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Phenomenon of Non-Grain Production of Cultivated Land Has Become Increasingly Prominent over the Last 20 Years: Evidence from Guanzhong Plain, China

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Abstract: Cultivated land is the carrier of food production. As a populous country that regards cultivated land as the most valuable strategic resource, China has faced the challenge of the phenomenon of non-grain production of cultivated land (NGP) in recent years, which has attracted great attention from the Chinese government. Based on the cultivated land and grain data at the plot scale in 2000, 2010, and 2019, this study explored the evolutionary characteristics and spatial pattern of NGP in the Guanzhong Plain of Shaanxi Province from 2000 to 2019 with the Geographic Information System spatial analysis. The study found a clear trend in the spatial expansion of NGP in the past 20 years. In the 54 counties and districts of Guanzhong, there were different degrees of NGP, showing an annual expansion trend. The spatial agglomeration effect of NGP was significant. This study has important scientific value in understanding the phenomenon and patterns of non-grain production of cultivated land in China and provides a scientific basis for the formulation of cultivated land management policies.

Keywords: non-grain production; cultivated land; Guanzhong Plain

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1. Introduction

Cultivated land is the fundamental guarantee of food security, and cultivated land is the most valuable strategic resource in the world [1]. The "State of Food Security and Nutrition in the World 2022" report pointed out that the number of people affected by hunger in the world in 2021 has reached 828 million, an increase of about 46 million compared with 2020, and a cumulative increase of 150 million since the outbreak of the new corona epidemic. The latest evidence presented in the report shows that the world is moving further away from its goal of ending hunger, food insecurity, and all forms of malnutrition by 2030 [2,3].

In the context of rapid urbanization and industrialization, the protection of cultivated land resources is the basis for ensuring food security and promoting sustainable agricultural development, and this is a severe challenge for both developed and developing countries [4,5]. Throughout the international practice of farmland protection in developed countries such as the United States, the United Kingdom, and Japan, legislation and planning are the mainstays, supplemented by other administrative and economic measures to comprehensively protect cultivated land [6,7]. This is achieved by determining urban growth boundaries and agricultural protection areas through urban and agricultural development planning [8,9] and strictly controlling the occupation of cultivated land for construction; in addition, reliance on a sound legal system to supervise the implementation of plans and cultivated land protection also plays a role in a comprehensive manner [10,11]. At the same time, farmland protection in these countries focuses on enhancing public participation and enthusiasm [12,13]. The participants in farmland protection include not only the government but also farmland owners, experts, farmers, non-profit organizations, and non-governmental volunteers. The government has increased the enthusiasm of farmers and landowners to protect their cultivated land [14,15], through economic incentives, tax incentives, agricultural infrastructure subsidies, and other measures to increase farmers' income and protect their basic interests, so that the cost of cultivated land protection is borne by the whole society rather than solely by farmers [16]. In addition, in the process of arable land protection, attention should be paid to landscape and ecological protection to promote the harmonious development of land–society–ecology [17,18].

As the most populous country in the world, solving the problem of feeding 1.4 billion people is always the first priority [19], which determines that China must implement the strictest arable land protection system [20]. In recent years, the Chinese government has paid unprecedented attention to the protection of cultivated land [21]. Adhering to the red line of 120 million ha of cultivated land will be the top priority of land and resource management at present and for a long time to come [22].

In recent years, with the ever-changing situation, China's cultivated land protection has faced greater pressure and challenges [23]. In many places, due to the continuous increase in the scale of construction land for residence, industry, and infrastructure, driven by urbanization [24], the demand for occupied arable land for construction is increasing year by year [25]. Over the years, the reduction in cultivated land, especially high-quality cultivated land due to construction occupation, has begun to affect the basis of food security. China's urbanization and industrialization have led to the conversion of a large amount of cultivated land every year [26], directly threatening the red line of 1.8 billion mu of cultivated land for protection and national food security [27]. In fact, in addition to this explicit reduction in arable land, a hidden loss of grain production capacity cannot be ignored, that is, non-grain production on cultivated land (NGP) [28]. Due to the relatively low comparative returns in agriculture, some high-yield cash crops have replaced food crops on a large scale driven by economic interests, which not only seriously threatens national food security [29] but also triggers huge risks such as rural social imbalance, fragmented agricultural landscapes, and ecosystem degradation [30].

At present, the tendency of NGP in some areas is obvious [31]. In recent years, non-food crops are being planted on cultivated land to promote economic development in many areas [32], and agricultural activities such as planting nurseries, trees, tropical fruits, and characteristic crops have led to serious NGP phenomenon [33]. In some places, the adjustment of agricultural structure is simply understood as reducing food production, some business entities illegally planting trees and digging ponds on permanent basic farmland, and some industrial and commercial investment institutions transferring arable land to non-food crops on a large scale [34]. With China's population growth, people's consumption level continues to improve, and the carrying capacity of resources and the environment is tightening; thus, grain production and demand will remain in a tight balance [29]. How to promote the solution of NGP has become the focus of the government, academia, and the public [35].

