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Spatio-Temporal Evolution of Traditional Villages in Southern Hebei (China): A Multi-Factor Analysis of Dynamic Driving Mechanisms

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Abstract

Traditional villages are important carriers of rural cultural heritage, yet their spatio-temporal distribution and underlying mechanisms remain insufficiently understood, particularly regarding the interaction between environmental and socio-cultural drivers over long historical periods. Focusing on 131 nationally recognized traditional villages in southern Hebei, China, this study integrates GIS-based spatial analysis with historical interpretation to examine their spatial patterns, temporal evolution, and driving factors from the pre-Sui period to the Qing Dynasty and post-Qing period. The results show that traditional villages exhibit a highly clustered and uneven distribution, primarily concentrated in mountain-front zones in the western and southwestern parts of the region. Spatial analysis reveals a multi-core clustering structure, and spatial autocorrelation confirms that this pattern is statistically significant. Temporally, village formation follows a non-linear process of concentration, expansion, and stabilization, with the Ming Dynasty representing a key peak period. The findings further indicate that dominant driving mechanisms shifted over time: early settlement was mainly constrained by environmental conditions, whereas later development increasingly depended on socio-cultural processes such as migration, defense, clan organization, and regional exchange. In the contemporary context, economic development and accessibility introduce complex and non-linear effects. These results suggest that traditional villages should be understood as dynamic cultural landscapes shaped by long-term human–environment interactions. This study provides an integrated framework for understanding rural settlement dynamics and offers insights relevant to rural heritage conservation and sustainable development in transitional regions.

Keywords: rural heritage; cultural landscape; spatial autocorrelation; kernel density estimation; human–environment interaction; rural sustainability

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1. Introduction

Traditional villages and rural settlements are important carriers of cultural heritage worldwide. They preserve not only vernacular buildings and settlement forms, but also local knowledge, agricultural practices, social memory, community identity, and long-term

human–environment relationships [1–5]. International heritage studies increasingly understand rural landscapes as living cultural landscapes rather than isolated monuments, emphasizing the interaction between settlement, livelihood, ecological adaptation, and local identity [6–8]. This perspective is also reflected in international heritage frameworks, including the cultural landscape approach promoted by UNESCO and the ICOMOS principles concerning rural landscapes as heritage [9]. In this context, the study of traditional villages contributes not only to heritage conservation, but also to broader debates on sustainable rural development, landscape resilience, and the continuity of local communities.

In China, traditional villages have become an increasingly important object of rural heritage protection. However, with rapid urbanization and rural–urban migration, many historic TVs are facing challenges such as deterioration and abandonment [10,11]. In response, the Chinese government initiated the Rural Revitalization Strategy to preserve rural cultural heritage [5,12]. This strategy established systematic mechanisms for the identification and protection of TVs. As of 2024, the Ministry of Housing and Urban–Rural Development (MOHURD), in collaboration with other governmental agencies, has officially recognized 8155 TVs through a multi-stage evaluation process [13,14].

In the aftermath of the designation of the first batch of TVs in 2012, a substantial body of research has emerged examining their spatial characteristics and influencing factors [15–26]. At the macro scale, studies have applied GIS-based methods such as kernel density estimation and Multi-Scale Geographically Weighted Regression (MGWR) to analyze topographic influences on spatial distribution [27]. At the meso scale, research has focused on factors such as water systems [28], cultural genealogies [29], architectural typologies [26,30], and settlement morphology [17]. At the micro scale, scholars have examined internal village structures, including spatial configurations of streets, buildings, and public spaces [23], as well as architectural characteristics using methods such as space syntax and 3D scanning [16,25].

However, despite these advances, most existing studies remain largely synchronic, focusing on present-day spatial patterns while paying insufficient attention to long-term evolutionary processes. Furthermore, although both natural and socio-cultural factors have been widely acknowledged, their interactive and evolving roles across historical stages remain underexplored. In particular, existing studies tend to examine environmental, social, and economic variables separately, rather than as part of an integrated process of spatial transformation. As a result, the mechanisms underlying the spatio-temporal evolution of TVs remain insufficiently understood.

The southern Hebei region, located at the transition between the Taihang Mountains and the North China Plain, provides a representative case for addressing these gaps. Historically situated at the intersection of multiple political regimes and cultural systems, this region contains 47.46% of the TVs in Hebei Province [31]. The TVs in southern Hebei have a long historical trajectory, spanning from early agrarian settlements to the Ming (1368–1644) and the Qing dynasties and the post-Qing period (1644 onwards), and reflect the combined influence of environmental adaptation, military defense, migration, and regional exchange [32–34]. However, in recent decades, these villages have faced increasing pressure from urbanization and socio-economic transformation, raising urgent challenges for their preservation and sustainable development [35].

Against this background, this study addresses three key research questions:

(1) What are the spatio-temporal distribution patterns of TVs in southern Hebei?
(2) How has the spatial structure of these villages evolved across different historical periods?
(3) How do natural, socio-cultural, and contemporary factors interact in shaping this evolution, and how does their relative importance change over time?

By integrating GIS-based spatial analysis with a historical perspective, this study makes three main contributions. First, it moves beyond static spatial description by reconstructing the evolutionary trajectory of TV distribution across multiple historical stages. Second, it develops a multi-factor analytical framework that captures the shifting balance between environmental constraints and socio-cultural processes, thereby providing new insights into the mechanisms underlying village formation and persistence. Third, by incorporating contemporary variables such as accessibility and economic development, the study reveals the non-linear relationships between modernization and heritage preservation.

2. Literature Review

TVs have become an increasingly important topic in rural heritage and settlement studies because they preserve not only vernacular buildings, but also long-term interactions among environment, economy, social organization, and local culture. Existing scholarship generally agrees that TVs are spatially selective rather than randomly distributed, and that their formation and persistence are closely related to terrain, water systems, livelihoods, historical mobility, and institutional change [1–3,11]. In China, this field has expanded rapidly since the establishment of the national TV protection system, with growing attention to spatial distribution, environmental dependence, cultural value, and conservation under urbanization pressure [2,10]. However, despite the rapid growth of the literature, three limitations remain evident: many studies are still predominantly descriptive of present-day patterns, the relative importance of natural and socio-cultural factors is rarely examined across historical stages, and contemporary drivers such as transport, tourism, policy intervention, and population mobility are often analyzed separately rather than as part of an integrated restructuring process. These issues are particularly significant for southern Hebei, a transitional region between the Taihang Mountains and the North China Plain, where TVs were shaped by environmental gradients, defense, migration, and interregional exchange.

This broader perspective is well established in international heritage studies. Studies of historic rural landscapes in Italy show that rural heritage planning must connect conservation, landscape governance, sustainable development, and local action [6]. Di Fazio and Modica argue that historic rural landscapes should be understood through a holistic and dynamic approach that recognizes the interaction among physical form, historical land use, cultural perception, and planning practice [6]. Recent research on the Prosecco Hills of Conegliano and Valdobbiadene further shows that terrain morphology, agricultural intensification, tourism, and World Heritage designation together reshape the persistence and transformation of rural cultural landscapes [36].

Cultural landscape theory provides an appropriate conceptual basis for this study. The intellectual foundation of this perspective is usually traced to Carl O. Sauer, whose 1925 essay The Morphology of Landscape established the argument that landscape should be understood not as a purely natural setting, but as the product of the interaction between culture and nature [37]. Building on this foundation, J. B. Jackson shifted scholarly attention from monumental scenery to the vernacular landscape, emphasizing the everyday, inhabited, and historically accumulated character of settlements and rural space [38]. Peirce F. Lewis further developed this tradition by arguing that ordinary landscapes can be "read" as material records of social values, cultural practice, and historical change, thereby providing a methodological bridge between visible form and social meaning [39]. Together, Sauer, Jackson, and Lewis moved landscape studies away from a narrow concern with scenery or isolated monuments and toward a broader understanding of settlement as the material outcome of long-term human–environment interaction. The later incorporation of "cultural

landscapes" into the UNESCO World Heritage framework further reinforced the relevance of this perspective for heritage studies [40].

International studies also highlight the role of rural heritage in constructing identity. In Europe, Silva and Leal's study of the Historic Villages of Portugal demonstrates that rural tourism and historic conservation contribute to national identity building, while also producing tensions among official heritage narratives, visitor expectations, and residents' local interpretations [41]. Dragan et al.'s research on rural landscapes along a Romanian river similarly shows that rural landscapes remain important carriers of regional identity, sense of belonging, and community memory [42].

In North America, Mitchell's study of rural heritage commodification shows that heritage-based development can generate economic revitalization, but may also lead to the "creative destruction" of rural place if heritage is transformed primarily into a consumable landscape [43]. Labrador's study of agricultural land conservation in New England further demonstrates that rural heritage protection can be understood as a form of shared heritage practice that mobilizes cultural identity, social cohesion, and ecological responsibility [44].

This theoretical tradition is especially useful for traditional-village research. It encourages scholars to move beyond individual buildings and to interpret villages as living cultural landscapes in which topography, water systems, agricultural adaptation, defensive needs, kinship organization, trade contact, and religious practice are materially inscribed in spatial form. It also provides a useful bridge to the three questions addressed in this article. First, it supports the reading of spatial distribution as a historical projection of collective human activity. Second, it offers a framework for understanding how the relative roles of natural and socio-cultural factors may shift across time. Third, because cultural landscape theory stresses dynamism rather than stasis, it also allows contemporary urbanization, tourism, transport improvement, and rural revitalization policy to be understood as ongoing phases of landscape transformation rather than merely external disturbances.

2.1. Spatial Pattern Characteristics and Evolutionary Trajectory

A substantial body of scholarship has used GIS-based methods to examine the spatial distribution of TVs in China. At the national scale, Bian et al. demonstrate that TVs show significant clustering and are unevenly distributed across different environmental and historical regions [2]. Similar findings recur in studies of the Yangtze River Basin, the Yellow River Basin in Henan, Fujian Province, and Shandong Province, where kernel density, nearest neighbor, standard deviation ellipse, and spatial autocorrelation analyses reveal multi-core agglomeration, marked regional imbalance, and directional concentration in mountain and foothill zones [10,20,27,45]. These studies have been valuable in establishing that TVs form identifiable spatial structures rather than simply mirroring present-day administrative or demographic patterns.

International rural heritage studies also provide a useful comparative perspective on this spatial issue [6,36,42]. European research on historic rural landscapes shows that settlement distribution and landscape persistence are closely related to land-use history, terrain morphology, agricultural systems, and planning regimes [6,36]. For example, work on Italian historic rural landscapes emphasizes the need to read rural settlements within long-term territorial structures rather than as isolated heritage objects [6]. The study of the Prosecco Hills further shows that steep terrain helped preserve traditional landscape forms in core areas, while more accessible buffer zones experienced stronger agricultural intensification, urbanization, and tourism pressure [36]. Research in Romania likewise demonstrates that rural landscapes along river corridors are shaped by settlement history, regional identity, and everyday attachments to place [42].

Yet this literature remains limited in its treatment of historical evolution. Much of the current work is essentially synchronic: it maps the present distribution of officially recognized villages and then explains this pattern through current physical or socio-economic variables. Even in studies that describe themselves as "spatio-temporal," time is often simplified into broad dynastic phases or listing batches, while more precise questions of centroid migration, directional adjustment, contraction and expansion, or the emergence of core clusters are not fully reconstructed [10,27]. As a result, existing research is better at describing pattern than at explaining trajectory.

A second weakness is that many studies identify spatial clustering without sufficiently interpreting its historical meaning. Concentration along mountain fronts, river systems, or transitional zones is often recognized statistically, but less often explained in relation to migration, frontier defense, agrarian expansion, or commercial exchange. For a borderland and transition region such as southern Hebei, this omission is significant. The present distribution of TVs there cannot be adequately understood without considering long-term processes of settlement expansion, state formation, warfare, mobility, and local adaptation. A more historically grounded interpretation is therefore needed.

2.2. Changing Dominant Factors Across Historical Stages

A second major strand of scholarship examines the factors influencing traditional-village distribution. Most studies agree that natural environmental conditions provide the basic locational foundation for village formation. Elevation, slope, aspect, river proximity, and climatic suitability are repeatedly identified as significant variables shaping where villages emerge and survive [1,2,10,27,46]. In many regions, TVs are concentrated in areas of moderate elevation, gentle slope, and good access to water, because such conditions support cultivation, reduce environmental risk, and provide relatively secure and sustainable settlement environments. Research in western Hunan, the lower Yangtze, and other parts of China has repeatedly confirmed that mountain foothills, river valleys, and ecologically suitable transitional belts tend to contain dense concentrations of traditional settlements [1,20,46].

However, recent studies have increasingly emphasized that natural explanation alone is insufficient. Historical and socio-cultural factors also play an important role in shaping village distribution and persistence. Yuan et al., in their study of historical rural settlements in Taihang Baxing, show that terrain and historical–cultural processes operate together to produce strong spatial heterogeneity [27]. Bi et al. likewise argue that the distribution mechanisms of TVs in Jiangnan can only be understood by integrating natural geography, human history, and socio-economic context [40]. Other research has highlighted the importance of trade routes, human settlement systems, and regional cultural interaction in reorganizing rural spatial patterns [28,45]. Collectively, these studies correct earlier environmentally deterministic tendencies and show that rural space is actively produced by human institutions, historical processes, and cultural practice.

