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Exploring the Factors Driving Seasonal Farmland Abandonment: A Case Study at the Regional Level in Hunan Province, Central China

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Abstract: Farmland abandonment, including perennial and seasonal abandonment, is an important process of land use change that matters most to food security. Although there is a great deal of studies on farmland abandonment, seasonal abandonment, which is as serious as perennial abandonment, has attracted little academic attention. This paper takes Hunan Province in central China as its study area and uses a spatial regression model to examine the driving factors of seasonal farmland abandonment at the county level. Our results show that farmland abandonment has striking spatial relativity, and there are two clustering zones with a high index of farmland abandonment (*IFA*) in the Dongting plain and the basin in south-central Hunan, while a clustering zone of low *IFA* can be found in the mountains of southwest Hunan. Farmland abandonment at the regional level is negatively affected by the land productive potentialities, proportion of mechanized planting, ratio of effective irrigation, and distance to provincial capital, while it is positively associated with the variables mountainous terrain, per capita farmland area, and labor shortage. Additionally, farmland abandonment is also affected by adjacent areas through its spatial dependence. In short, seasonal farmland abandonment is also driven integratedly by the socioeconomic and environmental dimensions and spatial interaction of farm abandonment.

Keywords: farmland abandonment; spatial pattern; natural environment features; socioeconomic conditions; facilities of farming systems; location; spatial regression model; Hunan Province of China

1. Introduction

Farmland abandonment has become a common land use change process observed worldwide [1,2]. It has brought about many positive effects, such as forest re-growth [3], recovery of ecosystem services [4], and enhancement of carbon sink capacity and biodiversity [3,5–7]. However, many negative effects have also been found, including the disappearance of traditional farming practices; loss of habitats with high ecological, cultural, and aesthetic value; increased risk of wildfires; and species invasion [8–13]. What is worthy of more attention is the consequent challenges for food security, especially in areas where arable land is highly scarce, such as China and Japan [12,14]. Although the global grain yield has increased continuously in recent decades, the probability of hunger remains high because of population growth and global environmental change [15]. Hence, the decline of cultivated areas resulting from arable land abandonment significantly threatens food security.

"Farmland abandonment" refers to a less-intensive pattern of land use or total termination of productive use [1,16,17]. According to this change process, farmland abandonment can be divided into implicit and explicit abandonment [16–20]. The former refers to farming with reduced investment in labor and capital—namely, a less-intensive pattern of land use [12,17]. The latter means that the land is given up completely and sees no more farming activity [9,16]. Based on the duration of the abandonment, we can classify explicit abandonment as either seasonal or perennial [18,19]. Most previous studies on agricultural abandonment focused on explicit abandonment, and implicit abandonment is often referred to as marginalization of cultivated land [10,21].

With regard to explicit farmland abandonment, many scholars have sought to explore the drivers from the natural environment and socioeconomic dimensions [20]. These studies revealed that the determinants of farmland abandonment mainly include the following four aspects. First, farmland abandonment often occurs in unfavorable environmental conditions [22]. Factors that affect agricultural production, such as elevation, slope, soil fertility, soil quality, distance to water source, and climate change, are important drivers of farmland abandonment [9,22–25]. The lower the suitability of the natural environment, the higher the risk of farmland abandonment. Second, farmland abandonment is driven by socioeconomic factors, including population change, migration, labor, labor age, technological advances, land rent and revenue, and density of settlements [26–28]. Third, the conditions of agricultural production and land management have important influences on arable land abandonment. For example, heavy usage of farm machinery and fertilizer often improves yield and productivity, thus indirectly triggering the abandonment of arable land in marginal or remote areas [29–31]. Kosmas et al. (2015) claimed that the irrigation percentage of arable land, measures for soil and water conservation, and grazing control were negatively associated with land abandonment [20]. Fourth, location matters most in the process of arable land abandonment. At the micro level, parcels in remote areas are more likely to suffer from abandonment—particularly those that are far from roads and settlements [29,30,32–34]. At the macro level, regions far from agricultural markets and centers of non-farm employment have a higher probability of farmland abandonment [12,29,34–38]. In sum, farmland abandonment is a complex process of land use change that is affected integratedly by these multi-dimensional factors. It is precisely because of the complex causal relations of farm abandonment, our understanding of the influential factors of cultivated land abandonment is still inadequate in most countries [2,13,34,39]. Additionally, relevant studies are usually focused on perennial abandonment, rather than seasonal abandonment. Hence, it is still questionable whether seasonal abandonment can also be explained under the framework constituted by these four aspects.

In China, where arable land is highly scarce, farmland abandonment is also becoming a serious threat to food security [8]. Statistics from the Food and Agriculture Organization of the United Nations (FAO) from 2013 show that China's per capita arable land was less than half of the world average. Meanwhile, cultivated land abandonment is continuously expanding nationwide. The abandonment of cultivated land in China includes perennial and seasonal abandonment. In some areas, the proportion of seasonal abandonment is much higher than perennial abandonment. For example, a sample survey covering 10 cities in Sichuan Province conducted by the province's agriculture department in 2008 showed that 5.35% of total arable land had been given up; perennial abandonment accounted for 43.5% of the total abandoned area, and seasonal abandonment accounted for 56.5% [19]. In Changsha of Hunan Province, a survey from 2007 showed that abandoned farmland constituted 23,138 ha (accounting for 9.37% of total arable land), 98.54% of which had been seasonally abandoned [37]. Furthermore, based on SPOT NDVI data from a long time series, Zhai et al. (2012) found that about 45.49% of farmland (20.55×104 km^2) was kept unused during the winter in the middle and lower reaches of the Yangtze River [39]. Therefore, seasonal farmland abandonment, as serious as perennial abandonment, also seriously threatens Chinese food security.

At the same time, China is facing serious farmland decline and increasing food demand. From 1996 to 2008, the country suffered a continuous decline at an annual pace of 0.59524 million ha [40], which

dropped to 0.05275 million ha from 2010 to 2014 [38], seriously aggravating the scarcity of cultivated land resources. Meanwhile, China's food demand will increase significantly as a result of population growth and increasing income levels in coming decades. In this context, it is of great importance to increase the effective use of abandoned land to ensure Chinese food security [39,41]. A better understanding of the driving factors of Chinese arable land abandonment is vital to develop agriculture and land management policies.

