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Analysis of Spatial and Temporal Changes in Land Use in Lushan City over the Past 20 Years

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Abstract— In the past two decades, with rapid urbanization and economic development, the land use structure of Lushan City has undergone significant changes, posing challenges to ecological security and food supply. It is necessary to explore its spatiotemporal dynamics and driving factors to optimize land management. This study is based on land use data from 2000 to 2020 and uses GIS to analyze the spatiotemporal changes and transfer status of land use types. The main method is to use the land use transfer matrix and the single land use dynamic degree to study the land use change and its driving forces. The results indicate that the land use change in Lushan City is characterized by the conversion of arable land into construction land and the conversion of wetlands into water bodies. The area of arable land and wetlands has significantly decreased, while construction land and water bodies continue to increase. From the perspective of spatial distribution, the increase in construction land is concentrated in the central part of Lushan City. The driving factors of land use change in the city include the policy of returning farmland to forests and lakes, rapid economic development, changes in population, and the continuous promotion of the tourism industry.
Keywords— Land use; Temporal and spatial changes; Transition matrix; Dynamic degree; Lushan City

I. INTRODUCTION

Land is the most fundamental natural resource for the development of human society, and it is of great significance for maintaining ecosystem stability and protecting the ecological environment [1]. In recent years, with the acceleration of urbanization, the natural environment has been increasingly affected by human activities, and changes in land use types are also increasingly influenced by human activities and the dynamic changes in the ecological environment [2]. Therefore, land use and land cover change (LUCC) has become one of the hot research topics. The investigation of land use types within the region to understand the interrelationship between human activities and spatiotemporal changes in land use has important guiding significance for protecting the ecological environment and rationally planning urban space [3].

Lushan City is located in the core development area of the central urban area of Jiujiang City. According to the overall land use plan of Lushan District in Jiujiang City from 2006 to 2020, due to the economic development of the city, the demand for construction land is bound to increase significantly in the future. In conjunction with major policies and measures, including the restoration of farmland to forests in protected areas and the establishment of infrastructure for "prosperous tourism," it will inevitably be reflected in the continuous increase in building land area. In the early days, in addition, the cultivated land in this area was the dominant land type outside the protected area. However, since the historic flood of the Yangtze River in 1998, the State Council has made the decision to "return farmland to the lake and relocate to build towns." After years of implementation, the changes and distribution patterns are worth paying attention to.

In view of this, this study uses land use data from 2000 to 2020 in Lushan City to analyze the spatiotemporal changes, transfer status, and dynamic changes of various land use types in the past 20 years in order to obtain the spatial patterns and quantitative data of their changes and explore their spatial changes in environmental suitability, providing a scientific basis for the high-quality transformation and development of Lushan City and regional ecological environment protection.

II. STYDY AREA AND DATA SOURCES

2.1 Study Area

Lushan City is located in the northern part of Jiangxi Province and in the southern part of Jiujiang City. It is managed by Jiujiang City and is situated on the west bank of Poyang Lake. Its geographical coordinates range from 115°48′ to 116°10′ and from 29°8′ to 29°36′ north latitude. It is 35 kilometers wide from east to west and 52 kilometers long from north to south, with a total area of 913 square kilometers. As of October 2022, Lushan City governs 9 towns and 1 township, including Nankang Town, Guling Town, Haihui Town, Bailu Town, Wenquan Town, Hengtang Town, Hualin Town, Xingzi Town, Jiaotang Town, and Liaonan Township (Figure 1). According to the seventh national census data, as of midnight on November 1, 2020, the permanent population of Lushan was 231525.

Located against the Lushan Nature Reserve, Lushan City was established in 1981 with the approval of the People's Government of Jiangxi Province. It is a comprehensive nature reserve mainly protected by the subtropical forest ecosystem and natural historical relics, with the Lushan Ring Road at the foot of the mountain as the boundary. In 1982, it was designated as one of the first national-level scenic spots by the State Council. It was listed as a World Heritage Site on December 6, 1996. On February 13, 2004, it was selected as one of the first global geoparks. On March 7, 2007, it was rated as a national 5A-level tourist attraction. In May 2022, Lushan Yunhai was listed as one of the first 15 "weather climate landscape viewing sites" in China, as announced by the China Meteorological Service Association.

