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The Impacts of Rapid Urbanization on Farmland Marginalization: A Case Study of the Yangtze River Delta, China

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Abstract: Farmland is the most precious natural resource and the primary source of food for human beings. Urbanization not only occupies a large amount of farmland spatially, but also economically squeezes agricultural production, resulting in farmland marginalization and causing serious threats to food security. However, the manner in which rapid urbanization drives farmland marginalization in surrounding areas and the factors that might play a dominant role in this process remain elusive. Therefore, the present study considered rapidly urbanized regions of 128 county-level units in the Yangtze River Delta (YRD) of China from 2000 to 2020 as the study area. Methods such as spatial autocorrelation analysis, hotspot analysis, and multiple linear regression analysis were used to explore the spatiotemporal evolution characteristics and the driving factors of farmland marginalization. The results showed that: (i) the marginalization ratio of farmland in YRD from 2000 to 2020 was 31.34%, with a distinctly increasing trend, generally high in the central and southern and low in the north areas; (ii) marginalization exhibited different spatial agglomeration under different influencing factors: the economy-induced marginalization ratio was 23.19%, playing a dominant role, in general, distributed as high in the middle and low on the sides, while the nature-induced marginalization ratio was 8.15%, and in general, the spatial pattern shifted from discrete- to a clear-distribution of high in the south and low in the north; and, (iii) farmland area per capita, total power of agricultural machinery, GDP per capita and government farmland subsidies were the main factors driving farmland marginalization. In addition, nature-induced marginalization was primarily driven by economic level and topographical conditions, whereas economy-induced marginalization was primarily driven by production conditions. We suggest that in the future, corresponding policies and measures should be established to reduce farmland marginalization in rapidly urbanized areas and to ensure food security.

Keywords: rapid urbanization; farmland marginalization; spatial characteristics; driving factors

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1. Introduction

Farmland is an important resource for human survival, but the area devoted to it per capita is a very limited resource [1,2]. Since the middle of the 20th century, the global development characterized by urbanization and industrialization has become an irresistible torrent. In some countries in Europe, and in the United States, a large number of rural populations have migrated to cities, causing agricultural land abandonment [3,4], and farmland marginalization has become a common phenomenon [5–7]. Rapid urbanization has profoundly affected agricultural production activities [8] and caused dramatic changes in land use [9,10]. Especially in metropolitan areas, the amount of farmland and production capacity has kept declining [11]. Since the beginning of this century, the wave of urbanization has further swept through the developing countries [12]. The population has been continuously migrating to cities [13], destroying the relatively fragile agricultural production bases of developing countries [14], and contributing to the global marginalization of farmland [15]. In addition, the raging COVID-19 epidemic and the outbreak of the Russian-Ukrainian War have further exacerbated the vulnerability of global food production and supply chains. According to the Food and Agriculture Organization (FAO), nearly 690 million people in the world faced hunger in 2020, and with no measures taken, this number will surpass 840 million by 2030 [16]. Therefore, it is vital to pay attention to farmland marginalization on a global scale.

Farmland marginalization can be designated a change in farmland use under the interaction of nature, economy, society, and policy [17]. As of now, the definition of farmland marginalization still lacks a unified standard. Early studies generally used indicators such as "farmland abandonment" [18] and "conversion of cultivated land into forests" [19] to describe the degree of farmland marginalization. Currently, most scholars prefer to divide it into dominant marginalization and recessive marginalization [20–22]. They use indicators such as "intensive degree", "marginal income" and "sowing area" [23,24] to describe recessive marginalization, and use the term "conversion of farmland use" [15,25] to describe dominant marginalization. Some scholars have discussed the process of farmland marginalization in different regions from various perspectives. For example, Prishchepov et al. [24] found that the changes in land use regulations affected the marginalization degree of farmland, and that the abandonment ratios of farmland were relatively high in countries with inconsistent regulations. Van et al. [26] revealed that fallow land had both negative and positive effects in Europe, and attention should be paid to its spatial diversity. Mantero et al. [27] explored the impact of farmland abandonment on natural forests on a global scale. Wang et al. [28] took the southwestern mountainous areas of China as their research object and found that the rising cost of agricultural production was the primary reason for farmland marginalization. Tan et al. [25] explored the impact of farmland marginalization on changes in land use in mountainous and hilly areas. Lu et al. [29] and Hua et al. [30] used social survey methods to investigate the influence of farmers' family characteristics on farmland marginalization, and revealed that small-scale and young families were more likely to abandon farming. In addition, a sample survey report showed that the abandonment ratio of farmland in hilly and mountainous areas in China was 14.32% in 2014–2015 [31]. Such reduction of farmland input and changes in farmland use not only lowered the food security in China, but also destroyed the local ecological balance [32], and even seriously threatened the stability and sustainable development of rural society [33,34]. However, previous studies have mostly focused on hilly and mountainous areas with low degrees of urbanization [7,25,28], and little attention has been paid to farmland marginalization in rapidly urbanized areas. The problem of farmland marginalization in urbanized areas has become more and more prominent [29]. Farmlands in urbanized areas not only provide food for cities, but also undertake functions such as air purification, landscape services, and recreation services [32,35]. Therefore, it is urgent to increase the research on farmland marginalization in rapidly urbanized areas.

China is the world's largest food consumer, but its arable land resources are very scarce [15,36,37]. In the past 20 years, rapid urbanization has utilized a large amount of high-quality cultivated land in China and has also exerted a vicious squeeze on agriculture, resulting in agricultural abandonment [25], non-grainization of farmland [23], and lack of rural labor [38], seriously threatening food security in China. Therefore, clarifying the driving mechanism and main driving factors of farmland marginalization during the rapid urbanization in China is crucial for protecting high-quality cultivated land, ensuring food security and maintaining social stability. In the present investigation, 128 county-level units in the Yangtze River Delta (YRD) region, China where urbanization developed most aggressively were selected as study sites. In this research, remote sensing images and socioeconomic data were adopted to explore the characteristics and driving factors of farmland marginalization. The specific goals were as follows: (i) to reveal the degree and distribution of farmland marginalization in YRD from 2000–2020; (ii) to explore the spatial pattern and differentiation characteristics of farmland marginalization in YRD by hot spot analysis; and (iii) to identify the main driving factors of farmland marginalization in YRD by spatial econometric model. This research can make up for the past lack of understanding of farmland marginalization and balance the relationship between farmland protection and food security for the rapid urbanization process in China and other developing countries.

2. Data Sources and Research Methods

2.1. Research Framework

To reveal the current situation and the evolutionary trend of farmland marginalization in rapidly urbanized areas, this study established a research framework. The goal was to explore and identify the spatial differentiation characteristics and main driving factors of farmland marginalization in 128 county-level study sites (Figure 1). The framework consisted of four steps.

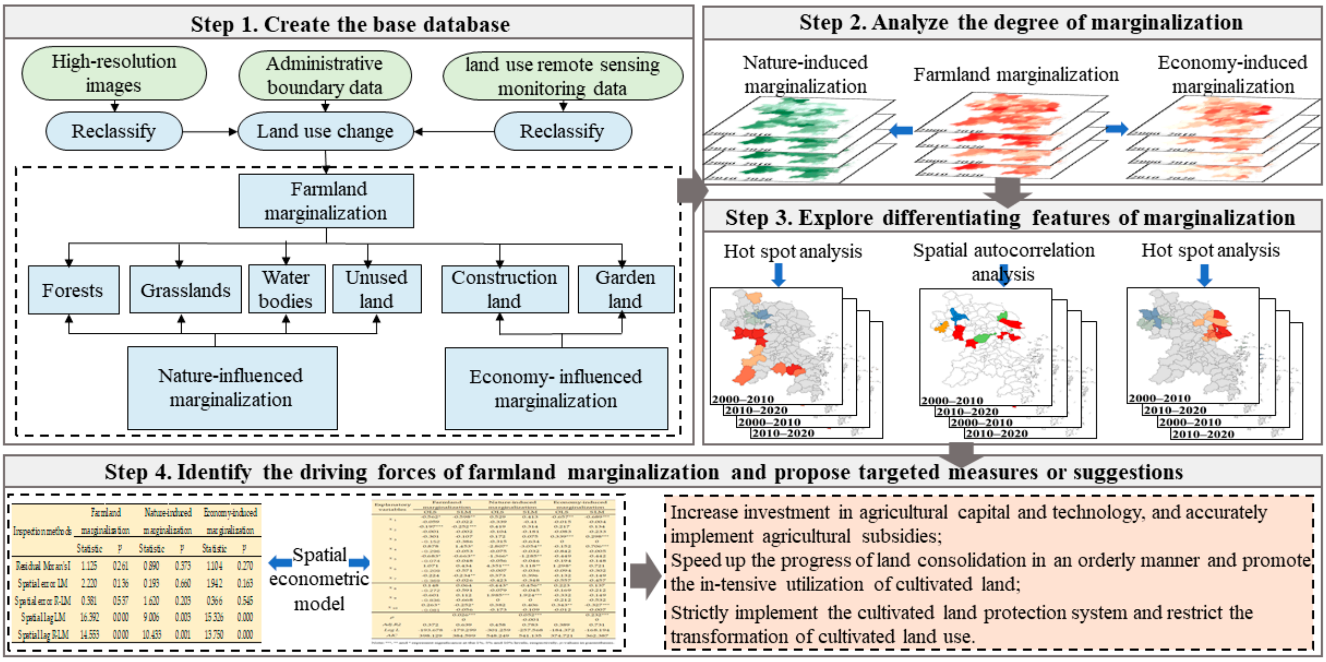


Figure 1. The technical roadmap of this study.

(1) Establishment of a basic database: Based on high-resolution remote sensing images and land use remote sensing monitoring data, ArcGIS 10.2 was used to extract data on farmland use changes in YRD between 2000–2010, 2010–2020, and 2000–2020. The conversion of farmland to forests, grasslands, water bodies, unused land, construction land, and garden land was regarded as farmland marginalization. The conversion of farmland into forests, grasslands, water bodies, and unused land was treated as nature-induced marginalization, while the conversion of farmland into construction land and garden land was treated as economy-induced marginalization.

(2) Analysis of the degree of farmland marginalization: The county-level data were treated as a unit; as concerning farmland marginalization, the area and ratio were extracted, the distribution was plotted, and then the degree was analyzed.

(3) Exploration of the spatial differentiation characteristics of farmland marginalization: The spatial autocorrelation analysis was conducted on the spatial differentiation characteristics of farmland marginalization between 2000–2010 and 2010–2020. Hot spot analysis was then carried out to explore the distribution characteristics of cold and hot spots of farmland marginalization under various influencing factors.

(4) Identification of the driving factors of farmland marginalization: The spatial econometric model was conducted to identify the driving factors of the farmland marginalization from 2000–2020, and the formation mechanism of farmland marginalization under various

influencing factors was investigated. Based on the main driving factors, targeted measures or suggestions were proposed to reduce farmland marginalization and ensure food security.

