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Expanded Residential Lands and Reduced Populations in China, 2000–2020: Patch-Scale Observations of Rural Settlements

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Abstract: The spatiotemporal transformations of rural residential lands and populations reflect changes in rural human–land relations. This study uses high-precision rural residential land patches and population distribution data to detect the area, population density, and spatial heterogeneity of newly added rural residential land (NARRL) in China from 2000 to 2020 through spatial local clustering and geographically weighted regression. The patch results were summarized into county-level units for regional comparison, spatial clustering identification, and policy recommendations. The main conclusions are as follows: (1) The total rural residential area increased by 13.86% between 2000 and 2020. The average population density of NARRL (APDNARRL) at patch scale is 701.64 person/km^2, significantly exceeding the 507.23 person/km^2 of the remaining patches. (2) There are obvious spatial differences in the distribution of APDNARRL as per county-level statistics. There are significant differences in APDNARRL on both sides of the Hu Huanyong Line; the APDNARRL on the left is significantly lower than that on the right. (3) Spatial heterogeneity was found to be among the driving factors of APDNARRL. This study also detected the number and location of hollowing counties; it is significant for monitoring dynamic changes in rural residential lands, revealing their spatial distribution patterns and driving factors, thus improving the optimization of rural land resources.

Keywords: rural residential land; population density; patch scale; geographically weighted regression; spatial local clustering; China

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1. Introduction

Rural residential areas, which constitute an important type of land-use category in rural areas, are also spatial carriers of rural development [1,2]. After reform and opening-up, with rapid regional socioeconomic development, China embarked on an accelerated urbanization process unprecedented in global history, leading to sharp changes in urban–rural land-use patterns, particularly in regard to two aspects. First, because of the consistently increasing urbanization levels, urban construction land has rapidly expanded and spread [3,4]. Second, a large share of the rural labor force has transferred to cities, but the scale of rural residential areas has increased instead of decreasing [5]. This has led to continuing changes in the spatial layout and morphological characteristics of rural residential areas [6–8].

The changes to China's urban–rural land-use patterns are driven by transformations in social structures, as can be clearly seen in the rapid increase in the population's urbanization rate, from 19.72% in 1978 to 65.22% in 2022. This shows that China's traditional agricultural social structure has been giving way to a predominantly urban society [9] over the course of just 40 years. While the social and structural development of cities in China has been much researched globally, the country's rural areas have received far less attention from scholars. For example, in the Web of Science database, there are only 901 articles with the keywords "rural residential land, China" from 1978 to 2023, which is much lower than the 22,719 records retrieved with the keywords "urban land, China". The key topics in the few existing rural studies include the spatial patterns of rural residential land [6,7], its spatial and temporal evolution [1,10,11], analyses of the driving mechanisms of change [8,12], its consolidation and optimization [13–15], and the dynamics of human–land relations [16,17].

This study focuses on the area and population density of rural residential land. Scholars have found that the area of rural residential land in China has been expanding, by using GIS, remote sensing, and other methods. For example, based on the data interpreted from remote sensing images, from 1990 to 2000 the rural residential area increased by 7.88×10^5 ha [18], and from 2009 to 2016 the rural residential area increased at an average annual rate of 0.55%, which are significantly higher than the average annual growth rate of 0.10% between 1996 and 2008 [1] and 0.09% between 2000 and 2005 [5]. Most of the new rural residential land is used for cultivation [19,20], which poses a potential threat to the regional ecological environments [21]. Although the size of residential areas has been expanding, the rural population has continued to decline. China's rural population decreased at an average annual rate of 2.07% from 2009 to 2016. A similar change was noted in the Yellow River Basin, for example, from 2010 to 2016 [17]. The average annual decline in the rural population has been 2.57% [22]. The urbanization rate of China's permanent population reached 65.22% in 2022. However, most of those who live in cities and towns all year round but have a rural registered residence continue to choose to return to their registered residences to build housing. This peculiar phenomenon of a fall in population without a fall in settled land has led to the increased use of rural residential land in many rural areas, although there is a trend of consistently high housing vacancy rates [23]. The consequent problems of population loss and the hollowing out of villages, and scattered and disordered village construction, places enormous pressure on resources and the environment; the destruction of rural landscapes, as well as urban villages, is increasingly prominent [24], resulting in a clear imbalance in rural human–land relations [25].

Relative to the previous extensive analysis of the decoupling relationships between rural residential land and the resident population at the national, regional, and individual city levels, based on statistical yearbook data at the administrative district level [22], there has been limited research on the relationship between rural residential land changes and population changes at the micro-patch scale. Because of the fragmented and scattered distribution of rural residential areas, patch-scale analysis can be used to detect additional spatial details, such as the spatial clustering and differentiation that are characteristic of human–land relationships within a region, relative to an administrative-district-scale analysis. Therefore, this study uses vector polygons (patches) of rural residential land, interpreted from 30×30 m remote sensing images, and a 1×1 km grid LandScan population distribution produced by Oak Ridge National Laboratory, United States, as the basic data to explore human–land changes in China's rural areas from 2000 to 2020. We attempted to answer the following questions: what is the state of the average population density of the newly added rural residential land (APDNARRL) in China? Are there obvious agglomeration and differentiation characteristics across space, and what drives them? To the best of our knowledge, this study is the first to determine APDNARRL on a fine-patch scale across China, and by using the same data over time, it supports the possibility of cross-regional comparisons.

2. Study Area and Data

Mainland China, excluding Taiwan, Hong Kong, and Macau, was selected as the research area, covering a total of 2877 county-level administrative regions (Figure 1). While there are many forms of county-level administrative units in China, the main types are municipal districts, counties under the jurisdiction of cities, and county-level cities. A prominent feature of a municipal district is that the urban built-up area is a core component, with urban residents constituting its main population, and the urbanization of this core is generally at a high level. However, counties that are under the jurisdiction of cities are usually dominated by rural populations that have low urbanization rates. County-level cities are usually county-level units adjusted after their economic development level, population urbanization rate, total population, and other indicators meet certain conditions, which were set at the beginning of China's reform and opening-up. County-level cities have more authority in terms of economic management and urban construction than counties under the jurisdiction of cities.

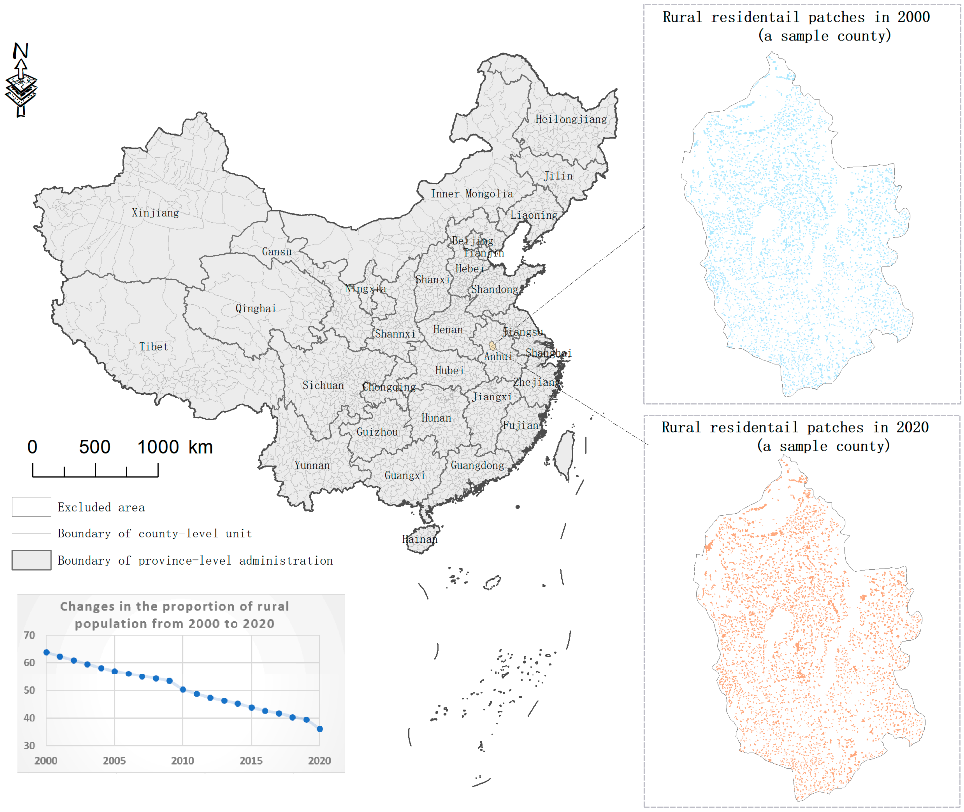

Figure 1. Study area.

