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The Ecological Sensitivity of Traditional Villages Based on Multi-Source Data and Spatial Mechanisms: A Comparative Study of Typical Provinces in China

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Abstract

Ecological sensitivity provides a critical scientific foundation for enhancing the resilience and sustainable development of traditional villages. However, regional differences in ecological sensitivity remain underexplored. This study investigated the spatial heterogeneity in representative northern (Hebei) and southern (Hubei) Chinese provinces using a sensitivity–resilience–pressure model. Our integrated indicator system incorporates natural ecological and socioeconomic dimensions. Through AHP-GIS analysis, we revealed a significantly higher ecological sensitivity in Hebei than in Hubei. The core drivers include GDP density, population density, and road network density, which critically constrain rural sustainability. We elucidate region-specific natural–socioeconomic coupling mechanisms and provide targeted insights for optimising conservation strategies, particularly for reconciling environmental resilience with economic advancement.

Keywords: ecological sensitivity evaluation; traditional village; multi-source data; ecological resilience mechanism; rural planning and evaluations; resilient human environments; provincial spatial analysis

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1. Introduction

Ecological sensitivity is a key metric for ecosystem resilience and recovery potential. This is crucial for biodiversity conservation, land use planning, and sustainable development [1,2]. Traditional villages refer to rural settlements established in China before the Republic of China. They represent invaluable historical legacies of China's agrarian civilisation, characterised by well-preserved settlement environments and architectural features. These villages retain rich cultural landscapes and historical narratives while continuing to serve as human habitats. Furthermore, they constitute crucial repositories of regional cultural genes and ecological wisdom [3]. The stability of their ecosystems is intrinsically linked to synergistic urban–rural development and the inheritance of cultural heritage. Beyond serving as a tangible foundation for villagers' livelihoods, traditional

villages provide significant venues for exploring China's distinct approach to rural revitalisation. Their resurgence not only exemplifies modernisation pathways for other Chinese villages but also offers vital practical references for national rural revitalisation strategies. Quantifying the ecological sensitivity of traditional villages fundamentally constitutes the decomposition and implementation of the "nature–society" dimension objectives within sustainable development. This process translates abstract goals into quantifiable and actionable parameters. The identification of ecologically vulnerable zones enables targeted interventions for subsequent sustainable development initiatives and effectively avoids decision-making oversights in rural development and conservation. However, rapid urbanisation and industrialisation threaten these areas through ecological degradation, landscape homogenisation, and cultural erosion. China has implemented targeted policies to enhance rural sustainability, including systematic ecological sensitivity assessments that identify environmental constraints and inform restoration mechanisms in ecologically fragile zones, such as Tibetan villages in Sichuan [4]. Research has further linked rural resilience to robust ecosystem services [2], positioning these services as a critical priority for village ecological conservation.

Ecological sensitivity research has expanded across multiple scales: macroscale investigations focus on major geographic regions [5,6]; mesoscale studies target provinces [7] and cities [8,9]; and microscale analyses encompass diverse ecosystems, including rivers [10], landscape parks [11,12], and mountains [13]. Current research emphasises driving factor analysis [14], sensitivity assessment [15], and spatiotemporal evolution [16,17]. While these multi-scale investigations have significantly advanced the understanding of ecological sensitivity across administrative units and ecosystem types, they have predominantly focused on intra-regional patterns. Consequently, a critical research gap persists in conducting systematic inter-regional comparative analyses that can uncover the divergent mechanisms driven by macro-geographical and socio-economic gradients. However, regional differences in ecological sensitivity across distinct geographic realms remain underexplored.

Ecological sensitivity assessment models are key tools for ecosystem stability evaluation. Common frameworks include pressure–state–response [18,19], the vulnerability coping diagram [15], and sensitivity–resilience–pressure (SRP) [4,20]. The SRP model defines ecosystem stability based on three dimensions: ecological sensitivity, resilience, and environmental pressure. This structure effectively integrates diverse assessment factors. Therefore, we adopted the SRP framework and constructed a village-specific ecological sensitivity assessment model. The following key indicators were incorporated: elevation, water proximity, vegetation coverage, land cover type, population density, and road density.

No unified standard exists for the evaluation of ecosystem services evaluation. Common methods include the analytic hierarchy process (AHP) [21–23], fuzzy AHP [24,25], principal component analysis [26], entropy weight method [16,26], and spatial analysis [20,27–29]. These methods effectively assess the regional ecology but have limitations. AHP and fuzzy AHP are computationally simple but involve subjective weighting. Principal component analysis reduces dimensionality but handles non-linear data poorly. The entropy weight method is often combined with the AHP for integrated weighting. Spatial analysis enables factor sensitivity assessment and visualisation. When integrated with the AHP or entropy weighting, credible results are obtained. Given our multi-source geospatial data, we combined AHP and GIS spatial analyses. This robust approach ensured strong interpretability and comparability. In developing the ecological sensitivity assessment, we implemented specific multi-source data preprocessing; these enhanced sensitivity measures ensured the reliability of the results.

China's vast territory spans the subtropical and temperate zones, supporting a rich ecology. Accordingly, various zoning standards have been developed; climate-based build-

ing zoning and four geographical zones are common classification criteria [30,31]. Current ecosystem services research on traditional Chinese villages focuses on internal ecological heterogeneity [32] and socioeconomic impacts on environmental quality [33,34]. These studies offer valuable insights for village protection. However, the research is confined to single or small regions, and cross-regional comparative studies are scarce. Methodologically, frameworks such as the pressure–state—-response and SRP have deepened. However, indicator systems often overemphasise natural factors, and economic and social dimensions are insufficiently integrated. Urban/rural ecological sensitivity studies typically include natural factors (e.g., elevation, slope, and vegetation) [34–36], while economic factors primarily appear in tourism assessments [37]. There are significant climatic, topographical, and human differences between northern and southern China: villages in the northern cold region near the suburbs face strong human disturbance.; warmer southern villages often benefit from terrain barriers and dense vegetation that enhance their stability. The driving mechanisms of village ecological sensitivity remain inadequately analysed, and this regional differentiation limits the universality of the policies. Future work will require expanded study areas and advanced multi-factor models.

This study compares the ecological sensitivities of traditional villages in northern and southern China. These regions exhibit distinct climates, topographies, and ecosystems. Population growth and rapid urbanisation have intensified conflicts between land development and conservation, and modern industries have replaced traditional livelihoods, resulting in landscape homogenisation and cultural loss [35]. Simultaneously, artificial structures have encroached on farmlands and forests, degrading ecological landscapes [38]. Functioning as key assets for rural revitalisation, traditional villages offer rich ecological resources and regional distinctiveness. These provide essential natural assets for urban development [39,40]. Therefore, it is critical to study their ecological sensitivity. This study supports regional ecological planning, identifies universal patterns, reveals unique mechanisms, and mitigates biased assessments [41].

To address this research gap in inter-regional comparison, this study selected Hebei and Hubei Provinces as representative cases of northern and southern China, respectively, according to three criteria: typological representativeness, environmental diversity, and sample size balance. This selection is strategically informed by their pronounced contrasts in natural endowments and socio-economic dynamics, which provide a robust basis for testing hypotheses about divergent ecological sensitivity mechanisms.

Hebei, representing the northern cold region, is characterised by a temperate semi-arid climate, a transition from plateau to plain typology, stone-based architecture, and an economy historically oriented towards resource-intensive and agriculture-supported industries. In contrast, Hubei typifies the southern non-cold region, featuring a humid subtropical monsoon climate, basin-and-mountain topography, forest-adapted settlements, and a more diversified, market-driven economy increasingly reliant on manufacturing and services. These foundational differences are hypothesised to generate distinct pathways of human–environment interaction, making the two provinces ideal for comparative analysis of regional determinants of ecological sensitivity [42–45].

By focusing on this strategically chosen pair of provinces, the study enables a controlled investigation into the spatial mechanisms driving ecological sensitivity across a major geographical divide. The findings are expected to yield a foundational understanding of these mechanisms and provide a transferable methodological framework for future large-scale interprovincial studies.

Despite the numerous traditional villages throughout China, conducting a controlled comparative analysis necessitates the selection of representative provinces that embody fundamental north–south divergences in climate, topography, and socioeconomic conditions.

Hebei and Hubei were selected as representative cases of northern and southern China based on three criteria: typological representativeness, environmental diversity, and sample size balance. Hebei exemplifies northern village patterns, featuring a temperate semi-arid climate, plateau–plain topography, stone-based architecture, and agriculturally oriented economies. In contrast, Hubei represents southern village types, characterized by a subtropical monsoon climate, mountainous river basins, and forest-adapted settlements. Although this study focuses specifically on these two provinces, the deliberately circumscribed geographical scope enables a systematic comparative analysis of key regional contrasts.

This study makes three key contributions to research on ecological sensitivity and conservation planning for traditional villages: (1) Methodological Advancement: We introduce an integrated SRP–AHP–GIS framework that incorporates multi-source geospatial data and socioeconomic metrics, facilitating a nuanced, spatially explicit, reproducible, and scalable assessment of ecological sensitivity in rural and culturally significant landscapes. (2) Theoretical Insight: Through a north–south comparative analysis (Hebei vs. Hubei), we elucidate the divergent mechanisms underpinning ecological sensitivity. Notably, we demonstrate that socioeconomic factors—such as GDP density and road network density—exert stronger influences than natural factors in highly urbanised regions, offering a new perspective for regional ecological governance. (3) Practical Relevance: The findings provide tailored ecological zoning strategies for traditional village conservation, differentiated by cold and non-cold regional contexts. Furthermore, the proposed framework is transferable to broader ecological assessments and policy formulation, supporting sustainable rural revitalisation in China and potentially in comparable international contexts. Together, these contributions establish a foundational understanding of spatial mechanisms of ecological sensitivity and provide a transferable methodological framework for future large-scale interprovincial studies.

2. Materials and Methods

This study develops a novel framework for assessing ecological sensitivity by integrating the SRP model with multi-source geospatial data encompassing both natural and socio-economic dimensions. Its methodological innovation is the incorporation of cross-regional comparative analysis, which systematically reveals the divergent mechanisms driving ecological sensitivity in traditional villages across northern and southern China. By embedding objective weighting techniques within this comparative approach, the framework strengthens both the robustness and the spatial interpretability of the evaluation. This replicable methodology offers a valuable tool for supporting region-specific resilience planning and promoting sustainable development of traditional villages.

2.1. Study Area and Sample Selection

2.1.1. Principles of Sample Selection

This study aimed to compare differences in ecological sensitivity between cold and non-cold areas and between northern and southern traditional villages across diverse natural and humanistic geographic environments based on provincial administrative regions.

Building on prior research, this study addresses this gap by examining the regional ecological sensitivity driving mechanisms through a comparative analysis of Hebei and Hubei Provinces, selected as representative cases of northern and southern China, respectively. This selection is strategically grounded in their contrasting profiles across three critical dimensions. First, based on *Climate zoning of Chinese buildings* [46] (https://ndls.org.cn/ (accessed on 15 August 2025)), regions with an average temperature of the coldest month below 0 °C were classified as cold areas, encompassing extremely cold and severely cold climate zones. All other zones were designated as non-cold areas. Cold areas included

Northeast, North, and Northwest China, along with the Qinghai–Tibet Plateau, whereas non-cold areas comprised the remaining regions. Second, we overlaid the geographical boundaries of northern and southern China with cold/non-cold regional delineations to approximate the northern and southern study areas. The north–south demarcation adhered to China's standard geographical division along the Qinling–Huai River line [47]. Third, we compiled basic information on nationally recognised traditional villages across the provinces (Table A1). To ensure representativeness, Hebei Province (276 villages) in the north and Hubei Province (270 villages) in the south were selected as the focal research areas (Figure 1) based on the following criteria:

1. Typical representativeness: Selected provinces must exemplify the characteristic natural climate, topography, and geomorphology of their geographic region. Provinces lacking distinctive regional features were excluded.
2. Environmental diversity: Priority was given to areas exhibiting diverse geographical settings and varied traditional village typologies.
3. Sample balance: Regions with comparable numbers of traditional villages in the north and south were selected to reduce quantitative discrepancies.
4. These fundamental differences in natural endowment and human systems are hypothesized to generate divergent pathways of human–environment interaction, making the two provinces ideal natural laboratories for probing the spatial mechanisms of ecological sensitivity across China's primary north–south divide.

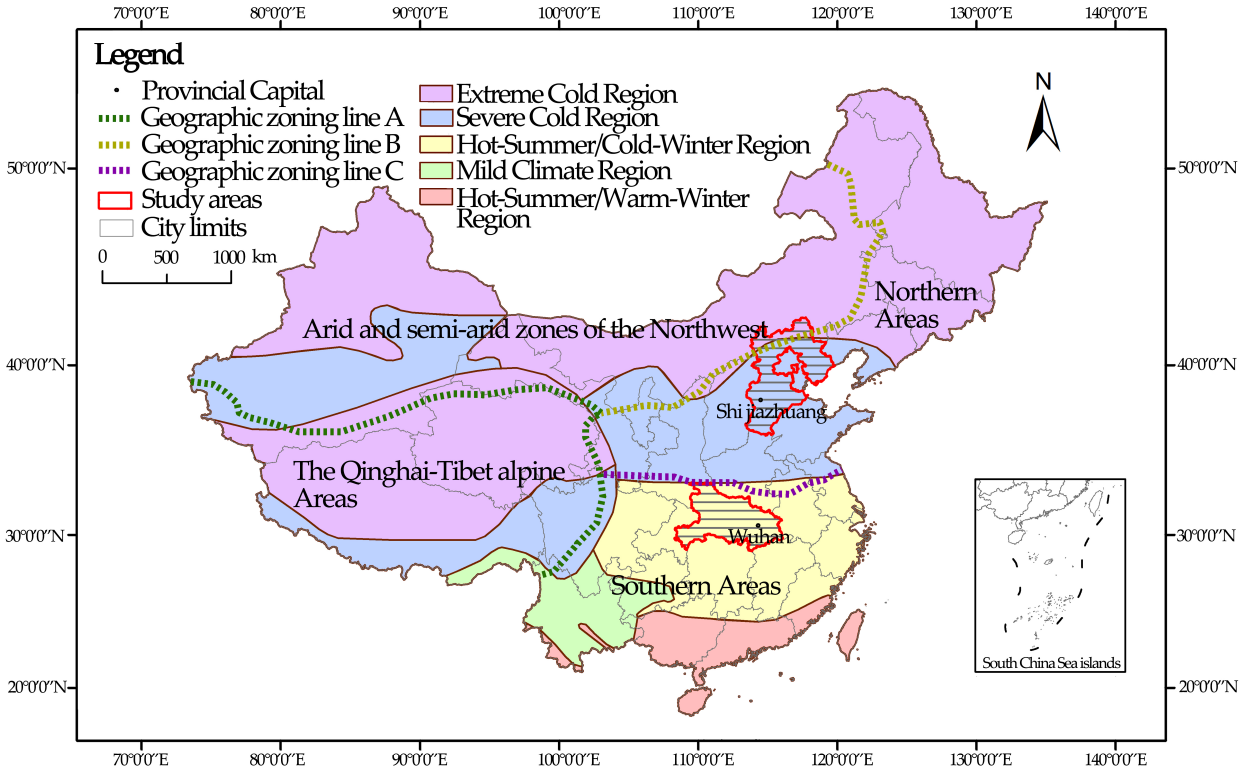


Figure 1. Map of the study area (drawn by the authors). This image is based on the standard map produced by the Ministry of Natural Resources and the standard map service website GS (2024) 0650, with no modifications to the boundaries of the base map.