This area is a typical horst-type fault block mountain, with a composite landform formed by the superposition of tectonic landforms, ice erosion landforms, and flowing landforms, with an altitude of 23–1474 meters [4]. The average annual temperature is around 16.5 ℃, and the annual precipitation is between 1800 and 2000 millimeters. The total area of regional land is 45253 hectares, including 12811 hectares of arable land and gardens, 14160 hectares of forest land, and 12145 hectares of water surface. 4289 hectares of residential and industrial transportation land and another 2700 hectares of barren mountains have not yet been developed and utilized. According to government planning, ecological space accounts for about 78% of the total urban area, agricultural space accounts for about 17%, and urban space accounts for about 5%. The ecological protection red line is approximately 289 square kilometers, the permanent basic farmland boundary is approximately 97 square kilometers, and the urban development boundary is approximately 37 square kilometers.

2.2 Data Sources

The analytical data used in this study includes the following:

1. Select land use data from Lushan City in 2000, 2010, and 2020, which are sourced from global land cover data (GlobeLand30) (http://www.globeland30.org). The website also provides global land cover data with a spatial resolution of 30 m x 30 m.

2. Referring to the existing land classification system in China [5], according to the classification system interpreted by the Chinese Academy of Sciences and the Classification of Land Use Status (GB/T21010-2017), and in combination with the actual situation of land use types in Lushan City, the land use types are divided into

six types: cropland, forest land, grassland, wetland, water area, and construction land.

III. METHOD

This study is based on the land use type data of Lushan City in 2000, 2010, and 2020. The main analysis steps (Figure 2) are as follows:

1. Data collection and processing. Download the 3-year land use type data with map number N50_25 from the Global Land Cover Data (GlobeLand30) website. After importing ArcGIS, extract according to the mask of Lushan City.

2. Calculate the transfer matrix of land use. Use ArcGIS's grid calculator to calculate the data changes for the years 2000, 2010, and 2020, and then use a transfer matrix model to digitize the changes in land use types and calculate the total area of all land use types.

3. Calculate the dynamic degree of single-land use. Use the grid-to-surface conversion function of ArcGIS to calculate the transfer amount of the fused land use type area.