Since 2020, the State Council has successively issued the "Notice on Resolutely Stopping the "Non-Agriculturalization" of Cultivated Land" and the "Opinions on Preventing the "Non-agriculturalization" of Cultivated Land and Stabilizing Grain Production, Resolutely Curbing the "Non-Agriculturalization" of Cultivated Land and Preventing "Non-Agriculturalization" of Cultivated Land Grainization". The successive releases of relevant policies show that China's containment of NGP is urgent [36]. The strictest arable land protection system needs to be implemented. In the current century, the epidemic and the conflict between Russia and Ukraine have impacted the trade chain and supply chain of grain and other bulk agricultural products, and the supply uncertainty in the international agricultural product market has increased [37], which further highlights the importance and urgency of scientific understanding and a systematic solution to the NGP problem [38].

Shaanxi is a major agricultural production province in northwestern China [39], and it is also the main production area of apples, greenhouse vegetables, and other economic forest fruits in the whole country and even the world [40]. For a long time, due to the comparative economic benefit gap between grain crops and economic forest fruits, and the drive of society's one-sided pursuit of economic interests, the phenomenon of NGP has become prominent, especially in the traditional main producing areas of wheat and corn in Guanzhong [41]. The development of industrialization has resulted in a serious problem of the fragmentation of grain fields. The hidden loss of grain productivity caused by NGP is far greater than the explicit loss of farmland loss, seriously endangering food security, ecological security, and social stability [42].

The Guanzhong Plain is the main grain-producing area in Shaanxi Province [43]. The objectives of this study are to (1) construct distribution maps of NGP for 2000, 2010, and 2019; (2) quantitatively measure NGP in the Guanzhong Plain and identify its 20-year evolutionary characteristics; and (3) propose NGP management and control strategies. A systematic understanding of the occurrence law of NGP is a major issue related to the comprehensive revitalization of China's rural areas and the guarantee of the food security system. This research comprehensively studies the temporal and spatial evolution characteristics of NGP in the Guanzhong Plain of Shaanxi Province from 2000 to 2019, which provides an important scientific basis for China to solve the NGP problem and provides a reference for other countries in the world at the same development stage.

2. Materials and Methods

2.1. Research Methods

2.1.1. Land Use Transfer Matrix

Using the land use data of the third phase and ArcGIS 10.2 software to superimpose the analysis and other types of processing, the land use transition matrix of the Guanzhong Plain was obtained. The matrix adopts an *n*-order matrix structure, which not only can intuitively and concisely display the area information of each category at the beginning and end of the study but can also express the dynamic changes in each category in this time period in detail. The general expression for torque is:

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix} \tag{1}$$

where S represents the transition matrix of land use change, n is the total number of different land types (n = 8); i and j represent the initial and final land types, respectively, in the study area (i, j = 1, 2, . . . , n); S is the area of the ith land type converted to the area of the jth land type; the larger the value, the more severe the change, and vice versa.

2.1.2. Land Use Transfer Matrix

The global Moran's I statistic measures the relationship between the attribute values of adjacent spatially distributed objects and can judge whether the object has agglomeration in the spatial distribution. Moran's I value ranges from −1 to 1, with 0 to 1 indicating that the spatial distribution of the object has a positive autocorrelation, −1 to 0 indicating that the spatial distribution has a negative correlation, 1 or −1 indicating a complete spatial positive or negative correlation, and 0 indicating complete spatial randomness. The global Moran's I statistic measures the overall correlation and is calculated as follows:

$$Moran's\ I = \frac{n \sum_i \sum_j W_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\left(\sum_i \sum_j w_{ij}\right) \sum_i (x_j - \overline{x})^2} \tag{2}$$

where x_i and x_j are the attribute values of the variables in the adjacent units of the region; W_{ij} is the spatial weight matrix; and $\overline{x}$ is the average attribute value. The value range of $Moran's\ I$ index is [−1, 1], which means that the positive correlation of similar spatial proximity transitions to the negative correlation of spatial proximity dissimilarity. When $Moran's\ I > 0$ the spatial correlation is positive, and the unit attribute value presents spatial clustering characteristics, and the closer the value is to 1, the higher the degree of agglomeration. When $Moran's\ I < 0$, the space is negatively correlated, and the unit attribute values show spatially discrete characteristics. When $Moran's\ I = 0$, there is no spatial correlation, and the unit attribute values are random with an independent distribution status.