2.1.2. Overview of the Study Area

Hebei Province (36°05′–42°40′ N, 113°27′–119°50′ E) occupies central North China [48]. It borders the Inner Mongolia Plateau (north), Taihang Mountains (west), and Bohai Bay (east). Situated at China's second–third topographic transition, it features higher western

elevations and eastern lowlands. This province integrates mountains, plains, hills, grasslands, and coastlines. Its temperate semi-arid monsoon climate delivers dry, windy springs; hot, humid summers; windy, rainy autumns; and cold, dry winters. The mean annual temperature is 11.8 °C with ~640 mm of precipitation. Northern areas have long cold winters and short summers, whereas southern zones experience bitter temperatures with uneven humidity. Rivers from the Taihang and Yanshan Mountains freeze seasonally. Hebei hosts northern China's highest density of traditional villages featuring stone architecture. The village economies focus on crops and poultry.

Hubei Province (29°02′–33°07′ N, 108°22′–116°08′ E) typifies the Yangtze River Basin settlements [49]. Mountainous peripheries (including the Daba and Wushan ranges) encircle the central lowlands. The eastern Han River Plain contrasts with the western highlands with additional karst and volcanic features. Its subtropical monsoon climate brings cold winters and intensely hot summers (mean 16.7 °C). The annual precipitation reaches ~1200 mm (higher southeast), peaking during June and July. Ice-free river networks support its "Province of a Thousand Lakes" status. Hubei has significant traditional southern villages, including minority communities, with green-brick/grey-tile structures and adaptable layouts. The village economies are centred on cash crops, tourism, forestry, and aquaculture.

2.2. Data Source and Preprocessing

To ensure temporal consistency and cross-regional comparability, this study utilised multi-source data from a representative baseline year (2023), except socioeconomic statistics, for which the most recent census data (2020) were employed. Data sources, specifications, and preprocessing procedures are comprehensively detailed in Table 1. The selection of a single-year dataset is justified by the study's focus on spatial heterogeneity rather than temporal dynamics, and by the minimal interannual variability of key environmental indicators (e.g., NDVI and land cover) during the study period [41–44]. All raster datasets were resampled to a uniform spatial resolution of 100 m to facilitate integrated spatial analysis.

Table 1. Data sources, specifications, and preprocessing details.

Data Type	Data Description	Spatial Resolution/Scale	Spatial Resolution/Scale	Preprocessing Steps	Data Source
Village Locations	Geographical coordinates of traditional villages	2023	Point data	Geocoding and coordinate verification; projected to WGS_1984.	http://www.chuantongcunluo.com https://www.dmctv.cn/ (accessed on 15 August 2025).
Topography	Digital elevation models (DEMs)	2023	30 m	Projected to WGS_1984; used to derive slope and aspect rasters in ArcGIS.	https://www.gscloud.cn (accessed on 15 August 2025).
Vegetation Index	Normalized Difference Vegetation Index (NDVI)	2023	30 m (Landsat 8)	Calculated from Landsat 8 OLI/TIRS imagery; cloud-free mosaics were obtained for the growing season (May–September); resampled to 100 m.	https://search.earthdata.nasa.gov/search (accessed on 15 August 2025).
Land Cover	Surface cover classification	2023	30 m	Reclassified into five major types (Construction, Plowland, Grassland, Forest, Wetland/Water); resampled to 100 m.	http://www.gis5g.com/home (accessed on 15 August 2025).

Table 1. *Cont.*

Data Type	Data Description	Spatial Resolution/Scale	Spatial Resolution/Scale	Preprocessing Steps	Data Source
Road Network	Vector data for highways, national & provincial roads	2023	Line data	Converted to raster format; kernel density estimation was performed with a search radius of 3 km to generate a continuous density surface.	https://lbs.amap.com (accessed on 15 August 2025).
Socioeconomic data	Gridded Population Density	2020	1 km	Masked and extracted for each province; values assigned to village point locations.	http://www.gis5g.com/home (accessed on 15 August 2025).
	Gridded GDP Density	2020	1 km	Masked and extracted for each province; values assigned to village point locations.	http://tjj.hebei.gov.cn/hbstjj/ (accessed on 15 August 2025). https://tjj.hubei.gov.cn/ (accessed on 15 August 2025).
	Traditional Village Kernel Density	2023	N/A	Calculated using the Kernel Density tool in ArcGIS with a search radius of 10 km to quantify spatial agglomeration patterns.	http://www.gis5g.com/home (accessed on 15 August 2025).

Key preprocessing steps conducted in ArcGIS 10.2 included: (1) Kernel Density Estimation for road networks and village distributions, converting linear and point data into continuous density surfaces; (2) Multi-ring Buffer Analysis for river networks to assess proximity effects; (3) reclassification of all input rasters according to the sensitivity grading criteria defined; and (4) Spatial Overlay using the Raster Calculator to execute the weighted overlay analysis based on the AHP-derived weights. These procedures ensured the integration of all datasets into a consistent spatial framework for subsequent analysis.

The three-year temporal discrepancy between the core demographic/economic data (2020) and the other datasets (2023) is acknowledged. However, this approach is methodologically justified for the following reasons:

(1) Research Focus on Spatial Comparison: The primary objective of this study is a *spatial comparative analysis* of ecological sensitivity between two provinces, rather than an analysis of temporal trends. The fundamental spatial patterns of population distribution and economic activity, particularly at the regional scale examined here, exhibit relative stability over a three-year period. The *relative differences* between Hebei and Hubei, and within each province, are the focus of the analysis.

(2) Data Authority and Consistency: The 2020 census data provide a consistent, high-resolution, and officially validated benchmark for inter-provincial comparison. Utilizing this robust dataset was prioritized over generating proxy estimates for 2023, which could introduce greater uncertainty and compromise the reliability of the comparative findings.

(3) Minimal Impact on Core Findings: The sensitivity weighting confirms the importance of socioeconomic factors. However, the analysis of these factors relies on their *spatial distribution patterns*, which are unlikely to have undergone fundamental restructuring between 2020 and 2023 that would alter the core conclusions of this spatial comparison.

Therefore, the use of the authoritative 2020 socioeconomic data is considered appropriate and reliable for achieving the study's primary comparative objective. Future research will incorporate multi-temporal data as newer authoritative census datasets become available.

2.3. Ecological Sensitivity Assessment Framework

This study evaluated traditional village sensitivity through natural ecological and socioeconomic dimensions using the SRP model. Spatial characteristics were visualised using ArcGIS-based normalisation, kernel density, and spatial autocorrelation analyses with multi-source data. Subsequently, an AHP weighted evaluation of factors was used to construct a multi-factor landscape ecological sensitivity assessment model. The spatially weighted superposition results were visualised in ArcGIS, classified into sensitivity grades, and used to identify villages at varying risk levels, providing a scientific basis for provincial conservation strategies. Finally, we comparatively analysed the factors influencing the sensitivity distribution patterns in Hebei and Hubei Provinces and proposed tailored protection strategies for cold and non-cold regions (Figure 2).

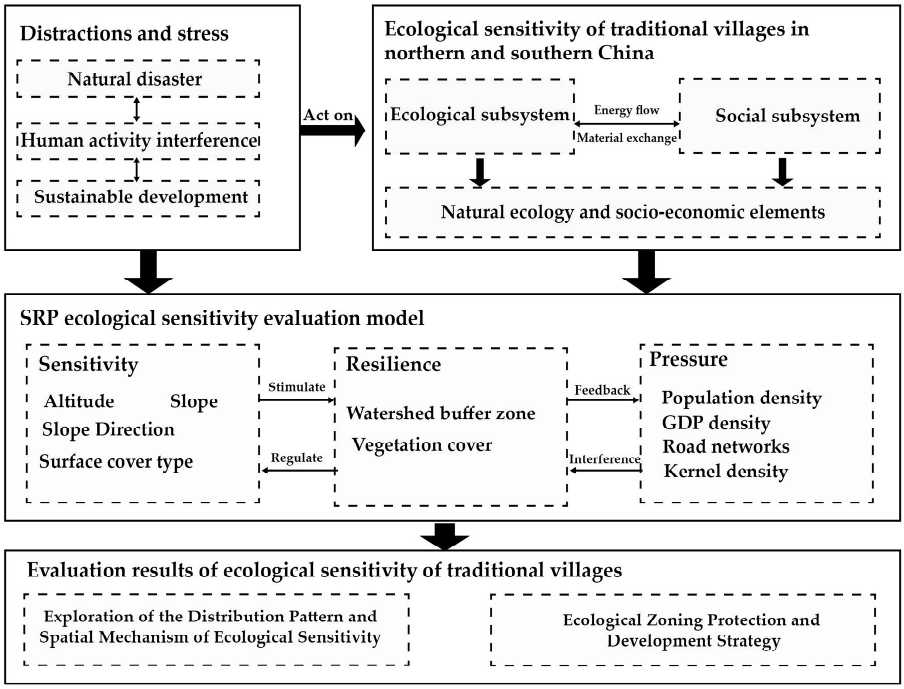


Figure 2. Technical flowchart of this study (drawn by the authors).

2.3.1. Construction of Ecological Sensitivity Assessment System Based on the SRP Model

This study initially selected natural and social evaluation indices but relied solely on the risks of excessive subjectivity and weak theoretical foundations, which compromised scientific rigour. Therefore, we adopted the SRP model [5], an ecosystem stability framework that evaluates ecological sensitivity through three components. Ecological sensitivity and resilience correspond to natural dimensions, whereas pressure represents social dimensions. Building on prior applications [5,20], we adapted this model for Hebei and Hubei using established indicators [20]. Traditional village landscapes face ecological challenges because of intertwined natural complexities and anthropogenic influences, necessitating integrated evaluation factors [35,36].

The SRP model defines ecological sensitivity as vulnerability to disturbances, assessed through elevation (layout), slope (safety), aspect (agriculture), and land cover [34]; resilience as the self-recovery capacity via vegetation (soil conservation) and water systems; and pressure as anthropogenic impacts via population density (urbanisation), GDP density (economic pressure), road density (disruption), and village kernel density (settlement intensity) [37].

2.3.2. Calculation of Ecological Sensitivity Assessment System Weights

We employed an enhanced AHP-GIS spatial analysis approach to process multi-source data while ensuring robust results. The basis for indicator scoring and threshold assignments was established by synthesising China's National Ecological Function Zoning guidelines, relevant literature on ecological sensitivity assessment [34–36,50–55], and the specific geographical characteristics of Hebei and Hubei. For instance, slope and elevation thresholds were defined according to standard landform classification systems and previous studies conducted in similar topographic settings. The specific grading criteria and their rationales are presented in Table 2.

Table 2. Evaluation Factor Grading Assignment Criteria.

Evaluation Factor		Non-Sensitive	Lightly Sensitive	Moderately Sensitive	Highly Sensitive	Hypersensitive	Factor Attribute	Weight
Ecological sensitivity	Altitude (m) [20]	<600	600~900	900~1200	1200~1800	≥1800	+	0.12
	Slope (°) [34,35]	<8	8~15	15~25	25~35	≥35	+	0.05
	Slope direction [37]	Flatland, South	Southeast, Southwest	East, West	Northeast, Northwest	North	Appropriate value	0.10
	Surface cover type [36,50]	Construction land	Plow land	Grasslands	Forest land	Wetlands and water areas	Appropriate value	0.02
Resilience	Watershed buffer zone (km) [20]	≥5	3~5	2~3	1~2	<1	-	0.03
	Plant cover [52]	<0.2	0.2~0.4	0.4~0.6	0.6~0.8	≥0.8	+	0.03
Pressure	Population density (people/km^2) [34]	<100	100~500	500~1000	1000~5000	≥5000	+	0.14
	GDP density (ten thousand yuan/km^2) [34]	<100	100~500	500~1000	1000~5000	≥5000	+	0.17
	Road network density (km/km^2) [54]	<1.5	1.5~2.0	2.0~2.5	2.5~3.0	≥3.0	+	0.29
	Traditional villages kernel density [34]	Least density	Low density	Medium density	Sub-high density	High density	+	0.03
Hierarchical assignment		1	3	5	7	9		

Note: "+" and "-" represent the positive and negative ratio relationship between the indicator score and the sensitivity. "+" indicates a direct proportion relationship, and "-" indicates an inverse proportion relationship.

The weights for the evaluation indices were determined using the Analytic Hierarchy Process (AHP) supported by the Delphi method. A panel of 35 experts specializing in ecology, urban planning, human geography, and cultural heritage conservation was invited to participate. The panel comprised 15 professors, 12 associate professors, and 8 senior researchers, all with over ten years of experience in their respective fields. We distributed 35 questionnaires and received 28 completed responses (an 80% response rate). After consistency checks, inputs from 25 valid responses were incorporated into the final analysis to construct the judgment matrix.

The final weights for the criteria layer (Sensitivity, Resilience, and Pressure) and the factor layer were derived from the aggregated expert judgments. The maximum eigenvalue, consistency index (CI), and consistency ratio (CR) for the primary judgment matrix were calculated to be 3.009, 0.005, and 0.008, respectively. Since the CR value was well below the threshold of 0.1, the consistency of expert judgments was deemed satisfactory. The complete judgment matrices and consistency test results for all layers are provided in Appendix A Table A2.

To mitigate the subjectivity inherent in AHP, we further applied the entropy weight method, which assigns objective weights based on the information entropy of each indicator. This method reflects the discriminative capacity of the data itself. The procedure was as follows.

(1) Standardisation: The original data matrix was normalised to eliminate dimensional differences.

(2) Calculation of Entropy Value (e_j): The entropy value for the j indicator was calculated as

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

where $p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}$, r_{ij} is the standardized value of the j th indicator in the i th sample, and m is the number of evaluation units.

(3) Entropy Weight Calculation (w_j^e): The objective weight was derived as

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

where n is the number of indicators.

