Spatial Differentiation and Influencing Factors of Traditional Villages in Fujian, China: A Watershed Perspective

Keyu Hu 1, Weipin Lin 1,*; Liwen Fan 2, Sisheng Yang 1 and Tiancong Zhang 1

Abstract: Watersheds provide a spatial framework for tightly coupling human activities and the natural environment. Investigating the spatial distribution patterns of traditional villages within watersheds is crucial for comprehending their origins and advancing conservation and development efforts. This study employs methods such as the nearest neighbor index, kernel density estimation, spatial auto-correlation analysis, stepwise regression, and geographically weighted regression to explore the watershed characteristics and influential factors governing the spatial differentiation of traditional villages in Fujian Province. The findings indicate that traditional villages in Fujian exhibit an overall clustered distribution within the watershed space, with a tendency to cluster along basin boundaries, primarily concentrated in three hot spot regions. In the remaining small watersheds, the distribution is more balanced. Traditional villages are predominantly located near low-order streams, displaying a distribution pattern along tributaries, while in the Huotongxi river basin, they are more evenly distributed near second-, third-, and fourth-order streams. Relief, annual average temperature, annual average precipitation, arable land, per capita GDP, distance to county-level or higher-grade cities, and the concentration of cultural heritage preservation units are the primary factors affecting the spatial differentiation of traditional villages within watersheds, exhibiting significant spatial heterogeneity. Finally, this study proposes recommendations for the cluster protection and development of traditional villages in watersheds, addressing spatial, cultural, landscape, industrial, and governance aspects.

Keywords: watershed; traditional villages; Fujian Province; spatial differentiation; influencing factors; human settlement unit; cluster protection and development

1. Introduction

Traditional villages, characterized by early formation and significant values, warrant protection [1]. Villages represent a crucial aspect of human agricultural and ecological civilization, encapsulating the evolution of human history and comprising diverse natural, historical, and cultural landscapes. However, the forces of urbanization and industrialization have precipitated a global decline or disappearance of villages [2]. Specifically, in China, the number of villages has significantly reduced from 3.77 million in 1990 to 2.63 million in 2021, marking a nearly 30% decrease. This decline has led to a loss of cultural diversity and inflicted irreversible damage on the cultural heritage these villages represent. Additionally, rural areas are facing challenges such as industrial homogenization [3], hollowing [4], environmental degradation [5], and loss of local identity [6], underscoring the critical need for the preservation of traditional villages. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has advocated for the protection of traditional culture and folk customs in villages since 1989 [7]. In response, since 2012, the Chinese government has been actively identifying traditional villages, resulting in the publication of six batches of national traditional village lists encompassing a total of 8155...
villages. This reflects a progressive enhancement of traditional village preservation efforts at the national level.

Civilizations around the world have historically flourished along the banks of major rivers such as the Yellow, Nile, Indus, Tigris, and Euphrates, developing extensively within the confines of river basins [8,9]. These basins, centered around rivers, represent distinct geographical entities defined by natural divides, serving as fundamental units for rural human settlement activities and industrial development [10]. The establishment of these villages is also closely linked to rivers, as they tend to cluster near bodies of water [11,12]. Rivers provide essential conditions for human livelihoods and production. Furthermore, the choice of residing near water aligns with traditional Chinese Feng Shui principles [13,14]. In Fujian Province, traditional villages with histories extending from the Shang and Zhou Dynasties through to the Ming and Qing Dynasties encompass 552 national traditional villages. The province is characterized by abundant rainfall and a network of rivers, including Minjiang, Jiulongjiang, Aojiang, Jinjiang, Tingjiang, Longjiang, Jiaoxi, and Mulanxi. These rivers contribute to the formation of distinct and independent river basins. Hou, a renowned geographer, suggests that material transport and cultural interactions within a basin are relatively enclosed, rendering the entire river system relatively independent [15]. Consequently, traditional villages exhibit heterogeneity across different river basins while demonstrating strong homogeneity within the same river basin. Meanwhile, in Fujian Province, there is a notable correlation between the distribution of traditional villages and water systems [16].

Therefore, this study hypothesizes that the distribution of traditional villages within each watershed in Fujian Province exhibits unique characteristics, termed watershed-specific distribution patterns. The purpose of this paper is to investigate these distribution patterns and identify the factors influencing them. The objective is to deepen the understanding of the relationship between traditional villages and watersheds, elucidating the dynamics of these influencing factors within watersheds. These insights can enhance conservation and development strategies for traditional villages, thereby promoting rural socio-economic revitalization [17,18].

2. Literature Review

In 1841, Johann Georg Kohl, a German geographer, undertook pioneering investigations into rural settlements, scrutinizing their interplay with the geographical milieu [19]. Subsequent scholarly endeavors have delved into the morphological aspects of rural settlements, with Conzen emerging as a notable figure in this domain [20]. Moreover, scholarly attention has been directed towards dissecting the functions and spatial distribution of rural settlements [21]. Recently, a burgeoning interest among scholars globally has been observed in the examination of traditional villages, primarily focusing on the preservation of rural heritage [22–24], governance structures [25,26], cultural landscape [13,27–29], tourism [30–32], cultural significance [3,33,34], and morphology [35–38]. Apart from the aforementioned studies, which often focus on micro- and typical cases, some scholars have leveraged geography’s macroscopic and integrative nature to explore spatial distribution and influencing factors. These studies encompass various research scales, including nations (China [1,17,18]), provinces (Guangxi [11], Fujian [16], Henan [39], Hebei [40], Shaanxi [41], Guizhou [42]), natural areas (Awa Mountain Area [43], Wuling Mountain Area [44], Yangtze River Basin [45,46], Yellow River Basin [47,48]), and cultural areas (Hakka [49]), examining static spatial layout [11,16,17,39,40,42–44,46–50] and dynamic spatial evolution [18,41,45]. The methodologies employed in spatial distribution research have evolved from rudimentary descriptive statistics to sophisticated spatial analyses, multidisciplinary cross-analyses, and other longitudinally deepened systematic approaches. Principal techniques encompass the nearest neighbor index, kernel density analysis, geographic concentration index, spatial Gini coefficient, imbalance index, and standard deviation ellipse [1,16,17,39–52]. The exploration of influencing factors entails statistical descriptions and spatial superposition analyses [1,11,16,39,40,46,47].
Furthermore, numerous scholars have categorized these influencing factors, quantified their effects using Geodetector [41–43,45,48,49,52], or utilized geographically weighted regression (GWR) models to scrutinize their spatial heterogeneity [43,44,51].

