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Research Article

Evolution of Green Space Based on Remote Sensing Images in Zhengdong New District

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With the continuous advancement of urbanization, the socioeconomic development and environmental damage in Zhengdong New District of Zhengzhou City seriously threaten the development of green space. The paper focused on Zhengdong New District and selected four important nodes in 2007, 2011, 2015, and 2019 to interpret the remote sensing image, explore the local spatial evolution through the method of land use transfer model construction, extract the green space area conversion analysis information of the study area, and analyze the influence factors of its transformation. The research shows that from 2007 to 2019, the internal structure of green space in Zhengdong New District that were cultivated land, woodland, grassland, and water bodies, its showed different trends, and the dynamic changes were different. Among them, the area of cultivated land continued to decrease, the area of construction land continued to increase, the total area of woodland increased, the area of grassland and water bodies fluctuated, and the total green space was greatly reduced; the conversion of land types in Zhengdong New District mainly focused on the conversion of cultivated land to construction land, woodland, and grassland. The results shows that the green space of Zhengdong New District is affected by social, economic, natural, and other factors and various factors interact with each other. However, social and economic development factors are obviously stronger than natural and administrative factors on the evolution of green space area.

1. Introduction

Urbanization leads to the reduction of green space, thus changing the urban space and land use pattern. According to the data of *China's Land Use Planning Outline (2016-2030)*, the urban rate of built-up urban areas in China has increased by about 113%, the green space in the periphery areas of the city has been eroded, and the biodiversity has declined. In the new period, people pay more attention to enjoying the green space activities represented by the leisure and entertainment activities and constantly develop the cultural landscape function and health protection function of land use to promote the continuous transformation of green space use function in the periphery areas of the city. Therefore, people urgently find ways to face this urgent problem.

Zhengdong New District has established itself as the window of Henan Province's reform and opening up, the regional modern service center, the center for finance, exhibition, culture, higher education and sports, as well as the provincial administrative center. With the rapid urbanization of Zhengzhou city, Zhengdong New District expands the urban construction land rapidly to accelerate the social and economic development, causing the substantial erosion of green space [1]. In order to quickly reveal the influencing factors and ecological impact of green space evolution in Zhengdong New District, this paper comprehensively interpreted the law of green space evolution in Zhengdong New District from 2007 to 2019 by using multistage remote sensing image and land use transfer model construction method, which provides a scientific basis for urban green space planning and ecosystem planning in the future.

2. Research Area and Data Source

2.1. Research Area. The research area was Zhengdong New District, with a control area of 370 km^2 (Figure 1). For easy comparison of data analysis, this paper interpreted and analyzed the law of green space evolution in Zhengdong New District by using the latest remote sensing data of the Administrative Boundary of Zhengdong New District in 2019.

2.2. Green Space. In China, green space contains two levels: one is the land used for greening within the scope of urban construction land, and the other is the land with green environment and positive effect on ecology, landscape, and residents' leisure life beyond the scope of urban construction land. In this paper, the landscape types of the research area were divided into green space and gray space. The green space included cultivated land, woodland, grassland, and water body [2]. The gray space included construction land and bare land.

2.3. Data Source. In this paper, the research data was the data on green space evolution in Zhengdong New District in the past 15 years. The green space cover in Zhengdong New District in 2007, 2011, 2015, and 2019 was adopted, and the remote sensing image data was used as the basic data. The original satellite resolution was 30×30 m. After screening the remote sensing images of plant growth in the peak seasons from May to October, the following remote sensing image data was selected as the interpretation data source (Table 1).

3. Research Method

3.1. Interpretation of Remote Sensing Images. To analyze the change of green space features, the basic data was obtained by remote sensing interpretation. First, the obtained remote sensing image data was subjected to geometric correction and atmospheric correction by The Environment for Visualizing Images software [3–5]. The image of Zhengdong New District was cut in the GIS software to obtain the satellite remote sensing images of Zhengdong New District in 2007, 2011, 2015, and 2019, respectively. Next, the dat format was exported and imported into ENVI to select and verify the five training sample points of cultivated land, woodland, grassland, water body, construction land, and bare land. Then, the maximum likelihood method was used for supervised classification to obtain the land use status classification and export the Tif format. After that, the *ArcGIS* platform was used for data processing, operation, and inspection, and the accuracy of the test results reached 87.69%, 86.85%, 91.63%, and 92.80%, respectively, all of which met the accuracy requirements. Finally, the property sheet analysis area was calculated and visualized to obtain the land use interpretation drawings in 2007, 2011, 2015, and 2019 (Figure 2).

3.2. Area Conversion Analysis—Transfer Matrix Conversion Model. The transfer matrix of land use can carefully describe the structure and direction within the study scope. First, the *Arc Toolbox-Conversion Tools* in *ArcGIS* were used for raster to vector algorithm of land use data in 2007, 2011, 2015, and 2019, respectively. Next, *Dissolve* of the land use vector of each period was operated. Then, two data for *Dissolve* in *ArcGIS* was opened, that is, 2007-2011, 2011-2015, and 2015-2019. The results for *Dissolve* were subjected to *Intersect* and added with the fields of *New Area*. The changes in land use area were calculated and analyzed by clicking "*Calculate Geometry*.". Finally, the area of conversion between various land use types can be calculated meticulously by making statistics in Excel [6–8].