2.1.3. Local Spatial Autocorrelation

The global Moran's I statistics show the overall correlation of spatial objects but cannot point out the specific spatial distribution of agglomeration phenomena. Therefore, the local Moran's I statistics are further used to measure the correlation between the attributes of each spatial object in the local space and to infer the range of spatial agglomeration and spatial specificity. Thus, the spatial agglomeration of the "non-grained" cultivated land is visualized, producing a cluster map that can delineate and classify locations by their corresponding type. Local Moran's I value is calculated as follows:

$$I_i = \frac{(x_i - \overline{x})\left[(n-1) - \overline{x}^2\right]}{\sum_{j=1}^{n} x_{ij}^2 \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(x_j - \overline{x})} \quad (3)$$

where x_i and x_j are the attribute values of the variable in the adjacent units of the region, W_{ij} is the spatial weight matrix, and $\overline{x}$ is the average attribute value. When $I_i \geq 0$, the attribute value of the ith unit is similar to the attribute value of the adjacent unit, and the attribute value of the unit presents spatial discrete characteristics, which is a positive spatial correlation. When $I_i < 0$, the attribute value of the ith unit is related to the adjacent unit, the attribute values of the units are quite different, and the unit attribute values show spatial discrete characteristics, which is a negative spatial correlation.

2.2. *Study Area and Data Source*

2.2.1. Study Area

The Guanzhong Plain of Shaanxi Province is located in the central and western parts of China, located at 33°34′~35°52′ N, 106°18′~110°38′ E, including 5 prefecture-level cities of Xi'an, Xianyang, Baoji, Weinan, and Tongchuan (Figure 1). The land area is 55,623 km^2, the altitude is 323~3771 m, the range is 3448 m, and the terrain is high in the southwest and low in the northeast [43]. The Guanzhong area belongs to the warm temperate semi-humid monsoon region, the annual average temperature is 7.8~13.5 °C, and the accumulated temperature is 2387~4668 °C. Precipitation is 400~800 mm. Water surface evaporation is 1000–1200 mm [44].

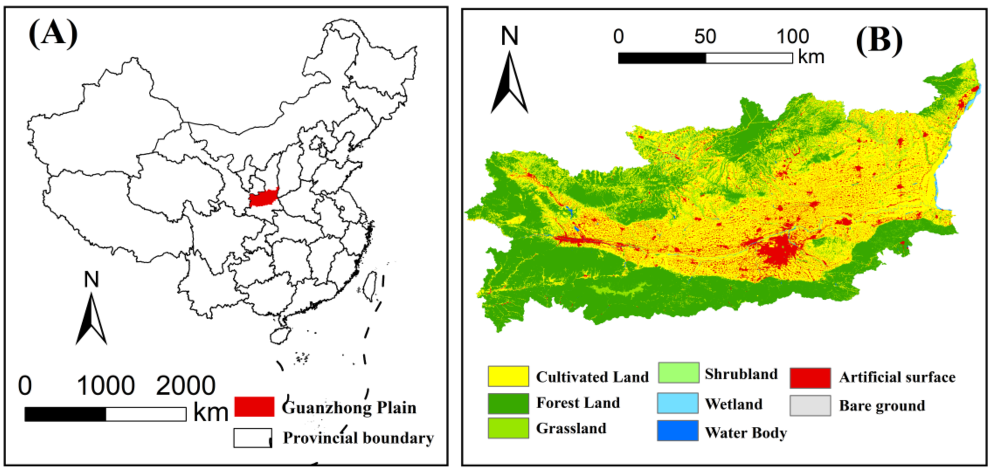

Figure 1. The location of the Guanzhong Plain (**A**) and the status of land use in 2020 (**B**).

2.2.2. Data Source

There were three periods of land use data from Guanzhong Plain, namely 2000, 2010, and 2020, that were used in this study, derived from the GlobeLand 30 surface cover dataset (raster data, with a resolution of 30 m) (http://www.Globallandcover.com/ (accessed on 1 July 2022). In addition, the spatial data for wheat, rice, and corn in China during 2000–2019 were obtained from a study by Luo et al. [45]. The data are available at https://data.mendeley.com/datasets/jbs44b2hrk/2, accessed on 16 April 2022. This dataset describes the annual spatial distribution of China's three most important ration crops at a 1 km resolution. The administrative boundary data were collected from the National Geographic Information Resource Directory Service System (https://www.webmap.cn/commres.do?method=globeDetails&type=brief, accessed on 26 April 2022). When estimating non-grain production, due to the lack of cultivated land data for 2019, the 2020 cultivated land data were used in the calculation instead of 2019.

2.3. Concept Definition and Measurement

Based on the "Opinions on Preventing Cultivated Land De-Graining and Stabilizing Grain Production" and existing research, the grain crops investigated in this paper only included the three categories of traditional rice, wheat, and corn, and all cultivated land planting behaviors other than these three categories of crops were treated as non-food production and measured by the "ratio of non-grain production (NGPR)". The specific calculation formula is as follows:

$$NGPR = 1 - L/C \tag{4}$$

where L is the sum of the area of wheat, corn, and rice; C is the cultivated land area.

