

# Spatial Distribution of Different Types of Villages for Rural Revitalization Strategy and Their Influencing Factors: A Case of Jilin Province, China

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**Abstract:** Village classification is the first step to implementing China's rural revitalization (RR) strategy, and understanding the geographic differences in the distribution of village types helps to grasp the pathway of their unique development. This study spatialized 9250 villages in Jilin Province (divided into six types) of China, and their distribution characteristics and influencing factors were examined using methods such as kernel density estimation, Ripley's K function, the co-location quotient, and Geodetector. The results indicate that the spatial distribution balance and density of village types are different. All types of villages show an agglomeration distribution pattern, but the scale and intensity vary. There is a strong spatial association between agglomerative promotion (AP) and stable improvement (SI) villages, as well as between characteristic protection (CP) and prospering frontier and enriching people (PE) villages. The factors affecting their distribution include terrain undulation, the percentage of arable land, the distance to the county town, road network density, population density, gross domestic product (GDP), and industrial enterprise density. The influencing factors for the distribution of village types are closely related to the function of each village. Based on the differences in the spatial distribution and influencing factors of different village types, policy suggestions are given for classified development.

**Keywords:** village classification; spatial differentiation; Geodetector; rural development; Jilin Province, China

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## 1 Introduction

Implementing China's rural revitalization (RR) strategy is critical in resolving inadequate, unbalanced rural development and promoting rural transformation and urban-rural integration (Liu and Li, 2017; Liu et al., 2020). Creating a new pattern of RR is an important part of the process, and this step cannot be separated from the co-

ordination of urban and rural development space. Furthermore, understanding the clustering features and current distribution of villages and reasonably determining their layout and scale play a crucial role in coordinating urban and rural development space. As a site for rural residents to engage in agricultural production activities, the village is the basic unit for implementing China's RR strategy (Yang et al., 2016; Li and Song, 2020). Re-

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search on the spatial distribution of villages and the influencing factors helps to identify a new pattern of RR through rational planning and layouts. With the acceleration of China's industrialization and urbanization, a sizeable agricultural population has moved from rural to urban areas, resulting in problems affecting villages such as weakened rural development, the emptying of villages, and limited space (Long et al., 2016; Li et al., 2021b). Influenced by factors such as the natural environment, location, resource endowment, and economic growth, the evolution of village types varies considerably (Saraceno, 2013; DeRosa et al., 2019; Sherry and Shortall, 2019). In the process of diversified rural development, village diversification and differentiation will continue (Marsden, 1998; Jia et al., 2020). Facing increasingly prominent 'village diseases' and substantial differences in development, it has become urgent to form a scientific classification of villages and to apply it to their development (Bański and Mazur, 2016; Long and Liu, 2016; Bai et al., 2021; Khalaf et al., 2022). Both strategic planning for RR and village planning, promoted by the Chinese government, entail specific requirements for classification. Accordingly, classification has become necessary for the in-depth development of the RR strategy and village planning (Li et al., 2020). Each province in China has actively carried out village classification; the patterns of such classification have been gradually clarified, laying a foundation for recognizing the patterns of village differentiation. Thus, systematically investigating the spatial distribution features and influencing factors of village types is the first step to understanding differences in village development and exploring different paths of corresponding revitalization. It is also crucial to guide village planning and to comprehensively promote the RR strategy.

Academic research has focused deeply on the classification and spatial distribution of villages, but most studies have examined classification and spatial distribution separately; the integration of the two is less common (Molestina et al., 2020). The research on village classification has mostly explored the identification of village types, primarily using step-by-step identification according to a logical process (Bański and Mazur, 2016), the inductive approach (Beyazli et al., 2017), social network analysis (Yue et al., 2021), cluster analysis (Hedlund, 2016; Hu and Wang, 2020), and Geographic Information System (GIS) spatial analysis (Ningrum et

al., 2020). However, in practice, village classification often involves a combination of diverse methods (Wen and Zheng, 2019). There are many perspectives on village type identification, including topography (Xu et al., 2019), location (Psaltopoulos et al., 2006), and rural functions (Kubeš and Ouředníček, 2022), as well as comprehensive approaches that combine natural location conditions and the level of a village's economic growth (van Eupen et al., 2012; Klufová, 2016). Scholars believe that village classification oriented toward RR should consider village characteristics, the living environment, development and construction, zoning location, and village functions (Li et al., 2020). More attention has been paid to the identification of village types in special geographic locales such as suburban areas outside metropolitan hubs. As connecting areas between cities and remote rural areas, village classification can lay the foundation for investigating the development path of urban-rural integration, and can serve as an important reference for other regions (Tian et al., 2021). The spatial distribution of villages embodies human production, life, and humans' relationship with the surrounding environment under different productivity levels (Lange et al., 2013; Ma et al., 2013). Guiomar et al. (2018) scrutinized the role of European farms in each unique regional context by locating their spatial distribution. Yang et al. (2016) studied the spatial distribution of villages in China and proposed four new village-town system patterns, such as the central place, the radially imbalanced, the multicore central place, and the corridor balanced and imbalanced distribution modes. The spatial distribution of special villages types—such as traditional (Liu et al., 2022; Ma and Tong, 2022), professional (Qiao et al., 2016), and poverty-stricken (Ma et al., 2018)—has received considerable attention. Scholars affirm that the analysis of the spatial distribution characteristics of special village types is helpful for implementing flexible and differentiated village development strategies. Some scholars focus on the key elements of the village and assert that natural and financial capital assets (Dasgupta et al., 2022), the inhabitants of changing villages (Thissen et al., 2021), institutional land regimes (Abdelkader et al., 2022) and location features (Ploeckl, 2021) have significant influences on the distribution and development of villages. Chinese scholars have mostly analyzed the influencing factors of village distribution from an overarching angle, and main-

tain that the spatial distribution of villages is due to the synergy and long-term influence of multiple geographic factors such as topography, climate, soil, transportation, population, and economic growth (Song et al., 2014; Yang et al., 2016; Zhou et al., 2020). Some scholars have put forward the village optimization model of assisting rural residents to relocate from small settlements to large ones according to a village's distribution features and the idle situation of rural homesteads (Li et al., 2021a), applying village distribution patterns to village layout optimization.

The current identification of village types centers on the natural, social, and economic elements of villages, whereas not enough attention has been paid to functional type classification of villages. Moreover, applied research on village classification is lacking. Village distribution research has mostly examined traditional, poverty-stricken, and professional villages and other single types of villages, but has not determined their overall distribution characteristics. There are few comparative studies on the distribution of different village types. Research on the influencing factors of village distribution lacks broad consideration of multiple factors and their interaction. Facing a new situation of insufficient understanding of village distribution rules and uneven development, the RR strategy puts forward new requirements to identify the features of village aggregation and classification development. Hence, it is necessary to comprehend the distribution characteristics and influencing factors of villages based on differences in type and space. Jilin Province in Northeast China is a large farming province at the vanguard of national agricultural and rural modernization. There are many villages in Jilin Province that are distributed across mountainous forests, plain farming areas, and the farming-pastoral ecozone (Li et al., 2021a). It is meaningful to understand the distribution and development patterns of villages, and to determine their layout and scale in this region to ensure China's food security and to recognize the complexity of village distribution.

As such, this study selected Jilin Province of China as the study area, systematically summarized the village classification scheme of the study area oriented toward the RR strategy, and analyzed the distribution features and influencing factors of different village types in the context of the RR strategy using spatial analysis methods such as kernel density estimation, Ripley's K func-

tion, the co-location quotient, and Geodetector. This study attempted to solve three pressing problems: 1) what are the characteristics of the spatial distribution of village types under the requirements of China's RR strategy? 2) What causes differences in the distribution of different village types from a geographic standpoint? 3) What stimulates the distribution patterns of different village types for future RR? This study could provide important theoretical and practical value for promoting the RR strategy through zoning and classification, and offers theoretical support and helpful guidance for rural spatial planning and optimization in developing countries.

