Spatial characteristics and influencing factors of Chinese traditional villages in eight provinces the Yellow River flows through

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Abstract
Along with global urbanization and the dominant trend toward urban-based policies, traditional villages are facing imbalanced development and the fate of revitalization or decline. In this study, 1,222 Chinese traditional villages in eight provinces the Yellow River flows through have been selected as the typical physical bearers of Chinese civilization of an investigation into the multi-scale spatial characteristics, and multiple influencing factors and mechanisms for regional patterns and spatial differentiation. Spatial analysis methods, including nearest neighbor index and kernel density, are applied to figure out the great regional differentiation in the overall pattern and specific distribution characteristics in each province. Physical environment factors and socioeconomic influencing factors are analyzed and compared using geographical detectors. The results show that: (a) The overall spatial distribution of the traditional villages shows great regional differentiation and is characterized by “two cores,” “three distribution modes,” and “four types of the absence” of traditional villages; (b) the spatial distribution of traditional villages in the Yellow River Basin is affected both by natural factors and by socioeconomic factors, with natural factors having the greater impact; and (c) there is no inevitable correlation between the level of economic development and the rise and fall of traditional villages. By analyzing and revealing the external forces and internal motivation and influencing factors of renewal and evolution, and the wisdom and culture behind the physical places, this research can deepen the understanding of traditional villages, enable traditional society to better adapt to contemporary society, and provide reference for rural revitalization and regional development of rural areas and the Yellow River Basin.

KEYWORDS
rural geography, spatial differentiation, the Yellow River, traditional villages

1 INTRODUCTION

Along with global urbanization, modernization, and the dominant trend toward urban policies, rural decline has become a global issue (Y. Li, Westlund, & Liu, 2019; Y. Liu & Li, 2017). The problems of “rural diseases” such as haphazard village construction, inefficient resource utilization, hollowing villages (Long, Li, Liu, Woods, & Zou, 2012), and impoverishment issues are attracting increasing attention (Liu, Zhou & Li, 2019). In China, hundreds of villages perish each year, while under the influence of changing socioeconomic and ecological environments and policies; thousands are facing imbalanced development and a fate of revitalization or decline in the process of reconstruction and

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transformation (Jia et al., 2020). Traditional villages are a typical type of rural settlement; they are bearers of traditional national arts and cultures and reflect the changing political, social, and economic background in various epochs (Kang, Zhang, Hu, Zhou, & Xiong, 2016). The distorted or reconstructed traditional culture of the villages has placed pressure on cultural continuity and diversity, led to the lack of cultural identity, and aroused great attention from the government and social concerns (Li et al., 2017). Countries around the world are implementing strategies to reinvigorate rural regions in the age of the “urban triumph” (Meijers & van der Wouw, 2019). In China, from 2012 till 2019, the national ministries selected and listed 6,819 Chinese traditional villages (CTVs) that were still alive and represented the most valuable and memorable villages among the 600,000 existing Chinese villages. According to the official Traditional Village Evaluation and Identification System, the term Chinese traditional villages refers to villages built before 1980 that have sufficiently maintained their historical evolution and architectural environment, features, and locations and have preserved unique folk customs, and still function today with a long history (Y. Hu, Chen, Cao, & Cao, 2014). In 2018, the CTVs were categorized as characteristic protected villages in the Chinese national strategic planning of rural revitalization, which attaches great importance to the issues of protection and development (Li et al., 2020).

Studies of rural settlements can be traced back to the mid-nineteenth century (Zhou, Huang, & Liu, 2020). Initially, they involved investigating factors such as the typology of landscape and settlements and the morphology of spaces and land use (Tu, Zhou, Long, & Liang, 2019; R. Yang & Chen, 2018). A deeper understanding of the hybrid factors of the multifaceted and co-constituted rural space (Murdoch, 2003) blurs the urban–rural division (Woods, 2009); and the rising global concerns such as climate change and food security (Woods, 2012) now stimulate the diverse focuses and multidisciplinary cooperation in the field of rural studies. In past decades, influenced by national and regional policies, studies of CTVs have sprung up in fields such as architecture (Li et al., 2019), rural geography (Chen, Xie, & Li, 2020), sociology, and tourism (Gao & Wu, 2017), and have been followed by a flourishing rural construction practice movement (Lu & Qian, 2020). The existing regional studies of traditional villages have explored mining features of domestic architecture and identifying the landscape gene from traditional settlements (Z. Hu, Zheng, Liu, & Liu, 2018; Xiang, Cao, Zhai, & Yi, 2019; X. J. Yang, Fang, & Wang, 2019), heritage protection and inheritance (Wang et al., 2017), tourism development and planning (Li et al., 2017; Shen & Shen, 2020), reconstruction and transformation (B. H. Li, Zhou, Liu, Chen, & Liu, 2018). In addition, studies of the spatial distribution, formation, and evolution of CTVs are being conducted on a national scale (Wu, Chen, Zhou, Liang, & Wang, 2020), in individual provinces (Song, Li, & Zhao, 2018), in geographical regions such as southwest China (Zhao & Tian, 2020), the Beijing–Tianjin–Hebei region (Tian, 2020), in river or mountain regions (Song et al., 2018; Zhang et al., 2020; Li, 2019), ethnic regions, or on the level of individual villages (Chen et al., 2020), however, not many have investigated the provinces the Yellow River flows through.