3. Results

3.1. Evolutionary Characteristics of Cultivated Land in Guanzhong Plain

From the perspective of the transfer types of cultivated land (Figure 2), the types of cultivated land transfer in Shaanxi are mainly forest land, grassland, shrub, wetland, water body, artificial surfaces, and bare land. Overall, the total amount of cultivated land that remained unchanged from 2000 to 2020 was 5416.67 thousand hectares. Among the types of cultivated land transferred out, grassland, artificial surface, and forest land accounted for the largest proportion, accounting for 96.5% of the cultivated land transferred out, and the spatial distribution was consistent. Among them, 36% were converted to grassland, 32% to artificial land, and 28% to forest land, which is closely related to the rapid urbanization process and the project of returning farmland to forest and grassland in the past 20 years. In terms of time periods, in the ten years from 2000 to 2010, the area of cultivated land converted to grassland, forest land, and artificial surfaces was 261.41 thousand hectares, 241.59 thousand hectares, and 171.22 thousand hectares, respectively. Forest land decreased by 14.95 thousand hectares, and human-made surface increased by 30.89 thousand hectares. The remaining types of transfer out accounted for a relatively small proportion of the total in the past 20 years. The areas transferred to water bodies, shrubs, wetlands, and bare land in the past 20 years were 19.06 thousand hectares, 9.30 thousand hectares, 3.21 thousand hectares, and 2.70 thousand hectares, respectively. Overall, before 2010, the area of arable land in the Guanzhong area gradually narrowed and stabilized. However, after 2010, the national new-type urbanization plan promoted the implementation of a series of measures such as accelerating the development of small- and medium-sized cities, developing small towns in a focused manner, and improving traffic conditions in small- and medium-sized cities and small towns, resulting in the conversion of large areas of arable land around towns to the construction of houses and small towns. In particular, large cities such as Xi'an, Xianyang, Baoji, and their surrounding districts and counties were greatly affected.

