



What Is the Impact of the Establishment of Natural Reserves on Rural Residential Land? An Empirical Study From Hunan Province, China

Yuanlai Wu¹, Houtian Tang¹, Ping Jiang^{2*} and Jinxiu Chen³

¹School of Public Administration, Central South University, Changsha, China, ²School of Resource and Environmental Sciences, Wuhan University, Wuhan, China, ³School of Public Administration, Guangxi University, Nanning, China

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*Correspondence:

Ping Jiang
longkangkang@whu.edu.cn

Specialty section:

This article was submitted to
Land Use Dynamics,
a section of the journal
Frontiers in Environmental Science

Received: 31 March 2022

Accepted: 06 May 2022

Published: 24 June 2022

Citation:

Wu Y, Tang H, Jiang P and Chen J
(2022) What Is the Impact of the
Establishment of Natural Reserves on
Rural Residential Land? An Empirical
Study From Hunan Province, China.
Front. Environ. Sci. 10:909554.
doi: 10.3389/fenvs.2022.909554

The rural residential land (RRL) in natural reserves has been deeply transformed due to the disturbance constrained by ecological protection policies. Exploring the distribution characteristics and driving factors of RRL in natural reserves and non-natural reserves will help to promote the governance of land space and alleviate the contradiction of land use. Therefore, taking 122 county-level administrative regions in Hunan Province as an example, this article analyzes and compares the spatiotemporal distribution characteristics of RRL in natural reserves and non-natural reserves by using land use change dynamics, nuclear density analysis, the transfer matrix model, and the ordinary least-squares model and explores how the establishment of natural reserves affects the RRL area change. The results show that (1) the overall RRL area in Hunan changed from 171,162.27 hm² in 2000 to 169,914.6 hm² in 2020, with a total reduction of 1,247.67 hm² and a decrease of 0.73%, and the distribution of the RRL area change presented a hot trend in the northeast and a cold trend in the southwest. (2) The occupation of urban construction land is the main reason for the reduction in RRL area, and the transformation of cultivated land and forestland into RRL is the main source of the increase in RRL area. (3) During 2000–2020, the overall RRL in natural reserves increased by 1,538.37 hm², with an increase of 0.11%, while the overall RRL in non-natural reserves decreased by 2,786.04 hm², with a decrease of 0.14%. (4) The establishment of natural reserves has a significant negative correlation with the area of RRL in 2000, 2010, and 2020, indicating that the establishment of natural reserves can limit the growth speed of the RRL area to a certain extent, but is affected by factors such as economic development and rural population growth; it cannot directly promote the overall reduction of RRL area. The results of this study can provide a reference for decision-making related to the spatial structure optimization of natural reserves and non-natural protected RRL and the coordinated development of urban and rural areas.

Keywords: rural residential land, natural reserves, driving factors, China, spatiotemporal variation characteristics

1 INTRODUCTION

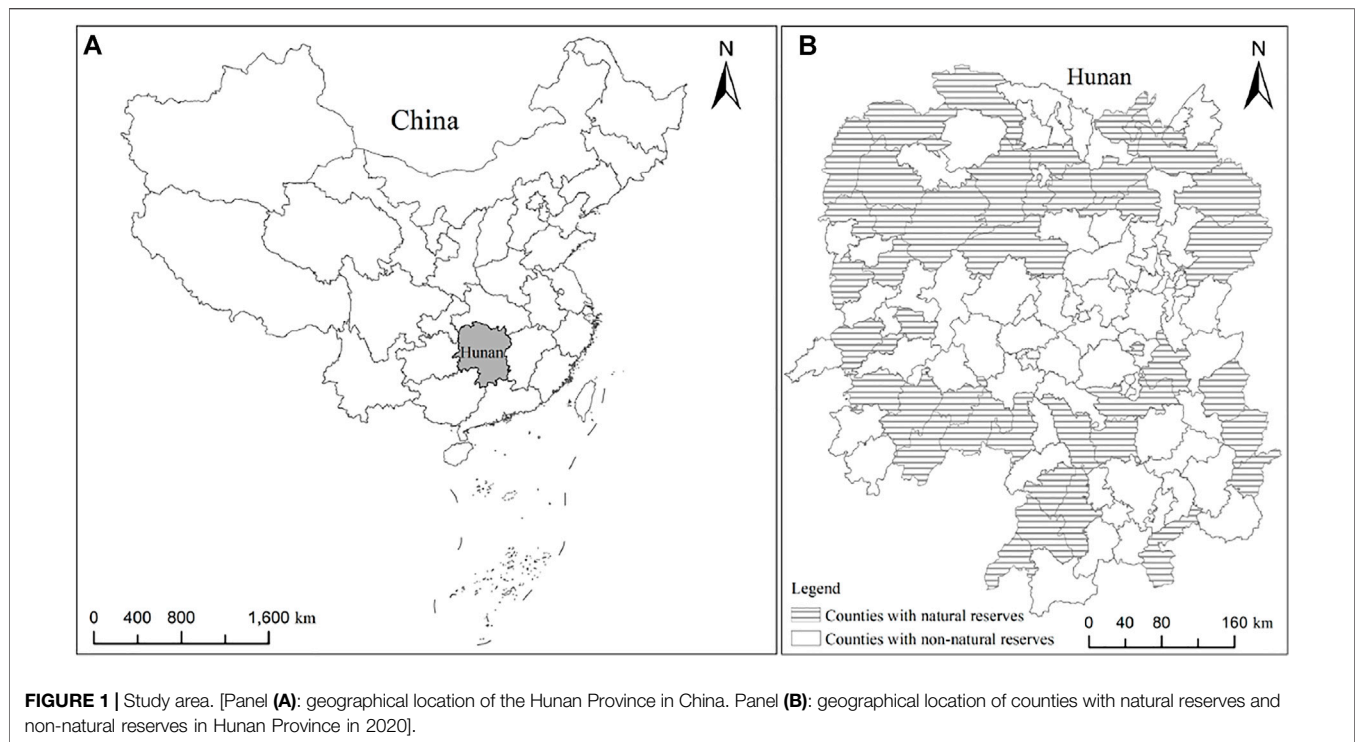
The contrast between urban expansion and rural recession is becoming increasingly serious (Long et al., 2012; Bai et al., 2014; Liu and Li, 2017; Li K. et al., 2021). As a very important land use type in rural areas, rural residential land (RRL) is an important carrier of farmers' production and life (Chen et al., 2019; Yang R. et al., 2019). Since its emergence in the specific natural and cultural environment, it has been affected by the natural increase and decrease in the rural population and the slow growth of the rural economy (Qu et al., 2017). However, with the rapid development of rural economies around the world, the functions and layout of rural settlements have changed significantly and are evolving toward heterogeneity and non-simplification (Zhu et al., 2014; Li G. et al., 2020; Rosner and Wesołowska, 2020). Meanwhile, due to the interaction of historical origin, customs, resource endowment, transportation convenience, and other factors, the spatial layout of RRL is mostly formed by the independent selection and lack of unified planning (Shcherbina and Gorbenkova, 2019; Wang and Zhang, 2021). This continuous disorderly expansion also exacerbates the fragmentation of RRL (Li G. et al., 2020). During the early stages, developed countries such as South Korea and Germany were the first to realize the importance of spatial planning of rural settlements and conducted the consolidation movement of RRL, including the "New Village Movement" in South Korea (Suh, 2015) and the "Village Renewal" in Germany (Zasada and Pierr, 2015). Moreover, with the gradual prominence of the contradiction between man and land, developing countries such as China, Uzbekistan, and Myanmar have paid more attention to the spatial planning of RRL and have issued corresponding policies (Conrad et al., 2015; Hoffman-Hall et al., 2019; Zhou et al., 2021). However, unlike developed countries, developing countries have some disadvantages in experience, technology, and capital, which makes it difficult to realize the consolidation of RRL (Njoh, 2011; Trukhachev, 2015; Rosner and Wesołowska, 2020). Therefore, promoting RRL consolidation has always been a thorny problem faced by China and other countries lacking land resources, and it is of great significance to make the rational use of RRL and alleviate the contradiction between land supply and demand (Li et al., 2014; Kong et al., 2021).