China's rapid urbanization has been widely studied globally. As a result of this process, a large number of farmers are leaving rural areas and moving to cities each year. Statistics show that the rural population has decreased year after year from 2000 to 2020, from 63.91% in 2000 to 36.11% in 2020, showing an average annual decline of 1.39 percentage points. However, the area of rural residential land in China has not declined with this massive loss of population; rather, it has shown a trend of increasing year after year, resulting in a huge waste of rural land resources. For example, according to the 2017 China Rural Development Report, published by the Rural Development Institute of the Chinese Academy of Social Sciences, between 2000 and 2010, the annual increase in rural idle housing caused by rural population transfer reached 594 million m^2, equivalent to a market value of about 400 billion yuan. The population leaving rural areas and the large number of empty houses left behind have resulted in significant rural hollowing out.

This study mainly examines three types of data: land-use data, the spatial distribution of the population, and basic auxiliary data (geographic maps and socioeconomic statistical data). The land-use data with 30 $\times$ 30 m spatial resolution are from the National Land Use/Cover Database of China (NLUD-C), released by the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences. They were produced using Landsat TM/ETM and China Brazil Earth Resources Satellite as the main sources of information through image correction, visual interpretation, supervised classification, and field investigation. It was found that the NLUD-C classification accuracy reached over

90% [26], enabling it to be considered accurate and reliable. This database includes multiple periods of land use over the years. This study selected the data between 2000 and 2020, and extracted the land class with code 52 as the analytical source for subsequent rural residential area patches. Figure 2 shows the spatial distribution of the area of rural residential land in each county-level unit in 2000 and 2020.

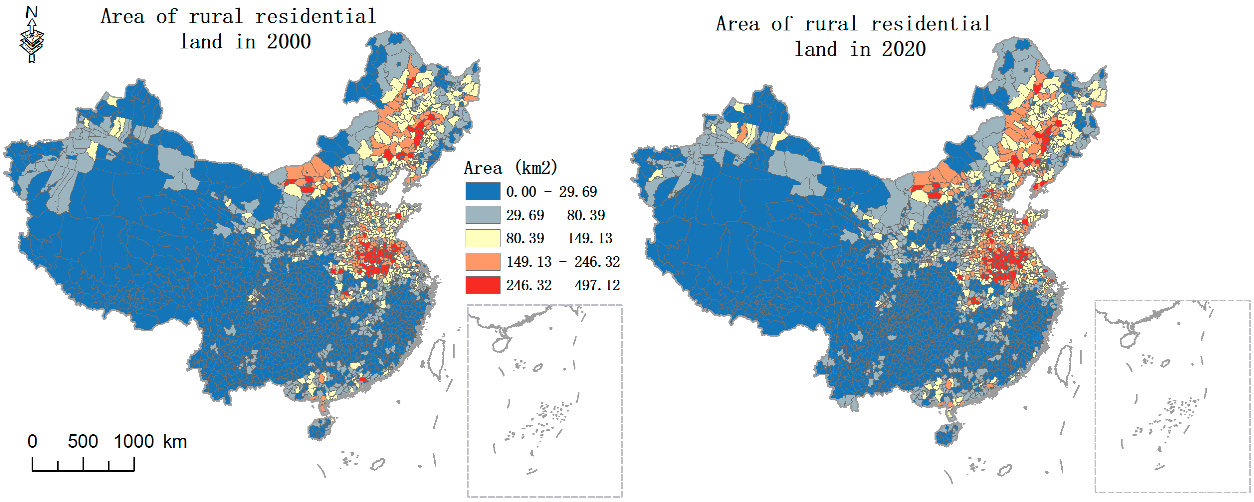

Figure 2. Spatial distribution of the area of rural residential land in each county-level unit in 2000 and 2020.

Because this study's aim was to calculate population density at the patch scale, it was not possible to use the population data based on administrative units for calculation, so we used the spatial distribution population program LandScan (Oak Ridge National Laboratory, Oak Ridge, TN, USA) with a high spatial resolution (about 1 × 1 km). LandScan uses the best available census data, which is recognized as authoritative and as providing accurate spatial population data, and is widely used in population research [27]. A weighted model based on geographic information systems and partition density models has been established to better reflect the spatial distribution of the population (https://landscan.ornl.gov, accessed on 5 July 2022). To improve the accuracy of the data, they were manually corrected and modified.

Other data, including geographic information data (including on roads, rivers, administrative boundaries, and government locations), were taken from the National Earth Systems Science Data Center of the Institute of Geography, Chinese Academy of Sciences (www.geodata.cn). The socioeconomic data (GDP, value added of primary/secondary/tertiary industries) are from statistical yearbooks and the social and economic development bulletins of various districts and counties.

3. Methodology

3.1. Research Framework

We designed the method framework diagram shown in Figure 3 based on the issues we sought to understand. Using the land-use vector-map patch data interpreted from remote sensing images, we detected the spatiotemporal changes of rural residential land in China between 2000 and 2020. During this period, China's economy grew rapidly, and the rural landscape underwent tremendous changes due to rapid urbanization and industrialization. Supported by high-precision data on the spatial distribution of the population, the population density of each newly added or retained patch was detected, and a county-scale summary analysis was conducted. Then, the spatial characteristics of the changes in the quantity, pattern, and density of the population of rural residential land were analyzed at the county scale, and the driving factors and differences in spatial heterogeneity between the changes in population density were detected. Conventional spatial analysis methods, such as spatial overlay, spatial statistics, vector to raster, raster to point, and summary statistics, which can be directly implemented in ArcMap software, have not been described in detail. We focus on the calculation of APDNARRL, spatial autocorrelation *t*-test, and geographically weighted regression (GWR) modeling in the following text.

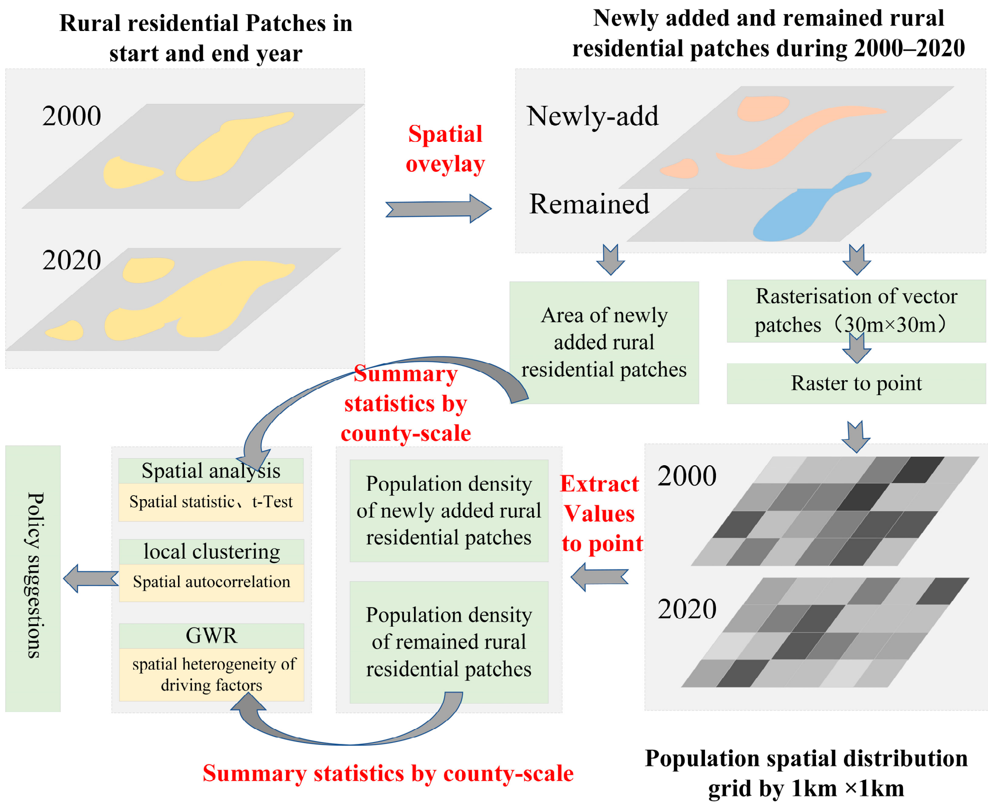

Figure 3. Diagram of overall method framework.