A river basin is a highly variable environment with complex human–land relationships and constitutes a geographical unit with the imprint of the earliest human activities (X. J. Li, Xu, Ren, & Li, 2012). The civilizing effect, the migration, and vicissitudes of human settlements in riverine regions are closely connected to the interrelationship of humans and nature and internal mechanisms of human beings and nature in river-related built environments (F. Wang & Gao, 2020). The Yellow River Basin is the birthplace of Chinese civilization and is one of the regions with the most complex human–land relationship in China (Wang et al., 2020) and is thus responsible for ensuring ecological security and economic and social development (Xu, Shi, Wu, & Zhang, 2020). In 2019, China promoted the ecological protection and high-quality development of the Yellow River Basin to the status of a major national strategy (Li et al., 2020; Xi, 2019). As the most typical bearers of the origins of Chinese civilization, of wisdom and cultural evolution that has survived for thousands of years, traditional villages in the Yellow River Basin play an essential role in cultural protection and inheritance. The regional differentiation and spatiotemporal characteristics of the villages represent the mutual relationship of the human and natural environment, revealing external forces and internal motivation and influencing factors of renewal and evolution on the macro scale. The formation, spatial distribution, development, and transformation of villages are influenced by multiple factors, such as physical geography (topography, climate, water resources, precipitation, ecology, etc.), and socioeconomic conditions (population, transportation networks, economy, policies, etc.) (Chen et al., 2020; R. Yang, Xu, & Long, 2016). These factors also continuously affect and form the dynamic equilibrium of the settlement–river system, showing a variety of distributional and functional changes throughout different periods of history (Fang & Jawitz, 2019).

This study is conducted using geographic information on 1,222 CTVs in the provinces along the Yellow River of the 6,819 officially listed ones. Investigations of the multi-scale distribution characteristics of villages are carried out using spatial analysis methods, including nearest neighbor index and kernel density estimation. Physical environment factors and socioeconomic influencing factors are analyzed and compared using the geographical detector. The influencing mechanism is articulated through both qualitative and quantitative methods. The findings are expected to provide references for policymaking and rural reconstruction practices in the process of rural revitalization and for the implementation of the national strategy of the high-quality development of the Yellow River Basin.

In this paper, the research is elaborated in five sections. Following the introduction, the geographical settings, research methods, and data sources are introduced in Section 2. Section 3 explores the spatial distribution of CTVs in eight provinces the Yellow River flows through, including the overall pattern and regional heterogeneity in each province from the upper and lower reaches of the Yellow River. Section 4 analyzes the multiple factors and influencing mechanisms of the regional patterns and spatial differentiation. Section 5 summarizes the main conclusions in each part, discusses the implications of the findings and possibilities for future research, and provides practical advice for the protection and
inheritance of traditional villages according to the natural and socioeconomic conditions in each province.

2 | RESEARCH DESIGN

2.1 | Geographical setting

The Yellow River is the second largest river in China. It stretches 5,464 km from Bayankala Mountains in Qinghai province to Yingkou city in Shandong province, crossing nine provinces and three geographical ladders with a wide diversity. The Yellow River Basin is regarded as the birthplace of the Chinese civilization. Instead of using the physical geographical boundary of the river’s watershed as the study area, this research is conducted within the scope of administrative divisions, since the policy-making, the nomination, and assessment of the CTVs are based on the units of administrative division. In this study, the geographical setting is extended from the physical geographical area of the Yellow River Basin to eight of the nine administrative provincial areas that the river flows through from west to east, including Qinghai, Gansu, (without Sichuan province), Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong provinces (Figure 1).

In Qinghai, Gansu, Inner Mongolia, Henan, and Shandong province, although the area of Yellow River Basin only covers less than one-third of the provincial area, the Yellow River plays an important part in local culture, regional policy-making, and development. Sichuan province is not included in this research, since the area of the Yellow River Basin in Sichuan province amounts to 18,700 square kilometers, accounting for only 2.4% of the river region’s total area. Most of Sichuan province is within the Yangtze River Basin, and only 175 km of the Yellow River flow through the province’s northwest corner.

2.2 | Study methods

In this study, 1,222 CTVs are treated as point objects in large-scale regional geographical settings. The following quantitative method is used to reveal the spatial distribution of geographical objects and articulate the formation mechanism and influencing factors of regional differentiation and spatial heterogeneity.

2.2.1 | Nearest neighbor analysis

The nearest neighbor analysis method uses the distance between the nearest pair of points to describe spatial distribution. The nearest neighbor index R is defined as the ratio of the actual nearest distance to the theoretical expectation of nearest distance:

\[ R = \frac{d_{\text{min}}}{E(d_{\text{min}})} \]  

Three types of spatial distribution patterns can be assessed by the nearest point index: uniform, random, and clustered. If \( R = 1 \), then...
the distribution of villages in the region is random. If R < 1, then the distribution of villages is clustered. If R > 1, then the average distance to the nearest neighbor is greater than that of a random distribution mode, and villages in the study area are uniformly distributed. The calculation is as follows:

1. Calculate the distance of every point to the nearest point ($d_{min}$).
2. Calculate the average distance of all ($\bar{d}_{min}$).

$$\bar{d}_{min} = \frac{1}{n} \sum_{i=1}^{n} d_{min}(S_i).$$

where $d_{min}$ is the distance of each rural settlement point to its nearest neighbor, $S_i$ is the study event, and $n$ is the number of points.

3. The average distance to the nearest neighbor is calculated in the random distribution mode, for which expectation is $E(d_{min})$.

$$E(\bar{d}_{min}) = \frac{1}{2}\sqrt{\frac{\pi}{h}}.$$  

The average distance to the nearest neighbor in the random distribution mode relates to the area of study ($A$) and the number of traditional villages ($n$).