## 2 Background of Village Classification and Theoretical Analysis

### 2.1 Policy background of village classification

Affected by the geographic environment, location conditions, resource endowment, development status, and other factors, rural development exhibits unique differences. The Strategic Plan for Rural Revitalization (2018–2022), adopted by the Chinese government, aims to promote the expansion of villages by category and divides all villages into four types: agglomerative promotion (AP), suburban integration (SIn), characteristic protection (CP), and removal and merger (RM) villages. The AP category is dominated by larger central villages. SIn includes villages in the suburban parts of cities and the urban zones of counties. CP refers to villages with rich natural, historical, and cultural resources. RM encompasses villages with a very poor natural environment and serious population loss or villages that need to be relocated due to major project construction. The Opinions on the Coordinated Promotion of Village Planning, issued by the Chinese government, required that each county combine the preparation and implementation of Strategic Planning for Rural Revitalization; study population changes, location conditions, and development trends on a village-by-village basis; and clarify village classification in each county. Village classification helps the government to understand the direction of rural development and the priority of various tasks. Moreover, classification is helpful for the overall allocation of numerous resources and quickly dealing with shortcomings in rural development. The classification of rural types at the national level also provides basic guidance for the formulation of relevant policies in each pro-

vincial region.

According to the requirements of national policies and actual circumstances, Jilin Province in Northeast China made successful efforts regarding village classification. Taking administrative villages as the basic unit and considering their current conditions and development potential, they were classified into six types: AP, SIn, CP, RM, stable improvement (SIm), and prospering frontier and enriching people (PE) villages. The classification criteria of each type are shown in Table 1. To ensure the accuracy of village classification, the villages were categorized in the following order: first, CP and SIn are determined with relatively clear classification criteria. Second, AP, RM, and PE are fully demonstrated and coordinated. Finally, villages with no obvious characteristics are deemed to be SIm. Different village types have different requirements for layout. CP focuses on effective protections based on maintaining the status quo. SIn attaches importance to connections with neighboring towns. AP centers on propelling and supporting surrounding villages. PE is located within 3 km of the border. Villagers' wishes and demonstration of the relocation and merger in RM are emphasized. SIm is classified without layout requirements. Drawing on the complete village classification, it is crucial to investi-

gate the geographic differentiation patterns and development paths of different village types for rural development.

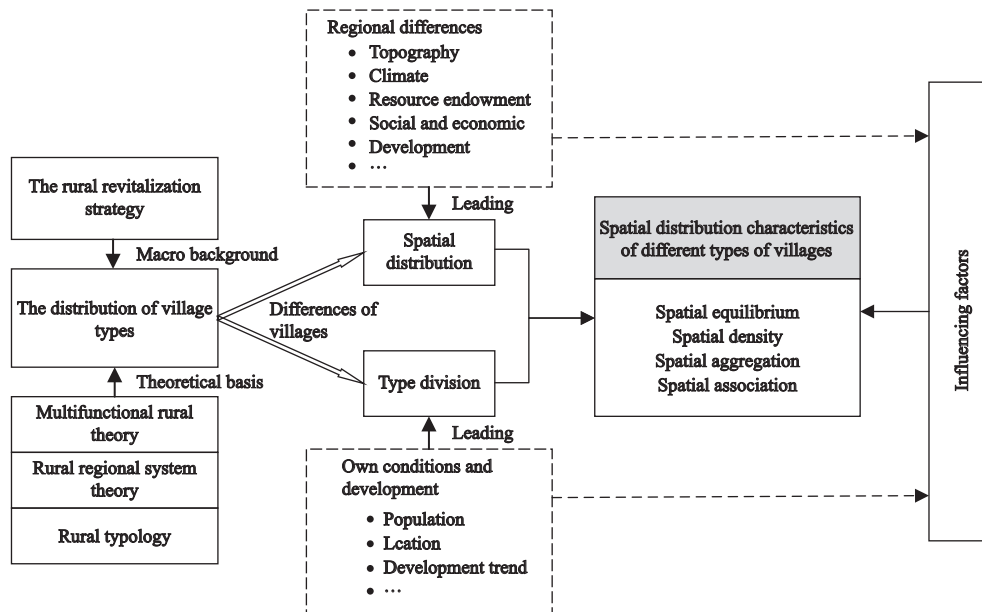
## 2.2 Analytical framework of village type distribution

Rural classification development, proposed by China's RR strategy, provides a macro background for the study of village type distribution (Fig. 1). Rural typology, rural regional system theory, and multifunctional rural theory provide guidance for villages' classification and distribution (van Eupen et al., 2012; Beyazli et al., 2017). Rural typology advocates for the classified development of rural areas and assumes that rural land can be divided into fairly homogeneous multiple units; the identification of these units helps to understand the features of the countryside and to formulate management policies. According to rural territorial system theory, the rural territorial system is a spatial system with a certain structure, function, and inter-regional connection that is formed through the interaction of the population, the economy, the resources, and the environment; it has a hierarchy, regionality, and dynamics (Liu, 2020). Rural territorial system theory can guide hierarchical and structural positioning, as well as the perception of regional differences in different village types. Multifunc-

**Table 1** Classification basis and spatial layout requirements of villages in Jilin Province, China

| Village type | Classification criteria                                                                                                                                                                                                                                                                      | Spatial layout requirement                                                                                                                                                                                                                          |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CP           | Historical and cultural villages; traditional villages; characteristic minority villages; characteristic tourism villages; villages rich in characteristic resources (e.g., intangible culture); villages with potential historical, cultural, and characteristic landscape protection value | Based on the present situation of nature and humanity, the integrity of conventional village patterns, the authenticity of traditional buildings, and the continuity of industrial development and residents' lifestyles are effectively protected  |
| SIn          | Villages outside the built-up areas of counties and towns and within the boundaries of urban development; villages closely related to the above villages in terms of space, industry, and infrastructure                                                                                     | Combined with the demarcation of urban development boundaries, village sites are determined in terms of industrial association with neighboring towns, the co-construction and sharing of infrastructure and public facilities, and urban functions |
| AP           | Villages where township governments are located; the central village is determined by superior planning; villages with great industrial agglomeration; villages with strong comprehensive service ability                                                                                    | Such villages need to highlight the leading role of rural industrial growth and the supporting role of basic public services                                                                                                                        |
| PE           | Villages near the national border with the functions of stabilizing the frontier, helping the frontier to prosper and enriching people                                                                                                                                                       | Villages within 3 km of the border should be classified as this type of village                                                                                                                                                                     |
| RM           | Villages with poor living conditions; villages with a fragile ecological environment; villages with frequent natural disasters; villages with serious population loss; villages that need to be occupied for ecological environment protection and major project construction                | Such villages need to focus on identifying villagers' wishes, demonstrating relocations and mergers, and formulating relocation and resettlement plans                                                                                              |
| SIm          | Villages with a small population and weak industrial growth but that are relatively stable; they will be preserved for a long time                                                                                                                                                           | Classification only; no layout requirements                                                                                                                                                                                                         |

Notes: CP, characteristic protection villages; SIn, suburban integration villages; AP, agglomerative promotion villages; PE, prospering frontier and enriching people villages; RM, removal and merger villages; SIm, stable improvement villages



**Fig. 1** Analytical framework of the distribution of village types

tional rural theory points out that rural areas have distinctive spatial heterogeneity and temporal variability; the expansion of urbanization has transformed rural areas such that they no longer have single functions of agricultural production, but rather multiple functions such as industry, leisure services, and commodity retailing (Wilson, 2008; Renting et al., 2009; Long et al., 2022). The emergence of rural multifunctionality lays the foundation for function-oriented village typology. The distribution of village types reflects differences from two perspectives: 1) type division and 2) spatial distribution. The differences in type classification are reflected in villages' functions, which are determined by their conditions and development. Population, location, and the development trend are the main influencing factors of village type classification. Spatial differences are revealed in the regional space, which is determined by regional differences. Topography, climate, resource endowment, and social and economic growth are the leading factors causing spatial distribution differences. The combination of village type division and spatial distribution can facilitate exploration of the spatial differentiation patterns of different village types. This is demonstrated in the dimensions of spatial equilibrium, density, aggregation, and association. The factors influencing village type division and spatial distribution also affect the spatial distribution of different village types, and relevant influencing factors can be used to investigate the mechanism of spatial differentiation in different

village types.

