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Exploring the Spatial Heterogeneity of Rural Development in Laos Based on Rural Building Spatial Database

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Abstract: The countryside is the principal area of population agglomeration with a high incidence of global poverty problems. As a shelter for the daily life of rural inhabitants, the rural buildings constitute the element of rural settlements. Moreover, they can directly characterize the level of rural development. Therefore, in the new stage of the Sustainable Development Goals (SDGs), this study selected Laos as the main study area and investigated the effect of different factors on the spatial heterogeneity of rural development based on the rural building spatial database. With the geodetector, the results are summarized as follows: (1) The spatial pattern of rural buildings in different regions of Laos varies significantly, with hot spots areas of rural buildings mainly located in the central and southern regions, while cold spots areas are mainly concentrated in the northern region. (2) Slope, transport infrastructure, and public service are the dominant elements influencing the spatial differentiation of rural buildings in Laos, but spatial heterogeneity existed in different regions of factors. (3) The interaction detector shows that slope ∩ road is the dominant interaction factor influencing the spatial distribution pattern of rural buildings nationwide, and there are marked divergences in the interaction factors. Finally, this study combines the findings to propose corresponding countermeasures for promoting the development and construction of rural areas in Laos.

Keywords: rural building; rural development; geodetector; spatial heterogeneity; Laos

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1. Introduction

In 2021, the rural population of the world was 3.43 billion, and rural settlements had been the primary residence of the inhabitants[1]. However, 80% of the extremely poor live in rural areas, and rural development varies significantly in different regions [1]. And the 17 Sustainable Development Goals set out to end poverty and promote rural development as a prime target [2]. The regional development level has been improved since the New Economic Mechanisms reform in Laos [3]. However, considerable disparities exist in the development of different regions, and the development of rural areas lags far behind that of urban areas [4,5]. Government policy support and joining the WTO have promoted rural development and agricultural in Laos [6,7]. Foreign investment has created rural non-farm employment and enhanced the incomes of the rural people [8]. But differences in rural development remain in different regions. Sivongxay et al. found that the livelihoods of local villagers in central Laos had been greatly improved through the construction of infrastructure such as hydropower projects [9]. Rural residents generally build rural buildings to fix assets after acquiring wealth, and on this basis, further create a satisfactory inhabited environment [10]. As the main element of rural settlements, rural buildings assume the function of living shelter and reflect the rural spatial pattern [11,12]. Therefore, it is important to estimate the spatial heterogeneity of rural development from the perspective of rural buildings and identify the driving effect of different considerations on the spatial pattern of rural settlements.

The countryside has been the focus area of scholars worldwide, and the construction of rural settlements is an essential way to promote rural development [13–15]. The spatial pattern of rural settlements is the result of the combined action of multiple elements, and existing literature on the role of different elements and rural settlements has been conducted to analyze the following aspects [16–18]. First, natural factors are the main considerations in selecting the location of the settlements and the main causes of the scale and layout of the settlements [19,20]. Robert [21] adopted natural factors as the main analysis criterion in the systematic classification of factors influencing the choice of village location. Among the natural factors, slope, elevation, and rivers influence rural settlements by the fertility of the land and the level of agricultural development [22]. And the spatial distribution of rural settlements in Guangdong Province, China, had a spatial directionality of low elevation, low slope, along rivers, and towns [23]. And the realm of rural settlements tends to be larger in areas with flat topography and lower elevation, indicating that topography and elevation are the two most influential indicators of natural factors [24]. Furthermore, new buildings have been encouraged in the naturally attractive areas and improved the living conditions of the residents [25]. However, whether the specific effects of these factors are consistent with the overall settlement for rural buildings should be further explored.

Secondly, transport infrastructure exhibited a guidance effect in the spatial disposition of settlements, and accessibility is the main basis for siting rural buildings [26,27]. Cyriac confirmed that rural settlements in low-altitude areas clustered around the city, while those in middle- and high-altitude areas tend to cluster near transportation corridors in Kerala State [28]. The majority of the households living in rural areas need to travel to urban areas for their livelihood activities and are highly dependent on transportation, and rural road construction has an irreplaceable influence on rural development and economic growth [29,30]. Liu et al. [31] explored the distribution situation of rural settlements in mountainous areas and found that the settlements were located within 500 m of the traffic network and were more concentrated when close to the road. The rural settlement pattern distributed along the road breaks the original mode and is also a spatial form of rural adaptation to development in poor mountainous areas [32,33]. In addition, transportation infrastructure not only affects site selection but also has a different effect on settlement size [34,35]. Overall, transportation infrastructure enhances the intensity of connection between rural and urban areas, providing extra opportunities and intervention conditions for rural development [36].

Third, the construction and centralized distribution of public service facilities such as education and health care produce a strong agglomeration effect on rural settlements [37,38]. The development of education and cultural environment in villages affects the quality of rural construction [39]. Rural residents' behavioral activities were greatly transformed by the integrated effect of public service facilities, and the spatial pattern of rural settlements was changed accordingly [40]. Residents living in settlements with better access to public facilities were eudemonic, while those without access to these services faced problems such as relocation [41]. A good educational and medical environment enhances the attractiveness of an area, and urban residents tend to live in areas close to hospitals and schools [42,43]. However, Andre-Bechely [44] found that there is spatial inequality in public service facilities, with low-income households preferring to go to a closer school. For rural residents, social public services such as hospitals and schools also play a significant role in the construction and location of rural buildings.

