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Analysis of Green Space Change in Qinhuangdao City under Urban Expansion

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Abstract: *With the rapid development of urbanization, the distribution of urban green space is increasingly affected by urbanization. Based on the land use data of 2000, 2010, and 2020, This study revealed the spatial-temporal change characteristics of green space in the process of urban expansion in Qinhuangdao City, applying the spatial analysis method in ArcGIS10.5 software and landscape expansion index analysis method. The results showed that from 2000 to 2020, the green space shrank and the non-green space expanded in Qinhuangdao city. The cultivated land decreased by 210km², while the grassland, forest land, and water bodies decreased slightly and remained relatively stable. From the perspective of the transfer matrix, the transformation between 2000 and 2020 is mainly among cultivated land, urban construction land, and other construction land. Among them, the transformation area of cultivated land during 2000-2010 is significantly higher than that during 2010-2020, and its transformation trend is consistent with the development direction of urbanization. Edge-expansion is the dominant type, in which the cultivated land converted into urban construction land is the largest, concentrated in the surrounding areas, especially the western and northern areas of the Haigang District and the eastern and southern areas of the Shanhaiguan District. The results of the study identified the urban expansion mode of Qinhuangdao, which was dominated by edge-expansion, and the most obvious change characteristics of cultivated land affected by the green space type, thus providing a scientific reference for the green space planning and ecological construction of Qinhuangdao city.*

Keywords: *Urban expansion; Green space; Dynamic change; GIS; Qinhuangdao*

1. Introduction

As a core subsystem of urban ecology, urban green spaces contain the main natural elements in cities and are a key indicator of the sustainability and level of civilization of urban development. Based on the urban green space system as the basic framework, with green vegetation as the main component in its constituting elements, it provides significant ecological benefits and a rich living, leisure, and recreational space for urban residents. Therefore, clarifying the dynamic characteristics of green space under urbanization is of great significance for sustainable urban development and the construction of healthy living environments.

Regarding urbanization expansion, the focus is mainly on changes in urban land use/cover, urban form, and expansion patterns, driving mechanisms of urban expansion, urban expansion models and dynamic simulations, ecological effects of urban expansion, and urban planning and growth control strategies. In terms of land expansion patterns, the Landscape Expansion Index (LEI) can reflect the dynamic changes in landscape patterns, quantifying the changes in landscape patterns in single or multiple periods, and has been used in various fields such as urban expansion [2]. Ma Chaonan et al. conducted a study on the dynamic changes in land use landscape patterns and landscape expansion index changes in Wuhan City based on image data from 2000, 2010, and 2020 using ArcGIS 10.3 and Fragstats 4.2 software [3]. Yali Zhang et al. analyzed the changes in forest cover and fragmentation under urban expansion and the correlation between these changes using Vegetation Change Tracking (VCT) algorithms and Morphological Spatiotemporal Pattern Analysis (MSPA) [4]. Yan Sun et al. quantitatively compared the urbanization rates and growth patterns of the Beijing-Tianjin-Hebei urban agglomeration,

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as well as investigated the changes in the aggregated urban block structure over time and space [5]. Wang Yixuan explored the changes in the orientation, center of gravity, spatial structure, and expansion coordination of newly developed areas in 2010-2018 using software platforms such as ArcGIS [6].

In terms of changes in green space, Sun Jiajia analyzed the spatiotemporal evolution and landscape pattern changes of green spaces in the main urban area of Xi'an from 1994 to 2018 based on Landsat image data [7]. Li Tingting classified the land use types in the main urban area of Chongqing from 2000 to 2016 and analyzed the spatiotemporal development patterns of forests, water bodies, grasslands, shrubs, and arable land [8]. Jin Jiali et al. studied the spatiotemporal evolution patterns of urban green space and the main influencing factors in Changsha, Dalian, Nanchang, and Shenzhen over the past 30 years [9]. Zhang Mengdi discussed the evolution of the green space pattern and changes in habitat quality in Tongzhou District, Beijing [10]. Yiyi Huang et al. quantified the spatial patterns of green space utilization through the combination of POIs and land use and coverage change (LUCC), using big data analysis to evaluate the actual use of green space in 366 cities in China, and explored the differences in the actual use of green space within cities and their surrounding areas [11].

