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Land Use Change and Driving Force Analysis of Wetland in Poyang Lake Based on Remote Sensing

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Land use change and driving force analysis of wetland in Poyang Lake based on remote sensing

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Abstract: As an important wetland in the world, Poyang Lake wetland is constantly changing its land use mode due to economic development and human activities, thus affecting the ecological environment of wetland.Landsat remote sensing images from 1986 to 2020 are utilized to obtain land use information data through supervised classification and interpretation. Combined with ENVI and ArcGIS software, five land use type maps are generated by taking 8 years or so as the interval period. Land use transfer matrix and land use dynamic attitude are adopted.This paper analyzes the wetland land use change in Poyang Lake and explores the driving factors of wetland land use change in Poyang Lake.The results show that the wetland land use types in Poyang Lake will change greatly from 1985 to 2020, and the change range of construction land, mudflat, paddy field and dry land is relatively large and shows an increasing trend.The area of water and grassland decreased on the whole, and the transferred area was large, which was mainly transferred to construction land, paddy field and dry land.The woodland area increased slowly, but the change range was not large from the perspective of dynamic attitude.The change of wetland area of reed flat decreased first and then increased, and the overall land use change was relatively gentle.According to the grey correlation analysis, the total population and annual precipitation are the main driving factors of land use change in Poyang Lake wetland.Through the above research, it provides important reference for wetland protection and land resource management of Poyang Lake.

Key words: Poyang Lake Wetland;Remote sensing;Land use;Driving force

1. Introduction

Land resources are the material basis of human survival and development, and the sustainable use of land is the necessary conditions and inevitable requirements of economic development(Comte Lise et al.2021).Wetland is an ecosystem with unique functions, as a special type of land use, plays an important role in human production activities(WANG and GAO,2020). It provides abundant natural resources for human beings and is one of the environments on which human beings depend for survival.Wetland is rich in land use types, and it is of great significance to study the change of land use types in wetland for wetland protection and ecological management(Han,2017).Wetlands not only provide abundant material resources for human beings, but also play an important role in regulating climate, water conservation, soil and water conservation, and biodiversity protection of biological resources. They are known as "the kidney of the earth".However, since the 20th century, the decrease of wetland area has led to the decrease of wetland ecological value and service function. In recent decades, human disturbance activities have continued to increase(REN et al.2016;Guo et al.2020). Wetlands around the world have been seriously reduced, wetland resources have been continuously developed and utilized, and wetland land use patterns have undergone significant changes(Cui et al.2019；Jian et al.2020).Among the freshwater lake wetlands in China, Poyang Lake is the largest inland freshwater lake wetland, and

its research is of great significance.In order to make rational and effective use of land resources, protect Poyang Lake wetland animal and plant resources, and improve the ecological environment, it is necessary to use real-time dynamic remote sensing images to monitor Poyang Lake wetland, obtain more accurate wetland information and land use change data, and improve the sustainable use of Poyang Lake wetland land resources(Kalogirou.S.,2002;TONG and YANG,2018).To provide reference data for the harmonious development of man-land relationship and man-bird relationship in Poyang Lake Basin, and to provide suggestions for wetland protection and management(Fang et al.2020).

2 .Material and methods

2.1 Study area

Poyang Lake National Nature Reserve (115° 47'E-116 ° 45'E, 28° 22'N-29 ° 45'N) is located in the northern part of Jiangxi Province, covering Yongxiu, Xingzi and Xinjian counties, with Wucheng Town of Yongxiu as the center.The reserve is composed of nine lakes: Beng Lake, Dacha Lake, Dahu Lake, Sha Lake, Changhu Lake, Zhonghu Lake, Xiang Lake, Meihu Lake and Zhushi Lake. In addition, it includes more than a dozen lakes and grasslands nearby, with a total area of 22400hm^2.Based on the limits of Poyang Lake National Nature Reserve, the study area selected in this paper extends about 1km around (about 5km to the southeast, including Vida Dou Lake) according to the topography and the distribution of rivers and lakes, with a total area of 42000hm^2(Figure 1).The wetland of Poyang Lake in Jiangxi has a subtropical monsoon climate, with high temperature and rain in summer and cold and dry in winter, with great seasonal changes.From 1986 to 2020, the annual average temperature of Poyang Lake wetland was 17.9℃, the highest temperature in 2007 was 18.1℃, and the lowest temperature in 2012 was 17.8℃.The average annual precipitation was 1550.1mm, with the minimum precipitation of 967mm in 2006 and the maximum precipitation of 3250.5mm in 1998.