Finally, as the growth pole of national economic development, cities and special economic zones (SEZs) promoted the development of surrounding villages and the construction of rural settlements [45,46]. Rural areas close to cities and SEZs can have better market potential, and villagers can obtain higher wages in the cities [47,48]. The small peasant economy is the main model that influences their land use pattern and settlement layout [49]. The diffusion effect of cities and SEZs promotes rural economic growth and changes the livelihood patterns of rural residents, thus breaking the shackles of a small peasant economy [50,51]. As people become wealthy, they invest the money in housing improvements [52]. Knight et al. [53] indicated that houses account for nearly 60 percent of rural household assets in China. In addition, with the progress of urbanization, the scale of rural settlements has expanded more significantly in traditional rural areas and hilly areas [54,55]. Overall, the above studies have mainly amplified the positive effects of cities and SEZs on the development of rural settlements, and the effects on the construction and spatial pattern of rural buildings still need to be further explored.

Analyzing the hierarchy of rural development from the perspective of rural buildings not only allows the analysis of spatial differences in the construction of villages but also refines the analysis toward the characteristics of rural settlements [56]. As the only land-based country in Southeast Asia, Laos has a distinctly undulating domestic topography, with highland mountainous and plain areas interspersed, and needs to integrate different elements to consider its rural development level [57]. As one of the world's poorest and most underdeveloped countries, agriculture has been the mainstay of the economy in Laos. In 2021, the population of Laos was 7.43 million, and its GDP was US$18.83 billion, ranking 121st in the world[2]. The agricultural land is about 23,900 square kilometers, mainly concentrated along the rivers and river valley plains. By 2020, approximately 4.63 million people in Laos remained living in the countryside, with about 60% of the labor force engaged in agriculture-related work [58]. With agriculture accounting for only 16.2% of GDP, rural development in Laos has been relatively backward, and promoting rural development is a central part of the government's efforts to eradicate poverty [59]. Therefore, the following three questions arise: (1) What is the influence of different elements on the spatial pattern of rural buildings in Laos? (2) What is the specific role of the interaction of different elements on the spatial distribution of rural buildings in Laos? (3) What are the discrepancies in the roles of different elements in rural development and construction in Laos?

Therefore, this study analyzed the spatial heterogeneity of these elements in rural construction in Laos through a rural building spatial database. Also, this study can analyze the level of rural development in Laos more precisely and analyze the specific effects of different elements on the spatial layout of rural settlements based on the rural building spatial database. In addition, as one of the extremely underdeveloped countries in the world, Laos is chosen as a case area in this study, which can provide scientific reference for rural development in other extremely underdeveloped countries and provide positive suggestions for promoting economic growth in backward areas [60]. The other parts of this study are structured as follows. Section 2 discusses the research data and research methodology. Section 3 focuses on the analysis of the spatial characteristics and the main results of the model for rural buildings in Laos. Section 4 explores the influencing factors and mechanisms of rural development in Laos. The last section presents the conclusions and recommendations.

2. Methodology

2.1. Study Data

The data used in the study mainly consisted of vector and raster data. Among them, data on administrative boundaries, provincial capitals, and special economic zones were obtained from the organization (Open Development Laos)[3]. And spatial analysis data such as road networks, schools, hospitals, and rivers were obtained from the organization (Open Street Map)[4]. In addition, elevation and slope data were obtained from the shuttle radar topography mission (SRTM)[5], while the land use data were from the GlobeLand30 database[6]. The rural building spatial database was based on the satellite image of Google Earth, and the Mask R-CNN building extraction framework was used for interpretation and recognition [61]. The accuracy rate can reach 85%, and the grid size is 1 km. The country is geographically divided into three regions (north, center, and south) and southern regions, comprising 17 provinces, one municipality, and 148 districts (Figure 1). In this study, 5720 villages were selected as the study units.

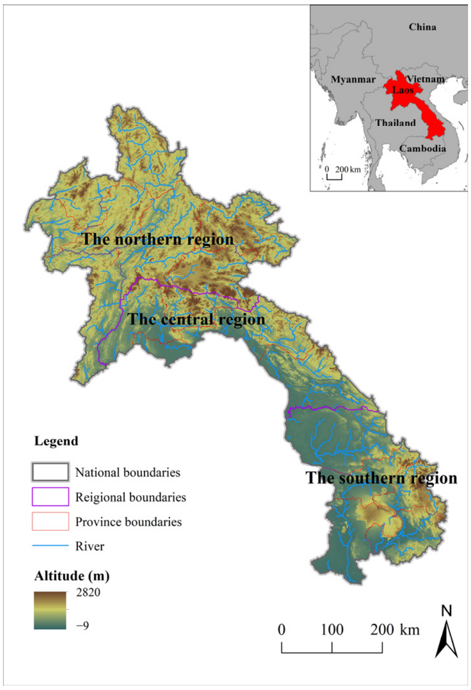

Figure 1. Location map of Laos.