In consideration of social and economic development, China's urban construction and development are relatively rapid, and relevant guidance planning and supporting infrastructure construction are also relatively abundant (Fernández, 2007; Guan et al., 2018; Li Y. et al., 2020). However, the construction and development of RRL lack planning guidance, which leads to the increasingly prominent phenomena of scattered layout, high degree of fragmentation, low utilization efficiency and serious illegal land occupation of RRL (You and Chen, 2019; Wen et al., 2020; Li J. et al., 2021). Moreover, it has further derived problems such as the extensive use of RRL, the lack of living infrastructure, and the fragile ecological environment, which have led to the continuous decline of rural development potential (Wu et al., 2017; Li Y. et al., 2018; Ristić et al., 2019). Nevertheless, with the improvement of rural

residents' income level, lifestyle transformation, and rural cultural progress, rural residents have also put forward new requirements for production, living conditions, and environment quality (Zhou et al., 2020; Deng et al., 2021). Using the Hunan Province of China as an example, statistical yearbooks of the Hunan Provincial Bureau of Statistics, the urbanization rate increased from 29.75% in 2000 to 58.76% in 2020, with extremely rapid growth. In the context of rapid urbanization, the nonagricultural rural population has led to a significant reduction in the rural resident population; a large amount of rural construction land has been gradually abandoned and left idle, and the abandonment of houses in villages has become very serious, which further intensifies the sharp contradiction between the current tight supply of urban construction land and the idle waste of land resources in rural settlements (Li L. et al., 2020; Huang et al., 2020; Zhu et al., 2020).

Previous studies have conducted rich theoretical research and practical explorations of RRL (Linard et al., 2012; Phokaides, 2018; Li S. et al., 2021; Nandi and Mistri, 2022). Scholars generally believe that the spatial distribution and evolution of rural settlements are the result of the comprehensive action of physical and geographical conditions and socioeconomic development (Yu et al., 2018; Li G. et al., 2020). The scale, shape, distribution, and other characteristics of rural settlements are closely related to natural conditions such as landform, soil, hydrology, climate, and vegetation and are affected by factors such as government regulation, economic development, urbanization level, traffic conditions, and scientific and technological strength (Linard et al., 2012; Liu et al., 2016; Tu et al., 2018; Cyriac and Firoz, 2022). Meanwhile, in a short period of time, RRL changes are more affected by human factors (Wang and Zhang, 2021). Specifically, in the existing studies, the research contents of rural settlements are relatively diversified, mainly focusing on the characteristics of spatiotemporal evolution and its driving factors, spatial layout optimization, functions, etc., gradually enriching the content system of rural settlement research (Heng et al., 2021; Tan et al., 2021). Moreover, the research on RRL also presents different research scales, including mainly analyses of the overall evolution and driving mechanism of RRL at the macroscale, explorations of the structure, function, and spatial layout optimization of RRL, and the gradual transformation from the national and provincial macroscale to the shrinking of the county, town, and even village at the microscale (Li G. et al., 2018; Chirisa, 2021). In addition, the research methods on rural settlements are diverse, mainly involving multifactor comprehensive evaluation methods, spatial econometric analysis, spatial autocorrelation, geographic information systems, geographic detectors, and other methods and models, revealing the general or local characteristics of the research content of rural settlements (Yang et al., 2019a; Gosch et al., 2021; Kong et al., 2021).

However, only a few scholars have conducted research on RRL in the natural reserve. Among them, Yao and Xie (2016) believed that the scale of RRL in the natural reserve should be the smallest, while the scale of ecological land should be the largest. Abelairas-Etxebarria and Astorkiza (2012) compared the difference in land



prices within and outside the natural reserve and found that the policy of establishing a natural reserve has a highly restrictive effect on land transaction volume and land use change. Martín and Chehébar (2001) researched indigenous communities and RRL inhabited by migrant populations in the federal protected area system of Argentinian Patagonia and found that the growth of RRL directly threatened the ecological environment. Previous studies have neglected to explore and compare the spatiotemporal variation characteristics of RRL in natural reserves and non-natural reserves. As an area designated by relevant government departments to protect special ecosystems for scientific research, natural reserves have played an important role in soil and water conservation, environmental improvement, biodiversity protection, and ecological balance (Zhou and Chen, 2006; Yang et al., 2019b). In the natural reserve, to protect the ecological environment, the government has issued a variety of policies and measures to encourage the relocation of residents in the ecological reserve or limit the new expansion of existing rural settlements, which makes the rural settlements in the natural reserve form a completely different spatiotemporal evolution characteristic (Yu et al., 2018). Therefore, comparing the spatiotemporal evolution characteristics of RRL in the natural reserves and non-natural reserves can not only enrich the research topics related to RRL in the natural reserve but also provide policy suggestions for the management organization of the natural reserve to optimize and reduce the land use of RRL.

Therefore, we explore the differences in the spatiotemporal evolution characteristics, change intensity, and driving factors of RRL between natural reserves and non-natural reserves. Based on the relevant spatial and panel data of rural settlements in natural reserves and non-natural reserves of Hunan Province, China, and

combined with the methods of land use dynamics, kernel density analysis, transfer matrix model, and ordinary least-squares model, this article intends to solve the following issues. (1) What are the overall spatiotemporal change characteristics of RRL in Hunan Province? (2) What are the spatiotemporal evolution characteristics of RRL in natural reserves and non-natural reserves? What is the difference? (3) What is the impact of the establishment of natural reserves on the spatiotemporal changes in RRL? Moreover, we believe that the results of this study can provide a decision-making reference for the spatial structure optimization of natural reserves and non-natural protected RRL and the coordinated development of urban and rural areas.

2 MATERIALS AND METHODS

2.1 Study Area

China's Hunan Province governs 14 prefecture-level cities (including autonomous prefectures), with a total of 122 county-level administrative regions (including county-level cities, districts, and autonomous counties, uniformly called counties), and is located in the middle reaches of the Yangtze River (Figure 1). Superior natural conditions have created the characteristics of rich animals and plant biodiversity and a beautiful natural landscape in Hunan Province (Ding et al., 2022; Fan et al., 2022). Provincial or national natural reserves in Hunan Province were distributed in 27, 42, and 44 counties in 2000, 2010, and 2020, respectively. By 2021, the permanent resident population of Hunan Province was 66.44 million, and the regional gross domestic product was 4,606.3 billion RMB. With the rapid development of the social economy, the disposable income of farmers has been significantly improved,

and its urbanization rate has increased from 29.75% in 2000 to 58.76% in 2020. However, due to the geographical conditions, the industrial structure and economic development of various regions in Hunan Province are quite different, resulting in the structure and functional space of RRL being significantly differentiated, which is mainly reflected in the scattered layout of RRL, a high degree of fragmentation, and obvious differences in hollowing (Tang et al., 2018; Han et al., 2021), especially in natural reserves and non-natural reserves. Therefore, this article selects Hunan Province with the characteristics of typical natural reserves and non-natural reserves as the research area, which has strong practical significance for the multifunctional promotion and coordinated optimization of RRL.