The final combined weight (W_j) was obtained by integrating the subjective AHP weight (w_j^a) and the objective entropy weight (w_j^e) using the following multiplicative synthesis method:

$$W_j = \frac{w_j^a w_j^e}{\sum_{j=1}^{n}\left(w_j^a w_j^e\right)} \quad (3)$$

This hybrid approach leverages both expert knowledge and the intrinsic information of the data, producing a more robust weighting system. Sensitivity analysis further confirmed that ecological sensitivity rankings were robust to minor perturbations in the final weights.

The basis for indicator scoring and the assignment of threshold values for each evaluation factor were established by synthesizing China's National Ecological Function Zoning guidelines, relevant literature on ecological sensitivity assessment [34–36,50–54], and the specific geographical characteristics of Hebei and Hubei Provinces. For instance, slope and elevation thresholds were defined according to standard landform classification systems and previous studies conducted in similar topographic settings. The specific grading criteria and their rationales are explicitly listed in Table 2.

2.4. Methods

2.4.1. Buffer Analysis

Buffer analysis, a standard GIS tool for spatial processing, creates polygonal layers representing influence zones around geographic features (points, lines, and polygons) at specified distances. This study applied buffer analysis to water features to evaluate how hydrological distribution shapes village ecological sensitivity [56].

2.4.2. Normalised Difference Vegetation Index Analysis

NDVI was used to quantify vegetation growth and coverage. Using Landsat 8 satellite imagery, we calculated the NDVI across the study area, classified vegetation coverage grades, and analysed spatial patterns using Equation (4) [57]:

$$\begin{gathered} \mathrm{NDVI} = (\mathrm{NIR} - \mathrm{Red})/(\mathrm{NIR} + \mathrm{Red}) \\ \mathrm{NDVI}_{0\text{–}255} = (\mathrm{NDVI} - \mathrm{NDVI}_{\min})/(\mathrm{NDVI} - \mathrm{NDVI}_{\min}) \times 255 \end{gathered} \quad (4)$$

where NIR denotes the near-infrared band reflectance and NDVI (0–255) represents the normalised vegetation index, scaled from 0 to 255.

2.4.3. Kernel Density Analysis

The kernel density analysis method computes the point and line densities of the grid cells using a moving window [58]. This approach examined the agglomeration level of villages within the study area, as shown in Equation (5):

$$fn(x) = \frac{I}{nh}\sum_{i=1}^{n} k(\frac{X - Xi}{h}) \quad (5)$$

where *f(x)* denotes the kernel function, *K* represents the spatial weight function, and $X - Xi$ indicates the distance from the density estimation point. Parameter *h* is the bandwidth, and *n* denotes the number of villages analysed. The kernel density values were positively correlated with the spatial agglomeration of traditional villages. Higher density values corresponded to a more concentrated village distribution.

2.4.4. Analytic Hierarchy Process

AHP calculates the evaluation factor weights to construct an index system. This qualitative–quantitative method builds a judgment matrix that incorporates expert decisions, which determine the factor weights. Consistency testing ensures the system's robustness [59], as per Equation (6):

$$CI = \frac{\lambda\text{max} - \text{n}}{\text{n} - 1}, CR = \frac{\text{CI}}{\text{RI}} \quad (6)$$

where λ_{max} denotes the maximum eigenvalue, *CR* is the consistency ratio, RI represents the random consistency index, and *CI* signifies the consistency index.

2.4.5. Spatial Overlay Analysis

Using ArcGIS 10.2, we integrated the evaluation factors using an overlay analysis. Factor distributions were analysed and classified into standardised levels. The raster data were resampled and converted into vectors. By combining these with the index weights, we calculated the unit-level ecological sensitivity. This produced a landscape ecological sensitivity zoning map for both provinces using Equation (7) [60]:

$$\text{Pj} = \sum_{i=1}^{n} AijW\text{j} \quad (7)$$

where j denotes the number of partitions of the evaluation unit, P_j indicates the ecological sensitivity value of cell j, and *n* represents the total raster cell count. Ai_j signifies the ecological sensitivity score for the jth raster cell under the *i*th index, and W_j denotes the weight value for cell j's evaluation system.

2.4.6. Spatial Autocorrelation Analysis

To quantitatively diagnose the spatial clustering patterns of ecological sensitivity and its driving factors—and to move beyond descriptive inferences—we employed spatial autocorrelation analysis. Global spatial autocorrelation was measured using Global Moran's I index to assess the overall clustering degree in the ecological sensitivity index across the study area. The significance of Moran's I was tested using a Z-score at a significance level of $p < 0.05$. The formula for Global Moran's I is given as

$$I = \frac{n}{S_0}\frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}z_i z_j}{\sum_{i=1}^{n} z_i^2} \quad (8)$$

where n is the number of spatial units (villages), z_i and z_j are deviations from the mean for the sensitivity value at locations i and j, $w_{i,j}$ is the spatial weight between locations i and j, and S_0 is the aggregate of all spatial weights.

Furthermore, Local Indicators of Spatial Association (LISA), specifically Local Moran's I, were computed to identify local spatial clusters (hotspots and coldspots) and spatial outliers. This analysis pinpoints specific locations where high or low sensitivity values are surrounded by similar (High–High and Low–Low) or by contrasting values (High–Low and Low–High) values. All spatial autocorrelation analyses were performed using the Spatial Statistics tools in ArcGIS 10.2.

3. Results

3.1. Ecological Sensitivity Assessment of Traditional Villages

(1) Altitude

This study classified evaluation levels by elevation characteristics in Hebei and Hubei and analysed the influence of elevation on the ecological sensitivity of traditional villages through a coupled analysis (Figures 3 and A1a,b). Hebei's terrain descends northwest to southeast (average elevation: ~1500 m) [49], comprising the Weichang Plateau (≥1800 m; minimal villages), sub-1200 m mountainous/hilly areas (16.67% villages), and sub-900 m piedmont/alluvial plains (81.16% villages).

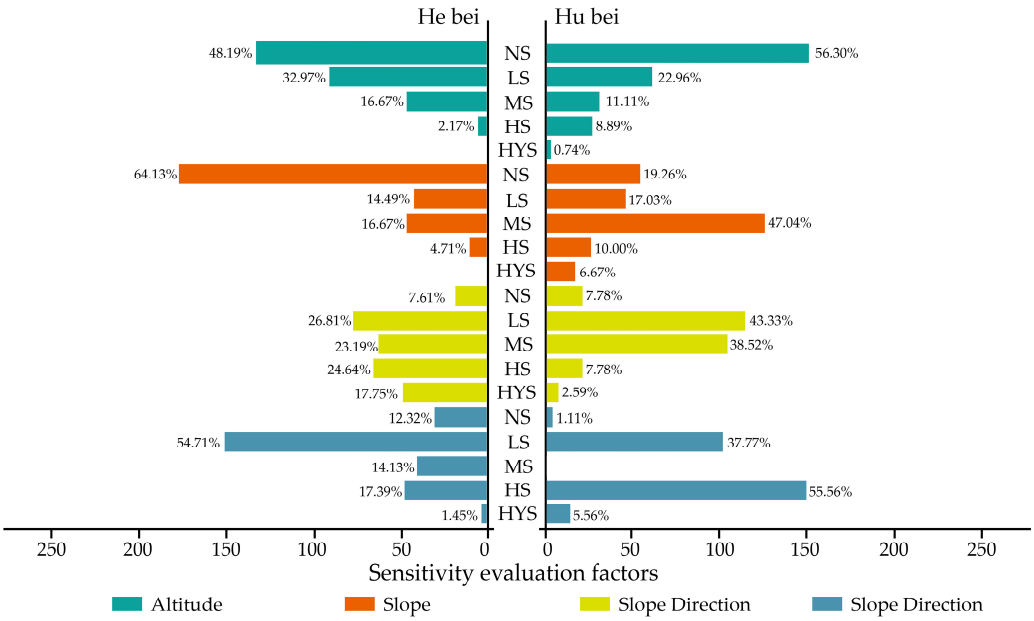


Figure 3. Comparison statistical analysis of the coupling between traditional villages and ecological sensitivity assessment in Hebei and Hubei Provinces (drawn by the authors). The *Y*-axis in this series of figures refers to the sensitivity levels illustrated in Table A2 and is expressed in each initial.

Hubei features peripheral mountains with central lowlands (elevation range: 34–3105 m) [61], where 99.26% of villages exist below 1800 m. Specifically, 22.96% are concentrated in the Dabie/Mufu Mountains (<900 m), and 56.30% occupy the Jianghan Plain/riverine plains (<600 m). Consequently, the traditional village distribution exhibited a negative correlation with elevation in both provinces.

(2) Slope

Using ArcGIS 10.2 and digital elevation model data, this study analysed slope characteristics in Hebei and Hubei Provinces, generating coupled distribution maps of traditional villages and slope gradients (Figures 3 and A1c,d). In Hebei, the terrain features moderately

sloped central areas, with flatter northern and southern regions. Here, 95.29% of the villages exist on slopes <25°, peaking at <8° (64.13%) and 15–25° (16.67%). Conversely, Hubei exhibited greater slope variability (0–79°), with 47.04% of the villages concentrated at 15–25°. The concentration of villages declines sharply beyond 25°, particularly above 35°. Only 16.67% exhibit steep slopes (>25°), while 83.34% exhibit gentle slopes (<25°). These patterns indicate a consistent preference for low-gradient terrain, although the settlement drivers differ. Hebei's plains support agriculture-intensive villages, whereas Hubei's mountainous terrain necessitates moderate-slope settlements.

(3) Slope Direction

Figures 3 and A1e,f illustrate the distribution of traditional villages relative to the slope in both provinces. Hebei exhibits a near-equitable aspect distribution (sunny-to-shady slope ratio of 0.85:1), indicating no directional preference. Conversely, Hubei shows pronounced aspect selectivity owing to its complex terrain and high precipitation: 51.11% of villages occupy sunny/semi-sunny slopes, versus 17.75% on shady slopes. This contrast reflects fundamental environmental differences. Hebei's flat topography and abundant sunlight diminish thermal resource dependence, enabling a balanced aspect distribution, whereas Hubei's mountainous landscape elevates solar access requirements, favouring sunny/semi-sunny slopes for extended daylight exposure.

(4) Surface Cover Type

Figures 3 and A1g,h illustrate the relationships between land-cover types and traditional village distributions. In Hebei, the predominant cover includes plain croplands and mountainous forests, with plateau grasslands in the northwest. Villages occur primarily within cultivated landscapes (54.71%), particularly in mountain plowlands and alluvial plain deposits. Approximately 31.52% of the area is forest/grassland mountainous terrain, whereas foothill plains are sparsely distributed (12.32%). Hubei exhibits distinct patterns dominated by central river plain croplands and peripheral mountain forests: 55.55% of villages are clustered near dense forests for natural protection, 37.77% occupy riverplain croplands, and 5.56% form waterside settlements utilising aquatic resources. A comparative analysis revealed cropland dominance in the plains of both provinces; however, Hubei's greater forest/river coverage correlated with higher ecological sensitivity. Settlement types diverge markedly; Hubei is concentrated in forest/cropland zones, whereas Hebei exhibits greater diversity, including grassland habitats.

3.2. Ecological Resilience Assessment of Traditional Villages

3.2.1. Watershed Buffer Zone

There are potential connections between the hydrographic networks and ecological sensitivity. Using multi-ring buffer analysis with concentric zones (0–1 km, 1–2 km, 2–3 km, 3–5 km, and ≥5 km), we mapped river proximity relationships (Figures 4 and A2a,b). In Hebei, most villages (67.03%) are more than 5 km away from rivers, with the remaining settlements concentrated near the Hutu, Fuyang, and Sanggan River basins: 13.04% within 1 km, 3.62% at 1–2 km, 5.43% at 2–3 km, and 10.87% at 3–5 km. Conversely, Hubei showed stronger hydrophilic tendencies, with 45.19% of villages within 5 km of waterways distributed across the following buffers: 10% (0–1 km), 8.52% (1–2 km), 12.22% (2–3 km), and 14.44% (3–5 km). The Yangtze River Basin villages cluster densely near the main channels and lakes, while the Qingjiang/Han River settlements form linear patterns along tributaries. In contrast to the overall water-oriented distribution of the province, the southwestern agglomeration zone exhibited minimal water affinity.

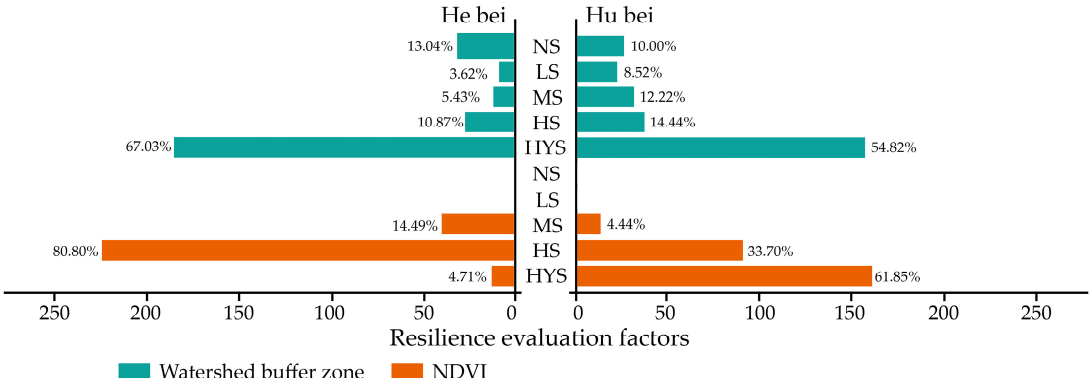


Figure 4. Comparison statistical analysis of the coupling between traditional villages and the resilience assessment in Hebei and Hubei Provinces (drawn by the authors).

3.2.2. Vegetation Cover

Vegetation coverage in Hebei and Hubei Provinces was calculated using the ArcGIS raster calculator on spectral vegetation bands. NDVI values, theoretically ranging from −1 to 1, were derived through floating-point conversion, yielding precise provincial distributions (Figures 4 and A2c,d). The NDVI ranges were −0.19 to 1 for Hebei and −0.04 to 1 for Hubei. These values were classified into five sensitivity tiers (−0.04–0.2, 0.2–0.4, 0.4–0.6, 0.6–0.8, and 0.8–1.0) according to model specifications. Statistical analysis of the relationship between vegetation cover and traditional village distribution revealed no villages in areas with inferior or poor vegetation cover, typically urban construction zones. Most of Hebei Province exhibited good vegetation coverage, with 80.8% of its traditional villages located there. Areas of superior coverage occur primarily in Chengde, Baoding, Xingtai, and Handan cities, although they are scattered; these ecologically critical zones contain only 4.71% of the villages. In Hubei Province, superior vegetation cover is concentrated in the western mountainous regions and the Shennongjia Forest District. This high-altitude area has a sparse population, low economic activity, and minimal development intensity; nevertheless, 61.85% of the traditional villages are distributed there. The central Yangtze River Plain in Hubei also demonstrates good vegetation cover, containing 33.7% of the villages. A comparison shows that Hubei exhibits higher overall vegetation coverage than Hebei, and Hubei's traditional villages exhibit a stronger association with densely vegetated areas. The plains in both provinces predominantly feature good or moderate cover; however, mountainous regions in Hubei possess higher vegetation density than those in Hebei.