2.2. Variables

This study used the number of rural buildings as the dependent variable to express the rural settlements and the level of rural development. To ensure the accuracy of the rural buildings data, the number of buildings in the grids belonging to villages was extracted as the rural buildings indicator in this study. The independent variables were selected from four aspects, including market access conditions, transport infrastructure, the development of public services, and natural factors. As rural buildings are fixed assets and immovable in spatial locations, the quantitative representation of each element was characterized by using the Euclidean distance (Table 1). Since the economy of Laos has been at a low-level development, the provincial capitals and special economic zones serve as the main markets to affect the surrounding areas. Roads, hospitals, and schools are the main facilities that provide public services to rural residents as well as the main index of the level of infrastructure and transport development. Natural geographic factors are the primary consideration for building houses in rural areas, and the average elevation, slope, and river location in the area of the village were chosen as the main indicators for quantitative analysis in this study.

Table 1. Variable definitions and descriptive statistics.

Variable	Definition	Mean	SD
Market access	Distance to the nearest provincial capital and special economic zone (km)	44.42	28.33
Transport infrastructure	Distance to the nearest road (km)	3.08	4.48
Public services	Distance to the nearest hospital (km)	22.04	15.65
	Distance to the nearest school (km)	20.95	16.38
Natural factors	Distance to the nearest river (km)	1.61	2.09
	Slope (°)	4.16	4.54
	Average altitude (m)	458.06	345.20

2.3. Method

2.3.1. Getis-Ord Gi*

The Getis-Ord Gi* is a standardized index to analyze the location of the space object where the congregative of high-value or low-value factors occurs [62]. The model was mainly used to analyze random events that exhibit some aggregation in space, i.e., cold spots and hot spots. The calculation method focuses on scoring the G_i^* statistics for each factor in the spatial database (z-score). For spatial units, the tighter the aggregation of high values (hot spots), the higher the Z-value, and the tighter the aggregation of low values (cold spots), the lower the Z-value. The formula is as follows:

$$G_i^* = \frac{\sum_{i=1}^{n} W_{ij} X_i - \overline{X} \sum_{i=1}^{n} W_{ij}}{S\sqrt{\frac{\left[n\sum_{i=1}^{n} W_{ij}^2 - \left(\sum_{i=1}^{n} W_{ij}\right)^2\right]}{n-1}}} \tag{1}$$

where $S = \sqrt{\frac{\sum_{i=1}^{n} X_i^2}{n} - \left(\overline{X}\right)^2}$; $\overline{X} = \frac{1}{n}\sum_{i=1}^{n} X_i$; X_i is the attribute value of village i; n is the total number of regions; W_{ij} is the spatial weight matrix, if G_i^* is significantly positive, it indicates that region i is a high-value aggregation area, which belongs to the hot spot area of rural buildings aggregation; if G_i^* is significantly negative, it indicates that region i is a low-value aggregation area, which belongs to the cold spot area of rural buildings aggregation.

2.3.2. Geodetector

Geodetector explores the spatial similarity between the explanatory variables and explained variables and serves as an effective tool for the analysis of spatial differentiation of the influencing factors. It is a new statistical analysis model to be used for the spatial stratified heterogeneity of the study object and its driving factors [63]. It enables measuring the single-factor driving effect as well as revealing the combination of two factors. The factors are classified into identical scales, and then the key factors are derived through the factor detector. The geodetector principle guarantees immunity to multiple independent variable collinearities. The formula is as follows:

$$q = 1 - \frac{1}{N\sigma^2}\sum_{h=1}^{L} N_h \sigma_h^2 = 1 - \frac{SSW}{SST} \tag{2}$$

where $SSW = \sum_{h=1}^{L} N_h \sigma_h^2$, $SST = N\sigma^2$, and q is a measure of the capacity that the driving factor has contributed to the spatial distribution of rural buildings. N is the number of villages. σ^2 is the variance, h is the strata of factors, and L is the number of strata. The value of q belongs to one of the values 0 to 1. The larger the value of q, the stronger the effect of the factor on the spatial properties of the rural buildings.

The interaction detector is able to determine whether two factors acting jointly enhance or diminish the q. The q capacities of the different factors are first calculated separately, followed by the q of the two variables superimposed on each other [64]. And the q comparison is used to determine the type of action. The formulas are as follows:

$$\begin{gathered}
\text{Nonlinear-enhance: } q(X1 \cap X2) > q(X1) + q(X2) \\
\text{Independent: } q(X1 \cap X2) = q(X1) + q(X2) \\
\text{Bi-enhance: } \mathrm{Max}(q(X1),\ q(X2)) < q(X1 \cap X2) \\
\text{Uni-weaken: } \mathrm{Min}(q(X1),\ q(X2)) < q(X1 \cap X2) < \mathrm{Max}(q(X1),\ q(X2)) \\
\text{Nonlinear-weaken: } q(X1 \cap X2) < \mathrm{Min}(q(X1),\ q(X2))
\end{gathered} \tag{3}$$

where $q(X1 \cap X2)$ is the driving force of the interaction between $X1$ and $X2$, Max($q(X1)$, $q(X2)$) is the maximum value between $q(X1)$ and $q(X2)$, and Min($q(X1)$, $q(X2)$) is the minimum value between $q(X1)$ and $q(X2)$.