This study applies ArcGIS 10.5 software combined with the Landscape Expansion Index to explore the spatiotemporal changes in green spaces in the process of urban expansion in Qinhuangdao City. It aims to reveal the impact of urban expansion on the spatiotemporal changes in green spaces, providing a scientific basis for the ecological construction of Qinhuangdao.

2. Overview of Study Area

Qinhuangdao City (118°33' to 119°51' E, 39°24' to 40°37' N) is a county-level city in Hebei Province, China, with a land area of 7812.4 km². It is located in the northeast part of Tianjin City, on the western coast of the Bohai Sea, in the core area of the Bohai Rim Economic Zone, and is an important connecting area between the two major economic development zones in North China and the East. The city has four urban districts and three counties (see Figure 1).

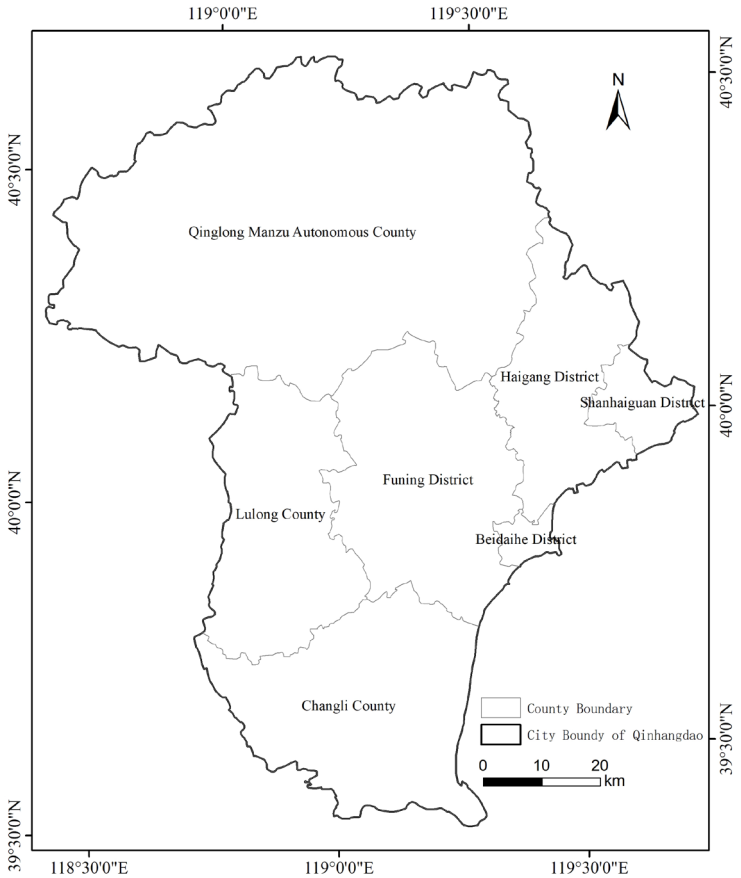

Figure 1: Geographical location of the study area

ISSN 2616-5872 Vol.6, Issue 6: 58-66, DOI: 10.25236/AJEE.2024.060609

3. Data and Research Methods

3.1 Data Sources

The land use grid data of Qinhuangdao City (for the years 2000, 2010, and 2020) with a resolution of 30m was obtained from the Resource and Environment Science and Data Center (https://www.resdc.cn/); the boundaries of Qinhuangdao's districts and counties were sourced from the Geographic National Conditions Monitoring Cloud Platform (http://www.dsac.cn/).

3.2 Research Methods

3.2.1 Analysis of Green Space Changes

(1) Analysis of Green Space Type Area Changes

Green space types include cultivated land, forest land, grassland, and water bodies [1]. Based on the land use grid data of Qinhuangdao City for the years 2000, 2010, and 2020, the area and proportion of green spaces for each period were calculated using the attribute table function in ArcGIS 10.5 software.