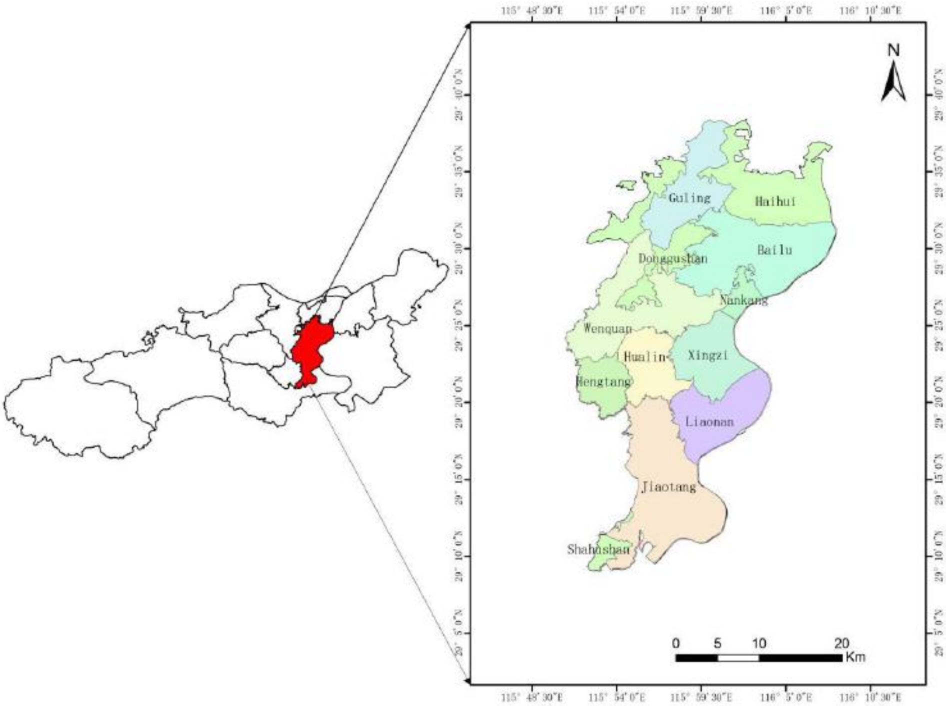

Fig.1 Administrative Division of Lushan City

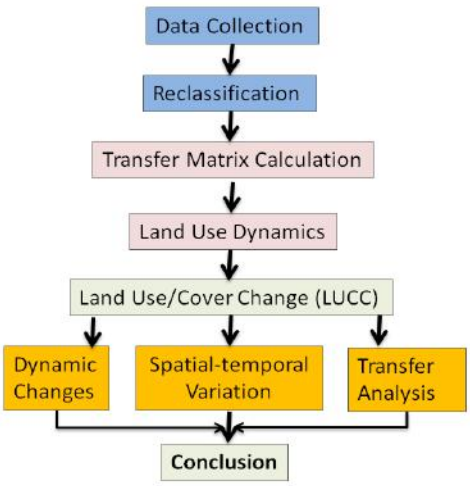

Fig.2 The Scheme of the Study

3.1 Land use transfer matrix

A research method was proposed by Russian mathematician Andrey Markov to represent the quantity and direction of transformation between different land use types. This study used ArcGIS 10.8 to overlay the grid data of six land use types in Lushan City in 2000, 2010, and 2020 [6], and calculated the transfer in/out areas of each land use type during each time period. The formula is as follows:

$$S_{ij} = \begin{Bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{Bmatrix} \quad \cdots\cdots\cdots\cdots(1)$$

In the formula, S represents the land area, N represents the number of land use types before and after land transfer, and i and j, respectively, represent the land use types before and after land transfer (i, j = 1, 2,..., n).

3.2 Dynamic degree of single land use

Refers to the magnitude of changes in land use area of a certain type of land use within a certain time scale [7], and the formula is as follows:

$$K = \frac{(U_b - U_a)}{U_a} \times \frac{1}{T} \times 100\% \quad \cdots\cdots\cdots\cdots(2)$$

In the formula, K is the dynamic degree of land use types, Ua and Ub are the initial and final areas of a certain land type, respectively, and T represents the time period of the study.

IV. ANALYSIS AND RESULTS

4.1 The Spatiotemporal Variation Characteristics of Land Use Types

Analysis shows that from 2000 to 2020, the land use types in Lushan City were forest land, cropland, and water bodies, accounting for 37.64% to 39.29%, 25.67% to 28.05%, and 22.71% to 23.99% of the total regional land area, respectively (Table 1). Over the past 20 years, there have been significant differences in the changing trends of different land use types, with significant changes in the proportion of cropland, forest land, wetlands, and construction land. However, there was no significant change in the proportion of water and grassland areas, indicating that local land use policies have relatively stable adjustments to water and grassland areas, and there have been no significant changes or reforms.

The area of water and construction land is increasing year by year, with the water area increasing from 84.36 km^2 in 2000 to 100.60 km^2 in 2020, an increase of 16.24 km^2. The construction land has increased from 4.47 km^2 in 2000 to 21.91 km^2 in 2020, an increase of 17.44 km^2. The four types of land use, namely cropland, forest land, grassland, and wetland, have all experienced significant changes in area, first increasing and then decreasing over the past 20 years (Figure 3). From 2000 to 2020, the cropland area first increased and then decreased, decreasing to 25.67% and 16.32 square kilometers in 2020. This may be related to urbanization, policy changes, and the optimization of agricultural structures. The fluctuation of forest land area may be caused by early afforestation activities and later deforestation, land development, or natural disasters. The increase or decrease of grassland may be related to grassland restoration projects, overgrazing, or land conversion. The initial increase and subsequent decrease of wetlands may reflect the initial effectiveness of protection measures and the subsequent degradation, drainage, landfill, and pollution issues of wetlands.