Even so, most of the literature still examines these factors in a static way. Researchers usually test current village distributions against a set of present-day explanatory variables, but rarely ask whether the balance between natural and socio-cultural forces changed across different historical periods. This is a major limitation for studies concerned with long-term evolution. In principle, early settlement formation may have been more strongly constrained by water access, slope, and security, whereas later expansion and persistence may have depended increasingly on migration, kinship organization, political stability, and commercial networks. Although this shift is often implied, it is seldom tested explicitly. Southern Hebei provides a strong case for such an analysis because its villages span

multiple dynastic periods and reflect the combined influence of environmental adaptation, military defense, migration, and cultural integration.

2.3. Contemporary Drivers Reshaping Survival and Distribution

A third strand of research shifts attention from historical formation to contemporary transformation. With rapid urbanization and rural restructuring, TVs are increasingly affected by demographic hollowing, industrial change, infrastructure expansion, tourism development, and policy intervention [3,11,28]. Wang et al. show that village hollowing can undermine the social basis of traditional settlements at the micro scale, while Liu et al. argue that sustainable revitalization depends not only on conservation value but also on village vitality and development capacity [3,11]. This line of research is important because it changes the central question from why villages formed historically to why some survive, decline, or transform under contemporary conditions.

Recent spatial studies also suggest that contemporary drivers do not operate in a simple linear manner. Improved accessibility may attract investment, tourism, and conservation resources, but it may also intensify redevelopment pressure and commodification. By contrast, remote villages may experience demographic decline and weak service provision, yet their relative isolation can also help preserve traditional architectural fabric. Tao et al. demonstrate that human-settlement factors significantly influence village spatial patterns in Liaoning, while Li et al. show that accessibility itself has become an important dimension in explaining present-day differentiation among TVs [20,45]. These studies imply that transport, policy, tourism, and demographic mobility should not be treated as isolated variables, but as interacting forces that can simultaneously support revitalization and accelerate transformation. In the case of southern Hebei, this issue is particularly important under the combined influence of urbanization and the rural revitalization strategy, both of which are actively reshaping the conditions for village persistence.

Overall, previous scholarship has made three major contributions. It has established that TVs are spatially clustered and regionally differentiated; it has shown that both environmental and socio-cultural factors matter; and it has highlighted the increasing importance of contemporary restructuring. International literature further enriches this field by demonstrating that rural heritage is a living cultural landscape tied to identity, memory, belonging, community practice, tourism, and contested values. Nevertheless, three gaps remain. First, long-term evolutionary trajectories of village distribution are still insufficiently reconstructed. Second, the changing balance between natural and socio-cultural drivers across historical stages has rarely been examined directly. Third, contemporary factors such as accessibility, policy, tourism, and migration are often discussed separately rather than as part of an integrated mechanism of cultural landscape transformation. This study addresses these gaps by treating southern Hebei as a historically layered and geographically transitional region and by linking spatial pattern, factor succession, and contemporary restructuring within a single cultural landscape framework.

3. Materials and Data Source

3.1. Study Area

In the Chinese administrative system, the term “city” often refers to a prefecture-level administrative unit rather than a continuously urbanized area. Therefore, Handan City and Xingtai City in this study include not only urban districts, but also counties, county-level cities, towns, and rural villages. The traditional villages analyzed in this paper are physically rural settlements, usually composed of residential houses, streets, ancestral or religious spaces, agricultural land, and surrounding landscape elements. Administratively, they are village-level settlements located within townships, towns, counties, county-level

cities, or districts under the jurisdiction of Handan and Xingtai. Their inhabitants have historically depended mainly on agriculture, handicrafts, local trade, and, more recently, tourism-related and service activities. Thus, the expression "villages within cities" refers to villages located within the administrative boundaries of prefecture-level cities, rather than villages located inside dense urban built-up areas.

The southern Hebei region, as delineated in Figure 1, encompasses the cities of Handan and Xingtai within its southernmost reaches. The total area of southern Hebei spans an expanse of 24,400 square km, constituting 12.93% of the province's total area. Handan City is located in northeastern China, with the Taihang Mountains to the west and the North China Plain to the east. The city shares boundaries with the provinces of Shanxi, Shandong and Henan and covers an area of 12,000 square km [47]. Xingtai City, abbreviated as "Xing," has a rich historical background. It was historically known as Xingzhou and Shunde Prefecture. It is a key city within the Beijing–Tianjin–Hebei urban agglomeration and a provincial-level historical and cultural city in Hebei, with a total area of 12,400 square km, accounting for 6.57% of the province's area [48].

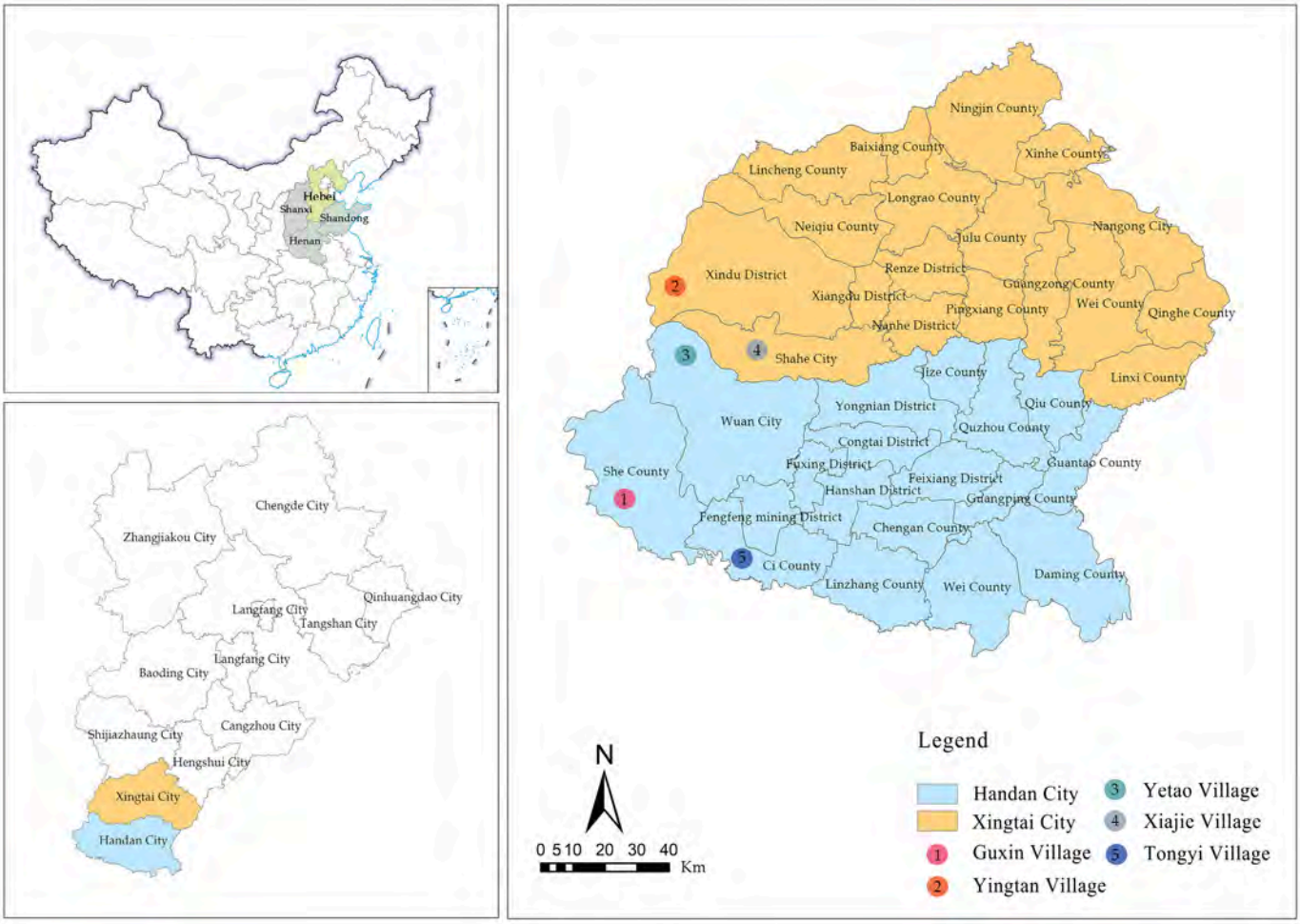

Figure 1. Location environment and representative villages in southern Hebei region.

The southern Hebei region is characterized by a topography that is high in the west and low in the east, with the Taihang Mountains and their foothills creating significant elevation changes [49]. As one moves eastward, the terrain gradually levels out. Major rivers, including the Zhang River, Fuyang River, and Sha River, flow from west to east, forming alluvial fan plains at the foot of the mountains [49]. This three-dimensional ecological system supports a spatial pattern of TVs that are situated with mountains at

their backs and water sources in front. This configuration preserves the compact defensive features of mountainous settlements while fostering a grid-like street system in the plains, resulting in a model of diverse coexistence. In addition, the region experiences a temperate monsoon climate, marked by distinct seasons: cold and dry winters, hot and rainy summers, and mild spring and autumn periods. Rainfall is primarily concentrated in the summer months, which underscores its typical agricultural economy [50].

For nearly a millennium, the economy of southern Hebei has been predominantly agricultural. However, in the past decade, the implementation of the Beijing–Tianjin–Hebei coordinated development strategy has gradually transformed the local economic structure [51]. Many villages have actively developed rural tourism centered around historical culture, ecological leisure, and folk experiences, while also revitalizing traditional handicrafts. This has led to the emergence of a new industrial pattern that integrates agriculture, culture, and tourism.

Historically, southern Hebei has been a crossroads of diverse cultures, profoundly influenced by neighboring provinces and cities, which has resulted in unique cultural fusion characteristics [52]. The traditional architectural styles of the region are varied, featuring both the structured layout of northern Siheyuan courtyards and cave dwellings influenced by the Shanxi and Henan provinces. Furthermore, the region retains rich traditional customs, including temple fairs, folk celebrations, and local operas, showcasing its distinctive cultural charm. Some villages have even become popular tourist destinations.

Driven by national strategies, such as the Beijing–Tianjin–Hebei coordinated development strategy (2014) and the rural revitalization strategy (2017), local governments in southern Hebei have actively promoted the protection and development of TVs. This includes the development of rural tourism and cultural creativity industries, which have breathed new life and vitality into the region's TVs [51,53].

3.2. Spatial and Socio-Economic Data Sources

The study focuses on the southern Hebei region, primarily Handan and Xingtai cities, using 131 TVs from the first six batches of national listings as research samples. The data sources for this study include:

(1) TV List: The list of TVs in southern Hebei is obtained from the six batches of the China TV Directory in 2024 [54]. The coordinates are determined using the API picker in Baidu Maps and Google Earth.
(2) Economic and Population Data: Data for the economy and population of southern Hebei are sourced from the "2022 China County Statistical Yearbook (County Volume)," local government websites, and local county records [55].
(3) Elevation, Hydrology, and Transportation Data: These data are sourced from the Resource and Environment Science and Data Center of the Chinese Academy of Sciences and the Geospatial Data Cloud website (http://www.gscloud.cn/, accessed on 10 December 2023) [56,57].

3.3. Historical Data and Periodization

The historical formation periods of the traditional villages were established through a combination of documentary sources and field verification. The main sources included local gazetteers, county chronicles, village records, historical documents, published local history materials, statistical yearbooks, and information collected during field surveys. When available, the earliest documentary reference to a village, records of settlement foundation, lineage or clan migration records, temple inscriptions, village stele texts, and local oral historical information were used to identify or verify the approximate period of village formation.

Because the foundation dates of historical villages are not always recorded as precise years, this study classified village ages into broader historical periods rather than exact dates. The classification includes the pre-Sui period, the Sui–Tang–Song–Liao–Jin period, the Yuan Dynasty, the Ming Dynasty, and the Qing Dynasty and post-Qing period. When different sources provided inconsistent information, priority was given to official local chronicles and county-level records, while field survey information was used for supplementary verification. In cases where only approximate historical information was available, the village was assigned to the most reliable corresponding historical period. This periodization allows the study to analyze long-term spatial evolution while acknowledging the uncertainty of historical dating.

4. Research Methodology

The overall methodological framework is shown in Figure 2. It integrates data collection, spatial statistical analysis, historical periodization, and multi-factor interpretation. The framework first establishes the spatial database of traditional villages, then examines their distribution characteristics and temporal evolution, and finally interprets the driving mechanisms from natural, socio-cultural, and contemporary perspectives.