4. Results Analysis

This study mainly analyzed three aspects, that is, the overall area changes of green space, the area change of different green space types, and the land transfer matrix of green space.

4.1. Holistic Analysis of the Green Space Evolution in Different Periods of Zhengdong New District. The *Arcmap* was used for statistics of the interpretation of various green space types of Zhengdong New District in 2007-2019 to obtain the statistical table of green space interpretation data and the land use interpretation map in 2007-2019 [9]. From Table 2 and Figure 3, it can be seen that both the total green space area of Zhengdong New District and the single green space area such as grassland, woodland, cultivated land, wetland and water body changed in 2007-2019. Generally, the change was obvious.

In 2007, the total green space area of Zhengdong New District was 269.57 km^2, accounting for 73.64%. The area of the four green space types from large to small according to size was: cultivated land > woodland > water body > grassland. Among them, the area of cultivated land, 175.09 km^2, was the largest, accounting for 47.83%, which was much higher than that of the other three green space types. The area of woodland, 43.63 km^2, was the second, accounting for 11.92%. The area of grassland and water body was 23.05 km^2 and 27.8 km^2, respectively, which made up less than 10%.

In 2011, the total green space area of Zhengdong New District was 276.32 km^2, accounting for 75.48%, which decreased a little. The area of the four green space types from large to small according to size was: cultivated land > grassland > water body > woodland. The area of cultivated land, 142.49 km^2, was still the largest, accounting for 38.92%, which decreased obviously. The area of grassland, 63.21 km^2, was the second, accounting for 17.27%. The area of water body increased to 36.6 km^2, accounting for 10%. The area of woodland decreased to 34.02 km^2, accounting for 9.29%.

In 2015, the total green space area of Zhengdong New District was 234.19 km^2, accounting for 63.97%, which decreased obviously. The area of the four green space types from large to small according to size was: cultivated land > grassland > woodland > water body. The area of cultivated land, 123.41 km^2, was still the largest, accounting for 33.71%, which decreased obviously. The area of grassland, 56.66 km^2, was the second, accounting for 15.48%. The area

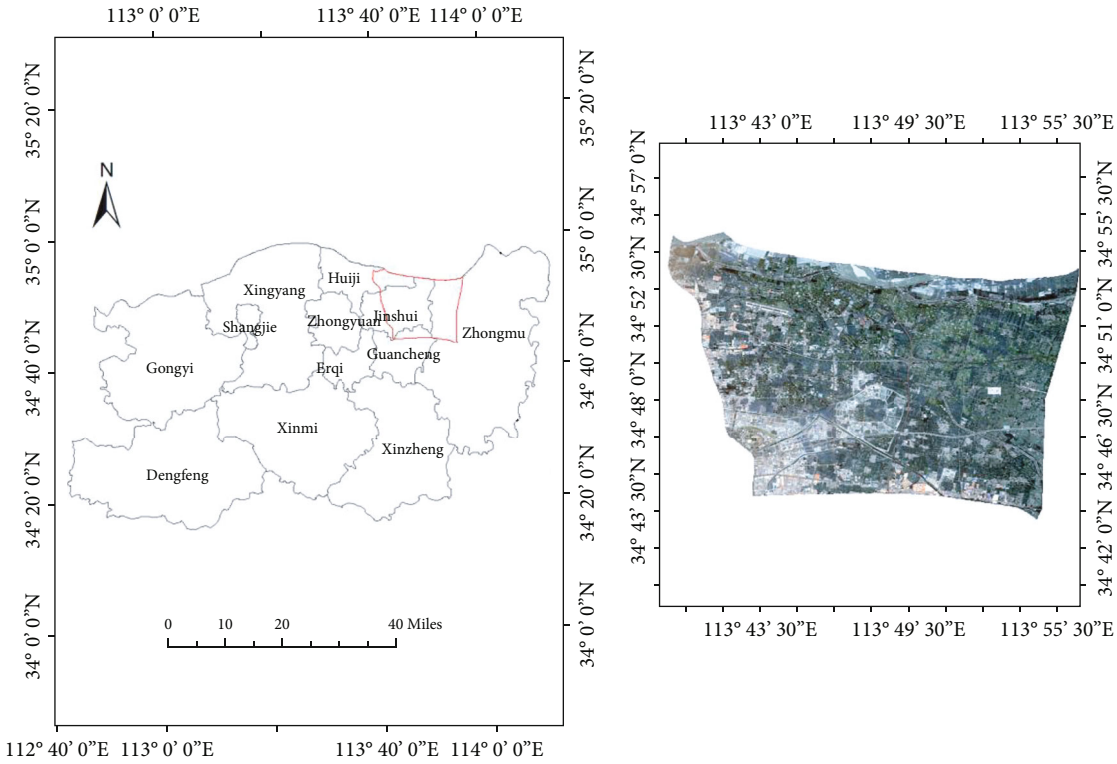

Figure 1: Overview of the research area.

Table 1: Satellite remote sensing image sources.

