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Article

Spatial and Temporal Characteristics and Driving Force Analysis of Cropland Change: Taking Dangyang City, Yichang City as Example

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Abstract: With the land use data of Dangyang City, Yichang City, Hubei Province in 2000, 2010, and 2020, 13 factors of nature, economy, and society were selected as the driving factors affecting the change of Cropland by using the land-use transition matrix and the kernel density analysis. In this study, the dynamic degree model of cropland use was introduced, combined with the geographic detector method, to explore the spatiotemporal variation characteristics and main driving factors of cropland in various towns in Dangyang City from 2000 to 2020. The results showed that the distribution of cropland generally showed a decreasing trend from southeast to northwest. From 2010 to 2020, the cropland in Dangyang City changed significantly, and the cropland area decreased. Economic and social factors turn out to be the main factors affecting the distribution of cropland. When interacting with other factors, the impact on cropland is weakened, and natural factors have interactive effects on cropland.

Keywords: Spatiotemporal Change of Cropland, Transition Matrix, Driving Factor, Geographic Detector

1. Introduction

Land is the space carrier of the main economic and social activities of human beings [1]. Land use is a mirror of society. Rural land use reflects various social and economic problems, and rural development can be studied through changes in land use patterns [2]. Cropland is not only an important factor of production but also the foundation of human existence [3]. With the development of industrialization and urbanization, China's population has gradually increased, the per-capita cropland area has been decreasing year by year, the quantity and structure of cropland are constantly changing, and the contradiction between man and land has become increasingly prominent. Therefore, exploring the temporal and spatial variation characteristics of cropland resources and clarifying the main influencing factors of the increase and decrease of cropland are of great significance for ensuring national grain and seeking sustainable utilization of cropland. Many scholars have carried out a series of studies on the change of cropland. With the development of industrialization and urbanization, China's population has gradually increased, the per-capita cropland area has been decreasing year by year, and the quantity and structure of cropland are constantly changing. Thus, scholars have studied the change of cropland based on the village, town, city, and nationwide [4] and introduced the spatial autoregressive model with the help of land transfer matrix, landscape pattern index [5], kernel density analysis [6], spatial lag model [7], geographic detector model [8], and PLUS model [6] from the perspectives of agroecology and geo-remediation [9], to analyze the temporal and spatial evolution characteristics of cropland use and the analysis of the impact driving force.

Based on the existing literature research theory, based on the 30-meter land use raster data, we used ArcGIS to calculate the land-use transition matrix during the study period to quantitatively study the changes in the land use quantity structure in the past 20 years. The transfer-in and -out area of cropland in the period, time was used to obtain the changing table of the quantity and structure of cropland in the study area. The dynamic degree model of cropland use is introduced to quantitatively describe the active degree of cropland use change in each town in different periods, the regional difference of cropland change, and the changing trend of cropland use. Through the kernel density analysis, the agglomeration of the spatial distribution of cropland was analyzed. Thirteen factors were selected as the driving force affecting the change of cropland, and the geographic detector was used to quantitatively analyze the driving factors of the temporal and spatial change of cropland use in each town of Dangyang City.