2.2. The Study Area

YRD lies in the middle of the eastern coastal area of China (36°46′–32°04′ N, 119°08′–121°15′ E), with a total area of about 110.5 × 10^3 km^2 (Figure 2). It includes: Shanghai; cities in Jiangsu Province such as Nanjing, Changzhou, Suzhou, Wuxi, Yangzhou, Taizhou, Zhenjiang, and Nantong; and cities in Zhejiang Province such as Hangzhou, Shaoxing, Ningbo, Huzhou, Jiaxing, Taizhou, and Zhoushan. A total of 128 county-level administrative units in the 16 cities are included in the research. Among these, there are no cultivated lands in eight districts, namely, Huangpu, Xuhui, Jing'an, and Hongkou (Shanghai), Gulou (Nanjing), Shangcheng and Xiacheng (Hangzhou), and Putuo (Zhoushan). As a result, no data was available for them. YRD is dominated by plains and hills, with low and flat terrain, and most elevations are below 10 m ASL. It has a subtropical monsoon climate, synchronized rain and heat, an average annual precipitation about 1000–1400 mm, and good water and heat conditions. As of 2020, the total population of YRD was about 122 million, accounting for 11.5% of the total population of China. The urbanization ratio of the permanent population was above 60%. It is one of the regions with the fastest economic development, with the highest degree of openness and with the strongest innovation ability in China. YRD was the main grain producing area in China before 1978 [9]. However, with the development of urbanization, the employment in the rural labor force kept decreasing, and agricultural investment declined.

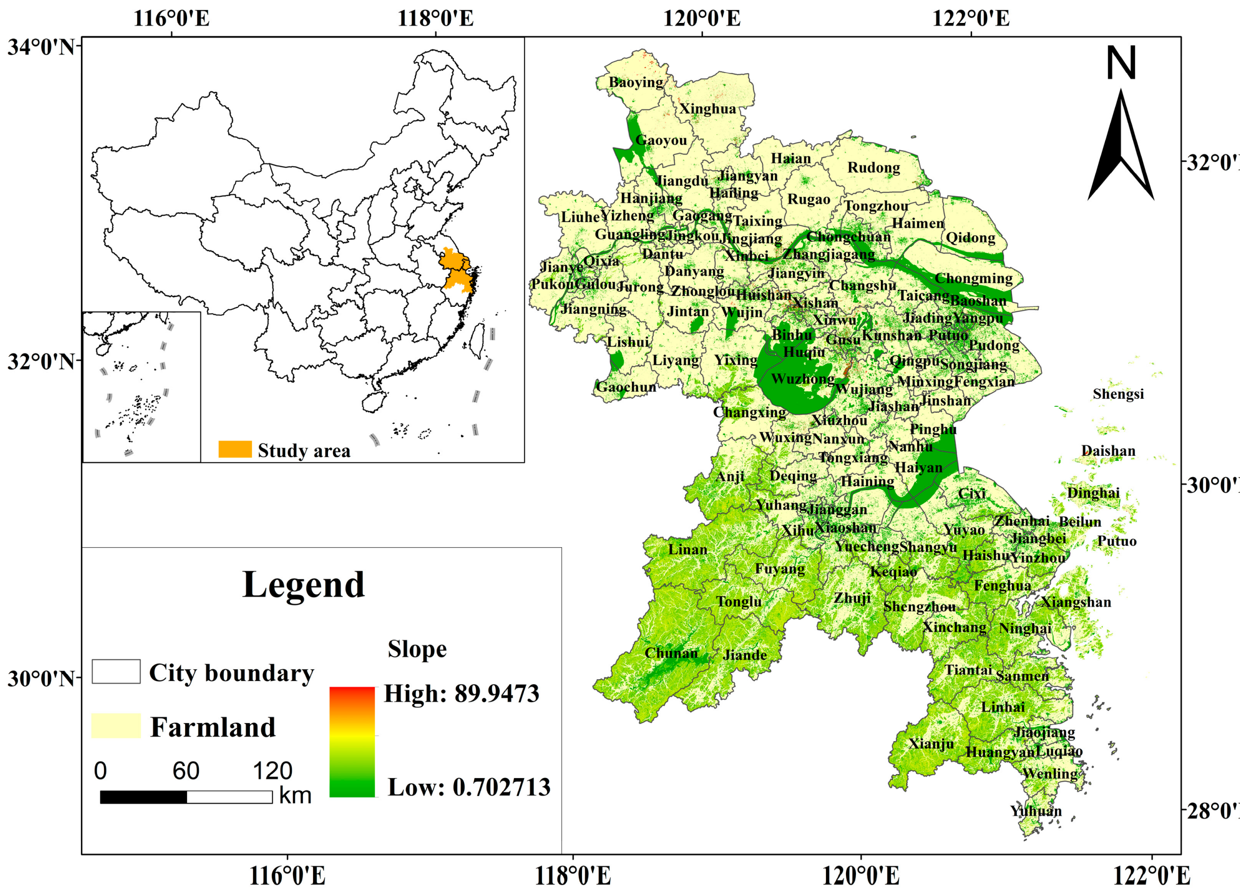


Figure 2. The location of the Yangtze River Delta (YRD) in China.

2.3. Data Source and Processing

This study collected remote sensing image data, vector data, and socioeconomic data of 128 county-level units in YRD. The detailed data sources are listed in Table 1. According to the available literature and as described in the purposes of this study, the conversion of farmland into construction land, garden land, forests, grasslands, water bodies, and unused land has been considered farmland marginalization. Among them, the conversion of farmland into forests, grasslands, water bodies, and unused land has been considered nature-induced marginalization. On the other hand, the conversion of farmland into construction land and garden land has been considered economy-induced marginalization. ArcGIS 10.2 was used to reclassify the remote sensing image data, dividing it into six land categories, i.e., farmland, forests, grasslands, construction land, water bodies, and unused land. The land use conversion in three stages, 2000, 2010, and 2020, was constructed by the ArcGIS 10.2 overlay analysis tools. Then, the data on the conversion of farmland into forests (including other forest land, i.e., the garden land, in the secondary land category), grasslands, water bodies, unused land, and construction land were extracted. The area of farmland and the number of farmland patches in county-level units were calculated. Thereafter, the average lot area of farmland was obtained. Based on digital elevation model (DEM) raster data, the ArcGIS 10.2 spatial analysis tools were employed to extract the average elevation and average slope of each county-level unit. Then, based on the farmland area and population data, the per capita farmland area was calculated in Excel 2018.

Table 1. Main data sources in this study.

Data Type	Index	Year	Resolution or Unit	Data Sources
Socioeconomic data	farmland per capita, total power of agricultural machinery, small agricultural machinery, urbanization ratio, GDP per capita, income of rural residents, government farmland subsidies	2020	County unit	The statistical yearbooks in Jiangsu Province, Zhejiang Province, and Shanghai in 2020
Remote sensing image	GlobeLand30, average area of farmland patch	2000/2010/2020	30 m	The Aerospace Information Research Institute (AIR), CAS (http://www.aircas.cas.cn/) (accessed on 16 March 2022)
Vector data	China's county-level administrative boundaries, land use remote sensing monitoring data	2015	County unit	Resource and Environment Science and Data Center (https://www.resdc.cn/) (accessed on 18 March 2022)
Natural environment data	Elevation, slope	2020	30 m	The National Aeronautics and Space Administration (https://www.nasa.gov/) (accessed on 18 March 2022)

2.4. Feature Selection

Based on the available research results [7,25], considering the research framework and the availability and standard referents of data, the primary driving factors for farmland marginalization were determined (Table 2). These factors could well explain the driving force on farmland marginalization from various aspects such as society, economy, policy, and nature. Among them, x_1 and x_2 represent the reverse effect of the scale of farmland and the degree of mechanization on marginalization, respectively. x_3 represents the reverse effect of small agricultural machinery on marginalization, x_4, x_5 and x_6 represent the positive or negative effect of economic development on marginalization, x_7 represents the reverse effect of government farmland subsidies on marginalization, x_8, x_9 and x_{10} represent the positive or negative effect of terrain conditions and farming conditions on marginalization.

Table 2. Analysis system of factors influencing the marginalization ratio of farmland.

Type	Dimension	Independent Variables	Expected Symbol	References
Socioeconomic	Production conditions	Farmland area per capita (x_1)	−	[39]
		Total power of agricultural machinery (x_2)	−	[40]
		Small agricultural machinery (x_3)	−	[17]
	Economic level	Urbanization ratio (x_4)	±	[41]
		GDP per capita (x_5)	−	[42]
		Income of rural residents (x_6)	+	[43]
		Government farmland subsidies (x_7)	−	[29]
Natural conditions	Terrain conditions	Elevation (x_8)	+	[17,44]
		Slope (x_9)	+	[32]
		Average lot area (x_{10})	−	[45]

2.5. Research Methods

Knowing the current status and spatial pattern of farmland marginalization are crucial to understanding the situation and formation mechanism of farmland marginalization. Spatial autocorrelation analysis is the most suitable method. Hot spot analysis and spatial econometric modeling could further help us to clarify the spatial differentiation pattern of farmland marginalization and to identify the main driving factors of farmland marginalization. The corresponding methods were described as follows.

(1) Local analysis of spatial autocorrelation:

Spatial autocorrelation analysis determines whether a variable is spatially correlated and measures the extent of correlation. Local spatial autocorrelation describes the similarity or correlation between the attribute values of each spatial unit and its neighbors within the study area [46]. It can be used to identify the "hot spots" and tell the agglomeration and differentiation characteristics of local spatial features.

The equation for calculating local Moran's I is:

$$I_i = \frac{n(x_i - \overline{x})}{\sum_{i=1}^{n} (x_i - \overline{x})^2} \sum_{j \neq i}^{n} W_{ij} (x_j - \overline{x}) \tag{1}$$

where n is the total number for features; W_{ij} represents the spatial weight between feature i and j; x_i and x_j represent the attribute values of features i and j, respectively; and $\overline{x}$ represents the mean. $I_i > 0$ indicates a small difference between the attribute value of feature i and the neighbors. On the contrary, $I_i < 0$ indicates a substantial difference. According to the calculation of local Moran's I, it can be concluded that the spatial difference between high-high/low-low agglomeration areas was small, and the attribute values of the study area and its adjacent areas were all high/low. The low-high/high-low agglomeration areas had large spatial differences, with a low/high attribute value of the study area and corresponding high/low attribute values of the neighboring areas.

(2) Hot spot analysis:

Hotspot analysis (Getis-Ord Gi*) can be used to measure the spatial correlation of regional features within a fixed distance, and to identify statistically significant hot and cold spatial clusters [47]. This study used Getis-Ord Gi* in ArcGIS 10.2 to identify the hot and cold spots of the farmland marginalization. The calculation equation is:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij} x_j - \overline{x} \sum_{j=1}^{n} w_{ij}}{s\sqrt{\frac{n \sum_{j=1}^{n} w_{ij}^2 - \left(\sum_{j=1}^{n} w_{ij}\right)^2}{n-1}}} \tag{2}$$

$$\overline{x} = \frac{\sum_{j=1}^{n} x_j}{n} \tag{3}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\overline{x})^2} \tag{4}$$

where x_j is the attribute value for feature j; W_{ij} is the spatial weight between feature i and j; n is the total number of features; S is the standard deviation; G_i^* is the Z score, and Z represents the significant level. In this study, the Z score was used for confidence interval, $Z \pm 1.65$ indicates a 90% confidence interval, $Z \pm 1.96$ indicates a 95% confidence interval, and $Z \pm 2.58$ indicates a 99% confidence interval.