Although the determinants of China's arable land abandonment have already been investigated by some scholars, almost all of these case studies concerned perennial abandonment and focused on the micro level (including households, villages, and land parcels) [8,24,25,27,42]. In addition, recent studies often focused on abandonment in mountainous areas, but little attention has been paid to the plains of China. In addition, few studies have sought to understand the issue at the regional level. Therefore, this study takes Hunan Province, which includes different landforms, as a case to explore the contributory factors of seasonal farmland abandonment at the regional level. Overall, our study attempts to have a better understanding of farmland abandonment in Mainland China and enlighten relevant policy decisions through achieving three objectives. The first is to answer the question that whether seasonal farmland abandonment can also be explained under the framework constituted by the four aspects mentioned in this section, and, what are the specific driving factors of seasonal farmland abandonment? Second, we seek to provide new empirical evidence about pattern and drivers of farmland abandonment at regional level through a case study, so that to update understanding of farmland abandonment in Mainland China. Third, we try to find whether farmland abandonment occurs in plain areas.

2. Materials and Methods

2.1. Study Area

Hunan Province is located in the middle reaches of the Yangtze River, south of Dongting Lake and north of the Nanling Mountains. The geographical range covers 24°38′ N–30°08′ N, 108°47′ E–114°15′ E. The province, which is rich in various types of landform, includes a lake plain located in the northeast, hilly areas mainly located in central Hunan, and mountains located in the southern and western parts (Figure 1). As it is in a subtropical humid monsoon climate zone, the province has a warm, humid climate with a mean annual temperature of 15.0 °C–18.0 °C. It is also exposed to plenty of sunshine, with an annual sunshine duration of 1300–1800 h, and annual precipitation is high at 1200–1700 mm. The temperature is above the agro-meteorological limits of 0 °C and 18 °C for 347.6 and 256 days, respectively. Besides these excellent agro-meteorological conditions, there also exists a dense water network consisting of Xiang River, Li River, Yuan River, and Dongting Lake, which provides an excellent irrigation resource for agriculture. Due to the excellent natural conditions for agriculture, Hunan is considered an important grain-producing province. However, agriculture in the province is facing serious challenges. Arable land has seen a sustained decline since the 1990s due to urbanization. In 2013, the per capita arable land area in Hunan was near the warning line (0.053 ha) defined by the FAO [43]. In addition, the increasing abandonment of cultivated land is becoming an important restricting factor for sustainable agricultural development. Remote sensor data shows that winter-idle land in Hunan accounted for 18.5% of the total cultivated land area in 2007–2008 [39]. In sum, as an important Chinese grain-producing area, Hunan Province has excellent natural agro-climatic conditions and a diverse geomorphic type, but also faces the serious challenges of farmland abandonment and the urbanization gradient. Hence, it is a typical and representative area to use as a case to understand the driving factors of farmland abandonment.

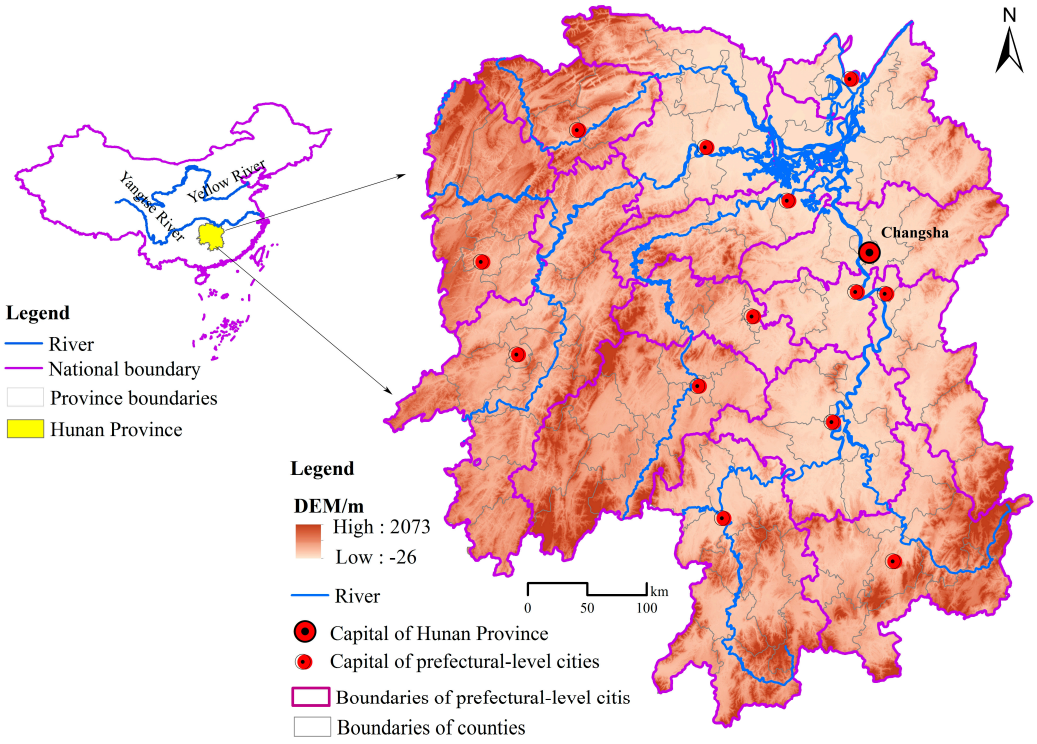

Figure 1. Location of the Hunan Province in Mainland China.

2.2. Indicators of Seasonal Farmland Abandonment

According to the definition of seasonal farmland abandonment in introduction section of this paper and Feng's literature [44], we propose an indicator expressed by Equation (1) to measure the seasonal farmland abandonment.

$$IFA = \frac{FA \times m - PA}{FA \times m} \times 100\% \quad (1)$$

In Equation (1), *IFA* refers to the index of seasonal farmland abandonment, *FA* refers to the total farmland area, and *PA* refers to the crop planting area, while *m* is the ideal multiple cropping index supported by the agro-meteorological conditions. The data on FA come from China' survey of land use change in 2012, and the data on PA were gathered from the 2013 statistical yearbook of Hunan Province. For *m*, all counties in Hunan Province can achieve three agricultural harvests per year if properly rain fed [45], so we set the ideal multiple cropping index of all counties to 3.

2.3. Explanatory Variables

Farmland abandonment is driven by both social and environmental dimensions of land use [4,34,46]. Following the claims of existing studies [10,21,31], we set the explanatory variables (see Table 1) from the following four aspects of the social and environmental dimensions: natural environment features, socioeconomic conditions, farming system facilities and locations.