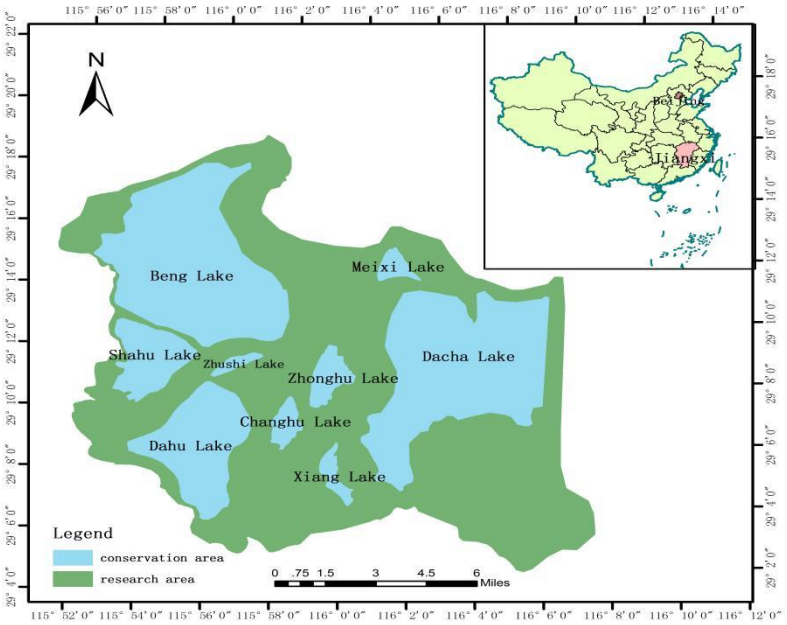


Figure 1 Geographic location of the study area

2.2 Data source and processing

The remote sensing images of 1986, 1994, 2002, 2012 and 2020 were selected. The basic image data came from the geo-spatial data cloud platform (http://www.gscloud.cn/), and ENVI was used for data preprocessing, such as atmospheric correction, image enhancement, image fusion and image cropping. By referring to the relevant research of domestic scholars, the classification of land use status and the characteristics of wetland land types in Poyang Lake, the land use types in the study area are mainly divided into eight types: water, construction land, paddy field, dry land, woodland, grassland, reed flat and mudflat. In terms of image selection, in order to ensure the accuracy of image selection, the images are mainly concentrated in November to February of the following year. On the one hand, the images are prevented from being disturbed by cloudy and rainy weather, and at the same time, the rising water level in the wet season is avoided to cover other land use types. On the other hand, the change range of land use type is small when the adjacent months are selected, which does not affect the later image accuracy. Combined with field mapping, the Kappa coefficient was all greater than 0.85, indicating a high accuracy of classification results.

2.3 Land use transfer matrix analysis

The land use transfer matrix is mainly used to analyze the transfer rate and direction between different land use types in different periods, so as to analyze the internal correlation and change trend among land use types.Transfer matrix formula (1) is as follows:

$$P_{ij}=\begin{bmatrix} P_{11} & P_{12} & \Lambda & P_{1n} \\ P_{21} & P_{22} & \Lambda & P_{2n} \\ \mathrm{M} & \mathrm{M} & \mathrm{O} & \mathrm{M} \\ P_{n1} & P_{n2} & \Lambda & P_{nn} \end{bmatrix} \quad (1)$$

Where, P represents the area transferred by land use type;N represents the classification number of land use types in the study area,i, j (i, j are 1, 2, 3...Integer of n) represents the area before and after the transfer of a certain land use type;P_{ij} represents the number of land use types converted from Class i land use type to Class j land use type.