Satellite types	Resolution/m	Acquisition time	Revisit cycle (d)
Landsat5TM	30	2007-05-19	16
Landsat5TM	30	2011-05-14	
Landsat8ETM	30	2015-07-28	
Landsat8ETM	30	2019-07-07	

of woodland decreased to 33.55 km^2, accounting for 9.16%. The area of water body decreased to 20.57 km^2, accounting for 5.62%.

In 2019, the total green space area of Zhengdong New District was 213.66 km^2, accounting for 58.36%, which decreased compared with previous years. The area of the four green space types from large to small according to size was: woodland > cultivated land > grassland > water body. The area of woodland increased to 86.99 km^2, accounting for 23.76%, which increased significantly. The area of cultivated land decreased to 71.41 km^2, accounting for 19.5%. The area of water body increased to 25.54 km^2, accounting for 6.98%. The area of grassland decreased to 29.72 km^2, accounting for 8.12%.

Overall, the total green space area of Zhengdong New District continued to decline, from 241.76 km^2 in 2007 to 213.65 km^2 in 2019. The area of cultivated land and woodland always occupied an important position in green space. The dominant green space type in Zhengdong New District was cultivated land in 2007, grassland in 2011 and 2015, and woodland in 2019 (Figure 3).

In 2007-2019, the total area of four green space types was converted out 200.23 km^2 and converted in 140.01 km^2, so the area of green space decreased by 57.21 km^2 (Table 3).

The conversion of cultivated land in Zhengdong New District was the first, and the area of cultivated land mostly decreased. The cultivated land was mainly converted from construction land and woodland and converted to woodland. The area of woodland mostly increased, as the amount of converted-in woodland exceeded the amount of converted-out woodland. It was mainly converted from cultivated land and construction land and converted to construction land. The area of construction land increased. And it was mainly converted from cultivated land and woodland and converted to woodland. The area of water body changed little, while the area of grassland increased slightly.

4.2. Analysis of the Conversion of Green Space in Different Periods of Zhengdong New District. To better understand the conversion characteristics of each green space type and land use type, this study drew the spatial distribution map of four green space types converting to all types of land by using the land use matrix to express the conversion between the green space and the nongreen space.

4.2.1. Conversion Analysis of each Green Space Type in 2007-2011. In 2007-2011, the total area of four green space types was converted out 128.62 km^2 and converted in 136.22 km^2, so the area of green space increased by 7.6 km^2 (Table 4).

The cultivated land was mainly converted to grassland and woodland in the north and construction land in the