3. Results

3.1. Results of Rural Buildings

The total number of buildings in Laos was found to be 2.64 million, with significant differences in the spatial pattern by interpretation. First, the grid data revealed that the grids with more buildings were located in the central region and the southern region (Figure 2a). Among them, the maximum of buildings per unit grid area was 2439, located in the capital city. Second, at the district scale, the number of buildings varied significantly, with a maximum value of up to 102,877 and the minimum value of only 609 (Figure 2b). And the data indicated that 55 districts had a number of buildings lower than the national average (17,900), accounting for 51% of the national proportion in Laos. Third, the agglomeration in different districts was obtained from the analysis of the Getis-Ord Gi*, and a map of the spatial distribution of cold and hot spots is shown in the figure. The cold spots areas were mainly located in the northern part of Laos, predominantly in the northern region. The hot spots areas were located in the southwestern part of the central and southern regions, mainly in the areas around the provincial capitals (Figure 2c). In summary, the data obtained from the identification and interpretation of satellite images indicated that significant spatial variation in development levels existed among the districts of Laos, with large disparities between different provinces and regions.

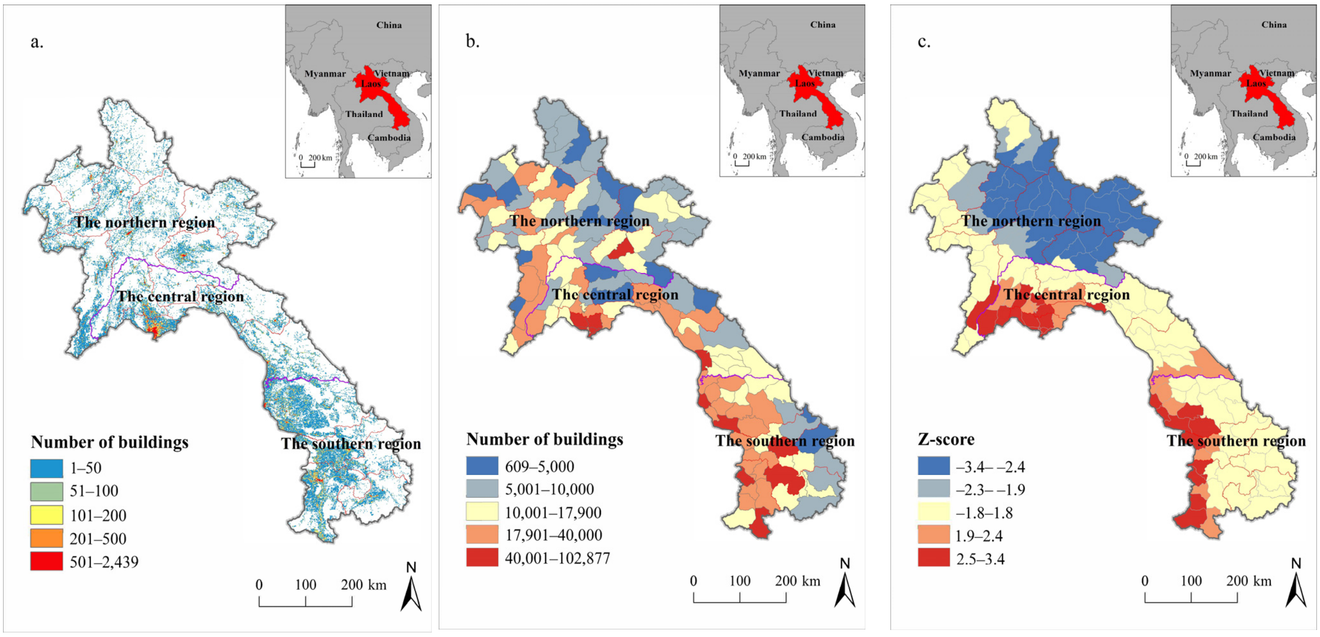

Figure 2. (**a**–**c**) Patterns of buildings in Laos.

Further analysis from the perspective of rural buildings showed that the 5720 villages selected in this study contained a total of 940 thousand rural buildings (Figure 3a). In the center, the aggregation characteristics of villages in the surrounding urban areas were obvious, and the number of rural buildings was comparatively higher. However, the spatial distribution of villages was more scattered in northern and southern regions. In terms of the number of rural buildings, significant disparities were found in the scale of development in different villages, with only 1794 villages exceeding the national average (165), accounting for 31%. And the Getis-Ord Gi* showed similar spatial characteristics to the cold and hot spot map of buildings, with hot spots areas concentrated in the areas around the provincial capitals and the capital city, and cold spots areas located in the highland mountainous areas (Figure 3b). As a result, the distribution of rural buildings in Laos exhibited significant spatial heterogeneity, and the level of rural development varied noticeably among different districts.