2.4 Land use change rate analysis

Single land use dynamic attitude represents the change of the number of land use types in the study area within a certain time range.Its specific expression is as follows:

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

In the formula, K represents the change of dynamic attitude of land use type in the study area;U_a and U_b represent the number of land use types in the early and late stage of the study area;T is the duration of the study;U_b-U_a represents the amount of land use type change in the study area (negative value means decreased area and positive value means increased area).

2.5 Grey correlation analysis

(1) Calculation of correlation coefficient

The correlation coefficient between $X_0(k)$ and $\Delta_i(k)$

$$\delta_i(K)=\frac{\min\limits_i \min\limits_k |x(k)-x_i(k)|+\rho \max\limits_i \max\limits_k |x(k)-x_i(k)|}{|x(k)-x_i(k)|+\rho \max\limits_i \max\limits_k |x(k)-x_i(k)|} \quad (3)$$

Remember $\Delta_i(k)=|x(k)-x_i(k)|$, then:

$$\delta_i(K)=\frac{\min\limits_i \min\limits_k \Delta_i(k)+\rho \max\limits_i \max\limits_k \Delta_i(k)}{\Delta_i(k)+\rho \max\limits_i \max\limits_k \Delta_i(k)} \quad (4)$$

$\rho \in (0, \infty)$, called the resolution coefficient.The smaller ρ is, the greater the resolution is. Generally, the value of ρ is (0,1), which is usually set as ρ=0.5.

(2) Calculate the correlation degree

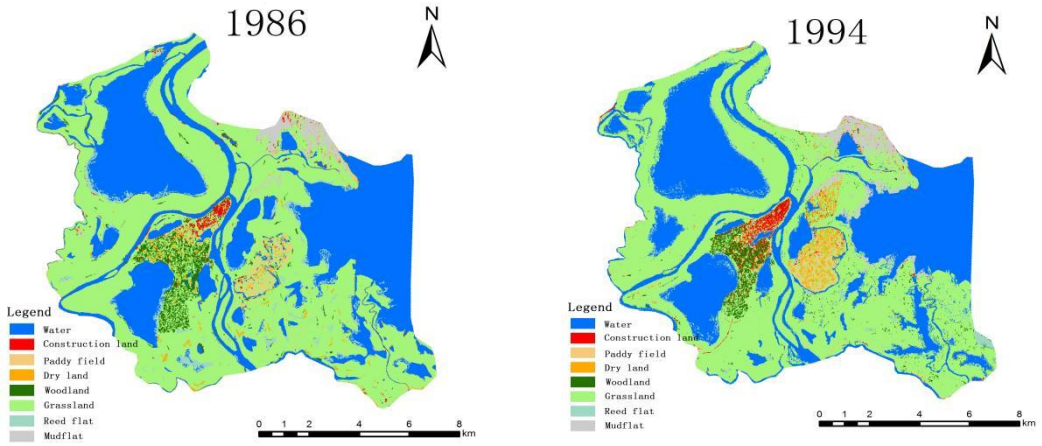
The correlation degree between the comparison sequence X_i and the reference sequence X_0 is reflected by N correlation coefficients, and the correlation degree between X_i and X_0 can be obtained by calculating the average value γ_{0i}:

$$\gamma_{0i}=\sum_{k=1}^{N}\delta_{0i}(k)/N \quad (5)$$

3. Results and analysis

3.1 Trend of land use change

Envi software was used to obtain the TM images of Poyang Lake Protective Area in five phases (Figure 2). ArcGIS, Excel and other software were used to make statistical analysis of the land use data of Poyang Lake wetland in five phases in 1986, 1994, 2002, 2012 and 2020, and the area of each category in this region was obtained (Table 1). Based on this, the variation trend of the area of each class in each time period is analyzed.