### 2.2.2 Kernel density estimation

The kernel density of CTVs in each province has been calculated to identify and visualize the agglomeration area of traditional villages and help to interpret the spatial distribution pattern. Compared with the traditional density estimation method, kernel density estimation can obtain a smoother result using the kernel function.

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

where $\hat{f}(x)$ is the estimated kernel density at point $x$; $k(\frac{x-x_i}{h})$ is the kernel function; $n$ is the number of traditional villages; $h$ is the bandwidth. In order to analyze the multi-scale distribution characteristics, smaller bandwidths are selected for provincial analysis and larger bandwidth for the whole regional analysis through testing the smoothness and obviousness of the agglomeration and visualization results.

### 2.2.3 Geographical detector

Geographical detector is a method based on the spatial differentiation theory in assessing the correlation and mechanisms of various influencing factors. It is a statistical tool to measure and explore the determinants of spatial stratified heterogeneity (SSH), which refers to the variance within strata being less than the variance between strata (J. F. Wang, Zhang, & Fu, 2016). It was first used in health risk assessment (J. F. Wang et al., 2010), and later on broadly applied to studies of economy, society, ecology, etc. (Ding, Cai, Ren, & Yang, 2014; Y. S. Liu & Yang, 2012; Ren et al., 2014). The q-statistic in geographical detector has already been applied in many fields of natural and social sciences, which can be used to measure SSH, detect explanatory factors, and analyze the interactive relationship between variables (G. Wang & Peng, 2021; J. F. Wang & Xu, 2017). The factor detection is applied in this research. Multi-factors can be tested for its relationship with a certain spatial distribution, by comparing the variance of the index in a subregion (J. F. Wang & Xu, 2017).

The calculation steps are as follows: (a) spatial overlay analysis was applied to the layer of traditional villages and influencing factor layers; (b) factors are stratified into categorical spatial types; (c) a test of significance was conducted at the .05 level. The p value of the test less than 0.05 is considered statistically significant. The detector formula for each factor is as follows:

$$q = 1 - \frac{\sum_{i=1}^{l} N_i \sigma_i^2}{N \sigma^2}.$$  

where $q$ is the determinant power of each influencing factor in the distribution of traditional villages, and the value will be [0,1]. The larger the value of $q$, the stronger the influence of the factor of area division. $N$ is the number of villages in the entire region; $l$ is the number of sub-regions. The variance of $R$ index for the village in the entire study region is denoted by $\sigma^2$.

### 2.2.4 Analytical structure

In order to better identify the spatial distribution and influencing factors and mechanisms of traditional villages, multi-scale investigations (including regional, provincial and prefectural city scale) have been conducted, and multivariate methods (including nearest neighbor analysis, kernel density estimation, and geographical detector) applied in this research, accompanied by visualization methods, in order to articulate the spatial characteristics and show how the multi-variations influence and lead to the spatial distribution and differentiation of traditional villages in eight provinces the Yellow River flows through, as shown in the analytical structure of the study (Figure 2).

### 2.3 Data collection

The study systematically integrated multi-source spatial data such as the geo-spatial coordinates of villages, geo-environments data, including hydrology, topography, natural resources, etc., transportation network, and socioeconomic levels.

1. **National and provincial boundaries and those of prefecture-level and county-level cities.** The boundary data are taken from Geographic Data Sharing Infrastructure, College of Urban and Environmental Science, Peking University (http://geodata.pku.edu.cn).
2. **Geographical locations of Chinese traditional villages.** The official list of five batches of CTVs was obtained from the Ministry of Housing and Urban–Rural Development of the People’s Republic of China website (http://www.mohurd.gov.cn). In total, 1,222 of the 6,819...
CTVs (17.9%) are in the study area (106 of 646 villages in the first batch announced in 2012, 100 of 915 villages in the second batch announced in 2013, 173 of 994 villages in the third batch announced in 2014, 334 of 1,598 villages in the fourth batch announced in 2016, 509 of 2,666 villages in the fifth batch announced in 2019). The number of villages in each batch and in each province is listed in Table 1. The geographical coordinates of each village were generated from the Baidu Map, according to the name and location in the official list. The point vector database was prepared in GIS.

3. Digital elevation data. The elevation data (90 m spatial resolution) were obtained from the Shuttle Radar Topography Mission (SRTM) website (http://srtm.csi.cgiar.org).

4. Geographical data of rivers. The GIS data of rivers are obtained from the National Water System Map updated in 2018, including vector of river streamline and lake reservoir area. These data were downloaded from Geographic Data Sharing Infrastructure, College of Urban and Environmental Science, Peking University (http://geodata.pku.edu.cn).

5. Normalized Difference Vegetation Index (NDVI). The normalized difference vegetation index (NDVI) is a geographical indicator for distinguishing and identifying vegetated areas from other surface types and quantifying the photosynthetic capacity of plant canopies. China’s annual 1KM vegetation index (NDVI) spatial distribution data are derived from the Data Center of Resources and Environmental Science, Chinese Academy of Sciences (http://www.resdc.cn). It is based on SPOT/VEGETATION NDVI satellite remote sensing data, and the annual vegetation index data set since 1998 are generated by the maximum value synthesis method on the basis of monthly data. The NDVI data set of 2018 is adopted in this study.