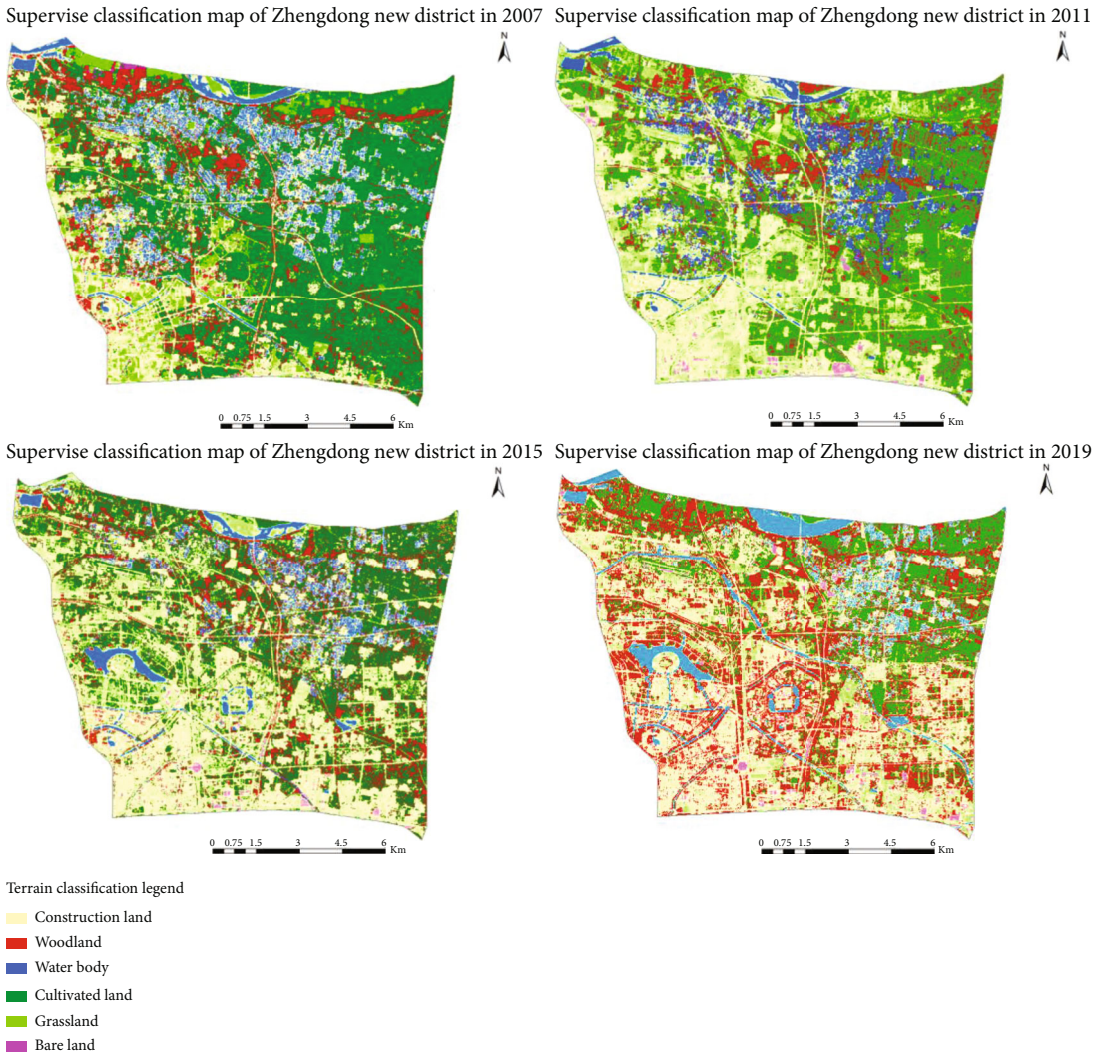

Figure 2: Land use interpretation map in 2007-2019.

Table 2: Statistical table of land use interpretation data (area (km^2); P.C. (%)).

Years		2007		2011		2015		2019	
Land use types		Area	P.C.	Area	P.C.	Area	P.C.	Area	P.C.
Green space	Cultivated land	175.09	47.83	142.49	38.92	123.41	33.71	71.41	19.50
	Woodland	61.94	16.92	34.02	9.29	33.55	9.16	86.99	23.76
	Grassland	23.05	6.30	63.21	17.27	56.66	15.48	29.72	8.12
	Water body	27.80	7.59	36.60	10.00	20.57	5.62	25.54	6.98
Non-green space	Construction land	76.84	20.99	85.95	23.48	130.08	35.53	146.92	40.13
	Bare land	1.47	0.40	3.83	1.05	1.83	0.50	5.52	1.51

south (Figure 4). The conversion of cultivated land to construction land was mainly affected by the construction of Longzihu College Park in Zhengdong New District, which thus mainly took place in some construction areas of Longzihu College Park and Zhengzhou Technology Development Zone. The conversion of cultivated land to woodland was mainly affected by the construction of Baisha Group, which thus mainly took place in Zhongmu County, northeast of Zhengdong New District.

The woodland showed linear and block reduction, but the reduction region was dispersed. The woodland was mainly converted to cultivated land and grassland, which mainly appeared in the north area of Zhengdong New District, Longzihu north area in the north of Zhengdong New District (Liulin, Yangjin Road District), and east-west of Zhongmu County. The conversion of woodland to block construction land mainly took place in the administrative area of Zhengdong New District.

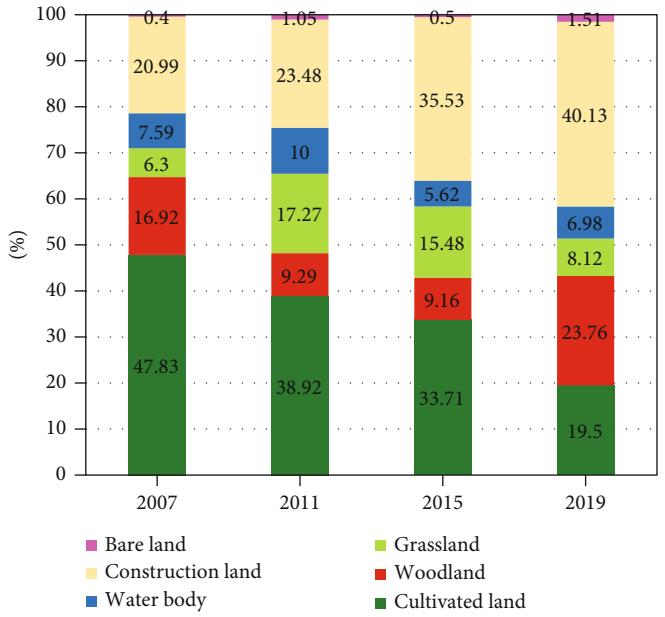

Figure 3: Comparison of land use area changes in Zhengdong New District in 2007-2019.

Table 3: Transfer matrix of land use types in 2007-2019 (unit: km^2).

Land use types	Grassland	Cultivated land	Construction land	Woodland	Bare land	Water body	Area reduction	Total area change
Grassland	—	2.57	11.52	5.22	0.51	1.50	21.33	6.06
Cultivated land	15.53	—	63.38	44.33	2.78	6.21	132.23	-106.51
Construction land	6.85	9.99	—	18.95	1.03	7.77	44.59	53.59
Woodland	3.19	8.38	14.37	—	0.40	1.47	27.81	45.11
Bare land	0.09	0.52	0.36	0.28	—	0.04	1.29	3.63
Water body	1.72	4.26	8.55	4.14	0.20	—	18.86	-1.87
Area increase	27.39	25.72	98.17	72.92	4.91	16.99	—	—

Note: the horizontal data in the table are the data of land use types in 2007, and the vertical data in the table are the data of land use types in 2019. All vertical data are the increase in land use types from 2007 to 2019, and all horizontal data are the decrease in land use types from 2007 to 2019.

Table 4: Transfer matrix of land use types in 2007-2011 (unit: km^2).