(1) Natural environment features. Natural environment features play an important role in land yields. When the natural agro-climatic conditions cannot ensure adequate yields or income, the land will be abandoned. At the regional level, land yields are mainly driven by soil fertility and agro-meteorological conditions, such as precipitation and sunshine. Here we select potential land productivity as explanatory variable of regional farm abandonment, which integrates photosynthetic potential productivity, light and temperature potential productivity, climate potential productivity and soil potential productivity. We expect a negative relationship between

potential land productivity and seasonal farmland abandonment as described in Hypothesis 1. The data are collected from the SoilProduData_Hunan_1981–2010 database of China's Data Publishing System for Global Change Science [47]. In addition, regional topography, as one feature of the regional background environment, plays an important role in productive efficiency through accessibility and convenience [48]. The effect of regional topography on farmland abandonment can be supposed as Hypothesis 2. According to the Chinese County Statistical Yearbook 2011, the counties of Hunan Province are categorized into three groups: plain counties, hilly counties, and mountainous counties. In this paper, we set two dummy variables, plain and mountain, to represent the regional topography. In plain counties, the variable plain takes 1, otherwise it takes 0, and in mountainous counties, the variable mountain takes 1, otherwise it takes 0. Furthermore, although technological progress and intensive labor input can largely improve agro-productivity, the cultivated land is still an essential and decisive productive factor for agriculture. Hence, the scarcity of arable land matters most in land abandonment, as a region with richer cultivated land will face more risk of farmland abandonment (see Hypothesis 3). Here, we used the per capita area of cultivated land to measure the scarcity of arable land. In sum, the first three hypotheses in this study are as follows:

Hypothesis 1. *Productive potentialities are negatively associated with seasonal farmland abandonment.*

Hypothesis 2. *Plains have restrictive effects on seasonal farmland abandonment, while mountainous and hilly topographies have accelerative effects.*

Hypothesis 3. *The scarcity of cultivated land is negatively correlated with seasonal farmland abandonment.*

Table 1. Variables for explaining seasonal farmland abandonment at the regional level.

Variables	Mean	Standard. Deviation	Expected Relationship
Dependent			
IFA (index of farmland abandonment)	30.2451	16.0831	
Natural environmental features			
Productive potentialities	42.9722	22.5907	Negative
Plain	0.1600	0.3666	Negative
Mountain	0.5100	0.4999	Positive
Per capita area of cultivated land	104.9962	32.8380	Positive
Socioeconomic conditions			
Proportion of non-agriculture	80.1773	9.4123	Positive
Urban wage	7582.0690	3891.7733	Positive
Ratio of off-farm income in rural residents' income	45.3415	12.3486	Positive
Rural per capita net income	34,001.8402	4468.0925	Positive
Facilities of farming systems			
Proportion of mechanized planting	118.0559	68.7884	Negative
Total power of agro-mechanization per square km of cropland	12.7195	5.6115	Negative
Irrigation percentage of arable land	74.4112	28.8881	Negative
Pumps per square km of cropland	57.2073	62.3392	Negative
Location factors			
Distance to prefectural capital	64.6717	48.2847	Positive
Distance to provincial capital	256.1449	122.9951	Positive

(2) Socioeconomic conditions. Generally speaking, the main purposes of Chinese household farming are to meet farmers' own food needs and to sell grain for economic benefits, respectively referring to self-sufficiency agriculture and commercial agriculture. Despite the fact that subsistence farming still plays an important role in modern rural China, the growing income level enables farmers to buy food to meet their survival demands, so that they may give up farming in whole or part. Thus, we arrive at Hypothesis 4:

Hypothesis 4. *Farmers' income is positively correlated with cultivated land abandonment.*

For commercial agriculture, farmland abandonment can be explained based on economic models of human behavior [2,27]. In China, since the economic reforms of the late 1970s, there has been unprecedented urbanization that brought about a high demand for labor. Compared with agriculture, which is frequently influenced by volatile prices and natural disasters, non-agricultural industries provide more job opportunities, higher wages, and more stable income. Consequently, with the increasing opportunity cost of investing labor in farming, rural laborers are migrating to urban areas to work in non-agricultural industries. As a result, rural agriculture is facing a labor shortage, so farmland has suffered from abandonment and less-intensive cultivation [25]. As peasant households invest more labor and work in non-agricultural industries, farms face more risk of being abandoned. Hence, we end up with the following Hypotheses 5–7:

Hypothesis 5. *The development level of non-agricultural industries is positively correlated with farmland abandonment.*

Hypothesis 6. *Urban wages have a positive influence on farmland abandonment.*

Hypothesis 7. *Off-farm workload is positively associated with farmland abandonment.*

In testing the above assumptions, we used rural per capita net income, the proportion of non-agricultural industry, urban wages, and the ratio of off-farm income to indicate the variables in Hypotheses 4–7. In consideration of the possible endogeneity between income and cultivated area, we set the variable rural per capita net income a year in advance. All of the data for these variables were gathered from the Hunan Statistical Yearbook (2012, 2013) and China Statistical Yearbook for Regional Economy (2013). Considering that there may exist an endogenous relationship between per capita income and land abandonment, we moved the per capita net income of rural residents ahead one year.

(3) Facilities of farming systems. As is well known, better agro-production infrastructures are favorable for productivity and adaptive capacity to hazards. In Hunan Province, the most important farming facilities are the machines used for sowing and harvesting, and the facilities for irrigation and drainage. A higher mechanization level means that the region's agriculture relies much more on mechanized production than labor, and can partially compensate for the impacts of a labor shortage. On the other hand, the effective adaptability can reduce the loss resulting from various natural hazards and market risk, thus guaranteeing the maximization and stability of agro-income, which encourages farmers to keep the land cultivated. Hence, another two hypotheses are developed:

Hypothesis 8. *The mechanization level of agriculture can contain arable land abandonment.*

Hypothesis 9. *The conditions of drainage and irrigation are negatively associated with farmland abandonment.*

In this paper, the proportion of mechanized planting and total power of agro-mechanization per square km of cropland are set to represent the variables in Hypothesis 8. In Hypothesis 9, irrigation and drainage facilities are described by irrigation percentage of arable land and pumps per square km of cropland. All of these data were collected from the Hunan Statistical Yearbook (2013).