3.3. Ecological Pressures Assessment of Traditional Villages

3.3.1. Spatial Distribution of Population Density

Population data for 2020 (1 km × 1 km grid cells) were analysed by superimposing traditional village coordinates and generating coupled maps of village distribution across population density gradients. Spatial grid-based population statistics ensured high accuracy and strong spatial matching. Using the 2020 Seventh Population Census, we calculated the average population density per prefecture-level city as a reference for the distribution patterns [62,63] (Tables A4 and A5; Figures 5 and A3a,b). Coupling maps revealed dense population clustering in urban centres and plains in both provinces. In Hebei, medium-high density areas (>500 persons/km^2) are concentrated in Shijiazhuang, Baoding, Xingtai, Handan, Langfang, and Tangshan. No traditional villages occur where density exceeds 5000 persons/km^2. Most villages (72.1%) occupy moderate-density zones (100–500 persons/km^2). Hubei exhibited a lower overall population density, with high-density areas confined to Wuhan and the surrounding urban regions. Traditional villages

are predominantly distributed in low-density zones (100–500 persons/km^2; 82.96%) and are absent where the density exceeds 1000 persons/km^2. Hebei's larger total population reflects its status as a populous province; its villages are often situated near cities but experience minimal demographic pressure. In contrast, Hubei's villages favour sparsely populated areas, including secluded ethnic minority settlements with stricter privacy requirements.

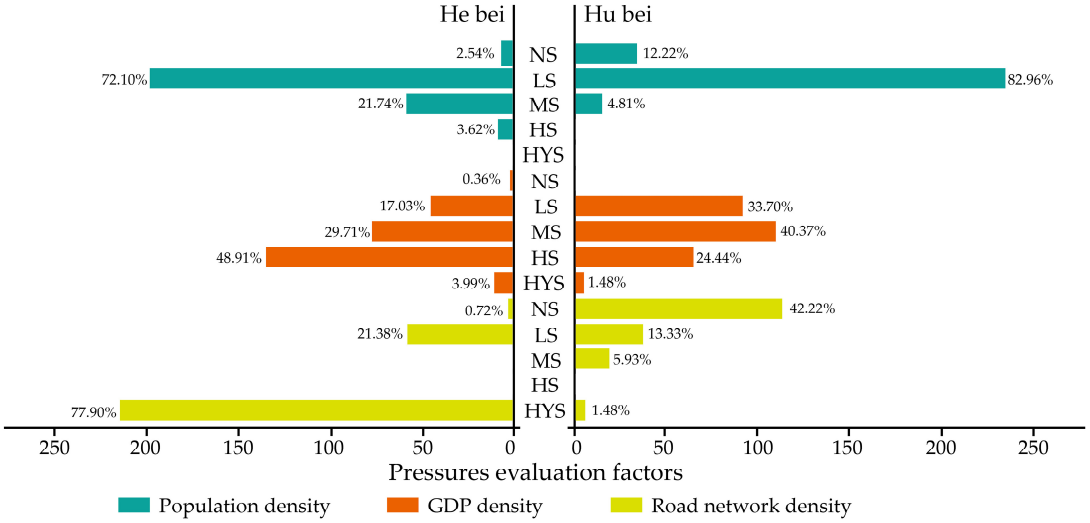


Figure 5. Comparison statistical analysis of the coupling between traditional villages and pressure assessment in Hebei and Hubei Provinces (drawn by the authors).

3.3.2. Spatial Distribution of GDP Density

The spatial distribution of traditional villages in the Hebei and Hubei Provinces was correlated with GDP and urbanisation. We superimposed the 2020 GDP data (1 km × 1 km grid) with village coordinates to analyse the economic influence on villages. Urbanisation data from prefecture-level cities (2020) were integrated to assess the correlations between economic sectors (agricultural, industrial, and service) and urbanisation, clarifying modern economic impacts (Tables A6 and A7; Figures 5 and A3c,d). In Hebei, the GDP peaks in the southeastern foothills and coastal plains showed a north–low and south–high gradient. Urbanisation rates are elevated in the Shijiazhuang, Zhangjiakou, and Handan regions, which have abundant traditional villages. Conversely, the highly urbanised Langfang and Tangshan are home to few villages. Most villages (78.62%) are clustered in moderately developed zones (GDP: 5–50 million yuan/km^2). A smaller subset (17.03%) exists in less developed areas (1–5 million yuan/km^2), particularly in Zhangjiakou. Hubei exhibited a predominantly negative correlation between economic development and village distribution. High-GDP regions (e.g., Wuhan, Xiaogan, and Jingmen) contain minimal villages, while economically disadvantaged areas (Enshi and Huanggang) contain numerous traditional settlements. This correlation weakens at a GDP level of 1–5 million yuan/km. Overall, Hubei cities exceed Hebei regarding total GDP and economic development balance. Both provinces showed positive GDP–urbanisation linkages with population density but negative associations with village density, which is particularly pronounced in Hubei.

3.3.3. Spatial Density of Road Networks

The composite road density was calculated by integrating the provincial and national highways, expressways, and railways. A spatial coupling analysis between the density results and traditional village coordinates revealed distribution relationships. Hebei's average road network density (2.9 km/km^2) exceeds that of Hubei's (1.8 km/km^2)

(Tables A8 and A9). Using urban areas as minimal units, the road network densities were classified into five categories using the natural breakpoint method to generate coupled maps (Figures 5 and A3e,f). Traditional villages exhibit low interference resistance and non-renewability, making transportation accessibility a key indicator of the frequency of external communication. High-density road networks exist in Hebei's Tangshan, Langfang, Cangzhou, Handan, and Hengshui, as well as in Hubei's Wuhan, Ezhou, Xiaogan, Huangshi, Tianmen, and Xiantao. These regions possess convenient transportation, which has spurred economic development and the replacement of traditional structures with modern buildings. Moderate-density areas (e.g., Hebei's Zhangjiakou and Hubei's Jingmen, Qianjiang, Xiangyang, Jingzhou, Xianning, and Suizhou) maintain village accessibility while minimising damage from frequent regional exchanges. A comparative analysis indicated that 77.9% of Hebei's traditional villages are located in high-density road networks with strong accessibility and active human activity. Conversely, 42.22% of Hubei's villages are clustered in low-density, less accessible regions.

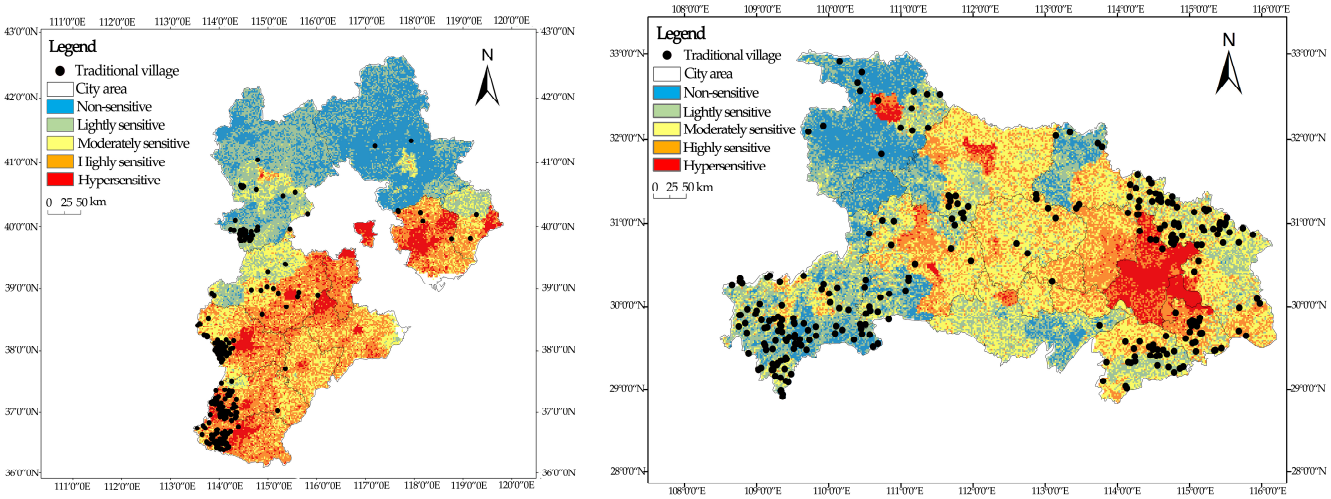
3.3.4. Traditional Village Kernel Density

The spatial distribution density of traditional villages in the Hebei and Hubei Provinces was calculated to analyse the clustering patterns. Hebei had the highest village counts in Xingtai, Shijiazhuang, Zhangjiakou, Handan, and Baoding. Hubei's top regions included the Enshi Prefecture, Huanggang, Xianning, Yichang, and Huangshi; however, Yichang was excluded from the top five density rankings because of its extensive administrative area (Tables A10 and A11). Kernel density estimation was employed to visualise the spatial aggregation patterns. Using ArcGIS tools, we generated raster datasets for the village distributions. Hebei's villages exhibited a highly uneven distribution and were predominantly concentrated in the western region, with four major clusters: Zhangjiakou, Shijiazhuang, Xingtai, and Handan. These clusters comprised approximately 90.6% of the province's traditional villages. Figure 5 shows Hubei's spatial kernel density distribution, revealing a "large dispersion and small agglomeration" pattern. Villages exist throughout the province, with distinct agglomerations in Enshi Autonomous Prefecture (southwest), Xiaogan–Huanggang (northeast), and Xianning–Huangshi (southeast). These areas collectively contain 78.5% of the villages in Hubei. Both provinces demonstrated spatial clustering; however, Hebei exhibited stronger aggregation, whereas Hubei showed a more scattered distribution (Figure A3g,h).

3.4. Superimposed Assessment Results of Ecological Sensitivity

Following the evaluation, the results were reclassified and converted into raster data. A multi-factor spatial overlay analysis was performed using the ArcGIS raster calculator with assigned index weights. The output raster was classified into five levels using the natural break (Jenks) method to generate ecological sensitivity zoning maps for both provinces. The mean ecological sensitivity index of Hebei (2.81) slightly exceeded that of Hubei (2.76) (Table A12; Figure 6). In Hebei, traditional villages generally showed high sensitivity, increasing spatially from northwest to southeast. Urban built-up areas exhibited peak sensitivity. The village sensitivity distribution included 44 extremely sensitive, 110 highly sensitive, 62 moderately sensitive, 50 slightly sensitive, and 10 insensitive villages. Highly sensitive villages were dominated by Xingtai (46.36%) and Handan (30%). Shijiazhuang's villages were moderately sensitive (64.52%), reflecting minimal human impact. Zhangjiakou contained the most resilient villages, with 80% insensitivity and 94% sensitivity. Hubei generally exhibited lower sensitivity, with most villages being moderately sensitive. The central region showed the highest sensitivity due to urbanisation (e.g., Wuhan: 42.86%; Huanggang: 23.4%), while the eastern and western areas were less

sensitive. Enshi Prefecture (southwest), an ethnic minority region with a well-preserved environment, hosts predominantly insensitive (55.17%) and moderately sensitive (48.65%) villages, representing the lowest sensitivity of the province.



Hebei's ecological sensitivity coupling results (**a**)

Hubei's ecological sensitivity coupling results (**b**)

Figure 6. Comparison of the coupling between traditional villages and ecological sensitivity zoning in Hebei and Hubei. (**a**) Coupling of ecological sensitivity zoning and traditional villages in Hebei Province; (**b**) Coupling of ecological sensitivity zoning and traditional villages in Hubei Province (drawn by the authors).

3.5. Quantitative Analysis of Spatial Drivers

To substantiate the descriptive analysis of driving factors, we conducted a quantitative assessment of spatial autocorrelation. The Global Moran's I value for the comprehensive ecological sensitivity index was 0.32 (Z-score = 15.67, $p < 0.001$) in Hebei and 0.25 (Z-score = 11.42, $p < 0.001$) in Hubei. These significantly positive values confirm a strong spatial dependence and clustering pattern of ecological sensitivity in both provinces, thereby justifying the need for further local analysis.

The LISA cluster maps reveal the precise location and type of significant spatial clusters. In Hebei, pronounced High–High clusters (hotspots) are identified in the southern prefectures of Xingtai and Handan, indicating spatial aggregation of highly sensitive villages. These areas coincide with regions of dense population, extensive road networks, and intense economic activity. By contrast, Low–Low clusters (coldspots) are predominantly located in the northwestern mountainous regions of Zhangjiakou, characterised by lower anthropogenic pressure.

In Hubei, the spatial pattern is more dispersed. A significant High–High cluster is observed in the central region, encompassing parts of Wuhan and Huanggang, aligning with the core urbanised and economically developed zone. In contrast, extensive Low–Low clusters dominate the western Enshi Prefecture and parts of the eastern mountain ranges, areas characterised by strong natural ecology and limited human disturbance.

This quantitative spatial autocorrelation analysis demonstrates that the distribution of ecological sensitivity is non-random but structurally shaped by distinct regional dynamics: in the north, by the spatial concentration of socioeconomic factors, and in the south, by the interaction between centralized economic cores and peripheral ecological barriers.

4. Discussion

4.1. Exploration of the Distribution Pattern of Ecological Sensitivity in Traditional Villages in the South and North

Non-sensitive zones exist primarily in mountainous/hilly regions. These areas are economically underdeveloped, sparsely populated, and poorly connected in terms of transport access. Their landscape ecology exhibited a slow environmental response and high resilience. In Hebei, non-sensitive villages are sparsely distributed in the northern plateau mountains of Chengde and Zhangjiakou. In Hubei, they cluster in Shiyan City and parts of Enshi, which are both economically underdeveloped; there are few villages in this area.