3.2. Calculation of APDNARRL

By employing the "erase" tool in ArcMap, the newly added rural residential patches during 2000–2020 were extracted from the two years of rural residential patches in 2000 and 2020. To determine the population density of each patch, the newly added patches (in vector format) were superimposed on the population distribution data (landscan in raster format). However, due to the irregularities and size differences of the residential patches, direct overlaying did not yield accurate average population density values. Consequently, an additional step was taken to convert the vector form into a grid form, with a resolution of 30 m × 30 m, using the "Raster to Point" tool in ArcMap. Subsequently, the grid was transformed into vector points, and these points were overlaid once again with the gridded population distribution layer. This process ensured that each patch contained multiple points, denoted as 'm'. By employing the "Extract values to points" function in ArcMap, the grid values (i.e., population density) corresponding to each point could be extracted. Ultimately, the population density of each patch was calculated using the following equation:

$$\text{APDNARRL}_{patch\_i} = \frac{\sum_{j=1}^{m} p_j}{m} \quad (1)$$

where APDNARRL_i represents the population density of the i-th patch, p_j is the population density of the j-th point under the patch, and m represents the number of all points covered under the patch.

Further, we obtained the APDNARRL for each county unit by summing the population density of all the new patches weighted by area.

$$\text{APDNARRL}_{county\_p} = \sum_{e=1}^{f} \text{APDNARRL}_{patch\_e} \times \frac{Area_{patch\_e}}{A} \quad (2)$$

where $\text{APDNARRL}_{county\_p}$ represents the population density of the p-th county, $\text{APDNARRL}_{patch\_e}$ and $Area_{patch\_e}$ are the population density and patch area of the e-th patch in the county, respectively, f is the total number of patches, and A is the total area of all patches.

3.3. Spatial Autocorrelation Detection

Spatial autocorrelation refers to the interdependence of variables on a spatial scale, which can be used to judge whether there is aggregation or outliers in the research areas. This study indicates the local similarities between the areas of newly added rural residential land (ANARR) and APDNARRL for the county-level units in China using the LISA cluster diagram [28].

$$I_i = \frac{n(x_i - \overline{x}) \sum_{j=1}^{n} w_{\text{ij}} (x_j - \overline{x})}{\sum_{i=1}^{n} (x_i - \overline{x})^2} \quad (3)$$

In this equation, n refers to the number of county-level units and x_i and x_j are the values for x for the i-th and j-th counties, where $\overline{x}$ is the average value of x_i and w_{ij} is the spatial weight matrix. I_i represents the local Morans' I value of the i-th county, and $I_i > 0$ indicates that there is a small spatial difference in the variable values between adjacent regions, which is either high-high clustering or low-low clustering. $I_i < 0$ indicates significant spatial differences in the variable values between adjacent regions, classified as high-low clustering or low-high clustering. The specific implementation can be achieved through the Cluster and Outlier Analysis (Anselin Local Morans'I) toolkit of the ArcMap 10.6 software.

3.4. t-Test

In this article, we aim to employ the t-test to examine potential significant differences in key indicators between the two distinct groups of samples. The groups under investigation were formed based on a comparison between APDNARRL and the average population density of the remaining rural patches (APDRRP) for all county-level units across the entire country. Specifically, one group comprises units where APDNARRL > APDRRP, while the other group consists of units where APDNARRL < APDRRP. Our objective is to assess whether significant differences exist in some key socio-economic indicators between these two groups of county-level units. The t-test process involves several steps, including assessing whether the distribution of data in each group conforms to the normal distribution, conducting hypothesis tests to determine the equality of average indicator values in the two sample groups (homogeneity test of variance), calculating t-values and significance levels, and performing other necessary operations. To facilitate these analyses, we utilized SPSS 25 software.

3.5. Spatial Heterogeneity of the Driving Forces of APDNARRL

GWR was used to detect the driving factors and spatial heterogeneity of APDNARRL. GWR is an improvement to an ordinary linear regression model. Its principle is to compare and analyze the data for a certain variable to other variables in the adjacent area, and the calculated values of the change in the model relative to changes in geographical location, thereby identifying the differences in various spaces according to heterogeneity [29]. The general expression for the GWR model is as follows:

$$y_i = \beta_0(\mu_i, v_i) + \sum_{j=1}^{k} \beta_k(\mu_i, v_i) x_{ij} + \varepsilon_i; i = 1, 2, \ldots, n \quad (4)$$

In the above equation, (μ_i, v_i) is the geographical spatial coordinate of the i-th sample and $\beta_k(\mu_i, v_i)$ is the i-th regression coefficient of the i-th sample. Positive or negative values of $\beta_k(\mu_i, v_i)$ represent the pushing or inhibitory effect of x_{ij} on y_i. ε_i is the random error. The difference between the explanatory variable, y_i, and the observed value, y, in the model is the residual. The smaller the value here, the better the fit between the GWR model and the observed data.

Based on the research case of this study and with reference to previous literature, 11 factors were selected from 4 dimensions: convenience of life/production, urban radiation, construction cost, and socioeconomic development level (Table 1). The factors of the first three dimensions were directly calculated based on the spatial location of the newly added patches, and then they were summarized by county. The socioeconomic factors were calculated from the regional statistical yearbook.

Table 1. Selected driving factors used in geographically weighted regression.

Dimension	Factors	Descriptions	Reasons	References
Convenience of life/production	Dis_TR	Distance to town-level road	Residential houses located alongside roads enhance accessibility to schools, hospitals, shopping centers, and various destinations via the road network. Conversely, buildings situated adjacent to rivers facilitate activities such as water collection and farm irrigation, thus supporting agricultural practices.	[14,30–35]
	Dis_CR	Distance to county-level road		
	Dis_R	Distance to river		
Construction cost	AE	Average elevation	The higher elevation entails potential topographical intricacies that can escalate the expenses associated with foundation filling and reinforcement of buildings.	
Urban radiation	Dis_CC	Distance to county center	Generally, the closer to the county center and city, the more convenient life is and the more services there are for residents.	
	Dis_EU	Distance to existing urban land		
Socioeconomic development level	IGDP	Increasing rate of GDP	The level and pace of social and economic development positively influence farmers' inclination to enhance housing conditions and encourage the establishment of new residential areas. The dynamics of the industrial structure mirror the transformations occurring in agriculture, industry, and the service sector. The primary industry's added value is directly linked to farmers' income levels, whereas the expansion of the secondary industry necessitates the occupation of rural land and the absorption of rural populations. Furthermore, the development of a tertiary industry also contributes to employment opportunities for rural and non-rural populations, exerting direct or indirect effects on rural residential patterns.	[24,31,36–40]
	IAPE	Increasing rate of added value of the primary sector		
	IASE	Increasing rate of added value of the secondary sector		
	IATE	Increasing rate of added value of the tertiary sector		
	CRP	Change rate of resident population		

4. Results and Analysis

Rural residential land exhibited rapid growth between 2000 and 2020, with the total number of patches growing from 782,052 to 812,382—increasing by 3.878%. The total area grew from 1.269×10^5 km^2 to 1.445×10^5 km^2, increasing by 13.86%. After taking the residential population into account, we found that the total rural population was reduced from 8.073×10^8 to 5.098×10^8, decreasing by 36.86%, meaning that the average population of each residential patch decreased from 1032.40 persons to 627.52 persons; the increasing inefficiency in the use of residential land is clear.

4.1. Area Change of Rural Residential Land

The average increase in the rural residential area of the 2877 county-level units covered in this study is 6.234 km^2, with 2307 county-level units increasing in area, accounting for 80.18% of the total county-level units. Then, 580 county-level units decreased in area, accounting for only 19.82% of the total county-level units, indicating that the vast majority of county-level units in China are experiencing increases in rural residential area. The county-level unit with the largest increase in area was Xinmi City, which is close to the urban area of Zhengzhou and the national airport economic comprehensive experimental zone, with an increase of 148.461 km^2. The potential driving force behind this is that farmers obtain huge economic benefits from the demolition of their rural houses to make way for urban construction, which is linked to the area of the houses to be demolished, thus enabling them to build new rural homesteads. Dongguan, known as the world's factory, saw the biggest decline in rural residential area, reaching 345.74 km^2, reflecting the encroachment of industrialized and urbanized land on rural areas.

