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Temporal and Spatial Characteristics of the Change of Cultivated Land Resources in the Black Soil Region of Heilongjiang Province (China)

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Received: 8 November 2018; Accepted: 19 December 2018; Published: 21 December 2018

Abstract: It is of great significance for the improvement of grain production capacity and the protection of cultivated land in the Black Soil Region to reveal the temporal and spatial evolution trend of the change in cultivated land resources. In this paper, the temporal and spatial variation pattern of cultivated land resources in Heilongjiang Province was analyzed based on the remote sensing images made in 1995, 2005, and 2015 with the 3S Technology by using the land use dynamic degree, kernel density analysis, and transfer matrix methods. The results showed that, during the two decades from 1995 to 2015, the total quantity of cultivated land increased slightly. To be specific, in 1995–2005, the total quantity of cultivated land increased; in 2005–2015, the number decreased. Spatially, the conversion of cultivated land was mainly concentrated in the west of Heilongjiang Province. During the study period, the high-density cultivated land area was concentrated in the west of Heilongjiang Province, and the largest increase came in Heihe City and Qitaihe City. The conversion between each land type and cultivated land was observed. The internal conversion of cultivated land was between dryland and paddy field. The transfer-out of cultivated land was mainly the conversion of dryland into construction land and woodland, and the transfer-in was mainly the conversion of woodland, unused land, and construction land into dryland, while only a small quantity of conversion involving paddy field was found. Spatially, the conversion mainly took place in Harbin City, Heihe City, and Suihua City in the center and west of Heilongjiang Province, and also in a moderate amount in Qiqihar City in the east of Heilongjiang Province.

Keywords: land use; cultivated land resources; spatial pattern; black soil region; Heilongjiang Province

1. Introduction

Cultivated land resources are the material basis for human survival and development. The report of the CPC's 19th National Congress pointed out that "we must Ensure national food security and secure the livelihood of our people". The basic requirement of protecting food security is to ensure that the quantity and quality of cultivated land resources are not reduced. The Black Soil Region is fertile and is one of the most suitable areas for farming. With the acceleration of the new urbanization process and the rapid economic and social development, land degradation in the Black Soil Region, such as soil erosion, secondary salinization of soil, and thinning of the thickness of the black soil layer, has become a severe problem, which considerably affects the grain production capacity. It is of great practical significance for the study of food security and sustainable development of regional cultivated land to analyze the temporal variation pattern and spatial trend evolution of cultivated land resources in Heilongjiang Province, a Black Soil Region of Northeast China [1].

At present, the research on the characteristics of the change of cultivated land resources at home and abroad mainly focuses on aspects including the temporal and spatial variation of cultivated land [2–4], its driving mechanism [5,6], and the influence of such change on grain production capacity [7,8]. Some scholars have analyzed the characteristics of cultivated land using conversion from the perspective of the dominant form according to the connotation of land-use transformation theory [9,10]. The temporal and spatial variation characteristics in terms of research scale include national, regional [11,12], city, and county [13]. Only a few studies focus on the Black Soil Region as the research area. In such studies, remote sensing is often used for analysis, and econometric models, such as transfer matrix [14], kernel density, and spatial autocorrelation [15], have also been gradually introduced. They focus primarily on aspects such as ecological effects [16] and soil quality evaluation of the region [17–20]. Further studies are required given this situation. In addition, some scholars have also proven the impact of changes in cultivated land resources on grain production capacity. Cultivated land is an important carrier of grain production, and scientific assessment of cultivated land productivity is of great significance to ensure food security [21]. The potential agricultural productivity was developed at a pixel level in mainland China [22].

In this paper, the temporal and spatial variation pattern of cultivated land resources in Heilongjiang Province from 1995 to 2015 is analyzed. The spatial distribution of cultivated land resources was analyzed by using kernel density to explore the law of temporal variation and the trend in spatial evolution of cultivated land resources in the study area, and to provide an important theoretical basis for ensuring the food security and the protection of cultivated land in the Black Soil Region.

Heilongjiang Province is an important grain production area in China. It is located in Northeast China, 43°26′~53°33′ north latitude, 121°11′~135°05′ east longitude. It is adjacent to Russia, with Wusuli River and Heilongjiang River as the boundary in the east and north. It is bordered by the Inner Mongolia Autonomous Region in the west, and connects Jilin Province in the south. Its western part belongs to Songnen Plain, and the northeast belongs to Sanjiang Plain. The cultivated land area accounts for 35.1% of the total land area, 4525.4×10^4 hm^2. Heilongjiang Province consists of 12 prefecture-level cities and 1 prefecture, including Harbin City, Qiqihar City, Mudanjiang City, Jiamusi City, Qitaihe City, Daqing City, Heihe City, Suihua City, Yichun City, Hegang City, Shuangyashan City, Jixi City, and Da Hinggan Ling Prefecture.