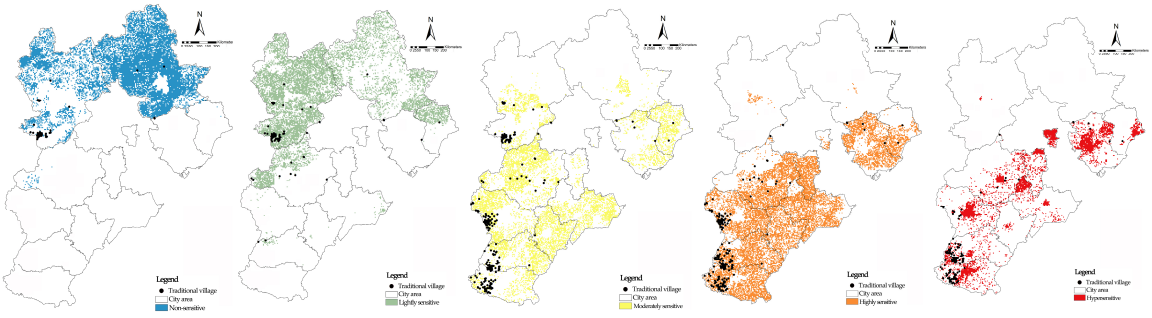
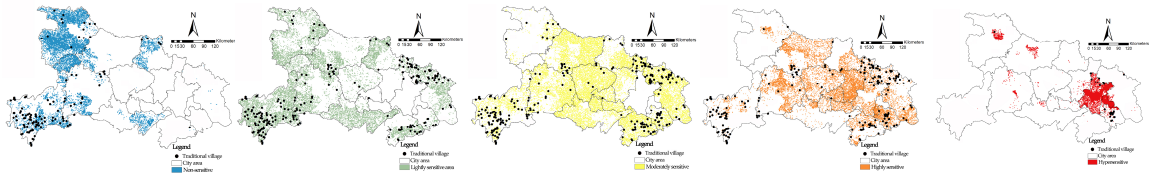
Lightly sensitive zones typically lie outside the urban cores. These are farming villages integrated with the local terrain, often surrounded by forests and fields. In Hebei, they are concentrated in southern Zhangjiakou, northern Baoding, and Qinhuangdao and comprise 20% of the provincial villages. In Hubei, they are found in western Suizhou, Enshi, and southwestern Yichang and account for 25% of the villages. Hubei's zones feature mountainous forest settlements with limited plains and villages near water.

Moderately sensitive zones exhibit clear transitional characteristics. In Hebei, these zones cover eastern Zhangjiakou, central Baoding, Shijiazhuang, western Xingtai, and eastern Cangzhou. Villages occupy foothill plains or waterside locations, with forested elevated terrain and developed transport near urban areas, yet they show low population activity. The village density resembles that of the lightly sensitive zones. In Hubei, the distribution is more dispersed, spanning the eastern regions and parts of Shiyan, Xiangyang, Yichang, and Enshi. Villages are concentrated in eastern areas where dense water networks and mountain proximity mitigate seasonal flooding, and forest and cropland support dense clusters in the northeastern/southeastern foothill plains, containing 50% of the provincial villages. Shared traits include foothill plain locations, limited population activity despite urban proximity, favourable environments, and moderate hydrophilicity (stronger in Hubei). Land cover differs significantly; woodland and grassland dominate Hebei, whereas Hubei features more cropland and woodland, with substantially higher overall village numbers.

Highly sensitive zones are concentrated along urban fringes and in economically advanced areas. In Hebei, these zones form the largest category, predominantly in the southern cities. They feature low-lying plains with abundant water resources, croplands, and dense transportation networks. Functioning as economic hubs, they contain 50% of the provincial villages. Two clusters emerge: Handan and Xingtai's western mountains. The Hubei zones exist in the central riverine plains with flat paddy landscapes. Villages show a scattered distribution yet high population/economic activity. The village numbers approximate the lightly sensitive zones. Common traits include superior environmental conditions, abundant land and water resources, and strong economic conditions. Spatially, villages typically occupy mountainous foothills distant from urban cores. A key provincial contrast exists: Hebei exhibits clustered, non-hydrophilic villages, whereas Hubei features dispersed settlements with pronounced hydrophilicity. This reflects the typical northern versus southern patterns. Hebei has the highest absolute village count in this category.

Hypersensitive zones are concentrated in central urban areas and are characterised by high urbanisation, intensive economies, and ecological fragility. Village numbers are significantly low in these areas in both provinces. The remaining peri-urban villages primarily serve urban populations and industries, exhibiting advanced modernisation levels (see Table 3).

Table 3. Ecological sensitivity distribution in traditional villages.

Province	Non-Sensitive Area	Lightly Sensitive Area	Moderately Sensitive Area	Highly sensitive Area	Hypersensitive Area
Hebei					
Sensitive area size(%)	22.21%	21.56%	19.22%	27.46%	9.55%
Hubei					
Sensitive area size(%)	15.30%	25.12%	34.02%	19.87%	5.69%

Note: The number of villages distributed in the figure are for reference purposes. Accurate village data are presented in Table A12.

4.2. Exploration of Spatial Mechanisms Affecting the Ecological Sensitivity of Traditional Villages

This study analysed the natural and anthropogenic influences on village ecological sensitivity using multi-source data and ArcGIS.

Villages are generally located on flat or sloping terrain at elevations < 600 m. In Hebei, villages concentrated in low-relief hilly transition zones and plains show no slope orientation preference [64]. In Hubei, settlements cluster in mountainous/hilly eastern/western regions with steeper slopes and distinct south-facing preference [65]. Both provinces show moderate water proximity, although Hubei show stronger proximity. Villages are located away from major rivers but are closer to minor tributaries for safety [66]. Vegetation coverage indicates favourable conditions, with Hubei being significantly higher than Hebei. The land cover differs markedly; Hebei villages occupy agricultural flatlands, whereas Hubei settlements are located in forested terrain with farmland, reflecting the abundant of forest resources.

The traditional Chinese village distribution exhibits contradictory patterns in the literature, showing concentrations in either underdeveloped areas with poor infrastructure [67,68] or industrialised zones with comprehensive facilities [69]. Our findings reconcile both perspectives. Hebei's villages exist in low-density regions with high economic/urbanisation levels and developed infrastructure, whereas Hubei's villages occupy remote areas with low economic development and sparse transportation. These divergent patterns reflect the fundamental differences in regional production systems and livelihood environments.

Optimal traditional village conservation occurs in sunny, low-altitude flatlands with mountain-forest and river-adjacent buffers. Hubei villages are clustered on gentle slopes near water, showing higher natural ecological sensitivity than Hebei villages. Human-land interaction underpins urban–rural sustainability. Urbanisation drives sociotechnological progress; however, it also disrupts villages and compromises their integrity. Thus, socioeco-

nomic factors outweigh natural factors in sensitivity weighting [70]. Hebei villages exhibit greater socioeconomic sensitivity than Hubei villages.

The Qinling–Huai River demarcates northern and southern China. Hebei's traditional villages exemplify the northern settlement patterns. This geography supports agriculture and industrial–urban development.

Hebei cities show divergent resilience trajectories; key development cities (e.g., Xingtai, Cangzhou, and Zhangjiakou) exhibit increasing environmental resilience, whereas industrial transition cities (e.g., Shijiazhuang, Hengshui, and Handan) follow a U-shaped pattern [71]. Frequent human activities affect village ecology. Provincial sensitivity comparisons confirm this; villages in densely populated, well-connected areas (e.g., Shijiazhuang and Handan) show higher sensitivity than those in Zhangjiakou, despite comparable natural conditions.

Hubei Province's favourable geography in the southern non-cold regions provides substantial natural advantages and policy support, mitigating the socioeconomic pressure on rural ecosystems. Rural resilience in key urban clusters increased steadily from 2005 to 2020, averaging 8.26% annual growth [72]. Topography-aligned village construction patterns enhance the long-term sustainability prospects.

Key spatial mechanisms driving north–south village disparities:

1. Water resources: Southern precipitation and discharge exceed northern levels. Critical northern scarcity (Beijing–Tianjin–Hebei water resources = 1/9 of the national average [73]) prompts reservoir construction, causing ecological damage.
2. Contrasting usage: Southern circular agriculture (e.g., Sanji ponds) versus northern drought crops/rainwater harvesting. Northern groundwater extraction fragments rivers.
3. Climate risks: Northern villages face cold waves/soil erosion; southern villages experience > seven annual storm surges [74]. The northern disaster exposure exceeded that in the southern region. Village location reflects hazard mitigation.
4. Economic models: Northern resource-based economies cause pollution by relying on protection policy constraints. Southern market-driven models foster tourism (>40% village empowerment) and urban–rural integration [75,76].
5. Interactive and Nonlinear Effects: Emerging evidence indicates synergistic interactions and nonlinear dependencies among key drivers. High GDP density, combined with dense road networks, amplifies environmental pressures through increased resource extraction and human mobility. Furthermore, population density may exhibit threshold behaviour, with ecological sensitivity rising sharply beyond approximately 500 persons/km^2, suggesting critical constraints on local environmental carrying capacity.
6. Fundamental contrast: Northern technology/policy transforms nature and southern circulation/integration achieves symbiosis.

Beyond the independent effects of individual drivers, our spatial analysis reveals critical interactions in which combined factors amplify or modify ecological sensitivity in nonlinear ways. These synergistic effects help explain pronounced spatial clustering and are not apparent when examining factors in isolation.

First, socioeconomic pressures exhibit clear amplification effects. For instance, in the high-sensitivity hotspots of southern Hebei, the combination of high GDP density and high road network density creates compounded pressure. Economic activity (GDP) drives infrastructure expansion (road density), which in turn facilitates resource extraction and human mobility, producing a self-reinforcing cycle of ecological disturbance. This synergy accounts for sensitivities that exceed the sum of the individual factors.

Second, natural factors can modulate the impact of human pressure. In Hubei, dense vegetation cover (high NDVI) and complex topography in western mountainous areas (e.g.,

Enshi) appear to mitigate anthropogenic pressures, even when road density is moderate. Conversely, the central plains, with flatter terrain and weaker vegetative buffering, are more vulnerable to comparable levels of economic and population pressure. Thus, the effect of socioeconomic drivers is contingent on the underlying natural landscape.

Third, threshold dynamics emerge with population density. The spatial coupling analysis (Section 3.3.1) indicates that ecological sensitivity increases markedly once population density exceeds approximately 500 persons/km^2. Beyond this threshold, the marginal impact of additional population pressure on sensitivity may become significantly greater.

Taken together, these interactions—synergistic amplification, buffering modulation, and threshold effects—form a more complex explanatory framework than linear, single-factor models. They elucidate why the spatial mechanisms in Hebei (dominated by synergistic socioeconomic pressures) and Hubei (characterised by the interplay between centralised pressure and peripheral natural buffering) are fundamentally divergent, as conceptualised in Figure 7. This confirms the marked geographic differentiation of China's traditional villages exhibit significant geographic differentiation and their "south-more/north-less" distribution [77].

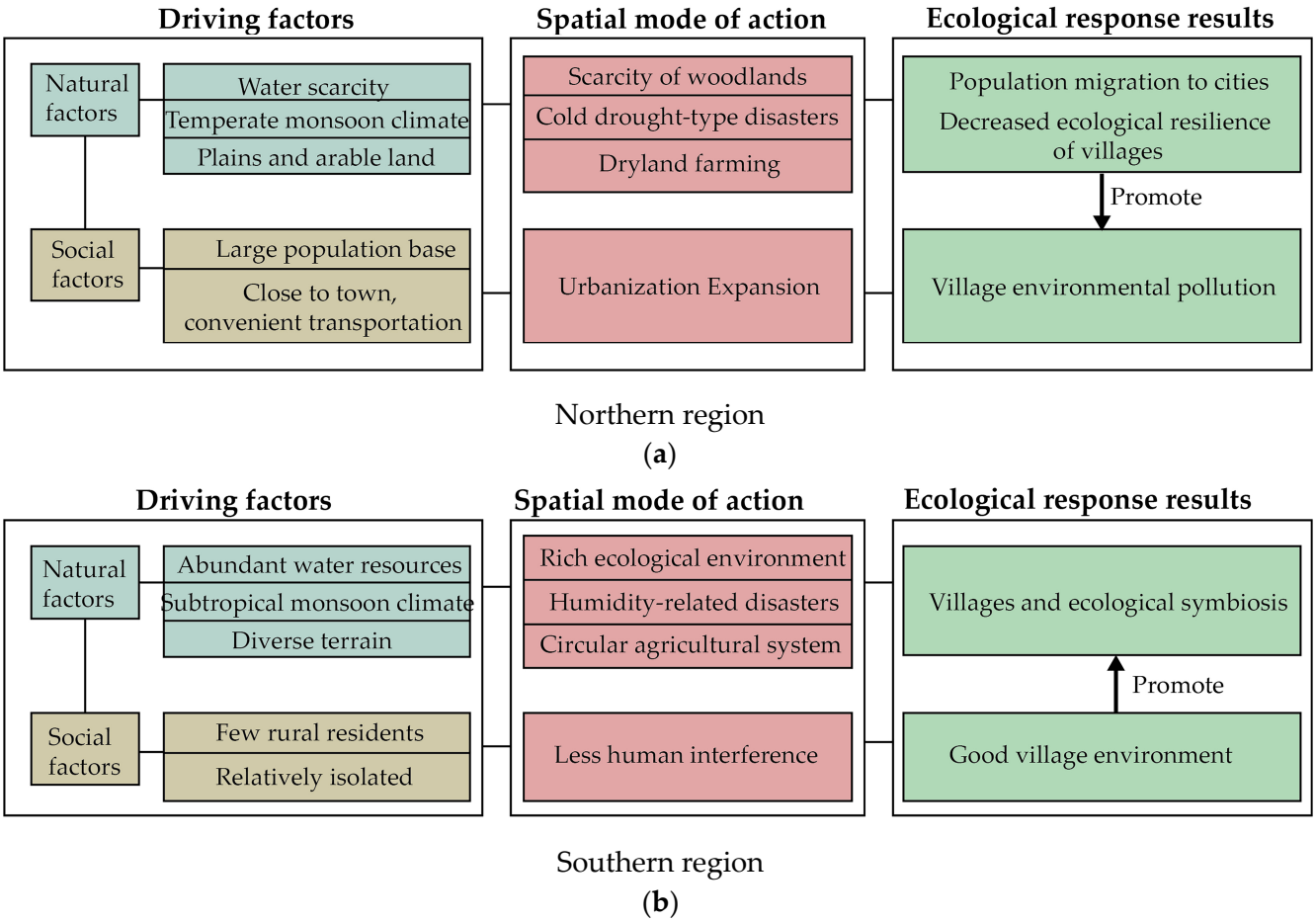


Figure 7. Analysis of spatial mechanisms of traditional villages in the northern and southern regions. (**a**) Northern region; (**b**) southern region (drawn by the authors).

4.3. Data-Driven Protection Strategy

China's traditional village zoning protection remains under development and lacks comprehensive regional studies and comparisons of spatial mechanisms [78]. The holistic ecological–social coordination also remains unresolved [79]. Protection strategies must be

tailored to the distinct ecological sensitivity patterns and drivers quantified in this study for each province.