### 3 Materials and Methods

#### 3.1 Study area

Jilin Province, located in the central part of Northeast China (Fig. 2) with an area of 191 200 km<sup>2</sup>, has jurisdiction in over 60 counties, 951 townships, and 9327 administrative villages (Jilin Provincial Bureau of Statistics, 2021). Jilin Province is near the sea and borders the Russian Federation and the Democratic People's Republic of Korea, with a total border length of 1438.7 km. Jilin Province is a large agricultural province, which is vital for the maintenance of national food security and the realization of agricultural modernization. Jilin Province is rich in black soil resources that are conducive to the growth of crops. The arable land area is  $7.03 \times 10^6$  ha, accounting for 37% of total land area in the province and ranking fifth in China. The grain output of the entire province is  $38.03 \times 10^6$  t, comprising 5.68% of China's total grain output, with the nation's leading grain commodity rate and per capita grain possession. In 2020, there were  $8.99 \times 10^6$  rural residents, making up 37.36% of the broader population. Compared to 2010, the rural population declined by  $3.81 \times 10^6$ , and rural population loss was serious. The proportion of primary industry output value accounted for 12.6% of regional gross domestic product (GDP), and the rural economy is depressed (Jilin Provincial Bureau of Stat-

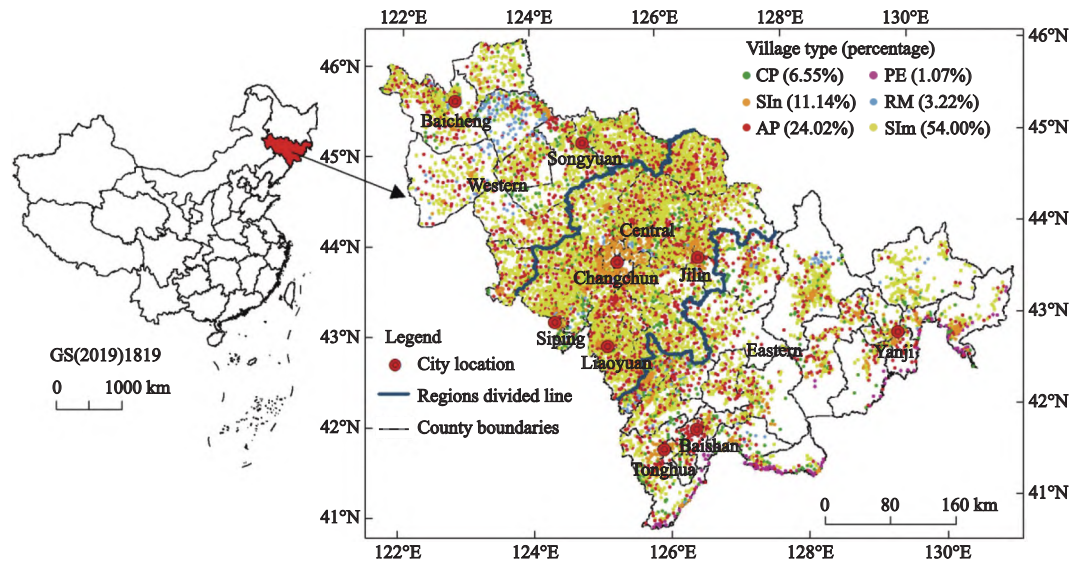


Fig. 2 Location of Jilin Province and the spatial distribution of different village types. The abbreviations are the same as in Table 1

istics, 2021). In general, Jilin Province has a prominent agricultural status but also some serious typical rural problems.

There are distinctive regional differentiation rules from the east to west in Jilin Province. The eastern region belongs to the Changbai Mountains, an important ecological barrier for China. The central region belongs to the Songliao Plain, with flat terrain and fertile soil. The western region belongs to the farming-pastoral ecotone, with a relatively fragile ecological environment and low arable land productivity (Li et al., 2021a). The GDP in 2020 of the eastern, central, and western regions accounts for 17.76%, 71.19%, and 11.05%, respectively. The population of the eastern, central, and western regions accounts for 23.80%, 56.87%, and 19.33%, respectively, and the transportation lines in the eastern, central, and western regions account for 23.50%, 51.97%, and 24.53%, respectively (Jilin Provincial Bureau of Statistics, 2021). Thus, there is strong heterogeneity in rural development in Jilin Province, which is more pertinent for recognizing the complexity and differences of village classification and distribution.

### 3.2 Data sources and processing

The administrative village classification data of Jilin Province were obtained from the Department of Natural Resources of Jilin Province (<http://zrzy.jl.gov.cn/>), whereas the geospatial locations of administrative villages were obtained using the Baidu Map. After deleting a small number of villages without coordinate informa-

tion, 9250 villages were identified. The village data were imported into ArcGIS10.4 software for Universal Transverse Mercator Projection of the coordinate system. Elevation data were derived from the Geospatial Data Cloud (<http://www.gscloud.cn>). Raster data on temperature, precipitation, land use, soil type, and GDP were provided by the Data Center for Resource and Environmental Sciences of the Chinese Academy of Sciences (<http://www.resdc.cn>). River and road data were procured from the 1 : 250 000 national basic geographic database in the National Catalogue Service for Geographic Information (<https://www.webmap.cn>). Road data include national, provincial, county, township, and rural roads, as well as streets. The data on population and industrial enterprises were obtained from the China County Statistical Yearbook (Township Volume) in 2021 (<https://data.cnki.net/>). The data of point of interest (POI) were obtained from the Amap. The list of Scenery Sites above National A-class was obtained from the Department of Culture and Tourism of Jilin Province (<http://whhlyt.jl.gov.cn>). Their spatial coordinates were derived using the Baidu Map and corrected and projected using ArcGIS10.4 software.

### 3.3 Methodology

#### 3.3.1 Geographic concentration index

The geographic concentration index (GCI) is a measure of the degree of concentration of the study object in a specific geographic space. This study used GCI to measure the equilibrium of the distribution of each type of

village at different spatial scales. The specific calculation process is detailed in the reference (Xie et al., 2018).

### 3.3.2 Kernel density estimation

Kernel density estimation (KDE) is a spatial density analysis method rooted in the data-intensity function clustering algorithm, which reveals the spatial density features and distribution trends of the study object (Fang et al., 2017). The study used this method to analyze the regional variability in the distribution of kernel density across all village types.

### 3.3.3 Nearest neighbor index

The nearest neighbor index (NNI) is used to determine the global spatial distribution pattern of point elements by comparing the degree of deviation from the random distribution (Clark and Evans, 1954; Li and Song, 2020). NNI is larger than, equal to, or less than 1, which corresponds to uniform, random, and clustered distribution, respectively. NNI is calculated as follows:

$$NNI = \frac{\overline{D_O}}{\overline{D_E}} = \frac{\sum_i^n d_i/n}{0.5 \sqrt{A/n}} \quad (1)$$

where  $\overline{D_O}$  is the observed average distance,  $\overline{D_E}$  is the expected distance,  $d_i$  is the distance between a village  $i$  and the nearest neighboring village;  $n$  is the number of villages, and  $A$  is the area of the study region.

### 3.3.4 Ripley's $K$ function

The spatial distribution of point elements may be different depending on the observation distance. Ripley's  $K$  function was used to explore the features of the global spatial distribution of point elements at different observation distances (Miron et al., 2021); it is formulated as:

$$K(d) = A \sum_i^n \sum_j^n \frac{w_{ij}(d)}{n^2} \quad (i, j = 1, 2, 3, \dots, n; i \neq j) \quad (2)$$

where  $A$  is the zone of the study area,  $n$  is the number of villages,  $d$  is the distance threshold, and  $w_{ij}(d)$  is the number of village  $j$  within distance  $d$  from village  $i$ . To maintain stable variance,  $L(d)$  was applied to facilitate the graphic interpretation of  $K(d)$ . The formula is:

$$L(d) = \sqrt{\frac{K(d)}{\pi}} - d \quad (3)$$

Under the assumption of random distribution, the expected value of  $L(d)$  is 0. When  $L(d) > 0$ , it means that villages are clustered; when  $L(d) < 0$ , it means that villages are dispersed.