6. Transportation data. The transportation data are the highway vector data exported from the OpenStreetMap website (https://www.openstreetmap.org/), supported by the Open Street Map FIGURE 2 Analytical structure

TABLE 1 Numbers in the five batches and percentages of the Chinese traditional villages in eight provinces the Yellow River flows through

<table>
<thead>
<tr>
<th>Province (from W to E)</th>
<th>Batch I</th>
<th>Batch II</th>
<th>Batch III</th>
<th>Batch IV</th>
<th>Batch V</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gansu</td>
<td>7</td>
<td>6</td>
<td>2</td>
<td>21</td>
<td>18</td>
<td>54</td>
<td>4.4</td>
</tr>
<tr>
<td>Qinghai</td>
<td>13</td>
<td>7</td>
<td>21</td>
<td>38</td>
<td>44</td>
<td>123</td>
<td>10.1</td>
</tr>
<tr>
<td>Ningxia</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>0.5</td>
</tr>
<tr>
<td>Inner Mongolia</td>
<td>3</td>
<td>5</td>
<td>16</td>
<td>20</td>
<td>2</td>
<td>46</td>
<td>3.8</td>
</tr>
<tr>
<td>Shaanxi</td>
<td>5</td>
<td>8</td>
<td>17</td>
<td>41</td>
<td>42</td>
<td>113</td>
<td>9.2</td>
</tr>
<tr>
<td>Shanxi</td>
<td>48</td>
<td>22</td>
<td>59</td>
<td>150</td>
<td>271</td>
<td>550</td>
<td>45.0</td>
</tr>
<tr>
<td>Henan</td>
<td>16</td>
<td>46</td>
<td>37</td>
<td>25</td>
<td>81</td>
<td>205</td>
<td>16.8</td>
</tr>
<tr>
<td>Shandong</td>
<td>10</td>
<td>6</td>
<td>21</td>
<td>38</td>
<td>50</td>
<td>125</td>
<td>10.2</td>
</tr>
<tr>
<td>Total</td>
<td>106</td>
<td>100</td>
<td>173</td>
<td>334</td>
<td>509</td>
<td>1,222</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: The Ministry of Housing and Urban–Rural Development of the People’s Republic of China announced five batches of Chinese traditional villages (CTVs) from 2012 to 2019, Batch I in 2012, Batch II in 2013, Batch III in 2014, Batch IV in 2016, and Batch V in 2019. According to the official list of five batches of CTVs obtained from the website (http://www.mohurd.gov.cn), the number of villages in each batch and in each province the Yellow River flows through from west to east is listed in this table with the percentage of each province counted. Among these eight provinces, Shanxi province has the largest number of CTVs, and Ningxia province has the least.
Foundation (OSMF). The road data of tertiary level and above, updated in 2020, were selected for spatial analysis. There are five levels of road in China, including the expressway, which is the skeleton of the national highway network, the primary road connecting important political and economic centers, the secondary road linking political and economic centers or large industrial and mining areas or suburban roads with busy transportation, the tertiary-level road connecting cities and towns at and above the county level, and fourth level road connecting counties, towns, and villages. Considering the impact on the traditional villages and the availability of data, the other transportation data such as waterway, railway system, air route, or the location of the railway station, airport, etc. are not involved in this study.

7. Economic data. The economic data have been obtained from China County Statistical Yearbook (county and city volume) 2015. It is an informative Yearbook that comprehensively reflects the social and economic development of counties in China. It contains the information of comprehensive economy, agriculture, industry, education, health, social security, etc.

3 | SPATIAL DISTRIBUTION OF TRADITIONAL VILLAGES

3.1 | Overall distribution of traditional villages in eight provinces

The overall distribution of the CTVs in the provinces the Yellow River flows through presents obvious regional differentiation and agglomeration. Previous national-level study of the traditional villages demonstrates that the Yangtze River, the Southeast River, and the Pearl River, rather than the Yellow River, are the main distribution basins of CTVs (Dong, Liu, Xu, & Su, 2021); most villages are east of the Hu Huanyong Line (J. S. Li, Wang, et al., 2020), which means the villages in the southeastern regions are denser than in the northwestern regions. The distribution of areas with the highest density of CTVs overlaps slightly with the Yellow River region, thus diverting research attention from the area within this river basin.

Firstly, the spatial distribution of the entire river region is analyzed by kernel density estimation (Figure 3). There are “two cores” (high-density agglomeration areas) of traditional villages: (a) the contiguous area of the Shaanxi, Shanxi, and Henan provinces, located in the Central Plains on the middle and lower reaches of the Yellow River. The area includes the northeast and east of Shaanxi province; the central, west, and southeast of Shanxi province; and north regions of Henan province. (b) The junction of the Qinghai and Gansu provinces in the upper reaches of the Yellow River, which mainly includes Haidong and Huangnan in the east of Qinghai province and the northwest corner of Gansu province. Cities with the greatest number (top 10) of traditional villages are Jincheng, Jinzhong, Changzhi, Luliang, Linfen, and Yangquan in Shanxi province, Haidong in Qinghai province, Yulin and Weinan in Shaanxi, and Pingdingshan in Henan province. They are all located within the high-density agglomeration areas visualized using kernel density estimation.