(2) Analysis of Green Space Type Transitions

In ArcGIS 10.5 software, overlaying land use maps from different periods enables the calculation of changes between different land use types during the study period. This forms a dynamic model of land use conversion, reflecting the degree and rate of change between different types. The transition matrix represents the quantity relationship of land use type conversions:

$$B = \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1n} \\ B_{12} & B_{22} & \cdots & B_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ B_{n1} & B_{n2} & \cdots & B_{nn} \end{bmatrix}$$

Here, Bij represents the area of land use i-th type transitioning to land use j-th type from period k to (k+1), where n is the number of land use types [12].

3.2.2 Analysis of Green Space Changes under Urban Expansion

The Landscape Expansion Index (LEI) can quantitatively identify the types of spatial expansion in cities, which mainly include infilling, edge-expansion, and outlying types (see Figure 2) [13-14]. Using ArcGIS 10.5 software, infilling, edge-expansion, and outlying types for the periods 2000-2010, 2010-2020, and 2000-2020 were analyzed by overlaying them with the transition maps of different green space types to study the changes in green space under different urban expansion types.

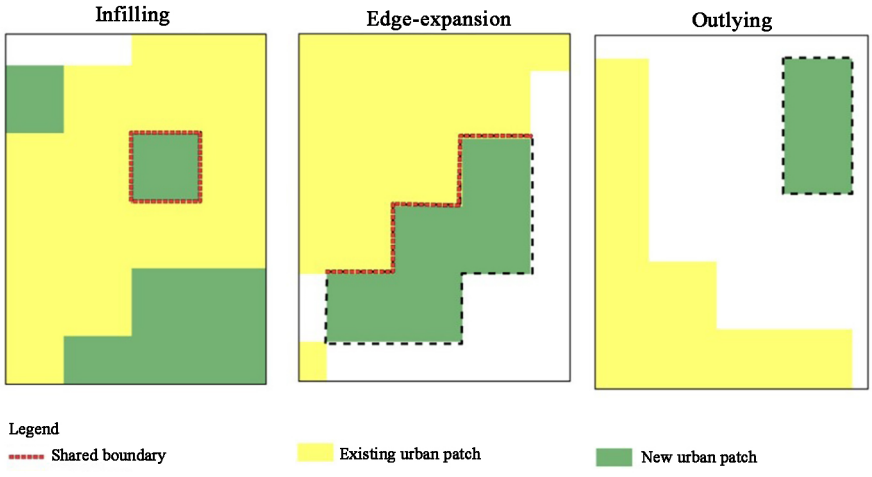

Figure 2: Mode of urban expansion

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4. Results and Analysis

4.1 Analysis of Green Space Changes

4.1.1 Changes in Green Space Types Area

As shown in Table 1, the total area of green spaces in Qinhuangdao City for the years 2000, 2010, and 2020 accounted for over 85% of the city's total area. Green space types mainly consist of cultivated land, forest land, grassland, and water bodies, with cultivated land being the largest, occupying around 36% of the total land area, followed by forest land at approximately 32.6%, grassland at around 15.8%, and water bodies accounting for less than 4%.

The overall green space in Qinhuangdao shows a decreasing trend. The cultivated land area has significantly decreased from 2950.64 km² in 2000 to 2740.91 km² in 2020, while forest land has shown an increase followed by a decrease. Grassland and water body areas have slightly decreased, with no significant changes. Among non-green spaces, urban construction land, rural construction land, and other construction land have shown an increasing trend, while unused land has slightly decreased. Urban construction land area increased from 154.00 km² in 2000 to 303.02 km² in 2020, while other construction land increased from 84.67 km² in 2000 to 159.83 km² in 2020, doubling in size over the 20 years. Rural construction land areas have also expanded to a certain extent.