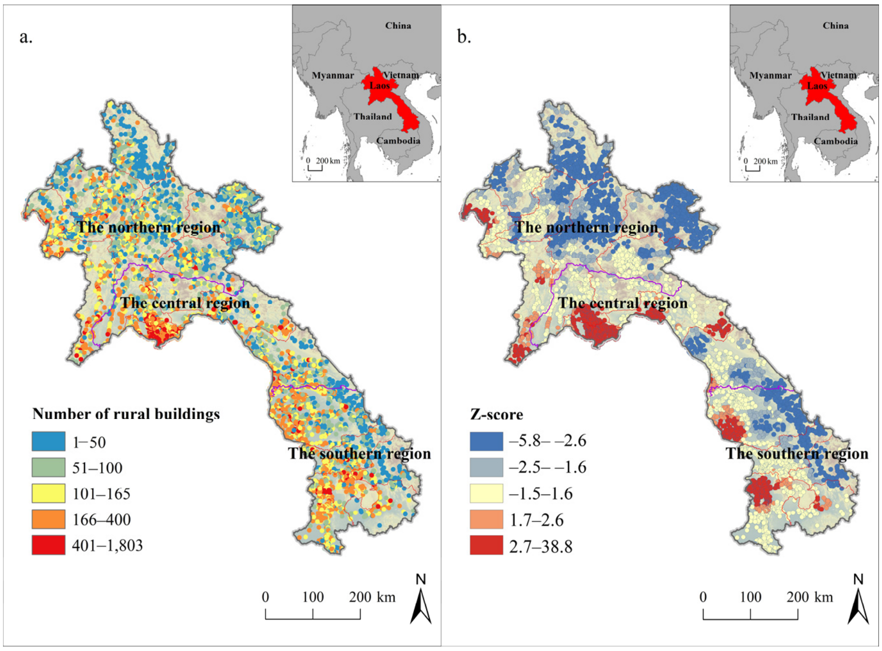

Figure 3. (**a**,**b**) Patterns of rural buildings in Laos.

3.2. Results of the Model

3.2.1. Results of the Factors

By using the geodetector model, this study explored the magnitude of the determinants on the spatial variation of rural buildings in Laos by the factors of average altitude (X1), slope (X2), river (X3), road (X4), hospital (X5), school (X6), provincial capital, and special economic zone (X7). Since the geodetector results were influenced by the variability of geographic units and classification methods in addition to the influence of elements, therefore, three numerical classification methods were used to synthesize the role of different elements in driving the spatial differentiation pattern of rural buildings in Laos [65,66]. As for the grid size selection, the analysis unit in this study was the village, and the grid size of 1 km satisfied the actual village range, while other grid sizes were not consistent with reality, thus no further scale attempts were made. From the results of q-statistic for each factor, the quantile method had higher values of the driving force for each factor, indicating that the model operation was more precise by using this method (Table 2). Specifically, q-statistic for average elevation (X1), slope (X2), and road (X4) were significantly higher than the other factors, with slope (X2) driving the strongest force (0.155). This result indicated that natural factors and transport infrastructure were the dominant factors influencing the spatial pattern of rural buildings in Laos, also the critical conditions influencing the development of rural construction.

Table 2. The q-statistic of factors.

	X1	X2	X3	X4	X5	X6	X7
NBM	0.023 ***	0.033 ***	0.005 ***	0.053 ***	0.008 ***	0.024 ***	0.017 ***
QM	0.118 ***	0.155 ***	0.045 ***	0.124 ***	0.050 ***	0.091 ***	0.078 ***
EIM	0.001 ***	0.009 ***	0.002 ***	0.008 ***	0.001 ***	0.006 ***	0.002 ***

Note: *** significant at the 1% level. NB means natural breakpoint method, QM means quantile method, and EI means equal interval method.

3.2.2. Results of the Driving Factors in Different Regions

This study further explored the partitioning of the three regions in Laos and found that the quantile method remained the most appropriate method for numerical classification operations, and the model results revealed that the effects of each driving factor were significant (Table 3). First, natural factors and transport infrastructure were the major elements affecting the spatial differentiation of rural buildings in the northern and southern regions. This result was consistent with the national-level analysis, whereby average altitude, slope, and road network influenced the spatial heterogeneity of rural development. The slope was the predominant driving factor in the northern region with a driving force of 0.117, while transport was the predominant driving factor in the southern region with a driving force of 0.159. Moreover, contrary to the national and other regional results, public service and market access are the primary elements influencing the layout of rural buildings in the central region. Schools, provincial capitals, and SEZs had been the primary factors influencing the distribution and clustering of rural buildings due to the relatively flat topography of the central region. The *q*-statistic values were much higher than the other factors with the value of 0.199 and 0.195, respectively. Finally, the villages had more rural buildings with gentle terrain, lower altitude, and closer to the transportation road network in the northern and southern regions from Table 3. In the central region, the villages located in areas near schools, provincial capitals, and SEZs had more rural buildings with larger spatial scale. The reason for this is that compared to other regions, SEZs and large cities were mostly located in the central region and had a stronger spread effect on the surrounding villages.