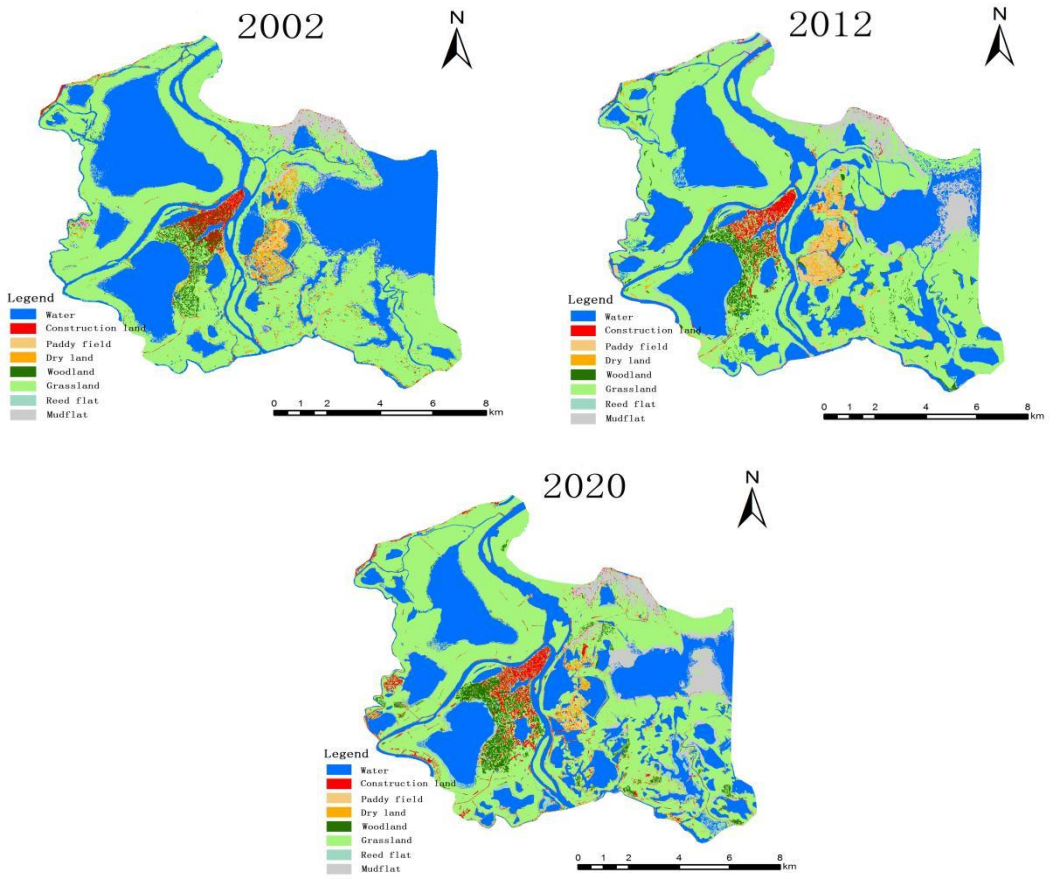


Figure 2 Classification of wetland land use types in Poyang Lake

Table 1 Data of land type area of Poyang Lake wetland in four stages

Year	Water	Construction land	Paddy field	Dry land	Woodland	Grassland	Reed flat	Mudflat
1986	16095.60	359.64	638.73	465.57	973.35	21465.27	1493.56	702.18
1994	15901.92	524.79	757.80	618.39	978.48	20780.64	1170.34	1161.54
2002	15234.01	636.03	937.80	696.33	1016.37	19470.33	1011.42	1091.61
2012	14760.09	820.08	762.39	516.15	1172.79	20118.42	1491.75	2452.23
2020	14536.60	1221.08	1092.29	858.15	1155.85	19680.73	1372.37	2176.85