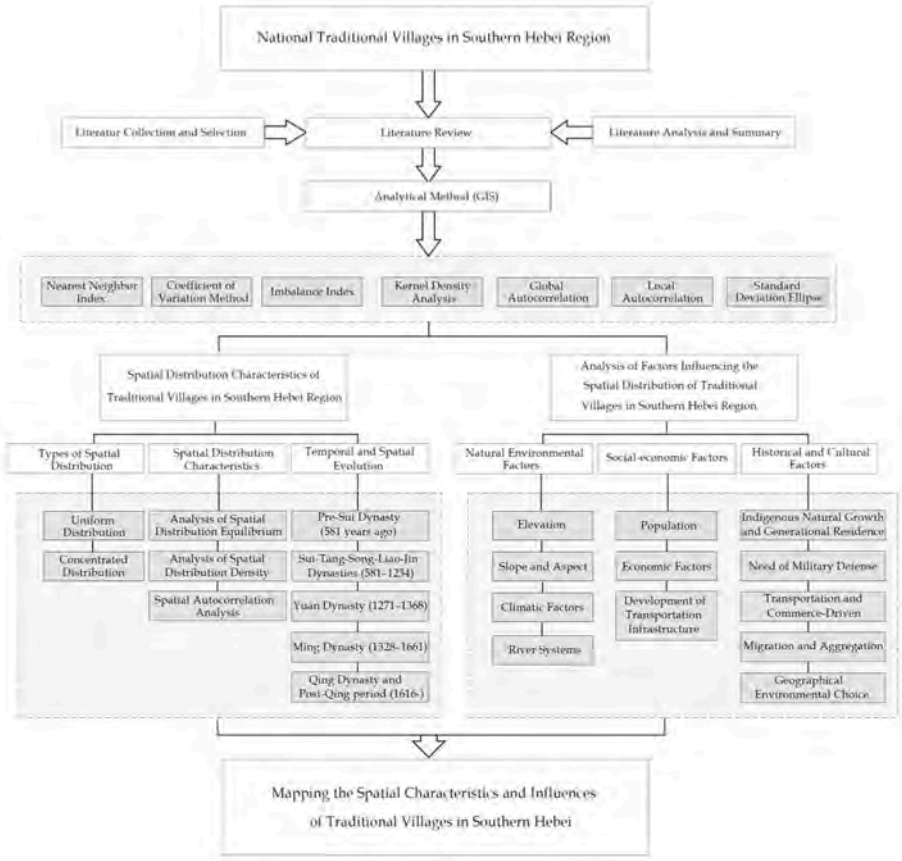

Figure 2. The methodology framework for TV spatial distribution and driving factor analysis in the southern Hebei region.

All spatial analyses and map visualizations were conducted using ArcGIS 10.8. The geographic coordinates of traditional villages were obtained through Baidu Maps API picker and Google Earth and were checked manually. Spatial statistical analyses, including nearest neighbor analysis, kernel density estimation, Moran's I, local autocorrelation, buffer analysis, and standard deviation ellipse analysis, were performed in ArcGIS 10.8 using

its spatial statistics and analysis toolboxes. Descriptive statistical calculations and table processing were conducted using Microsoft Excel.

4.1. Methods

4.1.1. Nearest Neighbor Index

The nearest neighbor index (NNI) is used to identify the overall spatial distribution pattern of TVs, particularly to determine whether the distribution is clustered, random, or uniform [58]. In this index, (R) represents the ratio of the actual average observed distance to the expected average distance, as shown in the following formula:

$$R = \overline{r_1}/r_E = 2\sqrt{Dr_1} \quad (1)$$

where (r_1) is the actual nearest distance, (r_E) is the theoretical nearest distance, (D) is the point density, and (R) is the nearest neighbor index. When (R > 1), it indicates that the TV distribution is uniform; when (R < 1), it suggests a clustered distribution; and when (R = 1), it indicates a random distribution [59].

4.1.2. Coefficient of Variation Method

The coefficient of variation (CV), based on Voronoi (Thiessen) polygons, is applied to measure spatial variability and to further verify the clustering characteristics identified by the NNI [60]. By constructing Voronoi polygons for discrete points, this method identifies areas that contain only specific associated points, implying that smaller areas correspond to denser point distributions. This can reflect the relative spatial variation of TVs in the southern Hebei region, thereby validating the accuracy of spatial types. The formula is as follows [2]:

$$c = \frac{x}{\varphi} \times 100\% \quad (2)$$

where (c) is the coefficient of variation for the Voronoi polygons, (φ) is the standard deviation of the polygon areas, and ($33\% \leq c \leq 64\%$) is the mean area. When ($c < 33\%$), it indicates a uniform distribution of TVs; when ($c > 64\%$), it indicates a clustered distribution; and when ($33\% \leq c \leq 64\%$), it suggests a random distribution.

4.1.3. Imbalance Index

The imbalance index is used to evaluate the degree of spatial inequality in the distribution of TVs across administrative units [2]. It is typically represented by the Lorenz curve. The Lorenz curve, proposed by American economist Max Otto Lorenz, uses percentage-based coordinates [61]. The curve is formed by a line and a curve; the greater the distance between the two, the more uneven the distribution of TVs, and vice versa. The formula for the imbalance index is [62]:

$$r = \frac{\sum_{i=1}^{n} \beta_i - 50(N+1)}{100N - 50(N+1)} \quad (3)$$

where (N) is the number of cities or counties, and (β_i) is the cumulative percentage of TVs sorted by quantity in the (i)-th position [63]. The value of the imbalance index (r) ranges from 0 to 1; a value close to 1 indicates a highly uneven distribution, while a value close to 0 suggests a more uniform distribution. If ($r = 0$), it indicates that TVs are concentrated in a specific county or city [64].

4.1.4. Kernel Density Analysis

Kernel density analysis is applied to identify spatial concentration intensity and to visualize hotspot areas of TV distribution [65], indicating the probability of a geographic

event occurring in a certain area [66]. The denser the points, the higher the probability, and consequently, the larger the kernel density value. The formula is as follows [67]:

$$\int (x) = \frac{n}{nh}\sum_{i=1}^{n} k(\frac{x - x_i}{h}) \quad (4)$$

where (n) is the number of points within the threshold range, (h) is the search bandwidth (greater than 0), (k) is the kernel function, and (x, x_i) is the distance from the estimation point (x) to (x_i) [68].

4.1.5. Global Autocorrelation

Global Moran's I is used to test whether the observed spatial clustering is statistically significant, thereby providing robustness to the results obtained from NNI and kernel density analysis [69]. A result close to −1 suggests that the villages are dispersed, implying smaller correlations. Typically, the Z-value is used to evaluate whether the study elements are clustered or dispersed. When ($p < 0.05$) (indicating a 95% confidence level), if ($Z > 1.96$), it indicates that the TVs in that area are in a clustered state; if ($Z < -1.96$), they are dispersed; and if ($-1.96 < Z < 1.96$), the distribution is random. The formula for Moran's I is as follows [68]:

$$\text{Moran's I} = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}(x_i - \overline{x})^2} \quad (5)$$

In this formula, (x_i) and (x_j) are the sample points in the study area for indices (i) and (j), (n) is the number of TVs, and (w_{ij}) is the spatial weight matrix.

The result of Moran's I is tested using the Z-value:

$$Z = \frac{I - E(I)}{\sqrt{VAR(I)}} \quad (6)$$

4.1.6. Local Autocorrelation

Local Moran's I is used to identify local clustering patterns and spatial heterogeneity, such as high–high and low–low clusters. The formula is as follows [70]:

$$I_i = \frac{n(x_i - \overline{x})\sum_{j=1}^{n} w_{ij}(x_j - \overline{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}(x_i - \overline{x})^2} \quad (7)$$

In this equation, when ($I_i > 0$), it indicates strong correlation, clustering, and small differences; when ($I_i < 0$), it suggests weak correlation, poor connectivity, and large differences; and when ($I_i = 0$), it reflects a random distribution.

4.1.7. Standard Deviation Ellipse

The standard deviation ellipse (SDE) is employed to analyze the directional trends, spatial dispersion, and centroid migration of TVs over time, thereby capturing their evolutionary trajectories [71]. The ellipse's major axis represents the direction of TV distribution, while the minor axis represents the distribution range. The formulas are as follows [72]:

Centroid:

$$\overline{X} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \; \overline{Y} = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i} \quad (8)$$

Azimuth:

$$\tan\alpha = \frac{\left(\sum_{i=1}^{n} w_i \overset{2\sim 2}{x}_i - \sum_{i=1}^{n} w_i \overset{2\sim 2}{y}_i\right) + \sqrt{\left(\sum_{i=1}^{n} w_i \overset{2\sim 2}{x}_i - \sum_{i=1}^{n} w_i \overset{2\sim 2}{y}_i\right)^2 + 4\sum_{i=1}^{n} w_1 \overset{2\sim 22\sim 2}{x\ y}}}{2\sum_{i=1}^{n} w_i \overset{2\sim 22\sim 2}{x\ y}} \quad (9)$$

Standard deviation along *X*-axis:

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^{n}\left(w_i \tilde{x}\cos\alpha - w_i \tilde{y}\sin\alpha\right)^2}{\sum_{i=1}^{n} w_i^2}} \quad (10)$$

Standard deviation along *Y*-axis:

$$\sigma_y = \sqrt{\frac{\sum_{i=1}^{n}\left(w_i \tilde{x}\cos\alpha - w_i \tilde{y}\sin\alpha\right)^2}{\sum_{i=1}^{n} w_i^2}} \quad (11)$$

In the equations, (X, Y) represents the centroid coordinates of the ellipse, (W_i) is the weight, ($\tilde{x}_i$, $\tilde{y}_i$) are the coordinates of the study objects, (α) is the orientation angle of the ellipse, and ($w_i\tilde{x}$, $w_i\tilde{y}$) indicates the positional deviation of the study objects from the centroid. (X) and (σ_y) represent the standard deviations along the X and Y axes, respectively. For the standard deviation ellipse, the more elongated the shape, the stronger the directional tendency of the study objects [73].

Overall, the combination of these methods allows for a multi-dimensional analysis of TVs, in which the nearest neighbor index and kernel density analysis identify clustering patterns, Moran's I validates spatial dependence, the coefficient of variation and imbalance index capture spatial inequality, and the standard deviation ellipse reveals temporal evolution and directional trends. This integrated approach ensures that spatial patterns, statistical significance, and evolutionary processes are examined in a coherent analytical framework.

4.2. Methodological Advantages, Data Challenges, and Limitations

This methodological framework has several advantages. First, it combines descriptive spatial statistics with spatial autocorrelation analysis, allowing the study to identify not only the distributional characteristics of traditional villages but also the statistical significance of their clustering patterns. Second, the use of the standard deviation ellipse makes it possible to reconstruct long-term directional trends and centroid shifts across historical periods. Third, by integrating natural, socio-economic, transport, and historical–cultural variables, the study moves beyond single-factor explanation and provides a multi-dimensional interpretation of village formation and persistence.

Nevertheless, the data collection process also involved several challenges. The historical formation periods of traditional villages were reconstructed from local chronicles, historical documents, statistical yearbooks, and field investigation, but the precision and consistency of historical records vary among villages. Some villages have incomplete documentary evidence, and their foundation dates may represent approximate historical periods rather than exact years. In addition, the study uses nationally recognized traditional villages as samples, which means that undocumented villages with historical or cultural value may not be fully represented.

The methods used in this study also have limitations. GIS-based spatial analysis can reveal spatial patterns, clustering intensity, and correlations, but it cannot fully explain

the causal mechanisms behind village formation. Contemporary datasets, such as GDP, population, road networks, temperature, and precipitation, are used to interpret present conditions and possible influencing factors, but they cannot completely represent historical environments. Therefore, the results should be understood as a spatial and historical interpretation rather than a deterministic causal model. Future research could combine GIS analysis with archival research, oral history, field survey, and village-scale morphological analysis to further explain the mechanisms behind individual village development.

5. Results

5.1. Overview of Village Distribution

As of 2024, 131 villages in southern Hebei have been identified as national-level TVs according to the China TV Directory [54], including 56 in Handan and 75 in Xingtai. As shown in Figure 3, these villages are mainly concentrated in the southwestern part of the region, indicating a clearly uneven and clustered distribution pattern.

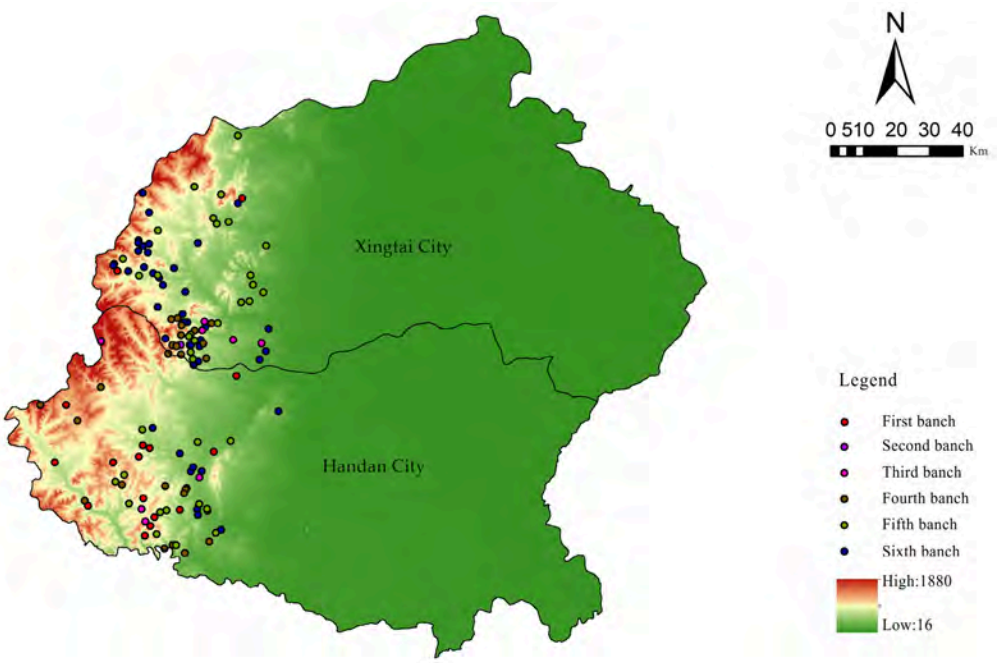

Figure 3. Geographical distribution of the six batches of TVs.