Table 1 Land Area and Proportion in Lushan City over the Past 20 Years（km^2）

	2000		2010		2020	
Land type	Area(km^2)	Proportions	Area(km^2)	Proportions	Area(km^2)	Proportions
Cropland	102.25	27.91%	123.96	28.05%	107.64	25.67%
Forest	137.86	37.64%	167.13	37.82%	164.74	39.29%
Grassland	20.52	5.60%	24.65	5.58%	22.68	5.41%
Wetland	16.83	4.60%	20.43	4.62%	1.76	0.42%
Water	84.36	23.03%	100.37	22.71%	100.60	23.99%
Building	4.47	1.22%	5.40	1.22%	21.91	5.22%

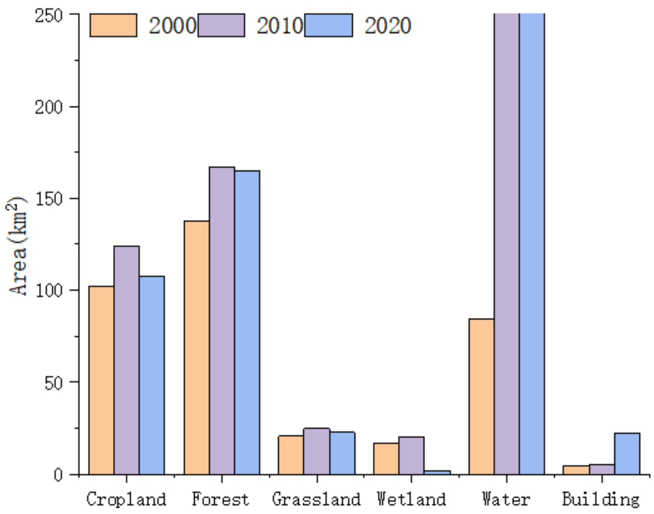

Fig.3 Histogram of Land Use Type Area in Lushan City from 2000 to 2020

4.2 Characteristics of Spatial Changes in Land Use Types

Analysis shows that from 2000 to 2020, the land use area of Lushan City was arranged in descending order, with water area>forest land>cultivated land>grassland>wetland>construction land (Figure 4). Forest land is distributed in Guling Town around the Lushan Mountain area, accounting for 37.64% to 39.29% of the total area of the region. Cropland is distributed in the plain areas along the river and lake, such as in Bailu Town, Xingzi Town, Hualin Town, Jiaotang Town, Hengtang Town, Guling Town, and Liaonan Township. It is distributed in a dotted pattern in Nankang Town, Wenquan Town, and Haihui Town. The water body is distributed in the western part of Poyang Lake, with a strip-like distribution and a planar distribution in the southern part of Liaonan Township. The proportion of construction land area is the smallest, accounting for 1.22% to 5.22% of the total area. Among them, the construction land area of Xingzi Town, Wenquan Town, and Nankang Town has significantly increased, mainly expanding to the north and middle of the urban area. The growth rate over the past 20 years is most significant, with a change from 2010 to 2020. This reflects the overall land use plan of Lushan District, which significantly increases the area of construction land through the conversion of cropland and the addition of construction land through other land use during this decade and strengthens the agglomeration and radiation functions of the central urban area around the periphery.

The population distribution in various towns and villages in the central region is dense, and land use types change frequently. It is in line with the economic development strategy of Lushan City, including building a core urban area, creating advantages with tourism characteristics, singing the Lushan brand, promoting new industrialization, new urbanization, and tourism industrialization, and continuously increasing the comprehensive economic and social strength of the entire region, with the aim of focusing on improving the comprehensive economic and social strength of the entire region, achieving faster and better development, and promoting urban-rural integration. The prominent ones are Xingzi Town, Wenquan Town, and Hengtang Town. The construction land in Hualin Town, Jiaotang Town, and Liaonan Township spreads in a dotted pattern to the surrounding areas. In addition, Wenquan Town, Xingzi Town, Nankang Town, and Bailu Town develop in a continuous and patchy manner, through the transfer of arable land [8] .