It is known that over the past 20 years, along with urbanization, Qinhuangdao City has shown a trend of shrinking green spaces and expanding non-green spaces, primarily characterized by a significant decrease in cultivated land, slight decreases in grassland, forest land, and water body areas, which have relatively remained stable.

Figures 3 show that cultivated land has significantly decreased, especially in the western part of Haigang District and the southern part of Shanhaiguan District, where a large amount of cultivated land has been converted into urban construction land.

Table 1: Area and percentage of different land types in 2000, 2010 and 2020

Land types	Area and percentage	2000	2010	2020
Cultivated land	Area(km²)	2950.64	2785.99	2740.91
	Percentage(%)	37.96	35.84	35.26
Forest land	Area(km²)	2538.36	2540.06	2531.97
	Percentage(%)	32.66	32.68	32.58
Grassland	Area(km²)	1242.05	1228.15	1227.61
	Percentage(%)	15.98	15.80	15.79
Water bodies	Area(km²)	296.94	295.94	293.43
	Percentage(%)	3.82	3.81	3.78
Urban construction land	Area(km²)	154.00	270.12	303.02
	Percentage(%)	0.99	0.91	0.91
Rural construction land	Area(km²)	429.22	441.69	444.89
	Percentage(%)	1.98	3.48	3.90
Other construction land	Area(km²)	84.67	139.76	159.83
	Percentage(%)	5.52	5.68	5.72
Unused land	Area(km²)	76.61	70.79	70.80
	Percentage(%)	1.09	1.80	2.06

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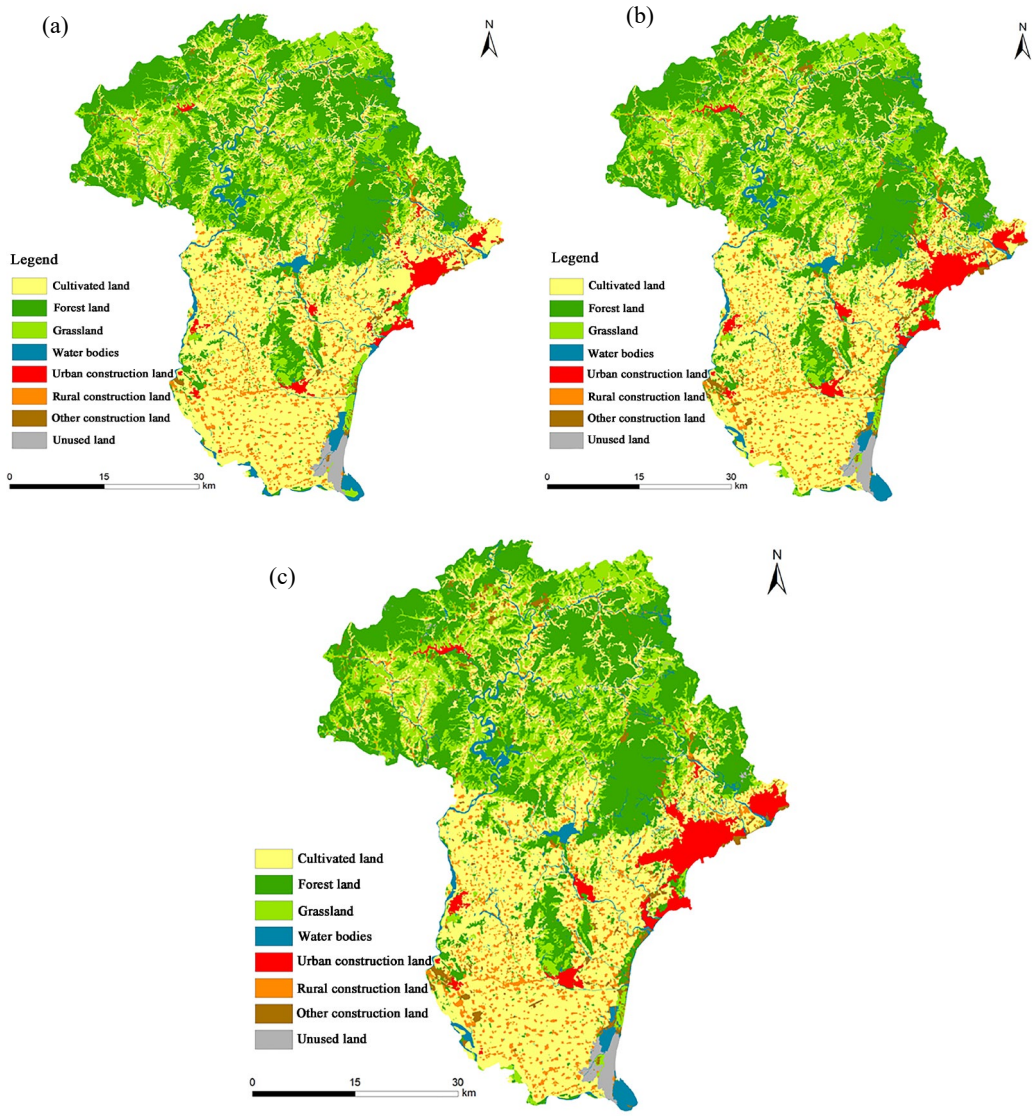