Heilongjiang Province has a temperate continental monsoon climate. The annual average temperature is between −5 °C and 5 °C. The annual average precipitation between 400 mm and 650 mm, with the most precipitation in the middle mountain area, then in the east, and the least in the west and north. The terrain is generally high in the northwest, north, and southeast, and low in the northeast and southwest. The Black Soil Region of Northeast China is one of the only "three major Black Soil Regions" in the world. It is mainly distributed in Heilongjiang Province, Jilin Province, Liaoning Province, and Inner Mongolia Autonomous Region, and concentrated in the central and western Heilongjiang Province, including Heihe City, Qiqihar City, Suihua City, Harbin City, Jiamusi City, Qitaihe City, and Shuangyashan City. The Black Soil Region of Heilongjiang Province is about 65% of the area of the Black Soil Region of Northeast China, and its cultivated land area accounts for about 83% of the area of the Black Soil Region of Heilongjiang Province. The cultivated land area in Qiqihar City, Harbin City, Suihua City, Heihe City, and Jiamusi City is large, while the cultivated land area in Yichun City and Daqing City is the smallest.

In 2016, Heilongjiang Province became the "No. 1 of Grain Production" in the whole country. The total grain production of Heilongjiang Province accounted for 1/10 of the national total grain production. However, at the same time, problems of soil erosion and thinning of the thickness of the black soil layer remain the main limiting factors for the utilization of cultivated land resources in Heilongjiang Province. Therefore, it is of great significance for the sustainable utilization of cultivated land resources and the improvement of grain production capacity to study the temporal and spatial variation characteristics of cultivated land resources by taking the Black Soil Region of Heilongjiang Province as the study area (Figure 1).

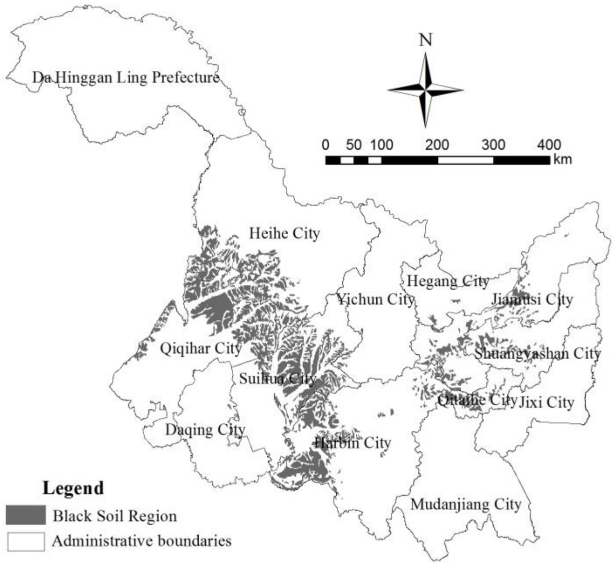

Figure 1. The Black Soil Region in Heilongjiang Province.

2. Materials and Methods

2.1. Data Sources and Processing

In this paper, Landsat TM/ETM remote sensing images from 1995 and 2005 and landsat 8 remote sensing images from 2015 were chosen as the data sources. The images were generated by artificial visual interpretation, which was supported by the "Resource and Environmental Science Data Center of the Chinese Academy of Sciences". By using ArcGIS10.2, the land-use types were divided into six categories: cultivated land, woodland, grassland, construction land, water area, and unused land, according to the actual situation in the study area. The secondary division of cultivated land was dryland and paddy field. Other data included the administrative boundary data of prefectures and cities in China, the Statistical Yearbook of Heilongjiang Province (1996–2016), the Yearbook of Heilongjiang Province (1996–2015), and the statistical yearbooks of other cities and prefectures.

2.2. Research Methods

2.2.1. Dynamic Analysis on the Change of Cultivated Land Resources

The comprehensive land-use rate was the index to describe the regional difference of the speed of the change of land-use type, which represented the speed of the change of the all land-use types over a certain period of time, reflecting the comprehensive influence of human activities on the land-use change in the Black Soil Region of Heilongjiang Province [23]. Its mathematical model was:

$$\mathrm{S} = \left(\sum_{n=1}^{m} \left(\Delta S_{i-j} \right) / S_i \right) \times \frac{1}{t} \times 100\% \tag{1}$$

where S was the comprehensive dynamic rate of land use in the study area, ΔS_{i-j} was the total area of land-use type i converted to the other land-use types from the beginning of the study period to the end, S_i was the total area of type i at the beginning of the study period, and t was the time period of land-use change.

The single land-use dynamic rate was used to analyze the quantity change and change rate of land-use type in the study area over a certain period of time [24]. Its mathematical model was:

$$\mathrm{K}_i = \frac{S_{t2} - S_{t1}}{S_{t1}} \times \frac{1}{t_2 - t_1} \times 100\% \tag{2}$$

where K_i was the dynamic rate of land use from t_1 to t_2, and S_{t1}, S_{t2} were the number of land-use types in t_1, t_2.