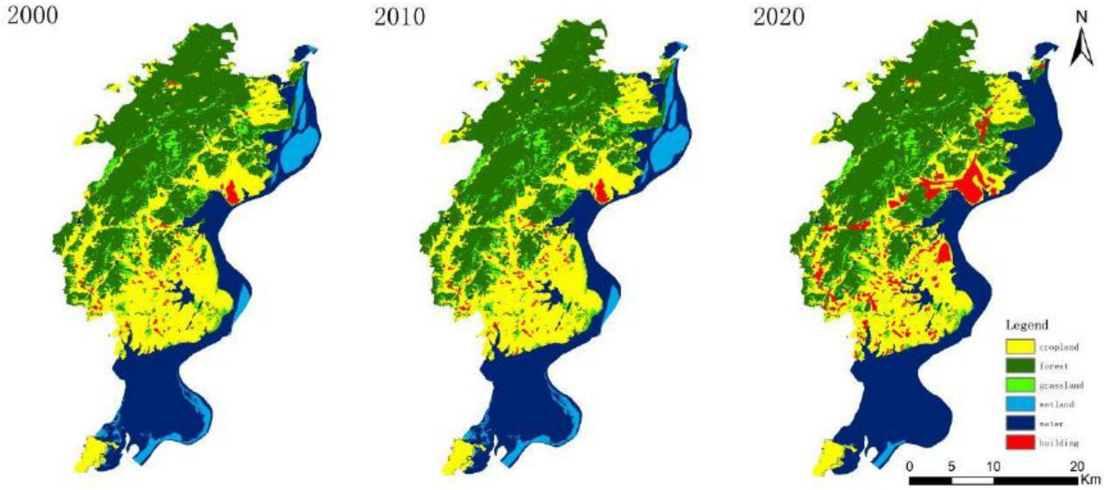

Fig.4 Land Use Types in Lushan City from 2000 to 2020

4.3 Transfer Status of Land Use Types

By comparing and analyzing the land use transfer matrix data from 2010 to 2020, it is shown that:

1. From 2000 to 2010, there was no significant change in the transfer of land use types (Table 2), while from 2010 to 2020, the transfer of land use types was the most active. Except for no transfer from wetlands to cropland, wetlands to forest land, wetlands to grassland, wetlands to construction land, and construction land to wetlands, all other land use types were transferred in and out (Table 3).

2. From 2010 to 2020, cropland and grassland were converted into construction land, leading to a significant increase in construction land, reflecting the acceleration of urbanization and the demand for economic development during this stage. The total area of cropland, grassland, forest land, and wetlands decreased by 62.51 km^2, with the most significant decrease being cropland, which decreased by 9.15% (equivalent to an area of 18.77 km^2). This change is due to the conversion of wetlands into water bodies, which has increased their attitude to 2.25%. This is related to the extreme rainfall event in June 2020, which led to an increase in water levels and flooding of wetlands (specific data is 18.77 km^2).

Exploring the driving factors, it was found that the rural population is shifting to cities (among the city's permanent residents, 2.4383 million people live in urban areas, accounting for 50.56%; 2.3844 million people live in rural areas, accounting for 49.44%). Compared with the sixth national population census in 2010, the urban population increased by 427.8 thousand people, the rural population decreased by 333.9 thousand people, and the proportion of the urban population increased by 8.04%, in addition, economic development (in 2015, the city achieved a regional GDP of 190.268 billion yuan, an increase of 9.7% compared to the previous year). It is the main driving force for the expansion of construction land. At the same time, the rapid development of the tourism industry has led to the launch of a series of preferential policies such as the "Luyi Card," "One Ticket Multiple Day Use System," and "Free Open Month." Innovative consumption scenarios have been created to create the "Southern Snow Village," and "Ice and Snow Tourism" has become a new growth point in the tourism economy. Despite being free of tickets for one and a half months, 1.61 million people in core scenic areas purchased tickets for the whole year, a year-on-year increase of 170.61%. 1.3998 million people purchased tickets for sightseeing vehicles, a year-on-year increase of 200.95%. The operating revenue of 110 million yuan has exceeded the 100 million yuan mark for the first time. The Lushan Transportation Cableway achieved revenue of 97.2 million yuan, a year-on-year increase of 60%. The city received 14.9917 million tourists, a year-on-year increase of 28.53%, and achieved tourism revenue of 80 million yuan, a year-on-year increase of 27.36%. This has also promoted infrastructure construction, leading to a reduction in arable land and wetlands.

The reduction of wetlands has had a significant impact on the ecological environment of Lushan City, including a significant loss of biodiversity and a significant weakening of water conservation functions. According to Zhang et al. (2023) [9], the reduction of wetlands leads to significant carbon emissions, which is equivalent to a significant weakening of wetlands as carbon sinks. Meanwhile, Kuang et al. (2022) pointed out in their analysis that the loss of wetlands annually leads to a significant loss of water conservation capacity [10], which is crucial for the stability of regional water cycles and the health of ecosystems. These changes have a profound negative impact on the ecological balance and climate regulation functions of Lushan City. In response to these changes, it is recommended to strengthen wetland protection policies, implement strict land approval systems, and promote green buildings and sustainable urban planning to balance the needs of economic development and environmental protection.