(3) Spatial econometric model:

Before establishing a spatial econometric model for analysis, the global Moran's I index should be used to test whether there is a spatial correlation in the farmland marginalization. The global spatial autocorrelation can reflect the spatial distribution and agglomeration degree of the research variables as a whole [48], and its calculation equation is:

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \sum_{i=1}^{n} (x_i - \overline{x})} \tag{5}$$

where n is the total number of features; W_{ij} is the space weight; x_i and x_j are the observed values of farmland marginalization in area i and j, respectively; $\overline{x}$ is the average value. The value range of global Moran's I is between $[-1, 1]$, and when it is greater than 0, it is spatially positive correlation, showing agglomeration distribution. When the value is less than 0, the spatial correlation is negative and the distribution is discrete. When is equal to 0, there is no spatial autocorrelation.

On this basis, the spatial lag model (SLM) and the spatial error model (SEM) were introduced to analyze the correlation between farmland marginalization and various variables, and to identify the main driving factors affecting farmland marginalization in rapidly urbanized areas [49]. The spatial lag model (SLM), also known as the spatial autoregressive model, is mainly used to measure the influence of a certain area on the surrounding area and its strength. Its calculation equation is:

$$Y = \rho WY + \beta X + \varepsilon \tag{6}$$

where Y is the dependent variable, namely farmland marginalization; W is the regional space weight matrix; X is the explanatory variable; ρ is the spatial lag autoregressive coefficient; β is the coefficient of the corresponding explanatory variable; ε denotes the random error vector.

The spatial error model (SEM) considers the influence of the independent variables in the adjacent regions on the regional dependent variables, and its calculation formula is:

$$Y = \beta X + \lambda W\varepsilon + \mu \tag{7}$$

where ε represents the spatial autocorrelation error term; λ represents the spatial error term autoregressive coefficient; μ is the random error vector.

3. Results

3.1. Spatiotemporal Pattern of Farmland Marginalization in YRD from 2000 to 2020

3.1.1. Spatiotemporal Evolution Characteristics of Farmland Marginalization

By superimposing the three periods of remote sensing interpreted data in 2000, 2010, and 2020, it was revealed that the total marginalized area of YRD farmland was 1.91×10^6 hm^2 from 2000 to 2020, accounting for 31.34% of the total farmland area. It can be seen from Figure 3 that the farmland marginalization kept rising. From 2000 to 2010, the area of marginalized farmland in the study area was 875,762 hm^2, and it was 1,591,993 hm^2 from 2010 to 2020. The area of cultivated-to-construction land conversion was the largest, accounting for 63.77% of the total marginal farmland area, followed by forests which accounted for 17.24%; and the area converted to unused land was the smallest.

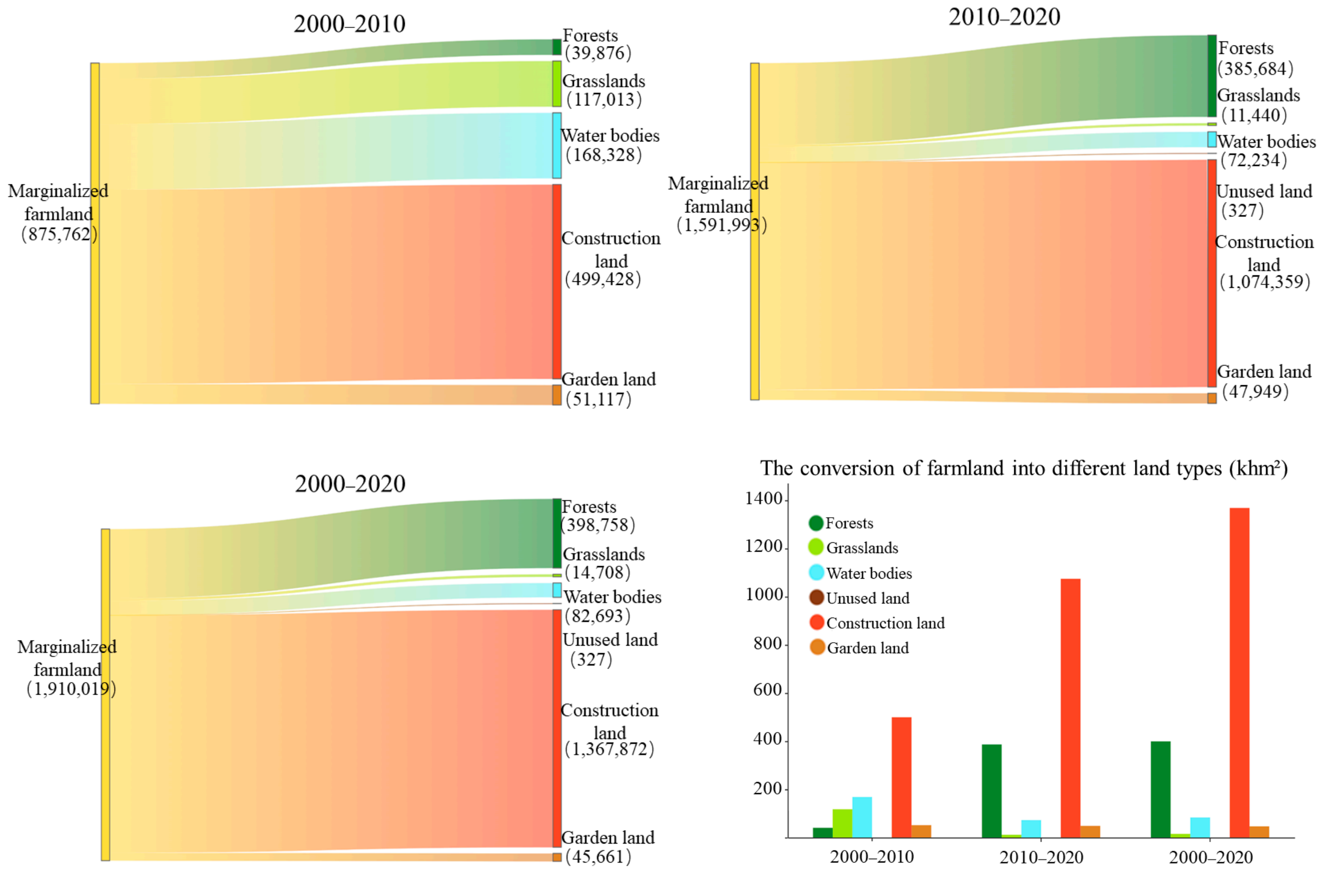


Figure 3. Conversion characteristics of the farmland marginalization in YRD from 2000 to 2020.

It can be seen from Figure 4 that due to differences in topographic conditions and socioeconomic development, the distribution of farmland marginalization exhibited significant spatial heterogeneity. The marginalized cultivated-to-construction land conversion was concentrated in the central and northern YRD, including Nantong, Shanghai, Suzhou, Wuxi, and central districts of Hangzhou. The marginalized cultivated-to-forests land conversion was mainly distributed in the mountainous and hilly areas such as Shaoxing, Hangzhou, and Taizhou in the southern YRD region. There were few farmlands converted into water bodies, grasslands and unused land, and they were distributed in a scattered manner. The total area of cultivated-to-garden land conversion was the smallest, but very concentrated, mostly in Taizhou and Ningbo in the southeast YRD.

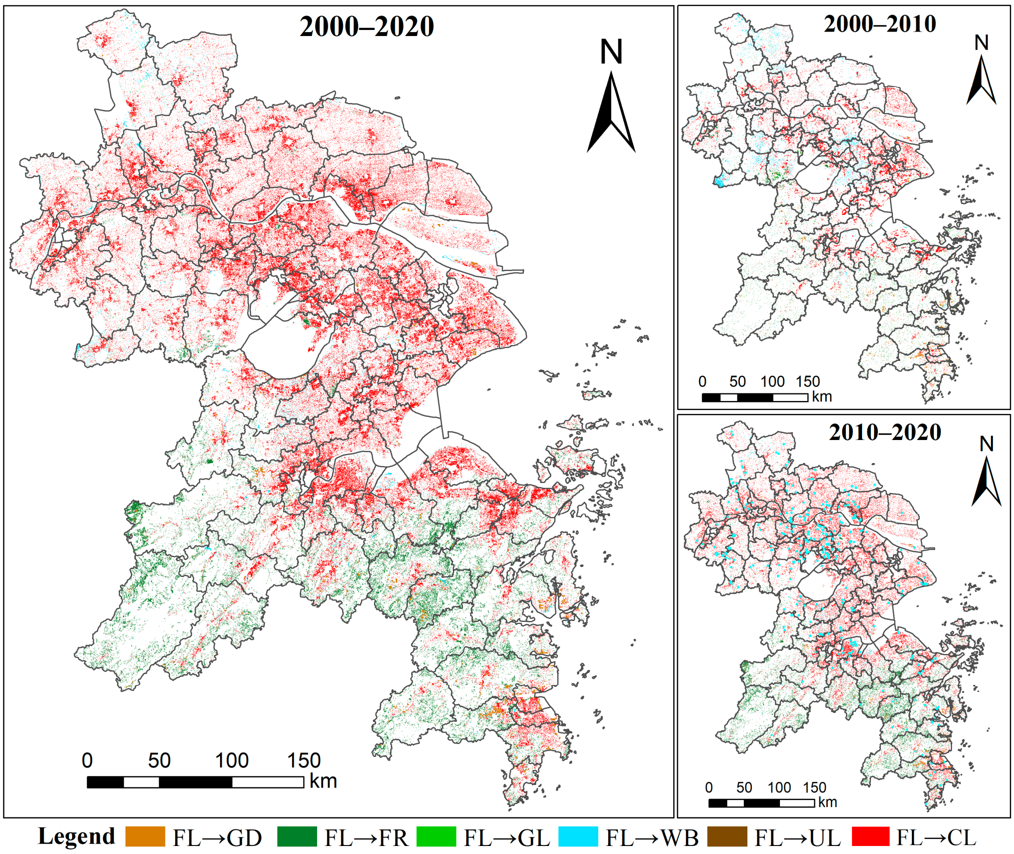
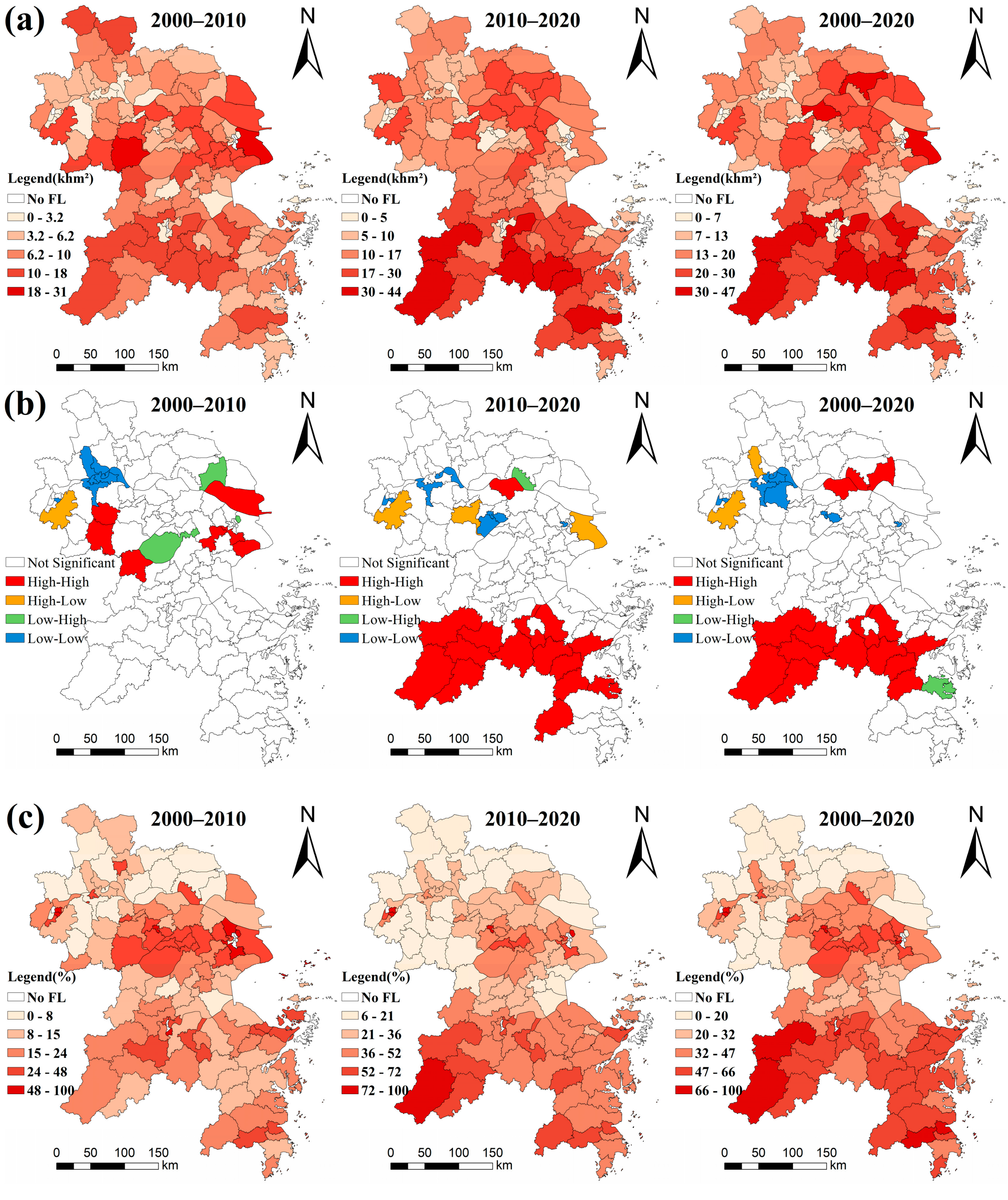