See from table 1 and figure 2, 1986-2020, the Poyang lake wetland of various land use area, grassland and water area to total area of big, small change, but the total area is decreasing, illustrate the Poyang lake wetland is given priority to with water and grassland development, change the opposite trend, there area to area of grassland change affected by the changes of water area.The area of construction land has been increasing continuously, with a large increase and a rapid increase from 2002 to 2020, mainly due to the influence of population increase and urbanization process.The fluctuation of paddy field and dry land is mainly affected by population factors and the policy of converting farmland to forest and lake.The woodland area increased continuously, and increased rapidly from 2002 to 2020, which was mainly affected by the policy of returning farmland to forest.The change of wetland area of reed flat first decreased, then increased and then decreased, which could be divided into three stages: the first stage, 1986-2002,

was natural wetland of reed, which was in the declining stage; The second stage, 2002-2012, this stage is the coexistence of artificial planting and natural growth. The area of artificial planting reed is increasing continuously, and the area of reed beach is rising rapidly. In the third stage, 2012-2020, there was a slight decline. The variation of mudflat area is mainly influenced by natural factors such as annual precipitation, water level and so on, and the inter-annual variation is great.

3.2 Transfer matrix

In this section, through the ArcGIS software, the land use data of different periods are fused and superimposed to obtain the land use transfer matrix of two periods, and the land use transfer matrix of 1986-2020 is established.

Table 2 Land use transfer matrix from 1986 to 2020

	2020							
1986	Water	Construction land	Paddy field	Dry land	Woodland	Grassland	Reed flat	Mudflat
Water	10390.56	118.59	311.56	123.02	68.98	3902.68	276.51	903.7
Construction land	36.63	226.86	11.32	20.24	25.15	20.23	10.86	8.35
Paddy field	122.36	23.56	353.25	59.36	32.25	25.32	12.38	10.25
Dry land	65.51	32.25	21.35	267.25	22.36	36.31	11.31	9.23
Woodland	50.38	59.17	32.13	43.25	731.12	31.48	15.61	10.23
Grassland	3298.76	680.23	250.13	316.29	216.71	15169.25	734.43	799.47
Reed flat	514.98	65.36	82.32	18.12	36.21	364.25	297.02	15.30
Mudflat	57.42	15.06	30.23	10.62	23.07	131.21	14.25	420.32

It can be seen from the above table that from 1986 to 2020, the areas of construction land, paddy field, dry land, woodland, grassland and reed flat were mainly transferred to water area, with a transfer of 36.63hm^2, 122.36hm^2, 65.51hm^2, 50.38hm^2, 3298.76hm^2 and 514.98hm^2, respectively.The water area base is large, and the above land types are adjacent to the water area. With the combined action of natural and policy factors in the past 34 years, the position around the water area has changed a little.According to the field investigation, it can be found that grassland is close to water and grassland. When the location of water and grassland begin to shift to other directions, the soil conditions are extremely suitable for the development of grassland.Although part of construction land, paddy field and dry land used by local residents for production and living have been transferred, it can be seen from Table 2 that the area of grasslands converted into construction land is as high as 680.23hm^2, the area of water and grassland converted into paddy field is 561.69hm^2, and the area of water and grassland converted into dry land is 439.31hm^2.Compared with 1986, the area of construction land, paddy field and dry land all doubled, with a large growth rate.With the increase of population, construction land, paddy field and dry land, as important carriers of residents' production and life, tend to be rationally utilized and developed under the joint guidance of the local protection zone administration and relevant administrative departments.

3.3 Rate of land use change

According to formula (2), the dynamic attitude of single land use type in Poyang Lake wetland during 1986-2020 can be obtained.