Table 2 Land Use Type Transfer Matrix in Lushan City from 2000 to 2010

2000\2010	Cropland	Forest	Grassland	Wetland	Water	Building	Sum	Minimize
Cropland	98.45	1.77	0.93	0.01	0.63	0.47	102.25	3.80
Forest	2.04	132.00	3.62	0.01	0.17	0.02	137.86	5.86
Grassland	0.71	4.02	15.68	0.01	0.10	0.01	20.52	4.84
Wetland	0.01	0.01	0.00	16.38	0.43	0.00	16.83	0.45
Water	0.80	0.17	0.20	0.46	82.72	0.01	84.36	1.64
Building	0.51	0.03	0.01	0.00	0.00	3.93	4.47	0.55
Sum	102.53	138.00	20.44	16.86	84.05	4.43	366.30	
Additional	4.07	6.00	4.76	0.48	1.32	0.51		

Table 3 Land Use Type Transfer Matrix in Lushan City from 2010 to 2020

2010\2020	Cropland	Forest	Grassland	Wetland	Water	Building	Sum	Minimize
Cropland	101.69	3.88	1.22	0.01	3.36	13.79	123.96	22.27
Forest	3.15	155.01	6.10	0.02	1.00	1.85	167.13	12.12
Grassland	1.36	5.57	15.30	0.02	1.00	1.41	24.65	9.35
Wetland	0.00	0.00	0.00	1.66	18.77	0.00	20.43	18.77
Water	0.86	0.25	0.06	0.06	100.36	0.08	100.37	0.01
Building	0.58	0.03	0.01	0.00	0.02	4.78	5.40	0.63
Sum	107.64	164.74	22.68	1.76	100.60	21.91	441.94	
Additional	5.95	9.73	7.39	0.10	0.24	17.13		

From 2010 to 2020, there were a total of 28 types of land use change map units, and the main transformed land use types were construction land. The conversion between different land use types was more frequent and distributed in a dotted pattern (Figures 5 and Figures 6). The areas with relatively concentrated transformation are mainly in Bailu Town, Xingzi County, and Wenquan Town, mainly manifested as the transformation of cropland into construction land and grassland into construction land. The transfer rate of cropland and grassland to construction land is very high in the periphery of the protected area due to economic development and urbanization [10]. In addition, due to being one of the earliest tourist attractions in China, most of the natural reserves overlap with the Lushan Scenic Area [11]. Moreover, a large number of studies have shown that tourism to some extent affects ecological risks, as the roads and infrastructure required for tourism development lead to vegetation degradation [12], resulting in a reduction in cropland area.