5.2. Spatial Distribution Characteristics of TVs in Southern Hebei

5.2.1. Types of Spatial Distribution

The nearest neighbor index (NNI) is first applied to determine the overall spatial distribution type of the TVs. The results show that the observed mean distance (3781.44 m) is significantly smaller than the expected mean distance (5229.20 m), with an NNI value of 0.723, indicating a clustered distribution pattern. The z-value (−6.062) and *p*-value ($p < 0.001$) further confirm that this clustering is statistically significant. Although the distribution in Handan appears close to uniform (R = 1.001), the overall regional pattern is clearly clustered, as illustrated in Figure 4. To further verify this result, the coefficient of variation based on Thiessen polygons is applied. The calculated value (482.61%) is far above the clustering threshold (64%), indicating strong spatial heterogeneity and reinforcing the conclusion that TVs exhibit a clustered distribution (see Figure 5).

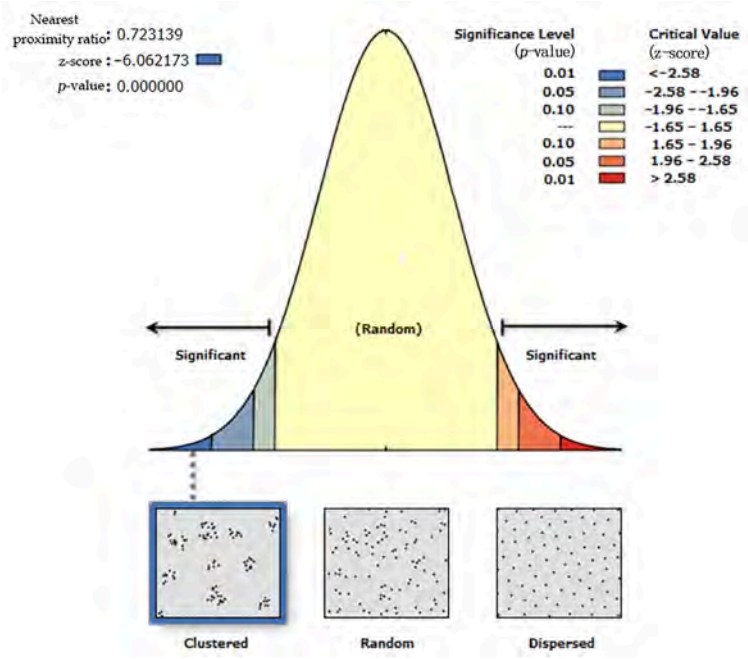

Figure 4. The average result of closest proximity in the southern Hebei region.

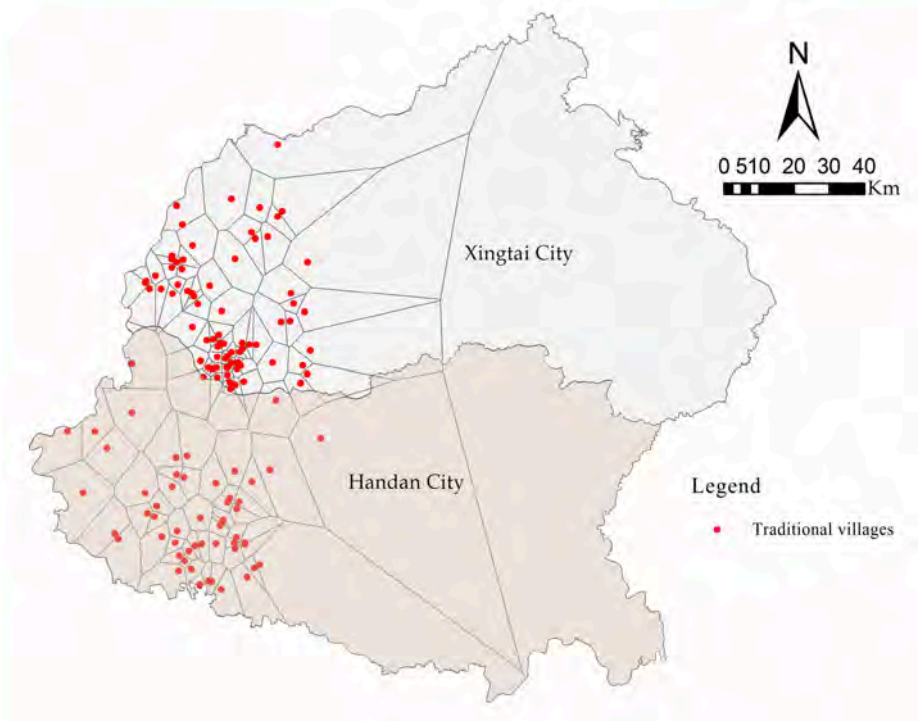

Figure 5. Theissen polygon distribution map of TVs in the southern Hebei region.

5.2.2. Analysis of Spatial Distribution Equilibrium

To assess the degree of spatial inequality, the imbalance index is calculated. The result (r = 0.654) indicates a highly uneven distribution of TVs across the region. The Lorenz curve (Figure 6) further shows that more than 70% of TVs are concentrated in a limited number of counties, particularly in Shahe, Xindu, Wu'an, and Cixian. These areas are primarily located along the Taihang Mountain-front zone, suggesting a strong relationship between spatial concentration and geographical conditions.

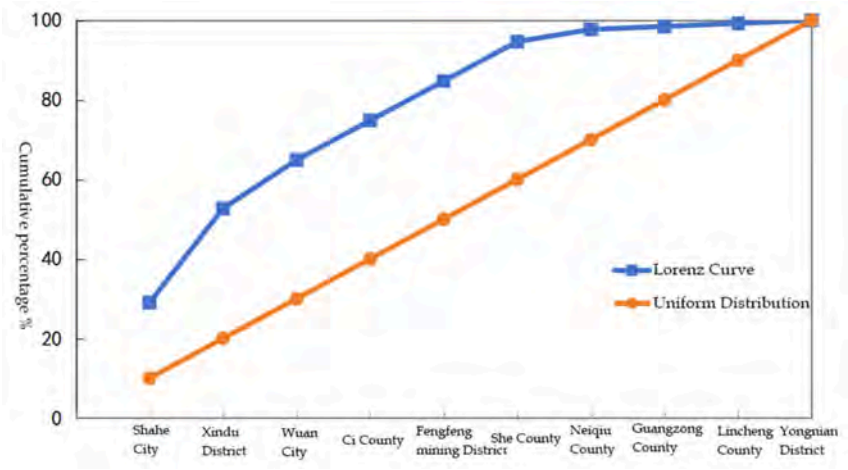

Figure 6. Lorenz curve of spatial distribution of TVs in the southern Hebei region.

5.2.3. Analysis of Spatial Distribution Density

Kernel density analysis is used to identify spatial concentration intensity and hotspot areas. The results (Figure 7) reveal three major high-density clusters located in western Xingtai, the Handan–Xingtai border, and southwestern Handan. These clusters are mainly distributed along river systems and mountain-front zones, indicating that water accessibility and terrain conditions play a key role in shaping settlement concentration. The spatial pattern can therefore be summarized as "multi-core clustering with peripheral dispersion," where most villages are concentrated in several core areas while others are scattered.

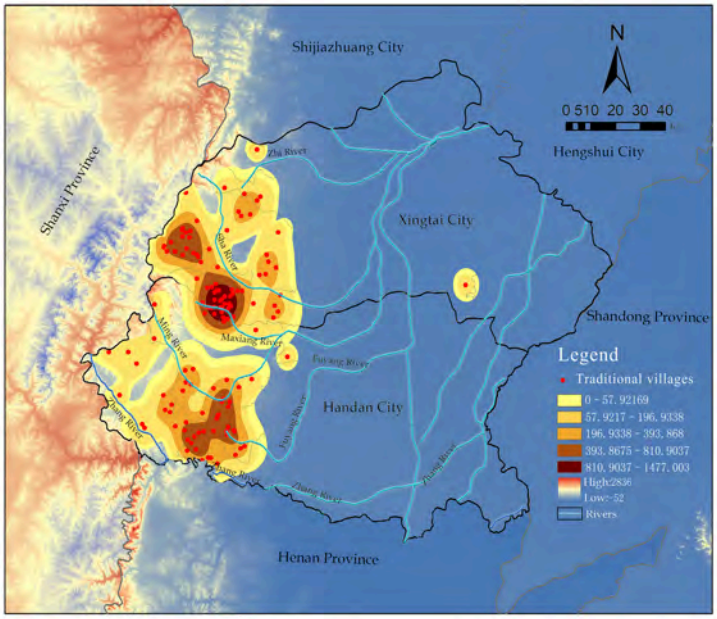

Figure 7. Nuclear density analysis diagram of TVs in the southern Hebei region.

5.2.4. Spatial Autocorrelation Analysis

To test the statistical significance of the observed clustering, global Moran's I is applied. The result (Moran's I = 0.1457, Z = 5.85, $p < 0.05$) indicates a significant positive spatial autocorrelation, confirming that the clustered pattern is not random. Local Moran's I further identifies "high–high" clusters as the dominant spatial pattern, indicating areas where high-density villages are surrounded by similarly high-density areas (Figure 8). To further explore local clustering intensity, hotspot analysis (Getis–Ord Gi*) is conducted

(Table 1). The results (Figure 9) show a clear spatial pattern of "hot in the west and cold in the east," with over 95% of TVs located in hotspot regions.

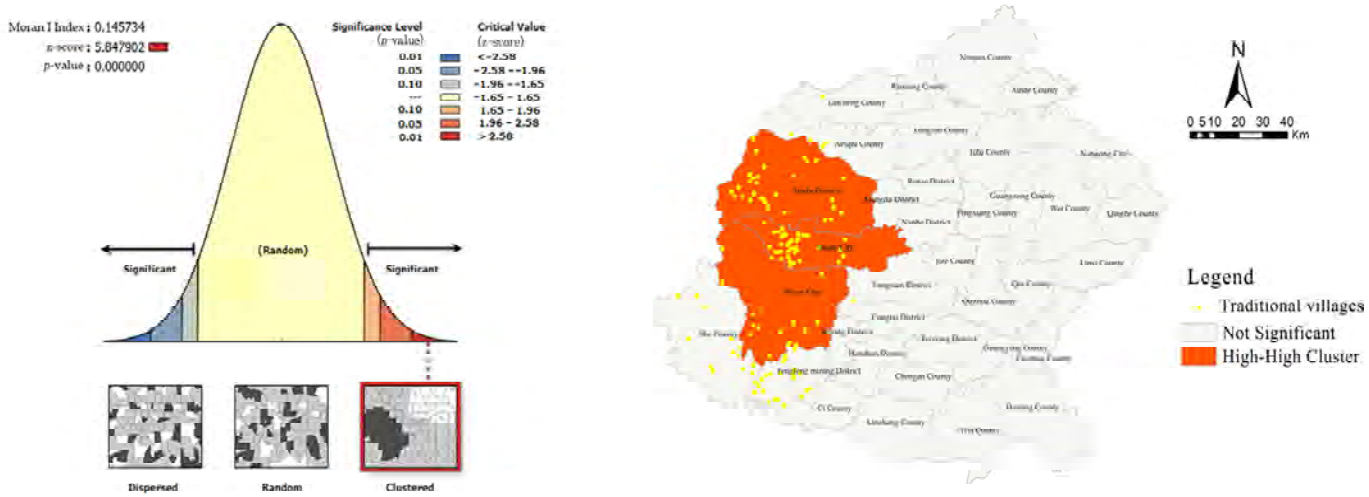

Figure 8. Spatial autocorrelation analysis of TVs in the southern Hebei region.

Table 1. Statistics on the number of different cold and hotspots in TVs in the southern Hebei region.