Local clustering detection (Figure 4) shows that increasing the area presents three typical regions, namely, the northeast (Heilongjiang and Jilin, marked 1) and the vast southwest (marked 3), forming a low-value clustering area. Significant differences can be seen between the terrains of the two regions; while the former constitutes largely plains, the latter is made up of plateaus and hills. In recent years, population loss in Northeast China has received widespread attention, and because of weak economic growth in the region, the proportion of those who have left and then returned is the lowest in this area. There is little motivation to expand rural residential areas, and cities also appear to be shrinking. The latter (marked 3) is the main export destination for migrant workers who support the prosperity of factories and the construction of infrastructure in the developed regions of China, such as Guangzhou and Shenzhen in the Pearl River Delta region, Shanghai, Hangzhou, and Suzhou in the Yangtze River Delta region, and Sichuan Province, Chongqing City, Guizhou Province, and others. The proportion of migrant workers who choose to live in cities has significantly increased, and more elderly people seem to have been left behind to live in rural houses. High-value areas are concentrated in the plains of North China and the Middle and Lower Yangtze Valley Plain (marked 2 in Figure 3). These areas have a high urbanization rate, including the Jing-Jin-Ji and the Yangtze River Delta Urban Agglomeration. The proportion of the rural population is lower, and the urban–rural income gap is likewise low. The enabling of the marketization of rural housing transactions has stimulated the construction of a large number of rural houses, thus forming a high-value cluster area.

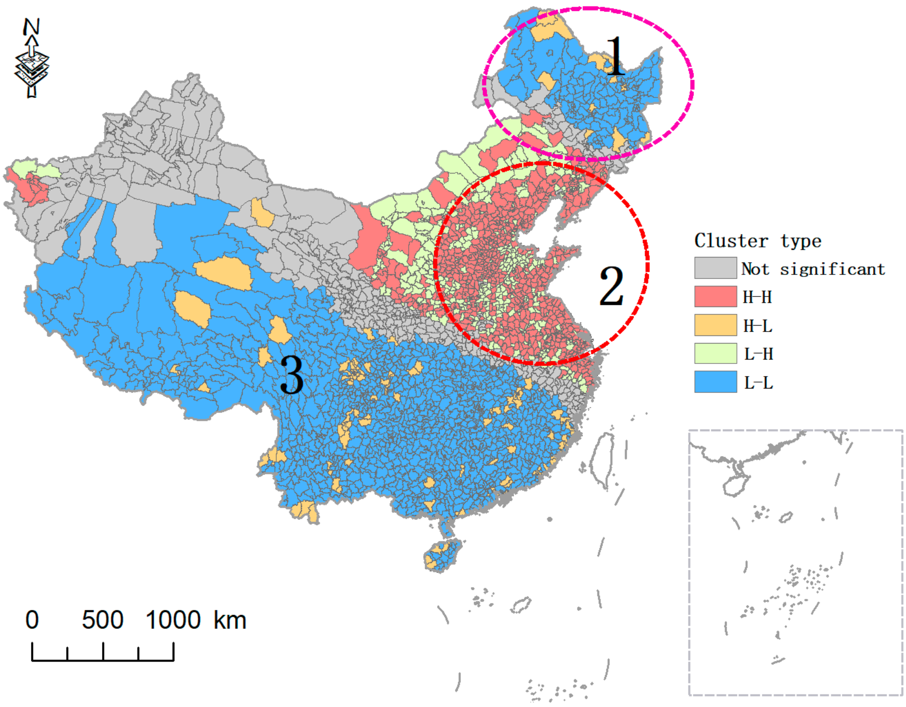

Figure 4. Local clustering distribution of the area of newly added rural residential land in county-level units.

4.2. Population Density of Newly Added Rural Residential Areas

The detection of population density per patch shows that the APDNARRL in 2000–2020 was 701.6446 persons/km^2. The distribution of APDNARRL is characterized by the eastern parts (782 persons/km^2) being greater than the central regions (634.31 persons/km^2), which are greater than the western parts (552.48 persons/km^2) of the country; a similar pattern to the basic overall pattern of population distribution and economic development level in

China. We first counted the APDNARRL for all provinces (Figure 5). Among the 11 eastern provinces, 7 are among the top 10 APDNARRL values. Shanghai, Guangdong, Fujian, Zhejiang, and Beijing have APDNARRL values that exceed 1000 persons/km^2. Shanghai, in particular, has the highest APDNARRL, 2507 persons/km^2, reflecting its role as the leading city in China's economy. High-density populations also directly promote the new residential density of rural residential land to meet the living needs of the employed population in suburban areas. Tibet, located in the west of China, has the lowest APDNARRL, with only 134.87 persons/km^2, far below the national average. This is related to the topographic conditions of Tibet, which is located on the Tibetan Plateau, often referred to as the Roof of the World, having the lowest population density in China because of its poor living environment. Further, we also found that Chongqing and Sichuan Province, in western China, have relatively high APDNARRL values, with 1410 and 883.6 persons/km^2, respectively. In particular, Chongqing ranks third in terms of APDNARRL. This is related to the rapid development of the twin-city economic circle between Chengdu (capital of Sichuan Province) and Chongqing (Chongqing), which exists across the two regions. Located at the intersection of the Belt and Road and the Yangtze River Economic Belt, they are the initiation points of the land and sea passages in the west, and they also rank among the most attractive cities in China all year round. Chengdu, in particular, tops the list of China's new first-tier cities (Shanghai, Beijing, Guangzhou, and Shenzhen are considered the traditional first-tier cities), and population inflows are also driving the increase in APDNARRL.

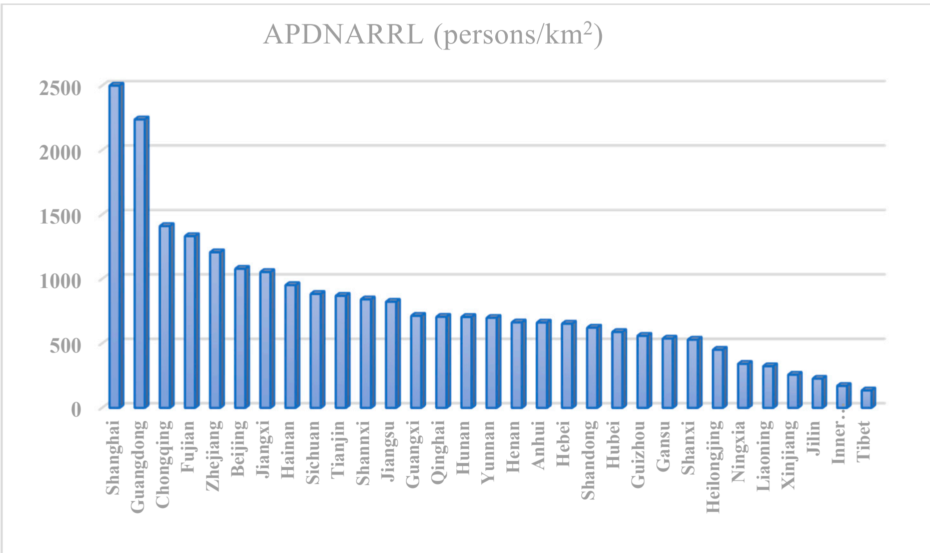

Figure 5. Provincial APDNARRL in descending order.

Figure 6 presents the spatial distribution of APDNARRL and local clusters in relation to county-level statistics. There is an obvious gap between the two sides of the Hu Huanyong Line, the famous dividing line for population density distribution in China; the APDNARRL on the left side is clearly lower than that on the right. In particular, the eastern and southern coastal areas (marked 1) and Chongqing and Sichuan Province (marked 2) form obvious high-concentration areas, confirming the conclusion we reached above using provincial statistics. Correspondingly, low-value accumulation areas can be seen in the three northeastern provinces (marked 3) and almost the entire left side of the Hu Huanyong Line.

