservation and accessibility connectivity.

4.3. Hierarchical Network Configuration

Integrating the density and corridor results reveals a hierarchical network composed of major heritage concentrations, principal source nodes, primary backbone corridors, secondary supplementary corridors, and dispersed linked sites. Ruijin constitutes the most prominent density concentration in the revised KDE analysis and also contains important source sites. Primary corridors form the municipal-scale backbone, whereas secondary corridors extend toward western, southern, and peripheral areas to improve the spatial linkage of dispersed non-source heritage (see **Figure 3**).

The strongest connections are concentrated in central-eastern and central-northern Ganzhou, with Yudu County and Huichang County functioning as important transitional areas for east-west and north-south connectivity. Compared with simple straight-line connections, the MCR-derived routes clearly avoid high-resistance mountainous areas and more often follow roads, river valleys, and gentler terrain. The resulting corridor network, therefore, links the heritage clusters identified by KDE with spatially continuous low-cost zones.

The network reflects a hierarchy among heritage resources without requiring all 134 sites to function as equivalent model sources. Major source nodes and high-density concentrations organize the backbone structure; primary corridors maintain cross-county continuity; and secondary corridors improve spatial proximity and linkage to dispersed heritage sites. The post hoc distance analysis confirms that the combined corridor products remain spatially close to the mapped heritage

inventory.

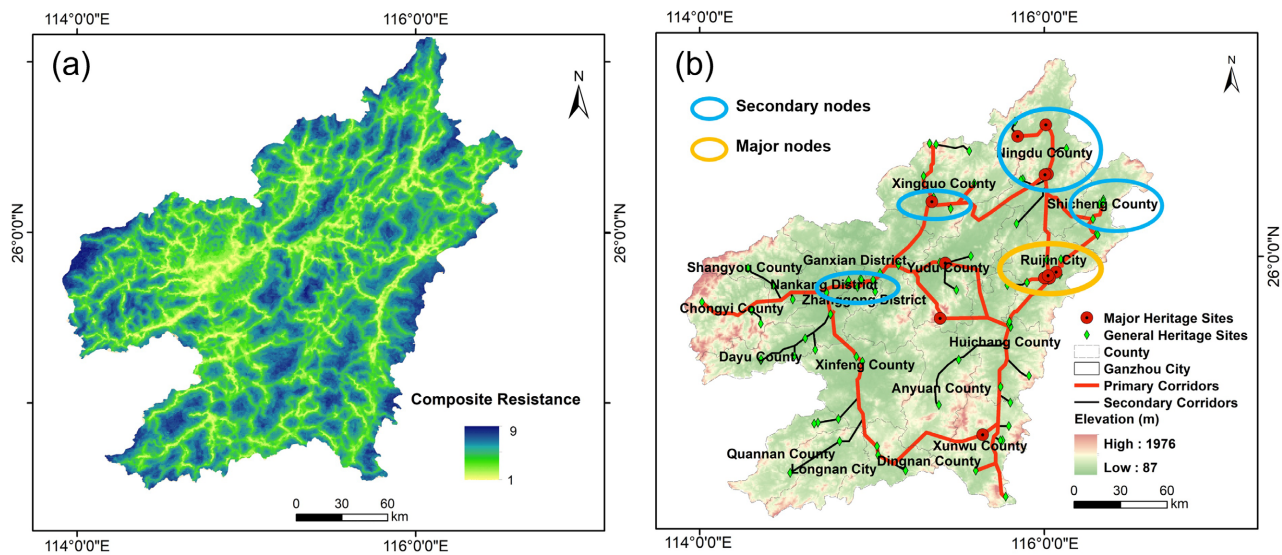


Figure 3. Composite resistance surface and heritage corridor network in Ganzhou: (a) Composite resistance surface; (b) Heritage corridor network. Circles indicate the dominant core and four secondary nodes.

5. Discussion

5.1. Historical and Geographical Context of Heritage Clustering

The significant clustering of RCH in Ganzhou is not simply a form of contemporary urban concentration; it is closely related to the historical geography of revolutionary activities. Ruijin contains the most prominent density concentration in the revised KDE analysis and is also the location of several source sites. Recent English-language research has likewise treated the Ruijin Soviet cultural heritage as an important case for conserving and communicating red cultural heritage [34]. More broadly, red heritage and red tourism have been discussed internationally in relation to political heritage, collective memory, and national identity [3] [35]. The concentration of protected heritage in several historically important parts of Ganzhou can therefore be understood as the spatial outcome of overlapping historical-event centers, revolutionary organizational activities, and subsequent heritage recognition and protection.

This interpretation also indicates that RCH clustering should not be equated with contemporary population or urban size. The revised KDE results show localized density peaks rather than a simple correspondence with the modern urban hierarchy. Understanding an RCH network requires simultaneous attention to the locations of historical events, official heritage designation and protection status, and current accessibility. In this sense, KDE provides a reproducible description of local concentration intensity that complements.

5.2. Accessibility, Terrain Resistance, and Least-Cost Connectivity

The entropy weights of distance to major roads and distance to watercourses (0.330

and 0.251) are higher than those of slope, elevation, and land use. This does not imply a strict causal priority of roads and watercourses in corridor formation; rather, it indicates that these variables exhibit greater spatial dispersion and information contribution within Ganzhou. Least-cost modeling converts such spatial differences into relative movement costs and identifies connections through continuous low-resistance space [16] [17]. Recent reviews also show that GIS applications in cultural heritage conservation are increasingly moving beyond inventories and visualization toward spatial relationship analysis and regional management [36].