### 3.3.5 Co-location quotient

The co-location quotient (CLQ) is primarily used to measure the spatial association between different types of point elements (Leslie and Kronenfeld, 2011; Cromley et al., 2014). In this study, CLQ was employed to gauge the association characteristics of spatial distribution among different villages types. The calculation formula is as follows:

$$CLQ_{A \rightarrow B} = \frac{C_{A \rightarrow B}/N_A}{N_B/(N-1)} \quad (4)$$

where  $CLQ_{A \rightarrow B}$  is the co-location quotient of  $A$  attracted by  $B$ ,  $C_{A \rightarrow B}$  is the number of  $A$  villages in the neighborhood of  $B$  villages at a certain distance threshold;  $N_A$  and  $N_B$  are the number of  $A$  and  $B$  villages, respectively;  $N$  is the total number of  $A$  and  $B$  villages.  $CLQ_{A \rightarrow B} < 1$ ,  $A$  tends to move away from  $B$ ;  $CLQ_{A \rightarrow B} = 1$ , both  $A$  and  $B$  are randomly distributed;  $CLQ_{A \rightarrow B} > 1$ ,  $A$  tends to move closer to  $B$ .

### 3.3.6 Geodetector

The Geodetector is a statistical method for detecting the spatial heterogeneity of geographic elements and the driving factors behind them. Geodetector quantitatively gauges the importance of explanatory variables relative to the response variables by analyzing the overall heterogeneity among the geospatial zones of each type (Wang et al., 2016). In this study, the factor detector of Geodetector was used to analyze the influencing factors of village distribution, which can be accomplished by the  $q$ -statistic. This method is mathematically represented as follows:

$$q = 1 - \frac{1}{N\sigma^2} \sum_{h=1}^L N_h \sigma_h^2 \quad (5)$$

where  $q$  is the explanatory power of the factors influencing village distribution,  $N$  and  $N_h$  are the numbers of units in the entire region and sub-region, respectively;  $L$  is the number of sub-regions; and  $\sigma^2$  and  $\sigma_h^2$  represent the variance of village density in the whole region and sub-region, respectively. The value of  $q$  is strictly within  $[0, 1]$ . If  $q = 0$ , it indicates no spatial heterogeneity in the spatial distribution of villages. If  $q = 1$ , it implies the strongest spatial heterogeneity in the distribution of villages.

The interaction detector of Geodetector can identify interactions between different factors and assess whether factor interactions increase or decrease the explanatory power of the response variable. The strength and

type of interaction are detailed in the References section (Wang and Xu, 2017).

The formation and distribution of villages are influenced by a combination of natural and human factors (Yang et al., 2016). This study took townships as the study unit. The density of all villages or certain village types within the township, as the response variable, was detected to characterize the spatial distribution of villages. Following the principles of data accessibility and factor detection accuracy, referring to existing research (Yang et al., 2016; Zhou et al., 2020), and considering the differences in the spatial distribution of different village types, 15 indicators were selected from the natural environment, resource endowment, location and transport, and socioeconomic status as the influencing factors of village distribution (Table 2). As for the natural environment, topography and climate factors play a key role in the distribution of villages by affecting the rural land use pattern and the growth of crops. In terms of resource endowment, the quantity and quality of arable land and the conditions of water resources determine the rural production capacity, which is the most essential material basis for rural economic growth and indirectly affects the distribution pattern of villages. In terms of location and transport, the distance to the county town and traffic conditions represent the convenience of village development and external contact, and superior loc-

ation and traffic is conducive to village gathering. As for socioeconomic status, the agglomeration of population, industrial enterprises and the increase of GDP cause the formation and expansion of villages; scenic spots reflect the level of regional cultural heritage and the amount of tourism resources.

## 4 Results

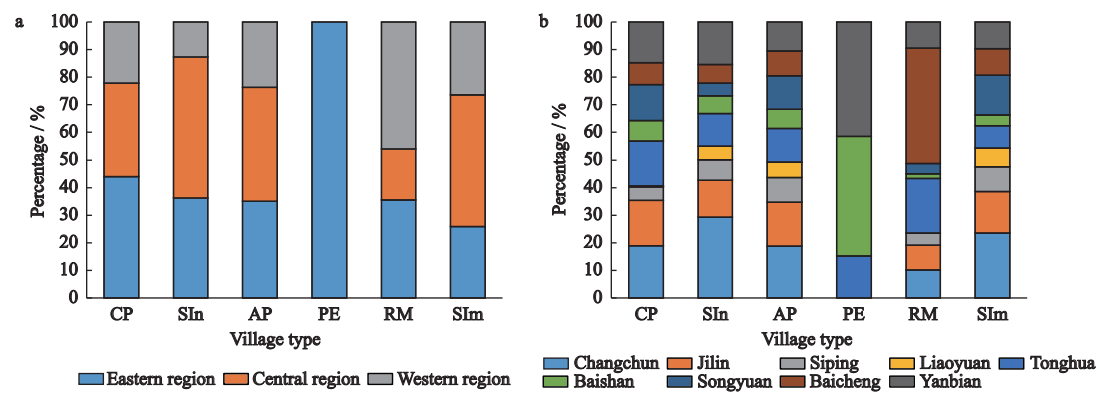
### 4.1 Distribution characteristics of different village types

#### 4.1.1 Spatial equilibrium

The number and proportion of different village types in Jilin Province of China are uneven in terms of spatial distribution, and there are differences in scale. According to the scale of different regions in the province (Fig. 3a), SIn, AP, and SIm are the most numerous in the central region, followed by the western and eastern regions. The number of CP is highest in the east, followed by the central and western regions. There are the most RM in the western region and the least in the center. PE are all concentrated in the east. According to the prefecture scale (Fig. 3b), the proportion of several village types in Changchun, Jilin, Yanbian, and Songyuan is fairly large, whereas the proportion in Liaoyuan and Baishan is relatively small; this is directly related to the area of the city. RM have a highly significant presence

**Table 2** Influencing factors of village distribution and description

| Type                   | Influencing factor                        | Code | Description                                         |
|------------------------|-------------------------------------------|------|-----------------------------------------------------|
| Natural environment    | Elevation                                 | X1   | Average value of elevation                          |
|                        | Slope                                     | X2   | Average value of the slope                          |
|                        | Terrain undulation                        | X3   | Difference between the highest and lowest elevation |
|                        | Precipitation                             | X4   | Average value of annual precipitation               |
|                        | Temperature                               | X5   | Average value of annual mean temperature            |
| Resource endowment     | Percentage of arable land                 | X6   | Arable land area/total area                         |
|                        | Soil type                                 | X7   | Data from soil genetic classification system        |
|                        | River network density                     | X8   | River length/total area                             |
| Location and transport | Distance to the county town               | X9   | Distance to the nearest county town                 |
|                        | Road network density                      | X10  | Road length/total area                              |
| Socioeconomic status   | Population density                        | X11  | Registered population/total area                    |
|                        | Gross domestic product (GDP)              | X12  | Average value of GDP raster data                    |
|                        | Density of industrial enterprises         | X13  | Number of industrial enterprises/total area         |
|                        | Distance to national A-level scenic spots | X14  | Average distance to national A-level scenic spots   |
|                        | Density of scenic spots                   | X15  | Number of scenic spots /total area                  |



**Fig. 3** Distribution differences of different village types among regions (a) and prefectures (b) in Jilin Province, China. The abbreviations are the same as in Table 1

in Baicheng; PE are concentrated only in Tonghua, Baishan, and Yanbian. The central part of Jilin Province has flat terrain, rich arable land resources, and concentrated cities and towns, which mostly include SIn, AP, and SIm. However, the ecological environment in the west is fragile, there are many mountainous areas in the east, and the traffic is inconvenient, so there is a large number of PE.

GCI of different village types at different scales is greater than the uniform distribution reference values (UDRV). The distribution of villages is somewhat concentrated, but there are scale-related differences in concentration (Table 3). RM, AP, CP, and SIm have the largest differences in GCI from UDRV at the county scale, with the most significant concentration. SIn have the largest difference in GCI from UDRV at the prefectural scale, with the best concentration. On the regional scale, the difference between the GCI and the UDRV of PE is the largest, indicating that PE are mostly concentrated on this scale and in the eastern part of Jilin Province.