Hot and Cold Zone	Number of TVs/pc	Ratio of Total Number of TVs (%)
First-level hotspot zone	86	65.80%
Secondary hotspot zone	26	19.80%
Third-level hotspot zone	18	13.70%
Transition region	1	0.70%
First-level cold spot zone	0	0%
Secondary cold spot zone	0	0%
Third-level cold spot zone	0	0%

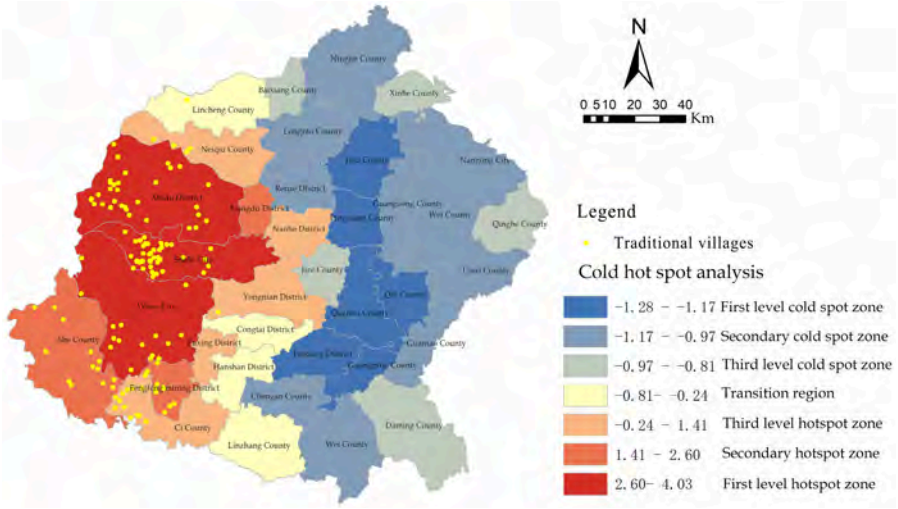

Figure 9. Cluster distribution of cold and hotspots in TVs in the southern Hebei region.

5.3. Spatio-Temporal Evolution Characteristics

By consulting local chronicles, historical documents, and statistical yearbooks, and conducting field surveys, the historical formation periods of TVs in southern Hebei were identified. The study samples were divided into five significant historical periods: pre-Sui, Sui–Tang–Song–Liao–Jin, Yuan, Ming, and Qing.

There were only 15 TVs formed before the Sui Dynasty, reflecting the turbulent historical environment and unstable governance. During the Sui–Tang–Song–Liao–Jin period, there was a small peak in village formation, reaching 23 villages, driven by rapid economic and social development. In the Yuan Dynasty, China experienced another period of instability, leading to slow growth in TVs, with only nine new villages formed. In contrast, the Ming Dynasty (1368–1644) saw a relative stabilization of society and an influx of new settlers, resulting in a peak of 67 new villages. By the Qing Dynasty and post-Qing period (1644 onwards), the development of TVs stabilized, with growth rates slowing and only a few areas seeing an increase in village numbers, as shown in Figure 10 and Table 2.

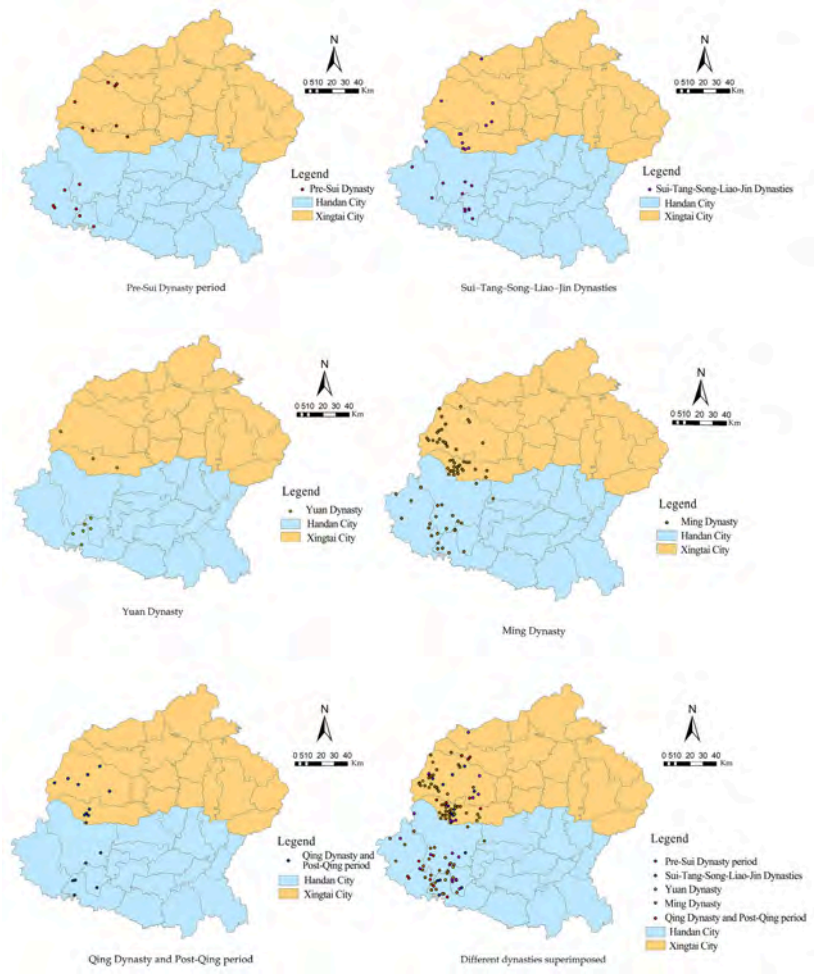

Figure 10. Distribution map of TVs in different ages.

Table 2. Distribution table of TVs in different ages.

Historical Period	Years	City	Quantity	Total
Pre-Sui Dynasty period	Before 581 AD	Xingtai Handan	8 7	15
Sui–Tang–Song–Liao–Jin period	581–1234 AD	Xingtai Handan	11 12	23
Yuan Dynasty	1271–1368 AD	Xingtai Handan	3 6	9
Ming Dynasty	1368–1644 AD	Xingtai Handan	42 25	67
Qing Dynasty and post-Qing period	After 1644 AD	Xingtai Handan	11 6	17

A quantitative analysis of the spatial distribution characteristics of villages was conducted using the standard deviation ellipse (SDE) (Figure 11). The results reveal the following patterns: before the Sui Dynasty, villages were closely clustered, with a smaller SDE and a larger axis ratio. During the Sui, Tang, Song, Liao, Jin, and Yuan dynasties, there was spatial expansion of villages, characterized by a larger SDE and a reduced axis ratio, indicating a wider but less concentrated distribution. This dispersion continued until the Ming Dynasty (1368–1644), during which the SDE approached a circular shape and the axis ratio was at its minimum, showing a high clustering state. In the Qing Dynasty, the SDE contracted and the axis ratio increased. From the Sui Dynasty to the end of the Qing Dynasty (581–1912 AD), the clustering center of villages slightly shifted around the western border between Handan and Xingtai. The main axis of spatial distribution consistently followed a northeast–southwest direction, closely aligning with the structural line of the Taihang Mountains and the extension direction of the regional water system.

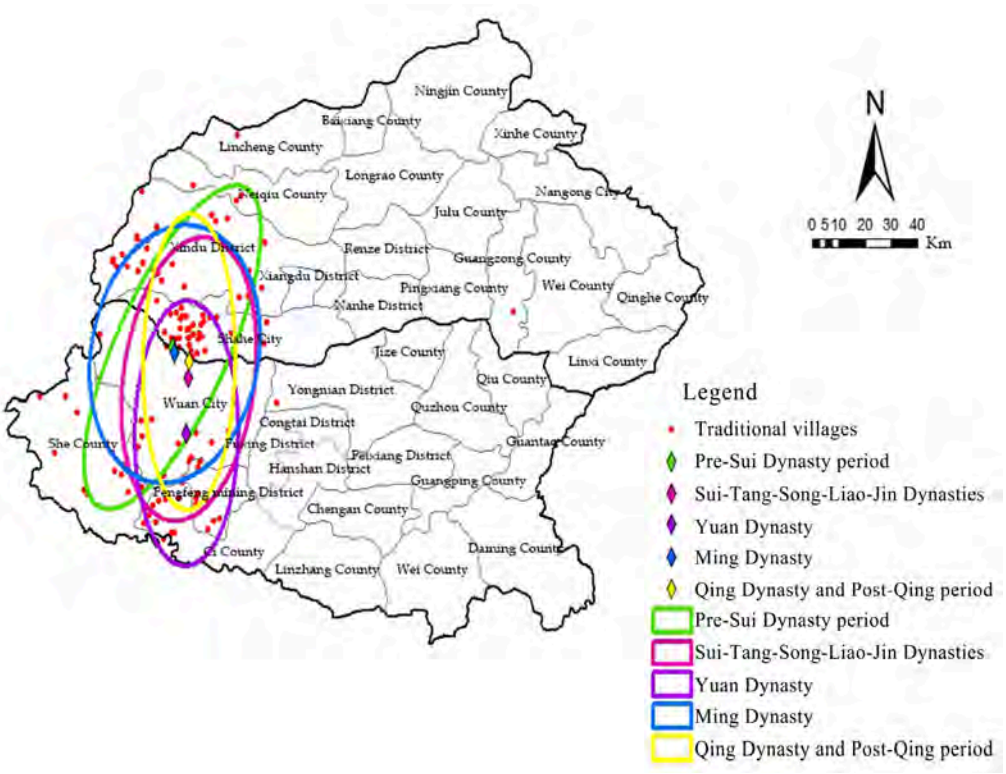

Figure 11. The standard deviation ellipse of TVs in the southern Hebei region.

Figure 12 illustrates the temporal variations in the density of TVs in the southern Hebei region. Prior to the Sui Dynasty, villages were sparse, primarily situated in the western areas of Handan and Xingtai. During the Sui, Tang, Song, Liao, and Jin dynasties, the number of villages increased, progressively extending into adjacent areas from their initial concentrations. In the Yuan Dynasty, village growth decelerated, with no notable expansion in their geographical distribution. The Ming Dynasty experienced rapid village development, characterized by a significant rise in numbers and increased density, resulting in the emergence of several core clusters. In the Qing Dynasty and post-Qing period, the number of villages reached its zenith, exhibiting minimal growth but achieving a more stable overall distribution. The predominant location of villages in the western mountainous areas of southern Hebei is attributable to strategic factors such as mountain shelter, water access, defensibility, and abundant resources.

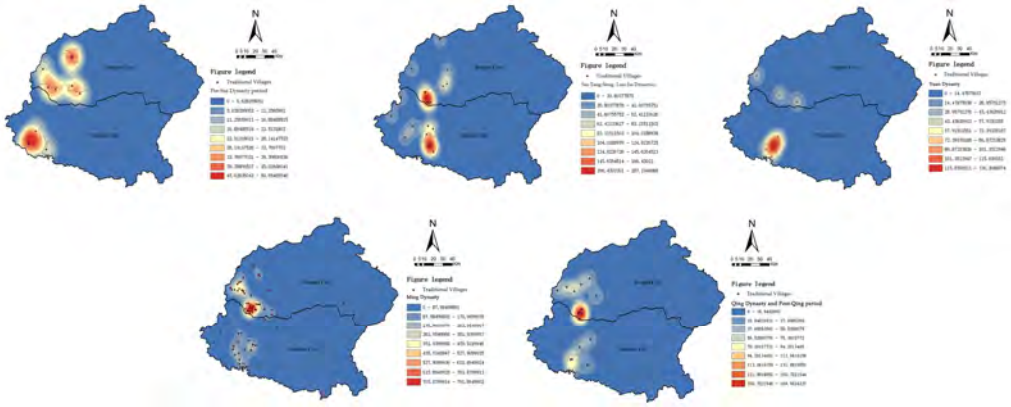

Figure 12. Spatial distribution density of TVs in the southern Hebei region at different time periods.

The results show that village formation experienced a non-linear process, with the Ming Dynasty representing the peak period (67 villages), accounting for nearly half of the total sample. Earlier periods show limited growth due to unstable social conditions, while later periods exhibit stabilization rather than expansion. The standard deviation ellipse (SDE) is applied to capture spatial evolution and directional trends. The results indicate that the distribution expanded from a concentrated pattern to a more dispersed one and then reconverged into clustered forms. The main axis consistently follows a northeast–southwest direction, aligning with the Taihang Mountain system. Overall, the evolution process can be summarized as a transition from initial concentration to expansion and subsequent stabilization, accompanied by a gradual shift in spatial center.

5.4. Analysis of Factors Influencing the Spatial Distribution of TVs in the Southern Hebei Region

The Chinese feng shui concept of "by the mountains and near the water" underscores the close relationship between the establishment of TVs and their geographical environments. Their development is influenced by various natural factors, including topography, altitude, and water systems. In addition, a strong correlation exists between the formation of TVs and their historical and cultural contexts.

5.4.1. Natural Environmental Factors

The topographical complexity and variety of the Southern Hebei region are evidenced by the presence of the Taihang Mountains in the west and plains in the eastern section. This region exhibits a stepped distribution, with a general gradient descending from high elevations in the west to lower elevations in the east, with an elevation range from 23 to 1658 m (see Figure 13). The analysis indicates a clear decline in the number of TVs with increasing elevation, with more than 80% of villages located in low- to medium-elevation zones. Higher elevations are generally associated with harsher climatic conditions and reduced suitability for human settlement, whereas lowland and basin areas offer more favorable conditions for agriculture and resource use.

This pattern reflects both environmental and historical factors. On the one hand, moderate elevation areas provide relatively stable conditions for cultivation and daily life. On the other hand, mountainous and foothill environments historically offered strategic advantages for defense, functioning as natural barriers during periods of conflict. In addition, constraints related to construction materials and transportation in earlier periods also influenced settlement location choices. As a result, TVs tend to be concentrated in areas that balance environmental suitability with security considerations.