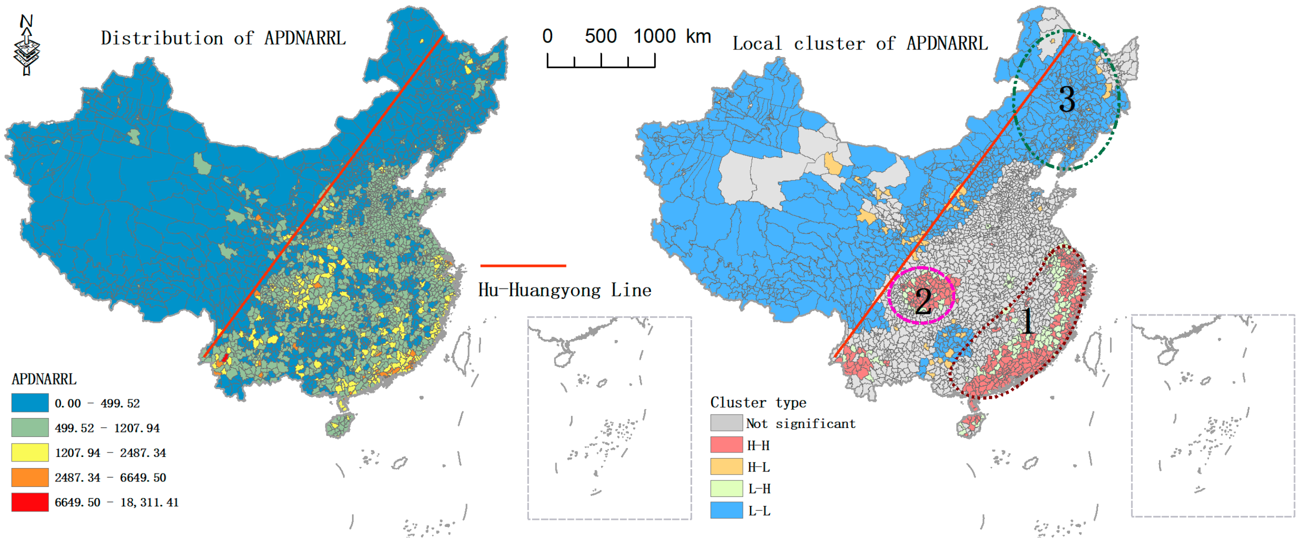

Figure 6. Spatial distribution and the local clusters of APDNARRL by county-level units.

4.3. Spatial Non-Stationarity of the Relationship between APDNARRL and Driving Factors

China is a vast country having tremendous differences in terms of social and economic development levels and natural conditions among its regions. As the geographical location varies, the relationship or structure of variables also changes. Using GWR, we found that the relationship between the selected associated factors and APDNARRL shows significant spatial heterogeneity (see Figure 7). This heterogeneity may have a guiding significance for regions as they develop targeted policy recommendations. We discuss the regions that have passed the significance test and several frequently occurring provinces as the objects of analysis, including Sichuan and Yunnan in the west and Guangdong in the east. Other significant regions are presented in Table 2. Among these, the APDNARRL of Sichuan Province shows a positive correlation with Dis_TR, CRP, and IAPE, whereas it shows a negative correlation with AE, Dis_CC, and IGDP. Thus, the newly added populations in the rural areas of Sichuan Province have mainly accumulated near county towns rather than along rural roads; there is a tendency to establish residential land in areas with low terrain and small surface undulations, leading to lower construction costs. The primary sector's development can be driven by the efficient improvement of labor. The transfer of the rural surplus labor to support urban development may not only improve the scale effect and production efficiency of the primary sector (which can be improved with agricultural machinery and technology) but also improve overall GDP growth. This is usually because the efficiency of the urban production sector is greater than that of the rural sector, but these require the transfer and supplementing of rural labor. Therefore, this will reduce APDNARRL. In Yunnan Province, APDNARRL is positively correlated with Dis_EU and IATE, and it is negatively correlated with Dis_TR, Dis_CR, CRP, and IGDP changes, indicating that the province is dominated by tourism (i.e., the tertiary sector). The distance from cities and along village and county roads can promote APDNARRL because they can minimize the impact of urbanization and maintain natural beauty in and among tourist attractions. However, increases in GDP and POP inhibit APDNARRL, suggesting that the new population is moving to cities, and the increase in urban productivity then further attracts people from the surrounding countryside. Guangdong Province, in the east, has the largest manufacturing sector in China, and it has the highest GDP. It likewise hosts a large number of migrant workers. We found that Dis_EU, CRP, IAPE, and SecondAdd are all negatively correlated with APDNARRL. On the one hand, industry (i.e., the secondary sector) has a huge demand for labor, which greatly promotes the transfer of rural labor and prompts rural populations to leave the countryside to work in cities. Simultaneously, it provides an opportunity for the primary sector to improve production efficiency and promote output value. On the other hand, the accumulation of a large number of workers in the industrial sector in cities has also promoted a boom in the rural housing rental market in suburban areas because rents are cheaper than in urban areas. The closer a rural area is to an urban center, the more attractive it is to workers looking for rental residences.

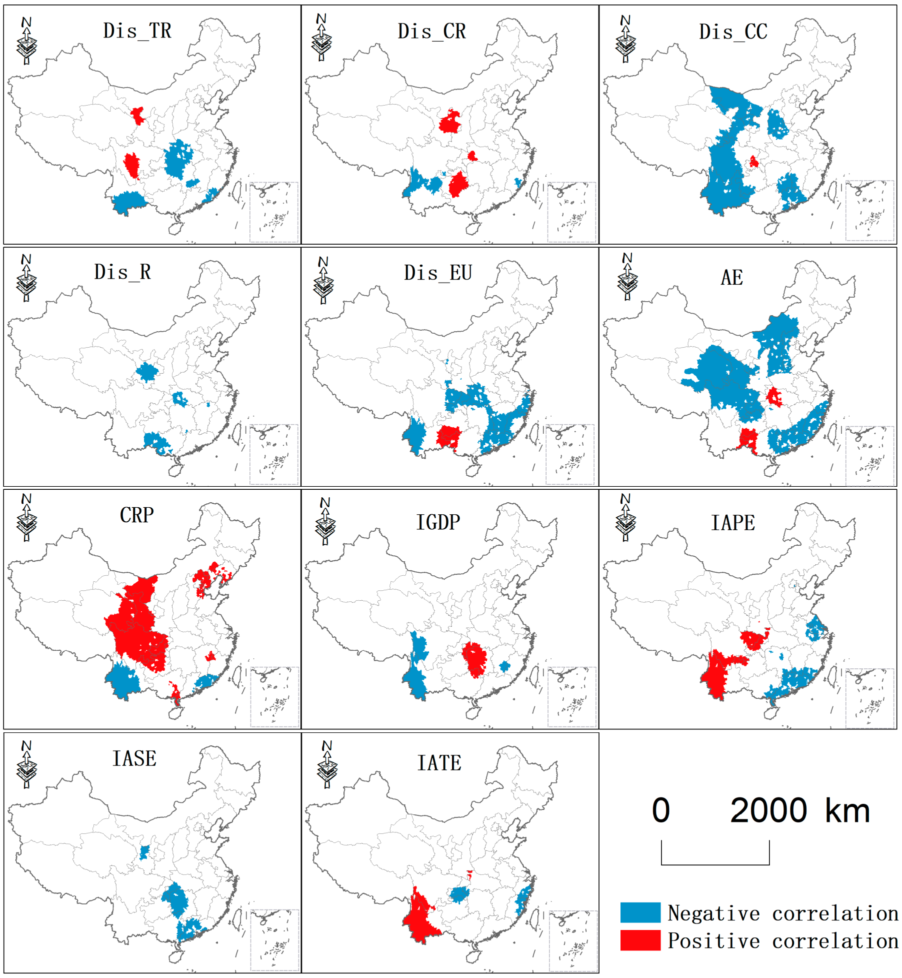

Figure 7. Areas where the relationship between driving factors and APDNARRL is significant.

Table 2. Main regions with a significant relationship between driving factors and APDNARRL.