(4) Location factors. Many studies confirm that distances to settlements, road networks, markets, and population centers are decisive determinants of abandonment [26,36,49]. In the context of a market economy, it is no longer profitable to cultivate far from roads and markets (Müller et al., 2013). As a result, unfavorable access to these places often means high risk of farm abandonment and dismal livelihood opportunities [35]. This study focuses on the regional level, and consequently we emphasize the distance to market and population centers with the following Hypothesis 10:

Hypothesis 10. *Distance to markets and population centers is positively correlated with cropland abandonment.*

We define markets and population centers as the capitals of prefectures and provinces. The distances to capitals were obtained via cost-distance analysis using the network analysis model of ArcGIS 10.1 [50]. The road network was obtained through map vectorization according to the Hunan Province Map published by China Map Publishing House in 2012.

2.4. Spatial Correlation and Pattern

Global and local spatial correlation is widely used to analyze the spatial correlation and pattern of a geographic phenomenon. Global spatial autocorrelation is measured using Global Moran's *I*, which is calculated using the following equation [51]:

$$Global\ Moran's\ I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\overline{x})(x_j-\overline{x})}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\right)\sum_{i=1}^{n}(x_i-\overline{x})^2} \quad (2)$$

where x_i and x_j are the *IFA* of regions i and j, respectively; $\overline{x}$ is the mean of the IFA of all counties; and w_{ij} is the spatial weight ($i \neq j$). If region i is adjacent to region j, w_{ij} = 1, and if not, w_{ij} = 0. The Global Moran's I is in the range of -1 to 1. If Global Moran's I is greater than 0, the abandonment of cultivated land is spatially positively correlated, and the high (low) values are distributed centrally. When it is less than 0, there is a negative correlation, which indicates that the IFA of one region is different from the surrounding regions. When it is equal to 0, it means that the land abandonment happens randomly.

Furthermore, we used a Moran's scatter plot and spatial hotspot analysis (Getis-Ord G_i^*) to identify the spatial features of IFA clusters. With a Moran scatter plot, the observed objects can be categorized into four groups: HH (high-high), HL (high-low), LH (low-high), and LL (low-low). HH (LL) indicates that the IFA is positively relevant in the local space and there are clusters of high (low) values [52]. HL (LH) indicates that the IFA is negatively correlated in the local space, and the high (low) value of the IFA is surrounded by low (high) values. Then, we employed spatial hot-spot detection to address the distribution of high or low IFA clusters. The spatial hotspot is measured by the $G_i^*(d)$ (Getis-Ord G_i^*) calculated using the following equation [53]:

$$G_i^*(d) = \frac{\sum_{j=1}^{n} W_{ij}(d)X_j}{\sum_{j=1}^{n} X_j} \quad (3)$$

$$Z(G_i^*) = \frac{G_i^* - E(G_i^*)}{\sqrt{Var(G_i^*)}} \quad (4)$$

where $G_i^*(d)$ is the statistic of region i, X_j is the IFA of region j, and $W_{ij}(d)$ is the spatial weight, which is the same as Equation (2). $Z(G_i^*)$ is the standardized value of $G_i^*(d)$, which is used to execute a Z statistic test for IFA. $E(G_i^*)$ is the average of G_i^* and $Var(G_i^*)$ is the coefficient of the variation of G_i^*. When $Z(G_i^*)$ passes the statistical test and is larger than 0, region i is surrounded by high observed values and there form clusters of high values (a hot-spot). When $Z(G_i^*)$ passes the statistical test and

is less than 0, region i is surrounded by low observed values and there form clusters of low values (a cold-spot).

2.5. Regression Model

Generally, the causal relationship between observed variables and their potential influence factors are explored with multiple linear regression. However, as a geographic phenomenon, farmland abandonment is correlated spatially [27]. Therefore, it was necessary to employ a spatial regression model that considered the spatial correlation among regions to identify driving factors of farmland abandonment. The spatial regression model includes a spatial lag model (SLM) and a spatial error model (SEM). Before executing the model, we needed to conduct an ordinary least square estimate (OLS) of the model using the Lagrange multiplier test to select the appropriate models. When the Lagrange multiplier of SLM reaches a higher level of significance than the SEM, and the robust Lagrange multiplier of SLM also reaches a higher level of significance than the SEM, the SLM will be selected; otherwise, the SEM will be employed [54]. The OLS model mentioned above can be set as the following equation [54]:

$$Y = \alpha + \sum \beta_i x_i + \varepsilon \quad (5)$$

where Y is the *IFA*, α is the constant term, x_i and β_i are explanatory variables and their estimated coefficients, and ε is random error. The SLM is set as the following equation [54]:

$$Y = \rho w Y + \alpha + \sum \beta_i x_i + \varepsilon \quad (6)$$

In Equation (6), Y, α, x_i, β_i, and ε are the same as those in Equation (5), and w and ρ indicate the spatial adjacency weight and its estimated coefficient. The formula of SEM is expressed as follows [50].

$$Y = \alpha + \sum \beta_i x_i + \varepsilon \quad (7)$$

$$\varepsilon = \gamma w \varepsilon + \mu \quad (8)$$

where Y, α, X_i, β_i, ε, and w are the same as those in Equation (6), λ is the coefficient of regression, and μ is independent random error. The regression models in this paper are executed in Geo Da 1.8 [55].

3. Results

3.1. County-Level Pattern of Seasonal Farmland Abandonment in Hunan

The results show that Hunan Province has a serious seasonal farmland abandonment phenomenon, which has led to obvious spatial differences. The cultivated acreage of the province is high at 420.1450 million ha. However, 28.63% is given up seasonally, and the highest *IFA* of counties reaches 86.09%, while the average of all the counties' *IFA* is high at 30.25%. Additionally, the standard deviation of the *IFA* index is 16.08%, which is more than half of the average. This suggests cultivated land abandonment across Hunan Province varies a lot.