Figure 3: Distribution map of green space in Qinhuangdao City in (a) 2000, (b) 2010 and (c) 2020

4.1.2 Changes in Green Space Types Transitions

Table 2 shows that from 2000 to 2010, the main types of cultivated land converted were urban construction land, other construction land, rural construction land, water bodies, and forest land, with conversion areas of 114.95 km², 27.71 km², 12.47 km², 8.06 km², and 1.46 km² respectively. With the rapid urbanization of Qinhuangdao City, a significant amount of cultivated land has been converted into urban construction land, transportation routes, industrial land, and new rural residential areas. The main types of forest land converted were other construction land and urban construction land, with conversion areas of 12.94 km² and 0.35 km², indicating that urban expansion has occupied a small portion of woodland. Grassland is mainly converted to forest land, other construction land, and water bodies, with conversion areas of 13.53 km², 7.96 km², and 5.69 km². The main types of water bodies converted were grassland and other construction land, with conversion areas of 9.98 km² and 4.68 km².

Table 3 shows that from 2010 to 2020, the main types of cultivated land converted to were still urban land, other construction land, and rural residential areas, with conversion areas of 31.60 km², 10.37 km², and 4.22 km². In addition, 0.92 km² of cultivated land was converted to forest land, 1.00 km² to grassland, and 0.29 km² to water bodies. The main type of forest land converted was other construction land, with a conversion area of 7.04 km². Grassland is mainly converted to forest land, with a conversion area of 1.23 km². The main type of water bodies converted to was other construction land, with a conversion area of 2.42 km².

Table 4 shows that from 2000 to 2020, the main types of cultivated land converted to were urban construction land, other construction land, and rural construction land, with conversion areas of 146.49

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km², 38.06 km², and 16.67 km² respectively. The main type of forest land converted was other construction land, with a conversion area of 19.96 km². Grassland is mainly converted to forest land, other construction land, and water bodies, with conversion areas of 14.75 km², 8.45 km², and 5.71 km². The main types of water bodies converted were grassland and other construction land, with conversion areas of 10.06 km² and 7.05 km². It can be seen that the focus is on the conversion between agricultural land, urban construction land, and other jointly developed urban and rural lands, aligning with the development direction of urbanization in China. Furthermore, the conversion area of arable land from 2000 to 2010 is significantly higher than that from 2010 to 2020.