Factors	Main Distribution Area/Coefficient Range (Positive Correlation)	Main Distribution Area/Coefficient Range (Negative Correlation)
Dis_TR	Sichuan/(0,19.45]	Yunnan, Hubei, and Hunan/[−11.43,0)
Dis_CR	Guizhou, border between Ningxia and Gansu/(0,45.53]	Yunnan/[−23.48,0)
Dis_CC	Chongqing/(0,18.59]	Guizhou, Sichuan, Shanxi, and Guangdong/[−33.79,0)
Dis_R	None	Gansu, Guangxi, and Hubei/[−21.56,−7.94)
Dis_EU	Junction of Guangxi, Yunnan, and Guizhou provinces/(0,45.38]	Zhejiang, Guangdong, Fujian, Chongqing, Hubei, Jiangxi, and western Yunnan/[−99.63,0)
AE	Western Hubei, western Guangxi, and southern Guizhou/(0,0.65]	Southeast coastal provinces, Qinghai, Sichuan, Gansu, and Shanxi/[−2.04,0)
CRP	Gansu, Sichuan, Chongqing, Guizhou, and northern Hebei/(0,5.93]	Yunnan, eastern Guangdong/[−7.63,0)
IGDP	Hunan/(0,0.76]	Western Yunnan and Western Sichuan/[−0.82,0)
IAPE	Western Yunnan and Sichuan/(0,0.79]	Guangdong and Jiangsu/[−1.82,0)
IASE	None	Guangdong and Hunan/[−0.45,−0.05)
IATE	Yunnan/(0,0.21]	Zhejiang, Fujian, and Chongqing/[−0.33,0)

5. Discussion

5.1. Comparison of Population Density between New and Remaining Rural Residential Lands

In comparing the APDNARRL with the average population density of the remaining rural patches (APDRRP), the remaining rural patches means patches of rural settlements that existed in both 2000 and 2020. It was found that, overall, APDNARRL significantly exceeds APDRRP, which is 507.22946 persons/km^2, indicating that the hollowing out of original residential areas is pronounced and should be a focus of future village renovations. However, not all counties have an APDNARRL exceeding the APDRRP. We found that the APDNARRL of 1239 counties in China (accounting for about 42.91% of the total number) is lower than the APDRRP, and the APDNARRL of the other 1628 counties exceeds the APDRRP. The spatial distribution of these counties is shown in Figure 8. It can be observed that the Qinghai Tibet Plateau and the eastern coastal and eastern inland regions, as well as the southern Guangdong and Hainan provinces, form low-value clustering areas, while high-value clustering areas have formed in the regions of Xinjiang and Northeast China.

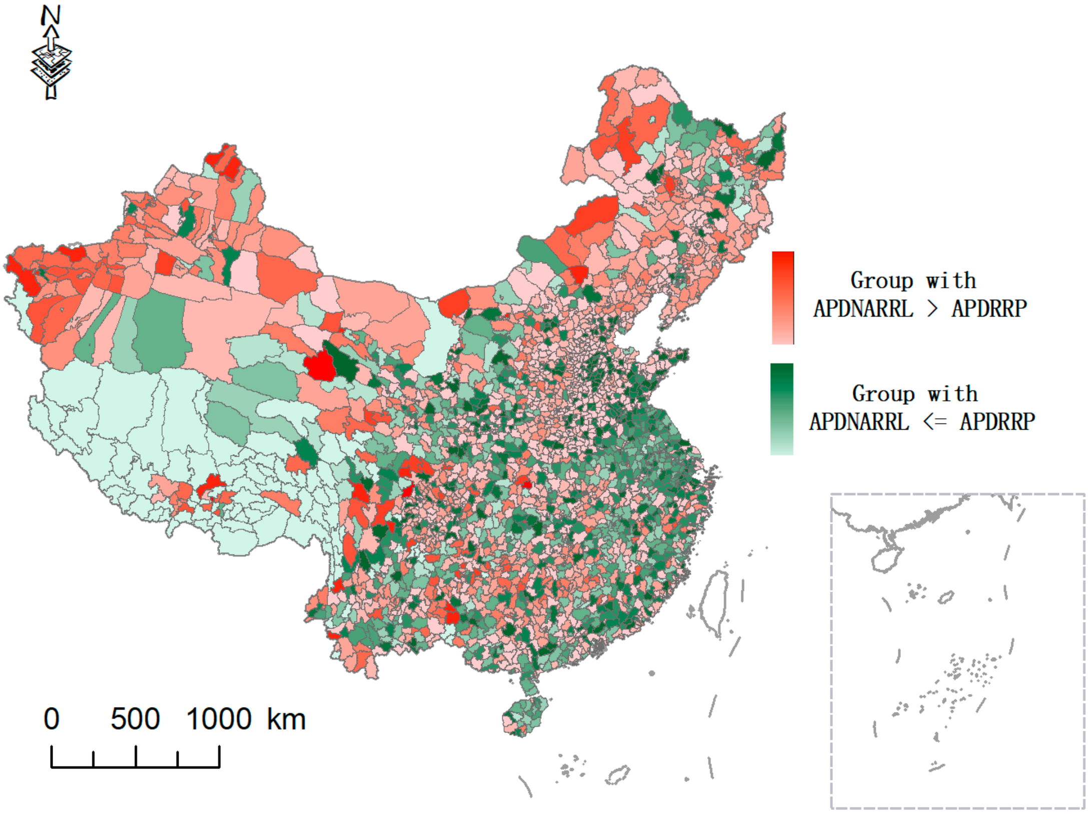

Figure 8. Spatial distribution of the two groups (note: the red group indicates districts with APDNARRL > APDRRP, and the green group indicates APDNARRL < APDRRP; the darker the color, the greater the difference).

Further, to identify whether there are significant differences in the socioeconomic indicators of the two groups of cities shown in Figure 7, we conducted a *t*-test on some of the important socioeconomic indicators for the two groups of county-level units (Table 3). A significant difference in the GDP growth rate and the change rate of added value in the tertiary sector can be observed (sig. (2-tailed) <0.05). The mean of the red group (i.e., APDNARRL > APDRRP) is significantly higher than that of the green group (Sig. (1-tailed) <0.05). We also found no significant differences between the two groups of cities in terms of the rate of change of the total population and the rate of change of the added value of the primary and secondary sectors. This potentially indicates that the GDP growth is faster and the employed population (not the total population) brought by the rapid growth of the service industry could promote population density in new rural residential land. This may be related to the fact that the tertiary industry can further attract employed people. According to the survey, the proportion of the employed population in China's tertiary sector significantly exceeds that of the primary and secondary sectors. For example, in China in 2021, the proportions of employed people in the primary, secondary, and tertiary sectors were 22.9%, 29.1%, and 48.0%, respectively (https://www.gov.cn/xinwen/2022-06/08/content_5694541.htm, accessed on 6 June 2023). The rapid growth of the service sector generated further employment in the sector; however, workers could not afford to purchase commercial housing in cities and chose cheaper suburban and rural newly built small property houses (also a type of rural construction land), thus driving the increase in APDNARRL.

Table 3. *t*-test for socioeconomic indicators among counties where APDNARRL > APDRRP and where APDNARRL < APDRRP.

Indicators	Group	Average Value	Equal Variances Assumed	Sig. (2-Tailed)	Sig. (1-Tailed)
IGDP	Red Group Green Group	1111.140 1052.363	Equal variances assumed	0.048	0.028
CRP	Red Group Green Group	−2.265 0.476	Equal variances assumed	0.604	0.302
IAPE	Red Group Green Group	498.216 478.313	Equal variances assumed	0.179	0.090
IASE	Red Group Green Group	1434.415 1303.976	Equal variances assumed	0.272	0.136
IATE	Red Group Green Group	1765.351 1616.987	Equal variances assumed	0.005	0.003

We also found that among the three main types of county-level administrative regions in China, that is, municipal districts, county-level cities, and counties under the jurisdiction of cities, the APDNARRL is lower than the APDRRP by 62.78%, 59.70%, and 57.53%, respectively. This indicates a trend that the higher an area's urbanization rate, the lower the population density of the newly added rural residential patches relative to the original rural residential patches. This could be because areas that have higher levels of urbanization tend to have a higher level of economic development. The driving force of land expropriation is stronger in urban development, which makes the function of new rural residential areas for direct residence weaker, showing economic strength or seeking greater compensation for demolition and other purposes, resulting in, to a certain extent, a decline in the utilization rate of new residential areas.

5.2. Policy Suggestions

Comparing the population densities of the remaining rural residential land between 2000 and 2020 revealed that the population density of 688 county-level units (24.00% of the total) features a declining trend (as shown in Figure 9 for spatial distribution); that is, there is a trend of hollowing out. In particular, Sichuan, Anhui, and Guizhou provinces have the largest number of such districts and counties, with 77, 61, and 59 counties, respectively, reflecting the phenomenon of the hollowing out of the remaining rural residential land. These three provinces also happen to have the largest number of migrant workers in China, and it is clear that the large number of farmers who are going to cities for work is the direct cause of this phenomenon. Therefore, we believe that in areas facing a hollowing out of their population, policy should focus on narrowing the income gap between urban and rural areas, and encouraging labor to return to their home areas of residence for employment. At present, the reason for farmers leaving the countryside and not intending to return is that the gap between urban and rural economic development is too large. The focus of policy should be on guiding rural areas to actively develop secondary and tertiary industries, increase the added value of their industries, promote the development of township enterprises, develop characteristic aspects of village collective economies, such as “one village, one product,” provide a large number of employment opportunities for young and middle-aged people, and reduce the gap between urban and rural per capita disposable income. The government should actively attract college students to return to their hometowns for construction and strongly support this policy by providing funding and land.