2.2.2. Analysis of the Cultivated Land Kernel Density

Kernel density estimation is a statistical method of nonparametric density estimation. It is a useful detection method for hot spot and cold zone identification and analysis [3]. Its main core content is to use the known points to estimate the unknown points. Specifically, a kernel function is set at each known point to represent the distribution of elements in the neighborhood around this point. In the spatial distribution study of cultivated land, the kernel density estimation calculates the agglomeration of cultivated land in the whole study area based on the input data of cultivated land. Usually, the higher the value of kernel density is, the greater the density of cultivated land. The kernel density was generally defined as follows. Suppose that $x_1, x_2, \ldots, x_n$ are independent co-distributed samples taken from the population of the distribution density function f, which is used to estimate the value of f at a point x. The Rosenblatt–Parzen kernel estimation model commonly used was:

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

where f_n was the estimated value of cultivated land plot distribution kernel density, n was the number of cultivated land plots, k was the kernel density function, $x - x_i$ was the estimated distance between the cultivated land plot x and the sample cultivated land plot x_i, and h was the smoothing parameter of the belt plot estimated by kernel density (Figure 2).

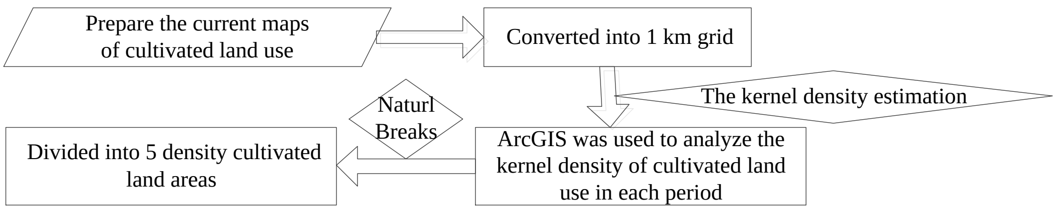

Figure 2. The kernel density flowchart.

2.2.3. Analysis of the Transfer of Cultivated Land-Use Types

The transfer matrix of land use derives from the quantitative description of the state and state transfer of the system in a system analysis, which can analyze the quantitative structural characteristics of regional land-use change and the direction of each change comprehensively and concretely [25,26]. In this paper, the temporal characteristics of the change of cultivated land resources in the study area were analyzed with the transfer matrix of land use.

The characteristics of regional land-use change, and the structure and direction of each change, can be described comprehensively and concretely by using the transfer matrix of land use. Its mathematical expression is:

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1j} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2j} & \cdots & S_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ S_{i1} & S_{i2} & \cdots & S_{ij} & \cdots & S_{in} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ S_{n1} & S_{n2} & \cdots & S_{nj} & \cdots & S_{nn} \end{bmatrix}$$

where S was the area of each land-use type; n was the number of land-use types; and i, j were the land-use types at the beginning and the end of the study period, respectively. When the number of land-use types is <10, the transfer matrix of any two periods can be obtained by substituting the maps of land-use types in the two periods into the map algebra expression shown below:

$$C_{i\times j} = A^{k}_{i\times j} \times 10 + A^{k+1}_{i\times j} \quad (4)$$

where $C_{i\times j}$ was the land-use change map from period k to period k + 1, which shows the types of land-use change and their spatial distribution.

3. Results

3.1. Analysis of the Temporal Variation of Cultivated Land Resources in the Study Area

According to the calculation of the dynamic rate of the change of cultivated land resources (Table 1, Figure 3) during the two decades from 1995 to 2015, great changes took place to the cultivated land resources in the Black Soil Region of Heilongjiang Province, as the total quantity of cultivated land increased only slightly, but there were certain internal conversions of cultivated land. In different periods, the rate of change of cultivated land resources varied. For example, from 1995 to 2005, the total area of dryland increased by 106,007 hm^2, the total area of paddy field decreased by 22,887 hm^2, the total quantity of cultivated land increased by 83,120 hm^2, and the dynamic rate of dryland and paddy field was 0.35% and 1.26%, respectively. Compared with the other land types, the dynamic rate of dryland was only higher than that of construction land, while the paddy field ranked third, indicating that the change rate was not particularly obvious in this period. Spatially, the increase of dryland area was mainly concentrated in Harbin City, Heihe City, and Qiqihar City, which was 53,265 hm^2, 33,649 hm^2, and 25,306 hm^2, respectively; the decrease of dryland was mainly seen in Shuangyashan City and Jiamusi City, which was 7563 hm^2 and 4216 hm^2, respectively. The decrease of paddy field was mainly in Harbin City, Qiqihar City, and Suihua City, which was 22,855 hm^2, 22,055 hm^2, and 2413 hm^2, respectively; the increase of paddy field mainly took place in Shuangyashan City and Jiamusi City, which was 14,879 hm^2 and 8592 hm^2, respectively. Except for Hegang City and Suihua City, the total quantity of cultivated land in other cities increased.