From the spatial perspective, farmland abandonment is characterized by convergences. As Figure 2 shows, the low and very low *IFA* are mainly distributed in the plains of northeast Hunan and Hengyang basin in southern Hunan, including all of the counties attached to Yueyang and Hengyang, and most of the counties of Changsha, Yiyang, Changde, and Yongzhou. The high and very high *IFA* are chiefly located in the mountainous areas of western, eastern, and southern Hunan, which cover Zhangjiajie, Xiangxi, Huaihua, Loudi, Shaoyang, and most counties from Chengzhou and Zhuzhou. Only server counties with low IFA are distributed sporadically across these areas. The global autocorrelation analysis further reports that the Global Moran's I is 0.3961. This reveals that farmland abandonment is interdependent in the spatial dimension. The Moran scatter plot (Figure 3) shows that most counties are distributed in the HH and LL quarter, implying obvious spatial dependence; only 8 and 12 counties are located in the HL and LH quarters, respectively. Moreover, the spatial

hot-spot detection identifies significant hot- and cold-spots (Figure 4), further clarifying the low and high *IFA* converge. The hot-spot zone of farmland abandonment forms in an area covering southern Huaihua and the corridor along the northeast to southwest axis of Shaoyang. There we find two cold spots: one in Dongting plain in southern Hunan and another in the corridor along the capital of Yongzhou and Hengyang. All of the above findings indicate that cropland abandonment involves spatial dependence and is distributed in a cluster.

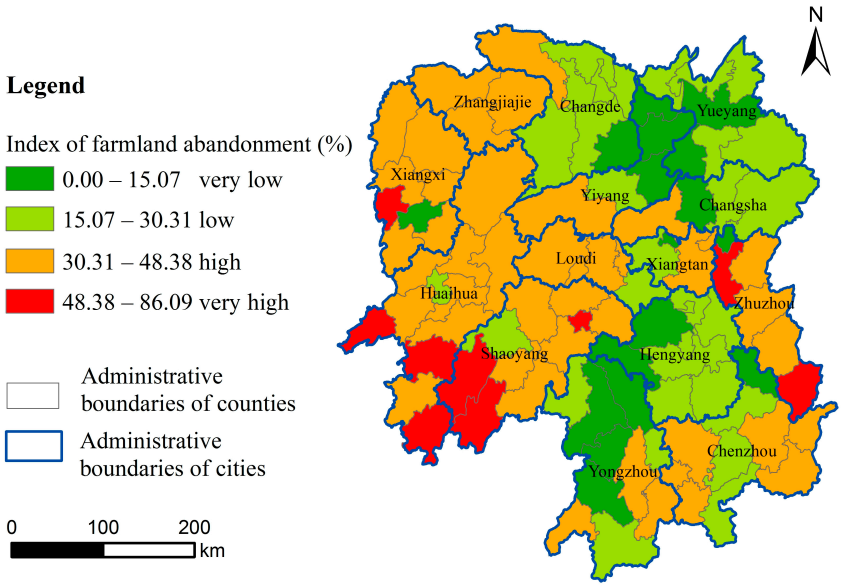

Figure 2. Pattern of farmland abandonment at the county level in Hunan Province, China.

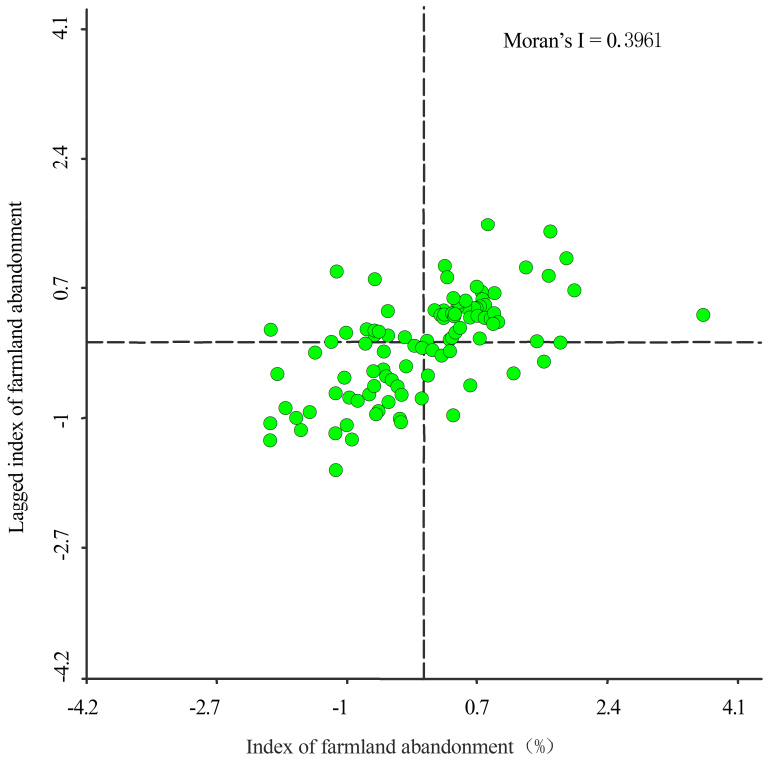

Figure 3. Univariate Global Moran's scatter plot of farmland abandonment of Hunan Province, China.

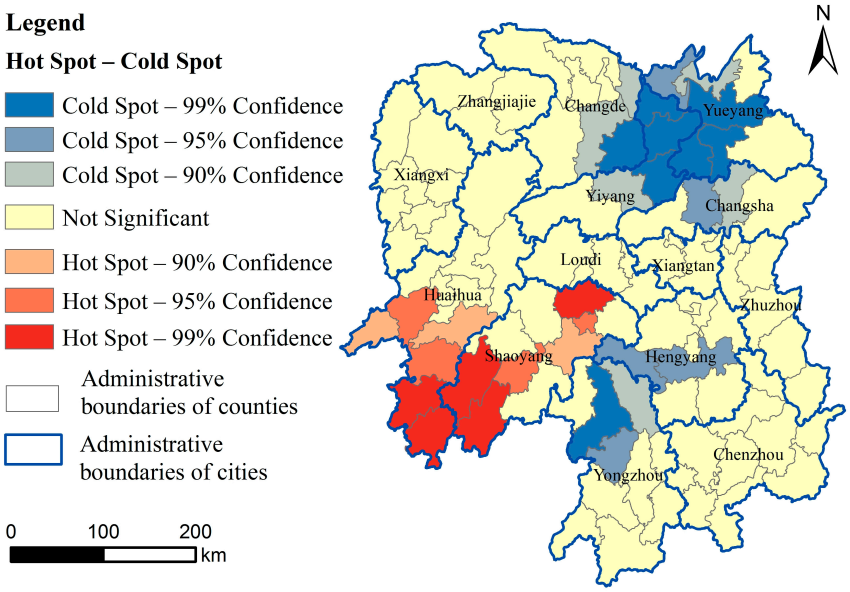

Figure 4. Hot-spot zones and cold-spot zones of farmland abandonment in Hunan Province, China.