3.2 | Spatial distribution of traditional villages in the provinces

The kernel density estimation and nearest neighbor analysis were conducted in each province at this stage to explore the detailed distribution characteristics. The spatial distribution characteristics in each of the eight provinces vary greatly (Table 2). Overall, there are “three
TABLE 2  Density and the nearest R index of the traditional villages in eight provinces the Yellow River flows through

<table>
<thead>
<tr>
<th>Province (from W to E)</th>
<th>R index</th>
<th>Distribution mode</th>
<th>Density(10^4/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qinghai</td>
<td>0.238543</td>
<td>Clustered</td>
<td>1.68</td>
</tr>
<tr>
<td>Gansu</td>
<td>0.859553</td>
<td>Random</td>
<td>1.24</td>
</tr>
<tr>
<td>Ningxia</td>
<td>1.16242</td>
<td>Discrete</td>
<td>1.15</td>
</tr>
<tr>
<td>Inner Mongolia</td>
<td>0.566073</td>
<td>Clustered</td>
<td>0.4</td>
</tr>
<tr>
<td>Shaanxi</td>
<td>0.683954</td>
<td>Random</td>
<td>5.49</td>
</tr>
<tr>
<td>Shanxi</td>
<td>0.580883</td>
<td>Clustered</td>
<td>35.16</td>
</tr>
<tr>
<td>Henan</td>
<td>0.528489</td>
<td>Clustered</td>
<td>12.30</td>
</tr>
<tr>
<td>Shandong</td>
<td>0.55786</td>
<td>Clustered</td>
<td>7.88</td>
</tr>
</tbody>
</table>

Note: The nearest R index in eight provinces was evaluated using ArcGIS to indicate the degree of geographical proximity of the point elements (Chinese traditional villages [CTVs]). A refined criterion for a quantitative description of R is applied to describe the distribution patterns of the traditional villages: if R ∈ (0, 0.6], it was defined as a clustered distribution; if R ∈ (0.6, 1.2], random distribution mode for values R ∈ (0.6, 0.9], discrete distribution mode for values R ∈ (0.9 to 1.2); if R > 1.2, it was defined as a uniform distribution. The density of CTVs in Shaanxi province is the highest and that in Inner Mongolia is the lowest.

distribution modes” in eight provinces, comprising clustered, random, and discrete modes. Shanxi is the province with the most densely distributed traditional villages, followed by Henan and Shandong provinces. In these three provinces, the spatial distribution of traditional villages presents a relatively bold pattern of agglomeration. According to the R index and density, traditional villages in these three provinces are distributed in a high-density clustered mode. Qinghai and Inner Mongolia have a vast, sparsely populated area of land, with the few traditional villages mostly distributed in low-density clustered mode in the belt along the Yellow River. The distribution of traditional villages in Shaanxi and Gansu province is random. In Ningxia province, villages are distributed discretely with low density (Figure 4).

In total, 97 prefectural cities are located within the research area, 15 of them have no officially listed traditional village within their jurisdiction. These 15 cities are mainly located in northern Shandong province (including Dongying, Dezhou, Liaocheng, and Binzhou), western Gansu (including Jinchang, Wuwei, Jiuquan), northern Ningxia (including Yinchuan and Shizuishan), and central Inner Mongolia (Wuhai, Xingan League, and Xilin Gol League). These cities with no traditional villages can be divided into “four types of absence” and the reasons can be articulated by their locality:

1. Cities that have suffered from severe environmental conditions or natural disasters in the past, typically those in the desert area where living beings find it hard to survive, such as Wuhai in Inner Mongolia; and those in the North China Plain, such as Dongying, Dezhou, Liaocheng, and Binzhou. There have been 26 disastrous river diversions and more than 1,500 inundations, overflows, and bank bursts in the lower reaches of the Yellow River in the past (Yu, Zhang, & Li, 2008), some cities in the North China Plain suffered disasters, some were buried or crushed. In some frequently flooded areas in the history, settlements find it difficult to survive, let alone develop.

2. Cities facing lack of abundant natural resources or harsh geographical conditions, in which populations tend to inhabit center hubs instead of small villages. For example, Jinchang, Wuwei, and Jiuquan are located in the Hexi Corridor, an arid region with a fragile ecological environment in Western China. With annual rainfall of less than 200 mm, the water supply of the river and settlements is mainly from glacial snowmelt. In this narrow belt, most of the population is gathered in several significant node cities in the Silk Road Economic Belt. So, few villages have emerged around these central cities.

3. Resource-based cities surrounded by a severe natural environment such as Shizuishan and Yinchuan in Ningxia. Located in the northemmost part of Ningxia, within the area of national coal field, Shizuishan city is a significant node city in the Golden Triangle Economic Zone in northeastern China. The economic development of Shizuishan city mainly depends on anthracite production. The economic development, ecological health of the oasis, and agriculture industry of Yinchuan city heavily depend on the Yellow River irrigation. Therefore, the limited population in northern Ningxia dwells in a few core settlements along the only river instead of in villages.

4. Cities located in the grassland pastoral area where people are used to living a nomadic life rather than in stable settlements, such as Xingan League, and Xilin Gol League in Inner Mongolia, located far from the Hetao Plain, an alluvial plain where the Yellow River is the main sources of industrial and drinking water for settlements. In order to protect the scarce water resources and ensure the sustainable use of grassland, the nomads rove around grasslands and make a living by animal husbandry instead of settling in a fixed location.