**4.1.2 Spatial density**

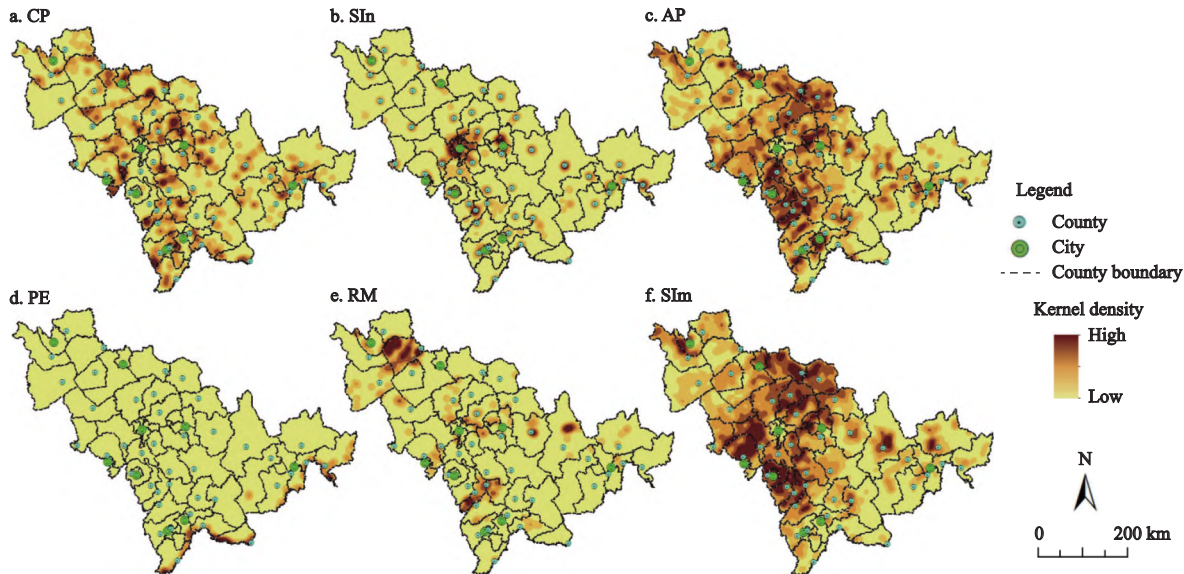
The distribution of kernel density of different village types in Jilin Province of China has significant regional variability (Fig. 4). The average density of CP is 32.34/10 000 km<sup>2</sup>, and density centers are more dispersed

and located at county boundaries. Most villages are historical heritage villages, far from the center of town. The average density of SIn is 54.96/10 000 km<sup>2</sup> in Jilin Province, with higher densities of SIn around the urban parts of prefecture-level cities. A high-density center is located around the city of Changchun and a sub-density center around the city of Jilin. Because such villages are required to be within the city’s urban development boundaries, the nuclear density centers are distributed around the built-up parts of cities. The average density of AP is 118.57/10 000 km<sup>2</sup> in Jilin Province, with the density center concentrated in the central zone of Jilin Province and close to the cities and towns where the natural environment, industrial development, and infrastructure construction are perfect. The average density of PE is 5.28/10 000 km<sup>2</sup> in Jilin Province, and the center of density is located at the southeastern border of the province, close to the border. The average density of RM is 15.90/10 000 km<sup>2</sup> in Jilin Province, and distinct density centers are in ecologically fragile, regionally inaccessible, and severely depopulated areas. The density of SIm is the largest at 266.54/10 000 km<sup>2</sup>. The density centers are concentrated in the central region of Jilin Province and are primarily located in the middle of the county or township. These villages tend to be flatter and

**Table 3** The geographic concentration index (GCI) of different village types at different scales in Jilin Province, China

| Scales     | CP    | SIn   | AP    | PE     | RM    | SIm   | UDRV  |
|------------|-------|-------|-------|--------|-------|-------|-------|
| Region     | 59.79 | 63.94 | 59.09 | 100.00 | 60.99 | 60.34 | 57.74 |
| Prefecture | 37.71 | 40.02 | 35.38 | 61.90  | 49.59 | 37.12 | 33.33 |
| County     | 17.75 | 15.39 | 16.18 | 41.78  | 37.44 | 17.12 | 12.91 |
| Township   | 7.61  | 10.53 | 5.05  | 21.74  | 14.65 | 5.08  | 4.07  |

Notes: UDRV is the uniform distribution reference values, and other abbreviations are the same as in Table 1



**Fig. 4** The distribution of kernel density of different village types in Jilin Province, China. The abbreviation means the same as in Table 1

have a better natural environment and resource endowment.

#### 4.1.3 Spatial aggregation

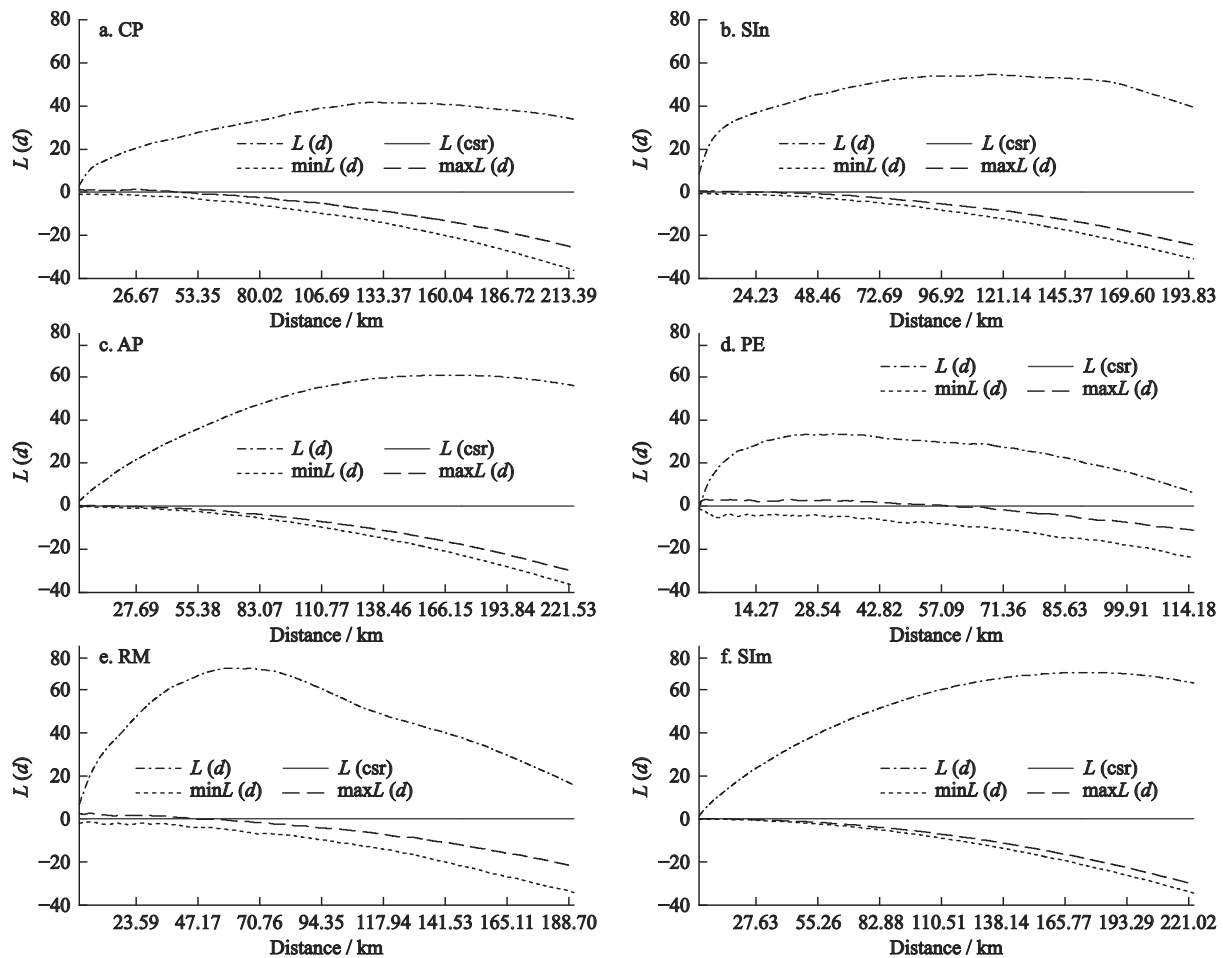
According to nearest neighbor analysis, the expected distance of all village types in Jilin Province of China is larger than the observed distance, and all NNI are less than 1. All village types are clustered with 99% confidence (Table 4). The NNI of SIn, RM, PE, CP, AP, and SIm become smaller in turn, indicating that the degree of spatial agglomeration decreases. SIn and PE are concentrated in the urban periphery and border areas, respectively, and RM are easily concentrated and contiguous due to the influence of the natural regional environment. These three village types have stronger geographic features and higher spatial clustering. SIm, AP, and CP have weak geographic distinctiveness and are somewhat evenly distributed in each region. These three types are clustered but with a low degree of agglomeration.