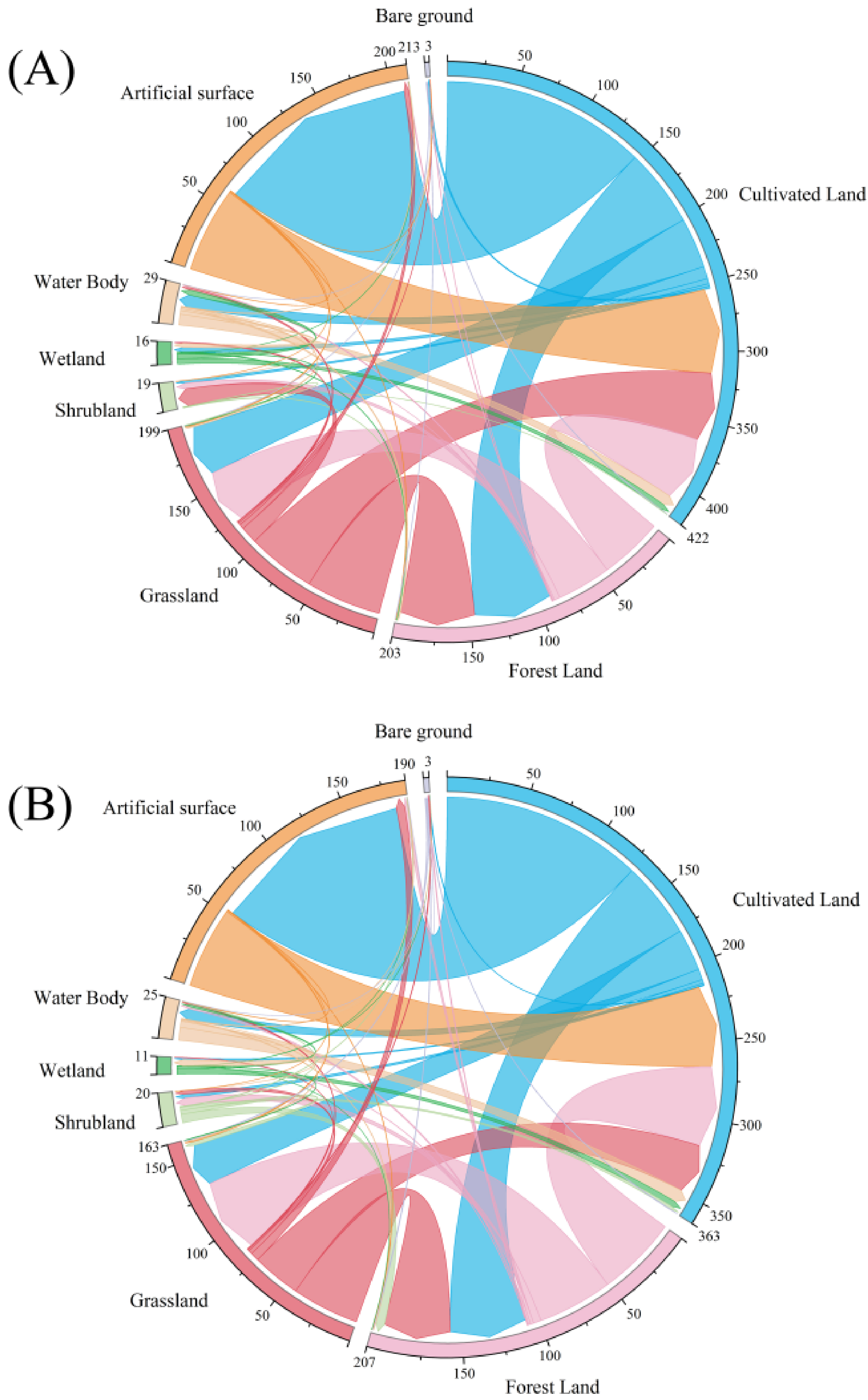

Figure 2. Chord diagram of land use transfer: (**A**) 2000–2010; (**B**) 2010–2020.

3.2. Evolutionary Characteristics of Non-Grain Production of Cultivated Land

Figure 3 shows the spatial distribution of NGP in Guanzhong in 2000, 2010, and 2019. The spatial expansion trend of NGP in the past 20 years is obvious. In 2000, the cultivated land for non-grain production (NGPCL) was 1438.2 thousand hectares, which increased to 1612.9 thousand hectares in 2010 and 1844.8 thousand hectares in 2020. Among the 54 counties in Guanzhong, there were NGP phenomena of different degrees, showing a trend of expansion year by year.

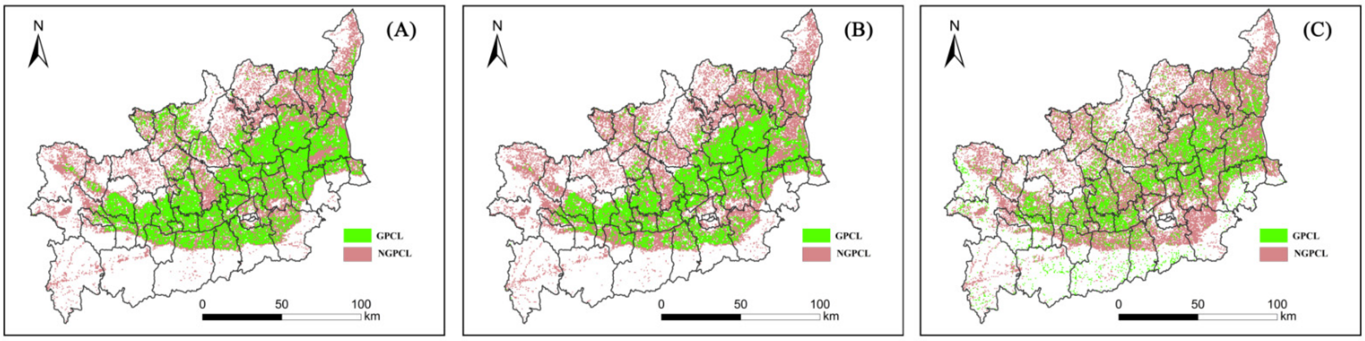

Figure 3. Spatial distribution of cultivated land of non-grain production (NGPCL) and cultivated land of grain production (GPCL): (**A**) 2000, (**B**) 2010, and (**C**) 2019.

As shown in Figure 4, NGPR is divided into five grades, which reflect the data of each county. In 2000, 19 counties had NGPR above 60%, which increased to 29 in 2010, and 42 in 2020. In order to further explore and analyze the spatial distribution characteristics of NPGR in the Guanzhong Plain, the spatial data structure was identified, and the X, Y, and Z axes were used to represent the due east, due north, and vertical directions, respectively, to generate a three-dimensional trend map (Figure 5). The agglomeration effect and the spatial interaction mechanism between them were visualized. The trend line of the cultivated land for non-grain production in the Guanzhong Plain in the east–west direction showed an obvious U-shaped trend in 2000, indicating that the difference between the east and the west was significant; with the passage of time, it gradually became smoother, indicating that the spatial difference between the east and the west became smaller. In the north–south direction, there was an obvious U-shaped trend with time, indicating that the spatial difference between the north and south gradually became larger. From the perspective of the whole period, both the east–west trend line and the north–south trend line basically showed obvious inclination or curvature, which confirmed the significant spatial differentiation of non-grained cultivated land in the Guanzhong Plain.