In Ganzhou, low-resistance belts are concentrated along roads, river valleys, and built-up areas, whereas elevation and slope increase cumulative cost in peripheral mountain areas. This is consistent with heritage-corridor research emphasizing the combined effects of terrain, accessibility, and land use on potential connectivity [37] [38]. Roads influence present-day accessibility and help create continuous low-resistance zones. Proximity to watercourses often coincides with valleys, settlements, and transport routes, strengthening some corridor directions. Importantly, water-body land-use cells and distance to watercourses represent different mechanisms: the former captures the resistance of crossing water surfaces, whereas the latter captures the potential corridor effect of river-valley proximity.

5.3. Methodological Implications: From Dispersed Sites to a Hierarchical Network

Unlike canals, historic trails, or the Great Wall, which have an inherent linear structure, RCH in Ganzhou is primarily a set of dispersed points. This study links KDE-based clustering, statutory source-site selection, data-driven resistance weighting, and MCR-based path analysis so that the question of where heritage is concentrated leads directly to the question of how clusters and source sites can be connected at relatively low cost. Recent international studies have used GIS and MCR to construct intangible-cultural-heritage corridors and cultural-ecology networks [37] [38], have combined circuit theory with heritage corridor prioritization [39], and have examined GIS-based spatial evolution, industrial-heritage corridors, and quantitative classification of serial heritage corridors [40]-[42]. Together, these studies indicate a transition from single least-cost paths toward multi-model and hierarchical network analysis.

A distinctive feature of the present study is that the observed clustered-yet-dispersed heritage pattern is incorporated into corridor interpretation, while the 12 national-level protected units provide a transparent set of principal source nodes and the remaining sites are considered during supplementary linkage and network optimization. This reduces path redundancy and avoids a subjective value-scoring system for all 134 sites. Nevertheless, classification into primary and secondary corridors still includes rule-based planning judgment. The post hoc site-to-network distance assessment provides a transparent diagnostic of the spatial

association between the retained corridor products and the mapped heritage sites. Future work should quantify corridor priority more explicitly using circuit-theory current density, network centrality, gravity-model interaction strength, or related network metrics.

5.4. Planning Implications, Limitations, and Future Research

The results suggest a tiered conservation network organized around major heritage concentrations, source nodes, backbone corridors, supplementary corridors, and dispersed sites. Ruijin may serve as an important focal area for cross-county resource integration, public cultural services, and heritage interpretation because it contains the most prominent density concentration and several important heritage nodes. Primary corridors can maintain backbone connectivity, while secondary corridors can improve the spatial linkage of dispersed heritage in the southern, western, and peripheral parts of Ganzhou. Because potential corridors show substantial spatial correspondence with existing roads, river valleys, and low-resistance terrain, future heritage-route planning should make use of existing transport infrastructure wherever feasible and avoid unnecessary disturbance of high-resistance mountain areas.

This study has two main limitations. First, the inventory excludes county-level protected sites, and the selection of 12 national-level protected sites as principal sources may overlook potentially important lower-level sites. Second, MCR and LCP identify potential regional conservation-and-accessibility connections but cannot fully represent alternative routes and network redundancy. Future research should incorporate more comprehensive heritage data and alternative connectivity models, together with field verification, to further evaluate corridor priorities and practical feasibility [39] [42].

6. Conclusions

1) The 134 validated RCH sites in Ganzhou exhibit significant spatial clustering. The revised ANN analysis yielded an observed mean nearest-neighbor distance of 5592.06 m and an expected distance of 8578.97 m within the 39448.94 km² municipal boundary, with $R = 0.652$ and $Z = -7.710$ ($p < 0.001$); boundary-constrained Monte Carlo simulation independently confirmed the clustering pattern ($p = 0.001$). The county-level imbalance index is 0.595. KDE using a 1.925 km bandwidth and 500 m cell size reveals strongly localized density concentrations, with Ruijin containing the most prominent high-density area.

2) Twelve National Key Cultural Relics Protection Units were selected as principal source heritage sites, and the remaining 122 provincial- and municipal-level protected sites were considered in supplementary linkage and network optimization. The composite resistance surface was constructed from elevation, slope, land use, distance to major roads, and distance to watercourses, with entropy weights of 0.157, 0.185, 0.077, 0.330, and 0.251, respectively. In this study, heritage connectivity refers to potential regional conservation, interpretation, and present-day ac-

cessibility linkage rather than reconstructed historical routes. Low-resistance areas are concentrated along built-up areas, roads, and river valleys, whereas high-resistance areas occur mainly in peripheral mountains.

3) MCR and LCP analysis generated a hierarchical primary-secondary corridor network. Primary corridors provide the cross-county backbone, while secondary corridors improve linkage to dispersed non-source heritage sites. Post hoc spatial assessment showed a mean site-to-network distance of approximately 155 m and a maximum distance of approximately 985 m; 122 of 134 sites (91.0%) were within 500 m of the combined corridor network, and all 134 were within 1 km. These distances are diagnostic proximity measures rather than corridor-selection thresholds. The main methodological contribution is the integration of spatial clustering, transparent source-site selection, resistance modeling, and hierarchical network organization for dispersed RCH.

4) The identified corridors represent regional-scale potential conservation-and-accessibility connections. The factor-weight sensitivity analysis showed strong resistance-surface consistency ($r = 0.973$) and high network persistence, with 86.02% and 93.07% of the equal-weight network located within 500 m and 1000 m of the baseline network, respectively. Local path displacement remained, and future research should further test source-site selection and resistance-class thresholds.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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