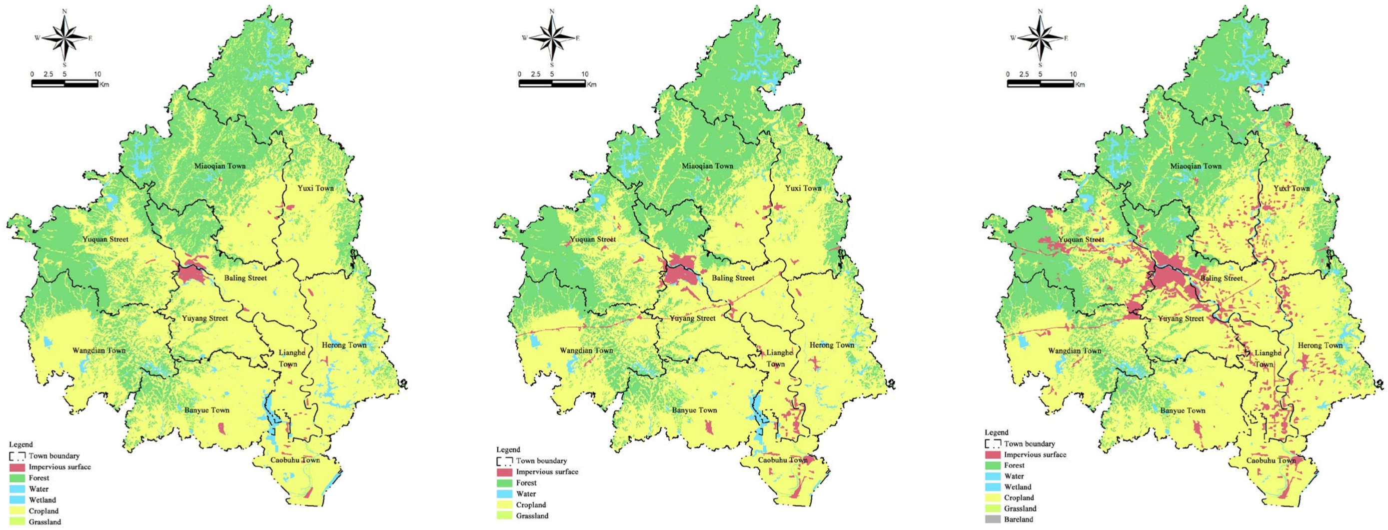
2. Study Area

Dangyang City is located in the eastern part of Yichang City, in the transition zone from the western Hubei mountains to the Jianghan Plain, spanning 111°32′-112°04′ east longitude and 30°30′-31°11′ north latitude. It borders Yichang City in the south, Yuanan County in the north, and Jingmen City in the east. The terrain is high in the northwest and low in the southeast. Dangyang City is located in the middle latitudes and has a subtropical monsoon humid climate, with four distinct seasons, rain and heat in the same season, and has the characteristics of north-south transition. In this study, there are 3 sub-district offices in Yuyang, Baling and Yuquan in Dangyang City, and 7 towns in Cuoxi Town, Herong Town, Wangdian Town, Banyue Town, Caobuhu Town, Lianghe Town and Miaoqian Town. Town, as the research object.

3. Data and Methods

3.1. Research data sources and data preprocessing

Based on the 30-meter grid land use data in the study area in 2000, 2010, and 2020, land-use type information was extracted. The raster data of the cropland in the study area were obtained by the ArcGIS as an attribute extraction tool. The classified images in the development of GlobeLand30 data are mainly 30-meter multispectral images, including TM5, ETM+, OLI multispectral images of the US Landsat (Landsat) and China Environmental Disaster Mitigation Satellite (HJ-1) multispectral images, 2020 version data A 16-meter resolution Gaofen-1 (GF-1) multispectral imagery was also used (http://www.globallandcover.com/home.html?type=data). The population and economic data are from 2000, 2010, and 2020 "Statistical Yearbook" data provided by the Dangyang Municipal Bureau of Statistics. The spatial interpolation dataset of the precipitation comes from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences.



Land Use in 2000 Land Use in 2010 Land Use in 2020

Figure 1. Land Use in Dangyang City from 2000 to 2020.

3.2. Research methods

We studied the temporal and spatial variation characteristics and driving factors of cropland use in Dangyang City from 2000 to 2020, and mainly use the following analysis methods.

(1) Land-use transition matrix

The land-use change matrix describes the quantitative structure characteristics of the land-use change at the beginning and end of the study area and the transfer changes of each category during the study period [10]. The mathematical form of the transition matrix is

$$S_{ij} = \begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nn} \end{bmatrix} \tag{1}$$

where S is the area, n is the number of land-use types before and after the transfer, i and j are the land use types at the beginning and end of the research period, respectively, S_{ij} is the area of land, type i at the beginning of the study period converted to land, and type j at the end of the period.

Table 1. Land use transfer matrix.

		T2				Pi+	Reduce
		A1	A2	----	An		
T1	A1	P11	P12	----	P1n	P1+	P1+- P11
	A2	P21	P22	----	P2n	P2+	P2+- P22
	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	An	Pn1	Pn2	----	Pnn	Pn+	Pn+- Pnn
P+j		P+1	P+2	----	P+n	1	
Add		P+1- P11	P+2- P22	----	P+n- Pnn		

(2) Dynamic degree of cropland use

The dynamic degree of cropland use quantitatively describes the speed of regional cropland use change [4]. The analysis of the overall situation of regional cropland use dynamics and its regional differences plays an important role in comparing the regional differences in cropland changes and predicting future cropland use trends. The calculation is done by the following equation.

$$S = \frac{\sum_{ij}^{n} \Delta S_{i-j}}{S_i} \cdot \frac{1}{T} \cdot 100 \tag{2}$$

where S is the dynamic degree of cropland use, S_i is the total area of, the i type cropland use type at the beginning of the monitoring period, ΔS_{i-j} is the area of the i type cropland use type converted to other land use types from the monitoring start to the monitoring end time, and T is the study period.

(3) Kernel density analysis

Kernel density analysis is a non-parametric method for estimating probability density functions to analyze and observe the agglomeration of the spatial distribution of cropland during the study period [11]. The original cropland data was resampled to raster data with a pixel size of 30 m, and then the raster data was converted into point data, and ArcGIS was used for kernel density estimation. The calculation equation is as follows.

$$f_n = \frac{1}{nh} \sum \left(\frac{x - x_i}{h} \right) \tag{3}$$

where f_n is the estimated value of the cropland kernel density, $K(x)$is the kernel function, h is the bandwidth, n is the number of cultivated site data in the bandwidth range, and $x - x_i$ is the distance from the cultivated site x to the sample point x_i.

(4) Geographical Detector

A geographical detector is a statistical method that can detect the spatial heterogeneity of geographic elements and their driving factors [12]. We use the differentiation factor detector and the interaction detector to quantitatively analyze the driving factors of the temporal and spatial changes of cropland use in Dangyang City and the interaction between the factors.

Spatial differentiation and factor detection: use the q value to measure the interpretation of the spatial differentiation of a detection factor X to Y. The specific model is as follows.