Table 2: Transfer Matrix (km²) of Different Land Use Types in 2000-2010

Years	2010							
	Type	CL	FL	GL	WB	UL	UCL	RCL	OCL
2000	CL	2785.99	1.46	0.00	8.06	0.00	114.95	12.47	27.71
	FL	0.00	2525.06	0.00	0.00	0.00	0.35	0.00	12.94
	GL	0.00	13.53	1214.87	5.69	0.00	0.00	0.00	7.96
	WB	0.00	0.00	9.98	282.19	0.00	0.09	0.00	4.68
	UL	0.00	0.00	3.29	0.00	70.79	0.00	0.00	0.00
	UCL	0.00	0.00	0.00	0.00	0.00	154.00	0.00	0.00
	RCL	0.00	0.00	0.00	0.00	0.00	0.00	429.22	0.00
	OCL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	84.67

Note: CL, Cultivated land; FL, Forest land; GL, Grassland; WB, water bodies; UCL, Urban construction land; RCL, Rural construction land; OCL, Other construction land; UL, Unused land.

Table 3: Transfer Matrix (km²) of Different Land Use Types in 2010-2020

Years	2020							
	Type	CL	FL	GL	WB	UL	UCL	RCL	OCL
2010	CL	2737.58	0.92	1.00	0.29	0.00	31.60	4.22	10.37
	FL	0.80	2529.53	1.32	0.13	0.02	1.12	0.10	7.04
	GL	0.92	1.23	1224.98	0.07	0.02	0.29	0.19	0.45
	WB	0.31	0.12	0.09	292.87	0.00	0.01	0.12	2.42
	UL	0.01	0.01	0.00	0.00	70.76	0.00	0.00	0.00
	UCL	0.08	0.01	0.01	0.01	0.00	270.01	0.00	0.00
	RCL	1.14	0.08	0.16	0.05	0.00	0.00	440.25	0.02
	OCL	0.08	0.07	0.04	0.03	0.00	0.00	0.01	139.52

Note: CL, Cultivated land; FL, Forest land; GL, Grassland; WB, water bodies; UCL, Urban construction land; RCL, Rural construction land; OCL, Other construction land; UL, Unused land.

Table 4: Transfer Matrix (km²) of Different Land Use Types in 2000-2020

Years	2020								
	Type	CL	FL	GL	WB	UL	UCL	RCL	OCL
2000	CL	2737.66	2.39	1.01	8.35	0.00	146.49	16.67	38.06
	FL	0.80	2514.57	1.32	0.13	0.02	1.47	0.10	19.96
	GL	0.92	14.75	1211.73	5.71	0.02	0.29	0.19	8.45
	WB	0.31	0.12	10.06	279.17	0.00	0.10	0.12	7.05
	UL	0.01	0.01	3.29	0.00	70.76	0.00	0.00	0.01
	UCL	0.03	0.00	0.00	0.00	0.00	153.95	0.00	0.00
	RCL	1.12	0.07	0.16	0.05	0.00	0.00	427.80	0.02
	OCL	0.07	0.05	0.03	0.02	0.00	0.00	0.01	84.49

Note: CL, Cultivated land; FL, Forest land; GL, Grassland; WB, water bodies; UCL, Urban construction land; RCL, Rural construction land; OCL, Other construction land; UL, Unused land.

4.2 Analysis of Green Space Changes in Different Types of Urban Expansion

From Table 5 and Figure 4(a), it can be seen that from 2000 to 2010, In edge-expansion, the highest area of cultivated land conversion to urban construction land was 109.86 km², mainly concentrated in the peripheral areas of urban districts in various counties, especially in the western and northern regions of Haigang District, and the eastern region of Shanhaiguan District. The next highest was in the infilling expansion, with an area of 4.22 km² of cultivated land converted to urban construction land, primarily concentrated in the northern region of Beidaihe District. In comparison, outlying expansion had the

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smallest area, only 0.86 km², scattered in the southern part of the urban district of Funing District and the northern part of the urban district of Shanhaiguan District. The areas of forest land and water bodies converted to urban construction land were mainly in the infill-type expansion, at 0.34 km² and 0.09 km² respectively. There was no grassland converted to urban construction land.