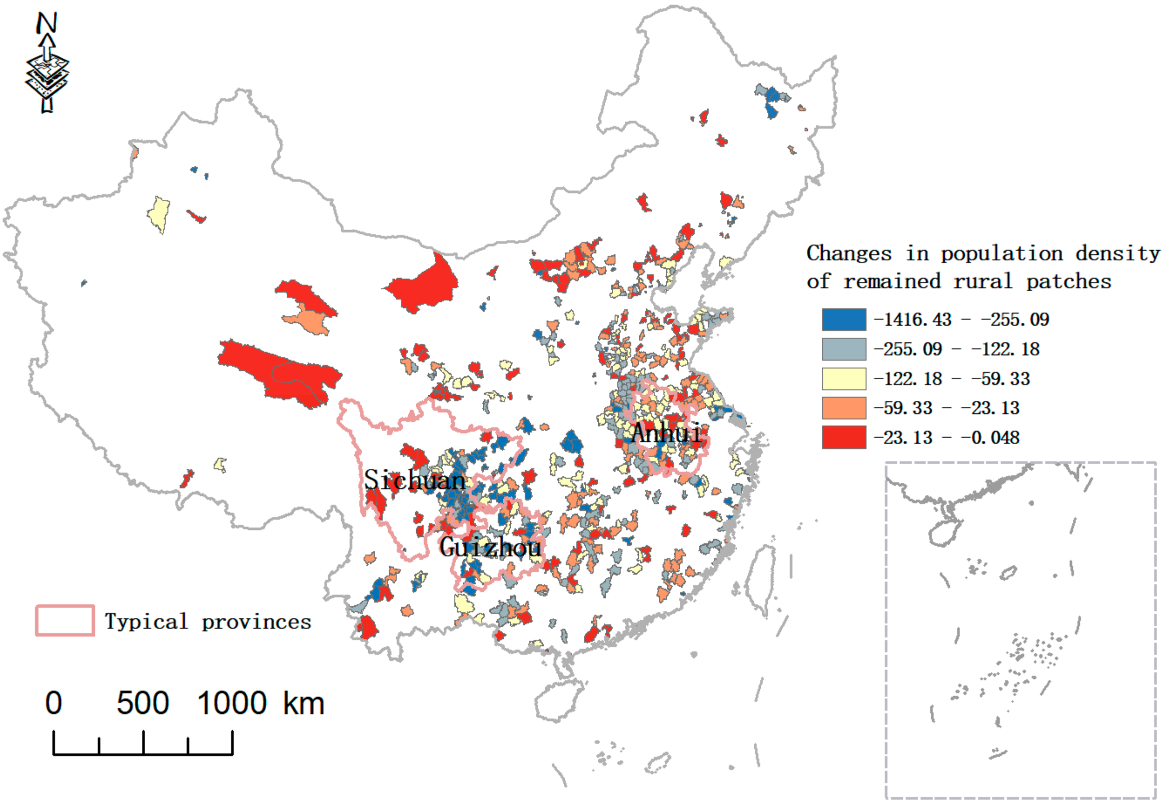

Figure 9. Spatial distribution of county-level units with a declining trend of population density in remaining rural patches.

An extensive and inefficient NARRL is mainly found in Hainan Province, eastern inland areas, and in southern Guangdong Province. In these areas, the unapproved construction of new houses and the development of arable land should be strictly prohibited. The “three rights separation” of ownership, qualification rights, and use rights should be explored for existing residential land, providing guidance and a policy basis for the circulation of rural households’ idle rural residential land, to improve the utilization efficiency of rural residential land, and effectively revitalize rural idle assets to demonstrate the resource and asset values of rural residential land.

In view of the large population density of the remaining rural residential land (with densities of more than 2000 persons/km^2), there is indeed a new demand for rural residential land; these areas are mainly concentrated on the eastern coast, where populations are dense and a township industry has developed. In these areas, policies may be considered to encourage centralized construction, prevent scattered construction, and develop large areas of residential land. At the same time, planned reserved villages (usually central villages) with potential can be sorted out and developed, together with carrying out centralized reconstruction in accordance with the standards of rural communities, thus encouraging the construction of multi-story housing, the building of multi-family rows according to local conditions, strictly controlling single family housing and single courtyards, and gradually realizing the coexistence of population aggregation with intensive land use.

6. Conclusions

As China's economy develops and urbanization advances, the rural population is constantly migrating to cities, and the permanent population in rural areas is decreasing. This trend is increasing year after year, leading to idle houses, low land-use efficiency, and a large amount of land resources being wasted in rural areas. In this context, this study breaks the traditional limitations of statistical data based on administrative units. At the patch scale, high-precision rural residential patches and population distribution data are used to detect ANARR areas in China from 2000 to 2020, as well as the spatial heterogeneity of APDNARRL's driving mechanisms. Regional comparisons, local spatial clustering, and policy recommendations are summarized and analyzed for units at the county level. The main conclusions of this study include the following three points:

(1) The total area of rural residential land in China grew rapidly between 2000 and 2020, from 1.269×10^5 km^2 to 1.445×10^5 km^2. In more than 80% of counties, the area of rural residential land has increased. In terms of spatial distribution, low-value clusters, in terms of ANARR, have formed in the northeast and the vast southwest, while high-value clusters have formed in the North China plain area and the Middle and Lower Yangtze Valley plain area.
(2) The APDNARRL of the new patches was 701.64 person/km^2 for 2000–2020, significantly exceeding the average of 507.23 person/km^2 of the remaining patches. The GDP growth rate and the rate of change of added value in the tertiary sector are important indicators for distinguishing the difference in density between the new and remaining patches. Overall, the APDNARRL in the eastern parts (782 person/km^2) is greater than in the middle regions (552.48 person per km^2), which is greater than in the western parts (634.31 person per km^2) of the country. In particular, the population densities on the two sides of the Hu Huanyong Line are significantly different; the APDNARRL on the left is significantly lower than that of the right.
(3) The spatial heterogeneity of the driving factors of APDNARRL was analyzed using Sichuan and Yunnan provinces in the west and Guangdong province in the east as examples. Of these, the APDNARRL of Sichuan Province is positively correlated with toVillage, POPChange, and FirstAdd; the APDNARRL of Guangdong Province is negatively correlated with toUrban, POPChange, FirstAdd, and SecondAdd. The APDNARRL of Yunnan Province is positively correlated with toUrban and Third, and the APDNARRL of Guangdong Province is negatively correlated with changes in toVillage, toCountryR, POP, and GDP. The spatial heterogeneity of the above provinces reflects the migration logic of populations that have been left behind by the improvement of agricultural efficiency (the primary sector), the development of the processing and manufacturing industry (the secondary sector), and the development of a new eco-tourism industry (the tertiary sector).

It should be acknowledged that we analyzed the two main indicators (ANARR and APDNARRL) relatively independently, but we have not investigated any coupling relationship between them or their correlation with other socioeconomic indicators. This is partly because our research scale is patchy, and socioeconomic indicators are difficult to calculate. Second, the calculation indicators of coupling relationships are usually based on multiple time series; however, our study was limited because of the limited acquisition of data, which were only obtained for one time period (2000–2020) and did not form a multi-period sequence. These deficiencies are data-level constraints. In the future, as more research data sharing and open-access technologies are developed, these deficiencies are expected to be resolved.