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma^2{}_h}{N\sigma^2} = 1 - \frac{SSW}{SST} \tag{4}$$

$$SSW = \sum_{h=1}^{L} N_h \sigma^2{}_h \text{，} \ SST = N\sigma^2 \tag{5}$$

where SSW is the sum of variance within the layer, SST is the total variance of the whole area, L is the classification of variable Y or factor X, N_h is the number of units in layer h, N is the number of units in the whole area, and $\sigma^2{}_h$ is the Y value variance of the whole area. The range of q is [0, 1], and the larger the value of q, the more obvious the spatial differentiation of cropland change Y. If the classification is caused by factor X, the larger the value of q, the stronger the explanatory power of factor X with the attribute Y of cropland change, and vice versa.

Factor interaction detection identifies the interaction between different factors and evaluates the explanatory power of the dependent variable Y when the two factors act together and independently. First, the q values of the two factors x_1 and x_2 are calculated respectively, and secondly, calculate the q value of the interaction between the two factors, and compare $q(x_1)$, $q(x_2)$, and $q(x_1 \cap x_2)$.

4. Results and Analysis

4.1 Analysis of temporal and spatial dynamic changes of cropland

From 2000 to 2020, the total cropland in Dangyang City remained above 110,000 ha, accounting for more than 50% of the land area of Dangyang City. From 2010 to 2020, the cropland changed significantly, and the cropland area decreased by 7297.26 ha. From the perspective of arable land holdings, Herong Town and Banyue Town have more arable land. From the perspective of cropland change, the cropland area in each town showed a decreasing trend during the study period, and only the cropland change in Banyue Town maintained an increasing trend.

In 2000, Yuquan Street had the largest area of arable land transferred out, with a total of 1095.44 ha, followed by Wangdian Town. Banyue Town had the smallest area of arable land transferred out. The largest transfer area of cropland is Herong Town, followed by Wangdian Town and Caoxi Town. The smallest transfer area of cropland is Baling Street, totaling 244.13 ha. In 2010, the amount of cropland transferred out of Yuquan Street became the largest, reaching 2,368.17 ha. The least amount of cropland transferred out was Caobuhu Town, which was only one-ninth of that of Yuquan Sub-district. Miaoqian Town had the largest transfer area of arable land, totaling 930.24 ha, followed by Wangdian Town and Yuquan Sub-district. Yuyang Sub-district and Baling Sub-district had less cropland transferred in the area.

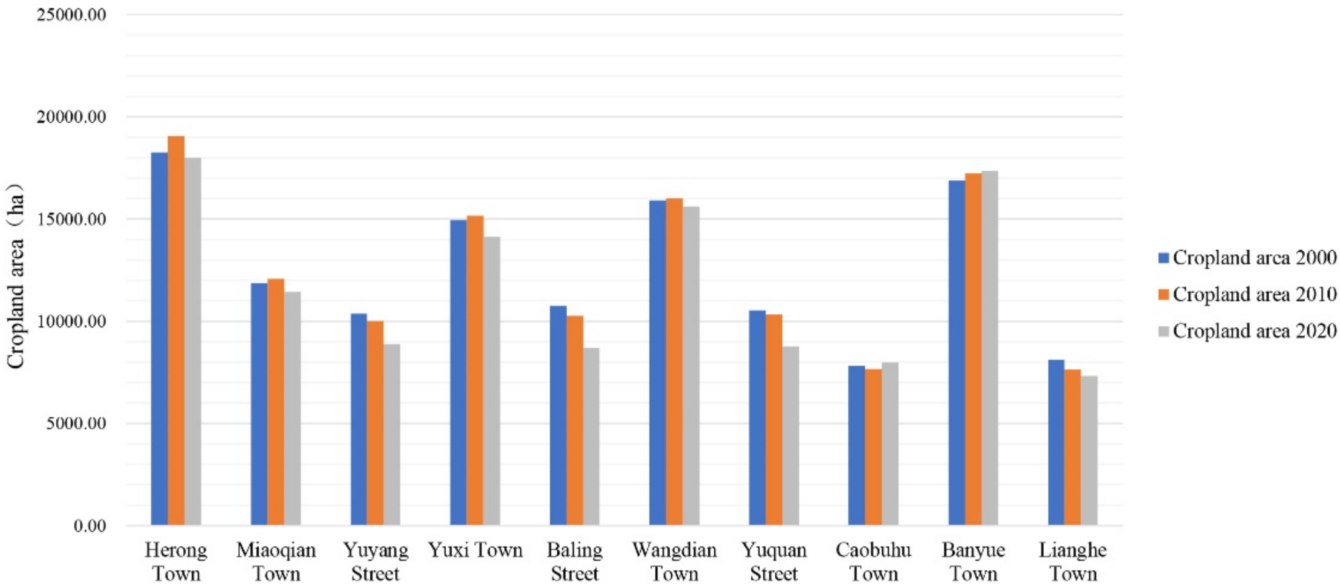


Figure 2. Cropland area of each town in Dangyang City from 2000 to 2020.

Using ArcGIS software, the land use transfer matrix in the two periods of Dangyang City from 2000 to 2010 and from 2010 to 2020 was calculated. The change in each land use during the study period was obtained, and the cropland of each town in Dangyang City was extracted in each period. The area of arable land converted from other lands was converted into cropland and analyzed to obtain a table of changes in the quantity and structure of cropland and 20 years in the study area.