2.2 Data Sources

The land use data and the provincial, municipal, and county-level administrative division boundary data of Hunan in this article are from the Resource and Environmental Science and Data Center of the Institute of Geographical Sciences and Resources, Chinese Academy of Sciences (<https://www.resdc.cn/>). Among them, the land use data cover the three periods of 2000, 2010, and 2020, with a 30 m resolution. Using the reclassify function of ArcGIS10.5 software, the land types were reclassified into eight categories: cultivated land, forestland, grassland, water area, urban construction land, RRL, other construction land, and unused land; the area data of each land type were obtained. In addition, the rural population, economic, and social data involved in the study are mainly from the statistical yearbooks of the Hunan Provincial Bureau of Statistics (<http://tj.hunan.gov.cn/>). On this basis, ArcGIS10.5 software is used to form the basic database for the study of RRL area change in Hunan Province through the spatial matching and link between attribute data and county-level administrative units, which lays the data foundation for this study.

2.3 Research Methods

2.3.1 Dynamic Degree of Land Use Change

The dynamic degree model of land use change is the quantitative change of a certain land use type in the study area during the study period (Stumpf et al., 2018). Through the dynamic degree of land use change, the area and change speed of various land types in the region at different time points can be obtained, the general change trend and structural evolution trend in different research periods can be grasped, and the core of the model is reflected by land use transfer flow (Gallant et al., 2004; Öztürk et al., 2013). This article uses this model to analyze the spatiotemporal changes in RRL in Hunan Province. The calculation formula is as follows:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

where K represents the dynamic degree of RRL change in the study period; U_a represents the initial value of the RRL area; U_b represents the final value of the RRL area; and T is the period time of the study.

2.3.2 Transfer Matrix Model

The transfer matrix model can effectively describe the structural characteristics and transformation direction of land use change in

the study area and can also analyze the change characteristics of the spatial conflict level of various land types during different periods (Romero-Calcerrada and Perry, 2004; Xue et al., 2018). This article uses this model to analyze the direction and quantity of mutual transformation between RRL and other land use types in Hunan Province. The calculation formula is as follows:

$$T_{ij} = \begin{bmatrix} a_{11} & \dots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \dots & a_{nn} \end{bmatrix} \quad (2)$$

where n represents the number of land use types; i and j represent the land use types at the beginning and end of the study periods, respectively; and T_{ij} represents the area converted from land use type i to land use type j during the study period.

2.3.3 Kernel Density Estimation Method

Kernel density estimation is a nonparametric calculation method that usually uses the built-in spatial analysis tool of ArcGIS10.5 software to define the nearest-neighbor object and realize the measurement of density distribution (Elgammal et al., 2002). At present, the kernel density estimation method has been applied to the study of spatial distribution patterns and change characteristics of various land use types (Gong et al., 2019). The higher the value of kernel density is, the greater the distribution density of RRL (Lin et al., 2022). This method mainly analyzes the spatiotemporal distribution pattern and change characteristics of RRL in natural reserves and non-natural reserves in Hunan Province. The calculation formula is as follows:

$$f_x = \frac{1}{nh} \sum_{i=1}^n k\left(\frac{x - x_i}{h}\right) \quad (3)$$

where f_x represents the estimated value of the kernel density of the RRL distribution; n represents the number of rural residential plots; h represents the bandwidth or smoothing parameter; k represents the kernel density function; and $x - x_i$ represents the distance between the measured x -th rural residential plot and the sample rural residential plot x_i .

2.3.4 Getis-Ord G_i^* Hot-Spot Analysis

Getis-Ord G_i^* hot-spot analysis is used to measure the spatial clustering intensity between each unit in the study area and its surrounding units. It mainly detects whether each geographical element belongs to a high-value or low-value aggregation mode in space by calculating the relationship between the geographical attributes of a location and the geographical attributes of its adjacent locations (Gao et al., 2019; Tan and Guan, 2021). This article uses this method to explore the degree of change and difference in RRL between natural reserves and non-natural reserves in Hunan Province. The calculation formula is as follows:

$$G_i^* = \frac{\sum_{j=1}^n w_{ij} X_j}{\sum_{j=1}^n X_j} \quad (4)$$

where G_i^* represents the statistical value of Getis-Ord; X_j represents the element attribute value of the j -th spatial unit; n represents the total number of rural settlements; and w_{ij} represents the spatial weight matrix. If the statistical value of G_i^* is positive and significant, it indicates that the value around the detected point is relatively high

TABLE 1 | Factors influencing RRL.

Target layer	Index layer	Calculation method (data source)	Variable type	Unit
Natural reserves	Whether there are natural reserves	List of natural reserves in Hunan Province (http://lyj.hunan.gov.cn/lyj/ztlz/gdzl/zrbhq/201512/t20151227_2587443.html)	D	—
Urban expansion	Per capita investment in fixed assets	Total investment in fixed assets/number of permanent residents	C	RMB
	Per capita investment in real estate development	Total investment in real estate development/number of permanent residents	C	RMB
Economic growth	Urban construction land area	https://www.resdc.cn/	C	m ²
	Per capita gross domestic product	Total regional gross domestic product/number of permanent residents	C	RMB
	The proportion of primary industry	Primary industry value/total regional gross domestic product	C	%
Rural development	Per capita fiscal expenditure	Total regional financial expenditure/number of permanent residents	C	RMB
	Per capita crop sowing area	The total sown area of crops/number of permanent residents	C	m ²
	Per capita cultivated land area	Total cultivated land area/number of permanent residents	C	m ²
	Per capita disposable income of farmers	Hunan statistical yearbook (http://tjj.hunan.gov.cn/)	C	RMB
	Rural resident population	Hunan statistical yearbook (http://tjj.hunan.gov.cn/)	C	People

Notes: D represents dichotomous, C represents continuous.

and belongs to a high-value spatial agglomeration (hot-spot area). If the statistical value of G_i^* is negative and significant, it indicates that the value around the detected point is relatively low and belongs to low-value spatial agglomeration (cold-spot area).

2.3.5 Ordinary Least-Squares Method

The ordinary least-squares method is used to evaluate the relationship between two or more element attributes. The principle of this method is to minimize the sum of squares of errors between the predicted value and the actual observed value of the regression empirical model (Sanchez, 2020; Liang and Qamruzzaman, 2022). This method is mainly used to explore the factors affecting the change in RRL. This article uses the change in the RRL area as the dependent variable and determines the model with better fitting through the forward stepwise regression method. The MNL-1 model only adds the influencing factors of the RRL area change, while the MNL-2 model adds the interactive term based on the MNL-1 model. The calculation formula is as follows:

$$Y_i = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + \dots + \beta_k X_{ki} + \varepsilon_i \quad (5)$$

The global parameter estimation vector can be obtained by using the ordinary least-squares model

$$\beta = (X^T X)^{-1} X^T Y \quad (6)$$

where β represents the parameter-estimated value vector influence coefficient; X represents the matrix composed of the observed values of the respective variables; Y represents the dependent variable; and ε_i is the random disturbance term.

2.4 Research Index System

The area change in RRL is closely related to natural, socioeconomic, land management, and other factors (Liu et al., 2013; Li G. et al., 2018, Li et al., 2020 G.). Based on the actual situation of Hunan Province and the availability of data, referring to previous research results (Zhou et al., 2013; Ristić et al., 2019; Wang and Zhang, 2021), and following the principles of scientificity and comprehensiveness, this article takes the area of RRL as a dependent variable. Meanwhile,

four dimensions, including natural reserves, urban expansion, economic growth, and rural development situation, were selected, including 11 dependent variable indicators as the influencing factors of the change in the RRL area (Table 1).

First, due to the high intensity of environmental regulation policies within the scope of natural reserves (Zhou et al., 2014), the delimitation of natural reserves may have a significant impact on the change in RRL areas. The indicator of whether there are natural reserves set in this article only explores whether the county-level administrative units have provincial or national nature reserves.