In Hebei Province, the high ecological sensitivity, particularly in the southern High-High clusters such as Xingtai (46.36% of highly sensitive villages) and Handan (30%), is strongly associated with intense anthropogenic pressure. This is evidenced by the province's high average road network density (2.9 km/km^2, Table A8), which is the highest-weighted factor in the evaluation system (weight = 0.29, Table 2). Therefore, interventions should prioritise mitigating socioeconomic impacts by using the sensitivity zoning map (Figure 6a) to enforce strict development boundaries around clustered villages and to promote green infrastructure retrofitting along high-density transportation corridors.

In Hubei Province, where sensitivity is generally lower and more spatially dispersed, strategies can leverage natural advantages. The central High–High cluster aligns with areas of higher population and economic activity, where watershed buffer zones (Section 3.2.1) should be applied to regulate development in flood-prone plains. For the extensive Low–Low clusters in western Enshi—which correlate with superior vegetation cover (NDVI $\geq$ 0.8, Section 3.2.2) and lower road density—policy should focus on maintaining low anthropogenic pressure while developing cultural–ecological corridors based on kernel density maps to support sustainable tourism without fragmenting the landscape.

The empirical findings, supported by spatially explicit sensitivity zoning, provide a robust evidence base for precision conservation, enabling policymakers to target interventions to the dominant drivers in each region.

Northern villages are divided into two classes by urban proximity. The first is high-sensitivity urban-proximate villages, which exhibit clustered distributions and strong connectivity, but low ecological resilience. These require digital twin-enhanced monitoring of intelligent databases and disaster simulations to inform restoration standards [80]. Modernised intervillage ties should maintain cultural links while creating new industrial connections to prevent disruption and enable urban–rural coordination [81,82]. The second class is moderate sensitivity remote villages. These have stronger ecological foundations. Protection-oriented strategies with supplemental transformation policies should be prioritised. Photovoltaic–grass grids (renewable energy + sand control), intelligent rainwater harvesting, and photovoltaic sewage treatment should be implemented to enhance economic development and pollution control should be implemented [83].

Traditional southern villages exhibit superior ecological conservation compared with their northern counterparts. Future studies should employ machine learning for large-scale classification and tailored protection pathways [84]. Mountain villages with limited access may introduce compatible industries for spatial revitalisation [85]. Combined with UAVs, this enables the automated detection of pollution and illegal fishing [86]. The flatland villages resemble northern high-sensitivity settlements, suggesting cross-regional strategic adaptations. Essential interventions include flood disaster mitigation in ecological planning and carbon fibre reinforcement for wooden structures. Minority villages face cultural pressures from urbanisation and tourism. Collaborative solutions include AI-enhanced cultural tourism laboratories and digital nomad hubs, potentially informing northern minority conservation (Figure 8).

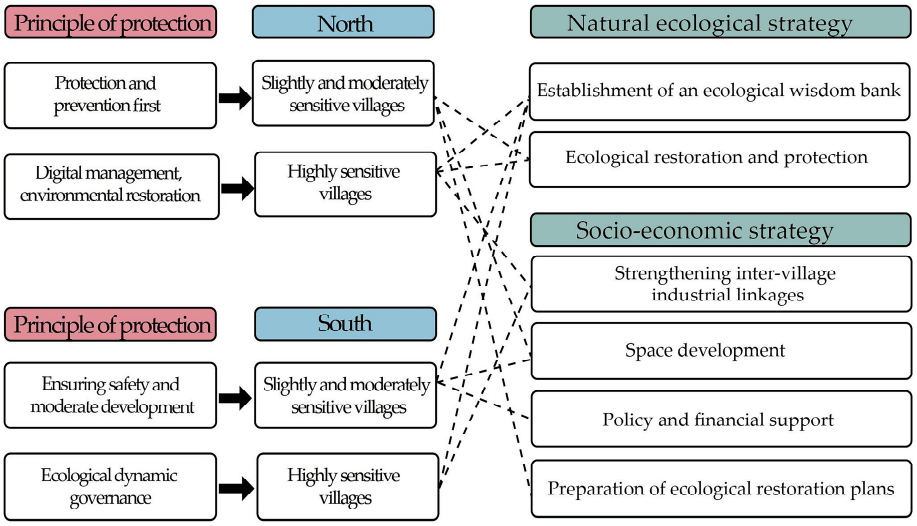


Figure 8. Path map of traditional village ecological zoning protection strategy (drawn by the authors).

5. Conclusions

This study developed an integrated SRP-AHP-GIS framework to comparatively assess the ecological sensitivity of traditional villages in northern (Hebei) and southern (Hubei) China. The analysis yields three principal findings and implications.

(1) Significant North–South Disparity in Sensitivity and Drivers: The comprehensive ecological sensitivity index was 10% higher in Hebei (2.81) than in Hubei (2.76). More critically, the spatial distribution and primary drivers diverged substantially. In Hebei, 60% of villages fell into high- or extreme-sensitivity zones, driven predominantly by socioeconomic pressure, particularly high road density (2.9 km/km^2). In contrast, Hubei's sensitivity was more moderate, with most villages (59.32%) in low- to moderate-sensitivity zones, and patterns were more influenced by natural environmental conditions.

(2) Quantified Validation of Spatial Mechanisms: Spatial autocorrelation confirmed the clustering of ecological sensitivity. Global Moran's I values were 0.32 for Hebei and 0.25 for Hubei, confirming significant spatial dependence. LISA cluster maps precisely identified hotspots: in Hebei, hotspots were concentrated in the southern prefectures of Xingtai and Handan, which account for over 46% and 30% of the province's highly sensitive villages, respectively. These results quantitatively validate the intense aggregation of sensitivity in areas of high anthropogenic pressure.

(3) Hierarchical Conservation Framework: The findings translate into a hierarchical conservation framework that prioritises interventions based on the dominant drivers identified in each sensitivity zone. For governments, this study provides a tool and an evidence-based decision-making workflow. For instance, in the high-sensitivity clusters of Hebei (e.g., Xingtai and Handan), where road network density is the paramount driver, the immediate priority is targeted monitoring of infrastructure expansion rather than broad-scale ecological simulation. The proposed strategies (e.g., digital twin monitoring and green infrastructure) are presented as a suite of context-specific options whose applicability and sequence of implementation are determined by the local sensitivity profile and primary pressures revealed in our maps. This moves conservation planning from a one-size-fits-all approach to a cost-effective, prioritised action plan.

In summary, this research conclusively demonstrates that effective conservation policies for traditional villages must be geographically differentiated and data-driven. The methodological framework provides a scientific basis for region-specific ecological governance, contributing to the sustainable revitalisation of rural landscapes in China and beyond.

This study has several limitations. Some ecological sensitivity remains in the ecological sensitivity assessment model, as the construction of the evaluation system, while reflecting regional variation, still involves subjectivity. Provincial sampling constrains generalisability, particularly for special village types (e.g., ethnic minority villages). Future studies should increase the sample size and apply machine learning to include diverse quantitative methods that enable a comprehensive comparison of the spatial resilience mechanisms across northern and southern China.

Author Contributions: Conceptualization, X.J. and M.Q.; methodology, X.J.; software, M.Q.; validation, M.Q. and X.J.; formal analysis, M.Q.; investigation, M.Q.; resources, J.L.; data curation, M.Q.; writing—original draft preparation, M.Q.; writing—review and editing, M.Q.; visualization, M.Q.; supervision, B.H., S.W. and J.J.; project administration, Y.L.; funding acquisition, X.J. All authors have read and agreed to the published version of the manuscript.

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

Abbreviations

The following abbreviations are used in this manuscript:

AHP	Analytic hierarchy process
NDVI	Normalised difference vegetation index
SRP	Sensitivity–resilience–pressure

Appendix A

Table A1. Statistics on traditional villages in the northern and southern regions.

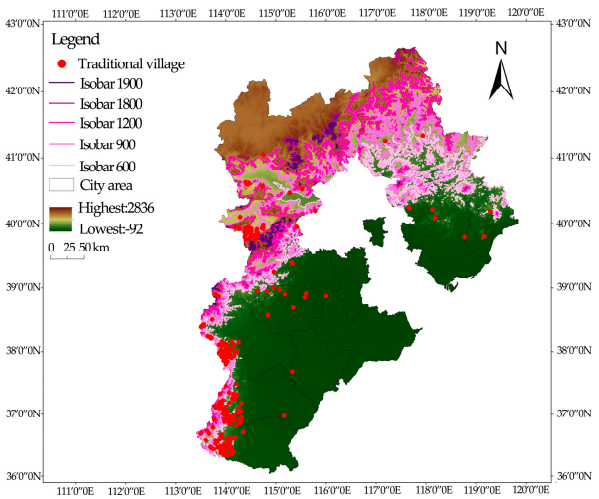
	Name of Province	Number of Villages	Name of Province	Number of Villages	Name of Province	Number of Villages
Northern Region	Heilongjiang Province	26	Beijing City	26	Shandong Province	167
	Jilin Province	23	Tianjin City	8	Shanxi Province	620
	Liaoning Province	45	Hebei Province (study area)	276	Shaanxi Province	182
	Inner Mongolia Autonomous Region	62	Henan Province	275	Ningxia Autonomous Region	26

Table A1. *Cont.*

	Name of Province	Number of Villages	Name of Province	Number of Villages	Name of Province	Number of Villages
Southern Region	Jiangsu Province	79	Hunan Province	704	Jiangxi Province	413
	Zhejiang Province	701	Hubei Province (study area)	270	Hainan Province	76
	Shanghai City	10	Guangdong Province	413	Sichuan Province	396
	Fujian Province	552	Guangxi Province	223	Yunnan Province	778
	Guizhou Province	757	Chongqing City	166	Anhui Province	470

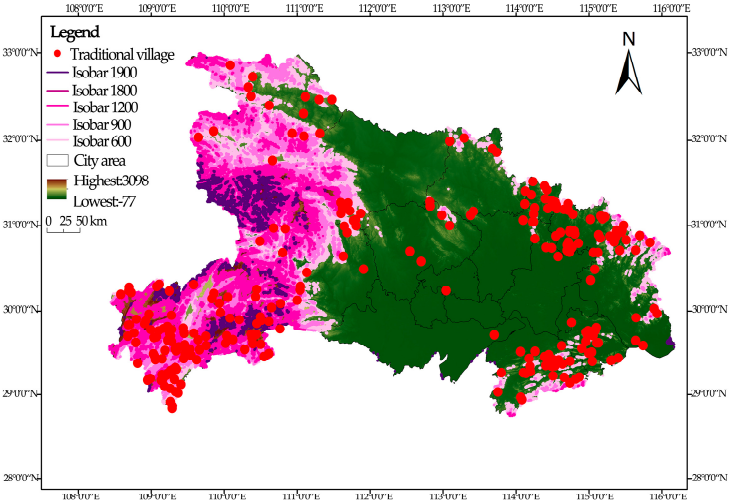
Table A2. Construction of the Evaluation Index System.

First Factor	Secondary Factor	Definition
Ecological sensitivity	Altitude	Absolute altitude
	Slope	The steepness of the village's location
	Slope Direction	The orientation that slope faces
	Surface cover type	The covering state of the land surface
Resilience	Watershed buffer zone	The straight-line distance from the village to the river
	Plant cover	The projection of vegetation perpendicular to the ground
Pressure	Spatial density of road networks	Regional road accessibility
	Spatial distribution of population density	The population situation within the region
	Spatial distribution of GDP density	Overall economic output value
	Traditional villages kernel density	The degree of concentration of villages



Altitude coupling results

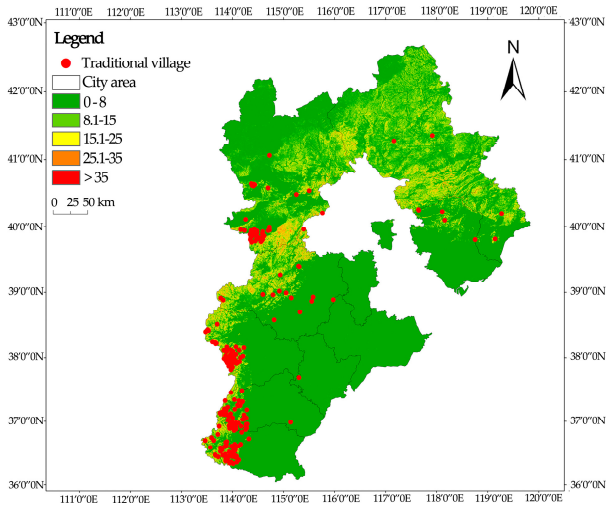
(**a**)



Altitude coupling results

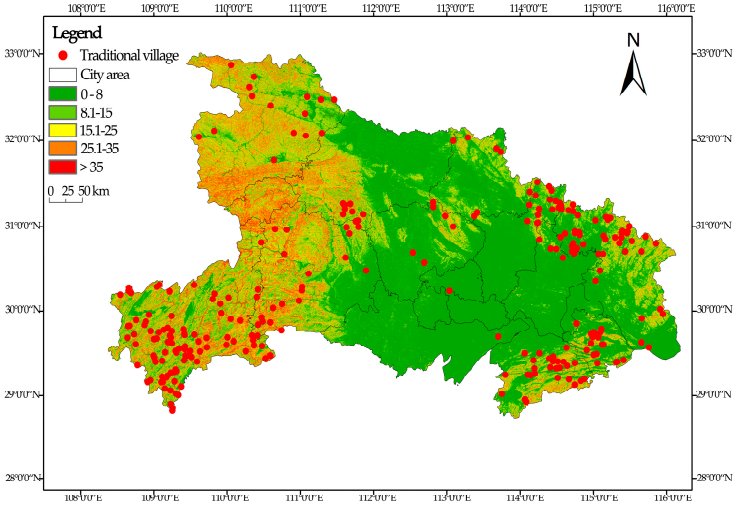
(**b**)

Figure A1. *Cont.*



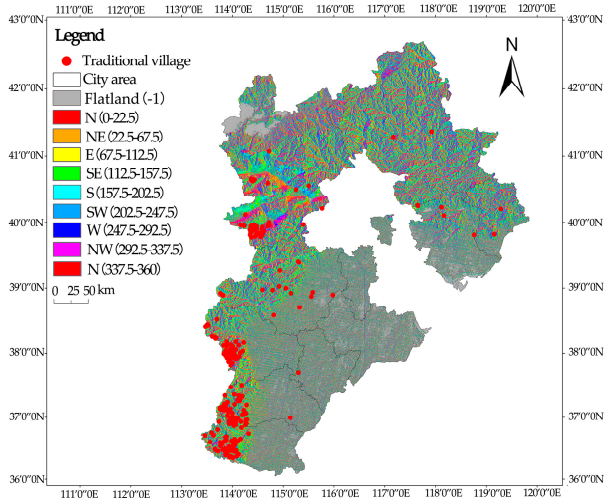
Slope coupling results

(**c**)