From 2000 to 2010, a total of 6919.48 ha of cropland were transferred out, most of which were transferred to construction land and forest land, with 2661.38 ha of construction land and 2360.51 ha of forest land, respectively. The transfer amount of cropland is 6922.91 ha, mainly from forest land and water bodies. The transfer amount of construction land is at least 70.46 ha, accounting for about 1% of the total transfer amount. The water body and construction land were relatively stable, and the total amount did not change. Compared with the previous 10 years, the changes in cropland from 2010 to 2020 were more significant. The amount of arable land transferred out was 13464.29 ha, and the amount transferred in was 6175.38 ha. During these 10 years, 53.25% of the cropland was transferred out to construction land, and 23.63% was transferred out to forest land; the transfer of cropland mainly came from forest land, with 3272.86 hectares of forest land transferred in, and the least amount of construction land converted to cropland was only 309.44 hectares.

Table 2. Land Use Transfer Matrix of Dangyang City from 2000 to 2010

	2010	Total	Reduce

		Grassland	Cropland	Forest	Impervious Surface	Water		
2000	Grassland	2.48	0.53	2.32	0.06	0.10	5.50	3.02
	Cropland	0.25	55.17	1.10	1.24	0.64	58.39	3.22
	Forest	0.08	1.71	29.77	0.03	0.14	31.73	1.96
	Impervious Surface	0.00	0.03	0.00	0.79	0.01	0.83	0.04
	Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Water	0.01	0.95	0.13	0.02	2.44	3.55	1.11
	Total	2.82	58.40	33.32	2.14	3.32	100.00	
	Add	0.34	3.22	3.56	1.35	0.88		

Table 3. Land Use Transfer Matrix of Dangyang City from 2010 to 2020

		2020							Total	Reduce
		Grassland	Cropland	Forest	Bareland	Impervious Surface	Wetland	Water		
2010	Grassland	1.67	0.35	0.68	0.00	0.08	0.00	0.04	2.82	1.14
	Cropland	0.40	52.13	1.48	0.03	3.34	0.00	1.02	58.40	6.27
	Forest	0.65	1.52	30.38	0.10	0.33	0.00	0.35	33.32	2.94
	Impervious Surface	0.01	0.14	0.01	0.00	1.96	0.00	0.02	2.14	0.18
	Water	0.00	0.86	0.09	0.00	0.05	0.00	2.32	3.32	1.00
	Total	2.73	55.01	32.63	0.13	5.75	0.00	3.75	100.00	
	Add	1.06	2.88	2.25	0.13	3.79	0.00	1.43		

Table 4. Changes in cropland structure from 2000 to 2010

change direction	Area of Cropland transferred out (ha)					Transfer area of Cropland (ha)					
Type	Cropland ↓ Grassland	Cropland ↓ Forest	Cropland ↓ Impervious Surface	Cropland ↓ Water	Total	Grassland ↓ Cropland	Forest ↓ Cropland	Impervious Surface ↓ Cropland	Water ↓ Cropland	Wetland ↓ Cropland	Total
Baling Street	16.04	83.06	494.88	152.11	746.09	33.95	110.40	3.15	96.64	0.00	244.13
Banyue Town	67.16	175.16	39.60	110.17	392.09	125.18	345.76	2.37	258.78	0.00	732.10
Caobuhu Town	26.28	1.20	373.88	132.38	533.73	42.23	0.80	46.51	266.75	5.62	361.91
Herong Town	73.60	76.02	90.07	192.51	432.20	195.63	202.85	4.13	810.40	0.00	1213.00
Lianghe Town	2.65	0.39	492.60	87.42	583.07	13.24	0.83	5.11	95.40	0.00	114.58
Miaoqian Town	60.06	463.15	59.73	105.84	688.79	93.21	661.84	3.91	137.61	0.00	896.57
Wangdian Town	111.02	433.24	266.60	164.60	975.46	240.14	732.87	0.00	117.76	0.00	1090.77
Yuquan Street	91.95	548.86	271.79	182.84	1095.44	193.07	633.55	1.78	79.82	0.00	908.22
Yuyang Street	26.62	77.91	481.83	96.73	683.09	55.40	180.09	1.38	96.78	0.00	333.66
Yuxi Town	57.94	501.52	90.40	139.67	789.53	152.64	799.93	2.12	73.28	0.00	1027.96
Total	533.33	2360.51	2661.38	1364.26	6919.48	1144.69	3668.92	70.46	2033.22	5.62	6922.91

Table 5. Changes in cropland structure from 2010 to 2020

change direction	Area of Cropland transferred out (ha)	Transfer area of Cropland (ha)