4  | INFLUENCING FACTORS AND MECHANISMS

4.1  | Natural factors

4.1.1  | Topography (elevation and ruggedness)

Topographical variation has a direct influence on the local climate and thus affects agricultural production indirectly (Sun, Niu, Zhang, &
Shao, 2017); and also has various effects on factors such as water and heat conditions, river system, soil, and vegetation, as well as traffic accessibility and cultural exchange, etc. (Tong & Long, 2015). In this study, topography is evaluated in terms of elevation and ruggedness. As shown in results (Figure 5), in terms of elevation, of the 1,222 villages in eight provinces, 834 are located at an elevation of less than 1 km, accounting for 68%; 21% of the villages are sited at an altitude of 1–2 km. For the remaining 10%, 98 villages are at an altitude of 2–3 km and 29 villages between 3 and 4 km. The villages with the highest elevation are above 4 km and located in Yushu Tibetan Autonomous Prefecture in Qinghai province. Ruggedness refers to the average interpolation between the elevation of the highest point and the lowest point in a specific area, which is used as a macro index of regional topographic characteristics (Tong & Long, 2015). According to the analysis of ruggedness, 1,122 villages lie in areas with ruggedness lower than 150 m, accounting for 92%; only 100 villages are located in very rugged areas. Compared with other provinces, there are more villages in Qinghai distributed in the areas of great ruggedness. Overall, the results of topographic analysis show that traditional villages tend to be located in areas with lower elevation and less ruggedness.

4.1.2 Hydrology (distance to the nearest river)

Previous findings demonstrated the significance of rivers and the availability of water resources as factors in location selection and settlement development (F. Wang & Gao, 2020). The result shows that (Figure 6), in eight provinces the Yellow River flows through, 41% of traditional villages are distributed within 5 km of river courses, which
is within a 10-min driving distance and a 1-hour walking distance; 807 villages are within 10 km from the river, accounting for 66%. In the lower reaches of the Yellow River, influenced by frequent shifts of the river course, traditional villages are sparsely distributed in the Yellow River floodplain. Most of Shandong province is located in the Yellow River floodplain. The river network is densely distributed in the plain, providing plentiful water resources for development. However, traditional villages are mainly clustered around Mount Tai and the Jiaodong Peninsula, with an average distance of approximately 10 km to river courses or sea to avoid the potential unexpected floods or tides and storms from the coast. In Inner Mongolia, most of the existing traditional villages tend to gather around the Yellow River and its tributaries in the Hetao Plain; however, the average distance between traditional villages and rivers is the greatest than other provinces because of its low-density river network. In sum, the distribution of traditional villages in the eight provinces presents the dual characteristics of a settlement–river relationship. On the one hand, the villages tend to settle close to rivers and take advantage of water for habitation, production, and communication. On the other hand, they stay at a sufficient distance from the river for long-term safety and stable development.

4.1.3 Ecology (vegetation coverage)

The location of traditional villages depends on the harmonious coexistence with the surrounding ecological environment (P. L. Liu, 1995). NDVI can represent the regional vegetation coverage and is an important indicator of regional ecological environment quality (Wang & Peng, 2021). In this study, NDVI data have been employed to analyze the proportion and obtain vegetation coverage at the county level. The results (Figure 7) show that 1,130 traditional villages were distributed in areas with an NDVI value greater than 0.5, more than 90% of the total villages. The average NDVI value of traditional villages in north Henan and Southeast Shanxi provinces is the highest, at approximately 0.75. The Mount Tai in Shandong province, Taihang Mountain area bordering the Shanxi and Henan provinces, and Qingling Mountain area in Shaanxi province form natural shelters for traditional villages. Many traditional villages are distributed in these areas and benefit from the abundant vegetation, which can conserve water, regulate climate, and improve the quality of local ecological and living environment. In areas with rivers flowing through, such as the North China Plain in Shandong province, the Fen River area and the Qin River in Shanxi province, Wei River in Shanxi province, and the Hetao Area in Ningxia and Inner Mongolia, the river breeds fertile environment with rich species and high vegetation coverage, creating a good foundation for agriculture. In addition, numbers of traditional villages cluster in southern Gansu where the vegetation coverage is relatively high in the province. In most areas of Qinghai, Ningxia, Inner Mongolia, and Northern Shaanxi with severe climatic conditions, the NDVI value is relatively low, and the environments and scarce natural resources are not suitable for living and constrained local agricultural and economic development. Only a small number of the traditional villages are located in areas with low NDVI value. Overall, most of the traditional villages are distributed in areas with high vegetation coverage. A favorable ecological environment provides suitable living conditions for settlements.

4.2 Socioeconomic factors

4.2.1 Urbanization (distance to the nearest prefecture-level city center)

Cities have a radiation effect on the countryside. In order to explore the relationship between the spatial distribution patterns of traditional
villages and the nearest prefecture-level cities, the distances between them have been measured and visualized (Figure 8). The lowest average distance between villages and city centers is in the Henan province, and the greatest distance to the nearest prefecture-level cities is in the Inner Mongolia Autonomous Region. The traditional villages closest to the prefecture-level cities are mainly distributed in the central and southern regions of Shanxi province and the eastern region of Qinghai province. The scatter diagram shows that 706 villages are randomly located within 50 km (a driving distance of around 0.5–1 hr) from the nearest prefecture-level cities, amounting to 58%; and the distance from 50 traditional villages to prefecture-level cities is more than 100 km. The average distance to the nearest prefecture-level cities in eight provinces is 111 km, around double the 50 km randomly distributed distance. Taking into account both the density and distribution of prefecture-level cities and traditional villages, there is no obvious tendency toward traditional villages being distributed close to cities.