Current research on the spatial patterns of traditional villages has employed river basins as the primary unit of analysis, covering regions such as the Yangtze [45,46] and Yellow [47,48] river basins. These studies have elucidated the spatial characteristics across the entire river basin extents. However, they have not examined the spatial differentiation among distinct small watersheds within these large basins. In contrast, studies focusing on spatial differentiation have primarily utilized administrative divisions as research units [16–18,39,40,42,50]. While convenient, administrative boundaries may disrupt the integrity of natural landscapes and diminish the influence of the geographic environment, potentially impacting research outcomes. As naturally occurring geographic entities, watersheds more faithfully capture the interplay between human settlement and the natural surroundings. Accordingly, this study adopts watersheds as the fundamental research unit to transcend the constraints of administrative boundaries and investigate the watershed-specific features of spatial differentiation for traditional villages in Fujian.

Extant literature elucidates that the determinants impacting the spatial distribution of traditional villages manifest considerable spatial heterogeneity [43,44]. Nevertheless, comprehensive statistical representations of the area under study often fail to elucidate intra-regional variances in the impact of these determinants. GWR models provide substantial methodological benefits for such analysis, thereby justifying their continued application in this study. Historically, GWR analyses have primarily employed administrative boundaries or grid systems as the basic unit of analysis [43,53]. Similarly, this investigation employs small watersheds as the primary analytical units to accentuate the interplay between traditional villages and their natural settings. This methodological choice not only facilitates a nuanced examination of spatial heterogeneity across watersheds but also offers valuable insights into bespoke conservation strategies for traditional villages at a watershed level. Furthermore, it introduces innovative approaches to leveraging the GWR model for environmental and cultural preservation.

In summary, this study adopts a watershed perspective to scrutinize the spatial distribution of national traditional villages in Fujian Province. Initially, the area of study was segmented into river basins and watersheds to delineate the watershed characteristics influencing the distribution of traditional villages. The GWR model was then utilized, employing small watersheds as the units of analysis to investigate these influencing factors. The findings culminate in proposed strategies for the sustainable development and preservation of traditional villages from a watershed perspective. The objective of this paper is to enrich the discourse on traditional village studies and the preservation and development of rural settlements. Furthermore, it seeks to contribute to the global dialogue on village preservation, offering valuable insights that may be applicable in other nations or regions with comparable village formation dynamics.

3. Materials and Methods

3.1. Study Area

Fujian Province is situated in the southeastern region of China. The province is characterized by a network of distinct river systems that flow directly into the East China Sea, forming numerous independent river basins. This study employs digital elevation model (DEM) data with a 90 m resolution to delineate the river basins in Fujian Province using the hydrological analysis module in ArcGIS Pro 3.0.1. Considering both the river basin area and the number of villages within, the analysis focuses on seven major river basins that exceed 2000 km² in area, namely, the Minjiang, Jinjiang, Jiulongjiang, Tingjiang, Aojiang, Jiaoxi, and Huotongxi river basins (Figure 1, Table 1).

The study area is further partitioned into small watersheds following the specifications for the division and coding of small watersheds published by the Ministry of Water
Resources of China. According to the standard, small watersheds typically range in area from 3 to 50 square kilometers, while watersheds larger than 50 square kilometers that are narrow and indivisible are also considered small watersheds [54]. In the context of fluvial geomorphology, the predominant determinant of the spatial extent of minor watersheds appears to be the minimal flow accumulation threshold within the drainage basin. An increased flow accumulation threshold correlates with a less dense river network and enlarged watershed territories, subsequently reducing the prevalence of smaller watersheds. This investigation established that a threshold of 3000 for flow accumulation optimizes the presence of smaller watershed areas, specifically between 3 and 50 square kilometers. At this threshold, a total of 2206 smaller watersheds were identified, with 1454 (65.91%) of these falling within the specified size range.

Fujian Province harbors 552 national-level traditional villages, of which 470 (85.14%) are located within the study area. The Minjiang river basin encompasses the largest area and the highest number of traditional villages, accounting for 41.30% of the provincial total. Despite being the smallest area, the Huotongxi river basin exhibits the highest density of traditional villages, exceeding the provincial average by 4.6 times (Table 1). These findings demonstrate significant spatial variations in the distribution of national-level traditional villages across the river basins of Fujian Province.


<table>
<thead>
<tr>
<th>Region</th>
<th>Area/km²</th>
<th>Number</th>
<th>Density/Units per 1000 km²</th>
<th>Proportion/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minjiang River Basin</td>
<td>59547.08</td>
<td>228</td>
<td>3.83</td>
<td>41.30</td>
</tr>
<tr>
<td>Jiulongjiang River Basin</td>
<td>14494.98</td>
<td>53</td>
<td>3.66</td>
<td>9.60</td>
</tr>
<tr>
<td>Tingjiang River Basin</td>
<td>12058.33</td>
<td>47</td>
<td>3.90</td>
<td>8.51</td>
</tr>
<tr>
<td>Jinjiang River Basin</td>
<td>5594.74</td>
<td>11</td>
<td>1.97</td>
<td>1.99</td>
</tr>
<tr>
<td>Jiaoxi River Basin</td>
<td>4587.08</td>
<td>64</td>
<td>13.95</td>
<td>11.59</td>
</tr>
<tr>
<td>Aojiang River Basin</td>
<td>2629.54</td>
<td>21</td>
<td>7.99</td>
<td>3.80</td>
</tr>
</tbody>
</table>
### 3.2. Data Sources