Type	Cropland↓Grassland	Cropland↓Forest	Cropland↓Impervious Surface	Cropland↓Water	Cropland↓Bareland	Total	Grassland↓Cropland	Forest↓Cropland	Impervious Surface↓Cropland	Water↓Cropland	Total
Baling Street	36.83	119.22	1296.35	323.07	0.00	1775.48	23.31	95.88	55.03	49.22	223.43
Banyue Town	100.14	282.12	91.81	155.79	10.09	639.96	89.41	268.68	8.09	404.73	770.92
Caobuhu Town	33.43	0.86	110.37	95.86	0.00	240.51	28.86	3.90	58.45	457.30	548.51
Herong Town	128.00	144.49	933.24	438.53	0.00	1644.26	106.45	129.79	13.01	322.64	571.89
Lianghe Town	8.23	1.16	624.49	122.20	0.00	756.07	6.10	1.42	59.76	370.13	437.41
Miaoqian Town	87.28	572.80	550.54	339.19	8.14	1557.96	90.42	787.54	11.52	40.77	930.24
Wangdian Town	179.00	584.22	278.09	185.63	0.00	1226.93	152.99	565.59	37.17	68.15	823.90
Yuquan Street	150.81	636.52	1414.83	166.01	0.00	2368.17	129.05	619.26	22.61	30.22	801.14
Yuyang Street	43.88	126.67	1118.20	142.80	0.00	1431.55	36.15	144.91	35.25	70.59	286.90
Yuxi Town	92.20	713.53	751.53	226.71	39.43	1823.40	82.50	655.90	8.54	34.09	781.04
Total	859.80	3181.59	7169.45	2195.79	57.67	13464.29	745.23	3272.86	309.44	1847.84	6175.38

4.2 Analysis of the spatial agglomeration of Cropland

To further analyze the spatial changes of cropland and the spatial agglomeration of cropland in Dangyang City from 2000 to 2020, the 30-meter raster images of cropland in each period were converted into point element data, and then the ArcGIS kernel density analysis tool was used to calculate the cropland in the study area. Using the natural breakpoint method, the kernel density values were divided into five grades: low-density area, medium-low density area, medium-density area, medium-high density area, and high-density area.

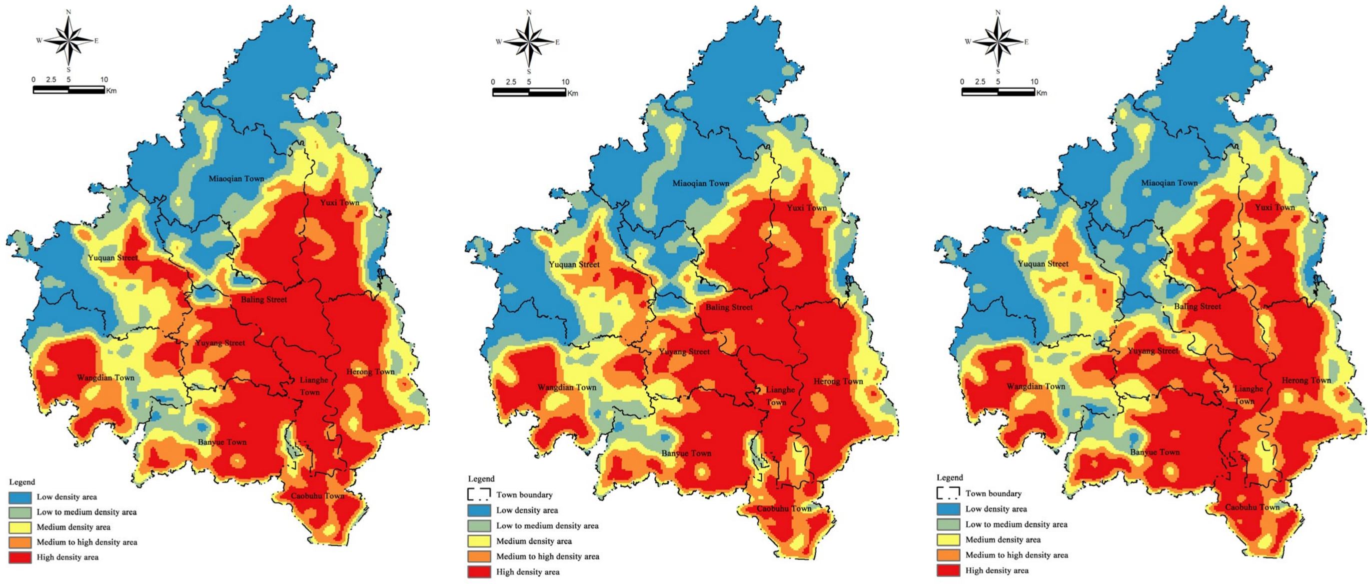
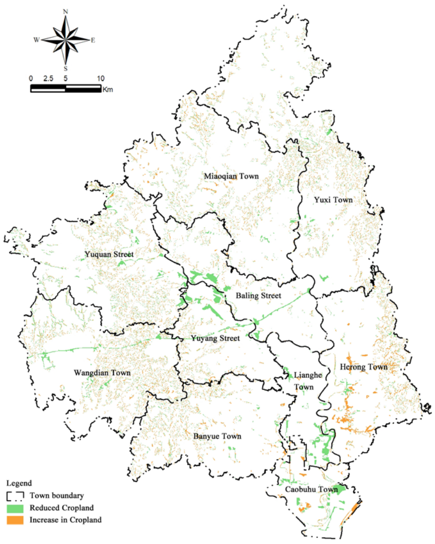
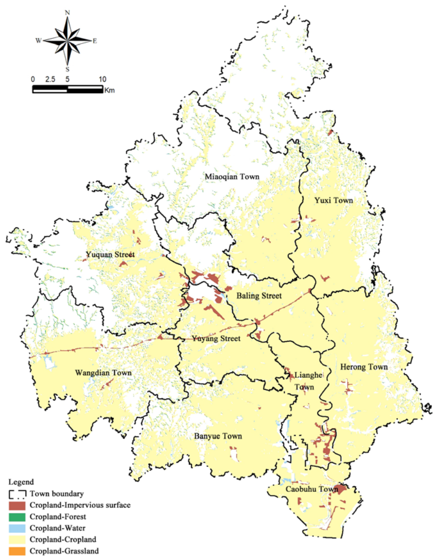


Figure 3. Spatial distribution of nuclear density grades from 2000 to 2020.