Second, there is a certain contradiction between urban expansion and RRL because the rapid expansion of urban areas will accelerate the urbanization process of rural populations and may reduce the demand area of RRL (Liu et al., 2017; Yang et al., 2018). Therefore, the urban expansion dimension in this article includes three indicators: per capita investment in fixed assets, per capita investment in real estate development, and the urban construction land area. Among them, the per capita investment in fixed assets represents the local construction investment level, the per capita investment in real estate development represents the local investment level in urban housing construction, and the urban construction land area represents the actual situation of local urban expansion.

Third, rapid economic growth can increase the per capita gross domestic product, increase government fiscal expenditure, adjust the structure of local industries, promote the improvement of the speed of rural economic development, and affect the number of people engaged in agricultural production, resulting in affecting the change rate in the RRL area (Ma et al., 2018; Qu et al., 2021). Therefore, the economic growth dimension of this article also includes three indicators: per capita gross domestic product, the proportion of primary industry, and per capita fiscal expenditure. Among them, the per capita gross domestic product represents the economic development of the research county, the proportion of the primary industry represents the importance of the primary industry in the local industrial structure, and the per capita fiscal expenditure represents the fiscal expenditure capacity of the local government.

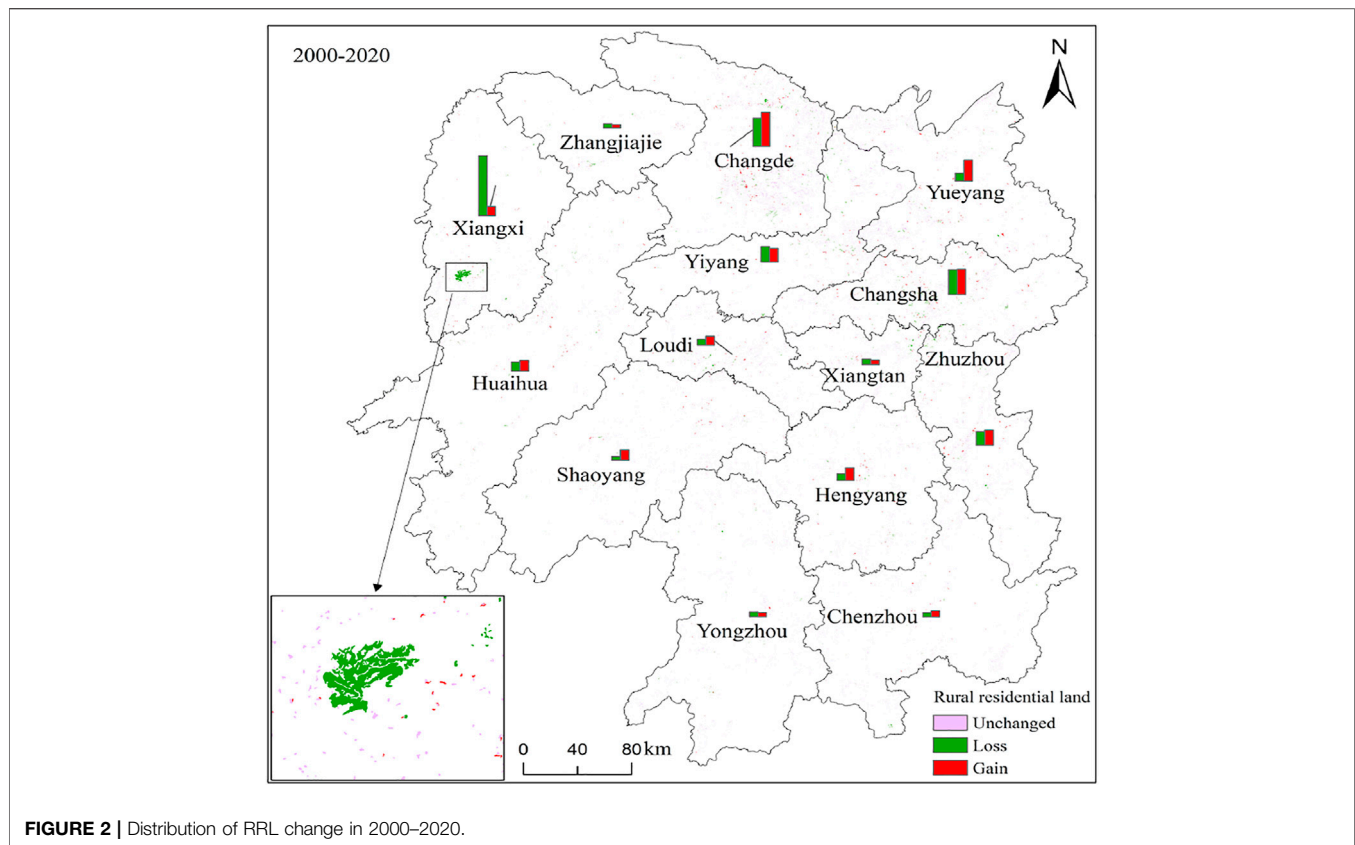


FIGURE 2 | Distribution of RRL change in 2000–2020.

Finally, there is a strong correlation between rural development and the change in the RRL area. Generally, areas with better rural development have greater population mobility, and farmers are more likely to change their place of residence due to work, transportation, and other factors (Sun et al., 2021). The dimensions of rural development in this article mainly include four indicators: per capita crop sowing area, per capita cultivated land area, per capita disposable income of farmers, and rural resident population. Among them, the per capita sown area of crops represents the agricultural planting status of the local rural surplus labor force, the per capita cultivated land area represents the cultivated land resources owned by local farmers to carry out basic agricultural production, the per capita disposable income of farmers represents the development degree of the local rural economy, and the rural resident population represents the number of people living in rural areas for a long time.

3 RESULTS

3.1 Change Characteristics of Rural Residential Land in Hunan Province

3.1.1 Spatiotemporal Characteristics of Rural Residential Land Change at the Macroscale

Based on the area change transfer matrix between RRL and other land types from 2000 to 2020 (**Supplementary Appendix**) and the spatiotemporal change distribution characteristic of RRL

(**Figure 2**), the RRL area decreased from 171,162.27 hm^2 in 2000 to 169,914.60 hm^2 in 2020, with a total reduction of 1,247.67 hm^2 and a decrease of 0.73%. The reason can be found that in 2000–2020, although RRL occupied the largest area of cultivated land, the net occupied area of cultivated land was as high as 5,773.32 hm^2 . However, due to a large number of RRLs occupied by urban and other construction lands, the RRL showed a downward trend from 2000 to 2020. This phenomenon can also be confirmed in **Figure 2**. The red spots (representing the gain of RRL) are significantly greater than the green spots (representing the loss of RRL). Specifically, the RRL area decreased by 5,165.10 hm^2 in 2000–2010; that is, the RRL area transferred out at this stage was greater than the area transferred in, while the RRL area increased by 3,917.43 hm^2 in 2010–2020. The main reason is that the urban expansion was relatively rapid, requiring higher amounts of urban construction land, resulting in a large amount of RRL occupied by urban construction land in 2000–2010. Moreover, due to the vigorous implementation of policies such as converting farmland to forestland during that time, some areas that reclaimed RRL were transferred to forestland. In 2010–2020, due to the stricter control over the expansion of urban construction land, the occupation of urban construction land to RRL was effectively alleviated. However, due to the reduction in the RRL area in 2000–2010 and the strong demand of farmers for RRL, a large amount of cultivated land and forestland around RRL was occupied. In addition, the distribution of RRL is too scattered, which is not obvious in **Figure 2**, but the

TABLE 2 | RRL change in prefecture-level cities from 2000 to 2020.