In addition, the distribution of cropland abandonment is consistent with the topography of Hunan. Cropland abandonment is positively correlated with elevation and regional relief. From Figure 5, we can see that the low and very low *IFA* are mainly located in central Hunan, rich in low-altitude hills and terraces, and the Dongting plain of northeast Hunan. While in the western and southern mountainous areas, there is a wide distribution of high and very high *IFA*. Comparing Figures 4 and 5, the spatial hot-spot zone covers the mountains of southwest Hunan, while the cold-spot zones are concentrated in the plains around Dongting Lake and the Hengyang basin.

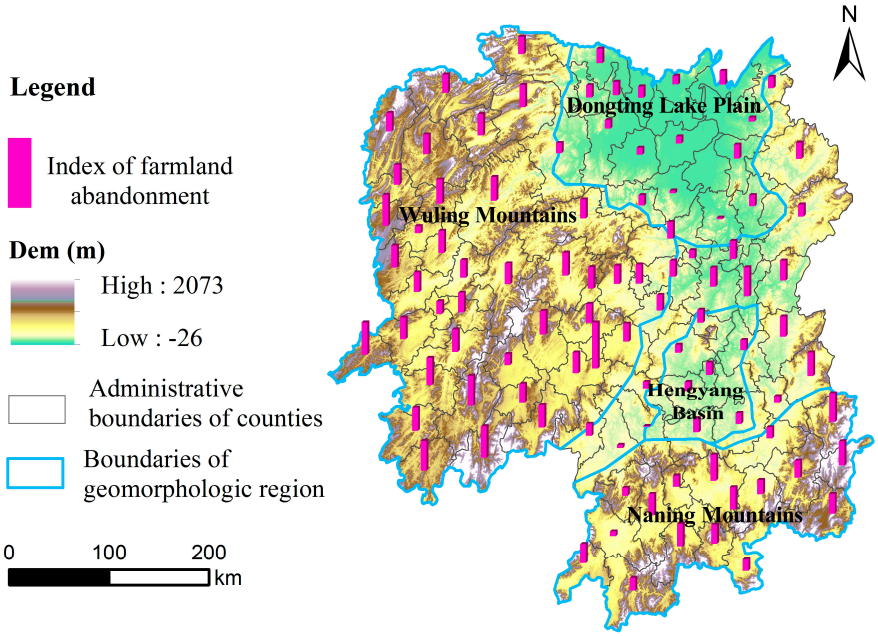

Figure 5. Coupling distribution of terrain and farmland abandonment in Hunan Province, China.

3.2. Estimated Results of Regression Model

Because of the spatial dependence described in the above section, we used a spatial regression model to identify the drivers of seasonal farmland abandonment. First, we executed a collinearity

diagnostic with a variance inflation factor (VIF) to detect correlations among the explanatory variables. The result shows that all the VIFs of variables were less than 10. According to the diagnosis rules [56], that means that no relevant collinearity existed and all of the variables could be included in the same regression model. Then, least squares estimation (OLS) was used in combination with the Lagrange multiplier test to discern the appropriate model, i.e., SLM or SEM. Table 2 shows that both the Lagrange Multiplier and Robust LM of the SLM pass the statistical test at a significance level of 5%, while those of the SEM are not significant. Therefore, it can be concluded that the spatial correlation of arable land abandonment in Hunan is due to the inter-regional interaction, i.e., spatial dependence, rather than spatial heterogeneity. Accordingly, we selected the SLM to examine the drivers of seasonal farmland abandonment. Table 3 reports that the SLM passes the test of statistical significance and gets a better goodness of fit than OLS, where the R-squared is raised from 0.6348 to 0.6699, while the Akaike info criterion and Schwarz criterion are less than that in the OLS. Hence, we will report and interpret the results of the SLM in detail.

Table 2. Diagnostics for spatial dependence.

Test	Value	*p*
Moran's *I* (error)	1.8041	0.0712
Lagrange Multiplier (lag)	5.5221	0.0188
Robust LM (lag)	5.9541	0.0147
Lagrange Multiplier (error)	0.9896	0.3198
Robust LM (error)	1.4216	0.2331

Table 3 reports that, in this aspect of natural environment features, there are three variables with an influence on farmland abandonment at the regional level. Productive potentialities are significantly and negatively associated with the dependent variable ($p < 10\%$) (see Table 3). The binary variable mountainous is significant and has the expected positive sign, while the variable plain is not significant. Moreover, per capita area of cultivated land is significantly and positively relevant to seasonal farm abandonment ($p < 1\%$). The regression coefficient is as high as 0.2035. These findings tell us that farm abandonment has a higher possibility of occurring in regions with rich cultivated land resources, mountains and low productive potentialities areas.

In the dimension of socioeconomic conditions, it is shocking that only the ratio of wage-income in rural residents' income is significantly and positively associated with farmland abandonment ($p < 5\%$). The regression coefficient is up to 0.1962 (see Table 3). Therefore, we can confirm Hypothesis 7 that off-farm workload is positively associated with farmland abandonment.

There are two variables to pass the significant test of regression model in the dimension of facilities of farming systems. The variable proportion of mechanized planting is found to be significantly and negatively associated with the dependent variable ($p < 1\%$), and the coefficient is -0.0953 (see Table 3). Another significant variable is the irrigation percentage of arable land. It is also negatively associated with the index of farmland abandonment ($p < 5\%$). As shown by Table 3, the estimated coefficient is -0.0862. These results mean that the probability of seasonal cropland abandonment decreases in regions where sowing is highly dependent on agricultural machinery, and the probability of seasonal cropland abandonment increases in regions with poorer irrigation conditions.

Regarding the location factors, the distance to capital of province is highly significant ($p < 1\%$) and negatively associated with the dependent variable (see Table 3). It gets a coefficient of -0.0468. However, the distance to prefectural capital does not significant. These results are not in accordance with Hypothesis 10 and tell us that the probability of regional farmland abandonment increases closer to the capital of Hunan Province, and the distance to prefectural capital does not play a role in farmland abandonment.

Beside the variables on natural environment features, socioeconomic conditions, and facilities of farming systems and location factors, the spatial dependence of dependent variable is also significant

($p < 1\%$) and positively associated with the dependent variable (coefficient = 0.2792, the second largest; see Table 3). This suggests that, similar to findings at the parcel level, farm abandonment also has strong neighborhood effects on nearby regions at the regional level [22].

Table 3. Regression results for the OLS and SLM.