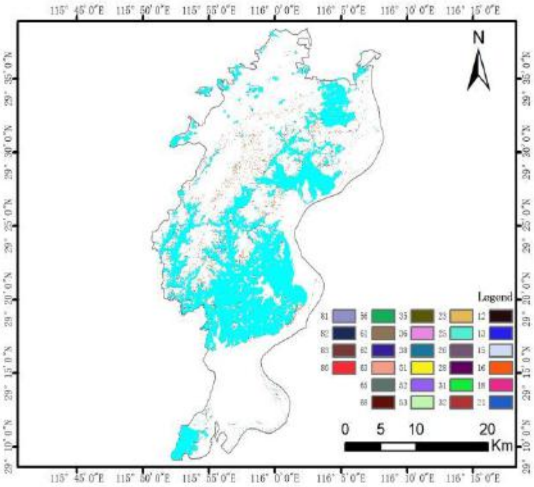

Fig.5 Transfer Map of Different Land Use Types in Lushan City from 2000 to 2010

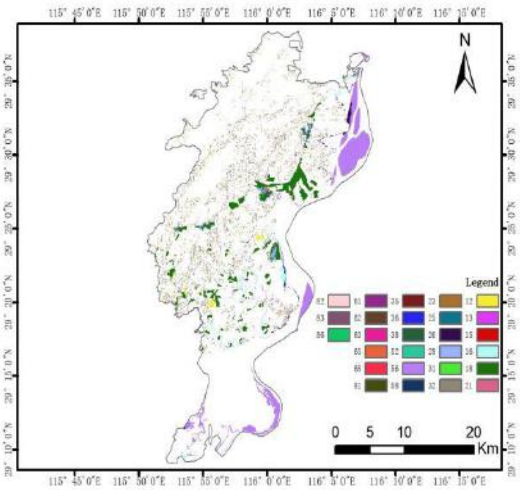

Fig.6 Transfer Map of Different Land Use Types in Lushan City from 2010 to 2020

Notes:1—Cropland、2—Forest Land、3—Grassland、5—Wetland、6—Water、8—Building Land

65 Water body to wetland 68 Water body to construction land 81 Construction land to cultivated land 82 Construction land to forest land 83 Construction land to grassland 86 Construction land to water 51 Wetland to farmland 52 Wetland to forest 53 Wetland to grassland 56 Wetland to water 58 Wetland to construction land 61- Water to farmland conversion 62- Water to forest conversion 63- Water to grassland conversion 31- Grassland to farmland conversion 32- Grassland to forest conversion 35- Grassland to Wetland 36- Grassland to Water 38- Grassland to Construction Land 21- Forest to Farmland 23- Forest to Grassland 25- Forest land to wetland 26- Forest land to water 28- Forest land to construction land 12- Farmland to forest 13- Farmland to grassland 15- Farmland to Wetland 16- Farmland to Water 18- Farmland to Construction Land

4.4 Dynamic Changes in Land Use

Analysis shows that from 2000 to 2010, the dynamic degree of grassland was the highest (Table 4), reaching 0.05%, and the area showed a decreasing trend. The dynamic degree of other land use types did not exceed 0.04%, with cropland, forest land, and wetlands increasing by 0.01%, 0.02%, and 0.03%, respectively. The water area is decreasing, but the magnitude is not significant, at -0.04%. The dynamic degree of construction land is 0. From the above data analysis, it can be seen that there was not much change in land use types from 2000 to 2010.

Through data analysis, it can be seen that there was a relatively significant change in land use types from 2010 to 2020. The dynamic degree of construction land from 2010 to 2020 was significantly higher than that of other land use types, indicating that the expansion of construction land was rapid, the urbanization process was accelerated, and the intensity of change in construction land was also enhanced. However, the area of cropland, grassland, forest land, and wetland was significantly decreasing, with the largest decrease in wetland being -9.08%. A large amount of wetlands are transformed into water bodies. The dynamic degree of the water body has significantly increased compared to the previous period and is showing an increasing trend, reaching 2.25%. Since June 2020, Lushan has been hit by continuous rainstorms, and the water level of rivers and lakes has continued to rise, reaching the highest value of Poyang Lake Hydrological Station Xingzi Station and also exceeding the highest value of Poyang Lake during the Yangtze River flood in 1998. Wetlands change their water conditions due to the rise in water levels, causing them to be heavily submerged and transferred into water bodies.

By 2020, the proportion of wetlands had significantly decreased (Figure 7), while the proportion of construction land, water bodies, and construction land had significantly increased, with no significant changes in grassland and forest land. The extent of land transfer was not significant from 2000 to 2010 (Figure 8), while the proportion of wetlands transforming into water bodies was the highest from 2010 to 2020 (Figure 9). The "wetland-to-water body" relationship was significantly negatively correlated with the terrain position index and positively correlated with the distance from the main road. Wetlands are distributed in low-territory gradient areas. In addition, driven by industrial restructuring and economic benefits, a large area of local wetlands has been transformed into aquaculture water surfaces, resulting in an increase in water area [13]. Secondly, the conversion of cropland into construction land.

Table 4 Dynamic Changes from 2000 to 2010 and from 2010 to 2020

Land Type	Cropland	Forest	Grassland	Wetland	Water	Building
2000-2010 dynamic index	0.01%	0.02%	-0.05%	0.03%	-0.04%	0.00%
2010-2020 dynamic index	-1.31%	-0.16%	-0.69%	-9.15%	2.25%	30.66%