Land use types	Grassland	Cultivated land	Construction land	Woodland	Bare land	Water body	Area reduction	Total area change
Grassland	—	3.25	11.24	0.23	0.96	0.44	16.12	39.39
Cultivated land	26.26	—	18.90	18.08	0.90	3.91	68.05	-32.55
Construction land	17.65	11.97	—	4.82	1.46	15.46	51.36	-9.87
Woodland	9.10	17.52	5.88	—	0.24	0.88	33.62	-9.12
Bare land	0.46	0.55	0.15	0.12	—	0.01	1.29	2.29
Water body	2.05	2.20	5.31	1.26	0.01	—	10.83	9.86
Area increase	55.52	35.49	41.48	24.51	3.57	20.7	—	—

Note: the horizontal data in the table are the data of land types in 2007, and the vertical data in the table are the data of land types in 2011. All vertical data are the increase in land use types from 2007 to 2011, and all horizontal data are the decrease in land use types from 2007 to 2011.

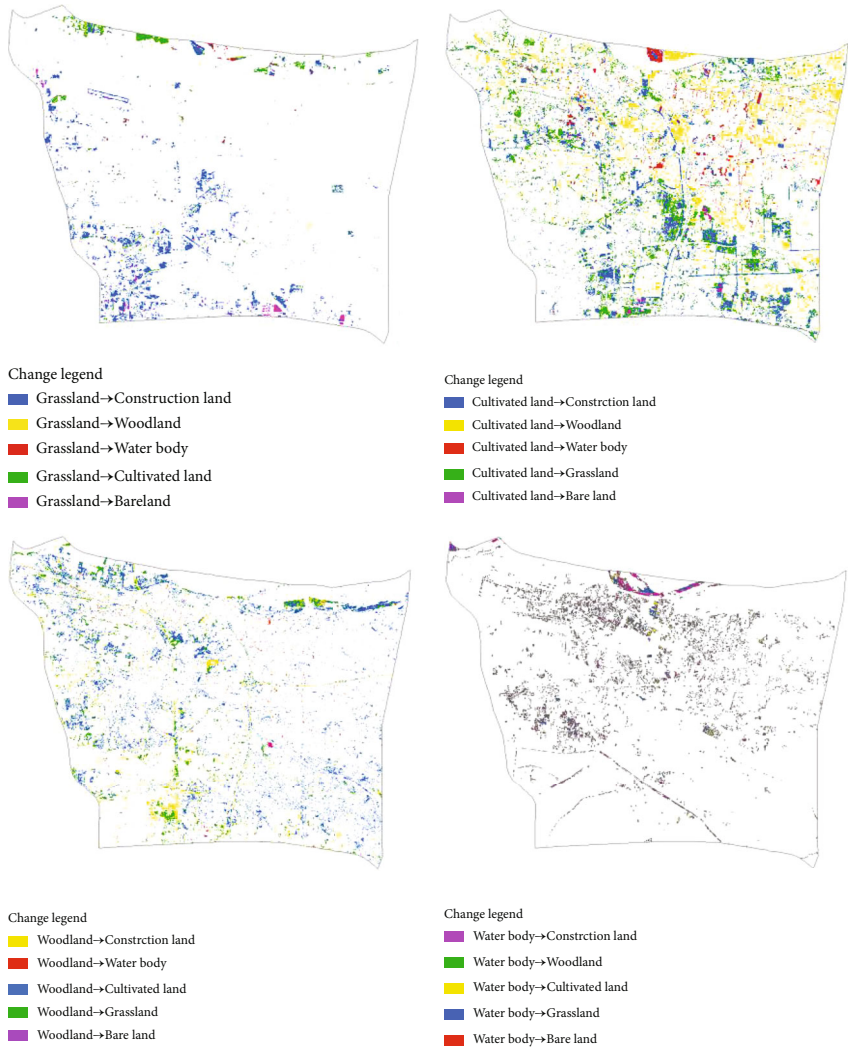

Figure 4: Spatial distribution map of green space conversion in 2007-2011.

The grassland was mainly converted to construction land in the northwest of Zhengdong New District, such as the CBD (Central Business District). The area of water body showed scattered conversion, which mainly distributed in the urban agriculture group along the Yellow River, and Longzihu north area in the north of Zhengdong New District (Liulin, Yangjin Road District).

According to the land use interpretation map of Zhengdong New District in 2007 and 2011 (Figure 2), the area of grassland and water body increased. The cultivated land and grassland were mainly converted to construction land, and the cultivated land was mainly converted to grassland. The area of cultivated land mostly decreased, and it was mainly converted from woodland and converted to grassland. The area of woodland decreased, as the amount of converted-out woodland exceeded the amount of converted-in woodland. The woodland was mainly converted from cultivated land and construction land and converted to cultivated land and grassland. The area of water body increased. Owing to the space integration in the initial construction period of Zhengdong New District, the green space also increased in some regions, but most of them were the small urban green space. Compared with 2007, the cultivated land was concentrated in the northeast of Zhengdong New District in 2011, and the grassland was distributed in Longzihu College Park and Longhu area.

4.2.2. Analysis of the Area Conversion of each Green Space Type in 2011-2015. In 2011-2015, the total area of four green space types was converted out 164.98 km^2 and converted in 121.02 km^2, so the area of green space decreased by 43.96 km^2 (Table 5).