From Table 6 and Figure 4(b), it is evident that from 2010 to 2020, compared to the period from 2000 to 2010, the area of green spaces converted to urban construction land significantly decreased. Among the green space types, cultivated land continued to be the most converted to urban land. Urban expansion still predominantly consisted of edge-expansion, with arable land conversion to urban land being the highest at 30.54 km², concentrating in the southern part of Funing District, western and southwestern regions of Haigang District, northern part of Beidaihe District, and southern part of Shanhaiguan District. The area of forest land converted to urban construction land was 1.12 km², while the areas of grassland and water bodies converted to urban construction land were both less than 0.3 km². In the infill-type expansion, the area of cultivated land converted to urban land was 1.06 km², primarily located in the northern part of Changli County.

From Table 7 and Figure 4(c), it can be seen that from 2000 to 2020, urban expansion still mainly consisted of edge-expansion. In edge-expansion, the highest area of conversion from cultivated land to urban construction land was 142.26 km², mainly concentrated in the peripheral areas of urban districts in various counties, especially in the western and northern regions of Haigang District, and the eastern region of Shanhaiguan District. The area of forest land converted to urban construction land was 1.12 km², while the areas of grassland and water bodies converted to urban construction land were both less than 0.12 km². In the infilling expansion, the area of cultivated land converted to urban construction land was 4.22 km², primarily located in the northern part of Beidaihe District. The areas of forest land, grassland, and water bodies converted to urban construction land were all less than 0.35 km². In the outlying expansion, only cultivated land was converted to urban construction land, with an area of 0.86 km².

Table 5: Green Space Change (km²) of Different Urban Expansion Types from 2000 to 2010

Transformation type	Edge-expansion	Infilling	Outlying
CL-UCL	109.86	4.22	0.86
FL-UCL	0.01	0.34	0.00
GL-UCL	0.00	0.00	0.00
WB-UCL	0.00	0.09	0.00

Note: CL, Cultivated land; FL, Forest land; GL, Grassland; WB, water bodies; UCL, Urban construction land.

Table 6: Green Space Change (km²) of Different Urban Expansion Types from 2000 to 2010

Transformation type	Edge-expansion	Infilling	Outlying
CL-UCL	30.54	1.06	0.00
FL-UCL	1.12	0.01	0.00
GL-UCL	0.29	0.01	0.00
WB-UCL	0.01	0.01	0.00

Note: CL, Cultivated land; FL, Forest land; GL, Grassland; WB, water bodies; UCL, Urban construction land.

Table 7: Green Space Change (km²) of Different Urban Expansion Types from 2000 to 2020

Transformation type	Edge-expansion	Infilling	Outlying
CL-UCL	142.27	4.22	0.00
FL-UCL	1.12	0.34	0.00
GL-UCL	0.29	0.01	0.00
WB-UCL	0.01	0.09	0.00

Note: CL, Cultivated land; FL, Forest land; GL, Grassland; WB, water bodies; UCL, Urban construction land.