Variables	OLS		SLM	
	Coefficient	*p*	Coefficient	*p*
W_Dependent			0.2792 ***	0.0062
Constant	27.1316	0.1339	18.0882	0.2568
Productive potentialities	−0.1180 **	0.0350	−0.0952 *	0.0517
Plain	−6.1899	0.1084	−3.7088	0.2804
Mountain	4.9796 *	0.0876	5.3676 **	0.0358
Per capita area of cultivated land	0.2038 ***	0.0000	0.2035 ***	0.0000
Proportion of non-agriculture	0.2675	0.1522	0.2561	0.1253
Urban wages	−0.0002	0.3733	−0.0003	0.1783
Ratio of off-farm income in rural residents' income	0.2130 **	0.0276	0.1962 **	0.0201
Rural per capita net income	−0.0006	0.2191	−0.0005	0.3093
Proportion of mechanized planting	−0.1106 ***	0.0000	−0.0953 ***	0.0000
Total power of agro-mechanization per square km of cropland	−0.1355	0.6368	−0.0721	0.7782
Irrigation percentage of arable land	−0.0832 *	0.0686	−0.0862 **	0.0314
Pumps per square km of cropland	−0.0261	0.2388	−0.0265	0.1743
Distance to prefectural capital	0.0259	0.3776	0.0182	0.4862
Distance to provincial capital	−0.0485 ***	0.0005	−0.0468 ***	0.0001
R-squared	0.6438		0.6699	
Log likelihood	−367.5500		−364.5850	
Akaike info criterion	765.0990		761.1710	
Schwarz criterion	804.1770		802.8530	

Note: The dependent variable used in the regression models is the index of seasonal farmland abandonment (*IFA*) at county level of Hunan Province, China; *** denotes significance at $p < 1\%$; ** denotes significance at $p < 5\%$; * denotes significance at $p < 10\%$; W_Dependent is the spatial dependence of the dependent variable.

4. Discussion

4.1. Pattern of Seasonal Farm Abandonment

Unlike the consensus that cultivated land abandonment often occurs in remote mountains, we found that seasonal arable land abandonment does not only occur in mountainous areas, but also in plains and marginal areas of metropolises. For example, Figures 2 and 5 integratedly show that the capitals of Xiangtan and Zhuzhou have high and very high IFA, respectively; they are parts of the Chang-Zhu-Tan Metropolitan Area, located on a low-altitude plain. The possible reason is that, despite the plains near the metropolises where it is easy to realize cultivation on a large scale and mechanize, the populations in the counties adjacent to an agglomeration center of non-agricultural industries are more likely to get non-farm jobs. Meanwhile, as mechanized cultivation becomes the standard farm practice, fragmented and small pieces of cropland are more likely to be discarded. Furthermore, farmers in plain areas often have enough arable land to choose cultivated land. However, farmers in mountains facing scarcity of arable land are not comparable with them.

In addition, based on the spatial characteristics of cultivated land abandonment, we think that not only perennial abandonment has spatial dependence and a proximity effect [22,27], but seasonal farm abandonment is also significantly correlated in the spatial dimension so that there is obvious characteristics of aggregate distribution. This opinion is also confirmed by the regression result of SLM, that the spatial dependence is significant and positively associated with the dependent variable (see Table 3). However, it should be pointed out that the spatial correlation of seasonal abandonment found in this paper is at the regional level only, and whether there are similar spatial features at the parcel level still needs to be discussed.

4.2. Drivers of Seasonal Farmland Abandonment

4.2.1. Natural Environment Suitability for Farm Abandonment Is Crucial

According to the results presented in Section 3.2, the significant variables in this study include productive potentialities, mountainous and per capita area of cultivated land. First, as predicted in Hypothesis 1, regions with higher productive potentialities suffer from less farmland abandonment. Owing to that, when other productive factors have coequal input, the higher productive potentialities often mean higher yields. Low-yield land is often abandoned first. This finding also confirms the previous findings at the parcel level [9,48].

Second, the results that *mountain* variable gets a coefficient of 5.3676 indicate that mountainous areas face more risk of seasonal farmland abandonment. Compared with plains and hilly areas, mountains are not conducive to mechanized farming and large-scale agricultural operations. On the contrary, peasant households in plain areas can save labor and improve productive efficiency through mechanized and large-scale farming to get more benefits, which will largely inhibit seasonal cultivated land abandonment. Although the variable *plain* does not play a role, we still have observed seasonal farmland abandonment in the plain area of Hunan, since terrain is not the only determinant.

Third, the variable *per capita area of cultivated land* gets a significant coefficient 0.2035 (see Table 3) tell us that the scarcity of regional arable land has a disincentivizing effect on farm abandonment. This maybe result from that the farmers in regions with rich farmland often have enough land to cultivate and ensure their food supply and income, so that they can give up the fragmented and low-quality cropland. Furthermore, the agriculture's high dependence on mechanized planting and manage in plain area which also often are regions with rich land would strengthen the trend of fragmented cropland abandonment. Meanwhile, in the region with high scarcity of farmland, farmers often face higher food pressure, so that they cultivate the land as more as possible. Many farmers we had interviewed told us, "if we do not cultivate the land, how to feed ourselves?"

Although the positive relationship between per capita arable land and farmland abandonment seems inconsistent with the observed fact that mountains often have high index of farmland abandonment, it is not groundless. The farmland abandonment in mountains is a result caused integratedly by multiple drivers, for example, the mountain terrain, labor migration and transfer, low yield and land fragmentation [17,46]. The arable land scarcity is merely one of multiple drivers in the process of abandonment. Per capita arable land is positively associated with farmland abandonment, but it does not turn back the tendency of farmland abandonment drove by some other forces.

4.2.2. Labor Transfer from Agriculture to Non-Farm Contributes to Farmland Abandonment

As indicated by the significant coefficient of 0.1962, the variable *ratio of off-farm income in rural residents' income* as we expected in Hypothesis 7 strongly affect farmland abandonment positively. This implies that landholders investing more labor and time in non-farm industries contribute to farmland abandonment. The higher the share of off-farm income, the less labor and time are spent on agriculture. Consequently, farming is given up because of a lack of labor which is result from labor transfer from agriculture. This finding is also consistent with the phenomenon where farm abandonment and out-migration coexist in some rural areas of Hunan.

What is worth noting is that Hypotheses 4, 5, and 6 are not proven. In Hunan Province, or even the whole of China, rural out-migration mainly involves moving to urban areas outside of indigenous cities. Therefore, the origin counties' urban wages and proportion of non-agricultural industries do not play a significant role in local farmland abandonment as expected in the theoretical model.