Figure 4. Spatial pattern of farmland marginalization in YRD from 2000 to 2020. (Note: FL, GD, FR, GL, WB, UL, CL represent farmland, garden land, forests, grasslands, water bodies, unused land, and construction land, respectively.)

3.1.2. Spatial Distribution Characteristics of Marginalized Farmland

To further explore the spatial differentiation characteristics of farmland marginalization, the area and ratio of farmland marginalization were extracted at the district and county level, and local Moran's *I* was introduced for in-depth analysis. The spatial distribution of topographic conditions and geographic locations determined the spatial agglomeration pattern of marginalized farmland. As can be seen from Figure 5a, the districts and counties with large areas of marginalized farmland from 2000 to 2010 were mainly distributed in Wuxi, Shanghai, Suzhou, and Nantong in the central YRD, whereas Hangzhou and Zhoushan in the south and Nanjing in the north had a small area of marginalized farmland. From 2010 to 2020, the marginalized farmland exhibited a significant distribution pattern of high in the south and low in the north. The districts and counties with large areas of farmland marginalization were concentrated in Shaoxing, Hangzhou, and Taizhou in the south, while marginalized areas in the central and northwestern part were small. The local spatial autocorrelation results of marginalization areas of farmland (Figure 5b) showed that the high-high agglomeration areas moved southward, mainly distributed in the middle region from 2000 to 2010, whereas they were in the mountainous and hilly areas in the south from 2010 to 2020, with significantly more involved districts and counties. And the low-low agglomeration areas were mainly distributed in the northern part of the study area.

As shown in Figure 5c, from 2000 to 2010, the marginalization ratio of farmland displayed a clear distribution of high in the middle, followed by a lower ratio in the south, and lowest in the north YRD. The districts and counties with a high marginalization ratio of farmland were mainly distributed in the center region, including Shanghai and central Nanjing. The marginalization ratios of the south region, Binjiang District of Hangzhou and Shengsi County of Zhoushan, were also high, at over 60%. The marginalization ratio of farmland in the northern region was low. From 2010 to 2020, the farmland marginalization moved south, showing a clear pattern of high in the south and low in the north. The districts and counties with a high marginalization ratio of farmland were mainly distributed in Hangzhou, Shaoxing, Taizhou, and Zhoushan. While Yangpu District of Shanghai, Qinhuai District and Xuanwu District of Nanjing and Liangxi District of Wuxi had small areas of farmland marginalization, they have high marginalization ratios due to their small areas of farmland. The local spatial autocorrelation results of the marginalization ratio of farmland (Figure 5d) revealed that the high-high agglomeration areas changed following the change in the spatial pattern of marginalization ratio, moving from the central region to the south region, while the low-low agglomeration areas were concentrated in the north YRD.



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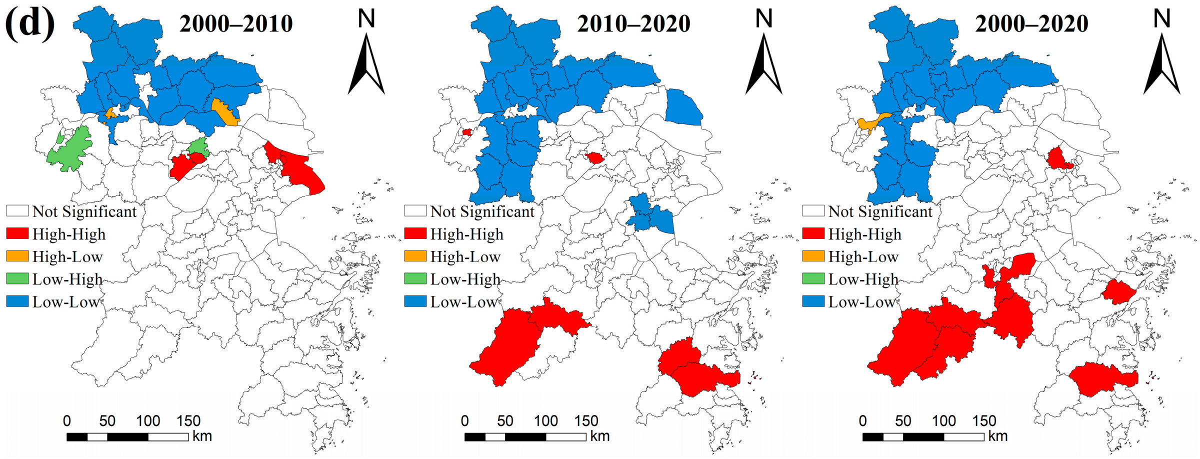

Figure 5. The marginalization distribution of farmland in YRD from 2000 to 2020: (**a**) the marginalization area of farmland at the district and county level; (**b**) local spatial autocorrelation of marginalization area of farmland; (**c**) the marginalization ratio of farmland at the district and county level; and (**d**) local spatial autocorrelation of marginalization ratio of farmland.

Overall, the marginalization area and ratio of farmland varied in the same direction, that is, in different time ranges, the key areas where the farmland marginalization occurred were different. Nevertheless, the marginalization area and ratio of farmland were different in spatial analysis, in that some districts and counties had small marginalization areas but high marginalized ratios.

3.2. The Influence of Different Factors on the Spatial Pattern of YRD Farmland Marginalization

3.2.1. Spatial Pattern of Farmland Marginalization in YRD under Different Factors

From 2000 to 2020, the area of nature-induced marginalization in YRD was 0.49×106 hm^2, accounting for 8.15% of the total farmland and 26% of the marginalized cultivated land. However, due to differences in geographical location and topographical conditions, the nature-induced marginalization of different units varied dramatically. It can be seen from Figure 6a that: (1) From 2000–2010, the nature-induced marginalization was distributed in a scattered manner, with no clear agglomeration. There were 6 units with a marginalization area of more than 10,000 hm^2, which were distributed in Yixing, Xinghua, Gaochun District, Liyang, Shengzhou and Chun'an County. There was no nature-induced marginalization occurring in 18 units, which were mostly distributed in Shanghai, Jiaxing and Taizhou. (2) From 2010 to 2020, the natural marginalization demonstrated a clear pattern of high in the southwest and low in the northeast. The units with large area of marginalization were concentrated in the southern YRD, such as Hangzhou, Shaoxing, Taizhou, and Ningbo, the mountainous and hilly areas. The number of units with a marginalization area over 10,000 hm^2 was increased from 6 to 16. The areas of marginalization in the northeast, such as Nantong, Shanghai, Taizhou, and Jiaxing, were small. The distribution of nature-induced marginalization ratios (Figure 6b) was consistent with the distribution of areas of marginalization in general, that is, the larger the marginalization area, the higher the marginalization ratio.

From 2000 to 2020, the area of economy-induced marginalization in YRD was 1.41×106 hm^2, accounting for 23.19% of the total farmland and 74% of the marginalized cultivated land. Affected by location and economic development, there were certain differences in the economy-induced marginalization among different units. It can be seen from Figure 6c that: (1) From 2000 to 2010, the economy-induced marginalization in general displayed a distribution of high in the central and eastern regions, and low in the south and north. Large areas of marginalization mostly occurred in Shanghai, Wuxi, and Nantong. Among them, Pudong New District of Shanghai had the largest marginalization area of 25,088 hm^2, primarily due to the large amount of farmland occupied by urban development.

The districts and counties with a low area of marginalization were mostly distributed in Nanjing, Hangzhou and Zhoushan. (2) From 2010 to 2020, the regions with a large area of economy-induced marginalization increased significantly, spreading outward from the economically developed areas, and were concentrated in the YRD northeastern coastal area and the central urban area of Hangzhou. Liangxi District of Wuxi, Yangpu District of Shanghai, and Qinhuai District and Xuanwu District of Nanjing had small areas of marginalization, but their marginalization ratios were as high as 100% (Figure 6d), mainly because that the small area of farmland resulted in a small marginalization area with a high marginalization ratio. Overall, there were significant differences in the spatial distribution of areas and ratios of socioeconomic marginalization, especially since the central urban regions with a high marginalization ratio usually had a small marginalized area.