Table 3. The *q*-statistic of factors in different areas.

	North			**Central**			**South**		
	NB	**QU**	**EI**	**NB**	**QU**	**EI**	**NB**	**QU**	**EI**
X1	0.008 ***	0.050 ***	0.001	0.017	0.085 ***	0.005	0.078 ***	0.128 ***	0.015
X2	0.022 ***	0.117 ***	0.002	0.072 **	0.037 ***	0.123	0.065 ***	0.074 ***	0.175 ***
X3	0.008 **	0.048 ***	0.004	0.002	0.017 ***	0.002	0.002	0.022 ***	0.001
X4	0.032 ***	0.097 ***	0.010	0.040 ***	0.087 ***	0.003	0.100 ***	0.159 ***	0.019
X5	0.003	0.049 ***	0.001	0.034 ***	0.110 ***	0.009	0.007	0.030 ***	0.005
X6	0.007 ***	0.027 ***	0.003	0.063 ***	0.199 ***	0.022 *	0.040 ***	0.075 ***	0.009
X7	0.009 ***	0.031 ***	0.003	0.045 ***	0.195 ***	0.023	0.020 ***	0.064 ***	0.004

Note: * significant at the 10% level, ** significant at the 5% level, and *** significant at the 1% level.

3.2.3. Results of the Interaction

The site selection and construction of rural buildings was a complex process and was influenced by multiple elements [67,68]. Therefore, the interaction detector was used to explore the combined effect of two different factors on the spatial pattern of rural buildings and to classify the explanatory power. The two driving factors presented two types at the national and regional scales. From Table 4, the dominant interaction factor was slope ∩ distance to the nearest road, with an explanatory power of 0.245. It showed that rural buildings were mostly concentrated in areas with gentle terrain and well-developed transportation from the nationwide perspective. Also, the interaction type revealed that the two-factor effect was much more potent than the single one.

At the regional level, the interaction of different factors showed spatial heterogeneity. In the northern region, the *q*-statistic of slope ∩ road was 0.190, consistent with national results. And in the southern region, average altitude ∩ road was the dominant interaction factor with an explanatory power of 0.274 and the most significant one of all the regions. As for the central region, average altitude ∩ school exhibited a stronger impact followed by the interaction factor of school ∩ provincial capital and special economic zone. The *q*-statistic of them were 0.259 and 0.258, respectively. The results indicated that natural factors were the essential factors to be considered in the construction of rural buildings in all regions, while transport infrastructure was more concerned in the northern and the southern regions, and public service in the central region.

Table 4. The *q*-statistic of the interaction detector.

	Laos	North	Central	South
X1∩X2	0.177 (BE)	0.149 (BE)	0.103 (BE)	0.178 (BE)
X1∩X3	0.140 (BE)	0.105 (NE)	0.114 (NE)	0.161 (NE)
X1∩X4	0.220 (BE)	0.136 (BE)	0.163 (BE)	0.274 (BE)
X1∩X5	0.167 (BE)	0.102 (NE)	0.176 (BE)	0.184 (NE)
X1∩X6	0.197 (BE)	0.089 (NE)	0.259 (BE)	0.167 (BE)
X1∩X7	0.184 (BE)	0.095 (NE)	0.237 (BE)	0.213 (NE)
X2∩X3	0.177 (BE)	0.155 (BE)	0. 074 (NE)	0.101 (NE)
X2∩X4	0.245 (BE)	0.190 (BE)	0.127 (NE)	0.219 (BE)
X2∩X5	0.194 (BE)	0.149 (BE)	0.146 (BE)	0.105 (NE)
X2∩X6	0.220 (BE)	0.141 (BE)	0.229 (BE)	0.151 (NE)
X2∩X7	0.204 (BE)	0.141 (BE)	0.216 (BE)	0.139 (NE)
X3∩X4	0.154 (BE)	0.132 (BE)	0.114 (NE)	0.182 (NE)
X3∩X5	0.095 (BE)	0.098 (NE)	0.134 (NE)	0.065 (NE)
X3∩X6	0.128 (BE)	0.084 (NE)	0.216 (BE)	0.107 (NE)
X3∩X7	0.116 (BE)	0.083 (NE)	0.242 (NE)	0.098 (NE)
X4∩X5	0.157 (BE)	0.135 (BE)	0.158 (BE)	0.186 (BE)
X4∩X6	0.185 (BE)	0.124 (NE)	0.236 (BE)	0.211 (BE)
X4∩X7	0.179 (BE)	0.132 (NE)	0.233 (BE)	0.190 (BE)
X5∩X6	0.120 (BE)	0.075 (BE)	0.228 (BE)	0.113 (NE)
X5∩X7	0.110 (BE)	0.083 (NE)	0.224 (BE)	0.106 (NE)
X6∩X7	0.137 (BE)	0.059 (NE)	0.258 (BE)	0.141 (NE)

Note: NE is nonlinear-enhance, and BE is bi-enhance.