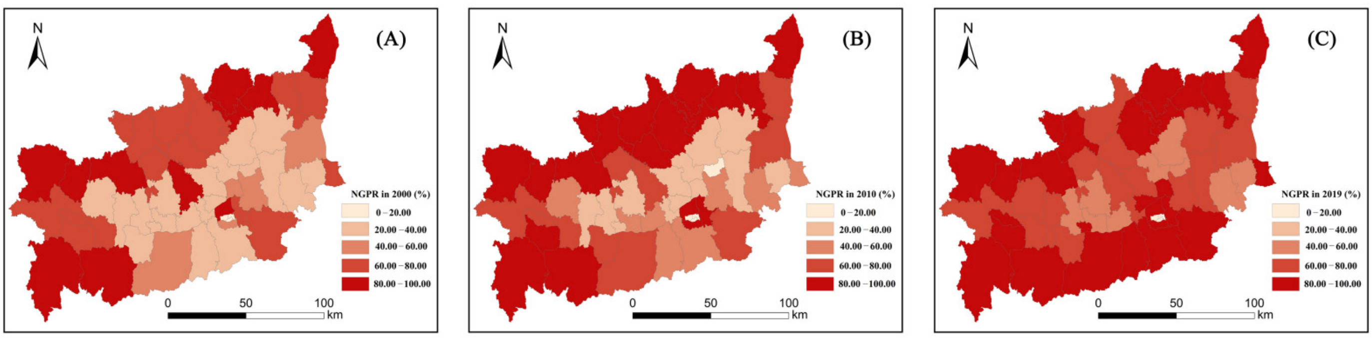

Figure 4. NGPR of 54 counties and districts in Guanzhong: (**A**) 2000, (**B**) 2010, and (**C**) 2019.

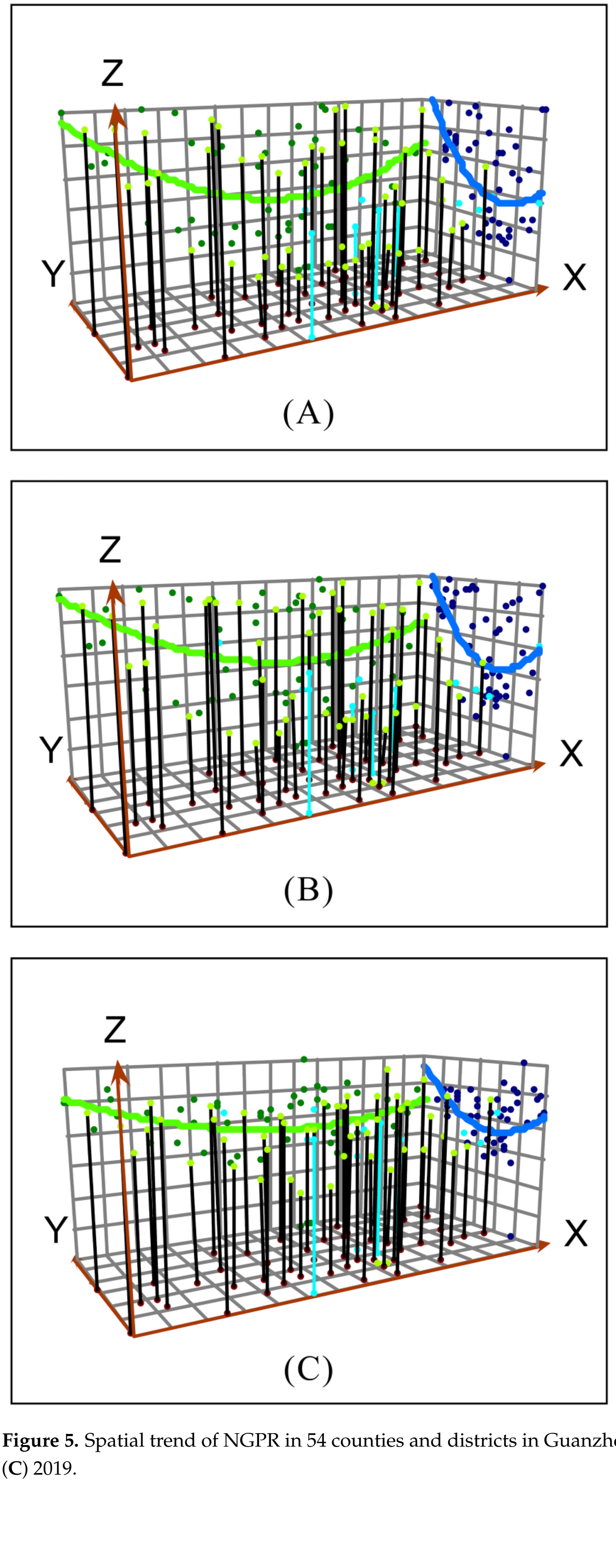

Figure 5. Spatial trend of NGPR in 54 counties and districts in Guanzhong: (**A**) 2000, (**B**) 2010, and (**C**) 2019.

3.3. Spatial Correlation Characteristics of Non-Grain Production of Cultivated Land

3.3.1. Global Spatial Correlation Characteristics

It can be seen from Table 1 that, from 2000 to 2019, NGPR showed a very significant positive spatial correlation, and Moran's I value increased from 0.369 in 2000 to 0.346 in 2010 and increased to 0.563 in 2019. At the same time, the z-values of NGPR in 2000, 2010, and 2019 were 25.845, 25.501, and 21.176, respectively, indicating that the spatial distribution elements were non-random processes. In addition, the calculated *p*-values were all equal to 0.001, indicating that the spatial autocorrelation was significant at the 99.9% confidence level.