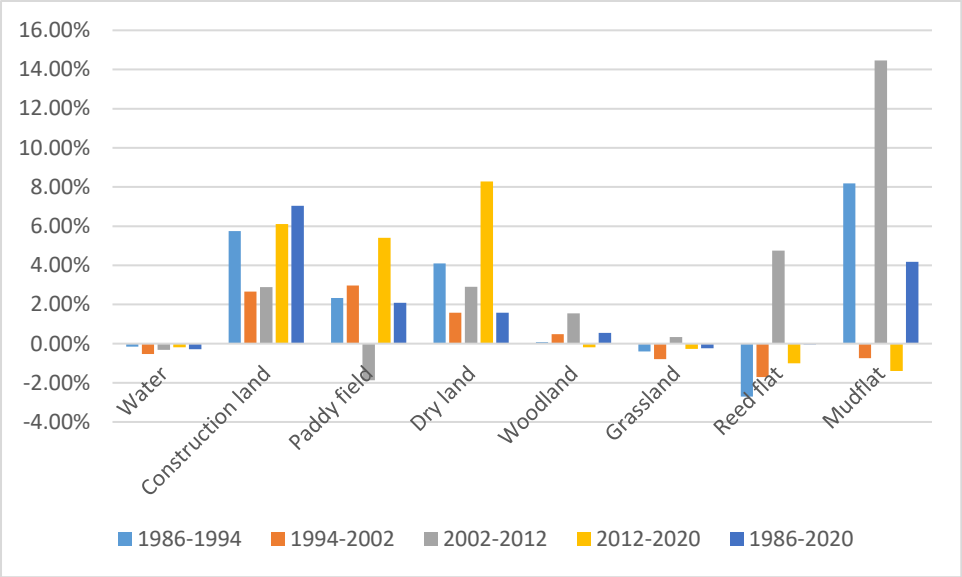


Figure 3 Dynamic attitude of land use

From the perspective of single dynamic attitude of land use, water area, woodland, grass flat and reed beach changed little during 1986-2020, and reed beach changed 4.75% from 2002 to 2012, which was mainly due to the policy support and guidance for the development of reed industry. Construction land has been increasing from 1986 to 2020, with a growth rate of 7.04%. From 1986 to 2020, the dynamic rates of paddy field and upland were 2.08% and 1.58%, respectively. The change range of mudflat land was 14.46% from 2002 to 2012, indicating that the area of mudflat land changed the most during this period, with a total growth rate of 4.17% from 1986 to 2020.

From 1986 to 2020(Figure 3), the construction land continued to increase, and it was the land type with the largest change, followed by mudflat, which was second only to the construction land.Paddy field, dry land and woodland are increasing, while the area of water , grassland and reed flat is decreasing.Population increase, economic development and environmental policy are all factors affecting land use change.

3.4 Driving forces of land use change

The driving force of land use change mainly uses qualitative and quantitative methods.In the qualitative analysis, three natural driving forces and three social and economic driving forces were selected to explore the impact of each driving factor on the land use change of Poyang Lake wetland.In the quantitative analysis, the grey relational degree analysis model was mainly selected. By selecting the driving factors, the correlation degree of driving factors of land use change in Poyang Lake wetland was calculated and obtained. The driving factors of each type of land use change were found, and finally the dominant driving factors of eight land use types were obtained.

3.4.1 Qualitative analysis

Among the natural factors, there are mainly three factors.(1) Topographic factors: The land use layout of Poyang Lake wetland is affected by topography and landform. Dingjiashan, Jishan and Yangshan are three hilly sites in Poyang Lake wetland. The topography is high in the middle, low around, high in the west and low in the east, and the overall topography is low.The study area can be roughly divided into mountain and hilly area, low plain area, and lake water area.Mountain and hills are mainly developed for construction land, woodland, dry land, low plain mainly

distributed paddy field, reed flat, etc.(2) Climate factor: As for climate factor, the study area belongs to subtropical monsoon climate, with high temperature and rainy summer and cold and dry winter, so it presents a scene of "abundant water and dry water".The annual average precipitation days of Poyang Lake wetland reached 143 days, and the rainfall days were mainly concentrated in June to September of each year. During this period, the water level area of Poyang Lake increased and the water surface area reached the maximum value. The total precipitation increased with the increase of annual precipitation days, and the annual average precipitation amount was 1135.55mm from 1986 to 2020.(3) Hydrological factors: the impact of hydrological factors on land use change is mainly manifested in water level, sediment concentration and other aspects.Under the influence of Ganjiang River, Xiushui River and Poyang Lake, Poyang Lake wetland is one of the lakes connecting the Yangtze River to regulate the water level of the Yangtze River. Flood from the middle and upper reaches of the Yangtze River flows into Poyang Lake, resulting in rapid hydrological rise of Poyang Lake, and the hydrological elements of Poyang Lake are one of the important driving factors of land change in the study area.