Cities	2000–2010		2010–2020		2000–2020	
	Area change (hm ²)	Change dynamics	Area change (hm ²)	Change dynamics	Area change (hm ²)	Change dynamics
Changsha	-28.62	-0.02%	87.39	0.07%	58.77	0.05%
Zhuzhou	-555.48	-0.45%	701.91	0.60%	146.43	0.12%
Xiangtan	-133.11	-0.24%	46.71	0.09%	-86.4	-0.16%
Hengyang	123.84	0.09%	381.51	0.29%	505.35	0.38%
Shaoyang	450.81	0.39%	137.97	0.12%	588.78	0.51%
Yueyang	552.51	0.34%	579.15	0.34%	1131.66	0.69%
Changde	-690.84	-0.26%	1186.92	0.46%	496.08	0.19%
Zhangjiajie	-115.29	-0.43%	37.26	0.15%	-78.03	-0.29%
Yiyang	-423.63	-0.35%	261	0.22%	-162.63	-0.13%
Chenzhou	-61.56	-0.04%	243.99	0.17%	182.43	0.13%
Yongzhou	-65.43	-0.04%	12.06	0.01%	-53.37	-0.03%
Huaihua	49.5	0.06%	110.61	0.12%	160.11	0.18%
Loudi	115.47	0.14%	165.33	0.20%	280.8	0.35%
Xiangxi	-4383.27	-4.12%	-34.38	-0.06%	-4417.65	-4.15%
Total	-5165.1	-0.30%	3917.43	0.24%	-1247.67	-0.07%

overall density is high in the northeast and low in the southwest. The reason for this scattered layout may be that northeastern Hunan is a traditional agricultural area with high residential density.

3.1.2 Spatiotemporal Characteristics of Rural Residential Land Change at the Microscale

By analyzing the changes in the RRL area in 14 prefecture-level cities in Hunan Province from 2000 to 2020 (Table 2), it can be found that the RRL area in different prefecture-level cities shows different changes, and the changes in RRL in the same prefecture-level city at different stages also show significant differences. It is worth noting that in 2000–2010 and 2010–2020, excluding the dynamic change degree of the RRL area in Xiangxi, which has been in a negative growth state, other prefecture-level cities showed an initial decreasing and then increasing or continuously increasing trend. Specifically, the reduction rate of the residential land area in Xiangxi in 2000–2020 is much higher than that in other prefecture-level cities, and the dynamic degree of the change of the RRL area in this prefecture in 2000–2010 indicates that the comprehensive improvement intensity of RRL in Xiangxi during 2000–2010 is high, which causes the area of RRL in this stage to show a significant trend of reduction. In addition, among the other 13 prefecture-level cities, the overall change dynamics of RRL in Xiangtan, Zhangjiajie, Yiyang, and Yongzhou showed negative growth in 2000–2020, indicating that the area of RRL in these cities decreased. In contrast, the dynamic change degree of the RRL area in Changsha, Zhuzhou, Hengyang, Shaoyang, Yueyang, Changde, Chenzhou, Huaihua, and Loudi positively increased and showed a small growth trend in 2000–2020.

The cold-spot and hot-spot analyses of RRL identify the spatial cluster distribution of high- and low-function values based on the spatial distribution of each function value domain. The hot-spot analysis tool in ArcGis10.5 software is used to

identify the statistically significant distribution characteristics of cold and hot spots in the current situation and changes in the RRL area in 122 counties of Hunan Province. Among them, the value of G_i^* is divided into five categories using the natural break method in ArcGis10.5 software, which are named hot-spot, sub-hot-spot, insignificant, sub-cold-spot, and cold-spot from high to low (Figure 3). There was little difference in the distribution of cold and hot spots in the RRL area of 122 counties in Hunan Province in 2000, 2010, and 2020. The overall performance is that it is hot in the northeast and cold in the southwest. However, the three phases of data are mainly in areas with insignificant clustering characteristics. Specifically, the hot-spots are mainly distributed in the urban counties of Changsha, Changde, Yiyang, Yueyang, and Zhuzhou and the sub-hot-spots are mainly distributed in northern Changde, western Yueyang, and southern Zhuzhou, which shows that the RRL area in these areas increased faster and that farmers have a strong demand for RRL. The sub-cold-spot areas are mainly concentrated in eastern–western Hunan, eastern Huaihua, and northern Xiangtan. Cold-spot areas are mainly concentrated in western Huaihua and eastern Xiangtan, indicating that the RRL area in these areas decreased faster. In terms of the dynamic degree of change in the RRL area at each stage, the hot-spot and sub-hot-spot areas in 2000–2010 were mainly concentrated in the east of Shaoyang, the east and south of Hengyang, while they were mainly distributed in the middle of Changde, the southeast of Hengyang, and the middle of Zhuzhou in 2010–2020, indicating that the growth rate of the RRL area in Hunan Province showed significant differences in different periods. The cold-spot and sub-cold-spot areas were mainly concentrated in the east of Xiangtan, the middle of Changsha, the north of Zhuzhou, and the southwest of western Hunan in 2000–2010, while it was mainly concentrated in the southwest of western Hunan in 2010–2020, indicating that the decreasing trend of the RRL