The conversion of cultivated land to construction land, woodland, and grassland became the core feature of green space conversion in Zhengdong New District. The area of cultivated land, which was mainly converted from woodland and grassland and converted to construction land, continued to decrease. The area of woodland obviously increased, and it was mainly converted from cultivated land and grassland and converted to construction land and cultivated land. In contrast, the area of water body and grassland decreased obviously.

Table 5: Transfer matrix of land use types in 2011-2015 (unit: km^2).

Land use types	Grassland	Cultivated land	Construction land	Woodland	Bare land	Water body	Area reduction	Total area change
Grassland	—	16.77	24.27	4.22	0.33	1.48	47.07	-7.84
Cultivated land	18.73	—	30.30	15.54	0.31	2.80	67.67	-19.70
Construction land	12.18	8.01	—	3.28	0.47	3.30	27.24	45.96
Woodland	3.12	16.04	5.15	—	0.05	0.87	25.23	0.12
Bare land	0.58	0.13	2.45	0.01	—	0.00	3.18	-2.00
Water body	4.61	7.04	11.03	2.30	0.03	—	25.00	-16.54
Area increase	39.23	47.98	73.20	25.35	1.18	8.46	—	—

Note: the horizontal data in the table are the data of land use types in 2011, and the vertical data in the table are the data of land use types in 2015. All vertical data are the increase in land use types from 2011 to 2015, and all horizontal data are the decrease in land use types from 2011 to 2015.

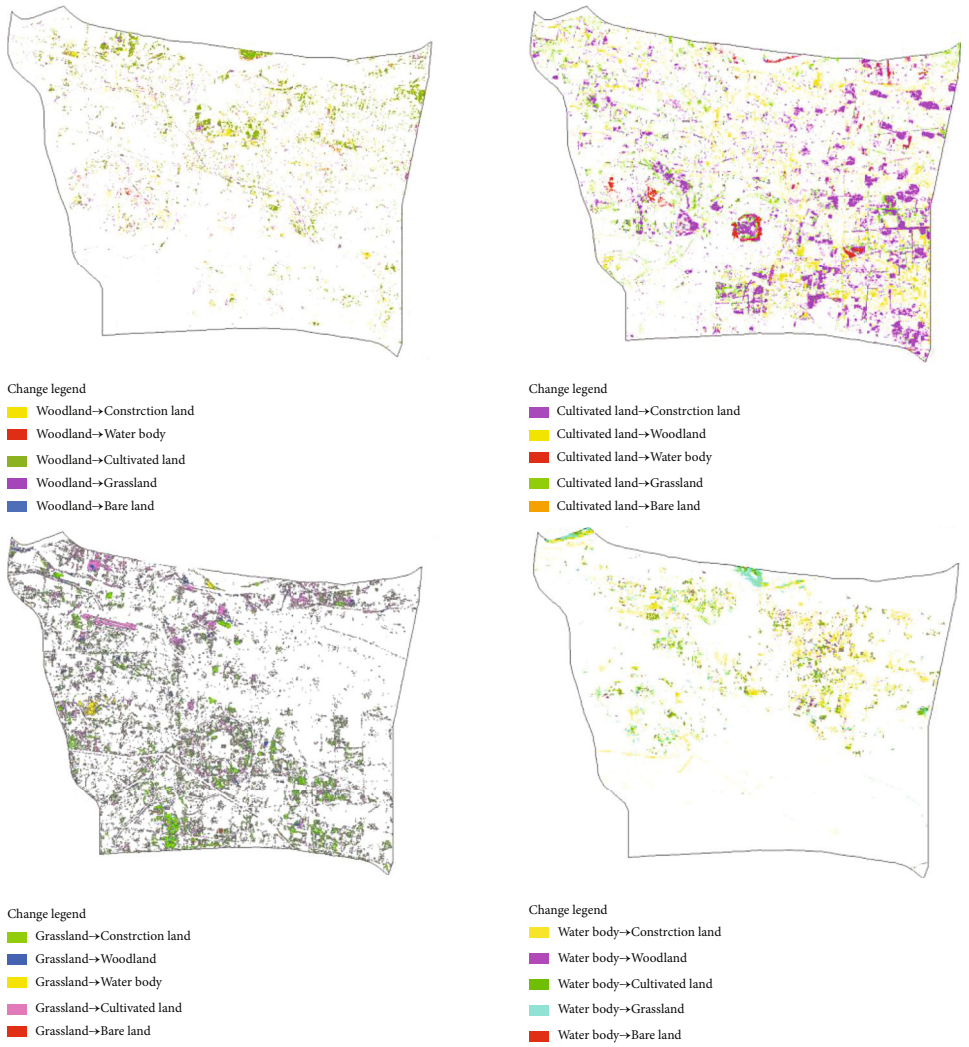

Figure 5: Spatial distribution map of green space conversion in 2011-2015.

The cultivated land decreased and substantially converted to woodland and grassland, which mainly took place in the urban agriculture group along the Yellow River in the northeast of Zhengdong New District, and Baisha Group in Zhongmu County (Figure 5). The block outward-shift of region where cultivated land was converted to construction land was also a prominent feature of urbanization in Zhengdong New District.