The 552 national-level traditional villages were sourced from batches 1 to 6 of the Chinese traditional village lists released by the Ministry of Housing and Urban-Rural Development (https://www.mohurd.gov.cn, accessed on 5 January 2024). Their geographical coordinates were acquired via Google Earth. Digital elevation model (DEM) data of Fujian Province, with a 90 m resolution, were acquired via the Geospatial Data Cloud (https://www.gscloud.cn, accessed on 5 January 2024). Per capita GDP, population, annual average temperature and precipitation, and NDVI were sourced from the Resource and Environment Science and Data Center (https://www.resdc.cn, accessed on 5 January 2024). Cropland and water area data were sourced from Zenodo (https://zenodo.org, accessed on 5 January 2024). Administrative divisions and roads were obtained from the National Geographic Information Resources Directory Service System (https://www.webmap.cn, accessed on 5 January 2024). Coordinate data of cities at the county level and higher grades were obtained from Google Earth. National and provincial cultural heritage preservation units were sourced from the website of the Fujian Provincial Bureau of Cultural Heritage (http://wwj.wlt.fujian.gov.cn, accessed on 5 January 2024).

### 3.3. Methods

#### 3.3.1. Kernel Density Analysis

Kernel density analysis effectively depicts local variations in density, revealing the level of concentration and dispersion [55]. It is calculated as follows:

$$ D(x_i, y_i) = \frac{1}{nh} \sum_{h=1}^{n} K \left( \frac{d}{h} \right) $$

where $D(x_i, y_i)$ denotes the kernel density value at $(x_i, y_i)$, $h$ denotes the bandwidth, $n$ denotes the quantity of point elements within a distance less than $h$ from $(x_i, y_i)$, $K$ denotes the spatial weight function, and $d$ denotes the distance from the current point to $(x_i, y_i)$.

#### 3.3.2. Nearest Neighbor Index

The nearest neighbor index of traditional villages could determine their spatial distribution types, which fall into three categories: dispersed, random, and clustered. It is calculated as follows:

$$ R = \frac{r_i}{r_E} $$

$$ r_E = \frac{1}{2} \sqrt{n/A} $$

where $R$ denotes the nearest neighbor index; $r_i$ and $r_E$ denote the nearest neighbor distance of actuality and theory, respectively; $n$ denotes the number of traditional villages; and $A$ denotes the study area acreage. If $R > 1$, $R = 1$, or $R < 1$, it indicates that traditional villages exhibit dispersed, random, or clustered distribution patterns, respectively [52].

#### 3.3.3. Spatial Autocorrelation Analysis

Spatial autocorrelation can be categorized into global and local spatial autocorrelation. Global spatial autocorrelation is generally reflected by Moran’s I, which is calculated as follows:

$$ I = \frac{Z_i}{Z_j} $$

where $Z_i$ and $Z_j$ denote the standardized values of two variables, and $W_{ij}$ is the spatial weight of the two points.
where $G_i$ denotes Moran’s $I$; $Z_i$ and $Z_j$ denote the observed standardized values for spatial units $i$ and $j$, respectively; and $W_{ij}$ denotes the spatial weight function. Moran’s $I$ ranges between -1 and 1. Positive, zero, or negative values of $I$ indicate positive, random, or negative spatial correlation, suggesting agglomeration, randomness, or dispersion of the variable of interest. Global spatial autocorrelation, however, cannot pinpoint the specific location of clustering areas, whereas local spatial autocorrelation can compensate for this limitation. This study employs cold–hot spot analysis to explore local spatial autocorrelation features, which are used to further assess the distribution of clustered and dispersed areas [56]. It is calculated as follows:

$$G_i = \frac{\sum_i W_{ij} x_i / \sum_j x_j}{\sum_i W_{ij}}$$

(5)

$$Z = G_i - E(G_i) / \sqrt{Var(G_i)}$$

(6)

where $x_i$ and $x_j$ denote the concentration of traditional villages in the $i$ and $j$ watersheds, respectively; $W_{ij}$ denotes the spatial weight function; $E(G_i)$ denotes the expected value; and $Var(G_i)$ denotes the variation coefficient.

3.3.4. Stepwise Regression Model

In a stepwise regression analysis, variables are excluded when they become non-significant with the introduction of new variables. Concurrently, variables that were previously excluded are reassessed upon the inclusion of new variables. Should a variable exhibit significant influence following the introduction of a new variable, it is reinstated into the model [57]. This iterative process ensures that the stepwise regression model retains significant factors, eliminates non-significant ones, and addresses collinearity among explanatory variables.

3.3.5. GWR

GWR was proposed by Fotheringham et al. [58]. Unlike ordinary least squares regression (OLS), the GWR model incorporates the geographical coordinates of the data into the regression equation, enhancing the reliability of spatial heterogeneity assessment. It is calculated as follows:

$$y_i = \beta_0(\mu_i, v_i) + \sum_{k=1}^k \beta_k(\mu_i, v_i) x_{ik} + \varepsilon_i$$

(7)

where $y_i$ denotes the dependent variable; $x_{ik}$ denotes the observed value of the independent variable; $(\mu_i, v_i)$ denotes the geographical coordinates; $\beta_k(\mu_i, v_i)$ denotes the constant term; $\beta_k(\mu_i, v_i)$ denotes the regression coefficient; $\varepsilon_i$ denotes the random error term.