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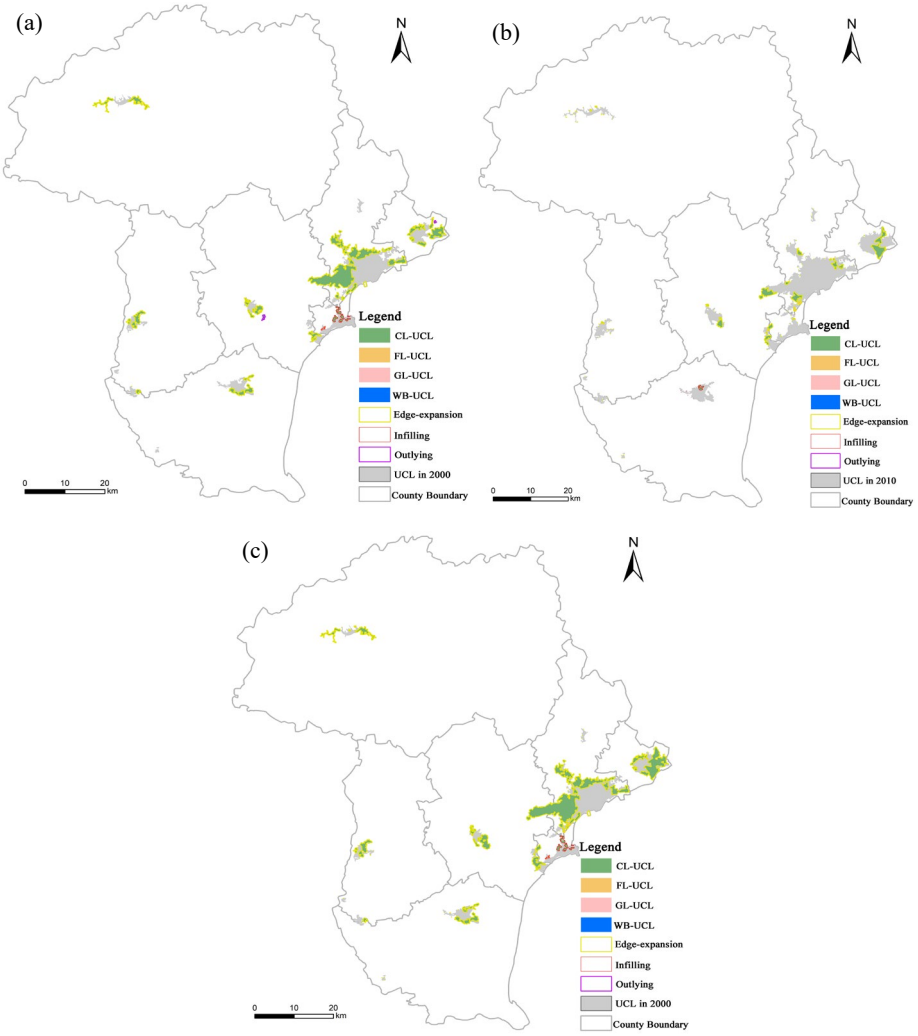

Figure 4: Distribution of green space changes in different urban expansion types (a) 2000-2010, (b) 2010-2020, and (c) 2000-2020

5. Conclusion and Discussion

5.1 Conclusion

This study utilized ArcGIS 10.5 software to explore the spatiotemporal changes of green spaces in Qinhuangdao City, revealing the impact of urban expansion on the spatiotemporal changes in green spaces. The results indicate that from 2000 to 2020, there was a trend of shrinkage in green spaces and expansion of non-green spaces in Qinhuangdao City, with a significant decrease in cultivated land, while grassland, forest land, and water bodies slightly decreased but remained relatively stable. Looking at the transition matrix, the main changes from 2000 to 2020 were between cultivated land, urban construction land, and other construction land, showing a trend that aligns with urbanization development. Edge-expansion was the dominant type, with the highest area of cultivated land conversion to urban construction land, concentrated in the peripheral areas of various counties, especially in the western and northern regions of Haigang District and the eastern and southern regions of Shanhaiguan District.

5.2 Discussion

In the process of urbanization in Qinhuangdao, through edge-expansion, the highest area of cultivated land conversion into urban construction land occurred in the urban districts of various counties. However, the majority of cultivated land conversion took place on the outskirts of the urban areas, gradually being developed and utilized as the county towns expanded, while the conversion areas of forest, grassland,

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and water bodies were minimal, maintaining a relatively stable state.

As urbanization accelerates, the rapid expansion of urban land area significantly impacts the original urban landscape layout, leading to a decline in ecological diversity, habitat destruction, exacerbated urban heat island effect, pollution, soil erosion, and various environmental issues. Many scholars are beginning to focus on and study the important role of green spaces in regulating ecological balance, beautifying landscapes, and improving environmental quality. Urban green spaces play a certain regulatory and coordinating role in urban ecological environments and resource allocation. Due to adjustments in urban spatial strategic positions, the increase in urban functional scale, and the adjustment of the layout of urban public infrastructure, the structure and distribution of urban green spaces also demonstrate corresponding developmental patterns. Therefore, studying the evolving relationship between urban functional expansion and urban green spaces is significant for the rational layout of urban green space structures and patterns, as well as the balanced development of urban ecosystems.

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