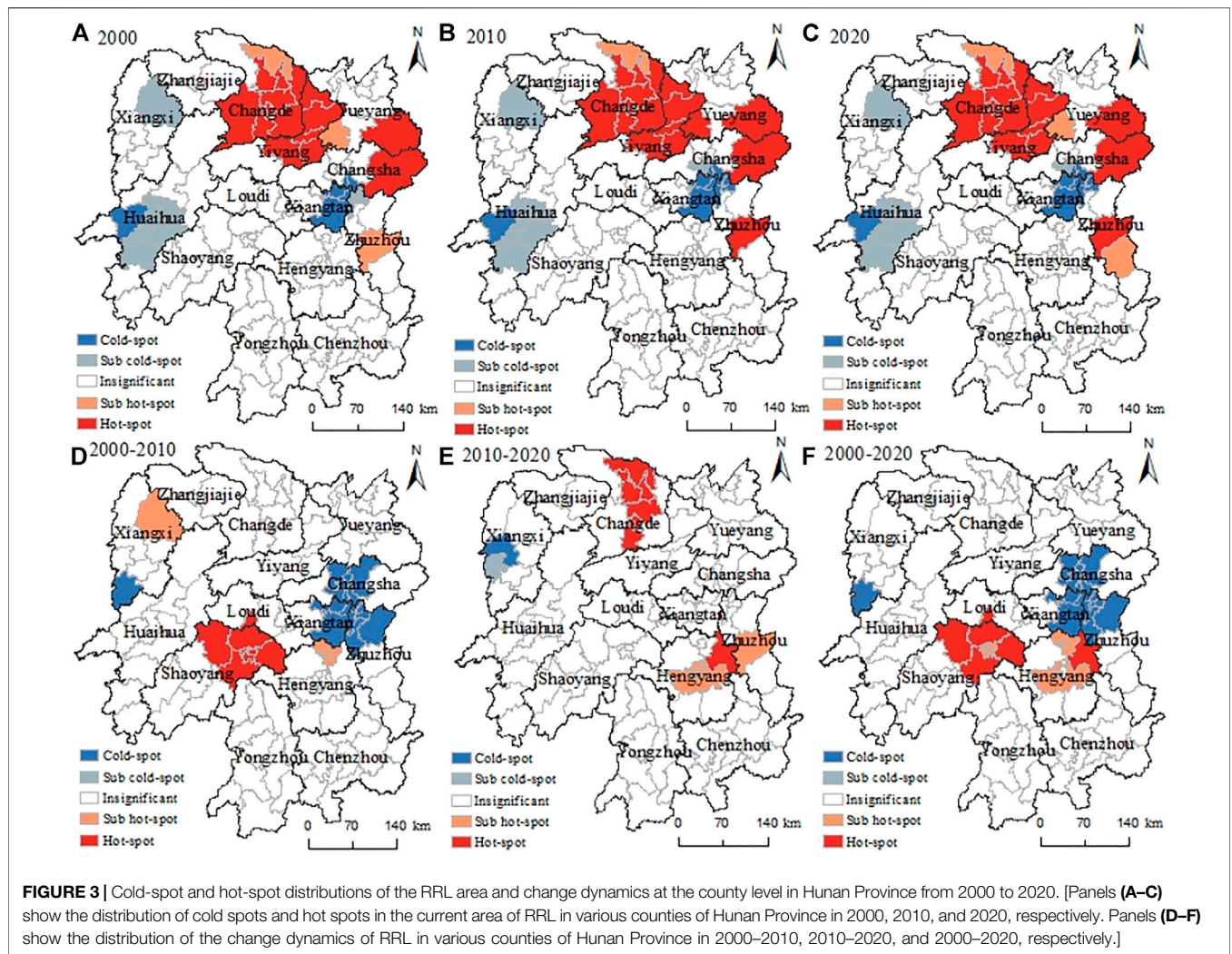


FIGURE 3 | Cold-spot and hot-spot distributions of the RRL area and change dynamics at the county level in Hunan Province from 2000 to 2020. [Panels (A–C) show the distribution of cold spots and hot spots in the current area of RRL in various counties of Hunan Province in 2000, 2010, and 2020, respectively. Panels (D–F) show the distribution of the change dynamics of RRL in various counties of Hunan Province in 2000–2010, 2010–2020, and 2000–2020, respectively.]

TABLE 3 | The overall change in the RRL area in natural reserves and non-natural reserves.

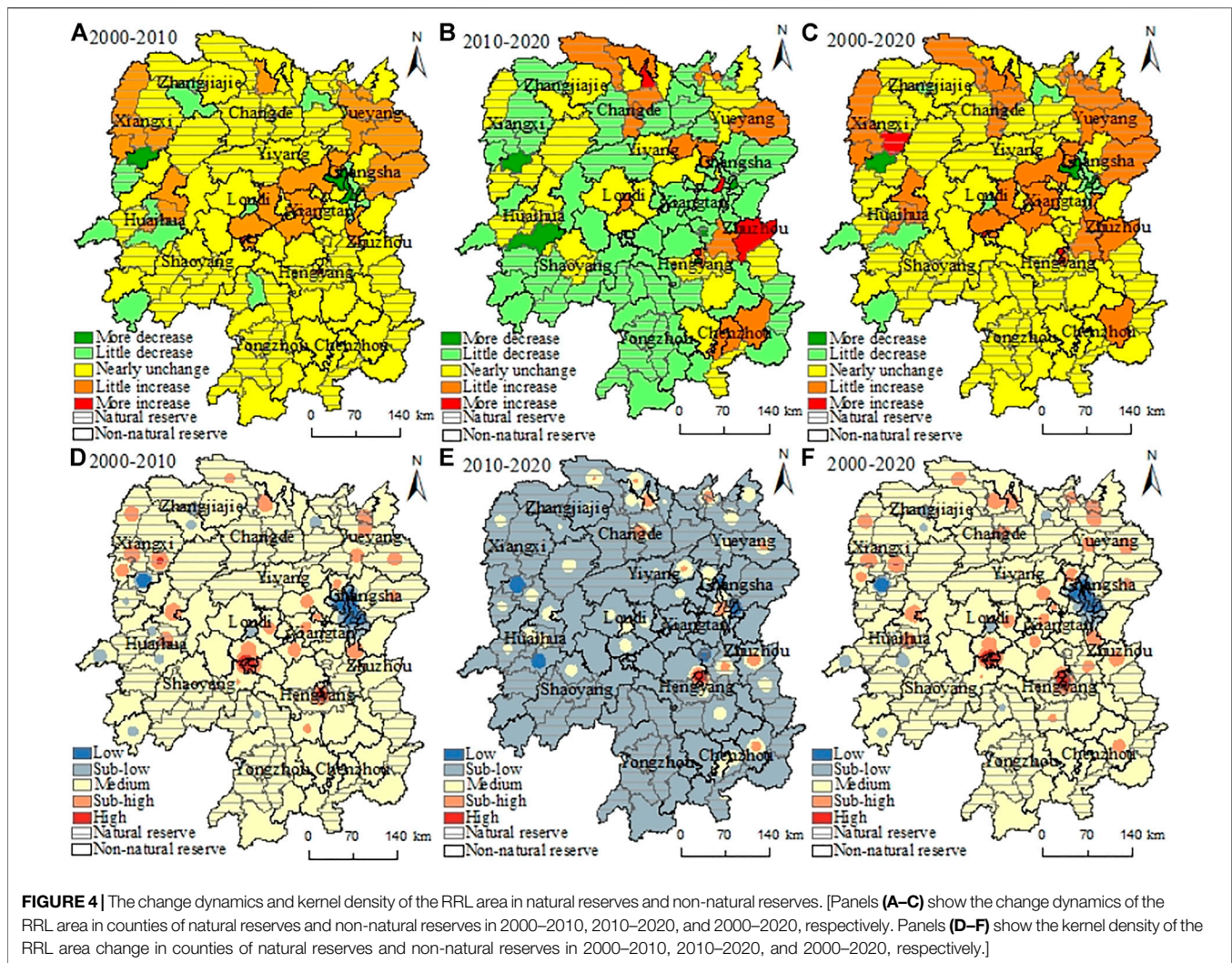
	2000–2010		2010–2020		2000–2020	
	Area change (hm ²)	Change dynamics	Area change (hm ²)	Change dynamics	Area change (hm ²)	Change dynamics
Natural reserves	-234.27	-0.03%	1709.46	0.25%	1538.37	0.11%
Non-natural reserves	-4930.83	-0.47%	2207.97	0.23%	-2786.04	-0.14%

area in Hunan Province gradually shifted from developed areas in the middle of the east to underdeveloped areas in the west.

3.2 Spatiotemporal Variation Characteristics of Rural Residential Land in Natural Reserves and Non-Natural Reserves

Table 3 shows that from 2000 to 2020, the RRL area in natural reserves and non-natural reserves decreased in 2000–2010 but increased in 2010–2020. It is worth noting that the overall area of

RRL in natural reserves increased by 1,538.37 hm² in 2000–2020, with an increase of 0.11%, while the overall area of RRL in non-natural reserves decreased by 2,786.04 hm² in 2000–2020, with a decrease of 0.14%. According to the dynamic degree of change in the RRL area of counties in natural reserves and non-natural reserves in 2000–2010, 2010–2020, and 2000–2020, it was divided into five intervals by using the natural break method in ArcGIS 10.5 software (Figures 4A–C). Meanwhile, to intuitively express the change characteristics of the RRL area in counties of natural reserves and non-natural reserves, the kernel density of the RRL area change in counties of natural reserves and non-natural



reserves in 2000–2010, 2010–2020, and 2000–2020 can be obtained by using the kernel density estimation method (Figures 4D–F). It can be found that the area and kernel density change of RRL in Hunan in 2000–2010 are very similar to that in 2000–2020, mainly concentrated in the non-natural reserves in the middle and the natural reserves in the northeast and northwest. We found that the growth of the RRL area in non-natural reserves is mainly affected by economic factors, while the growth of the RRL area in natural reserves is mainly affected by economic and policy factors. Furthermore, the area of RRL reduction is mainly concentrated in non-natural reserves, and the economic growth factor is the main factor of RRL change.

Moreover, it is also worth noting that from the change dynamics and kernel density of the RRL area in 2010–2020, the RRL area of non-natural reserves in Zhuzhou and Changde show a significant growth trend, while the counties with a small growth of the RRL area are mainly concentrated in the non-natural reserves in Chenzhou and Yiyang and the natural reserves in Changde and Yueyang. It can also be found that the counties

with the increase in the RRL area in 2010–2020 are mainly concentrated in the plain areas with high economic development and dense populations in eastern and northern Hunan. In addition, the RRL area in most regions of Hunan has decreased slightly, while the RRL area in some non-natural reserves in Huaihua and Xiangxi has decreased significantly. Additionally, this study found that urbanization and the poverty alleviation and relocation policy are the main factors for the reduction of RRL in these regions.