3.4. Research Framework

The research process was structured into four parts: data preparation and processing; analysis of the watershed characteristics in the spatial distribution of traditional villages; analysis of influencing factors; and cluster protection and development strategies for traditional villages within watersheds. Initially, data were collected, including DEM data, traditional village locations, population density, per capita GDP, precipitation, and temperature, to construct a comprehensive database. Hydrological analysis methods were employed on DEM data to delineate river basins and small watersheds in Fujian Province. The spatial distribution characteristics of watersheds, such as distribution type, density, spatial autocorrelation, and correlation with river class, were then investigated using the nearest neighbor index, kernel density analysis, spatial autocorrelation analysis, and mathematical statistics. Subsequently, a stepwise regression model was used to identify the optimal influencing factors, followed by a geographically weighted regression model to study the spatial heterogeneity of these factors. Finally, based on the study results, strategies for cluster protection and the development of traditional villages within watersheds.
were proposed. Except for the stepwise regression model, which was performed using SPSS 27, all other analyses were conducted in ArcGIS. The study framework is depicted in Figure 2.

Figure 2. Study framework. Source: Author.

4. Results

4.1. Watershed Characteristics of Spatial Distribution

4.1.1. Types of Spatial Distribution

The observed average distance between traditional villages within the study area was 5.922 km, compared to a theoretical average distance of 7.319 km. The nearest neighbor index was 0.809 with a p-value of 0.000, indicating a significant \((p < 0.01)\) agglomerative pattern of traditional villages within watersheds.

Specifically, the nearest neighbor indices for the Minjiang \((0.888, p < 0.01)\), Tingjiang \((0.750, p < 0.01)\), Aojiang \((0.693, p < 0.01)\), and Jiulongjiang \((0.839, p < 0.05)\) river basins all demonstrated significant agglomerative distributions of traditional villages. In contrast,
the Jinjiang, Jiaoxi, and Huotongxi river basins exhibited random distributions with nearest neighbor indices close to 1 and $p$-values greater than 0.05 (Table 2).

### Table 2. Spatial distribution types in different basins. Source: Author.

<table>
<thead>
<tr>
<th>Region</th>
<th>$r_i$/km</th>
<th>$r_p$/km</th>
<th>$R$</th>
<th>$p$-Value</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minjiang River Basin</td>
<td>7.182</td>
<td>8.080</td>
<td>0.888</td>
<td>0.001</td>
<td>Agglomeration</td>
</tr>
<tr>
<td>Jiulongjiang River Basin</td>
<td>6.934</td>
<td>8.268</td>
<td>0.839</td>
<td>0.025</td>
<td>Agglomeration</td>
</tr>
<tr>
<td>Tingjiang River Basin</td>
<td>6.009</td>
<td>8.008</td>
<td>0.750</td>
<td>0.001</td>
<td>Agglomeration</td>
</tr>
<tr>
<td>Jinjiang River Basin</td>
<td>11.224</td>
<td>11.274</td>
<td>0.995</td>
<td>0.997</td>
<td>Random</td>
</tr>
<tr>
<td>Jiaoxi River Basin</td>
<td>4.005</td>
<td>4.229</td>
<td>0.946</td>
<td>0.417</td>
<td>Random</td>
</tr>
<tr>
<td>Aojiang River Basin</td>
<td>3.875</td>
<td>5.591</td>
<td>0.693</td>
<td>0.007</td>
<td>Agglomeration</td>
</tr>
<tr>
<td>Huotongxi River Basin</td>
<td>3.260</td>
<td>3.478</td>
<td>0.937</td>
<td>0.415</td>
<td>Random</td>
</tr>
<tr>
<td>Overall</td>
<td>5.922</td>
<td>7.319</td>
<td>0.809</td>
<td>0.000</td>
<td>Agglomeration</td>
</tr>
</tbody>
</table>

### 4.1.2. Density of Spatial Distribution

Kernel density was calculated under search radii of 20 km, 30 km, 40 km, and 50 km, respectively. The kernel density result obtained using a 30 km search radius more clearly reflects the differences in traditional villages’ spatial distribution. Therefore, a 30 km search radius was selected for kernel density calculation.

This revealed two high-density and two medium-density agglomeration areas in Figure 3. The high-density clusters were located between the Jiulongjiang and Tingjiang river basins in western Fujian and within the Jiaoxi, Huotongxi, and Aojiang river basins in eastern Fujian. In western Fujian, the high-density cluster centered around the basin boundary, while in eastern Fujian, it exhibited a ring-shaped pattern closely following the basin boundary. Two medium-density agglomeration areas were also identified along the southern boundary of the Minjiang river basin, again aligning with the basin boundary. These findings indicate a strong spatial correlation between the distribution of traditional villages and watershed boundaries in Fujian Province.

![Figure 3. Kernel density map of traditional villages in Fujian. Source: Author.](image-url)
4.1.3. Spatial Autocorrelation Features

The Moran’s I and p-value calculated using ArcGIS Pro were 0.200044 and 0.000, respectively, indicating a statistically significant (p < 0.01) spatially positive correlation trend for traditional villages in the Fujian Province watersheds, suggestive of spatial agglomeration. Further analysis of local spatial autocorrelation through cold–hot spot mapping (Figure 4) revealed distinct clusters of high-value (hot spot) areas primarily concentrated in the central regions of the Jiaoxi, Huotongxi, northern Aojiang, southern Minjiang, and the central convergence of the Tingjiang and Jiulongjiang river basins. These hot spot regions, accounting for approximately 9.25% of the total small watersheds, comprised 47.25% of all traditional villages, indicating high spatial clustering. Conversely, the absence of cold spot areas suggests a relatively uniform distribution of traditional villages across the remaining small watersheds, likely attributable to the favorable natural geographical environment of Fujian Province that provides suitable conditions for human habitation and settlement across most watersheds.

Figure 4. Distribution of cold–hot spots of watershed traditional villages in Fujian. Source: Author.