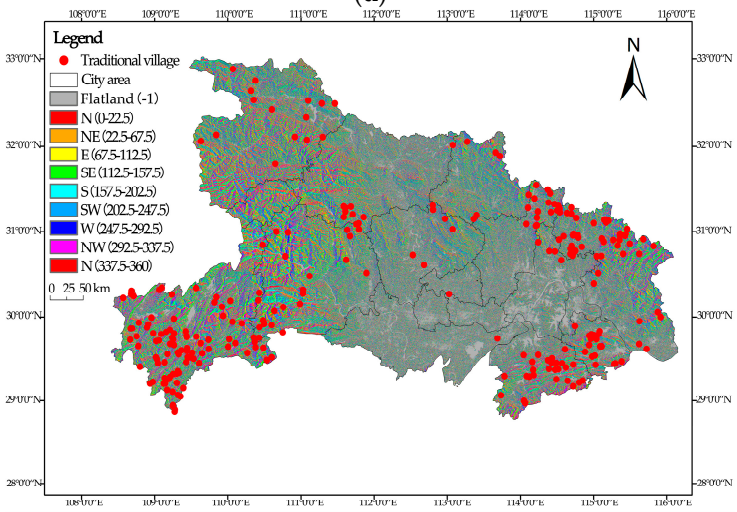
Slope coupling results

(**d**)



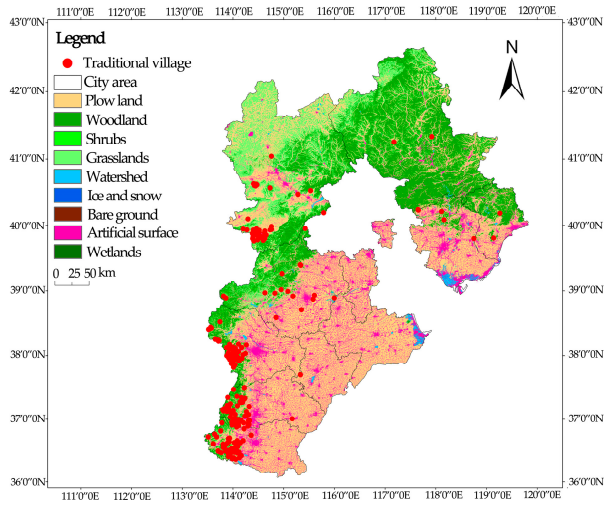
Slope direction coupling results

(**e**)



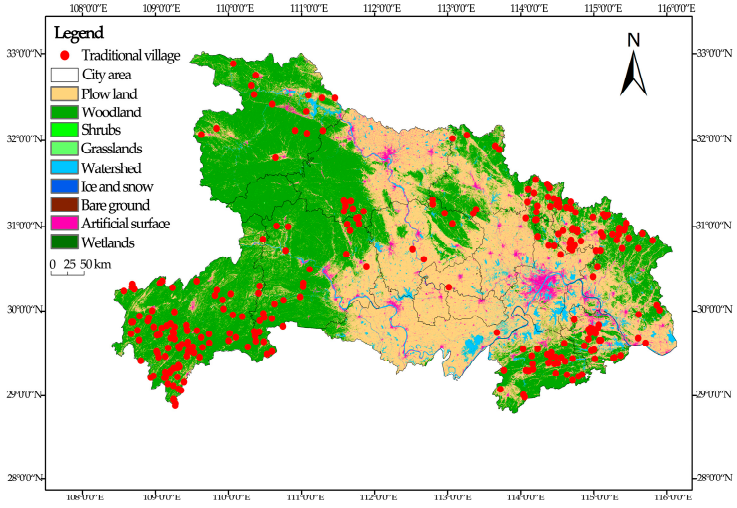
Slope direction coupling results

(**f**)



Surface cover coupling results

(**g**)

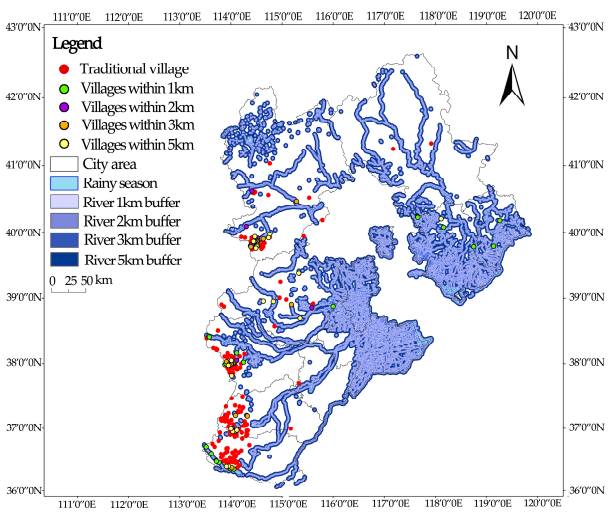


Surface cover coupling results

(**h**)

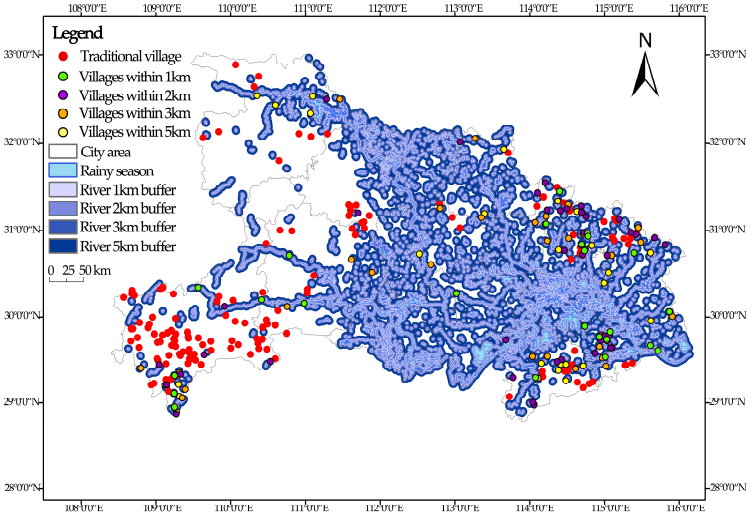
Figure A1. Coupling analysis of ecological sensitivity assessment in traditional villages. (**a**) Coupling of traditional villages and altitude terrain; (**b**) coupling of traditional villages with altitude contours

in Hebei Province; (**c**) coupling of traditional villages and slope in Hebei Province; (**d**) coupling of traditional villages and slope in Hubei Province (drawn by the authors); (**e**) coupling of traditional villages and slope direction in Hebei Province; (**f**) coupling of traditional villages and slope direction in Hubei Province (drawn by the authors); (**g**) coupling of traditional villages and surface cover in Hebei Province; and (**h**) coupling of traditional villages and surface cover in Hubei Province (drawn by the authors). Note: Based on the standard map produced by the Ministry of Natural Resources standard map service website GS (2024) 0650, with no modifications to the boundaries of the base map.



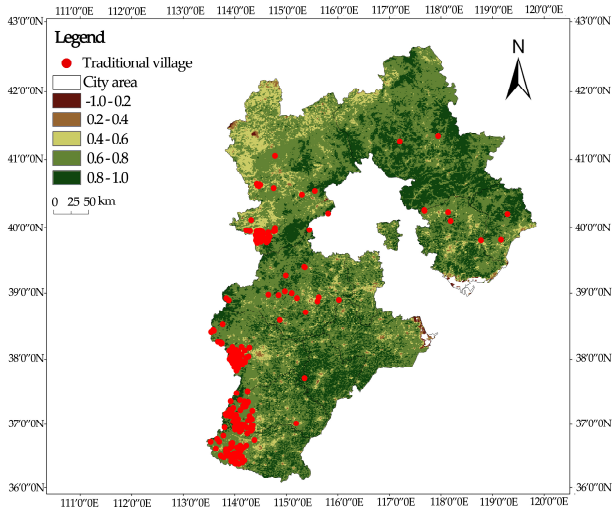
Water system buffer coupling results

(**a**)



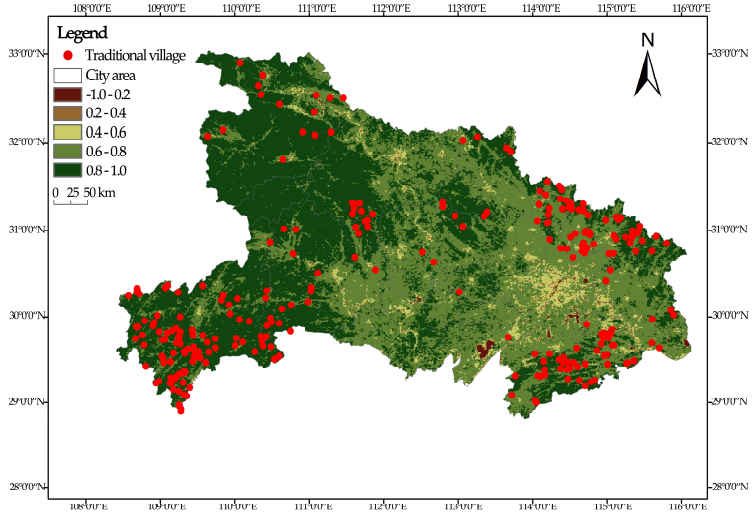
Water system buffer coupling results

(**b**)



NDVI coupling results

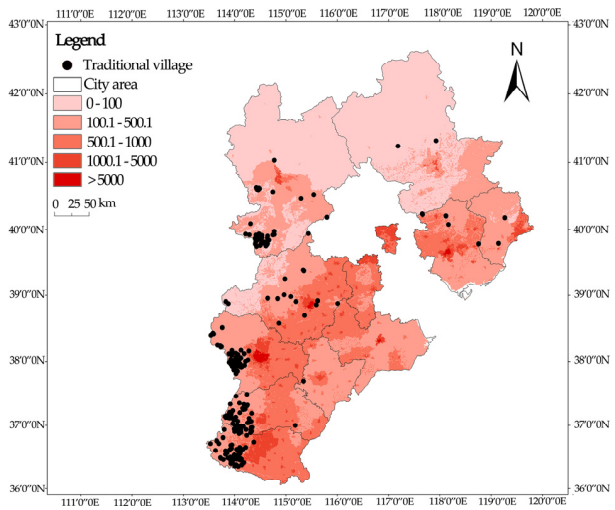
(**c**)



NDVI coupling results

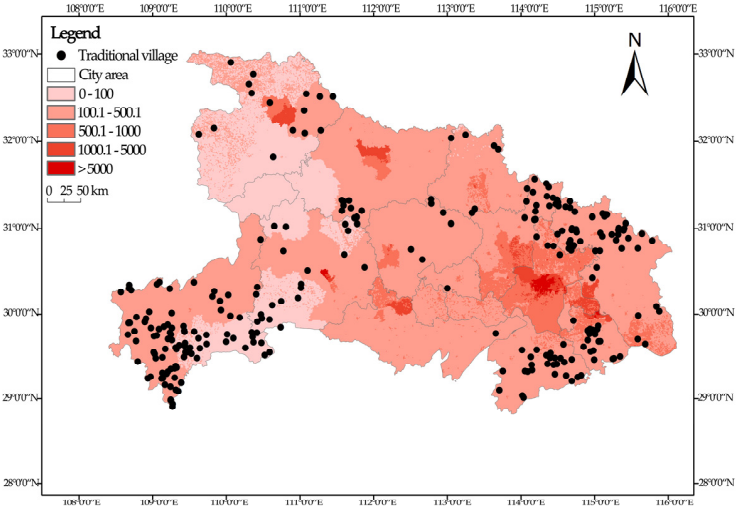
(**d**)

Figure A2. Coupling analysis of ecological resilience assessment in traditional villages. Comparison of the coupling between traditional villages and water system buffer in Hebei and Hubei Provinces. (**a**) Coupling of traditional villages and water system buffer in Hebei Province; (**b**) coupling of traditional villages and water system buffer in Hubei Province; (**c**) coupling of traditional villages and NDVI in Hebei Province; and (**d**) coupling of traditional villages and NDVI in Hubei Province (drawn by the authors). Note: Based on the standard map produced by the Ministry of Natural Resources standard map service website GS (2024) 0650, with no modifications to the boundaries of the base map.



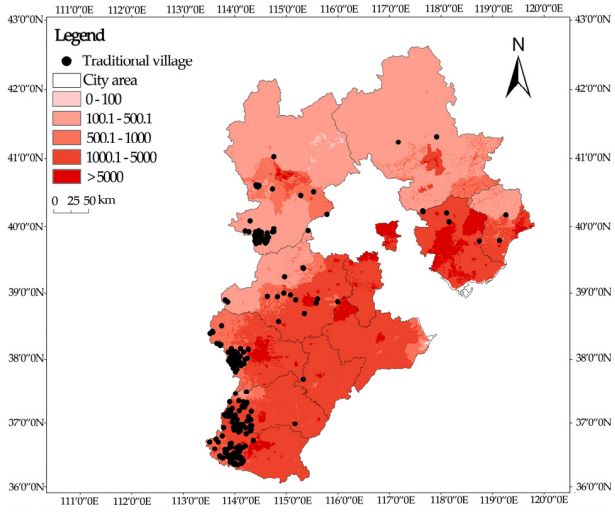
Population density coupling results

(**a**)



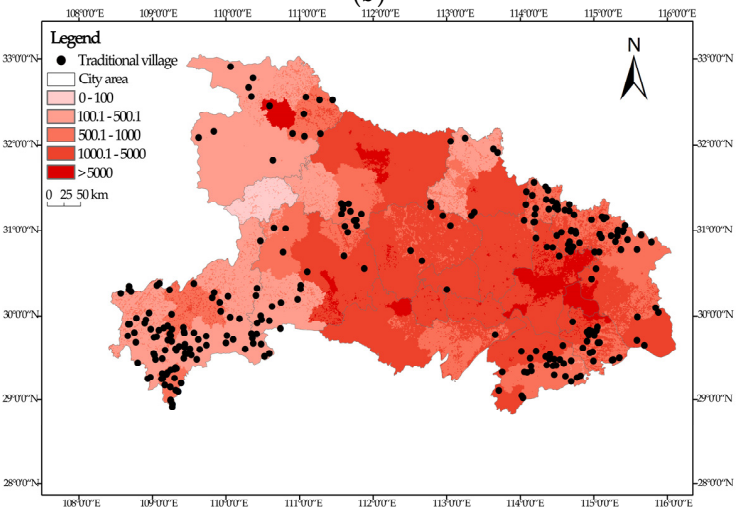
Population density coupling results

(**b**)