4. Discussion

From the results, it was found that all factors had a significant impact on the spatial pattern of rural buildings in Laos, with differences in the effects of various factors (Figure 4). This study analyzes the mechanisms of different elements that influence the spatial pattern of rural buildings in Laos and also analyzes the spatial differences in the impacts exerted by these factors. The innovation of this study is in fully recognizing the uniqueness and spatial heterogeneity of rural development in Laos by using the rural building spatial database. Therefore, this section emphasizes four aspects, natural factors, market access, transport infrastructure, and public service, to analyze the mechanisms of different elements that contribute to rural development and construction in Laos.

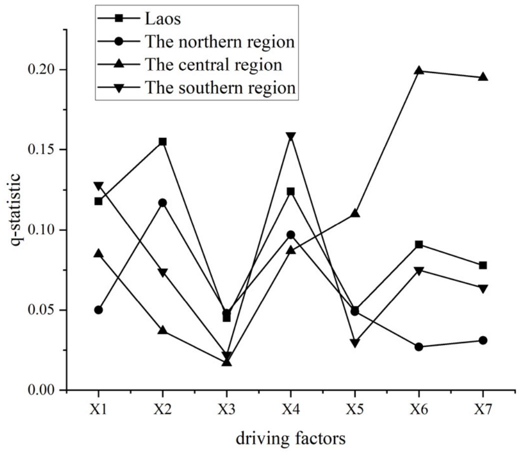

Figure 4. Line graph of *q*-statistic.

First, three factors contained in the natural elements all influenced the location of rural buildings, but the explanation power varied in magnitude, and a distinct spatial heterogeneity existed. From this, it can be concluded that the clustering of rural buildings was noticeable in areas with flat terrain and low altitude and near the river. This finding is consistent with the Loess Hilly and Gully Region, where rural settlements exist in spatial tropism distribution to topography [22]. The altitude mainly affects the southern region, and the reason is presumed to be that the slope varies significantly in the whole region, with a lower slope in the west and a higher slope in the east belonging to the Annamese Cordillera. The lower–altitude areas are conducive to farming, and the area of cultivated land in the south has increased, resulting in a gradual growth of rural settlements [69]. At the national level, areas with gentle terrain and lower slopes are more suitable for building houses, and such areas are characterized by a greater number of buildings, larger rural settlements, and rapidly growing levels of rural development [70]. For mountainous and plateau areas, rural settlements are principally distributed in areas where slopes are less than ten degrees, and the lower the slope, the larger the size of the settlement [71]. Similar to Wan et al. [72], the influence of river elements on the distribution of rural buildings is relatively moderate, indicating that residents paid less attention to rivers when building houses and mainly focused on the areas of flat terrain and fertile land.

Second, the impact of transport infrastructure on rural buildings is also obvious, and rural buildings are heavily concentrated in the villages near the roads. Road transport is the primary mode of conveyance in Laos, with National Road 13 as the main north–south route, which can strengthen the connection between different regions and external areas [73]. Roads can bring previously isolated areas into the market economy, changing the production patterns of rural people [74]. Also, transport has an effect on the structure of rural land values. Transport infrastructure is the dominant factor that affects the spatial pattern of rural buildings in the southern region. With higher road density in the southern region, villages in the areas near the roads have better development and residents can rely on the roads to seek livelihood, thus enabling them to build more houses for living. The accessible areas are more beneficial to village agglomeration, and the improvement of transport infrastructure can effectively promote regional development and economic growth [75]. On a national level, transportation infrastructure is not a primary affective element, with the driver ranking second. It indicates that the current national transportation infrastructure is inadequate in Laos, and the disparity of rural development is noticeable in villages with different transport conditions. The national road network should be further improved to narrow the development gap between villages. And the government should strengthen transport infrastructure, especially accelerating the development of basic transportation road networks in areas with backward rural development. And it can promote exchanges between backward regions and more well-developed regions, forming a pattern of complementary resources, functions, and positive interactions, and narrowing the development gap between different regions. In addition, the government should pay attention to the convergence of different modes of transportation, focus on the development of feeder transportation, and create an integrated road and rail transportation network in order to break the natural topographical constraints of landlocked countries, to achieve in-depth cooperation and exchanges with neighboring countries.

Third, public service is one of the main elements that rural residents commonly consider, with medical and educational facilities being the priority considerations for settlement. Schools are the dominant elements influencing the distribution pattern of rural buildings in the central region, and the driving force is the sharpest. And hospitals have a moderate impact across regions, but the influence is limited. This result showed that a convenient public social service can fulfill the basic requirements of rural residents and promote population agglomeration. Furthermore, hospitals and schools can educate and train residents, and thus promote the economic development of the villages [76]. The rural development level of the central region is generally better than that of other regions, and villagers have a higher demand for social and public services, especially for schools. Villagers prefer to live closer to schools so that children's educational needs can be served and to enhance their own literacy skills for better jobs [77]. Moreover, the central region has a positive economic development and more abundant hospital and school resources, which have a clear influence on rural development. But for other regions, public services develop slowly and therefore have a limited impact on rural settlements to bring better educational and medical experiences to villagers. In order to promote the rapid development of rural areas, the government should improve the level of social and public services and expand schools and hospitals to fulfill the needs of Lao residents. At present, the overall development of schools and hospitals in Laos is backward and meets the needs of residents in the better-developed rural areas. Hospital and school coverage in remote rural areas is far from adequate. In addition, the construction of schools and hospitals will not only improve the physical and business standards of the residents but also provide more employment opportunities and achieve the rapid development of the countryside as a whole.