4.1.4. The Correlation between Spatial Distribution and River Hierarchy

Stream order classification using the Strahler method investigated the correlation between river hierarchy and traditional village distribution (Figure 5, Table 3). First-order streams have 321 nearby traditional villages, comprising 68.30% of the total; second-order streams have 83, accounting for 17.66%; third-order streams have 38, accounting for 8.09%; fourth-order streams have 24, accounting for 5.11%; fifth-order streams have 4, accounting for 0.85%; and sixth-order streams have none, accounting for 0.00%. More than 60% of traditional villages are situated near first-order streams, and as the stream order increases, the quantity of traditional villages decreases. Evidently, traditional villages in Fujian are predominantly clustered along tributaries, particularly near low-order streams. Especially noteworthy is the Huotongxi river basin, where four, four, and five traditional villages are
found near second-, third-, and fourth-order streams, respectively. This defies the trend where higher river levels correspond to fewer villages. This is mainly because the catchment area of the Huotongxi river basin is small, thus limiting the scale of runoff volume, river width, and water regime changes in the main stream, which reduces the need for traditional villages to be distanced from it.

Figure 5. Distribution of river hierarchy and traditional villages in Fujian. Source: Author.

Table 3. Quantity of traditional villages by basin in relation to river hierarchy. Source: Author.

<table>
<thead>
<tr>
<th>Region</th>
<th>First-Order</th>
<th>Second-Order</th>
<th>Third-Order</th>
<th>Fourth-Order</th>
<th>Fifth-Order</th>
<th>Sixth-Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minjiang River Basin</td>
<td>163</td>
<td>41</td>
<td>10</td>
<td>10</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Jiulongjiang River Basin</td>
<td>32</td>
<td>12</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tingjiang River Basin</td>
<td>33</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jinjiang River Basin</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jiaoxi River Basin</td>
<td>32</td>
<td>15</td>
<td>10</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Aojiang River Basin</td>
<td>18</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Huotongxi River Basin</td>
<td>33</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>321</td>
<td>83</td>
<td>38</td>
<td>24</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Proportion</td>
<td>68.30%</td>
<td>17.66%</td>
<td>8.09%</td>
<td>5.11%</td>
<td>0.85%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

4.2. Influencing Factors of Spatial Distribution

4.2.1. Variable Selection for Influencing Factors

In 2012, China introduced the “Traditional Village Evaluation and Accreditation Indicator System (Trial),” which encompassed three primary criteria: traditional village architecture, village site selection and pattern, and intangible cultural heritage. In 2018, this evaluation index system was revised to include five major components: historical deposits, village environment, pattern and style, traditional architecture, and folk culture [59]. The primary factors influencing the accreditation of traditional villages are, therefore,
village architecture, village environment, and historical and cultural elements. Village architecture is significantly affected by economic development and urbanization, often resulting in repairs or demolitions. The village environment is largely determined by topography, climate, and hydrology. The preservation of historical and cultural elements relies on both the awareness of local villagers and the level of government attention. Building on the criteria for assessing traditional villages and previous research by Ma [16], Liu [39], Jia [40], Wu [42], Li [43], Chen [45], and others, this study selected 13 indicators across nine dimensions, including terrain, climate, ecology, hydrology, economy, population, urbanization, transportation, and culture, to examine the spatial heterogeneity of these factors using small watersheds as the unit of analysis and the GWR model (Table 4).

Table 4. Indicators and calculation of influencing factors. Source: Author.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dimension</th>
<th>Indicator</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variables</td>
<td>—</td>
<td>Concentration of traditional villages</td>
<td>Quantity of traditional villages in each small watershed</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>Elevation</td>
<td>The mean elevation of each small watershed</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>Relief</td>
<td>Difference between the highest and lowest points of each small watershed</td>
</tr>
<tr>
<td></td>
<td>Terrain</td>
<td>Annual average temperature</td>
<td>Calculate the average of the annual average temperature for each small watershed using zonal statistics</td>
</tr>
<tr>
<td></td>
<td>Climate</td>
<td>Annual average precipitation</td>
<td>Calculate the average of the annual average precipitation for each small watershed using zonal statistics</td>
</tr>
<tr>
<td></td>
<td>Ecology</td>
<td>NDVI</td>
<td>Calculate the average of the NDVI for each small watershed using zonal statistics</td>
</tr>
<tr>
<td></td>
<td>Hydrology</td>
<td>Arable land</td>
<td>The ratio of arable land to the watershed area</td>
</tr>
<tr>
<td></td>
<td>Economy</td>
<td>Per capita GDP</td>
<td>Calculate the average of the per capita GDP for each small watershed using zonal statistics</td>
</tr>
<tr>
<td></td>
<td>Population</td>
<td>Population density</td>
<td>Calculate the average of the Population density for each small watershed using zonal statistics</td>
</tr>
<tr>
<td>Socioeconomic factors</td>
<td>Urbanization</td>
<td>Distance to county-level or higher-grade cities</td>
<td>Distances from the geometric centers of each small watershed to cities of county level and higher grades are classified as follows: 0–5 km, 5–10 km, 10–15 km, 15–20 km, 20–25 km, and above 25 km as 5, 4, 3, 2, 1, and 0, respectively</td>
</tr>
<tr>
<td></td>
<td>Transportation</td>
<td>Road density</td>
<td>The ratio of road length to the watershed area</td>
</tr>
<tr>
<td></td>
<td>Culture</td>
<td>Concentration of cultural heritage preservation units</td>
<td>Number of national and provincial cultural heritage preservation units in each small watershed</td>
</tr>
</tbody>
</table>

4.2.2. Analysis of GWR Model Results

Spatial autocorrelation among variables is a prerequisite for GWR analysis, and the research in Section 4.1.3. has demonstrated the positive spatial autocorrelation of traditional villages in the watershed. Therefore, the GWR model is suitable for analyzing the influencing factors. Before the GWR analysis, it is crucial to exclude multicollinearity among explanatory variables and retain those with significant influence to optimize the model. A stepwise regression model is utilized in this study to handle explanatory variables. The results reveal that variables such as topographical relief, mean annual temperature, mean annual precipitation, extent of arable land, per capita GDP, proximity to urban centers at the county level or above, and the density of sites designated for cultural heritage conservation all significantly influence the outcomes at a 1% significance level. Each of these seven variables demonstrate a substantial and statistically significant impact on the studied phenomena. Moreover, the Variance Inflation Factor (VIF) is well below 7.5.
This resolves the collinearity issue among the explanatory variables, satisfying the criteria for constructing a GWR model (Table 5).