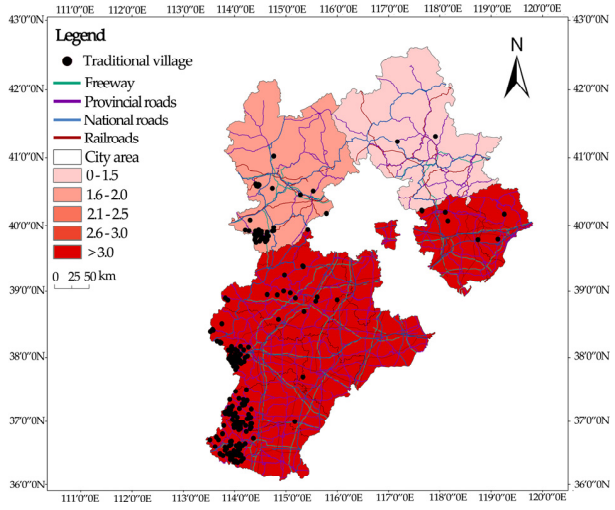
GDP density coupling results

(**c**)



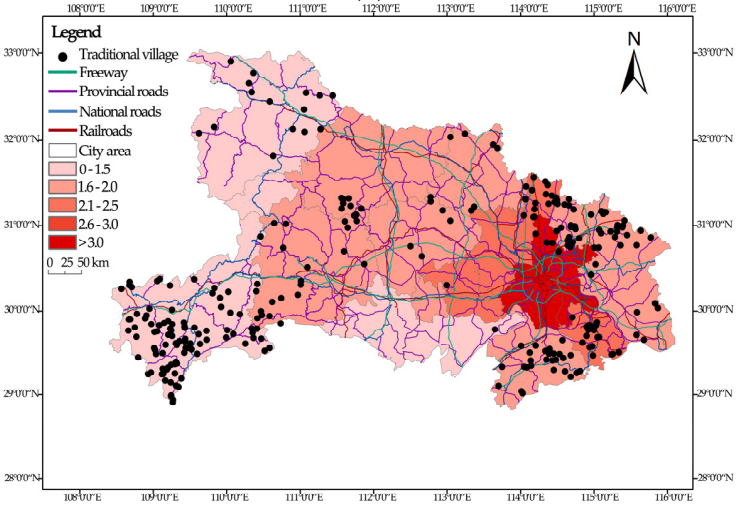
GDP density coupling results

(**d**)



Road network density coupling results

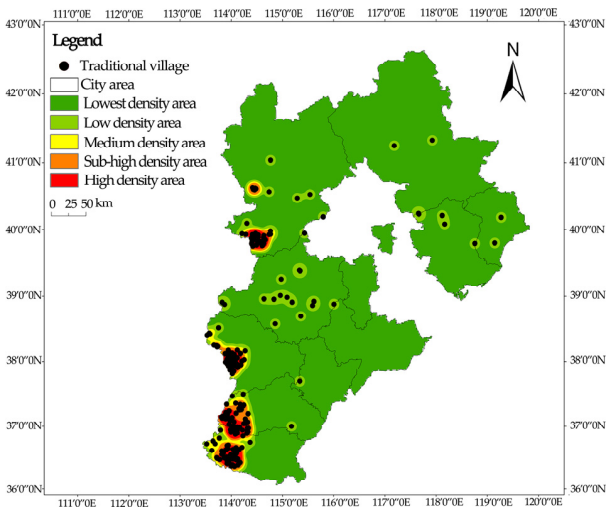
(**e**)



Road network density coupling results

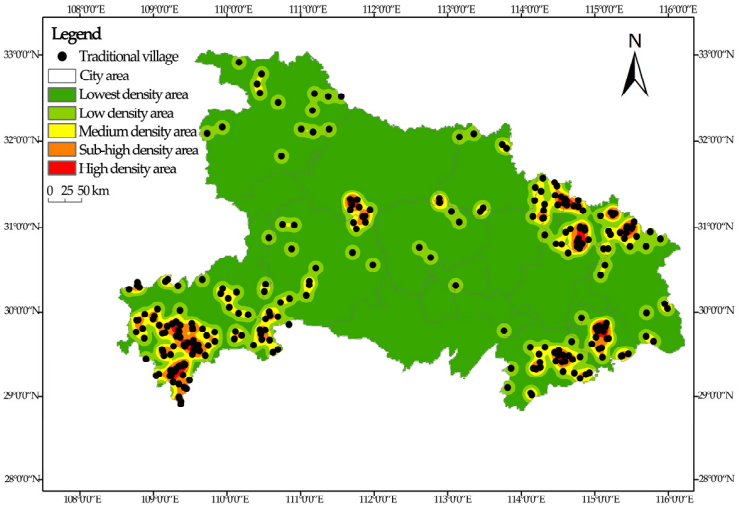
(**f**)

Figure A3. *Cont.*



Kernel density coupling results

(**g**)



Kernel density coupling results

(**h**)

Figure A3. Coupling analysis of ecological pressures assessment in traditional villages. (**a**) Coupling of traditional villages and population density in Hebei Province; (**b**) coupling of traditional villages and population density in Hubei Province; (**c**) coupling of traditional villages and GDP density in Hebei Province; (**d**) coupling of traditional villages and GDP density in Hubei Province; (**e**) coupling of traditional villages and road network density in Hebei Province; (**f**) coupling of traditional villages and road network density in Hubei Province; (**g**) coupling of traditional villages and kernel density in Hebei Province; and (**h**) coupling of traditional villages and kernel density in Hubei Province (drawn by the authors). Note: Based on the standard map produced by the Ministry of Natural Resources standard map service website GS (2024) 0650, with no modifications to the boundaries of the base map.

Table A3. Statistics on average population density and traditional villages in prefecture-level cities in Hebei Province.

Prefecture Level City	Number of Traditional Villages (Number)	Number of Population (Ten Thousand)	Average Population Density (man/km^2)	Average Population Density Ranking
Shijiazhuang	60	1123.51	711.08	3
Tangshan	5	771.80	572.89	5
Qinhuangdao	2	313.69	402.06	9
Handan	56	941.40	780.21	2
Xingtai	75	711.11	585.61	4
Baoding	16	1154.40	524.73	6
Zhangjiakou	59	411.89	113.29	10
Chengde	2	335.44	84.90	11
Cangzhou	0	730.08	510.40	7
Langfang	0	546.41	849.91	1
Hengshui	1	421.29	476.79	8
Total	276	7461.02	395.18	

Table A4. Statistics on average population density and traditional villages in prefecture-level cities in Hubei Province.

Prefecture Level City	Number of Traditional Villages (Number)	Number of Population (Ten Thousand)	Average Population Density (man/km^2)	Average Population Density Ranking
Ezhou	0	107.94	676.32	2
Jingmen	7	259.69	209.43	13
Xiaogan	15	427.04	479.28	4
Shiyan	15	320.90	139.52	16
Tianmen	0	115.86	441.88	7
Qianjiang	0	88.65	442.37	6
Xiantao	1	113.47	447.08	5
Enshi Tujia and Miao autonomous	92	345.61	143.34	15
Yichang	23	389.64	185.54	14
Xiangyang	11	526.10	267.06	11
Jingzhou	1	523.12	371.01	8
Huanggang	49	588.27	336.98	9
Wuhan	4	1244.77	1452.64	1
Xianning	27	265.83	269.58	10
Huangshi	19	246.91	538.75	3
Suizhou	6	204.79	212.53	12
Shennongjia	0	6.66	20.47	17
Total	270	5775.26	310.18	

Table A5. Statistics on urbanisation rate and traditional villages in prefecture-level cities in Hebei Province.

Prefecture Level City	Number of Traditional Villages (Number)	Urbanisation Rate (%)	Ranking of Urbanisation Rate
Shijiazhuang	60	78.79	1
Tangshan	5	64.32	4
Qinhuangdao	2	63.97	5
Handan	56	58.27	7
Xingtai	75	54.1	10
Baoding	16	63.28	6
Zhangjiakou	59	66.1	2
Chengde	2	56.58	8
Cangzhou	0	51.14	11
Langfang	0	64.84	3
Hengshui	1	54.74	9
Total	276	60.07	

Table A6. Statistics on urbanisation rate and traditional villages in prefectural-level cities in Hubei Province.

Prefecture Level City	Number of Traditional Villages (Number)	Urbanisation Rate (%)	Ranking of Urbanisation Rate
Ezhou	0	66.27	2
Jingmen	7	58.74	9
Xiaogan	15	60.47	7
Shiyan	15	61.94	5
Tianmen	0	43.41	17

Table A6. *Cont.*

Prefecture Level City	Number of Traditional Villages (Number)	Urbanisation Rate (%)	Ranking of Urbanisation Rate
Qianjiang	0	55.76	12
Xiantao	1	59.28	8
Enshi Tujia and Miao autonomous	92	46.56	16
Yichang	23	63.77	4
Xiangyang	11	61.66	6
Jingzhou	1	58.74	13
Huanggang	49	47.55	15
Wuhan	4	84.31	1
Xianning	27	56.74	11
Huangshi	19	65.96	3
Suizhou	6	56.83	10
Shennongjia	0	49.40	14
Total	270	62.94	

Table A7. Road network density in Hebei Province.

Prefecture Level City	Municipal Area (km^2)	Road Kilometres (km)	Road Network Density (km/km^2)	Density Ranking
Shijiazhuang	15,848	6139.68	0.39	6
Tangshan	13,472	6306.01	0.47	1
Qinhuangdao	7802	2839.39	0.36	8
Handan	12,066	4929.91	0.41	4
Xingtai	12,143	4522.21	0.37	7
Baoding	22,109	6890.51	0.31	9
Zhangjiakou	36,357	5998.36	0.16	10
Chengde	39,511	5539.79	0.14	11
Cangzhou	14,304	6167.10	0.43	3
Langfang	6429	2808.25	0.44	2
Hengshui	8836	3512.67	0.40	5

Table A8. Road network density in Hubei Province.

Prefecture Level City	Municipal Area (km^2)	Road Kilometres (km)	Road Network Density (km/km^2)	Density Ranking
Ezhou	1596	519.14	0.33	2
Jingmen	12,400	2273.40	0.18	8
Xiaogan	8910	2093.55	0.23	3
Shiyan	23,680	2797.66	0.12	15
Tianmen	2622	615.16	0.23	3
Qianjiang	2004	368.55	0.18	8
Xiantao	2538	582.97	0.23	3
Enshi Tujia and Miao autonomous	24,111	2925.42	0.12	15
Yichang	21,200	3679.06	0.17	10
Xiang yang	19,626	3060.32	0.16	12
Jing zhou	14,104	1961.95	0.14	14
Huanggang	17,457	3447.49	0.20	7

Table A8. *Cont.*

Prefecture Level City	Municipal Area (km^2)	Road Kilometres (km)	Road Network Density (km/km^2)	Density Ranking
Wuhan	8569	3958.41	0.46	1
Xianning	9861	1619.05	0.16	11
Huangshi	4583	946.48	0.21	6
Suizhou	9636	1675.13	0.17	10
Shennongjia	3253	182.38	0.06	17

Table A9. Statistics on the average density of traditional villages in each prefecture-level city in Hebei Province.

Prefecture Level City	Number of Traditional Villages (Number)	Municipal Area (10^4 km^2)	Average Density (units/10^4 km^2)	Density Ranking
Shijiazhuang	60	1.5848	37.86	3
Tangshan	5	1.3472	3.71	6
Qinhuangdao	2	0.7802	2.56	7
Handan	56	1.2066	46.41	2
Xingtai	75	1.2143	61.76	1
Baoding	16	2.2109	7.24	5
Zhangjiakou	59	3.6357	16.23	4
Chengde	2	3.9511	0.51	9
Cangzhou	0	1.4304	0	10
Langfang	0	0.6429	0	10
Hengshui	1	0.8836	1.13	8
Total	276	18.8877	14.61	

Table A10. Statistics on the average density of traditional villages in each prefecture-level city in Hubei Province.

Prefecture Level City	Number of Traditional Villages (Number)	Municipal Area (10^4 km^2)	Average Density (units/10^4 km^2)	Density Ranking
Ezhou	0	0.1596	0	14
Jingmen	7	1.2400	5.65	9
Xiaogan	15	0.8910	16.84	5
Shiyan	15	2.3680	6.33	7
Tianmen	0	0.2622	0	14
Qianjiang	0	0.2004	0	14
Xiantao	1	0.2538	3.94	12
Enshi Tujia and Miao autonomous	92	2.4111	38.16	2
Yichang	23	2.1200	10.85	6
Xiangyang	11	1.9626	5.60	10
Jingzhou	1	1.4104	0.71	13
Huanggang	49	1.7457	28.07	3
Wuhan	4	0.8569	4.67	11
Xianning	27	0.9861	27.38	4
Huangshi	19	0.4583	41.46	1
Suizhou	6	0.9636	6.23	8
Shennongjia	0	0.3253	0	14
Total	270	18.62	14.50	

Table A11. Sensitivity statistics of traditional villages in Hebei province.

Prefecture Level City	Non-Sensitive	Lightly Sensitive	Moderately Sensitive	Highly Sensitive	Hypersensitive	Total
Shijiazhuang	0	0	40	14	6	60
Tangshan	0	0	0	5	0	5
Qinhuangdao	0	0	0	1	1	2
Handan	0	0	5	33	18	56
Xingtai	0	1	4	51	19	75
Baoding	0	2	9	5	0	16
Zhangjiakou	8	47	4	0	0	59
Chengde	2	0	0	0	0	2
Cangzhou	0	0	0	0	0	0
Langfang	0	0	0	0	0	0
Hengshui	0	0	0	1	0	1
Total	10	50	62	110	44	276

Table A12. Sensitivity statistics of traditional villages in Hubei Province.

Prefecture Level City	Non-Sensitive	Lightly Sensitive	Moderately Sensitive	Highly Sensitive	Hypersensitive	Total
Ezhou	0	0	0	0	0	0
Jingmen	0	0	3	4	0	7
Xiaogan	0	1	7	7	0	15
Shiyan	8	3	3	1	0	15
Tianmen	0	0	0	0	0	0
Qian jiang	0	0	0	0	0	0
Xiantao	0	0	1	0	0	1
Enshi Tujia and Miao autonomous	16	36	37	3	0	92
Yichang	3	11	9	0	0	23
Xiangyang	0	3	5	3	0	11
Jingzhou	0	0	1	0	0	1
Huanggang	0	9	29	11	0	49
Wuhan	0	0	0	1	3	4
Xianning	0	9	13	5	0	27
Huangshi	0	1	3	11	4	19
Suizhou	2	1	2	1	0	6
Shennongjia	0	0	0	0	0	0
Total	29	74	113	47	7	270

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