From 2005 to 2015, the total area of dryland decreased by 37,129 hm^2, the total area of paddy field increased by 28,905 hm^2, the total quantity of cultivated land decreased by 8224 hm^2, and the dynamic rate of dryland and paddy field was 0.12% and 1.82%, respectively. At this time, the dynamic rate of dryland was only higher than that of woodland, while the rate of paddy field was the highest of all land types, indicating that the range of change of cultivated land was small, but its internal conversion was very obvious. Spatially, the decrease of dryland area was mainly found in Suihua City, Jiamusi City, and Qiqihar City, which was 13,956 hm^2, 13,079 hm^2, and 4252 hm^2, respectively; the increase of dryland area mainly happened in Qitaihe City, which was 1732 hm^2. The increase of paddy field was mainly concentrated in Jiamusi City and Suihua City, which was 14,310 hm^2 and 11,625 hm^2, respectively; the decrease of paddy fields was mainly concentrated in Qiqihar City, Harbin City, and Suihua City, which was 3732 hm^2, 2818 hm^2, and 2331 hm^2, respectively. The cultivated land area of Daqing City, Jiamusi City, Qitaihe City, Shuangyashan City, and Yichun City increased by 1826 hm^2.

Table 1. The change of land-use types and their dynamic change in the Black Soil Region of Heilongjiang Province from 1995 to 2015.

Land Types	Area Changes /hm^2		The Dynamic Rate /%	
	1995–2005	2005–2015	1995–2005	2005–2015
Dryland	106,007	−37,129	0.35	−0.12
Paddy field	−22,887	28,905	−1.26	1.82
Woodland	−44,314	867	−1.40	0.03
Grassland	−24,949	2571	−2.89	0.42
Construction land	1063	5517	0.06	0.32
Water area	5209	3078	2.08	−0.39
Unused land	−15,865	−3965	−1.34	1.02
Total	4264	−156	4.41	3.11

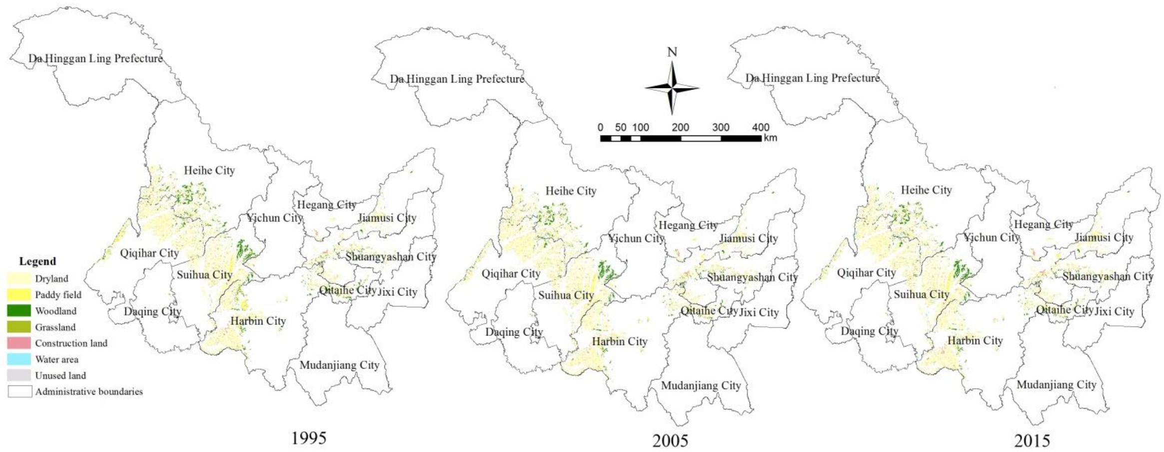

Figure 3. A map of land use in the study area in 1995, 2005, and 2015.

3.2. Analysis and Change Characteristics of the Cultivated Land Kernel Density

The current maps of cultivated land use in the Black Soil Region of Heilongjiang Province in 1995, 2005, and 2015 were converted into a 1-km grid. The analysis of kernel density was carried out according to the kernel density estimation to reflect the spatial distribution of cultivated land use in the study area. The cultivated land density areas were divided by Natural Breaks. To make the kernel density over the three periods more comparable, a slight adjustment was made in the boundary value of Natural Breaks; that is, the cultivated land was divided into five types of cultivated land area (Figure 4), including high-density cultivated land area (0.61–0.95), medium–high-density cultivated land area (0.41–0.60), medium-density cultivated land area (0.24–0.40), medium–low-density cultivated land area (0.09–0.23), and low-density cultivated land area (0–0.08). It can be seen that the high-density cultivated land area was concentrated in Qiqihar City, Suihua City, and Harbin City, and the kernel density of other cities was at the moderate level. From 1995 to 2015, the cultivated land kernel density of each city varied, and the range of high-density cultivated land area of Heihe City and Qitaihe City increased the most.