Table 1. Moran's I for the NGPR.

Year	Moran's I	Z
2000	0.369	25.845
2010	0.346	25.501
2019	0.563	21.176

3.3.2. Local Spatial Differentiation Characteristics

The local autocorrelation results showed that the dominant types of NGP in 2000, 2010, and 2019 were all H–H and L–L clustering (Figure 6). This is consistent with the regularity presented by the scatter plot (Figure 7). Most clustering patterns fell within the first and third quadrants of the Moran scatter plot. In general, the NGP in the Guanzhong Plain as a whole showed an obvious positive spatial correlation, indicating that NGP had a strong radiation effect, and NGP pioneers would drive and influence their surrounding farmers to join.

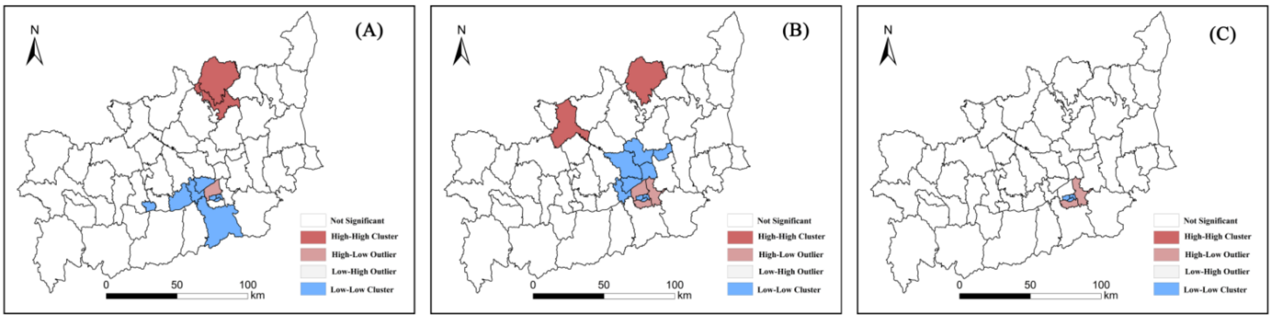

Figure 6. The LISA cluster distribution of NGPR: (**A**) 2000, (**B**) 2010, and (**C**) 2019.

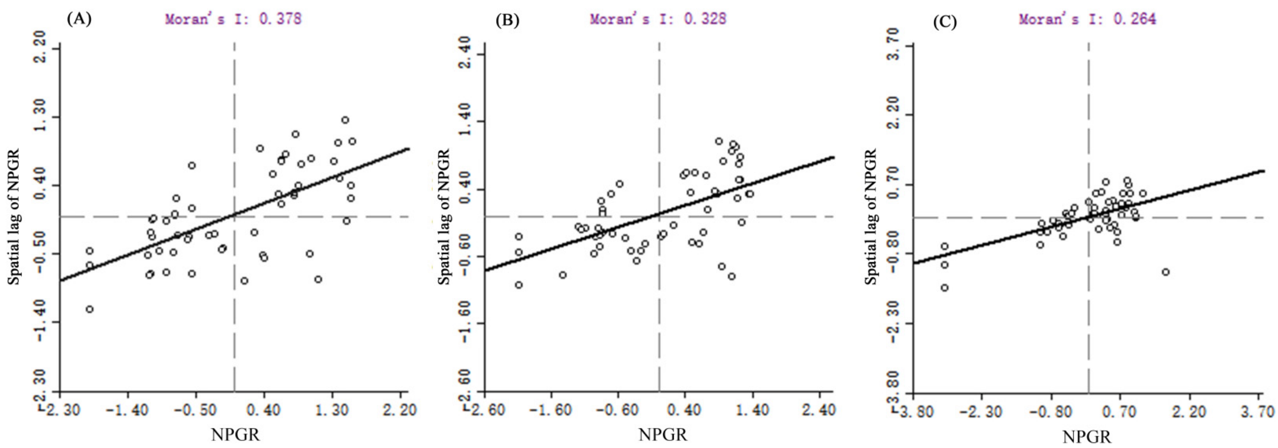

Figure 7. Moran's I scatter plot of NGPR: (**A**) 2000, (**B**) 2010, and (**C**) 2019.

4. Discussion

4.1. The Guanzhong Plain Is an Example of China's NGP, and the Significant Spatial Agglomeration Effect Is a Feature of the Spatial Expansion of NGP

The results of this study show that the NGP phenomenon in the Guanzhong region has been remarkable in the past 20 years, and there is a significant spatial agglomeration effect in the process of NGP expansion [46]. As is revealed by our analysis of the Guanzhong Plain, due to rapid urbanization in the past two decades, China's NGP has become increasingly serious, and it is time to pay attention [47].