### Table 5. Results of stepwise regression model. Source: Author.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Non-Standard Coefficient</th>
<th>Standard Coefficient</th>
<th>t</th>
<th>Sig.</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relief</td>
<td>0.00018</td>
<td>0.08279</td>
<td>3.45196</td>
<td>0.00057</td>
<td>1.42504</td>
</tr>
<tr>
<td>Annual average temperature</td>
<td>-0.10448</td>
<td>-0.26448</td>
<td>-8.37756</td>
<td>0.00000</td>
<td>2.46902</td>
</tr>
<tr>
<td>Annual average precipitation</td>
<td>-0.00063</td>
<td>-0.24897</td>
<td>-8.88006</td>
<td>0.00000</td>
<td>1.94732</td>
</tr>
<tr>
<td>Arable land</td>
<td>0.00533</td>
<td>0.08850</td>
<td>3.53634</td>
<td>0.00041</td>
<td>1.55150</td>
</tr>
<tr>
<td>Per capita GDP</td>
<td>-0.00002</td>
<td>-0.23089</td>
<td>-7.70822</td>
<td>0.00000</td>
<td>2.22268</td>
</tr>
<tr>
<td>Distance to county-level or higher-grade cities</td>
<td>-0.02612</td>
<td>-0.06529</td>
<td>-3.00049</td>
<td>0.00273</td>
<td>1.17287</td>
</tr>
<tr>
<td>Concentration of cultural heritage preservation units</td>
<td>0.13649</td>
<td>0.31590</td>
<td>10.89036</td>
<td>0.00000</td>
<td>2.08449</td>
</tr>
<tr>
<td>constant term</td>
<td>3.02728</td>
<td>—</td>
<td>9.11381</td>
<td>0.00000</td>
<td>—</td>
</tr>
</tbody>
</table>

This study conducted GWR calculations using ArcGIS Pro to investigate the spatial differentiation of influencing factors in seven river basins. The dependent variable was the concentration of traditional villages, while the explanatory variables included relief, annual average temperature, annual average precipitation, arable land, per capita GDP, distance to county-level or higher-grade cities, and concentration of cultural heritage preservation units. The neighborhood type employed Distance Band, the optimal bandwidth search utilized Golden Section Search, and the local weight selected the Bisquare function. The model yielded an R2 of 0.396. Spatial autocorrelation analysis of the model residuals revealed a Moran’s I of 0.015 with a p-value of 0.199, failing the significance test, indicating a randomly distributed residual and a satisfactory model fit. The GWR model calculated regression coefficients for each influencing factor in every small watershed. The mean values of these coefficients were aggregated across the seven river basins, demonstrating considerable variation in the extent to which influencing factors affected various watersheds (Table 6), and watershed characteristics of spatial differentiation were evident (Figure 6).

### Table 6. Average regression coefficients of influencing factors in different basins. Source: Author.

<table>
<thead>
<tr>
<th>Region</th>
<th>Relief</th>
<th>Annual Average Temperature</th>
<th>Annual Average Precipitation</th>
<th>Arable Land</th>
<th>Per Capita GDP</th>
<th>Distance to County-Level or Higher-Grade Cities</th>
<th>Concentration of Cultural Heritage Preservation Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minjiang River Basin</td>
<td>0.000221</td>
<td>-0.020506</td>
<td>-0.000383</td>
<td>0.004727</td>
<td>-0.000111</td>
<td>-0.033096</td>
<td>0.277082</td>
</tr>
<tr>
<td>Jiulongjiang River Basin</td>
<td>0.000062</td>
<td>-0.092189</td>
<td>-0.000441</td>
<td>0.008007</td>
<td>0.000003</td>
<td>-0.057368</td>
<td>0.138330</td>
</tr>
<tr>
<td>Tingjiang River Basin</td>
<td>0.000112</td>
<td>-0.112274</td>
<td>-0.000525</td>
<td>0.010174</td>
<td>-0.000024</td>
<td>-0.083180</td>
<td>0.123965</td>
</tr>
<tr>
<td>Jinjiang River Basin</td>
<td>-0.000024</td>
<td>-0.134454</td>
<td>-0.000397</td>
<td>0.007197</td>
<td>-0.000029</td>
<td>0.067155</td>
<td>0.113175</td>
</tr>
<tr>
<td>Jiaoxi River Basin</td>
<td>0.001585</td>
<td>0.182853</td>
<td>0.000667</td>
<td>0.011241</td>
<td>-0.000092</td>
<td>-0.231700</td>
<td>0.279445</td>
</tr>
<tr>
<td>Aojiang River Basin</td>
<td>-0.000065</td>
<td>0.026616</td>
<td>0.005990</td>
<td>0.014277</td>
<td>-0.000019</td>
<td>0.114608</td>
<td>0.094693</td>
</tr>
<tr>
<td>Huotongxi River Basin</td>
<td>0.001492</td>
<td>-0.003637</td>
<td>0.000087</td>
<td>0.026651</td>
<td>-0.000137</td>
<td>-0.106450</td>
<td>0.380535</td>
</tr>
</tbody>
</table>
4.2.3. Analysis of the Spatial Heterogeneity of Influencing Factors