4.2.3. Facility Conditions of Farming Systems Are Important Factors

According to the results presented in Section 3.2, the variable *proportion of mechanized planting* affect farmland abandonment negatively (coefficient = −0.0953). It is primarily because mechanized farming can compensate for the influence of labor shortages. On the other hand, in the context of

machinery for agricultural cultivation, landholders tend to cultivate as more land as possible, thereby reducing marginal costs to achieve a higher income.

The variable *irrigation percentage of arable land* has a negative effect on farm abandonment (coefficient = −0.0862), which enlightens us that farm abandonment occurs preferentially in areas with poor irrigation conditions. This negative relationship between irrigation percentage of arable land and dependent variable is not difficult to be understood. As we all know, agriculture has a high sensitivity and vulnerability to natural disasters, such as drought, floods, frost and so on. Due to the impact of climate change, the frequency of drought in Hunan Province, China has increased greatly [57]. Thus, the irrigation conditions became essential factors of adaptive capacities to drought. Better irrigation conditions provide more adaptive capacities to cope with climate variation and droughts. Hence, because of stable yields resulting from excellent adaptive capacities, regions with better irrigation conditions face less risk of farm abandonment than others.

4.2.4. Location Indirectly Affects Farm Abandonment by Influencing Labor Migration

Interestingly, distance to provincial capital passes the significance test but is negatively associated with farm abandonment (coefficient = −0.0468). As the regional population center and home to non-agricultural economic activities, the provincial capital attracts many rural laborers from other counties due to the wide variety of jobs and appealing wages. However, these regional interactions based on labor migration between capital and adjacent areas decrease as the distance from the provincial capital decreases. Hence, counties near to a major economic center face more risk of farm abandonment because of a shortage of labor. In addition, the effect of distance to capital of province is negative also suggests that the provincial capital affects farm abandonment by attracting agricultural laborers from neighboring areas, rather than as a market for agricultural products. The possible underlying reason is that the grain consumed by the provincial capital comes mainly from other provinces. Another possible reason is that landholders are not sensitive to the distance to markets because their grains are often purchased by food operators from the local area.

One factor that is reasonable but differed from our theoretical expectation is that the variable *distance to capital of prefecture* is not significant. This can be understood from the following two aspects. On the one hand, most prefecture-level capitals in Hunan Province are facing population and economic marginalization [58], so they lack the ability to attract labor from nearby areas. There is also an out-migration pattern, where rural migrants mainly move to the outskirts of indigenous cities [58]. On the other hand, because of population loss, the market potentialities for the agricultural products of prefecture-level capitals are not sufficient to encourage farmers from counties around the capital to expand the intensity and size of their farming operations. Therefore, counties close to prefectural-level capitals do not enjoy a lower risk of farm abandonment.

Of course, this conclusion does not imply that Hypothesis 10 is necessarily untenable in academia. As one important process of land use change, the drivers of farmland abandonment also tend to differ regionally [4,46]. This conclusion is only a revelation on the abandonment of cultivated land in a big agricultural province in central China.

4.2.5. The Spatial Interactive Strengthens the Farmland Abandonment

As the results presented in Section 3, regional farmland abandonment can be strengthened by adjacent regions through the spatial dependence of farmland abandonment (the coefficient = 0.2792). Perhaps because there is marked livelihood imitation and learning among peasant households from adjacent areas. Once the peasant households of one county give up farm and get a high income from non-farm industries, then the peasant households from the nearby counties would also do that. Thus, due to this proximity effect of farmland abandonment, regions close to a region with high IFA are more likely to experience farm abandonment. This reveals that seasonal farmland abandonment is driven integratedly by the socio-environmental dimensions and interregional interaction of farmland abandonment.

5. Conclusions and Policy Implications

Better understanding of seasonal farmland abandonment is essential for designing policy tools to shift to more sustainable agriculture and land use. With cultivated land abandonment in China, scholars have studied the pattern and driving factors from the micro-level of peasant households, parcels, and villages, mainly with the aim to understand perennial abandonment [8,24,25,27,42]. However, our understanding of seasonal abandonment is still insufficient. This paper uses a spatial regression model to explore the driving factors of seasonal abandonment of arable land at the regional level. It contributes to the existing literature by providing new evidence of seasonal farmland abandonment at the region level, and also has policy implications.

Based on a pattern analysis, we find that seasonal farmland abandonment varies greatly across the counties of Hunan Province, demonstrates striking spatial correlation, and is distributed in clusters. The mountainous area in western and southern Hunan has a higher IFA, with a zone of high-IFA clusters forming in southwest Hunan. While the cold zones with lower IFA concentrating distribution form in the Dongting plain in the northeast and Hengyang basin in the mid-south part of Hunan. The pattern of farm abandonment is in accordance with the terrain, particularly the relief and elevation. In addition, besides the mountainous areas, some counties near the metropolises and plain counties also experience severe seasonal farmland abandonment.

The driving factors identified by the spatial regression models cover the following aspects: natural environment, socioeconomic status, facilities of farming systems, and location. Concretely speaking, the variables regional productive potentialities, proportion of mechanized planting, irrigation percentage of arable land, and distance to provincial capital are negatively correlated with farm abandonment, but it is positively associated with the variables mountainous terrain, scarcity of cultivated land, and labor shortage represented by share of off-farm income. Furthermore, spatial dependence also plays an important role in farmland abandonment. From these findings, we can see that, like perennial abandonment, seasonal farmland abandonment can also be explained by a framework composed of natural environment, socioeconomic status, facilities of farming systems, and location. In sum, seasonal farmland abandonment is a complex, multi-dimensional process where socioeconomic and environmental forces and the spatial interaction of farm abandonment are interlinked. The influence of farming facilities, macro location, and spatial dependence on farm abandonment has not been discovered by previous studies on Chinese farm abandonment at the parcel and household levels; thus, this study updates and enriches our knowledge [24,27].

This study has the following policy implications. First, hot-spots that should draw the most focus include mountainous areas, areas with poor natural productivity or low agricultural suitability, and areas close to regional urban centers. Second, the improvement of agricultural mechanization, irrigation conditions and adaptive capacities to ensure stable yields should be the focus of policies to reduce farmland abandonment. Finally, agricultural and land policies should also consider the effect of policy on adjoining areas, i.e., the regional interaction of farm abandonment.

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