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References

1. Pan, W.; Wang, J.; Qin, X.; Li, Y. Trends and types of rural residential land use change in China: A process analysis perspective. *Growth Chang.* **2021**, *52*, 2437–2452. [CrossRef]
2. Li, Y.; Liu, Y.; Long, H.; Cui, W. Community-based rural residential land consolidation and allocation can help to revitalize hollowed villages in traditional agricultural areas of China: Evidence from Dancheng County, Henan Province. *Land Use Policy* **2014**, *39*, 188–198. [CrossRef]
3. Zhang, Z.; Wen, Q.; Liu, F.; Zhao, X.; Liu, B.; Xu, J.; Ju, H. Urban expansion in China and its effect on cultivated land before and after initiating "Reform and Open Policy". *Sci. China Earth Sci.* **2016**, *59*, 1930–1945. [CrossRef]
4. Liu, F.; Zhang, Z.; Zhao, X.; Liu, B.; Wang, X.; Yi, L.; Wang, Y. Urban expansion of China from the 1970s to 2020 based on remote sensing technology. *Chin. Geogr. Sci.* **2021**, *31*, 765–781. [CrossRef]
5. Song, W.; Liu, M. Assessment of decoupling between rural settlement area and rural population in China. *Land Use Policy* **2014**, *39*, 331–341. [CrossRef]
6. Zhou, Z. Landscape changes in a rural area in China. *Landsc. Urban Plan.* **2000**, *47*, 33–38.
7. Yang, R.; Xu, Q.; Long, H. Spatial distribution characteristics and optimized reconstruction analysis of China's rural settlements during the process of rapid urbanization. *J. Rural Stud.* **2016**, *47*, 413–424. [CrossRef]
8. Qu, Y.; Jiang, G.; Yang, Y.; Zheng, Q.; Li, Y.; Ma, W. Multi-scale analysis on spatial morphology differentiation and formation mechanism of rural residential land: A case study in Shandong Province, China. *Habitat Int.* **2018**, *71*, 135–146.
9. Chen, R.; Ye, C.; Cai, Y.; Xing, X.; Chen, Q. The impact of rural out-migration on land use transition in China: Past, present and trend. *Land Use Policy* **2014**, *40*, 101–110. [CrossRef]
10. Shan, Z.; Feng, C. The Redundancy of Residential Land in Rural China: The evolution process, current status and policy implications. *Land Use Policy* **2018**, *74*, 179–186. [CrossRef]
11. Tian, G.; Qiao, Z.; Gao, X. Rural settlement land dynamic modes and policy implications in Beijing metropolitan region, China. *Habitat Int.* **2014**, *44*, 237–246. [CrossRef]
12. Chen, Z.; Liu, X.; Lu, Z.; Li, Y. The expansion mechanism of rural residential land and implications for sustainable regional development: Evidence from the Baota District in China's Loess Plateau. *Land* **2021**, *10*, 172. [CrossRef]
13. Li, J.; Lo, K.; Zhang, P.; Guo, M. Reclaiming small to fill large: A novel approach to rural residential land consolidation in China. *Land Use Policy* **2021**, *109*, 105706. [CrossRef]
14. He, Q.; Tan, S.; Yin, C.; Zhou, M. Collaborative optimization of rural residential land consolidation and urban construction land expansion: A case study of Huangpi in Wuhan, China. *Comput. Environ. Urban Syst.* **2019**, *74*, 218–228. [CrossRef]
15. Pan, H.; Wu, Y.; Choguill, C. Optimizing the rural comprehensive land consolidation in China based on the multiple roles of the rural collective organization. *Habitat Int.* **2023**, *132*, 102743. [CrossRef]
16. Liu, S.; Ma, L.; Yao, Y.; Cui, X. Man-land relationship based on the spatial coupling of population and residential land–A case study of Yuzhong County in Longzhong Loess Hilly Region, China. *Land Use Policy* **2022**, *116*, 106059. [CrossRef]
17. Cai, E.; Chen, W.; Wei, H.; Li, J.; Wang, H.; Guo, Y.; Feng, X. The coupling characteristics of population and residential land in rural areas of China and its implications for sustainable land use. *Sustain. Dev.* **2020**, *28*, 646–656. [CrossRef]
18. Tian, G.; Yang, Z.; Zhang, Y. The spatio-temporal dynamic pattern of rural residential land in China in the 1990s using Landsat TM images and GIS. *Environ. Manag.* **2007**, *40*, 803–813. [CrossRef]
19. Zhou, Y.; Zhong, Z.; Cheng, G. Cultivated land loss and construction land expansion in China: Evidence from national land surveys in 1996, 2009 and 2019. *Land Use Policy* **2023**, *125*, 106496. [CrossRef]
20. Long, H.; Li, T. The coupling characteristics and mechanism of farmland and rural housing land transition in China. *J. Geogr. Sci.* **2012**, *22*, 548–562. [CrossRef]
21. Chen, Z.; Li, Y.; Liu, Y.; Liu, X. Does rural residential land expansion pattern lead to different impacts on eco-environment? A case study of loess hilly and gully region, China. *Habitat Int.* **2021**, *117*, 102436. [CrossRef]
22. Shi, L.; Wang, Y. Evolution characteristics and driving factors of negative decoupled rural residential land and resident population in the Yellow River Basin. *Land Use Policy* **2021**, *109*, 105685. [CrossRef]
23. Qu, Y.; Zhan, L.; Jiang, G.; Ma, W.; Dong, X. How to Address "Population Decline and Land Expansion (PDLE)" of rural residential areas in the process of Urbanization: A comparative regional analysis of human-land interaction in Shandong Province. *Habitat Int.* **2021**, *117*, 102441. [CrossRef]
24. Liu, Y.; Liu, Y.; Chen, Y.; Long, H. The process and driving forces of rural hollowing in China under rapid urbanization. *J. Geogr. Sci.* **2010**, *20*, 876–888. [CrossRef]

25. Zhu, S.; Kong, X.; Jiang, P. Identification of the human-land relationship involved in the urbanization of rural settlements in Wuhan city circle, China. *J. Rural Stud.* **2020**, *77*, 75–83. [CrossRef]
26. Lai, L.; Huang, X.; Yang, H.; Chuai, X.; Zhang, M.; Zhong, T.; Thompson, J. Carbon emissions from land-use change and management in China between 1990 and 2010. *Sci. Adv.* **2016**, *2*, e1601063. [CrossRef]
27. Anselin, L. Local indicators of spatial associations—LISA. *Geogr. Anal.* **1995**, *27*, 93–115. [CrossRef]
28. O'Sullivan, D. Geographically weighted regression: The analysis of spatially varying relationships. *Geogr. Anal.* **2003**, *35*, 272–275. [CrossRef]
29. Li, Y.; Liu, X. How did urban polycentricity and dispersion affect economic productivity? A case study of 306 Chinese cities. *Landsc. Urban Plan.* **2018**, *173*, 51–59. [CrossRef]
30. Feng, Y.; Yang, Q. Evolution characteristics and its driving force of rural residential land at village level during 1980-2012. *Trans. Chin. Soc. Agric. Eng.* **2016**, *32*, 280–288.
31. Zhou, Y.; Li, X.; Liu, Y. Land use change and driving factors in rural China during the period 1995–2015. *Land Use Policy* **2020**, *99*, 105048. [CrossRef]
32. Feng, C.; Zhang, H.; Xiao, L.; Guo, Y. Land use change and its driving factors in the rural–urban fringe of Beijing: A Production–Living–Ecological perspective. *Land* **2022**, *11*, 314. [CrossRef]
33. Chi, G.; Ventura, S.J. Population change and its driving factors in rural, suburban, and urban areas of Wisconsin, USA, 1970–2000. *Population* **2011**, *12*, 13. [CrossRef]
34. Wang, D.; Zhu, Y.; Zhao, M.; Lv, Q. Multi-dimensional hollowing characteristics of traditional villages and its influence mechanism based on the micro-scale: A case study of Dongcun Village in Suzhou, China. *Land Use Policy* **2021**, *101*, 105146. [CrossRef]
35. Wen, Q.; Li, J.; Ding, J.; Wang, J. Evolutionary process and mechanism of population hollowing out in rural villages in the farming-pastoral ecotone of Northern China: A case study of Yanchi County, Ningxia. *Land Use Policy* **2023**, *125*, 106506. [CrossRef]
36. Liu, Z.; Liu, S.; Jin, H.; Qi, W. Rural population change in China: Spatial differences, driving forces and policy implications. *J. Rural Stud.* **2017**, *51*, 189–197. [CrossRef]
37. Li, C.; Wu, K. Driving forces of the villages hollowing based on geographically weighted regression model: A case study of Longde County, the Ningxia Hui Autonomous Region, China. *Nat. Hazards* **2017**, *89*, 1059–1079. [CrossRef]
38. Zhang, H.; Zhang, S.; Liu, Z. Evolution and influencing factors of China's rural population distribution patterns since 1990. *PLoS ONE* **2020**, *15*, e0233637. [CrossRef]
39. Liu, Y.; Shu, L.; Peng, L. The Hollowing Process of Rural Communities in China: Considering the Regional Characteristic. *Land* **2021**, *10*, 911. [CrossRef]
40. Ma, W.; Jiang, G.; Wang, D.; Li, W.; Guo, H.; Zheng, Q. Rural settlements transition (RST) in a suburban area of metropolis: Internal structure perspectives. *Sci. Total Environ.* **2018**, *615*, 672–680. [CrossRef]