Although all village types are clustered, there are differences in the range and intensity of clustering (Fig. 5). Overall, the  $L(d)$  curves of all village types are above the  $L(csr)$  curves, indicating that all village types are clustered with 99% confidence. The  $L(d)$  curves of all village types show ‘single peak’ characteristics. From the distance of peak occurrence, SIm (174.13 km) > AP (163.34 km) > CP (127.16 km) > SIn (117.46 km) > RM (60.99 km) > PE (32.29 km). The difference in their clustered range is obvious. A clustered range of SIm is the largest and the clustered range of PE is the smallest. From the maximum value of the  $L(d)$  index, RM (69.96) > SIm (67.92) > AP (60.82) > SIn (54.57) > CP (41.71) > PE (33.45). The difference in their clustered intensity is also apparent. The clustered intensity of RM is the largest and the clustered intensity of PE is the smallest. There are numerous SIm and AP covering a large area, and their clustered range and intensity are at

**Table 4** Results of average nearest neighbor analysis of different village types in Jilin Province, China

| Village type | Observed distance / km | Expected distance / m | NNI  | Z-score | P-value | Distributed pattern |
|--------------|------------------------|-----------------------|------|---------|---------|---------------------|
| CP           | 7.02                   | 11.77                 | 0.60 | -19.02  | 0.00    | Clustered           |
| SIn          | 2.19                   | 8.00                  | 0.27 | -44.59  | 0.00    | Clustered           |
| AP           | 4.07                   | 6.44                  | 0.63 | -33.12  | 0.00    | Clustered           |
| PE           | 4.77                   | 11.34                 | 0.42 | -11.02  | 0.00    | Clustered           |
| RM           | 6.02                   | 14.95                 | 0.40 | -19.72  | 0.00    | Clustered           |
| SIm          | 2.93                   | 4.28                  | 0.68 | -42.69  | 0.00    | Clustered           |

Notes: NNI is the nearest neighbor index, and other abbreviation means the same as in Table 1



**Fig. 5** Ripley's  $L(d)$  index for different types of villages in Jilin Province, China.  $L(csr)$  means random distribution; the abbreviations are the same as in Table 1

a high level. Due to the geographic environment and policies such as Relocation to Alleviate Poverty, RM are more concentrated and have the greatest clustered intensity; however, the number of villages of this kind is small and its clustered range is small. PE are mainly concentrated in border zones, with the least number among the six village types. Thus, their clustered range and intensity are at the lowest level.

#### 4.1.4 Spatial association

By measuring the CLQ of the two types of villages, whether a certain type of village is attractive or dependent on other villages was evaluated (Table 5). The CLQ of villages of the same type is significantly greater than 1, indicating that villages of the same type have a close spatial association. In particular, the autologous spatial association of PE and RM is prominent. From the association between different types of villages,  $CLQ_{AP \rightarrow SIm}$ ,  $CLQ_{SIm \rightarrow AP}$ ,  $CLQ_{PE \rightarrow CP}$ , and  $CLQ_{CP \rightarrow PE}$  are 1.047,

1.099, 1.675, and 1.516, respectively, which are all greater than 1, suggesting a better spatial association between AP and SIm and between PE and CP. The reason is that the strong development momentum of AP can drive the expansion of surrounding SIm. There are many distinctive ethnic minority cultural villages in the border area, which makes the spatial association between CP and PE strong. There is no significant spatial proximity between RM and CP or between PE and SIn. Because these two pairs of villages differ greatly in their own conditions, development characteristics, and trends, it is not easy to be adjacent in space. Except for the above villages, the CLQ between two villages of the remaining types is less than 1. This means that they are not spatially related to each other. Notably,  $CLQ_{AP \rightarrow SIm} > CLQ_{SIm \rightarrow AP}$ ,  $CLQ_{CP \rightarrow SIn} > CLQ_{SIn \rightarrow CP}$ , and  $CLQ_{SIm \rightarrow SIn} > CLQ_{SIn \rightarrow SIm}$ , implying that the attractiveness of SIm to AP, CP, and SIm is greater than that of AP, CP, and

**Table 5** Analytical results of co-location quotient (CLQ) for different types of villages in Jilin Province, China

| CLQ | CP      | SIn     | AP      | PE       | RM       | SIm     |
|-----|---------|---------|---------|----------|----------|---------|
| CP  | 3.008** | 0.513** | 0.973   | 1.675**  | 1.084    | 0.850** |
| SIn | 0.379** | 6.503** | 0.386** | 0.474**  | 0.639**  | 0.252** |
| AP  | 0.912** | 0.535** | 1.166** | 0.805**  | 0.827**  | 1.047** |
| PE  | 1.516** | 0.821   | 0.864*  | 42.704** | 0.120**  | 0.285** |
| RM  | 1.114   | 0.629** | 0.841** | 0.121**  | 10.913** | 0.564** |
| SIm | 0.778** | 0.341** | 1.099** | 0.232**  | 0.600**  | 1.158** |

Notes: \*\*  $P < 0.01$ , \*  $P < 0.05$ . Abbreviations are the same as in Table 1

SIm to SIn. The role of SIn is critical in driving village development.

## 4.2 Influencing factors of distribution of different village types

### 4.2.1 Analysis of influencing factors

According to the results of the Geodetector, different factors have distinct influences on the distribution of all the villages and different types of villages (Table 6). Importantly, the number of PE is small and the spatial heterogeneity of PE distribution is not obvious; thus, the detection of impact factors of PE was not carried out. For all villages, multiple influencing factors have significant effects on their distribution, among which population density, percentage of arable land, and GDP have stronger explanatory power. The development of villages in Jilin Province of China is mainly based on planting, and population and arable land provide the manpower and space for planting. Population density and industrial enterprise density have the strongest explanatory power for AP, and arable land resources are an important factor influencing their distribution. In the SIn, the explanatory power of factors of socioeconomic status and location-transport is significantly stronger than that of the natural environment and resource en-

dowment, and population density, road network density, and industrial enterprise density have a strong influence on the distribution of SIn. The concentration of the population is the chief reason for the large scale of AP and SIn, and industrial companies drive the development of the village economy. The distribution of CP is scattered, with poor spatial heterogeneity. Thus, the explanatory power of influencing factors of CP distribution is generally weak. The population density and percentage of arable land have relatively strong explanatory power for CP distribution, but the density of scenic spots POI has no significant explanatory power related to it. CP and tourism resources are not well matched. The density of scenic spots POI, soil types, and GDP have strong explanatory power regarding the distribution of RM. Areas with low density of scenic spots and low GDP have a poor development environment, and RM are prone to aggregation. Moreover, the soil types of villages in the western part of Jilin Province are mostly saline-alkali soil, with low organic matter content, which is not conducive to the growth of crops and the survival of villagers. Considering SIm, the population density and proportion of arable land have the strongest explanatory power and play a fundamental, decisive role. The share of SIm is large, and the characteristics of SIm are not