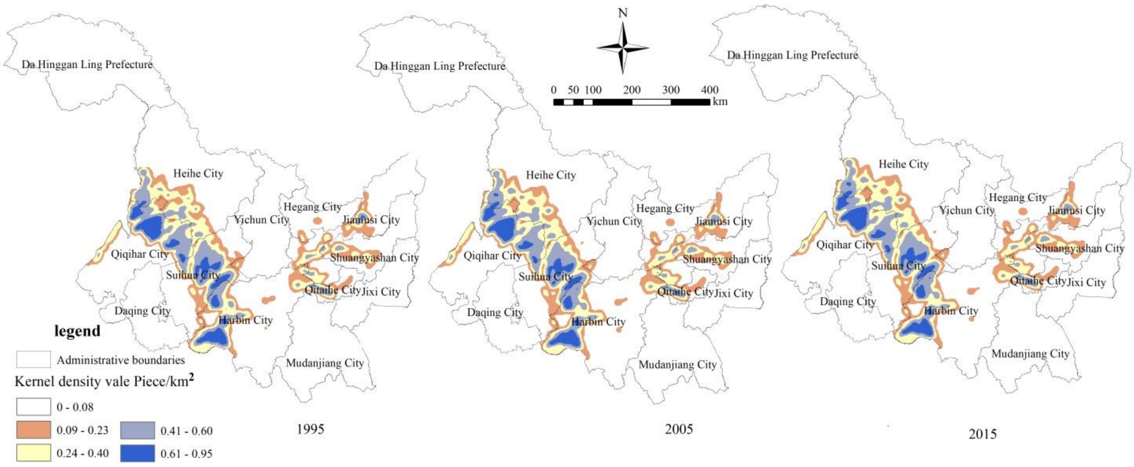

Figure 4. The spatial distribution of cultivated land kernel density in the study area.

3.3. Analysis of the Spatial Variation of Cultivated Land Resources in the Study Area

The spatial distribution characteristics of cultivated land use are the basis for analyzing the driving mechanism of cultivated land conversion characteristics, and are also an important part of a LUCC study. In this paper, the original vector data were converted into plane data, and a superposition analysis was carried out by using ArcGIS. By the calculation method of the transfer matrix, the spatial variation characteristics of cultivated land resources from 1995 to 2005 and from 2005 to 2015 were obtained, respectively.

3.3.1. Characteristics of the Internal Conversion of Cultivated Land

The secondary classification of cultivated land was dryland, paddy field, and irrigated field. The cultivated land in the Black Soil Region of Heilongjiang Province was mainly divided into dryland and paddy field. Therefore, the analysis of internal conversion of cultivated land mainly focused on the conversion between dryland and paddy field. From 1995 to 2005 (Figure 5, Table 2), the conversion area of dryland into paddy field was 66,161.67 hm^2, with a conversion ratio of 9.46%, which was mainly concentrated in Harbin City and Suihua City in the south of Heilongjiang Province as well as Shuangyashan City and Jiamusi City in the east of Heilongjiang Province. The conversion area of paddy field into dryland was 79,974.95 hm^2, with a conversion ratio of 11.43%. Harbin City ranked first, with a conversion ratio of 51.26%, followed by Qiqihar, with a conversion ratio of 23.46%. From 2005 to 2015, the conversion area of dryland into paddy field was 34,221.57 hm^2, with a conversion ratio of 47.30%, which was mainly concentrated in Jiamusi City, Suihua City, and Harbin City. The conversion area of paddy field into dryland was 10,363.59 hm^2, with a conversion ratio of 14.32%, which was mainly concentrated in Harbin City, Jiamusi City, and Suihua City.

During the two decades from 1995 to 2015, great changes took place within the cultivated land. The number of spots in the transfer map can reflect the level of the internal conversion of cultivated land. The number of spots in the transfer map from 1995 to 2005 was more than the number of spots in the transfer map from 2005 to 2015; that is, the internal conversion of cultivated land in the first period was more obvious than that in the second period.