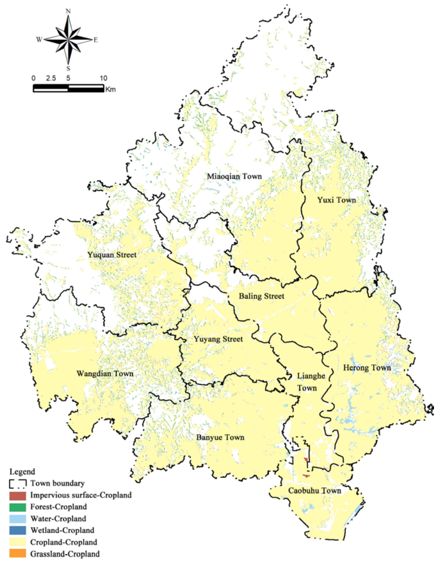
The analysis results show that the spatial distribution of cropland in Dangyang City is different at different stages, but the distribution of cropland in Dangyang City presents a trend of "sparse in the north and dense in the south" in general. The high-density areas of cropland distribution are mainly distributed in the southeastern part of Dangyang City, where the terrain is flat. The low-density areas are mainly distributed in the northwest area, mainly in the north of Canoxi Town, Miaoqian Town, and Baling Street. These areas have high altitudes and high terrain, and the proportion of cropland is small. The spatial distribution of the core density of cropland in three periods in Dangyang City in the past 20 years shows that the distribution range of high-density areas has been shrinking year by year, and the low-density areas gradually expanding in space. The change of cropland in the Dangyang urban area and the township area with better urban development is more significant, indicating that the degree of cropland agglomeration in Dangyang City is not only affected by natural conditions such as topography and landforms, but also by social factors such as urbanization construction. distribution has an impact.



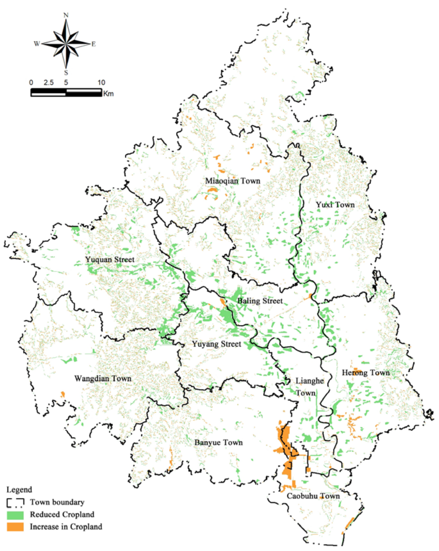
2000–2010 cropland Changes



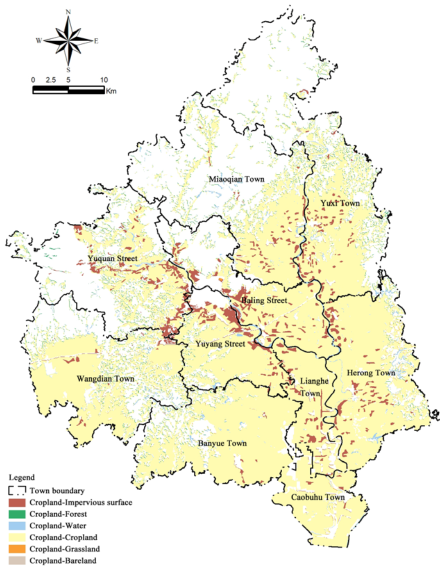
2000–2010 cropland transferred to other lands



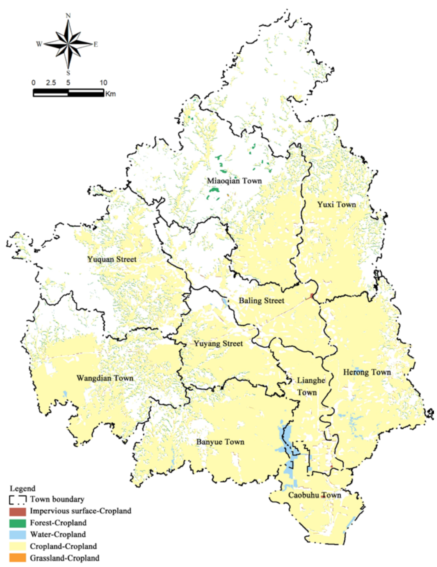
2000–2010 other land transferred to cropland



2010–2020 cropland Changes



2010–2020 cropland transferred to other lands



2010–2020 other land transferred to cropland

Figure 4. 2000–2020 cropland Changes

4.3 Cropland use dynamics

The dynamic degree model of cropland use was introduced to calculate the dynamic degree of cropland use in each town in Dangyang City during the study period and to study the active degree of dynamic changes of cropland.