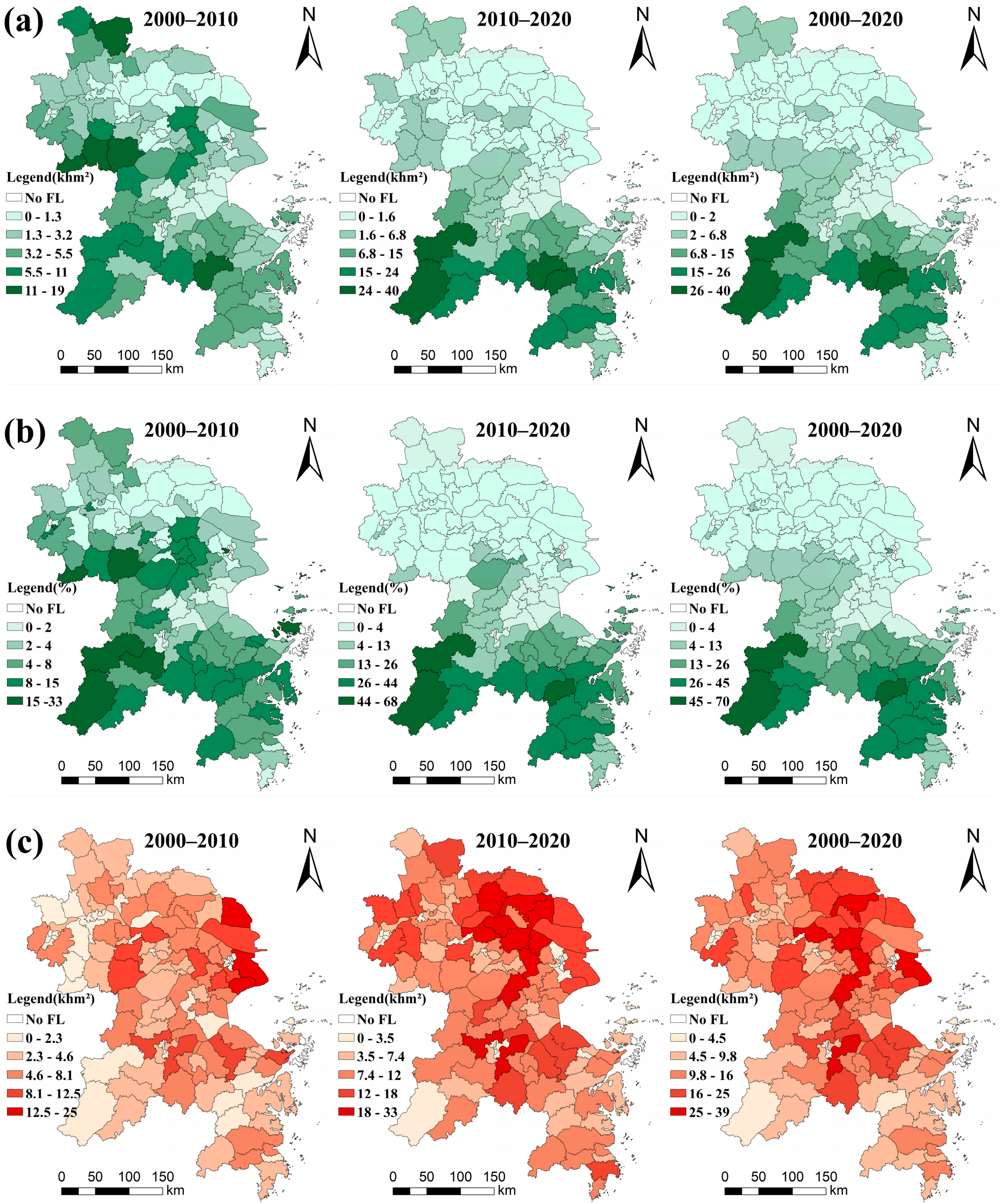

Figure 6. *Cont.*

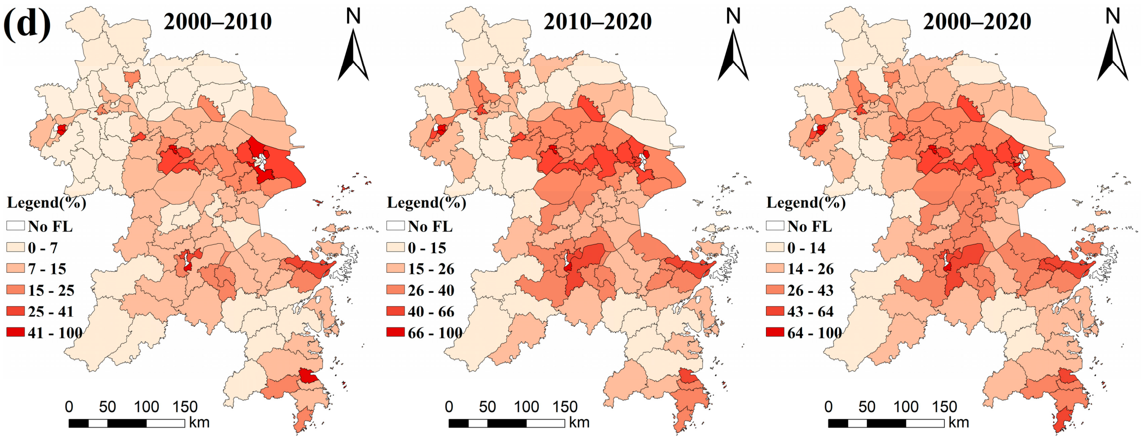

Figure 6. Spatial distribution of farmland marginalization under different factors: (**a**) nature-induced marginalization area at the district and county level; (**b**) nature-induced marginalization ratio at the district and county level; (**c**) economy-induced marginalization area at the district and county level; and (**d**) economy-induced marginalization ratio at the district and county level.

3.2.2. Spatial Differentiation Characteristics of Farmland Marginalization in YRD under Different Factors

The Getis-Ord Gi* tool in ArcGIS 10.2 was used to analyze the local spatial agglomeration of marginalized farmland, and to identify the distribution characteristics of hot and cold spots. It can be seen from Figure 7a,b that: (1) From 2000 to 2020, the field of nature-induced marginalized hot spots in YRD expanded significantly, and the field of cold spots increased as well. (2) From 2000 to 2010, there were relatively few hot and cold spots. The hot spots were mostly distributed in the west of the study area, including Nanjing, Changzhou, Wuxi, Huzhou, and Hangzhou. They were also seen in Shaoxing and Taizhou. The cold spots were concentrated in the middle northern part of the study area, largely in Taizhou and southern Yangzhou, eastern Zhenjiang and northern Wuxi. (3) From 2010 to 2020, the degree of nature-induced marginalization elevated significantly. The hotspot areas were clearly clustered, and their coverage expanded, resulting in significant regional differences. The hotspot areas were concentrated in the northern part of the study area, including most districts of Hangzhou, Shaoxing, Taizhou, Ningbo and Huzhou. The cold spots were also distributed in those areas, but with a significantly expanded area, covering some districts and counties of Shanghai and Suzhou.

It can be seen from Figure 7c,d that: (1) From 2000 to 2010, the economy-induced marginalization hot spots of YRD were concentrated in the central and eastern regions, centered at Shanghai and spreading outward, involving neighboring districts and counties of Nantong, Suzhou, and Jiaxing. The cold spots of the economy-induced marginalization area had a wide range, mostly in the northwest of the study area, including some districts and counties of Nanjing, Zhenjiang, and Yangzhou. There were fewer cold spots of economy-induced marginalization ratio, and they were distributed in Lishui District of Nanjing. (2) From 2010 to 2020, the hot spots of economy-induced marginalization area and marginalization ratio were both expanded, but inconsistently in the expanding direction. The hot spots of marginalization area were expanded to include some districts and counties of Shaoxing in the South. The hot spots of marginalization ratio shifted and expanded from the central and eastern to the northwest YRD, covering most areas of Suzhou, Wuxi and Nanjing. The cold spots of marginalization area shrunk, while the cold spots of marginalization ratio expanded significantly and trended toward the northwest.

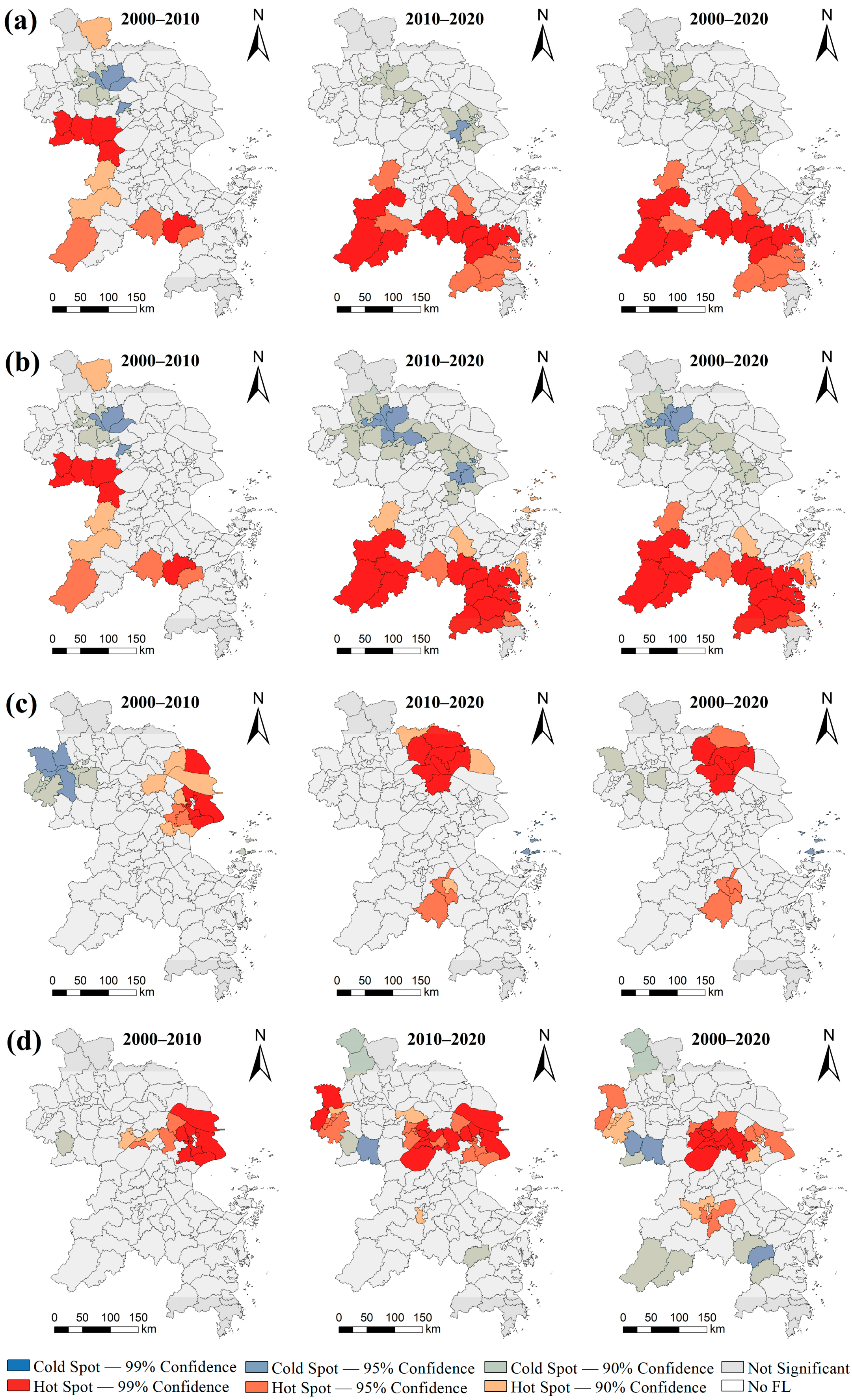

Figure 7. Hot spot analysis of farmland marginalization under different factors in YRD from 2000 to

2020: (**a**) hot spot analysis of nature-induced marginalization area; (**b**) hot spot analysis of nature-induced marginalization ratio; (**c**) hot spot analysis of economy-induced marginalization area; and (**d**) hot spot analysis of economy-induced marginalization ratio.