The reason for the spatial agglomeration effect is that, on the one hand, the first group of land operators who turned to NGP may rent the surrounding arable land to expand the scale of production and operation after obtaining higher economic benefits [48]. On the other hand, farmers' land use decisions are usually aimed at maximizing economic benefits, and they are easily influenced by their surrounding farmers [49]. After witnessing the first adopters of NGP and obtaining high economic benefits, the surrounding farmers will follow them and turn to NGP. Since 2000, the transfer of rural labor to the secondary and tertiary industries has led to a continuous decline in the number of rural laborers and has induced great changes in its structure [50]. Most of the remaining farmers in China's rural areas are old and have a low level of education and, therefore, are further limited by their weak ability to acquire information and inadequate learning capacity [51]. Farmers are accustomed to sharing production materials, experience, technology, and sales with their surrounding farmers, so developing the same type of NGP as that of the surrounding farmers will be a reasonable and low-risk option [52].

4.2. Farmers' Income and Willingness to Grow Grain Are the Keys to Understanding and Managing NGP

Over the years, China's development of the cash crop industry has been an important means to increase farmers' income, but it has also exacerbated NGP. Forcing the "non-grained" arable land to change to grain production will easily cause farmers to question the stability of the government's industrial policy and damage the government's prestige [53,54]; if alternative varieties or industries cannot be found in time, it will affect farmers' continued income increase. Especially for some areas and peasant households that mainly rely on industries to eliminate poverty, the consequences are not conducive to increasing farmers' income [55–57]. The development of cash crops can help farmers eradicate poverty, and it is difficult for farmers to accept the immediate request to "return the economy and return the grain". In addition, the development of cash crops in some places has formed a complete supporting industrial chain. If the forced resumption of grain cultivation has an impact on the entire industrial chain, it will also have a great impact on the increase in farmers' income [58–60].

Over the years, some farmers have always chosen to plant less or no grain, considering factors such as cost and benefit. The current Chinese law clearly stipulates that farmers have the autonomy to produce and operate, and the government shall not interfere with the production and business projects independently arranged by farmers [61,62]. The law does not stipulate that grain must be grown. If the disposal of NGP goes too far or goes wrong, it may infringe on farmers' autonomy in production and operation, and for farmers, in order to increase their income and grow cash crops, it is reasonable and legal to require farmers to change to grain crops [63,64].

4.3. Policy Suggestions

(1) Determine the base of NGP: It is recommended researchers scientifically define NGP according to local conditions and focus be placed on grain production capacity, grain sown area, and cultivated land quality construction; furthermore, an index system should be built to create the conditions necessary for measuring the degree of NGP in different regions. In-depth inspections of the status of NGP should be carried out, and under the premise of stabilizing the grain sown area and improving unit yields, local

governments need to gain support to release crop varieties and practice intercropping and intercropping rotation methods that are not included in NGP treatment, so as to stabilize the expectations of business entities.

(2) Dispose of NGP stock by classification: Guidance should be provided for all localities to properly dispose of NGP stock based on the actual situation, so as to prevent problems such as reducing farmers' income. For the production and operation of digging ponds and raising fish on permanent basic farmland that damage the plowing layer, they must be resolutely removed according to the law; for the NGP behavior that does not destroy the plowing layer, they must be guided to gradually withdraw through market means, so as to avoid unrealistic rigidity. For large-scale business entities that have signed legal land transfer contracts, if their production and business operations are not within the scope of immediate liquidation, they can be disposed of after the contract expires. Places should be designated for which conditions allow for the appropriate exploration of production models such as the integrated planting and breeding of "grain crops + cash crops", "rice–fish", or "rice–shrimp", and the simultaneous promotion of increases in grain production and farmers' income.

(3) Establish a long-term mechanism to prevent NGP: it is further recommended that modern information technologies such as satellite remote sensing be extensively used to regularly monitor and evaluate the situation of arable land and grain cultivation across the country and establish a notification mechanism for NGP. The Food Security Law should be promulgated as soon as possible to clarify the specific requirements for preventing NGP. Increasing the publicity of laws and policies and stimulating the enthusiasm, consciousness, and sense of honor of farmers to protect arable land and grow grain are some of the other recommended strategies.

5. Conclusions

This study analyzed the evolution law and spatial pattern of NGP in the Guanzhong Plain from 2000 to 2019. The results showed that the NGP in the Guanzhong Plain expanded significantly in the past 20 years, and the non-grain transformation of cultivated land had a significant positive spatial correlation. Our research findings can provide an important scientific basis for understanding the laws of NGP and formulating management policies. In the future, further research on NGP can be carried out to study the driving mechanisms of NGP, farmers' willingness to grow grain, and the impact of NGP on the ecosystem.

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