1. Relief

The results of the GWR model unveil a nuanced interplay of positive and negative influences exerted by topographic relief on the clustering of traditional villages. While the Aojiang and Jinjiang river basins demonstrate predominantly adverse effects, the...
remaining five basins exhibit positive correlations. Furthermore, the positive coefficient attributed to relief in the stepwise regression model implies a prevalence of beneficial impacts over detrimental ones (Table 6). This suggests a general trend wherein elevated relief corresponds to a denser distribution of traditional villages within the watersheds. Historically, the emergence of traditional villages in Fujian can be traced back to the migration of central plains inhabitants seeking sanctuary from conflicts, thereby establishing their concentration in mountainous terrains [16]. Additionally, regions characterized by substantial relief tend to nurture secluded environments endowed with heightened defensive attributes, rendering them less susceptible to developmental encroachment and consequently fostering relative preservation [43]. Spatially, elevated regression coefficients manifest prominently in the Jiaoxi and Huotongxi river basins, while lower values are discernible in the Aojiang, northern Jinjiang, and southeastern Minjiang river basins, alongside the confluences of the Tingjiang and Jiulongjiang river basins, indicating pronounced spatial heterogeneity (Figure 6a).

2. Annual Average Temperature and Precipitation

The livability and formation of traditional villages are strongly influenced by temperature and precipitation. Overall, these climatic factors have similar influencing effects within the same basin. With the exception of the Huotongxi river basin, where temperature exerts negative effects and precipitation exerts positive effects, temperature and precipitation exhibit negative impacts in the Minjiang, Jiulongjiang, Tingjiang, and Jinjiang river basins, while positive effects are observed in the Jiaoxi and Aojiang river basins (Table 6). High-value areas of temperature regression coefficients are concentrated in the boundaries of the Jiaoxi, Huotongxi, and Aojiang river basins and the central southwest Minjiang river basin, while low-value areas are found in the junction zones of the Jiulongjiang and Tingjiang river basins, as well as the southern Minjiang river basin (Figure 6b). High-value areas of precipitation regression coefficients are mainly in the Aojiang, northwestern Jiulongjiang, and northern Jiaoxi river basins, while low-value areas are concentrated at the junction of the Jiulongjiang and Tingjiang river basins, the southern Minjiang river basin, as well as the junction zones of the Huotongxi, Jiaoxi, and Minjiang river basins (Figure 6c).

3. Arable Land

Across all watersheds, arable land demonstrates a positive correlation with the concentration of traditional villages, underscoring the critical role of agriculture in their establishment and development (Table 6). Regions with higher regression coefficient values are located in the southern Tingjiang river basin, the southern Minjiang river basin, the Jiaoxi river basin, and the Huotongxi river basin, highlighting the significant influence of arable land in these areas (Figure 6d). Additionally, there is a notable overlap between the distribution of high-value areas and regions with high kernel density (Figure 3), further evidencing the reliance of traditional villages on cultivated land.

4. Per Capita GDP

Per capita GDP is generally inversely related to traditional village concentration, except for the Jiulongjiang river basin, which shows a positive impact (Table 6). Overall, the low level of economic development fosters the preservation of traditional villages. This phenomenon may arise from the stable relationship between people and land created by the underdeveloped economy, resulting in fewer disruptions to traditional villages [44]. The Jiulongjiang river basin is the primary Hakka village area, which benefits from successful tourism development due to Hakka Tulou and its rich cultural resources. This not only boosts income but also fosters traditional village preservation and development. Spatially, positive impacts are concentrated in the southern Tingjiang river basin and the western and northern Minjiang river basin, which receive less attention due to their proximity to provincial boundaries and lagging economic development (Figure 6e). Economic growth can effectively catalyze traditional village revitalization in these areas.
5. **Distance to County-Level or Higher-Grade Cities**

The distance to county-level or higher-grade cities exhibits a predominantly negative correlation with traditional village concentration; as cities draw closer, traditional village concentration diminishes (Table 6). Spatially, positive impact zones are primarily observed in the Jinjiang and Aojiang river basins. In these regions, urban development has not led to the rapid disappearance of traditional villages. Instead, it has sustained their growth. However, many watersheds are witnessing city encroachment while villages recede. These watersheds require increased attention to protect traditional villages during urban development, ensuring the preservation of historical and cultural continuity (Figure 6f).

6. **Concentration of Cultural Heritage Preservation Units**

There was a positive correlation between the concentration of cultural heritage preservation units and that of traditional villages. The Minjiang, Jiaoxi, and Huotongxi river basins experience the most significant positive impact, while the other river basins exhibit similar positive effects (Table 6). Although impacts are positive in all river basins, there are significant spatial variations in the extent of influence within the study region. The regression coefficient manifests in three prominent zones across the Minjiang river basin, gradually decreasing towards the surrounding areas (Figure 6g). Cultural heritage preservation units serve as reflections of the region’s historical and cultural characteristics, providing a crucial foundation for the sustainable development of traditional villages. Therefore, each river basin should proactively explore valuable cultural heritage and enhance the value of villages in a stepwise manner.

5. **Discussion**

5.1. **Strategies for the Protection and Development of Traditional Villages within Watersheds**

The spatial distribution of traditional villages and their influencing factors in Fujian exhibit distinct watershed characteristics shaped by both natural geography and socioeconomic drivers. Numerous scholars have investigated spatial governance and high-quality urban-rural development from a watershed perspective [60–64]. Given the strong correlation between traditional villages and watersheds, as well as the high level of homogeneity within watersheds, it is feasible to undertake the development and protection of traditional villages from a watershed-based approach. Hence, this article proposes the following recommendations from a watershed standpoint.

Firstly, the protection and development of traditional villages can employ a watershed management approach, with the watershed serving as both a geographical and cultural entity. Traditional villages within a particular watershed share similar natural environments, histories, cultures, and customs. It is imperative to collectively protect these villages within the watershed framework, avoiding their isolation by administrative boundaries. Sub-watershed divisions can be established to create protection units to address non-uniform distribution within watersheds, facilitating targeted and hierarchical management for areas of dense traditional villages.