4.2.2 | Transportation (distance to contemporary road network)

Considering air transportation network has little influence on the accessibility and cross-communication among settlements, and waterway transportation has little impact on traditional villages compared with ancient times, and the function has mostly been replaced by contemporary road transport (Wang, Gao, & Hu, 2020), the spatial relationship with road networks is analyzed here. As shown in Figure 9, 892 traditional villages (73%) are within 1 km of a road above tertiary level. Since the implementation of the “village access” system project in 2004, China has greatly improved rural infrastructure and improved the accessibility of rural traffic. But at present, there are still 26 traditional villages, mostly in Inner Mongolia, Ningxia, Shaanxi, and Henan that are more than 5 km away from roads above tertiary level. Among these eight provinces, the average traffic accessibility of traditional villages in Ningxia and Inner Mongolia is poor, with the average distance to the nearest tertiary-level road being more than 5 km. These areas are vast, sparsely populated, with a relatively backward infrastructure construction. In addition, in the south of Henan province and the south of Shaanxi province, traditional villages are far from roads, owing to the large number of existing traditional villages. In contrast, the accessibility of traditional villages in Gansu province is higher, and the average distance to the nearest road is approximately 500 m. In middle and southern Shanxi, traditional villages are also close to roads. In general, most of the existing traditional villages are distributed in areas where the contemporary road network is rather developed; a small number of traditional villages far from the road network are generally located in sparsely populated areas.

4.2.3 | Economy (GDP per capita)

In this study, the county-level GDP per capita obtained from the statistical yearbook is used to explore the influence of regional economic development on the distribution of traditional villages. GDP per capita is an effective tool for understanding and grasping national or regional macroeconomic operations, and is often used in research to measure economic development. It directly affects the regional investment capacity (He, Gong, Hu, & Xu, 2019; G. Wang & Peng, 2021). The study results demonstrate that the correlation between the level of economic development and the prosperity or number of traditional villages is not significant. The results show (Figure 10) that 56% of the villages are located in counties with a GDP per capita of less than 20,000 yuan per year. These villages are mostly distributed in the
Gansu, Qinghai, and Shaanxi provinces. Only 10% of the villages are located in counties with a GDP per capita of more than 50,000 yuan per year, mainly in central and northern Shandong province and central Henan province. Areas with highly urbanized and developed social and economic conditions, traditional culture and lifestyle are vulnerable to modernization. However, it is noteworthy that for some villages, the county's GDP per capita is relatively high and yet the locality of a large number of villages has still been preserved, such as villages in the Zichuan District of Zibo City in Shandong Province, indicating that the development of a social economy can enhance and protect the development of villages. In other words, to some extent, the development of regional economy would positively influence and not be an obstacle to the protection and inheritance of traditional villages.

### 4.3 Influencing mechanisms

The spatial distribution of traditional villages in the Yellow River Basin is influenced by both natural and socioeconomic factors. In this study, we examine the natural factors, including topography (elevation and ruggedness), hydrology (distance to the nearest river), and ecology (vegetation coverage), as well as socioeconomic dimensions, including economy (GDP per capita), transportation (distance to contemporary...
road networks), and urbanization (distance to the nearest prefecture-level city center).

Firstly, the six independent variables listed above were stratified and transformed from numerical to categorical variables. Then we used the geographical detector (http://www.geodetector.cn) for factor detection. Spatial overlay analysis was applied for the layer of traditional villages and influencing factor layers; factors are stratified into categorical spatial types; the statistical significance was tested at a 95% confidence level. The results (Table 3) show that five of the seven independent variables passed the significance test, these being the vegetation coverage, the distance to the rivers, the distance to the contemporary road system, elevation, and ruggedness. Thus, these five factors are the major factors that correlate with the spatial distribution of traditional villages in the study area. The significant factors were ranked according to the determinant power of influence on the distribution of traditional villages: Distance to contemporary road network > Elevation > Vegetation coverage > Distance to the nearest river > Ruggedness. There is no obvious correlation between GDP per capita and distance to the nearest prefecture-level city center.

4.3.1 Influencing mechanisms of natural factors

Overall, natural factors have a greater impact on the distribution of traditional villages. The influencing factors are closely correlated with each other. The topography has a strong influence on the location of settlements (Du, Peng, & Wang, 2019). Traditional villages tend to be located in areas with lower elevation and less ruggedness. Settlements located at a low elevation tend to be closer to water resources; however, a higher elevated site has a better view or is sheltered by the land’s relief, enjoys a cooler climate or species variation. Less ruggedness facilitates and increases the accessibility of villages; however, a certain degree of ruggedness creates shelter for a site’s safety and maintenance of local features.

Vegetation is an important component of the ecosystem. It adapts to climatic, topographic, and soil conditions and has a strong dependence on, and sensitivity to, a variety of natural factors (2021). A high vegetation coverage usually indicates a pleasant basis for habitation or forestry, and a river fosters the environment with species richness. The water supply and fertile alluvial plains provided by rivers encourage cultivation (Mozzi, Piovan, & Corrò, 2020), and the waterway transportation on rivers was advantageous for transporting goods and stimulating communication (Wang et al., 2020). Thus, rivers and settlements constitute a co-evolutionary system (2017). Even though rivers provide benefit and convenience for local inhabitants, areas close to rivers are more likely to suffer from floods. The collective memory, living witnesses, generational experiences, and lessons from catastrophic floods make people aware of the risk of floods for two generations, thus limiting further development and additional construction in floodplains or causing resettlement away from the flood-prone areas (Collenteur, de Moel, Jongman, & Di Baldassarre, 2015; Fanta, Šálek, & Sklenicka, 2019). In order to reduce or prevent risks of flooding, some human societies applied adaptive landscape strategies such as constructing protective dikes and walls and creating ponds to reduce the possibility of flooding (Yu et al., 2008). Some cities have suffered and overcome disasters; however, some small towns and villages suffered destruction and found it hard to survive after a catastrophe.