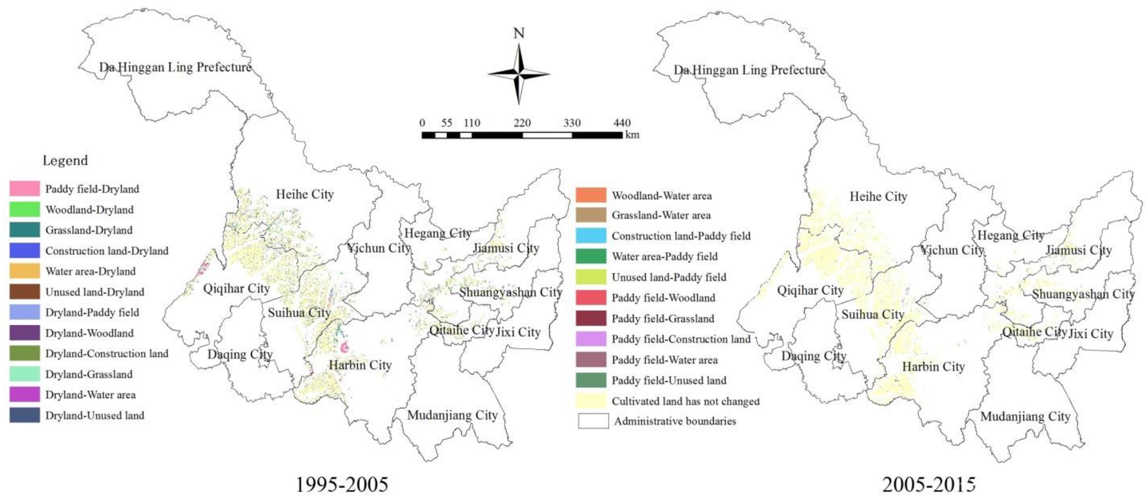

Figure 5. The characteristics of the spatial conversion of cultivated land resources in the study area in 1995–2015.

Table 2. The characteristics of cultivated land conversion in the study area.

Period	Land Conversion	The Number of Transfer Polygon/Pcs	Cultivated Land Conversion Ratio /%	Conversion Area /hm^2	Conversion Ratio of Land Conversion Area to Total Conversion Area in Every City/%									
					Harbin City	Daqing City	Hegang City	Heihe City	Jiamusi City	Qitaihe City	Qiqihar City	Shuangyashan City	Suihua City	Yichun City
1995–2005	Dryland–Paddy field	148	9.46	66,161.67	29.18	0	1.26	0.15	18.45	2.79	1.04	21.24	23.30	2.61
	Paddy field–Dryland	155	11.43	79,974.95	51.26	0.09	1.09	0.08	7.17	2.05	23.46	0.98	13.20	0.61
2005–2015	Dryland–Paddy field	87	47.30	34,221.57	12.69	0	0.83	0.29	40.50	1.34	1.44	4.20	34.16	4.56
	Paddy field–Dryland	58	14.32	10,363.59	39.50	0	0	0	22.78	15.10	0.24	5.97	14.72	1.69

3.3.2. Characteristics of Cultivated Land Transfer-In

The characteristics of cultivated land transfer-in mainly indicated the ways in which the quantity of cultivated land increased. Based on the analysis of the characteristics of cultivated land conversion in the Black Soil Region of Heilongjiang Province (Table 3, Figure 4, Figure 6), it can be seen that, from 1995 to 2005, the conversion of cultivated land was mainly the conversion of other land types into dryland. The conversion ratios of construction land, woodland, grassland, and unused land into dryland were large, which were 15.28%, 13.01%, 7.59%, and 6.51%, respectively. Spatially, the largest conversion of construction land into dryland was mainly concentrated in Qigihar City, Suihua City, and Harbin City; the conversion of woodland into dryland was mainly in Hehe City, Harbin City, and Qiqihar City; the conversion of grassland into dryland was mainly found in Harbin City, Qiqihar City, and Heihe City; and the conversion of unused land into dryland was mainly in Heihe City, Suihua City, and Qiqihar City. From 2005 to 2015, the characteristics of cultivated land transfer-in changed in both dryland and paddy field, and the transfer-in was mainly the conversion between construction land, woodland, and dryland, and unused land and paddy field, with a conversion ratio of 3.93%, 3.91%, and 2.42%, respectively. Spatially, the conversion of construction land into dryland was mainly concentrated in Harbin City, Jiamusi City, and Suihua City; the conversion of woodland into dryland was mainly in Harbin City, Heihe City, and Qitaihe City; and the conversion of unused land into dryland was mainly in Jiamusi City, Suihua City, and Harbin City.

The transfer-in of cultivated land was mainly the conversion between dryland and other land types, while the number of conversions of other land types into paddy field was small. The number of spots in the transfer map from 1995 to 2005 was larger than the number of spots in the transfer map from 2005 to 2015. Spatially, the conversion of cultivated land was mainly concentrated in Harbin City, Heihe City, and Suihua City in the center and west of Heilongjiang Province, and also in Qiqihar City in the east of Heilongjiang Province.

Table 3. The main types of changes in the study area.