**Table 6**  $q$ -value of factors affecting village distribution in Jilin Province, China

| Village type | X1      | X2      | X3      | X4      | X5      | X6      | X7      | X8      | X9      | X10     | X11     | X12     | X13     | X14     | X15    |
|--------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|--------|
| All          | 0.194** | 0.206** | 0.271** | 0.145** | 0.232** | 0.336** | 0.120** | 0.089** | 0.143** | 0.126** | 0.520** | 0.293** | 0.201** | 0.033** | 0.076  |
| CP           | 0.062*  | 0.121** | 0.082** | 0.043   | 0.100** | 0.137** | 0.116*  | 0.089*  | 0.066*  | 0.068   | 0.155*  | 0.119   | 0.104*  | 0.078*  | 0.140  |
| SIn          | 0.063   | 0.056   | 0.136*  | 0.045   | 0.089   | 0.027   | 0.075   | 0.108*  | 0.243** | 0.413** | 0.442** | 0.230** | 0.383** | 0.228** | 0.175  |
| AP           | 0.103** | 0.076** | 0.099** | 0.069** | 0.096** | 0.131** | 0.054*  | 0.103** | 0.060** | 0.054** | 0.214** | 0.158** | 0.137** | 0.041** | 0.053  |
| RM           | 0.165   | 0.097   | 0.268   | 0.260** | 0.088   | 0.083   | 0.442** | 0.250*  | 0.078   | 0.137   | 0.121   | 0.335*  | 0.321   | 0.047   | 0.568* |
| SIm          | 0.237** | 0.257** | 0.261** | 0.208** | 0.212** | 0.433** | 0.098** | 0.056** | 0.057** | 0.049*  | 0.445** | 0.313** | 0.059   | 0.028   | 0.051  |

Notes: \*\*  $P < 0.01$ , \*  $P < 0.05$ . Abbreviations and variables are the same as in Table 1 and Table 2

distinct; thus, the influencing factors of SIm are similar to those of all the villages.

From the perspective of influencing factors, the terrain undulation and the proportion of arable land have the strongest explanatory power regarding the distribution of SIm. The reason is that the flat topography and abundant arable land resources make it convenient provide convenience for SIm to engage in agricultural production activities. Distance to the county town, road network density, and industrial enterprise density have the strongest explanatory power for the distribution of SIn, which is in line with the current situation where SIn have outstanding advantages in terms of location, transport, and industry. The special geographic location of the suburban area makes this type of village outstanding regarding location, transport and industry, which radiate outward and driven by the city. Population density has a greater impact on the distribution of SIm and AP, and the population is still the decisive factor in the distribution of these two types, which account for the largest share of villages. GDP has the strongest explanatory power of the distribution of RM, which proves the conclusion that the economic growth of RM is underdeveloped due to the harsh ecological environment and limited resource endowment.

#### 4.2.2 Interaction of influencing factors

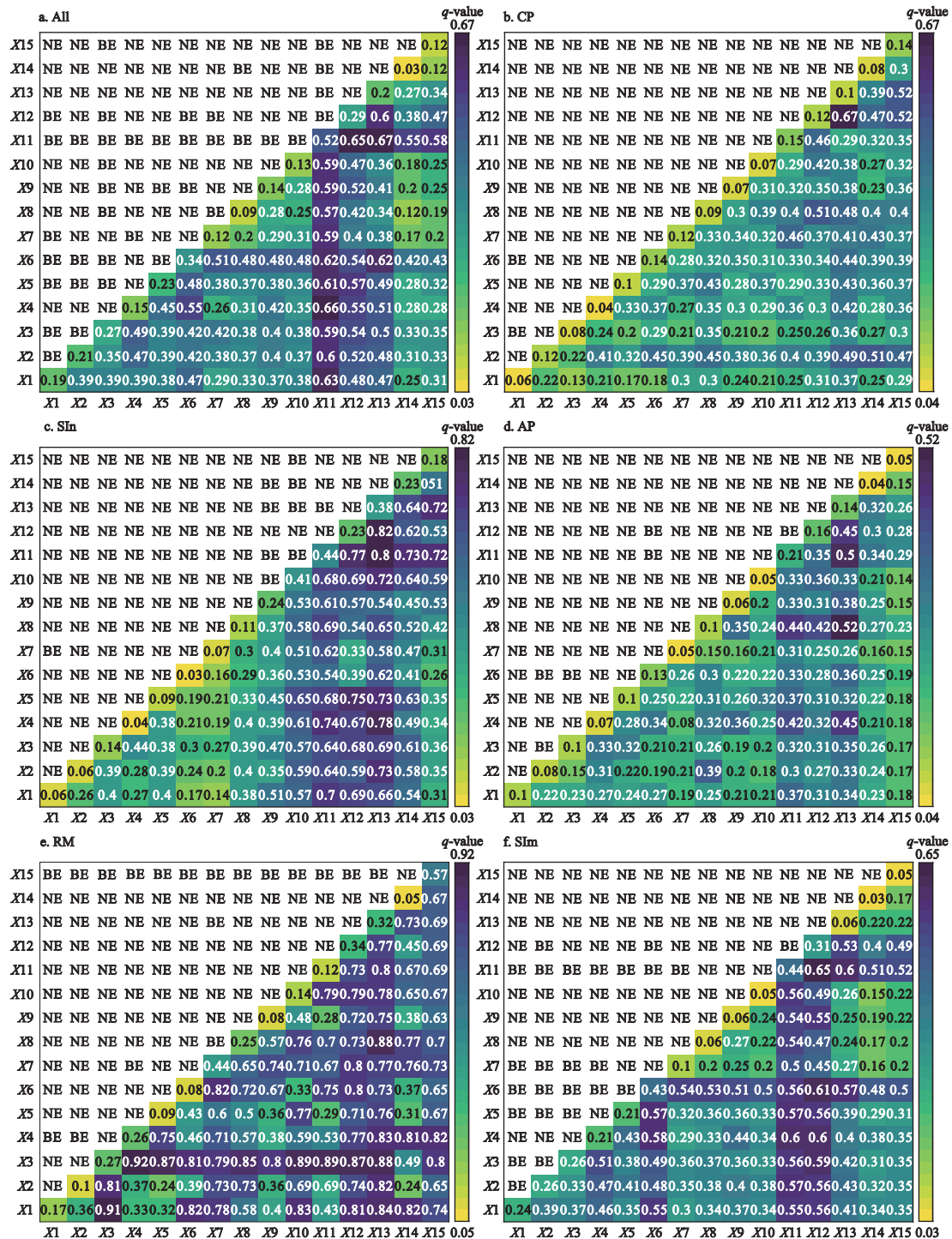
The explanatory power of interactions of different influencing factors is stronger than that of a single action. The interaction types of influencing factors include non-linear and bivariate enhancements, and there are no independent influencing factors (Fig. 6). Each influencing factor has an internal relationship to the spatial differentiation of different village types, but it is not independent. Among all villages, the interactions of the proportion of arable land ( $X_6$ ) and population density ( $X_{11}$ ) with other factors significantly enhance the explanatory power of village distribution, and the interaction types are mostly bivariate enhancements. This further illustrates that population and arable land resources, as the decisive factors of village development, play a very important role in village distribution. Among the CP, only the elevation ( $X_1$ )  $\cap$  slope ( $X_2$ ), and elevated ( $X_1$ )  $\cap$  proportion of arable land ( $X_6$ ) are bivariate enhancements; the rest are non-linear. GDP ( $X_{12}$ )  $\cap$  industrial firm density ( $X_{13}$ ) has the greatest explanatory power (0.67) regarding the distribution of CP. The interaction between socioeconomic factors and other factors is

stronger than the interaction between the natural environment and other factors in SIn, which underscores the vital influence of socioeconomic status on the distribution of SIn. The types of factor interactions in AP are predominantly non-linearly enhanced, and the explanatory power of the interactions is enhanced to a small extent. In the RM, the explanatory power of the interaction between the natural environment and socioeconomic factors with other factors is enhanced, which indicates that the distribution of RM is affected by the complex interactions of various factors. In the SIm, the interaction between the proportion of arable land ( $X_6$ ), population density ( $X_{11}$ ), and GDP ( $X_{12}$ ) with other factors enhances the explanatory power of the distribution of SIm, and the interaction types are mostly bivariate enhancements.