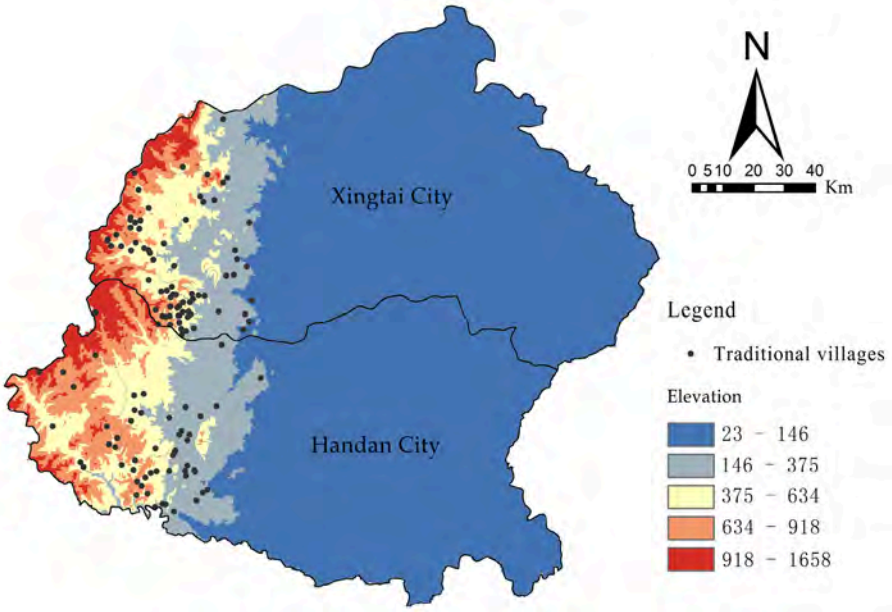

Figure 13. Elevation distribution map of TVs in the southern Hebei region.

In the preliminary phases of conventional village site selection, slope, in conjunction with elevation, emerges as a pivotal factor influencing the layout of settlements. The analysis indicates that over 90% of TVs in the southern Hebei region are located in areas with slopes less than 15°, while the number of TVs gradually decreases as the slope values increase, demonstrating an overall negative correlation (Figure 14).

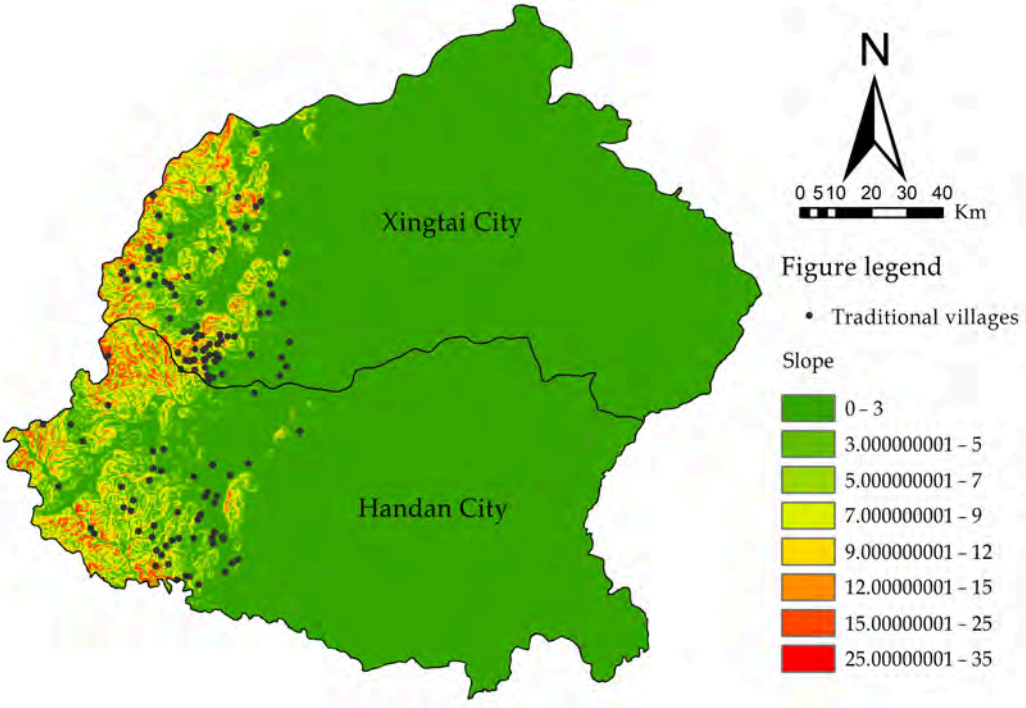

Figure 14. Slope distribution of traditional villages in southern Hebei.

This distribution suggests that the primary reasons for the location of most TVs in relatively flat areas are twofold: first, to facilitate the construction of houses, historically and presently, most villages have been established in flatter regions, which reduces construction costs. Secondly, the topography is conducive to agricultural production, facilitating the cultivation of land and the planting of crops. Beyond a slope of 25°, however, the terrain

becomes susceptible to natural disasters such as landslides and debris flows, as well as severe soil erosion, rendering these areas unsuitable for human habitation. Consequently, very few TVs are established in these regions. The configuration of TVs is often aligned with topographical conditions, typically following contour lines, thus presenting a stepped distribution pattern.

In this study, the term "aspect" is employed to denote the directional orientation of a slope on a mountain, positing that variations in aspect can lead to differences in temperature and precipitation. As demonstrated in Figure 15, approximately 70% of TVs are situated on sunny slopes. Sunny slopes are favourable for cultivating food crops due to their adequate sunlight and suitable temperatures, providing better conditions for living and agriculture. However, around 30% of villages are located on shady slopes. Despite the comparatively reduced sunlight levels in these shaded regions, precipitation zones often develop, resulting in a more abundant water supply. This increased access to water mitigates the limitations associated with reduced sunlight, thereby explaining the presence of some villages in these shaded areas.

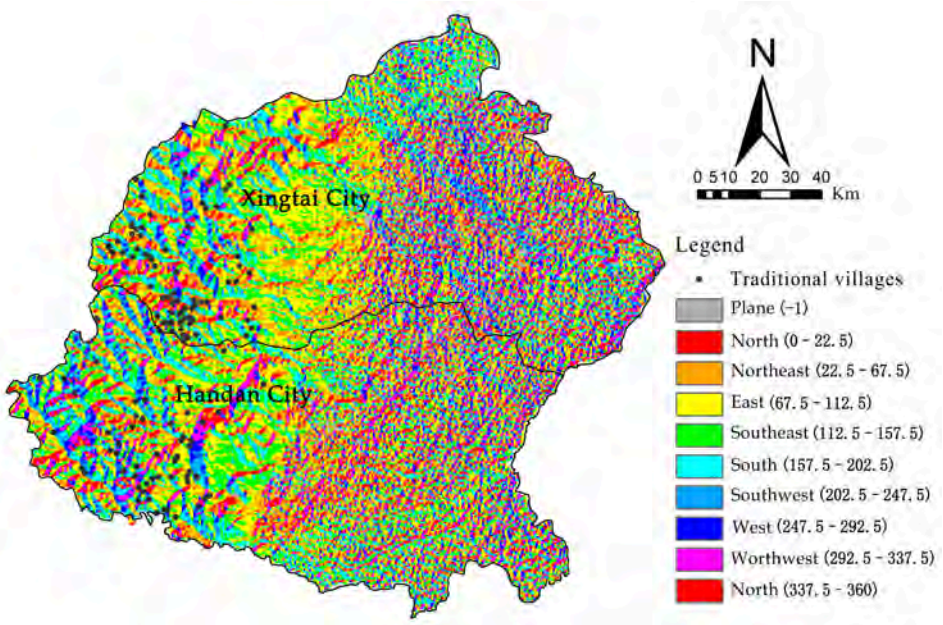

Figure 15. Aspect distribution of traditional villages in southern Hebei.

The southern Hebei region predominantly lies within a warm temperate zone, characterized by minor temperature fluctuations and generally favorable conditions. While the eastern part of the region is warmer, it receives less precipitation, which can lead to faster evaporation and potential water scarcity or drought in some areas. In contrast, the western part, located within the Taihang Mountains, experiences cooler temperatures that are more conducive to the formation of cold air. This results in higher precipitation and reduced evaporation rates, creating a more humid environment.

As illustrated in Figure 16, most villages are located in relatively cooler climatic zones. Notably, the eastern part of the region experiences less rainfall compared to the western part. In fact, most villages are found in areas with higher precipitation, as shown in Figure 17. This indicates that the distribution of villages is significantly influenced by both precipitation and temperature conditions. Regions with ample rainfall and favorable temperatures are more likely to have a higher number of villages. In a social structure predominantly reliant on agriculture, sufficient rainfall and suitable temperatures provide an optimal environment for human settlements.

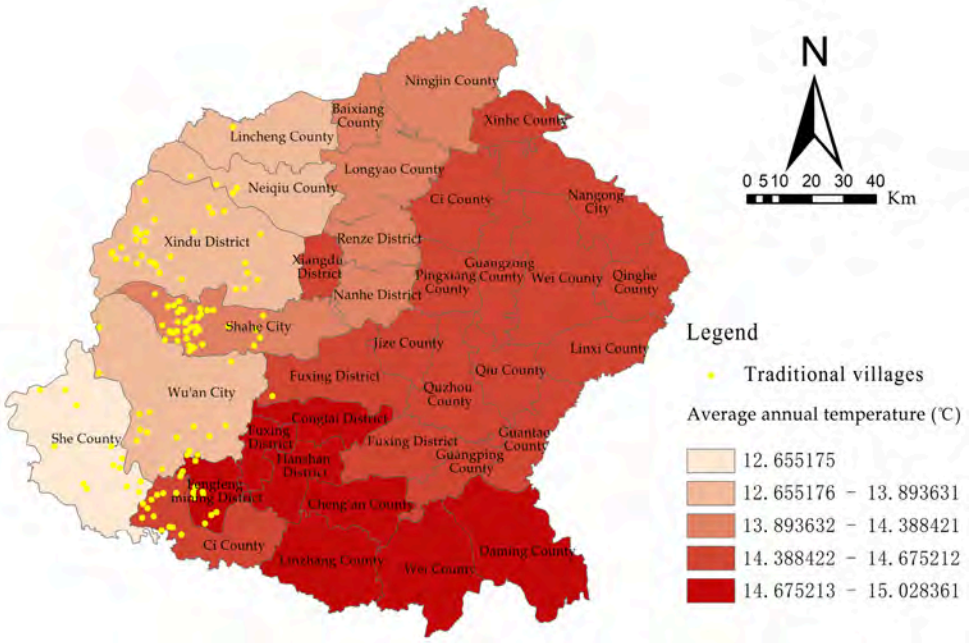

Figure 16. Average temperature distribution map of TVs in the southern Hebei region in 2022.

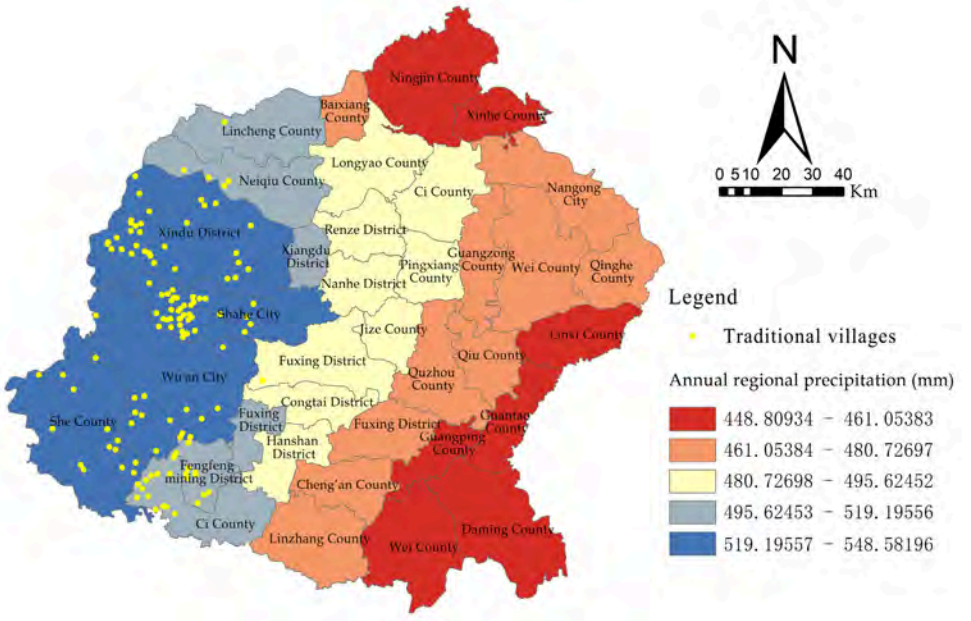

Figure 17. Average precipitation distribution map of TVs in the southern Hebei region in 2022.

Water is fundamental to human existence, particularly during the agricultural period, when people relied on weather conditions for sustenance. In times of hot and dry climates with low precipitation, soil fertility and cultivation are adversely affected, making water sources critically important. Using current hydrological data, this study employs ArcGIS 10.8 to map the river systems in the southern Hebei region and to quantify the proximity of TVs from the river systems (as illustrated in Figure 18).