Table 6. Dynamics of land use in Dangyang City from 2000 to 2020

Area	Baling Street	Banyue Town	Caobuhu Town	Herong Town	Lianghe Town	Miaoqian Town	Wangdian Town	Yuquan Street	Yuyang Street	Yuxi Town
2000-2010	4.08%	3.30%	5.15%	2.89%	5.42%	4.33%	9.27%	13.99%	4.04%	9.73%
2010-2020	9.32%	5.30%	2.40%	10.84%	7.37%	9.72%	11.87%	30.92%	8.31%	23.84%

From 2000 to 2010, the change of cropland in Yuquan Street, Wangdian Town, and Ganxi Town was relatively active. These areas were mainly distributed in the western part of Dangyang City, and the change of cropland was mainly dominated by transfer. The dynamic degree of cropland use in Herong Town is the lowest at 2.89%. From 2010 to 2020, the dynamic degree of cropland use in Yuquan Street, Wangdian Town, and Kuoxi Town still maintained a high level. From 2010 to 2020 in Dangyang City, only Caobuhu Town showed a downward trend in cropland change activity. The degree of activity in all regions has increased, among which Herong Town has the most significant change, and the dynamic degree of cropland use has increased to 10.84%. According to the above analysis, it is concluded that the dynamic degree of cropland use shows an increasing trend in the two periods, and the period from 2010 to 2020 is the period when the dynamic degree of cropland use is relatively active. With the development of the social economy, urban construction, industrial development, and urban development, the demand for land is gradually increasing.

4.4 Driving factors of spatial and temporal changes of cropland in Dangyang City

4.4.1 Driver detection

The temporal and spatial changes in cropland use in Dangyang City are affected by natural, economic, social, and other factors. The driving factor affecting the change of cropland include elevation (x_1), slope (x_2), annual precipitation (x_3), river density (x_4), population density (x_5), rural Population density (x_6), urbanization rate (x_7), local fiscal revenue (x_8), gross agricultural production (x_9), number of rural labor resources (x_{10}), migrant workers (x_{11}), total grain output (x_{12}), and the per capita cropland (x_{13}). Using ArcGIS software, the 13 driving factors from 2000 to 2020 were graded and divided into 5 grades using the natural breakpoint method, and the geographic detector model was used to analyze the influence intensity q value of the driving factors in different periods. The larger the factor, the stronger the explanatory power of the factor to the change of cropland.

Table 7. 2000-2020 driver detection

q	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}
2000-2010	0.593	0.155	0.306	0.402	0.366	0.338	0.402	0.474	0.657	0.537	0.657	0.745	0.557
2010-2020	0.593	0.155	0.306	0.537	0.346	0.537	0.777	0.370	0.785	0.777	0.462	0.848	0.530

The q values of the driving factors of cropland change in Dangyang City from 2000 to 2010 are in descending order: $q(x_{12}), q(x_{11}), q(x_9), q(x_1), q(x_{13}), q(x_{10}), q(x_8), q(x_7), q(x_4), q(x_5), q(x_6), q(x_3)$, and $q(x_2)$. Among them, the total grain output and outbound employees play a leading role, and the total output value of agricultural production and elevation have a strong influence. From 2010 to 2020, the q value of the driving factor of cropland change in Dangyang City is sorted from largest to smallest: $q(x_{12}), q(x_9), q(x_{10}), q(x_7), q(x_1), q(x_4), q(x_6), q(x_{13}), q(x_{11}), q(x_8), q(x_5), q(x_3), q(x_2)$. The total grain output and agricultural output are dominant, and other factors with stronger explanatory power are the number of rural labor resources and the urbanization rate. During this period, the q value of the driving factor affecting the temporal and spatial changes of cropland increased significantly compared with the previous period, and the changes in cropland were also more significant. The influence of the factors of local fiscal revenue and out-of-home employees has been significantly reduced, and the influence of the urbanization rate has been significantly improved. The influence trend of natural factors on the temporal and spatial changes of cropland in Dangyang in the past 20 years is relatively stable, and the influence of economic and social factors on the changes of cropland is relatively strong.

4.4.2 Driver interaction detection

The Spatio-temporal change of cropland in Dangyang City is the result of the joint action of a variety of driving factors. We use geographic detectors to obtain the interaction of 13 driving factors on the Spatio-temporal change of cropland from 2000 to 2010 and from 2010 to 2020. By calculating and comparing the q-values after the superposition of a single factor and a double factor, the geographic detector judges the strength, linearity, or nonlinearity of the interaction of factors. The analysis result shows that several driving factors have stronger two-factor interactions than single-factor interactions, and the interaction type is mainly two-factor enhancement. Compared with the single-factor effect, the q-values of each influencing factor were reduced to different degrees when they acted together.