3.3. The Main Driving Factors of Farmland Marginalization in YRD from 2000 to 2020

3.3.1. Spatial Autocorrelation Test and Model Selection

The use of spatial econometric models requires the existence of a correlation between spatial element units, and the spatial correlation test of the explained variables is required first. In this study, farmland marginalization, nature-induced marginalization and economy-induced marginalization from 2000 to 2020 were taken as the explained variables, and their Moran's I indices were 0.298, 0.291 and 0.367, respectively. All p values passed the significance test of 0.001, indicating the existence of spatial autocorrelation, and a spatial econometric model can be used to measure the driving factors. Therefore, the cross-sectional data of the study area in 2020 was selected, and the Stata 17.0 software (Stata 17.0, StataCorp LLC, Texas, The United States) was used for LM test. It can be seen from Table 3 that the LM and R-LM of the spatial error model do not reject the null hypothesis, while the LM and R-LM of the spatial lag model have both passed the 0.01 level test, and both consider that there is a spatial effect, so the spatial lag model is selected to analyze the driving factors.

Table 3. Spatial dependence diagnosis of farmland marginalization function from 2000 to 2020.

Inspection Methods	**Farmland Marginalization**		**Nature-Induced Marginalization**		**Economy-Induced Marginalization**	
	Statistic	***p***	**Statistic**	***p***	**Statistic**	***p***
Residual Moran's I	1.125	0.261	0.890	0.373	1.104	0.270
Spatial error LM	2.220	0.136	0.193	0.660	1.942	0.163
Spatial error R-LM	0.381	0.537	1.620	0.203	0.366	0.545
Spatial lag LM	16.392	0.000	9.006	0.003	15.326	0.000
Spatial lag R-LM	14.553	0.000	10.433	0.001	13.750	0.000

3.3.2. Spatial Econometric Model Results and Analysis

By comparing the results of OLS and SLM, it is found that the Adj. R2 and Log L of the latter are both greater than those of the former, indicating that SLM is the optimal model in this paper, and OLS ignores or reduces the impact of most factors on farmland marginalization in the YRD. The results of the spatial lag model of farmland marginalization (Table 4) show that production conditions are the main driving factors of farmland marginalization, and x_1 and x_2 have significant negative correlations with farmland marginalization. These two variables represent the dominant factors of farmland marginalization in YRD. The results indicate that the larger the area of the farmland per capita, the more conducive it might be to large-scale farming, which could improve the degree of mechanization and reduce the occurrence of farmland marginalization. Compared with the southern YRD, the northern regions had a flatter terrain and better-connected farmlands. Spatially, the marginalized area of farmland in the northern part was lower than that in the southern part. Economic levels are important factors affecting farmland marginalization. x_4 showed a positive correlation, indicating that the increase of urbanization level led to the occurrence of farmland marginalization. x_5 and x_7 were negatively correlated at a significant level of 5%, which indicates that residents' living standards and government subsidies for farmland are directly related to farmers' enthusiasm for grain cultivation. Unfavorable terrain conditions are the main factors leading to farmland marginalization. x_{10} demonstrated a clear negative effect; the average plot area directly affected the mechanization level of agricultural production, and thus it could intuitively demonstrate the fragmentation of farmland. The smaller the plot size, the more fragmented the farmland, and the more inconvenient the mechanized farming; as a result, farmland marginalization was favored.

Table 4. Estimation results of farmland marginalization spatial lag model from 2000 to 2020.

Explanatory Variables	Farmland Marginalization		Nature-Induced Marginalization		Economy-Induced Marginalization	
	OLS	**SLM**	**OLS**	**SLM**	**OLS**	**SLM**
x_1	−0.562 * (0.059)	−0.598 ** (0.022)	0.529 (0.339)	0.413 (0.410)	−0.657 ** (0.015)	−0.689 *** (0.004)
x_2	−0.197 *** (0.001)	−0.252 *** (0.002)	0.419 (0.104)	0.314 (0.181)	0.217 (0.083)	0.134 (0.233)
x_3	−0.301 (0.152)	−0.107 (0.386)	0.172 (0.315)	0.075 (0.634)	0.339 *** (0.000)	0.298 *** (0.000)
x_4	0.878 (0.296)	1.453 * (0.053)	−2.807 * (0.075)	−3.054 ** (0.032)	−0.152 (0.842)	0.706 *** (0.005)
x_5	−0.683 * (0.074)	−0.663 ** (0.048)	−1.366 * (0.056)	−1.285 ** (0.046)	−0.449 (0.194)	−0.442 (0.148)
x_6	1.071 (0.209)	0.434 (0.571)	4.351 *** (0.007)	3.118 ** (0.036)	1.298 * (0.094)	0.721 (0.302)
x_7	−0.224 (0.369)	−0.234 ** (0.026)	0.373 (0.423)	0.396 (0.348)	−0.132 (0.557)	−0.149 (0.457)
x_8	0.148 (0.272)	0.064 (0.591)	−0.443 * (0.079)	−0.456 ** (0.045)	0.223 (0.169)	0.137 (0.212)
x_9	−0.601 (0.836)	0.112 (0.668)	1.985 *** (0.000)	1.924 *** (0.000)	−0.332 (0.212)	−0.149 (0.532)
x_{10}	0.263 * (0.081)	−0.252 * (0.056)	0.382 (0.173)	0.406 (0.109)	0.343 ** (0.012)	−0.327 *** (0.007)
ρ		0.026 *** (0.000)		0.052 *** (0.001)		0.232 *** (0.000)
Adj.R2	0.372	0.639	0.458	0.783	0.389	0.731
Log L	−193.678	−179.299	−301.259	−257.568	−184.372	−168.194
AIC	398.129	384.599	548.249	541.135	374.721	362.387

Note: ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively; p-values in parentheses.

To investigate the spatial heterogeneity of the driving factors of farmland marginalization under different factors, nature-induced marginalization area and economy-induced marginalization area from 2000 to 2020 were used as dependent variables, respectively, to carry out spatial autoregressive analysis. From the results of the spatial error model in Table 4, we can see that: (1) Nature-induced marginalization was mainly affected by x_4, x_5, x_6, x_8, and x_9. x_4 and x_5 were significantly negatively correlated with nature-induced marginalization, indicating that nature-induced marginalization mostly occurred in areas with low urbanization and poor economic development. x_6 shows a positive effect, indicating that the improvement of rural residents' income to a certain extent is at the expense of farmland marginalization, such as farmland abandonment. x_8 had a negative effect, and x_9 had a significant positive effect. It can be seen that, affected by natural factors such as elevation and slope, in mountainous and hilly areas with poor cultivation conditions, farmland was more likely to be converted into forests and grasslands, shifting toward nature-induced marginalization. As to spatial distribution, nature-induced marginalization was concentrated in the northern Zhejiang. (2) Economy-induced marginalization was mainly affected by x_1, x_3, x_4, and x_{10}. x_1 and x_3 were positively and negatively correlated at the significance level of 1%, respectively. The number of areas using small agricultural machinery can reflect the degree of farmland fragmentation, that is, areas with small farmland area per capita and high degree of farmland fragmentation are more prone to economy-induced marginalization. x_4 had a significant positive impact on socioeconomic marginalization. Compared with nature-induced marginalization, economy-induced marginalization mainly occurred in areas with high urbanization ratios. Affected by urban expansion, a large amount of farmland has been converted into construction land. Spatially, economy-induced marginalization was concentrated in the central and eastern developed regions. x_{10} had a significant negative effect. Affected by topographic conditions, small tracts of cultivated land are more likely to be transformed into other land types, thus tending to be marginalized.

4. Discussion

4.1. General Trend of Farmland Marginalization in the Process of Rapid Urbanization

Farmland marginalization is a common phenomenon that occurs when the social economy develops to a certain extent, and it has become an important part of land use change. Most of the early studies on farmland marginalization focused on hills and mountainous areas, and scholars paid more attention to the problem of abandoned cultivated land. For example, Wang et al. [31] through a follow-up survey of farmers, found that the abandonment rate of cultivated land in the mountainous areas of southwest China increased from 21.57% in 2011 to 27.19% in 2018; Tan et al. [25] conducted a study on farmland marginalization in China's hilly and mountainous areas, and the results show that from 1990 to 2020, the marginalized farmland in hilly and mountainous areas in China accounts for 64.77% of the total arable land in mountainous areas. This study showed that the marginalization ratio of farmland in YRD was 31.34% from 2000–2020, with a significant upward trend. However, compared with the 60% marginalization ratio of farmland in the hilly and mountainous areas of Southwest China [25], it was remarkably lower. There are two main reasons for this. Firstly, the huge income gap between urban and rural residents compelled many rural labor workers to migrate to large and medium-sized cities in China [50–52], and the ratio of farmland abandonment exceeded 30% in some remote mountainous areas [53]. Secondly, the poor natural conditions of farmland in hilly and mountainous areas seriously restricted agricultural mechanization [17,54]. Farmers usually have to adjust the agricultural structure to adapt to the rising labor cost, resulting in a high ratio of farmland marginalization [55,56]. From 2000 to 2010, the units with a large area of farmland marginalization in YRD were mainly concentrated in the central part, such as Wuxi, Shanghai, Suzhou, and Nantong. The farmland marginalization in this period was mostly due to urban expansion, which occupied a large amount of farmland. With the rapid development of urbanization and the influence of natural conditions of farmland, rural labor workers migrated to cities, resulting in a shortage of rural labor workers. Farmland of inferior quality was gradually abandoned, resulting in the conversion of farmland into forests or grasslands. From 2010 to 2020, the focus of farmland marginalization shifted to the southern mountainous and hilly areas with poor farming conditions, such as Shaoxing, Hangzhou, and Taizhou.

In addition, the distribution of farmland marginalization under different factors exhibited clear spatial heterogeneity. Firstly, economy-induced marginalization was significantly larger than nature-induced marginalization, indicating that marginalization in rapidly urbanized areas was more affected by urban expansion and socioeconomic development than in mountainous and hilly areas. Secondly, considered spatially, nature-induced marginalization has shifted from discrete distribution to continuous distribution in the mountainous and hilly areas of Hangzhou, Shaoxing, Taizhou, and Ningbo in the south of the study area, with increased internal spatial differences. The economy-induced marginalization was mostly distributed in the central and eastern regions with high urbanization, and the regions with a large area of marginalization were clearly expanding.

4.2. The Main Driving Factors of Farmland Marginalization in YRD

Generally speaking, it is believed that poor farming conditions [57,58], labor transfer [59], and low planting efficiency [60] drive farmland marginalization. For example, Li et al. [61] found that the rising opportunity cost of farming and the rapid extraction of rural labor caused by urbanization were the main driving forces for farmland marginalization in mountainous areas of China. Zhao et al. [7] showed that low land management profit was the primary reason for farmland marginalization in Renhuai, Guizhou. Tan et al. [25] conducted research on farmland marginalization in mountainous and hilly areas and indicated that the higher the slope, the higher the degree of farmland marginalization. However, most of the previous studies focused on mountainous and hilly areas [15,54], and little attention has been paid to the characteristics and formation mechanism of farmland marginalization in rapidly urbanized areas.