## 5 Discussion

### 5.1 Differences between different village types

Similar to previous studies, this study concluded that the most number of villages is in the central region of Jilin Province of China, followed by the western region, and the least number of villages is in the east (Li et al., 2021a). On this basis, this study focused on the differences in the spatial distribution and influencing factors between different village types, aiming to overcome deficiencies of existing research. The prominent feature of SIn and PE is that they were determined to be distributed near cities or borders when they were classified. However, the SIn have a unidirectional attraction to the AP, CP, and SIm, which proves that suburban villages have a positive impact on the development of surrounding villages (Banski and Mazur, 2016). Location and economic growth are important for the distribution of SIn. Rural transport and other kinds of infrastructure in the suburbs of cities gradually realize urban-rural integration, and the industrial structure is primarily non-agricultural, with high economic benefits (Mantey and Sudra, 2019). CP and RM are scattered and mostly concentrated in areas with poor resource endowments and transport conditions. The distribution features of these two types have high similarity with traditional villages and ex-situ poverty alleviation villages (Zou et al., 2019; Wu et al., 2020). The aggregation intensity of RM is the largest among all types, which is clearly influenced by the geographic environment and the govern-



**Fig. 6** Interactive effects of pairwise factors on village distribution in Jilin Province, China. NE, nonlinear enhancement; BE, bivariate enhancement; other abbreviations are the same as in Table 1

ment's ability to improve rural living conditions (Chen et al., 2021). The influence of population is not significant for RM. The main reason for the relocation of villages in Jilin Province is not serious population loss, but the poor living conditions of villages (Zou et al., 2019). Further, the distribution characteristics of 'scattered on a

large scale and gathered on a small scale' have a positive effect on the governance of RM. The integration of CP and tourism resources needs to be strengthened. The difference between them is that AP is closer to the town than the SIm, reflecting the advantages of the AP in terms of location and transport, as well as its driving

force to surrounding villages (Liu et al., 2021). Arable land and industrial enterprises also have great influence on the distribution of AP. A previous study pointed out that AP could be divided into two types: agricultural production-oriented, and industrial and commercial development-oriented (Galeana-Pizaña et al., 2021; Reisman, 2022). Arable land and industrial enterprises form the basis of agricultural production and industrial growth, respectively, indicating that cultivated land resources and industrial enterprises are critical for the development of AP.

## 5.2 Policy implications of the classified development of villages

The classification of villages is the first step of RR; understanding the results and exploring different development paths will be important in promoting RR through classification and a step-by-step process (Zhou et al., 2021). By determining the regional differences and influencing factors of different village types from a geographic perspective, differentiated measures can be taken to promote village revitalization based on the identification of different development potentials. 1) CP have the characteristics of a remote location, inconvenient transport, and insufficient integration of tourism resources. CP should strengthen road construction, improve public service facilities in combination with traditional features, and enhance the quality of life in villages. For villages with tourism development value, it is necessary to properly develop the tourism industry, make full use of the attraction and driving effect of AP to CP, and strengthen the villages' external connection. 2) SIn have the unique advantages of location, transport, human resources, and a history of economic growth. These villages can develop multi-functional special agriculture by relying on their location advantages, promoting the development of urban-rural integration by speeding up the interconnections of infrastructure, and advancing the free flow of diverse resource elements between urban and rural areas. 3) AP have driving effects on the surrounding villages, and population, economic, and industrial growth are the key factors for their distribution. These villages need to improve infrastructure and public service facilities, play a supporting role in basic public services, and enhance the ability of population gathering. It is necessary to strengthen the development of industries, to play a leading role in rural in-

dustrial development, and to attract the population of surrounding resettlement villages. 4) PE are responsible for stabilizing the border, facilitating prosperity along the border, and enriching the lives of those who cross; they should be supported by the policy of garrisoning the border and guided by industries (such as rural tourism) to boost the development vitality of border villages, drive villagers to work, and start businesses locally. The village living environment and the quality of life among people living along the border should be improved to ensure that they will not become lost. 5) RM are mostly distributed in areas with a harsh natural environment and inconvenient traffic. Before these villages were relocated, the wishes of the villagers should have been fully respected and the resettlement sites should have been selected scientifically. Also, a stable source of income should be ensured for the villagers after relocation. The land, vacated by relocation, needs to be restored through engineering or natural measures. 6) The number of SIm is relatively large, and they are mostly adjacent to AP. Hence, they need to be based on agricultural production activities, strengthen the spatial connection with agglomeration and upgrading villages, and assume the basic function of agricultural production in regional development.

## 5.3 Innovations of the study

This study has several innovations. First, the classified development of villages is key to RR. This study differs from previous studies that only examined the spatial distribution of villages, and analyzes the spatial distribution of villages in the whole area of Jilin Province from the perspective of categories. Second, on the basis of summarizing the spatial differentiation features and influencing factors of the six village types, this study puts forward targeted development suggestions, which are of great significance and practical value to realize RR in Jilin Province. Third, this study focuses on the spatial differences and connections between different village types, and compares the factors influencing the distribution of each village type, which enriches the theory and demonstration of rural classified development. Last, point data and classification information on villages in the entirety of Jilin Province were obtained, and the data were balanced in terms of scale and accuracy. This study focuses on the correlation and comparison of village types when choosing methods. It analyzes the inter-

actions between different influencing factors grounded in the identification of individual factors using Geodetector, which makes the explanation of influencing factors of village distribution more multidimensional.

#### 5.4 Research limitations and prospects

There are still some shortcomings in this study. First, this study determined the distribution characteristics of different village types, more from the macroscopic scale, and the microscopic interpretation of the differences in the internal functions of different village types is insufficient. Furthermore, the temporal evolution pattern of village distribution was not addressed. Second, due to the limitations of data availability, this study focused on the geographic environment and population economic factors when selecting the influencing factors of village distribution. Hence, it did not investigate the factors of village development and rural households. In the future, the analysis of spatial distribution features of different village types can be extended to the study of spatio-temporal evolution patterns, and typical villages can be selected for in-depth investigation and collection of multi-source data of villages and rural households to interpret the influencing mechanism and development mode of village distribution more comprehensively.

## 6 Conclusions

This study constructed a theoretical, analytical framework of multi-type village distribution from the two perspectives of spatial difference and type difference, and quantitatively analyzed the distribution characteristics using spatial analysis methods (e.g., KDE, NNI), spatial aggregations of different village types through CLQ, and the differences of influencing factors of village spatial distribution by using Geodetector. The main conclusions are as follows:

(1) The spatial distribution of different village types in Jilin Province of China is uneven, and the kernel density centers are diversified. SIn, AP, and SIm are concentrated in the central region. The number of CP and RM is small, and their distributions are somewhat scattered. PE are primarily distributed near the border.

(2) All village types in Jilin Province of China show clustered distribution patterns, but there are differences in the range and intensity of clustering among different village types. The agglomeration scale of SIm is the

largest and the agglomeration intensity of RM is the largest.

(3) The spatial association between different village types varies by type. AP and SIm are adjacent to each other in space, and PE and CP are adjacent to each other in space. SIn are more prominent in promoting the development of AP, PC, and SIm.

(4) The factors affecting village distribution include terrain undulation, the percentage of arable land, distance to the county town, road network density, population density, GDP, and industrial enterprise density. There are clear differences in the influencing factors of the spatial distribution of different village types. The explanatory power of the interaction of different factors affecting village distribution is greater than that of the individual effects.

## Conflict of Interest

WANG Shijun is editorial board member of *Chinese Geographical Science*. He was not involved in the journal's review of, or decisions related to, this manuscript. The authors have no other competing interests to disclose.

## Author Contributions

YANG Zhipeng: conceptualization, methodology, formal analysis and investigation, writing-original draft preparation; WANG Shijun: conceptualization, writing-review and editing, funding acquisition, resources, supervision; HAO Feilong: conceptualization, formal analysis and investigation, writing-review and editing, funding acquisition, resources, supervision; MA Li: writing-review and editing; CHANG Xiaodong: methodology; LONG Wang: methodology.

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