Secondly, utilizing the watershed as a unit, we propose cluster protection and the development of traditional villages across five dimensions: space, culture, landscape, industry, and governance. Clusters are not mere spatial collections of settlements but rather a synthesis of structural relationships presented by region, topography, society, history, and culture [65,66]. The geographical and cultural attributes inherent to watersheds precisely align with the connotations of clusters. Previous studies on rural clusters have predominantly focused on economic factors such as industry and tourism [67–69]. In contrast, the cluster concepts presented in this paper are more integrated and comprehensive.

1. **Space**: Kernel density analysis and hot–cold spot analysis revealed that traditional villages in the watershed exhibit multi-core agglomeration, characterized by proximity to bodies of water. Watersheds with dense concentrations of traditional villages
serve as central hubs for cluster protection, and a linear heritage protection corridor can be established along rivers to safeguard these traditional villages spatially.

(2) Culture: The three cores of traditional villages represent Eastern Fujian, Central Fujian, and Western Fujian Hakka cultures. The cultural heritage within these cores should be thoroughly explored as a basis for protecting traditional village cultures.

(3) Landscape: The watershed’s water system significantly influences the morphological characteristics of surrounding settlements \[70\]. Additionally, village culture is also closely linked with village landscapes, which can be used as cores to carry out cluster protection of traditional village landscapes.

(4) Industry: Based on the characteristics of the watershed economy \[71,72\], efforts should be made to coordinate resources and diversify village development to foster the growth of village industry chains. This approach helps prevent single-industry dominance and homogeneous development while stimulating the formation of traditional village industry clusters within the watershed.

(5) Governance: Small watersheds represent typical human settlement units characterized by high integrity and correlation \[73\]. Local development and construction initiatives within small watersheds must prioritize the holistic interests of these areas \[74\]. Spatial governance could be implemented at the scale of small watersheds to promote the cluster governance of traditional villages by enhancing the spatial connectivity of traditional villages and coordinating watershed governance responsibilities.

5.2. Advantages and Limitations

This study investigates the spatial distribution of traditional villages in Fujian Province’s watershed regions, utilizing the GWR model with small watersheds as the basic analytical unit. This methodological choice enables an examination of spatial variations in the factors influencing these distributions. By focusing on watersheds rather than administrative boundaries, this research circumvents the limitations associated with heterogeneity in regional characteristics and cultural traditions, thus providing insights into more effective strategies for village preservation and avoiding cultural homogenization. Moreover, the application of the GWR model to small watershed units introduces a novel perspective on spatial analysis. The insights garnered from the GWR model regarding influential factors are crucial for guiding the sustainable development and conservation of traditional villages within these hydrological boundaries.

Nonetheless, this study has several limitations. Primarily, the proposed strategy is generalized and does not account for the unique characteristics of individual villages. Future research will employ cluster analysis to categorize traditional villages in greater detail, enabling the development of more specific and targeted strategies for the protection and development of different types of traditional villages in watersheds. Moreover, while this study offers a macroscopic analysis of distribution patterns and determinants, it does not delve into microscale dynamics. Certain small watersheds, for instance, show a high concentration of traditional villages; identifying the drivers behind such clustering and the micro-level interactions between these villages and their aquatic environments is critical. Furthermore, the study will explore watershed-specific cultural and tourism resources and formulate targeted conservation and development strategies. Addressing these microscale questions is essential for the future preservation and enhancement of traditional villages in watershed regions, which will be a focal point of subsequent inquiries.

6. Conclusions

This study examines the spatial differentiation of traditional villages in the watersheds of Fujian Province using methods including the nearest neighbor index, kernel density estimation, and spatial autocorrelation analysis. Thirteen indicators across nine dimensions were selected for analysis using stepwise regression and GWR models to investigate the factors influencing the spatial distribution of traditional villages within
watersheds. The watershed-specific characteristics of these influencing factors were also analyzed. The main research conclusions are as follows.

(1) Traditional villages in Fujian generally exhibit a clustered distribution within watersheds, except for the Jinjiang river basin, Jiaoxi river basin, and Huotongxi river basin, where a random distribution pattern is evident.

(2) Traditional villages tend to aggregate along basin boundaries and, while they are evenly distributed in remaining small watersheds, primarily cluster in three hot spot regions: Bopingling between the Jiulongjiang and Tingjiang river basins; the Jiaoxi, Huotongxi, and Aojiang river basins in eastern Fujian; and the southern Minjiang river basin.

(3) Most traditional villages are situated near low-order streams, indicating a distribution pattern along tributaries. However, in the Huotongxi river basin, traditional villages are relatively evenly dispersed near second-, third-, and fourth-order streams, showcasing unique characteristics.

(4) Relief, annual average temperature, annual average precipitation, arable land, per capita GDP, distance to county-level or higher cities, and the concentration of cultural heritage preservation units are identified as the primary factors influencing the spatial distribution of traditional villages. The extent and effect of these factors exhibit significant spatial heterogeneity within watersheds.

(5) Natural environmental factors play a pivotal role in the genesis of traditional village formations, with relief and arable land predominantly exerting positive influences. Temperature and precipitation generally manifest consistent effects within the same river basin, barring the Huotongxi river basin. Meanwhile, socioeconomic factors emerge as principal determinants in traditional village evolution, marked by an inverse relationship between per capita GDP and urban proximity, juxtaposed with a positive correlation with the presence of cultural heritage preservation units.

In summary, this study identifies the watershed characteristics of traditional villages in Fujian Province and elucidates their influencing mechanisms. Based on these insights, we propose a watershed management model for traditional villages and present cluster protection and development strategies across five dimensions: space, culture, landscape, industry, and governance. Furthermore, this study explores the use of watersheds as the basic unit for GWR, thereby extending the model’s applicability. The findings aim to provide a reference for the conservation and sustainable development of traditional villages.

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