In the context of rapid urbanization, the problem of farmland marginalization in areas with high socio-economic development level has become more and more prominent, and the driving factors behind it are different from those in hilly and mountainous areas. The research of Li et al. showed that the rapid development of urbanization, the slope and the quality of cultivated land and other natural and economic conditions determine the types of farmland marginalization in the process of urbanization [15]. In addition, the scale of arable land management, government support and household income are also closely related to farmland marginalization in rural suburban cities [29]. These findings are similar to those of the present study, further demonstrating the scientific nature and reliability of this study's results.

The present study took YRD as the research area and considered the conversion of farmland to construction land, garden land, forests, grasslands, water bodies, and unused land as farmland marginalization. It was shown that though the average plot area (representing the farming condition), the total power of agricultural machinery (representing planting efficiency), and the farmland area per capita were still the main driving factors of farmland marginalization. However, the main driving factors of farmland marginalization were different under different influencing factors. Table 4 reveals the differences in the formation mechanisms between nature-induced and economy-induced marginalization. Nature-induced marginalization was mainly driven by topographic conditions and economic level. Slope had the most significant impacts on farmland marginalization. Urbanization ratio, GDP per capita, income of rural residents, and elevation had significant effects, while the impacts of other driving factors were not significant. Economy-induced marginalization was mainly driven by production conditions. The farmland area per capita and small agricultural machinery had the most significant impacts on it. The urbanization ratio and average lot area also affected the differentiation pattern of economy-induced marginalization to a certain extent. It can be seen that compared with the mountainous and hilly areas, the formation mechanism of the farmland marginalization in the rapidly urbanized areas was more diversified and complicated.

4.3. Limitations and Application of This Study

This study only considered the conversion of farmland to forests, grasslands, water bodies, unused land, construction land, etc., that is, the dominant marginalization. The impact of recessive marginalization, such as the reduction of farmland input and output and the decline of the multiple cropping index, was not taken into account. This may have a certain impact on the actual rate of farmland marginalization. Nevertheless, in the rapidly urbanized areas, the dominant marginalization dominated [62,63], which was significantly different from the mountainous and hilly areas of Southwest China [25]. The dominant marginalization may more concisely describe the driving force of rapid urbanization on the farmland marginalization.

In this study, the causes of farmland marginalization were divided into nature-induced marginalization and economy-induced marginalization, which is very useful for future landscape management and planning in rural areas. From the results of this study, the characteristics and formation mechanism of farmland marginalization in rapidly urbanized areas were more diversified and complicated. The nature-induced marginalization is mainly caused by unfavorable terrain conditions, while economy-induced marginalization is affected by the comprehensive influence of production conditions and economic level. Therefore, in the process of controlling farmland marginalization in rapidly urbanized areas, we should focus on the causes of marginalization, analyze the main driving factors of farmland marginalization based on our own actual conditions, and formulate and improve the corresponding institutional measures, so as to effectively reduce farmland marginalization. (1) For areas where nature-induced marginalization dominates, such as the hilly and mountainous areas of southwest China, it is necessary to improve agricultural production conditions and build high-standard farmlands, increase agricultural subsidies, boost farmers' willingness to grow grain, and minimize nature-induced marginalization.

(2) For areas where economy-induced marginalization is dominant, such as the eastern coastal areas, it is necessary to shift urban construction to connotative development, control disorderly expansion, and reduce the occupation of high-quality farmland, restrict the conversion of farmland, and thoroughly protect farmland to safeguard farmers' interests and national food security.

5. Conclusions

Based on remote sensing image data and socioeconomic data, this study performed spatial autocorrelation analysis, hotspot analysis, and multiple linear regression analysis to explore the spatial pattern, differentiation characteristics, and main driving factors of farmland marginalization in rapidly urbanized areas. The main results were as follows: (1) From 2000 to 2020, the marginalization ratio of farmland in YRD was 31.34%, with a clear increasing trend, and in general, distributed as high in the central and southern and low in the north. (2) Marginalization presented different spatial agglomerations under different influencing factors. The nature-induced marginalization ratio was 8.15%, and the spatial pattern switched from discrete distribution to a clear distribution of high in the south and low in the north. The economy-induced marginalization ratio was 23.19%, distributed as high in the middle and low on the sides. (3) Farmland area per capita, total power of agricultural machinery, government farmland subsidies and average plot area were the main driving factors for farmland marginalization. In addition, nature-induced marginalization was primarily driven by economic level and topographical conditions, whereas economy-induced marginalization was primarily driven by production conditions. Based on the results of the analyses, this study believes that relevant policies can be formulated from the following three aspects to provide a scientific basis for controlling farmland marginalization and ensuring food security during the rapid urbanization in China, as well as in developing countries.

(1) Increase investment in agricultural capital and technology, and accurately implement agricultural subsidies. Considering the significant impact of terrain conditions on nature-induced marginalization, increase investment in agricultural capital and technology, improve the quality of cultivated land through the implementation of cultivated land consolidation, carry out terrace construction in mountainous and hilly areas according to local conditions, improve agricultural production conditions, and build high-standard farmland, so as to increase the productivity of arable land. At the same time, attention should be paid to the impact of economic level on nature-induced marginalization: strengthen agricultural subsidies and implement subsidies to grain planting to ensure farmers' income related to grain production, stimulate farmers' enthusiasm for grain planting, and minimize the nature-induced marginalization.

(2) Speed up the progress of land consolidation in an orderly manner and promote the intensive utilization of cultivated land. Unfavorable farming conditions are the main reason for the transformation of cultivated land to other types of land, and the fragmentation of cultivated land limits the large-scale operation of cultivated land. Considering the significant impact of per capita arable land, total power of agricultural machinery, and average land plot area on the farmland marginalization, it is necessary to speed up land consolidation, integrate scattered arable land in suburban areas, and adjust arable land structure, so as to promote large-scale arable land management, improve the level of mechanization and cultivation efficiency of cultivated land, reduce the input cost of cultivated land, and effectively control the marginalization caused by the fragmentation of cultivated land; secondly, we should further improve the intensity of urban land use, strengthen the transformation of old cities, ease the pressure on urban land use, and reduce the occupation of cultivated land by urban expansion.

(3) Strictly implement the cultivated land protection system and restrict the transformation of cultivated land use. In response to the transformation of the use of dominant marginalized farmland, the cultivated land protection system should be strictly implemented, and the cultivated land within the permanent basic farmland should be strictly

prohibited from being converted into other land types, and the cultivated land outside the permanent basic farmland can then be appropriately used for economic crop production. Moderately increase farmers' income from grain cultivation, encourage the cultivation of grain crops, and provide that cultivated land in permanent basic farmland can only be used for food production to ensure food security and social stability.

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References

1. Deng, X.; Huang, J.; Rozelle, S.; Uchida, E. Cultivated land conversion and potential agricultural productivity in China. *Land Use Policy* **2006**, *23*, 372–384. [CrossRef]
2. Shi, T.; Li, X.; Xin, L.; Xu, X. The spatial distribution of farmland abandonment and its influential factors at the township level: A case study in the mountainous area of China. *Land Use Policy Int. J. Cover. All Asp. Land Use* **2018**, *70*, 510–520. [CrossRef]
3. Alcantara, C.; Kuemmerle, T.; Prishchepov, A.V.; Radeloff, V.C. Mapping abandoned agriculture with multi-temporal MODIS satellite data. *Remote Sens. Environ.* **2012**, *124*, 334–347. [CrossRef]
4. Renwick, A.; Jansson, T.; Verburg, P.H.; Revoredo-Giha, C.; Britz, W. Policy reform and agricultural land abandonment in the EU. *Land Use Policy* **2013**, *30*, 446–457. [CrossRef]
5. Zhao, Y.L.; Zhang, M.; Li, X.B.; Dong, S.Z.; Huang, D.K. Farmland Marginalization and Policy Implications in Mountainous Areas: A Case Study of Renhuai City, Guizhou. *J. Resour. Ecol.* **2016**, *7*, 61–67.
6. Swette, B.; Lambin, E.F. Institutional changes drive land use transitions on rangelands: The case of grazing on public lands in the American West. *Glob. Environ. Change* **2021**, *66*, 102220. [CrossRef]
7. Stampini, M.; Davis, B. Does nonagricultural labor relax farmers' credit constraints? Evidence from longitudinal data for Vietnam. *Agric. Econ.* **2009**, *40*, 177–188. [CrossRef]
8. Martellozzo, F.; Amato, F.; Murgante, B.; Clarke, K.C. Modelling the impact of urban growth on agriculture and natural land in Italy to 2030. *Appl. Geogr.* **2018**, *91*, 156–167. [CrossRef]
9. Wang, L.; Herzberger, A.; Zhang, L.; Xiao, Y.; Wang, Y.; Xiao, Y.; Liu, J.; Ouyang, Z. Spatial and Temporal Changes of Arable Land Driven by Urbanization and Ecological Restoration in China. *Chin. Geogr. Sci.* **2019**, *29*, 809–819. [CrossRef]
10. Wang, Y. Population-land urbanization and comprehensive development evaluation of the Beijing-Tianjin-Hebei urban agglomeration. *Env. Sci. Pollut. Res. Int.* **2022**, *4*, 1–10. [CrossRef]
11. Wang, Y. Effects of urbanization on spatial-temporal changes of cultivated land in Bohai Rim region. *Environ. Dev. Sustain.* **2022**, *5*, 1–18. [CrossRef]
12. Yan, H.; Liu, J.; Huang, H.Q.; Tao, B.; Cao, M. Assessing the consequence of land use change on agricultural productivity in China. *Glob. Planet. Change* **2009**, *67*, 13–19. [CrossRef]
13. Wu, Y.; Luo, J.; Zhang, X.; Skitmore, M. Urban growth dilemmas and solutions in China: Looking forward to 2030. *Habitat Int.* **2016**, *56*, 42–51. [CrossRef]
14. Li, H.; Huang, X.; Kwan, M.P.; Bao, H.X.H.; Jefferson, S. Changes in farmers' welfare from land requisition in the process of rapid urbanization. *Land Use Policy* **2015**, *42*, 635–641. [CrossRef]
15. Li, H.; Wu, Y.; Huang, X.; Sloan, M.; Skitmore, M. Spatial-temporal evolution and classification of marginalization of cultivated land in the process of urbanization. *Habitat Int.* **2017**, *61*, 1–8. [CrossRef]
16. Zhang, R.; Li, P.; Xu, L.; Zhong, S.; Wei, H. An integrated accounting system of quantity, quality and value for assessing cultivated land resource assets: A case study in Xinjiang, China. *Glob. Ecol. Conserv.* **2022**, *36*, e02115. [CrossRef]
17. Shao, J.A.; Zhang, S.; Li, X. Farmland marginalization in the mountainous areas: Characteristics, influencing factors and policy implications. *J. Geogr. Sci.* **2015**, *25*, 701–722. [CrossRef]