The decrease and distribution of woodland was broken, and the woodland was mainly converted to cultivated land

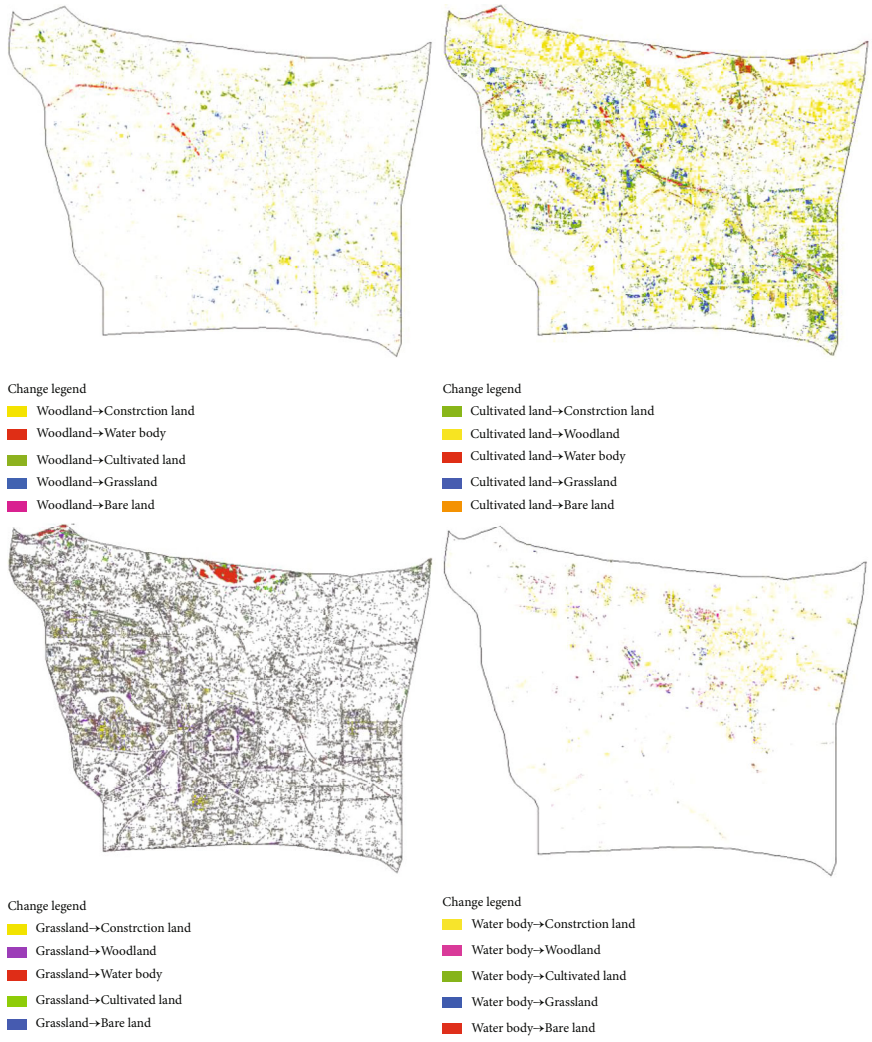

Figure 6: Spatial distribution map of green space conversion in 2015-2019.

in Urban Agriculture Area along the Yellow River, which was scattered.

Instead of concentrated distribution in Zhengdong New District, the grassland was mainly distributed in Longzihu north area (Liulin, Yangjin Road District) in the north of Zhengdong New District, Longzihu north area, Longhu area, CBD, and Longzihu College Park. The wetland and water body were mainly converted to construction land and grassland in a patchy way, which mainly took place in Longzihu north area (Liulin, Yangjin Road District), Longhu area, Longhu CBD, urban agricultural area along the Yellow River, and the north of Baisha Group.

According to the map (Figure 2), in 2011-2015, except woodland was converted in, the cultivated land, grassland, and water body were converted out, especially the cultivated land and grassland. This was related to the construction of "build a new city in ten years" in Zhengdong New District in 2011-2015. In 2011, the housing area exceeded 38 million km^2, the land construction area reached 90%, and the project construction rate reached 80-90%. Long Lake, the largest artificial lake in Zhengdong New District, is also the center of the ecological water system there. The construction of Longhu area has been proposed by the government since 2004. Then, 40 km^2 demolition of Longhu area was completed on August 25, 2012 after years of preparation. After Long Lake was formed, the total water area of Zhengdong New District, including the Long Lake and other waters, was scheduled to reach 11 km^2, making up about 1/10 of the planned area of Zhengdong New District.

4.2.3. Analysis of the Area Conversion of each Green Space Type in 2015-2019. In 2015-2019, the total area of four green space types was converted out 151.78 km^2 and converted in 130.87 km^2, so the area of green space decreased by 20.91 km^2 (Table 5).

The conversion of woodland and grassland to construction land, part of construction land to water body and grassland, massive cultivated land to woodland became the core features of green space conversion in Zhengdong New District. The area of cultivated land continued to decrease, which was more significant than previous years. And it was mainly converted from construction land, woodland, and grassland and converted to construction land and woodland. In contrast, the area of woodland

Table 6: Transfer matrix of land use type in 2015-2019.