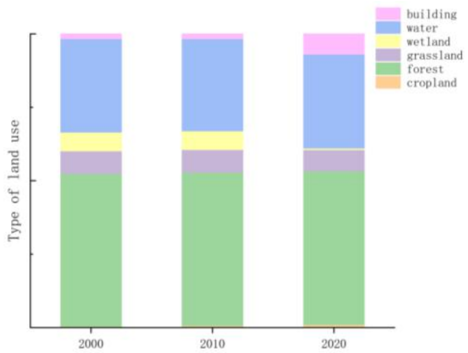

Fig.7 Percentage Bar Chart of Land Use Types in Lushan City

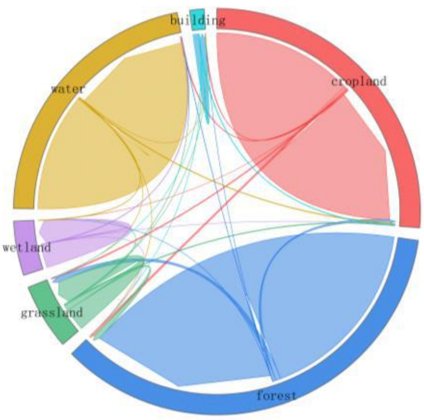

Fig.8 LUCC Chord Chart of Lushan City from 2000 to 2010

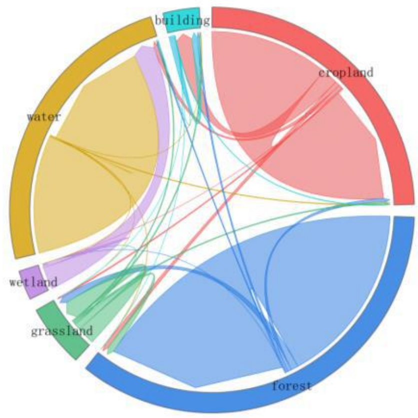

Fig.9 LUCC Chord Chart of Lushan City from 2010 to 2020

V. CONCLUSION

This study is based on land use data from 2000, 2010, and 2020, and uses methods such as single land use dynamic degree and transfer matrix to analyze the spatiotemporal evolution characteristics of land use in Lushan City from 2000 to 2020, providing reference for maintaining the layout optimization and sustainable use of land resources in Lushan City. Based on the above research, the following conclusions can be drawn:

1. Lushan City is divided into six types of land use in descending order of area: forest land, cropland, water area, grassland, wetland, and construction land. The proportion of cropland, water bodies, wetlands, and construction land has shown significant changes. However, the proportion of forest and grassland areas has not changed significantly, indicating that the local land use policies have relatively stable adjustments to

forest land and have not undergone significant changes or reforms.

2. The construction land area has significantly increased, mainly expanding to the north and middle of the urban area. This reflects the overall land use plan of Lushan District, Jiujiang City. In 2010 and 2020, by occupying agricultural and other land and adding construction land, the area of construction land was increased, and the agglomeration and radiation functions of the central urban area were strengthened.

3. Cropland is converted into construction land. Due to the growth trend of local per capita GDP and total population changes, economic development is needed, and the dependence of economic development on construction land is relatively high, especially for the infrastructure required for urban construction and industrial development, which requires the occupation and consumption of a large amount of land resources. Low-terrain gradient areas (such as cropland and grassland) are highly consistent with the spatial distribution of population and rapid economic growth areas. Low terrain gradient areas are ideal areas for converting into construction land due to their relatively low altitude, relatively flat terrain, fewer natural obstacles, and conducive to strengthening transportation connections and saving construction investment. The development of tourism also has an impact on the occupation of arable land.

4. Wetlands are transferred to water bodies. Since June 2020, Lushan has been hit by continuous rainstorms, and the water level of rivers and lakes has continued to rise, reaching the highest value at Xingzi Station of Poyang Lake Hydrological Station. Wetlands change their water conditions due to the rise in water levels, causing them to be heavily submerged and transferred into water bodies. Moreover, wetlands are distributed in low-territory gradient areas. In addition, driven by industrial restructuring and economic benefits, a large area of local wetlands has been transformed into aquaculture water surfaces, resulting in an increase in water area.

In summary, the conversion of a large amount of cropland into construction land and the conversion of wetlands into water bodies in Lushan City reflect issues such as unreasonable land resource utilization, ecosystem damage, and hidden dangers to food security. Therefore, it is necessary to scientifically plan land, strengthen ecological protection, ensure food security, strictly approve land, strengthen supervision, promote sustainable development, and achieve optimized land allocation and ecological environment protection.

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