Period	Land Conversion	The Number of Transfer Polygon/Pcs	Cultivated Land Conversion Ratio /%	Conversion Area /hm^2
1995–2005	Woodland–Dryland	175	13.01	90,986.5
	Grassland–Dryland	159	7.59	53,085.92
	Construction land–Dryland	185	15.28	106,912.14
	Water area–Dryland	115	0.86	6020.43
	Unused land–Dryland	140	6.51	45,558.98
	Construction land–Paddy field	78	0.78	5430.3
2005–2015	Woodland–Dryland	52	3.91	2827.23
	Grassland–Dryland	35	0.87	630.98
	Construction land–Dryland	68	3.93	2846.71
	Unused land–Dryland	39	0.73	525.42
	Construction land–Paddy field	52	1.09	787.76
	Unused land–Paddy field	37	2.42	1748.81

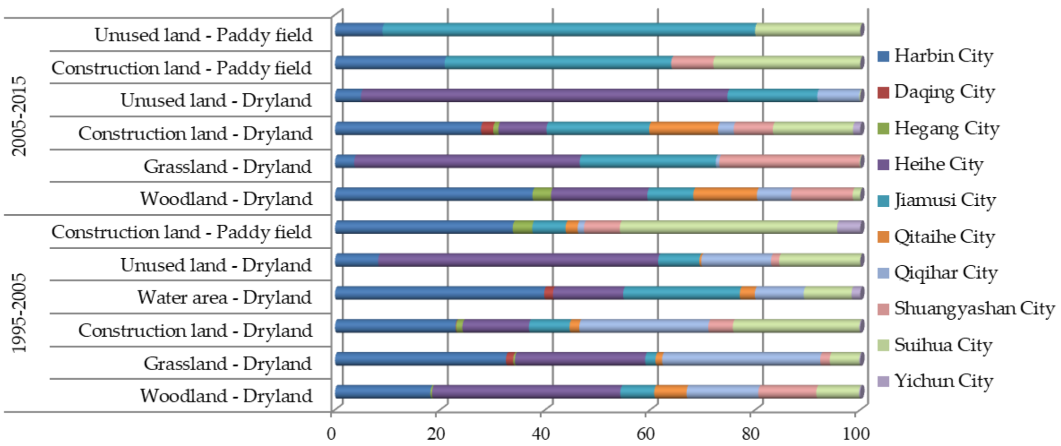

Figure 6. The ratio of land conversion area to total conversion area in every city/%.

3.3.3. Characteristics of Cultivated Land Transfer-Out

The characteristics of cultivated land transfer-out were the direct reflection of the decrease of cultivated land quantity. From 1995 to 2015, the characteristics of cultivated land transfer-out changed obviously, and the transfer-in was mainly the conversion between construction land, woodland, and dryland. From 1995 to 2005 (Table 4, Figure 4, Figure 7), the transfer-out of cultivated land was mainly from dryland into other land types. The conversion ratios of dryland into construction land, woodland, and unused land were large, which were 14.69%, 7.06%, and 4.51%, respectively, while the number of conversions of paddy field into other land types was small. Spatially, the conversion of dryland into construction land was mainly concentrated in Suihua City, Qiqihar City, and Harbin City; the conversion of dryland into woodland was mainly in Heihe City, Qiqihar City, and Harbin City; and among the conversions of dryland into unused land, Heihe city ranked first, with a conversion ratio of 63.44%. From 2005 to 2015, the conversion ratio of dryland into construction land was the highest, which was 11.88%, followed by the conversion ratio of dryland into water area and woodland, which was 4.55% and 4.40%, respectively. Spatially, the conversion of dryland into construction land was mainly concentrated in Harbin City and Suihua City; among the conversions of dryland into water area, Qiqihar City ranked first, with a conversion ratio of 78.59%; and the conversion of dryland into wood land was mainly concentrated in Heihe City, Jiamusi City, and Harbin City. There was basically no conversion of cultivated land in Daqing City and Yichun City because of their small area of cultivated land. By analyzing the characteristics of cultivated land transfer-out, it was found that the transfer-out ratio of cultivated land transfer was lower than the transfer-in ratio, indicating that the decrease of cultivated land was well-controlled, which was achieved by the conversion between dryland and other land types. The range of change from 1995 to 2005 was higher than that from 2005 to 2015. Spatially, the conversion of cultivated land was mainly concentrated in Suihua City, Harbin City, and Heihe City in the center and west of Heilongjiang Province, and also in Qiqihar City in the east of Heilongjiang Province.

Table 4. The changes of the main types of cultivated land reversal in the study area.

Period	Land Conversion	The Number of Transfer Polygon/Pcs	Cultivated Land Conversion Ratio /%	Conversion Area /hm^2
1995–2005	Dryland–Woodland	162	7.06	49,403.77
	Dryland–Grassland	127	4.04	28,263.49
	Dryland–Water area	108	0.93	6536.99
	Dryland–Unused land	114	4.51	31,551.16
	Dryland–Construction land	183	14.69	102,790.89
	Paddy field–Unused land	57	0.90	6304
2005–2015	Dryland–Woodland	59	4.40	3181.3
	Dryland–Grassland	64	3.09	2237.14
	Dryland–Water area	55	4.55	3294.4
	Dryland–Unused land	38	0.18	133.57
	Dryland–Construction land	58	11.88	8598.31
	Paddy field–Construction land	38	0.41	298.38