3.3 Analysis of Driving Factors of Area Change in Rural Residential Land

Due to the different units and magnitudes of each index, the data are standardized to narrow the fluctuation range of the data to [0,1] to better show the changes to each index and the area of RRL in Hunan Province (Huyan and Li, 2021). Meanwhile, by analyzing the research data, we find that the dependent variable RRL in this article satisfies the normal distribution; the influencing factors are independent of each other as

TABLE 4 | Ordinary least-squares regression results of influencing factors of RRL.

Variable	2000		2010		2020	
	MNL-1	MNL-2	MNL-1	MNL-2	MNL-1	MNL-2
Constant	-0.188***	-0.161***	-0.142***	-0.122***	-0.107***	-0.131***
WNR	0.021	-0.348**	0.029**	-0.186***	0.021	-0.234***
PIFA	0.008	-0.008	0.081	0.091	0.081	0.104**
PIRED	-0.276***	0.136	-0.065	-0.024	-0.063	-0.074
UCLA	0.289***	0.172**	-0.086*	-0.063	-0.271***	-0.183**
PGDP	-0.104*	-0.066	0.011	0.034	-0.063	-0.031
PPI	0.057	0.022	-0.114***	-0.095*	-0.135**	-0.009
PFE	0.116	0.011	-0.005	-0.081	-0.011	-0.051
PCSA	0.045	0.165**	0.016	0.034	0.004	-0.091
PCLA	1.125***	1.026***	0.638***	0.641***	0.724***	0.791***
PDIF	0.081	0.084	0.009	-0.036	0.053*	0.071
RRP	0.404***	0.364***	0.552***	0.503***	0.661***	0.551***
PIFA * WNR		-0.484		0.254		0.202
PIRED * WNR		-0.159		-0.161		0.711***
UCLA * WNR		0.066		0.065		0.012
PGDP * WNR		0.568		-0.401		-0.713***
PPI * WNR		0.309*		-0.018		-0.167
PFE * WNR		1.218***		0.426***		1.219***
PCSA * WNR		-0.623***		0.007		0.271**
PCLA * WNR		0.917***		0.038		-0.071
PDIF * WNR		-0.396**		0.111		-0.128
RRP * WNR		0.551***		0.253***		0.493***
R-squared	0.861	0.914	0.917	0.933	0.891	0.926
Sig.	0.000	0.000	0.000	0.000	0.000	0.000
Number of samples	122	122	122	122	122	122

Note: (1) ***, **, and * show statistical significance at the levels of 1%, 5%, and 10%, respectively. (2) WNR represents whether there are natural reserves, PIFA represents the per capita investment in fixed assets, PIREDD represents the per capita investment in real estate development, UCLA represents the urban construction land area, PGDP represents the per capita gross domestic product, PPI represents the proportion of the primary industry, PFE represents the per capita fiscal expenditure, PCSA represents the per capita crop sowing area, PCLA represents the per capita cultivated land area, PDIF represents the per capita disposable income of farmers, and RRP represents the rural resident population.

independent variables, and there is no multicollinearity problem, and there is a linear relationship between the dependent variable and the independent variable. Therefore, the research data in this article meet the requirements of using an ordinary least-squares model for analysis (Gómez et al., 2020).

The calculation results of the ordinary least-squares model (Table 4) show that the overall significance level of all models is within 1%. Compared with the R-squared values of various models in 2000, 2010, and 2020, it is found that the MNL-2 model has a better fitting and is more suitable for further research. Overall, the presence of natural reserves has a negative correlation with the area of RRL within the significance level of 5%, indicating that the delimitation of the natural reserve will limit the growth of the area of local RRL to a certain extent. The per capita cultivated land area and the rural resident population are significantly positive at the 1% level, indicating that with the growth of per capita cultivated land area and the rural resident population, the RRL area will also increase. It is worth noting that the urban construction land area did not show a significant correlation in 2010, while the proportion of the primary industry showed a significant negative correlation at the 10% level, indicating the growth of the urban construction land area after 2000. The area of RRL also showed a trend of initial growth and then decline. Meanwhile, the reduction of the proportion of the primary industry will promote the reduction of RRL areas. In addition, there is a significant positive correlation between the per capita crop sowing area in 2000 and the per capita

investment in fixed assets in 2020 at the 5% level, indicating that the growth of the crop sowing area and fixed asset investment will also promote the growth of the RRL area.

From the overall results of the interaction analysis of influencing factors, the interaction items of whether there are natural reserves and per capita financial expenditure and whether there are natural reserves and rural resident population are significantly positive at the 5% level, indicating that with the government delimiting the natural reserve, the impact of financial expenditure and rural resident population on the change in the RRL area in the natural reserve will increase. In 2000, the interaction terms of whether there are natural reserves and the proportion of the primary industry and whether there are natural reserves and the per capita cultivated land area were significantly positive at the levels of 10% and 1%, respectively, indicating that the growth of the proportion of the primary industry and the per capita cultivated land area will lead to the growth of the RRL area of the natural reserve. This growth may be because the proportion of the primary industry and the growth of per capita cultivated land area will lead to an increase in rural population, while the growth of farmers' per capita disposable income will lead to the improvement of rural residents' consumption ability and accelerate the process of farmers' urbanization, which restricts the growth of the RRL area. Different from 2000 to 2020, the interaction between whether

there were natural reserves and the per capita crop sowing area in 2010 was not significant, while the per capita cultivated land area in 2010 greatly affected the change in the RRL area in the natural reserve. Moreover, it is worth noting that in 2020, the interaction term between whether there are natural reserves and per capita real estate development investment and whether there are natural reserves and per capita GDP is significant, indicating that the delimitation of natural reserves will enhance the impact of GDP on the growth of the RRL area and improve the impact of per capita real estate development investment.

4 DISCUSSION

4.1 The Distribution and Change in Rural Residential Land Show Differentiated Characteristics

The current RRL area showed a trend of hot in the northeast and cold in the southwest from 2000 to 2020. The hot spots were mainly concentrated in Changsha, Changde, Yueyang, and other cities, while the cold spots were concentrated in some counties of Xiangtan and Huaihua. Among them, economic development was the main factor affecting the increase in RRL (Fan et al., 2019). The difference is that the RRL area in Xiangxi decreased the most (4,417.65 hm²). In addition to economic factors, the government's policy of poverty alleviation and relocation in other places also has an important impact. In addition, the change dynamics of RRL also show significant spatial differences. The RRL area is growing due to the constraints of economic development and the farmers' thought of "going home" in eastern Shaoyang and Hengyang. For the counties in the middle of Changsha, east of Xiangtan, and north of Zhuzhou, the demand for urban construction land increases due to the development of the Chang Zhu Tan metropolitan area, which leads to the occupation of RRL, resulting in a significant reduction in the area of RRL (He et al., 2019). Furthermore, we explore the change forms of transfer in and transfer out of RRL and find that the main reason for the reduction of RRL is the occupation of urban construction land, which is mainly caused by the strong demand for urban construction land with rapid urbanization. However, the increase in RRL mainly comes from the cultivated land and forestland around the original RRL. The main reason is that the occupied cultivated land and forestland close to the original RRL are more convenient to develop into new homesteads, and the protection intensity of cultivated land and forestland by the local government is not enough. Moreover, different from other countries and regions, the distribution and change in RRL in Hunan Province of China are not only related to the terrain and socioeconomic development but also closely related to the immigration and relocation policies implemented by the government (Liu et al., 2020).