Finally, provincial capitals and SEZs play an important role in the nation and the central region, but they are not the foremost factors that influence the spatial pattern of rural buildings, indicating that market access only has a relative impact on the villages. The government has established 12 SEZs in the country, which can create an environment that has various incentives and policies for business growth and development [78]. The rural residents have more assets to build houses in these areas closer to the SEZs. And villages are more affected by the "diffusion effect" of scale economies by SEZs, which can drive local economic growth and rural development [79]. Seven special economic zones and the capital are located in the central region, so the function of market access elements is much stronger than in other regions. Moreover, the rural buildings are located in the villages around cities and SEZs, and the closer to the growth poles, the better the development of the village. The services and opportunities of the city can also be essential ways to develop and construct the villages [80]. In particular, large cities and provincial capitals have a more obvious role in driving the economic development of the surrounding areas [81]. But for the other regions in Laos, the cities are still in a rapid development stage and the economic radiation effects on the countryside remain limited. The government should actively attract foreign investment and strengthen the construction of cities and special economic zones, thus enhancing economic vitality. Special economic zones, as the "leaders" of economic development, provide jobs and more market opportunities to promote economic growth in Laos. Therefore, the government should formulate appropriate policies to attract more foreign investment and promote cooperation with the international community. At present, the layout of special economic zones in Laos is concentrated in the central region. In the next development stage, it can rely on major road networks to connect special economic zones in different regions, forming a point–axis development model, developing deeply into underdeveloped areas, and driving the economic development of Laos.

5. Conclusions

Rural areas serve as important locations for population agglomeration, as well as major areas containing a predominant distribution of poor people in underdeveloped countries. At this critical stage of achieving the SDGs, promoting rural rapid development has become a primary goal of national concern. Moreover, the development level of different regions can be reflected through the pattern of rural settlements. Therefore, this study has analyzed the spatial heterogeneity of rural development in Laos by using geodetector and explored the mechanisms of disparate factors. The contributions of this study were as follows. Firstly, this study fully explored the differences of rural areas by using the rural building spatial database to enrich the existing studies of rural settlements, which made the analysis results more accurate and specific. Secondly, this study analyzed not only the spatial heterogeneity of single factors on the spatial pattern of rural buildings but also the interactions of multiple factors through the geodetector.

(1) The distribution of rural buildings in different regions of Laos varied significantly, and rural buildings were concentrated in the center areas and around the provincial capitals. In 2021, the total number of buildings in the country of Laos was nearly 2.64 million, containing a total of 940 thousand rural buildings in 5720 villages. The cold spots areas of the buildings emerged in the northern region, and the hot spots areas were concentrated in the central and southern regions from the Getis-Ord Gi*. For rural buildings, cold spots areas were mainly clustered in the northeast, and hot spots areas were concentrated in the southwest of Laos. Promoting rural development and reducing the disparity between rural settlements in different regions was still a difficult and long-term task.

(2) Spatial heterogeneity in the influence of different elements on the pattern of rural buildings through the analysis of the villages was found by using geodetector. Natural factors, transport infrastructure, public services, and market access all had significant effects, but the driving forces were varied in magnitude. In the northern region, the dominant factor was slope, which affected the agglomeration of rural buildings; but in the central and southern regions, schools and roads were the dominant factors, respectively. Moreover, the mechanisms of different factors' effect on rural buildings were distinct, and the construction of buildings should also consider the effect of socio-economic factors in addition to the natural factors.

(3) The expansion of rural settlements and the construction of rural buildings were more obviously influenced by the interaction of two different factors. And the interaction driving force was much stronger than a single-factor one. By using the interaction detector, it was found that slope ∩ road was the dominant interaction factor affecting the spatial differentiation of rural buildings in the northern region and the whole nation. Average altitude ∩ school and average altitude ∩ road were the dominant interaction factors in the central and southern regions, respectively.

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Notes

1. Data Sources: https://data.worldbank.org/indicator/SP.RUR.TOTL (accessed on 25 March 2023).
2. Data Sources: https://data.worldbank.org/ (accessed on 25 March 2023).
3. Data Sources: https://laos.opendevelopmentmekong.net/ (accessed on 6 March 2023).
4. Data Sources: https://www.openstreetmap.org/ (accessed on 18 March 2023).
5. Data Sources: https://srtm.csi.cgiar.org/srtmdata/ (accessed on 22 October 2022).

6 Data Sources: http://www.globallandcover.com/ (accessed on 17 October 2022).

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