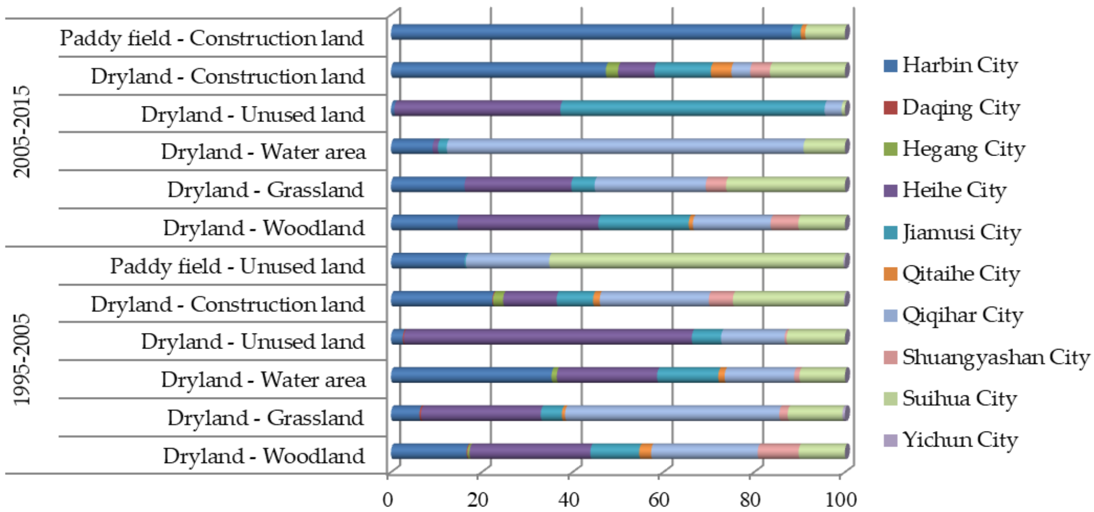

Figure 7. The reversal ratio of land conversion area to total conversion area in every city/%.

4. Discussion

The methods and means used in this paper can correctly explore the temporal and spatial characteristics of the change of cultivated land resources in the study area, and have a certain practical significance for the intensive utilization and protection of cultivated land in the Black Soil Region. However, the factors that affect the change of cultivated land resources do not only include the change of cultivated land quantity, but also the change of quality. In such regions as the Black Soil Region, the change of cultivated land quality in is especially important, and the driving factors in the process of cultivated land resource change have a great influence on the quantity and quality of cultivated land resources. In the future, the effect of cultivated land quality and driving factors on cultivated land in the study area should be further explored.

5. Conclusions

This paper takes the Black Soil Region of Heilongjiang Province as the study area, and analyzed the temporal and spatial variation characteristics of cultivated land resources in the periods 1995–2005 and 2005–2015, from which the following conclusions were drawn:

During the two decades from 1995 to 2015, great changes took place in the cultivated land resources in the Black Soil Region of Heilongjiang Province, as the total quantity of cultivated land increased slightly. However, there were certain internal conversions of cultivated land. The characteristics of the change of cultivated land resources from 1995 to 2005 and from 2005 to 2015 were different. In the first time period, the total quantity of cultivated land increased, but the dynamic rate of cultivated land was not obvious. In the second one, the total quantity of cultivated land decreased, and the dynamic rate of paddy field was the highest of all land types. Spatially, the conversion of cultivated land was mainly concentrated in Harbin City, Suihua City, Jiamusi City, and Qiqihar City.

In the analysis of cultivated land kernel density, the high-density cultivated land area was mainly in Qiqihar City, Suihua City, and Harbin City, and the cultivated land kernel density of other cities was at the moderate level. The range of high-density cultivated land area of Heihe City and Qitaihe City increased the most.

Through the superposition analysis by ArcGIS and the calculation method of the transfer matrix, it was found that a conversion between each land type and cultivated land took place. The internal conversion was between dryland and paddy field. The transfer-out of cultivated land was mainly the from dryland into construction land, woodland, and unused land, and the transfer-in was mainly from woodland, unused land, and construction land into dryland, while the number of conversions of other land types into paddy field was small. Spatially, the conversion of cultivated land was mainly concentrated in Suihua City, Harbin City, and Heihe City in the center and west of Heilongjiang Province, and also in Qiqihar City in the east of Heilongjiang Province.

Funding: This research was funded by the Youth Science Foundation of Heilongjiang University (Humanities & Social Science) (QW201501); the Basic Scientific Research Business Expenses of Universities in Heilongjiang Province, Special Fund Project of Heilongjiang University (Humanities & Social Science Planning Projects) (HDRC201611); and the Innovative Talents Program of Heilongjiang regular universities in 2018.

Conflicts of Interest: The authors declare no conflict of interest.

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