The application of proximity analysis (see Table 3) reveals a conspicuous aggregation of TVs located within a 3000 m radius of rivers. It is noteworthy that 59.62% of villages are positioned in such close range. This finding underscores the pivotal role of rivers in shaping village locations. In contrast, only 43 villages are located beyond 6000 m from rivers, reflecting the challenges posed by water scarcity on settlement patterns and agricultural development.

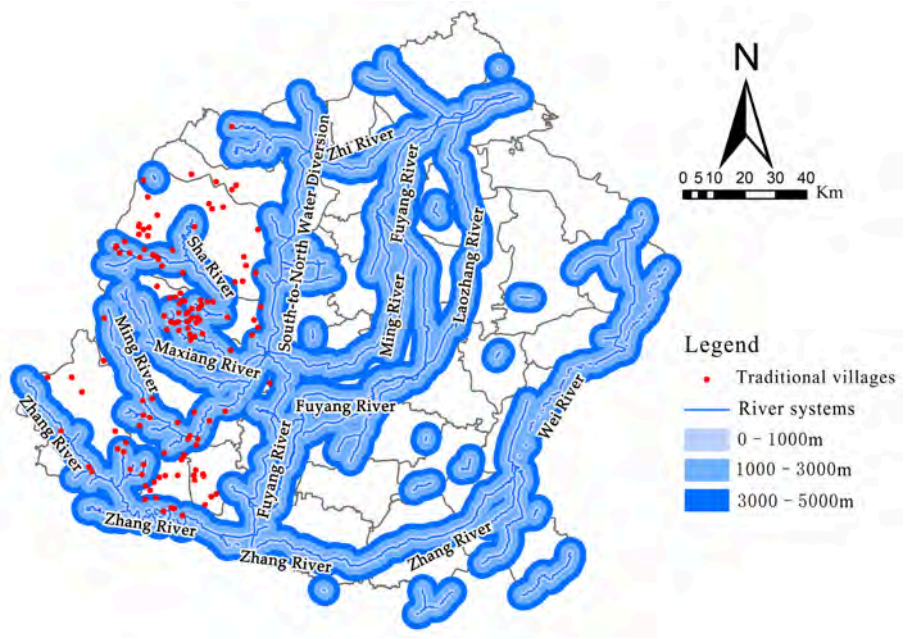

Figure 18. Analysis map of the river system of TVs in the southern Hebei region.

Table 3. Statistics of the number of TVs in different buffer zones in the southern Hebei region.

Buffer Width (m)	Number of TVs	Ratio of Total Number of TVs (%)
<1000	35	26.72%
1000–3000	30	22.90%
3000–5000	23	17.56%
>5000	43	32.82%

5.4.2. Social–Economic Factors

As illustrated in Figure 19, the relationship between TV distribution and population density is evident. The image reveals that villages have a primary concentration in regions of moderate population density, leaning towards areas of medium to low population density. A high population density has been found to be correlated with advanced urbanization, which can have a detrimental effect on the conservation of traditional architecture. Conversely, a low population density can result in the phenomenon of "hollow villages," leading to gradual abandonment and the eventual disappearance of TVs [74].

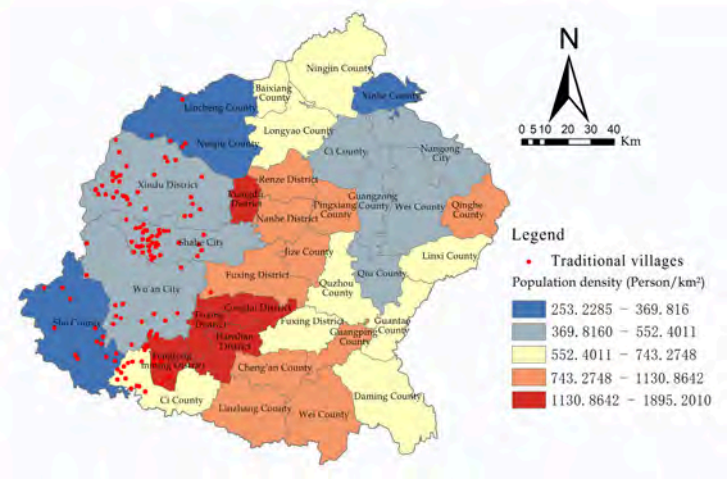

Figure 19. Population density distribution map of TVs in the southern Hebei region.

Compared with northern and eastern Hebei, the southern part has lagged behind in development and experienced a slower urbanization process, so many TVs have been preserved [55]. Based on the economic indicators and GDP growth rates from the *China County Statistical Yearbook* [75], we made a comparison between various countries and districts in the southern Hebei region. It is evident that economic development in the southern Hebei region is uneven, with considerable disparities between different areas.

Figure 20 shows that TVs are less distributed in economically developed areas, while cities with lower levels of development have more TVs. In regions with a total GDP of more than CNY 50 billion, there are 16 TVs, representing 12.21% of the total. In regions with a GDP of less than CNY 50 billion, there are 115 TVs, representing 87.89% of the total (Table 4). This suggests that less economically developed areas tend to preserve more TVs. The reason for this could be that faster urbanization in economically developed regions often leads to TVs being replaced by modern development, whereas less developed areas face less development pressure, allowing TVs to be better preserved.

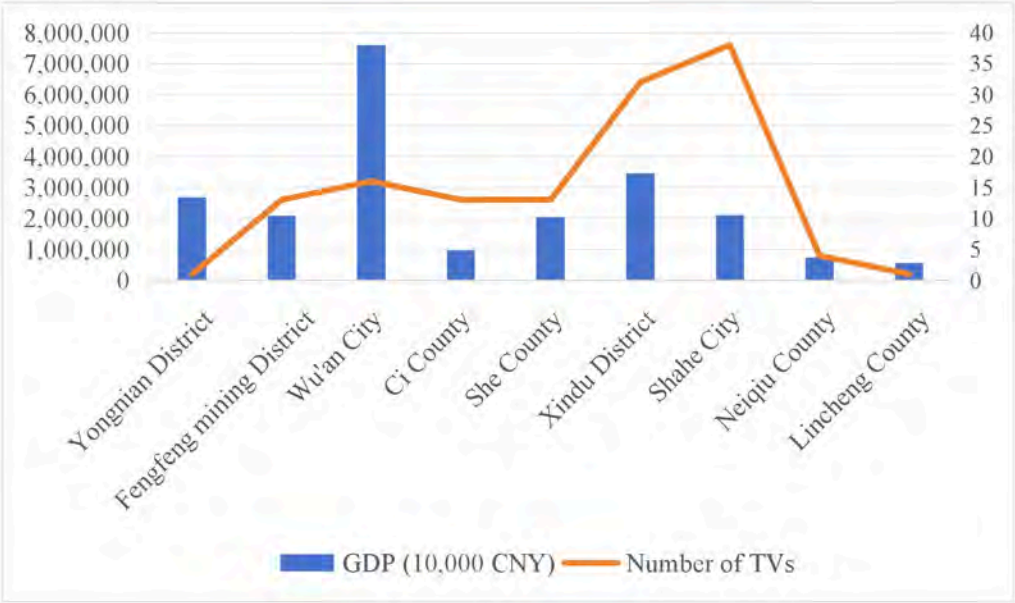

Figure 20. Distribution of TVs and GDP of each district and county in the southern Hebei region in 2021.

Table 4. Distribution of TVs and GDP of each district and county in the southern Hebei region in 2021.

City	Counties	GDP (CNY 10,000)	Number of TVs	Total Number of TVs (%)
Handan	Yongnian District	2,682,226	1	0.76%
	Fengfeng mining District	2,090,226	13	9.92%
	Wu'an city	7,581,344	16	12.21%
	Ci County	966,962	13	9.92%
	She County	2,038,745	13	9.92%
Xingtai	Xindu District	3,461,802	32	24.43%
	Shahe city	2,106,739	38	29.03%
	Neiqiu County	752,589	4	3.05%
	Lincheng County	564,756	1	0.76%

Due to the absence of direct railway access and airports connecting TVs in the region, external connectivity primarily relies on road networks. This study utilizes road data from Hebei Province (available at https://openmaptiles.org/, accessed on 10 December 2023)

and analyzes vector data for national highways, provincial roads, and expressways in the southern Hebei region as of 2023. Using ArcGIS 10.8, we conducted a buffer analysis to categorize roads by their classification levels and performed multi-ring buffer analyses to evaluate the accessibility of each TV (see Table 5).

Table 5. Accessibility of TVs in the southern Hebei region.

Distance from Road/m	0–1000	1000–2000	2000–3000	3000–5000	≥5000
Accessibility	Extremely easy	Easy	Medium	Difficult	Extremely Difficult
Number of TVs (count)	36	17	17	25	36
Percentage (%)	27.48%	12.98%	12.98%	19.08%	27.48%

The analysis reveals a distribution pattern of accessibility characterized by "proximal convenience–intermediate sparsity–distal closure." As transportation convenience improves, the number of villages initially decreases before subsequently increasing. Villages with extremely high accessibility are represented by 36 cases, accounting for 27.48% of the total. This finding suggests that regions with better transportation facilities are more likely to form and retain TVs, which is closely related to the historical development patterns along transport routes. Conversely, TVs classified as having average accessibility (easy, medium, difficult) comprise less than 20% of the total. These areas lack transportation advantages and do not exhibit completely isolated geographical conditions, contributing to the lower preservation rates of TVs in these regions. Notably, villages categorized as extremely difficult to access, influenced by terrain and road classifications, constitute another 27.48%. This reflects that remote areas, less affected by modern influences, tend to preserve their traditional characteristics more effectively.

From a spatial distribution perspective (see Figure 21), regions such as the western and southwestern parts of Handan city and the southwestern area of Xingtai city exhibit poor transportation accessibility yet contain many well-preserved TVs. In contrast, areas with well-developed transportation infrastructure, such as central and eastern Handan city and northeastern Xingtai city, have nearly zero TVs. This indicates that while limited transportation access may constrain the economic development of TVs, it concurrently fosters the preservation of historical architecture and cultural heritage due to reduced modern interference.

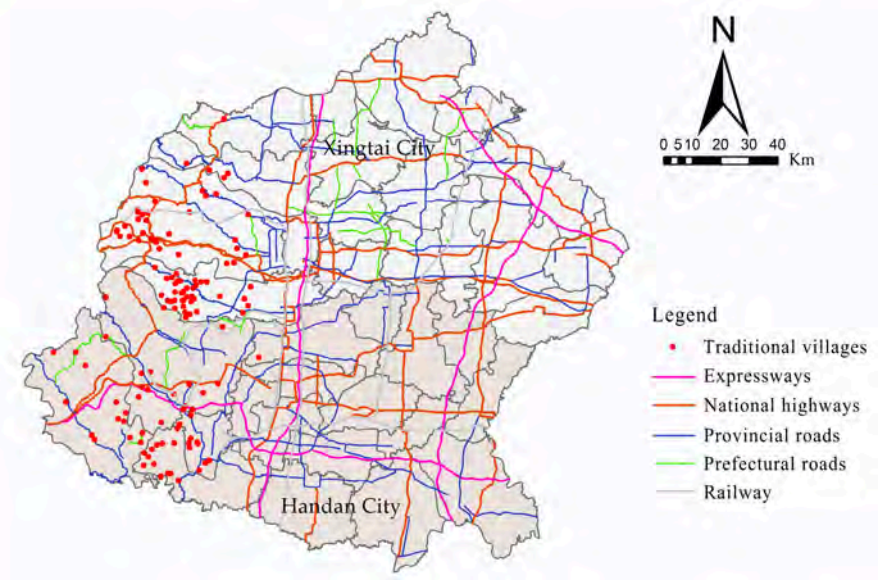

Figure 21. Traffic distribution map of TVs in the southern Hebei region.

5.4.3. Historical and Cultural Factors

The southern Hebei region serves as a transitional zone between the Central Plains (Zhong Yuan) and northern China (Hua Bei), and the configuration of TVs is the result of a dynamic fusion of historical and cultural influences [76]. During the period of the Warring States (475–221 BC), the southern Hebei region was part of the State of Zhao, located within the overlapping spheres of influence of multiple states [77]. During this period, the agricultural practices of the Central Plains interacted with the nomadic traditions of northern China, resulting in a rich tapestry of customs and political dynamics. Consequently, early settlements developed near water sources in elevated and flat terrains, laying the groundwork for the initial prototypes of villages.

The unification of China during the Qin and Han periods (221 BC–220 AD) resulted in the establishment of a relatively stable social environment in the southern Hebei region, thereby facilitating advancements in agricultural production techniques. This social stability is evidenced by a notable increase in both the number and scale of villages. These settlements began to expand beyond areas with favorable natural conditions, extending into broader plains and hilly regions, resulting in a denser distribution pattern. However, during the Song, Liao, and Jin dynasties (907 AD–1279 AD), the region experienced significant disruptions due to social unrest and frequent warfare. Trade interactions from the Jin dynasty and population movements from Shandong and Henan converged in this area, prompting many villages to adopt military defensive structures for security, as exemplified by Yingtan Village in Xintai city. The subsequent Yuan, Ming, and Qing dynasties (1271 AD–1912 AD) witnessed a period of relative stability and development, with southern Hebei undergoing a phase of sustained growth and maturation. During this era, social structures became increasingly centred around family and clan units, thereby reinforcing the social fabric of residents' living style.