18. Macdonald, D.; Crabtree, J.R.; Wiesinger, G.; Dax, T.; Stamou, N.; Fleury, P.; Lazpita, J.G.; Gibon, A. Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response. *J. Environ. Manag.* **2000**, *59*, 47–69. [CrossRef]
19. Strijker, D. Marginal lands in Europe—Causes of decline. *Basic Appl. Ecol.* **2005**, *6*, 99–106. [CrossRef]
20. Li, Y.; Zhou, T.; Jiang, G.; Li, G.; Zhou, D.; Luo, Y. Spatial pattern and mechanisms of farmland abandonment in Agricultural and Pastoral Areas of Qingzang Plateau. *Geogr. Sustain.* **2021**, *2*, 139–150. [CrossRef]
21. He, Y.; Xie, H.; Peng, C. Analyzing the behavioural mechanism of farmland abandonment in the hilly mountainous areas in China from the perspective of farming household diversity. *Land Use Policy* **2020**, *99*, 104826. [CrossRef]
22. Ma, L.; Long, H.; Tu, S.; Zhang, Y.; Zheng, Y. Farmland transition in China and its policy implications. *Land Use Policy* **2020**, *92*, 104470. [CrossRef]
23. Ying, L.; Chunshan, Z.; Wanling, H.; Qianqiong, Z. Spatial features and forming mechanism of rural land non-agricultural degree in metropolitan areas: A case study of Guangzhou City. *Prog. Geogr.* **2018**, *37*, 1119–1130.
24. Prishchepov, A.V.; Radeloff, V.C.; Baumann, M.; Kuemmerle, T.; Muller, D. Effects of institutional changes on land use: Agricultural land abandonment during the transition from state-command to market-driven economies in post-Soviet Eastern Europe. *Environ. Res. Lett.* **2012**, *7*, 024021. [CrossRef]
25. Tan, Y.; Chen, H.; Xiao, W.; Meng, F.; He, T. Influence of farmland marginalization in mountainous and hilly areas on land use changes at the county level. *Sci. Total Environ.* **2021**, *794*, 149576. [CrossRef]
26. Van, D.; Verburg, P.H.; Schulp, C.; Verkerk, P.J. Trade-offs of European agricultural abandonment. *Land Use Policy* **2017**, *62*, 290–301.
27. Mantero, G.; Morresi, D.; Marzano, R.; Motta, R.; Mladenoff, D.J.; Garbarino, M. The influence of land abandonment on forest disturbance regimes: A global review. *Landsc. Ecol.* **2020**, *35*, 2723–2744. [CrossRef]
28. Wang, Y.; Li, X.; Xin, L.; Tan, M. Farmland marginalization and its drivers in mountainous areas of China. *Sci. Total Environ.* **2019**, *719*, 135132. [CrossRef]
29. Lu, Z.L.; Pan, X.C.; Zhou, G.L.; Tang, Z.T.; Li, X.C.; Guo, Y.J.; Huang, J.T.; Zhuang, D.C. Study on the Characteristics and Influencing Factors of Farmland Marginalization in Suburban Rural Areas of Metropolis: A Survey of Rural Households in Suburban Areas of Guangzhou City. *China Land Sci.* **2021**, *35*, 67–74.
30. Hua, X.B.; Yan, J.Z.; Zhou, C.J.; Chen, L. Marginalization of Agricultural Land Use in Hilly Areas and Its Explanation from the Livelihood Strategy of Farmers: A Case Study on Youyang County. *Acta Sci. Nat. Univ. Pekin.* **2013**, *49*, 0479–8023.
31. Wang, Y.H.; Xin, L.J.; Zhang, H.Z.; Li, Y.Q. An Estimation of the Extent of Rent-Free Farmland Transfer and Its Driving Forces in Rural China: A Multilevel Logit Model Analysis. *Sustainability* **2019**, *11*, 3161. [CrossRef]
32. Liu, Y.; Wang, J.; Long, H. Analysis of arable land loss and its impact on rural sustainability in Southern Jiangsu Province of China. *J. Environ. Manag.* **2010**, *91*, 646–653. [CrossRef] [PubMed]
33. Zhang, J.; Zhang, F.; Zhang, D.; He, D.; Zhang, L.; Wu, C.; Kong, X. The grain potential of cultivated lands in Mainland China in 2004. *Land Use Policy* **2009**, *26*, 68–76. [CrossRef]
34. Lu, H.; Chen, Y.; Huan, H.; Duan, N. Analyzing Cultivated Land Protection Behavior From the Perspective of Land Fragmentation and Farmland Transfer: Evidence From Farmers in Rural China. *Front. Environ. Sci.* **2022**, *10*, 901097. [CrossRef]
35. Mawois, M.; Aubry, C.; Bail, M.L. Can farmers extend their cultivation areas in urban agriculture? A contribution from agronomic analysis of market gardening systems around Mahajanga (Madagascar). *Land Use Policy* **2011**, *28*, 434–445. [CrossRef]
36. Xiao, R. The Impacts of Farmland Loss on Regional Food Self-Sufficiency in Yangtze River Delta Urban Agglomeration over Last Two Decades. *Remote Sens.* **2021**, *13*, 3514.
37. Lichtenberg, E.; Ding, C. Assessing farmland protection policy in China. *Land Use Policy* **2008**, *25*, 59–68. [CrossRef]
38. Zhang, M.; Chen, Q.; Zhang, K. Influence of the variation in rural population on farmland preservation in the rapid urbanization area of China. *J. Geogr. Sci.* **2021**, *31*, 1365–1380. [CrossRef]
39. Song, W.; Wu, K.; Zhao, H.; Zhao, R.; Li, T. Arrangement of High-standard Basic Farmland Construction Based on Village-region Cultivated Land Quality Uniformity. *Chin. Geogr. Sci.* **2018**, *29*, 325–340. [CrossRef]
40. Chen, F.; Liu, J.N.; Chang, Y.Y.; Zhang, Q.; Yu, H.C.; Zhang, S.L. Spatial Pattern Differentiation of Non-grain Cultivated Land and Its Driving Factors in China. *China Land Sci.* **2021**, *35*, 33–43.
41. Lu, Q.; Soderlud, L.; Wu, P.L.; Li, J. Cultivated land loss arising from the rapid urbanization in China. *Agrifood Res. Rep.* **2005**, *68*, 313–327.
42. Hu, Y.; Wang, X.L. Analysis on the Change of Land Use Structure and Its Driving Factors in Wuhan City. *Res. Soil Water Conserv.* **2014**, *21*, 234–239.
43. Huang, H.; Zhou, Y.; Qian, M.; Zeng, Z. Land Use Transition and Driving Forces in Chinese Loess Plateau: A Case Study from Pu County, Shanxi Province. *Land* **2021**, *10*, 67. [CrossRef]
44. Zhan, J.Y.; Shi, N.N.; He, S.J.; Lin, Y.Z. Factors and mechanism driving the land-use conversion in Jiangxi Province. *J. Geogr. Sci.* **2010**, *20*, 525–539. [CrossRef]
45. Xie, H.; Lu, H. Impact of land fragmentation and non-agricultural labor supply on circulation of agricultural land management rights. *Land Use Policy* **2017**, *68*, 355–364. [CrossRef]
46. Viaggi, D.; Signorotti, C.; Marconi, V.; Raggi, M. Do agri-environmental schemes contribute to high nature value farmland? A case study in Emilia-Romagna (Italy). *Ecol. Indic.* **2015**, *59*, 62–69. [CrossRef]
47. Getis, A.; Ord, J.K. The Analysis of Spatial Association by Use of Distance Statistics. *Geogr. Anal.* **1992**, *24*, 189–206. [CrossRef]

48. Das, M.; Ghosh, S.K. Measuring Moran's I in a Cost-Efficient Manner to Describe a Land-Cover Change Pattern in Large-Scale Remote Sensing Imagery. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* **2017**, *10*, 2631–2639. [CrossRef]
49. Yang, F.; Liu, G.; Cheikhrouhou, O. Research on Spillover Effect of Urbanization on Rural Land Transfer Based on the SDM Model of Intelligent Computing. *Mob. Inf. Syst.* **2022**, *2022*, 1–10. [CrossRef]
50. Li, Y.R.; Liu, Y.S.; Long, H.L.; Cui, W.G. 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]
51. Long, H.; Li, Y.; Liu, Y.; Woods, M.; Jian, Z. Accelerated restructuring in rural China fueled by 'increasing vs. decreasing balance' land-use policy for dealing with hollowed villages. *Land Use Policy* **2012**, *29*, 11–22. [CrossRef]
52. Zhang, R.J.; Jiang, G.H.; Zhang, Q. Does urbanization always lead to rural hollowing? Assessing the spatio-temporal variations in this relationship at the county level in China 2000e2015. *J. Clean. Prod.* **2019**, *220*, 9–22. [CrossRef]
53. Shi, T.; Li, X.; Xin, L.; Xu, X. Analysis of Farmland Abandonment at Parcel Level: A Case Study in the Mountainous Area of China. *Sustainability* **2016**, *8*, 988. [CrossRef]
54. Xiao, M.; Zhang, Q.; Qu, L.; Hussain, H.; Dong, Y.; Zheng, L. Spatiotemporal Changes and the Driving Forces of Sloping Farmland Areas in the Sichuan Region. *Sustainability* **2019**, *11*, 906. [CrossRef]
55. Cao, Y.G.; Yuan, C.; Zhou, W.; Jin, T.; Rong, H. Analysis on Driving Forces and Provincial Differences of Cultivated Land Change in China. *China Land Sci.* **2008**, *22*, 17–22.
56. Qian, F.K.; Chi, Y.R.; Lal, R. Spatiotemporal characteristics analysis of multifunctional cultivated land: A case study in Shenyang, Northeast China. *Land Degrad. Dev.* **2020**, *31*, 1812–1822. [CrossRef]
57. Burra, D.D.; Parker, L.; Than, N.T.; Phengsavanh, P.; Nam, V. Drivers of land use complexity along an agricultural transition gradient in Southeast Asia. *Ecol. Indic.* **2021**, *124*, 107402. [CrossRef]
58. Khanal, N.R.; Watanabe, T. Abandonment of Agricultural Land and Its Consequences. *Mt. Res. Dev.* **2006**, *26*, 32–40. [CrossRef]
59. Sun, L.; Yan, J.; Yang, Z.; Li, Z.; Xin, L. Drivers of cropland abandonment in mountainous areas: A household decision model on farming scale in Southwest China. *Land Use Policy* **2016**, *57*, 459–469.
60. Abdollahzadeh, G.; Azadi, H.; Sharifzadeh, M.S.; Jahangir, L.; Janeková, K.; Sklenika, P.; Tan, R.; Witlox, F. Landholders' perception of conversion of steep lands to orchard schemes: Land use policy implications in North Iran. *Land Use Policy* **2021**, *102*, 105205. [CrossRef]
61. Li, S.; Li, X. The mechanism of farmland marginalization in Chinese mountainous areas: Evidence from cost and return changes. *J. Geogr. Sci.* **2019**, *29*, 531–548. [CrossRef]
62. Yu, M.; Yang, Y.; Chen, F.; Zhu, F.; Qu, J.; Zhang, S. Response of agricultural multifunctionality to farmland loss under rapidly urbanizing processes in Yangtze River Delta, China. *Sci. Total Environ.* **2019**, *666*, 1–11. [CrossRef] [PubMed]
63. Song, W. Decoupling cultivated land loss by construction occupation from economic growth in Beijing. *Habitat Int.* **2014**, *43*, 198–205. [CrossRef]