4.3.2 Influencing mechanisms of socioeconomic factors

Further analysis of the q statistics of the five significant factors showed that transportation (distance to contemporary road network) was the dominant factor affecting the distribution of traditional villages in the Yellow River Basin, with an explanatory power of 11% (Table 3). Over a long period of historical evolution, the original...
implementing relevant policies for revitalization. In regions with higher life slows down the speed of renewal of physical spaces and cultural memory (Y. Li et al., 2019; F. Wang & Sun, 2015). Distance from urban such as the over-aging of the remaining residents and a loss of cultural memory to the impact of urbanization processes and urban and local industries, with natural landscapes and resources, and a profound accumulation of ancient culture (Sun et al., 2017). In contrast, a sparse transportation network can form a relatively enclosed and isolated environment for villages. Nestling in this kind of independent surroundings, the original locality of villages is less likely to be invaded by external forces (Sun et al., 2017; Tong & Long, 2015). Even though remote and occlusive conditions enable the living habits of local residents in traditional villages to be preserved and protect traditional features from urbanization to some extent, the low level of accessibility and the secluded regional environment block the village from external communications and lead to a lack of opportunity for potential social and economic development.

According to the test results, the distance to the nearest prefecture-level city centers and GDP per capita have no significant relationship with the spatial distribution of traditional villages; however, they both play multiple roles in preserving and developing traditional villages. On the one hand, traditional villages closer to cities are more vulnerable to the impact of urbanization processes and urban culture and may cause population outflow and negative chain effects, such as the over-aging of the remaining residents and a loss of cultural memory (Y. Li et al., 2019; F. Wang & Sun, 2015). Distance from urban life slows down the speed of renewal of physical spaces and cultural iteration in villages and avoids the rapid destruction of local features. On the other hand, a location close to large cities lays a good foundation for the development of rural tourism and new industries and for implementing relevant policies for revitalization. In regions with higher levels of economic development, local governments may have more potential capital to invest in the protection and development of traditional villages.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Natural factors</th>
<th>Socioeconomic factors</th>
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<tbody>
<tr>
<td></td>
<td>Topography</td>
<td>Hydrology</td>
</tr>
<tr>
<td></td>
<td>Elevation</td>
<td>Distance to the nearest river</td>
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</tr>
</tbody>
</table>

Note: Three natural factors and three socioeconomic factors are tested for its relation with spatial distribution of traditional villages in eight provinces. The q-statistic is the power determinant of each influencing factor in the distribution of traditional villages, and the value will be [0,1]. The larger the value of q is, the stronger the influence of the factor. A test of significance was conducted at the 0.05 level. The significant factors were ranked according to the determinant power of influence on the distribution of traditional villages: Distance to contemporary road network > Elevation > Vegetation coverage > Distance to the nearest river > Ruggedness.

5 | CONCLUSIONS AND DISCUSSION

In this study, multi-scale analysis was conducted to investigate the spatial characteristics of traditional villages in the Yellow River Basin as well as the influence and mechanisms of natural and socioeconomic factors. The results demonstrate: (a) The overall spatial distribution of traditional villages shows great regional differentiation and is characterized by “two cores,” “three distribution modes” and “four types of absence” of traditional villages. (b) The spatial distribution of traditional villages in the Yellow River Basin is affected both by natural factors and by socioeconomic factors, with natural factors having greater impact. (c) There is no inevitable correlation between the level of economic development and the rise and fall of traditional villages.

The regional heterogeneity of CTVs along the upper, middle, and lower reaches of the Yellow River shows the dynamics of human reliance on the river’s hydrological system, presents diverse trajectories and periodic changes of settlement proximity to major rivers, with influence of the varying social, economic, and cultural factors of successive dynasties and generations. Research and reality have proved that economic development of and the preservation and inheritance of traditional villages and culture are not contradictory and mutually promote each other when new economic production functions and relationships are properly adapted to the needs of contemporary development. There is no inevitable correlation between the degree of economic development and the rise and fall of traditional villages.

At present, it is difficult to tell when the villages were founded, given the large sample size, and the dynamic research of village evolution is often based on individual village case studies. Based on the spatial distribution database, further research could supplement information about when the traditional villages were built and explore the temporal and spatial dynamic relationships between settlements and rivers in the process of historical evolution. Current research has not considered the specific situation of each village. Viewed in
combination with local advantages and problems in each province, revitalization strategies and methods need to be developed according to local conditions. There are few systematic studies on the policy refinement and methods of traditional village revitalization targeted in the various regions. It would be valuable to comb through the policies and the development status of specific regions, systematically absorbing the experience from the successful cases and applying them to the revitalization of rural areas.

Future research needs to expand the research of spatial distribution and evolutionary characteristics of traditional villages to a micro-level, further focus on the evolution of small-sized and medium-sized regions or single typical villages, and conduct in-depth research from multiple perspectives such as social, economic, ecological, cultural perspectives. In addition, we should not only explore the spatial, morphological, and physical aspects of traditional villages, but also fully interpret the historical intangible culture and traditional wisdom, taking local individuals and human needs into consideration. We can thus deepen the understanding of Chinese culture and combine locality with the current national policies and development priorities so as to better harmonize traditional villages with contemporary society and strengthen cultural continuity.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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