Among the social and economic factors, there are mainly three factors.(1) The number of population: the number of population directly affects the degree of land use and the efficiency of land use.As human beings are engaged in production and life, land is bound to be transformed. The pressure of population growth on land increases, and more land is needed to meet the needs of their own development. Studies show that population growth is directly proportional to the area of construction land and the area of arable land.(2) Economic factor: it plays an important role in the process of land use change. GDP can reflect the extent of land resources development and utilization in a region, and it is also an important indicator to measure the level of economic development in a region.In the process of economic development, the industrial structure is constantly optimized and adjusted, which promotes the improvement of social infrastructure construction and changes the land use structure accordingly.(3) Policy factor: Policy factor plays a driving role in land use change and is an important factor affecting land use structure in the region.The introduction of policies can optimize the layout of industrial structure, promote the transformation of land use mode, and drive the coordinated development of regional economy. Under the control and influence of government policies, the land use types of Poyang Lake wetland are constantly changing.

3.4.2 Quantitative analysis

The change of wetland land use in Poyang Lake is affected by many factors. Besides the natural environment, the change of wetland land use is also caused by the change of human utilization mode.Since the qualitative analysis of the driving forces of land use change is unable to determine the dominant driving factors of land use change in Poyang Lake wetland, based on the principles of scientific nature, correlation with wetland change, and data availability, this paper makes a quantitative analysis of the driving forces of land use change by using the grey correlation analysis model.The main driving factors affecting the change of land use types were found.

Combined with the actual situation of Poyang Lake wetland and the needs of the research, the driving factors of this paper are determined as follows:Natural factors include total annual precipitation (X_1), average annual temperature (X_2), annual mean water level difference (X_3), etc. Social and economic factors include total population (X_4), total output value of primary industry (X_5), total output value of secondary industry (X_6), total output value of tertiary industry (X_7), total grain output value (X_8), total output value of fishery (X_9), etc.The data were obtained from

Jiangxi Province Statistical Yearbook and Yongxiu County Statistical Yearbook, and the economic data of Poyang Lake wetland were obtained after correction, and the correlation degree was calculated.

Table 3 Correlation coefficient of driving factors of land use change in Shengjinhu wetland

Grey relational degree	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Water	0.4891	0.4292	0.4934	0.4866	0.4100	0.3811	0.3808	0.4589	0.3956
Construction land	0.4486	0.2529	0.4337	0.4774	0.4210	0.4714	0.4205	0.4705	0.4011
Paddy field	0.4676	0.4778	0.4626	0.4806	0.4820	0.3795	0.3808	0.4646	0.3935
Dry land	0.4649	0.4629	0.4656	0.4730	0.4745	0.3720	0.3729	0.4576	0.3564
Woodland	0.4771	0.4805	0.4688	0.4931	0.4864	0.4151	0.3853	0.4700	0.4003
Grassland	0.4937	0.4333	0.4931	0.4903	0.4126	0.3848	0.3839	0.4599	0.3954
Reed flat	0.4879	0.4728	0.4980	0.4761	0.4248	0.3915	0.3919	0.4692	0.4068
Mudflat	0.4796	0.4678	0.4710	0.4587	0.4125	0.3838	0.3829	0.4483	0.3978

As can be seen from Table 3, each type of land use change has its dominant driving factors. The dominant driving factors of water change and reed flat change are the annual mean water level difference, and the grey correlation coefficients are 0.4934 and 0.4980, respectively.The main driving factor for the change of construction land, paddy field and woodland was the total population, and the grey correlation coefficient was 0.4774, 0.4806 and 0.4931, respectively.In dry land, the total output value of primary industry was the main driving factor, and the grey correlation coefficient was 0.4745.The area of grassland and mudflat was mainly driven by the total annual precipitation, and the grey correlation coefficient was 0.4937 and 0.4796, respectively.