Table 8. 2000–2010 driver interaction detection results

q	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}
x_1	0.593												
x_2	0.785	0.155											
x_3	0.978	0.978	0.306										
x_4	0.914	1.000	0.612	0.402									
x_5	0.914	0.656	0.806	0.778	0.366								
x_6	0.892	0.634	0.591	0.799	0.455	0.338							
x_7	0.914	1.000	0.806	0.799	0.799	0.799	0.402						
x_8	1.000	0.656	1.000	0.569	0.656	0.656	1.000	0.474					
x_9	1.000	1.000	0.806	1.000	1.000	0.806	0.914	0.914	0.657				
x_{10}	0.699	0.978	0.978	0.914	0.892	0.892	0.914	0.914	1.000	0.537			
x_{11}	1.000	1.000	0.806	0.806	1.000	1.000	0.914	1.000	0.914	1.000	0.657		
x_{12}	0.806	1.000	1.000	0.978	1.000	1.000	1.000	0.914	1.000	0.778	1.000	0.745	
x_{13}	0.978	0.634	0.978	0.914	0.656	0.634	0.806	0.656	0.914	0.957	0.978	0.978	0.557

Table 9. 2010–2020 Driver Interaction Detection Results

q	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}
x_1	0.593												
x_2	0.785	0.155											
x_3	0.978	0.978	0.306										
x_4	1.000	1.000	0.806	0.537									
x_5	0.892	0.634	0.785	0.978	0.346								
x_6	1.000	0.656	0.806	1.000	0.656	0.537							
x_7	0.892	0.892	0.978	1.000	0.892	0.978	0.777						
x_8	1.000	0.569	0.806	0.806	1.000	0.957	0.892	0.370					
x_9	1.000	0.914	1.000	0.978	1.000	1.000	0.914	0.828	0.785				
x_{10}	1.000	1.000	0.978	0.957	0.978	0.978	0.914	1.000	0.978	0.777			
x_{11}	0.978	0.978	0.978	0.656	0.957	0.978	0.978	1.000	1.000	0.978	0.462		
x_{12}	1.000	1.000	0.978	0.978	1.000	0.978	0.914	0.978	0.978	0.885	1.000	0.848	
x_{13}	0.978	0.634	0.785	0.785	0.612	0.656	0.978	0.806	0.978	0.978	0.957	0.978	0.530

Note: The gray fill represents the single-factor effect, the yellow fill represents the interaction type is a nonlinear enhancement, and the light blue fill represents the interaction type is two-factor enhancement.

During the study period, the slope had the strongest influence on the interaction of factors, and the q value increased exponentially when other driving factors and slopes which interacted with each other. The influence of annual precipitation x_3 on the interaction of factors is second to that of slope x_2, and the q value increases more when it interacts with other factors. From the perspective of interaction type, elevation and slope $(x_1 \cap x_2)$, elevation and annual precipitation $(x_1 \cap x_3)$, slope and annual precipitation $(x_2 \cap x_3)$ are natural factors, and annual precipitation and population density $(x_3 \cap x_5)$, the explanatory power of annual precipitation and local fiscal revenue $(x_3 \cap x_8)$, river density and population density $(x_4 \cap x_5)$ to the change of cropland use is significantly improved, and there is a nonlinear strengthening relationship between them. When other influencing factors interacted in pairs, the q-value decreased slightly, the driving force of the interaction was relatively weak, and the interaction types were all enhanced by two factors.

5. Conclusions

From 2000 to 2020 in Dangyang City, with the increase in population, the development of industrialization, and urbanization, the cropland has changed significantly. The overall cropland area decreased with a total reduction of 7292.77 ha. The cropland in Baling Sub-district and Yuquan Sub-district has decreased significantly, and the cropland in Baling Sub-district has decreased by up to 2055.64 ha, and the total cropland in Caobuhu Town and Banyue Town has increased. Most of the cropland in Dangyang City has been transferred to construction land and forest land, and the central area of Dangyang City is the area with the most significant changes in cropland.

The distribution of cropland in Dangyang City presents a distribution pattern of “dense in the southeast and sparse in the northwest”. The high-value areas of cropland density are mainly distributed in the plains and hilly areas in the southeast of the region. Miaoqian Town and Ganxi Town in Dangyang City are the main low-density areas. In the past 20 years, the area of high-density areas has gradually shrunk, the scope of low-density areas has continued to expand, and the development of cities and towns has gradually reduced the distribution of cropland.

The temporal and spatial change pattern of cropland in Dangyang City is the result of the combined action of natural and social factors. In the same period, under the action of a single factor, the explanatory power of total grain yield is the strongest in the two study periods. With the change of time, the urbanization rate has a great influence on the change of cropland, the influence of natural factors is small, and the influence of social factors is gradually strong. Under the interaction of influencing factors, the interaction of driving factors in different periods has different effects on cropland change. From 2000 to 2010, the interaction effect of driving factors was mainly manifested as a two-factor enhancement. From 2010 to 2020, the two-factor enhancement of driving factors decreased, and the nonlinear enhancement increased.

The effect of driving factors provides a scientific basis for the protection of cropland and the formulation of agricultural policies in Dangyang City. In the process of ecological civilization construction and soil pollution prevention and control, it is necessary to focus on the situation of cropland and make rational use of cropland. The research results provide a reference value for protecting cropland resources and ensuring national food security. There are still many factors that affect the change of cropland. In the future, it is necessary to explore the factors affecting the change of cropland from different perspectives to have a more comprehensive consideration.

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