4.2 The Growth of Rural Residential Land Area in Natural Reserves Is Higher Than That in Non-Natural Reserves

By analyzing the changes in the RRL area in natural reserves and non-natural reserves from 2000 to 2020, we found that

the area of RRL in natural reserves increased by 1,538.37 hm², while the area of RRL in non-natural reserves decreased by 2,786.04 hm². Combined with the local social, economic, and policy constraints, it is found that to protect the healthy and sustainable development of the natural environment, the local government has formulated relatively strict land control policies for the natural reserve, limiting the speed of its socioeconomic development and urbanization, resulting in the urbanization development speed of the natural reserve being lower than that of the non-natural reserve. Therefore, the area of RRL in the non-natural reserve shows a significant reduction trend. It is worth noting that although the establishment of natural reserves is negatively correlated with the change of RRL, the RRL area in natural reserves is increasing. The main reason for this increase is that the growth of RRL is affected by many other factors, such as rural economic development and population growth, and the factor of whether there is a natural reserve cannot directly promote the overall reduction of the RRL area.

Meanwhile, some residents who moved to the urban areas did not change their registered residence. To enjoy the dividend policy brought by the establishment of natural reserves, the new rural settlements in the natural reserves were brought to the advantage by their registered residents in rural areas, which to a certain extent led to the increase of the RRL area in the natural reserves (Ristić et al., 2019). It is worth noting that the RRL area in wetland nature reserves, such as the East Dongting Lake National Nature Reserve in Yueyang, increased rapidly in 2000–2020. When analyzing the management policy of the natural reserve, it is found that the management department divides the wetland natural reserve into three levels: core area, test area, and buffer area. The core area is prohibited from development, the test area is moderately developed, and the buffer area is allowed to be fully developed. However, the test area and buffer area do not strictly restrict the expansion of RRL, which leads to the rapid growth of RRL in these areas to a certain extent (Xiao et al., 2021). Although the area of RRL in the natural reserve shows a trend of growth, through the analysis of the ordinary least-squares model, it is found that the presence of natural reserves has a significant negative correlation with the area of RRL, which also shows that the establishment of natural reserves still limits the growth rate of RRL to a certain extent.

4.3 Diversification of Factors Affecting the Change in Rural Residential Land

Although the spatial distribution change of RRL is the result of the joint action of natural, social, and economic factors (Liu et al., 2019), the establishment of natural reserves limits the change of RRL from the aspects of social economy and land management policies to a certain extent. Through the analysis of the ordinary least-squares model, it is found that the growth of per capita cultivated land area and rural resident population from 2000 to 2020 leads to a large

number of farmers living in rural areas, and more RRL is needed to build new houses. The growth of urban construction land area during the early stage has no direct impact on the growth of the RRL area, while the promotion of urbanization needs to absorb a large rural population, and this factor reduces the demand for the RRL area to a certain extent. In addition, the establishment of natural reserves will enhance the impact of government financial expenditure and rural resident population on RRL; that is, in natural reserves, more government financial expenditure and an increase in rural resident population will promote the growth of the RRL area. The per capita crop sowing area from 2000 to 2020 shows the influence of first limiting and then promoting the growth of the RRL area. The summary and analysis can divide the driving factors of RRL change in Hunan Province into three categories: endogenous demand for urbanization development, exogenous catalysis of unbalanced regional development, and policy resettlement measures (Yang et al., 2016). The establishment of natural reserves does not play a decisive role but regulates some factors affecting the change in RRL and then affects the change in the RRL area through the comprehensive action of multiple factors.

4.4 Research Contribution and Deficiency

The research contributions of this article are as follows: (1) based on the perspective of whether there are natural reserves, this article compares and analyzes the spatiotemporal change characteristics of RRL between natural reserves and non-natural reserves in Hunan Province; and (2) this article analyzes the influencing factors of the RRL area change and explores how the establishment of natural reserves affects RRL.

There are some deficiencies in this study. (1) Although this article selects 11 influencing factors based on the relevant literature and the actual conditions of RRL in Hunan Province, it does not involve the level of subjective factors such as farmers' will, which requires data to be obtained through field research. (2) Due to the weak protection and policy constraints of county-level natural reserves, this article only considers provincial and national nature reserves. (3) Since the research scale of this article is 122 county-level administrative regions in Hunan Province, the research results of this article may not apply to all regions of China but can provide some reference for regions with similar natural, social, and economic conditions.

5 CONCLUSION AND POLICY IMPLICATIONS

Based on the spatial and panel data of 122 county-level administrative regions in Hunan Province, this article analyzes the spatiotemporal distribution characteristics of RRL in natural reserves and non-natural reserves by using land use change dynamics, nuclear density analysis, transfer matrix modeling, and ordinary least-squares modeling and

explores how the establishment of natural reserves affects RRL. The results show that (1) affected by rapid urbanization, the overall RRL area in Hunan shifted from 171,162.27 hm^2 in 2000 to 169,914.6 hm^2 in 2020, with a total reduction of 1,247.67 hm^2 and a decrease of 0.73%, and the distribution of the RRL area change presented a hot trend in the northeast and a cold trend in the southwest. (2) The spatial distribution of RRL has significant heterogeneity due to natural conditions. The traditional agricultural areas in the east and northeast of Hunan have high residential density and large land scale, while the RRL in the hills and mountainous areas in the west and southwest of Hunan has low aggregation degree and obvious sporadic distribution characteristics, and the RRL area in western Hunan shows a sharp reduction trend due to immigration policy. (3) The occupation of urban construction land is the main reason for the reduction in RRL area, and the transformation of cultivated land and forestland into RRL is the main source of the increase in the RRL area. (4) There are significant differences in the spatiotemporal variation characteristics of the RRL area between natural reserves and non-natural reserves. The RRL area mainly shows an increasing trend in natural reserves, while it mainly shows a decreasing trend in non-natural reserves. Furthermore, the growth of the RRL area is mainly concentrated in the non-natural reserves in central Hunan and the natural reserves in northeast and northwest China, while the non-natural reserves are the main areas where the RRL area decreases. (5) The establishment of natural reserves cannot directly promote the overall reduction of the RRL area. Although there is a significant negative correlation between the establishment of natural reserves and the area of RRL, the total area of RRL in the natural reserve still shows an increasing trend, indicating that the area of RRL is more affected by economic development, government financial expenditure, rural permanent population, etc. Meanwhile, the per capita cultivated land area and rural resident population promote the growth of the RRL area, while urban construction land initially limits and then promotes the growth of the RRL area from 2000 to 2020.

In addition, this article puts forward the following policy implications for the optimization of RRL in natural reserves. (1) The government should strengthen the planning and management of RRL in natural reserves and relocate RRL that are not suitable for living or have a fragile ecological environment. (2) The government can strictly restrict the construction of new RRL in the natural reserve and protect and merge the original RRL suitable for living in the natural reserve to strictly control the growth of RRL in the natural reserve. (3) If farmers have a high demand for RRL, the local government needs to protect and develop the natural reserve according to local conditions. For example, the construction of new RRL is prohibited in the core zone, and the area of RRL is strictly limited in the experimental zone and buffer zone. (4) The local government should also introduce relevant welfare policies to encourage residents in natural reserves to migrate to non-natural reserves and to reduce the area of RRL in natural reserves.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**; further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

YW: Formal analysis, software, and writing—review and editing. HT: Conceptualization, formal analysis, data curation, software, visualization, and writing—original draft. PJ: Conceptualization, formal analysis, data curation, software, methodology, supervision, writing—review and editing, and funding

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- acquisition. JC: Data curation. All authors contributed to this article and approved the submitted version.

FUNDING

This research was supported by the National Key Research and Development Program of China (2018YFD1100801).

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2022.909554/full#supplementary-material>

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