The land use type is not affected by a single driving factor, but by many driving factors at the same time(Di,2019).Among the natural factors, the main driving factor of the grassland and mudflat is the total annual precipitation, but the annual mean water level difference will also cause the changes of the grassland and mudflat area.In social and economic factors, the change of the population for there are significant effects of various land use type, reed flat, for example, in the natural state, the wetland area of reed flat is only affected by climate and precipitation. However, in the table of land use type area of Poyang Lake wetland from 1986 to 2020, the wetland area of reed flat has been declining from 1986 to 2002, but it has started to increase since 2012, mainly due to the introduction of emerging industries and characteristic planting. Policies support and guide the development of reed industry, and the relevant administrative departments gradually realize the importance of wetland protection and economic development in parallel, strengthen the protection of wetland resources, and promote the harmonious coexistence of man and nature.In general, population change and climate change are the main driving factors of wetland land use change in Poyang Lake.

4. Conclusion and discussion

First,the wetland land use types in Poyang Lake changed significantly. The wetland of Poyang Lake is dominated by water area and grassland land, followed by reedy beach and woodland. Construction land and arable land are relatively small. From 1986 to 2020, water area

and grassland land are the two most important land use types, but the area of land use is decreasing. On the whole, the area of woodland showed a slow rising trend. The area of mudflat land fluctuates greatly due to the natural factors such as hydrology and annual precipitation. The trend of reeds beach was decreasing first and then rising. The area of land used for construction increased year by year, and the rate of increase was fast, mainly due to the increase of land used for infrastructure construction and development. The area of arable land made up of paddy and dry land is increasing.

Second,the results of the transfer change among different land use types showed that the water area and grassland land were the most reserved from 1986 to 2020, and the areas of water area and grassland land were the most stable during the study period of nearly 40 years. The area of dry land was the least retained, with an area of only 265hm2, which was mainly affected by the rising water level, and the low-lying dry land was flooded. The grassland area was transferred out to 6296.02hm2, and the water area was transferred out to 5705.04hm2. Construction land transfer was the least, which was 132.78hm2. Other types of changes are more balanced. From 1986 to 2020, the dynamic attitude of comprehensive land use is 1.02%, 0.74%, 0.89% and 0.49%, indicating that the speed of land use change in Poyang Lake wetland is relatively slow.

Third,the driving force analysis of land use change mainly adopts qualitative and quantitative methods. In the qualitative analysis, three natural driving forces and four social and economic driving forces were selected to explore the impact of each driving factor on the land use change of Poyang Lake wetland. In the quantitative analysis, the grey relational degree analysis model was mainly selected to calculate the correlation degree of driving factors for land use change in Poyang Lake wetland by selecting driving factors. The driving factors for each type of land use change were found, and the leading driving factors for eight land use types were finally obtained, respectively as follows: The main driving factor of the change of water area and wetland area of reed was the difference of annual mean water level, and the grey correlation degree was 0.4934 and 0.4890, respectively. The main driving force of the change of construction land area, paddy field area, dry land area and woodland area was the total population, and the grey correlation degree was 0.4774, 0.4806, 0.4730 and 0.4931, respectively. The main driving factor of the change of grassland area and mudflat area was the total annual precipitation, and the grey correlation degree was 0.4937 and 0.4796, respectively.

Fourth,from the perspective of optimizing the land use layout and improving the wetland environment, the land use structure of Poyang Lake wetland is unbalanced, the construction land is increasing, the constructed wetland landscape area is decreasing, and the wetland ecological environment is threatened. Therefore, it is necessary to optimize the land use layout and improve the wetland environment through land use planning, controlling the scale of construction land, optimizing the industrial layout, adjusting the industrial structure, doing a good job in the overall planning and rational distribution of wetland land, and establishing the dynamic monitoring mechanism of wetland.

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Declarations

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B.Conflicts of interest

We have no competing interests.

C. Ethics approval

Not applicable.

D. Consent to participate

We agreed toparticipate.

E.Consent for publication

We agreed to publish.

F.Availability of data and material

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

G. Code availability

Not applicable.

H.Authors' contributions

CR wrote the most paper. BD,PW,LF and XG have gathered the experimental data and processed the data model and TM images;HX,TW,ZX,YL,SL and WX edited the English language, grammar and the discussion part. All of the authors read and approved the final manuscript.

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