The spatial distribution of TVs in southern Hebei reflects the interaction of multiple historical, socio-cultural, and environmental factors, including external invasions, migration patterns, trade activities, geographical conditions, and political strategies. These intertwined processes have shaped a distinctive village landscape in the region [78]. Based on these influences, village formation in southern Hebei can be categorized into five models, primarily driven by endogenous growth and long-term residence, as well as by the need for military defense.

(1) Indigenous Natural Growth and Generational Residence: Benefiting from fertile soil and plentiful water sources, early residents engaged in stable agricultural practices, leading to natural population growth and subsequent expansion of the village, such as Guxin village in Shexian. Organized by family units, these communities cultivated surrounding lands and constructed homes, resulting in orderly spatial layouts that promote communication and collaboration among family members.
(2) Need of Military Defense: Due to the strategic significance of the southern Hebei region, many villages historically faced threats of warfare and developed unique defensive layouts. Yingtan village utilized its rugged terrain to enhance security through the construction of fortifications.
(3) Transportation and Commerce-Driven: Serving as a commercial corridor linking four provinces, some villages in southern Hebei emerged primarily as trade hubs. Notable examples include Yetaocun in Wu'an city, which developed in response to the dynamics of trade activities.
(4) Migration and Aggregation: Historical events such as wars and famines prompted significant population migration into southern Hebei, with those populations settling down afterwards. Initially characterized by chaotic layouts, these villages adapted

over time, leading to more organized spatial structures as diverse groups integrated, such as Xiajie village in Shahe city.

(5) Geographical Environmental Choice: Villages situated in the hilly areas at the junction of the Taihang Mountains and the North China Plain are shaped by the region's rugged terrain and the verticality of loess. This environment supports the development of cave dwellings, with residents drawing inspiration from the cave-dwelling culture of Shanxi, as seen in Tongyi village in Cixian.

6. Discussion

6.1. Comparison with Previous Studies and International Relevance

The results of this study confirm that the spatial distribution of traditional villages (TVs) in southern Hebei is highly clustered and uneven, which is consistent with a large body of research conducted in other regions of China [2,10,20,27,79]. However, rather than simply reaffirming this general pattern, this study provides a more process-oriented and region-specific interpretation. In contrast to studies in regions such as the Yangtze River Basin or Fujian Province, where village distribution is often strongly associated with hydrological systems and agricultural suitability, the southern Hebei case highlights the importance of mountain-front environments, historical defense requirements, and long-term population mobility. This suggests that similar spatial patterns of clustering may arise from different underlying mechanisms depending on regional historical and geographical contexts. Therefore, the clustered distribution observed in southern Hebei should not be understood as a purely environmental outcome, but as the result of a historically contingent process shaped by the interaction between environmental constraints and socio-historical dynamics.

From the perspective of cultural landscape theory, these findings can be interpreted as evidence of a dynamic process of human–environment interaction rather than a static correspondence between physical geography and settlement location. While previous studies often emphasize the determining role of environmental factors such as elevation, slope, and proximity to water, the results of this study suggest a more nuanced mechanism in which environmental suitability provides a set of constraints and opportunities but does not directly determine settlement outcomes. Instead, local communities actively negotiate these conditions through practices related to subsistence, defense, social organization, and mobility. In this sense, the spatial distribution of TVs in southern Hebei reflects a shift from environmental constraint to socio-cultural mediation. This interpretation not only reinforces the relevance of cultural landscape theory but also contributes to ongoing debates on whether rural settlement patterns should be understood primarily as environmentally determined or socially constructed.

The findings also resonate with international studies on rural cultural landscapes, where rural heritage is increasingly understood not only as a collection of historic buildings but also as the outcome of long-term interactions among settlement, livelihood, environment, memory, and identity. Similar to European studies on historic rural landscapes, the southern Hebei case shows that rural heritage is embedded in everyday productive landscapes and cannot be separated from agricultural adaptation, local social organization, and regional mobility. Similarities can also be found with studies of rural heritage in other world regions, where remoteness, limited accessibility, and slower modernization often contribute to the preservation of vernacular settlement forms.

However, the southern Hebei case also differs from many international rural heritage contexts. In some European or Australian cases, rural cultural landscapes are often discussed through land-use continuity, scenic value, or heritage management frameworks. In southern Hebei, by contrast, the spatial pattern of traditional villages is more strongly

associated with mountain-front settlement, historical defense, migration, clan-based social organization, and the long-term transition between mountainous and plain environments. This indicates that similar rural heritage patterns—such as clustering, persistence in less urbanized areas, or strong landscape dependence—may be produced by different historical mechanisms. The contribution of this study is therefore not only to confirm the general importance of landscape in rural heritage studies, but also to show how regional historical processes mediate the relationship between environment and village preservation.

More broadly, this finding gives the southern Hebei case international relevance. It addresses a general question in rural heritage studies: how historically layered rural landscapes can be conserved while adapting to modernization, demographic change, infrastructure expansion, and development pressure. Similar challenges have been observed in international studies of rural cultural landscapes, where heritage is increasingly understood not only as historic fabric, but also as a living system involving livelihood, memory, identity, accessibility, and community continuity [6,36,41–44,71–77].

6.2. Historical Interpretation of Driving Mechanisms

The temporal analysis further deepens this interpretation. As shown in Figures 10 and 11, the formation and expansion of TVs in southern Hebei did not follow a single linear path, but instead passed through several historical stages characterized by concentration, expansion, agglomeration, and stabilization. The relatively small number of villages formed before the Sui Dynasty suggests that early settlement was highly selective and strongly dependent on basic environmental security. During the Sui–Tang–Song–Liao–Jin period, the number of villages increased and their distribution expanded, indicating the gradual strengthening of agrarian development and regional integration. By contrast, the Yuan Dynasty witnessed slower growth, likely reflecting social instability and disrupted settlement continuity. The Ming Dynasty marked the most important phase of village formation, with nearly half of the sampled villages established during this period, suggesting that political stability, demographic recovery, and agricultural expansion created favorable conditions for rural development. In this sense, the temporal reconstruction presented here responds directly to a key limitation in existing research, which has often emphasized present-day spatial patterns while paying less attention to long-term evolutionary trajectories [10,20,27].

A further important finding is that the relative influence of different driving factors has shifted over time. In the early stages of village formation, natural environmental conditions—such as elevation, slope, climate, and proximity to water—played a dominant role in determining settlement locations. These factors were essential for subsistence agriculture, daily life, and risk avoidance in premodern contexts. However, the southern Hebei case demonstrates that natural conditions alone are insufficient to explain the persistence and transformation of villages. Over time, socio-cultural processes, including warfare, migration, kinship-based settlement, and regional commercial exchange, became increasingly important. This is particularly evident in southern Hebei as a borderland and transitional region between the Taihang Mountains and the North China Plain, where historical dynamics of defense, mobility, and cultural interaction significantly shaped settlement patterns. As a result, the spatial distribution of TVs should be understood as the combined outcome of environmental adaptation and socio-historical selection, consistent with recent studies emphasizing the joint role of natural and socio-cultural mechanisms [27,79].

The results concerning economic development and transport accessibility further reveal a complex and non-linear relationship between modernization and village preservation. On the one hand, areas with lower levels of economic development tend to contain more TVs, suggesting that slower urbanization and reduced redevelopment pressure may contribute to their survival. On the other hand, underdevelopment cannot be simply

regarded as beneficial for heritage conservation, as issues such as population decline, aging, and lack of economic vitality may threaten long-term sustainability. A similar duality is observed in accessibility patterns: villages are concentrated in both highly accessible and highly remote areas, while intermediate zones contain fewer cases. This indicates that accessibility operates as a non-linear factor, simultaneously enabling development opportunities and intensifying pressures of transformation. Such findings support the view that infrastructure and market forces reshape rural socio-spatial systems in complex ways, rather than producing uniform outcomes.

This historical interpretation also has implications for sustainable development. It shows that rural heritage conservation should not focus only on present-day buildings, tourism value, or accessibility conditions, but should also consider the long-term relationships between communities, landscapes, livelihoods, and local identity. For southern Hebei, the sustainability of TVs depends on maintaining these historically formed relationships while responding to population decline, regional inequality, and modernization pressure.

6.3. Theoretical and Practical Implications for Sustainable Rural Heritage Conservation

Building on the above analysis, the findings of this study can be further synthesized from a combined empirical and theoretical perspective. First, the spatial distribution of TVs reflects not only environmental suitability, but also the historical embedding of socio-cultural processes within specific geographical contexts, suggesting that rural settlement patterns are historically contingent rather than purely environmentally determined. Second, TVs should be understood as dynamic socio-spatial systems that have long supported regional economic and social stability, rather than as static heritage units. Third, the interaction between infrastructure development, economic change, and accessibility generates non-linear and sometimes contradictory effects on village preservation and transformation, reshaping the micro-scale organization of rural space. Taken together, these propositions indicate that the study of TVs should move beyond descriptive spatial analysis toward an integrated understanding of cultural landscapes as evolving systems shaped by interacting environmental, historical, and socio-economic forces.

Theoretically, this study contributes to rural heritage and cultural landscape studies in three ways. First, it demonstrates that the spatial distribution of traditional villages should not be interpreted as a static result of environmental suitability, but as a historically layered process shaped by changing relations between nature, society, and culture. Second, it shows that similar spatial outcomes, such as clustering in foothill or marginal areas, may be generated by different historical mechanisms, including defense, migration, agricultural expansion, and accessibility. Third, by incorporating contemporary variables such as economic development and transport accessibility, the study links historical formation with present-day restructuring, thereby extending rural heritage research from the question of "where heritage villages are located" to "why they persist, transform, or decline under changing socio-economic conditions."

In practical terms, these findings suggest that the conservation and development of TVs in southern Hebei should adopt differentiated and context-sensitive strategies. Villages located in mountain-front and river-adjacent clusters should prioritize the protection of landscape integrity and traditional spatial structures. Remote villages may require targeted policy support to address demographic decline while maintaining their relatively intact cultural fabric. In contrast, villages with high accessibility should adopt controlled development approaches that balance tourism utilization with the preservation of cultural authenticity. More broadly, effective conservation should move beyond isolated architectural preservation toward sustaining the relationships between settlement space, historical context, and local livelihoods, thereby supporting the long-term resilience of TV systems.

These findings also have broader implications for sustainable rural development. The southern Hebei case shows that rural heritage conservation cannot be separated from questions of settlement continuity, livelihood transformation, accessibility, and regional inequality. Traditional villages are not only cultural resources but also living rural systems in which heritage, community identity, ecological adaptation, and local development are closely connected. Therefore, their conservation should contribute not only to the preservation of historic buildings and landscape features, but also to the long-term resilience of rural communities. This perspective is relevant beyond China because many rural heritage regions worldwide face similar tensions between depopulation, modernization, tourism development, infrastructure improvement, and the need to maintain cultural landscape integrity.

7. Conclusions

This study investigated the spatio-temporal evolution and driving mechanisms of traditional villages in southern Hebei by integrating GIS-based spatial analysis, historical interpretation, and multi-factor analysis. Focusing on 131 nationally recognized traditional villages, the study examined their spatial distribution, historical evolution, and the changing roles of natural, socio-cultural, and contemporary factors.

In response to the first research question, the results show that traditional villages in southern Hebei present a highly clustered and uneven spatial distribution. They are mainly concentrated in the western and southwestern mountain-front zones, especially along the transitional area between the Taihang Mountains and the North China Plain. Kernel density analysis reveals a multi-core clustering structure, while Moran's I confirms that this spatial pattern is statistically significant rather than random.

In response to the second research question, the study demonstrates that the spatial structure of traditional villages evolved through a non-linear historical trajectory. Village formation was limited in the early periods, expanded during the Sui–Tang–Song–Liao–Jin period, slowed during the Yuan Dynasty, and reached its most important peak in the Ming Dynasty. The standard deviation ellipse further shows that the overall distribution maintained a northeast–southwest orientation, corresponding to the structural direction of the Taihang Mountains and regional water systems. This indicates that the present spatial pattern is the cumulative outcome of long-term historical layering rather than a single-stage settlement process.

In response to the third research question, the findings reveal that the dominant driving mechanisms changed over time. In the early stages, settlement formation was strongly constrained by natural conditions, including elevation, slope, climate, and river proximity. Over time, however, socio-cultural factors such as warfare, migration, clan organization, trade, and regional cultural interaction became increasingly important. In the contemporary period, economic development and transport accessibility have introduced more complex and non-linear effects: both remote villages and highly accessible villages may be preserved, while areas under stronger urbanization pressure may experience greater heritage loss.

To sum up, this study contributes to international research on rural heritage and cultural landscapes by showing that traditional villages should be understood as dynamic cultural landscapes shaped by long-term human–environment interaction. The southern Hebei case complements existing studies by demonstrating that similar spatial patterns of rural heritage, such as clustering in marginal or foothill areas, may result from different historical mechanisms in different regional contexts. Practically, the findings suggest that conservation strategies should be differentiated according to spatial location, accessibility, development pressure, and historical–cultural value. Future research should further incor-

porate undocumented traditional settlements, village-scale morphological analysis, oral history, and field-based socio-cultural investigation to deepen the understanding of how rural heritage landscapes are formed, preserved, and transformed.

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