Land use types	Grassland	Cultivated land	Construction land	Woodland	Bare land	Water body	Area reduction	Total area change
Grassland	—	6.77	21.61	16.22	0.43	3.31	48.34	-25.53
Cultivated land	9.40	—	25.99	38.09	0.88	2.94	77.29	-54.31
Construction land	10.74	7.18	—	15.96	2.75	5.84	42.47	17.57
Woodland	2.01	7.33	6.99	—	0.11	1.20	17.64	54.14
Bare land	0.08	0.02	0.73	0.07	—	0.01	0.90	3.34
Water body	0.59	1.69	4.72	1.44	0.07	—	8.50	4.80
Area increase	22.82	22.98	60.03	71.78	4.24	13.30		

Note: the horizontal data in the table are the data of land use types in 2015, and the vertical data in the table are the data of land use types in 2019. All vertical data are the increase in land use types from 2015 to 2019, and all horizontal data are the decrease in land use types from 2015 to 2019.

continued to increase, and it was mainly converted from cultivated land and converted to construction land and cultivated land. The area of grassland decreased while the area of water body increased a little.

The area of cultivated land decreased significantly in a patchy way, as various regional groups were converted to construction land and woodland (Figure 6). Due to the mature development of various regional groups in Zhengdong New District, the radiation scope was increased, the development of the periphery areas was increased, and the urban expansion space was moved outward. Therefore, the number and area of cultivated land converted to construction land were reduced during this period, which mainly took place in Beilonghu area and Baisha Group. Especially the Longhu area of Zhengdong New District, where the open green space along the Long Lake coast [10–12] was mostly composed of low-rise buildings to create a beautiful city in water area and form a distinctive urban space. During this period, another feature of the conversion of cultivated land was the massive cultivated land to woodland in the north and northeast of Zhengdong New District.

The converted woodland was distributed in a more linear and patchy way, and it was mainly converted to construction land. The converted patchy woodland was mainly the park in Zhengdong New District, and the converted linear woodland was mostly urban green road, riverside belt park, and radial belt park leading to the lake. We strengthen the construction of greening and recreational environment, keep open space in moderation for pedestrians to stop and look out, and enhance the main life road connection to form a complete space sequence (Table 6).

The area of grassland decreased and was evenly distributed in various regional groups, and the water body was converted in a little in a dotted plaque manner.

According to the map (Figure 2), in 2015 and 2019, there was also an increase in subclasses such as woodland and water body in some regions in 2015-2019 due to the conversion of cultivated land to woodland in the northeast as well as the conversion of construction land or grassland to urban parks. Its construction space distribution was scattered, including CBD Central Park, National Forest Park, Longzihu Park, Qilihe Park, and various community parks.

5. Conclusion

The research found the development of Zhengdong New District was mainly divided into three stages: the first stage was administrative drive, the second stage was policy support plus market drive, and the third stage was market-oriented, policy fine-tuning, and government-oriented to market-oriented transformation [13]. The paper made the analysis of the influencing factors of the evolution of green space in Zhengdong New District from three aspects of nature, social economy, and policy and came to the following conclusions.

5.1. Natural Environmental Factors Are the Development Basis for the Increase and Decrease of Green Space in Zhengdong New District. Natural environmental factors play a role in the evolution of green space area in Zhengdong New District, and their role is relatively static [14–16], and not as obvious as social and economic factors. Zhengdong New District is flat, so the conversion of each green space type is less affected by its topography.

5.2. Social and Economic Development Is the Fundamental Driving Force for the Increase and Decrease of Green Space in Zhengdong New District. Judging from the conversion places, the conversion of cultivated land and woodland mainly took place in the typical areas of Zhengzhou in recent years, such as CBD, Beilonghu area, Longzihu College Park, Baisha Group and so on. It is speculated that social and economic development may be an important factor for the increase and decrease of green space area [4, 13, 17, 18]. During the research period, the population of Zhengzhou continued to increase. By the end of 2018, in Zhengdong New District, the total population reached 693,377, and the urbanization rate reached 68.83%. Thus, Zhengdong New District has become an area of Zhengzhou to relieve population and land pressure in the central area. The negative effect was to occupy other types of land, especially the cultivated land [19–21]. In addition, the promotion of social and economic level enhanced the government's attention to greening, increased the investment in greening, and boosted the demand for leisure and recreation to meet the need of population growth [22]. Therefore, the construction of parks in

Zhengdong New District increased, and the area of woodland there increased accordingly.

5.3. Policy Is the Direct Driving Force to Guide the Construction of Large Green Space in Zhengdong New District. The study found that in the typical areas of green space conversion, the large-scale converted-in of woodland was mostly related to the construction of urban parks and green corridors, indicating urban planning policies played an important role in promoting the construction of large green space [23–25]. The urban green space system of Zhengdong New District is an integral part of the whole urban green space system of Zhengzhou city. In general, the policies affecting the development of green space in Zhengzhou in recent years have begun to favor the protection of cultivated land and woodland in urban-rural integrated areas, and vigorously build urban parks to optimize land use layout, which directly affects the development and conversion of green space and plays an important role in promoting the formation of green space structure in Zhengdong New District.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that they have no competing interests.

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