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Study on the Ecosystem Service Value of Dongting Lake Based on Land Dynamic Analysis Methods

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Abstract: *Based on remote sensing images and regional land cover data from 2000 to 2020, this paper systematically analyzes the spatial distribution and structural change characteristics of land use in the Dongting Lake area using the land use dynamics analysis method, the land use transfer matrix method and the ecosystem service assessment method. The results show that as of 2020, land use changes in the Dongting Lake area are mainly characterized by an increase in farmland and construction land, as well as a decrease in forest land, wetland, grassland, shrubs and bare land to varying degrees. Among them, the wetland area had a net decrease of 75,258.81 ha, which was mainly transformed into farmland, construction land, forest land, grassland and bare land. The values of various types of ecosystem services in the Dongting Lake area in 2000 and 2020 were, in descending order, woodland and shrub, wetland, farmland, grassland and bare land. It is noteworthy that the ecosystem service value of Dongting Lake wetlands increased by 9.56% during these 20 years. The results of this study reveal the dynamic changes of land use and its ecosystem service value in the Dongting Lake area, and provide a scientific basis for the ecological environmental protection and sustainable utilization of land resources in this area.*

Keywords: *Analysis of land use dynamics, Land use transfer matrix, Ecosystem services*

1. Introduction

Dongting Lake is an important storage lake in the middle reaches of the Yangtze River and an important economic region in Hunan Province, known as the "land of fish and rice". However, global climate change and human activities have aggravated the pressure on land use and ecosystems in the Dongting Lake area. As one of the three major ecosystems on earth, wetlands have important functions such as regulating climate, purifying water and maintaining biodiversity, and are known as the "kidneys of the earth", but they are also highly vulnerable to human activities and climate change. According to the survey of China Meteorological Administration, the area of natural wetlands in the world has been declining for a long time, and has been reduced by about one third in the past 45 years, and the rate of reduction has been accelerated since 2000 [1].

Based on remote sensing images and land cover data from 2000 to 2020, this paper systematically analyzes the spatial distribution and structural changes of land use in the Dongting Lake area by using land use dynamics analysis, land use transfer matrix method and ecosystem service assessment method. The results show that by 2020, farmland and construction land in Dongting Lake area will increase, and forest land, wetland, grassland, shrubs and bare land will decrease, among which wetland will decrease by 75,258.81 ha net, which is mainly transformed into farmland, construction land, forest land, grassland and bare land.The value of each type of ecosystem service in 2000 and 2020, from largest to smallest, is forest land and shrubs, wetland, farmland, grassland and bare land. The ecosystem service value of Dongting Lake wetland increased by 9.56% in 20 years.

Land use/cover change (LUCC) reflects the changes in human utilization of land resources, reflecting both development needs and revealing environmental problems. The comparative analysis of land use changes in the Dongting Lake area between 2000 and 2020 demonstrates the changes in the spatial structure and quality of the region and provides a basis for improving land use and environmental protection. This paper explores the changes in Dongting Lake wetlands over a 20-year period and applies the equivalent factor method to calculate the changes in their ecological service value, providing theoretical support for ecological restoration and land use improvement.

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2. Materials and methods

2.1 Data sources

In this paper, relevant data of the study area in 2000 and 2020 were collected. The scope of the study area was visually interpreted from the landsat remote sensing images in 2000 and 2020 as well as from the land use data of the two scenes, and the study area starts from 111°1′12" in the west to 114°4′28" in the east, which constitutes a rectangle that basically covers the Dongting Lake basin. The land use change map is summarized and extracted using GIS map processing software, and the land use of the study area is classified into seven categories, such as construction land, grassland, shrubs, bare land, arable land, forest land and wetland, according to the research needs of the project and the limitations of the acquired data [2].

2.2 Research methodology

2.2.1 Land use transfer matrix

The land use transfer matrix refers to the transformation process of mutual changes between the areas of various land use types in the early and late stages of a specific region and a specific time period, which not only refers to a static area of each land use type in a specific region at a certain point in time, but also expresses the information that the area of each land use type is an increase or decrease [3]. The general form of the land-use transfer matrix.

$$\mathrm{P} = \begin{bmatrix} P11 & \cdots & P1n \\ \vdots & \ddots & \vdots \\ Pn1 & \cdots & Pnn \end{bmatrix} \tag{1}$$

Where P represents the land use area; n represents the number of land use types before and after the transfer; i, j $(i, j = 1, 2 \ldots . n)$ represent the land use types before and after the transfer, respectively; P_{ij} represents the area of land type i transferred to land type j. Each row element contained in the matrix represents the flow direction information from the feature type i before the transfer to the feature type j after the transfer, while each column element in the matrix represents the area of feature type j after the transfer derived from the information of each type before the transfer, respectively. The number of land use types before and after the transfer can be different, then the number of rows and columns of P_{ij} is different, it is a general matrix, but this study set the same classification system before and after the transfer, so the number of rows and columns are the same, and it is an n-order square matrix.

2.2.2 Equivalent factor approach

Ecosystem service is the process by which human beings obtain ecosystem products and services directly or indirectly through ecosystem structures, functions and processes. The ecosystem service value of construction land has not yet formed a more authoritative and unified measurement method, so it is not considered in this study, and its equivalent factor is calculated as 0 for the time being [4]. The formula for calculating the ecological service value of the remaining land use types is as follows:

$$ESV = {}_iVC_i \tag{2}$$

Where ESV represents the total value of ecosystem services; A_i represents the area of the ith land use type in the study area; VC_i represents the unit ecosystem service value coefficient of the ith land use type; ESV_i is the service value of a single ecosystem service function in the study area; VC_{ij} represents the service value coefficient of the j ecosystem service function of the i land use type; and i can be categorized into grassland, shrubs, Bare land, farmland, woodland, wetland 6 land use types (Table 1).

The area of agricultural land is 4799706.57 hectares, and the value of ecosystem services per unit area is 19291.27 yuan, with the total value reaching 92592435362.6439 yuan. The area of forest land is 392.22 hectares and 2203106.13 hectares, respectively, with an ecosystem service value per unit area of 92,796.84 yuan and a total value of 204,477,683,825.214 yuan. The area of grassland is 731.79 hectares, and the ecosystem service value per unit area is 72,037.28 yuan, with a total value of 52716161.1312 yuan. The area of wetlands is 617,117.04 hectares, the ecosystem service value per unit area is 179,268.69 yuan, and the total value is 110,626,976,3337.4776 yuan. The area of bare land was 77.4 hectares, the ecosystem service value per unit area was 903.59 yuan, and the total value was 69,937.866 yuan. To summarize, the total value of ecosystem services (ESV) of Dongting Lake in 2000 was 407,752,668,624.2327 yuan.

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Table 1: Value Coefficient of Ecological Services by Region (VC_i)

Type of ecological service	Cropland	Woodland	Grassland	Wetlands	Bare ground	Building site
Gas regulation	4 495.27	9 555.27	8 674.29	8 380.63	90.36	0
Climate regulation	2 326.70	28 598.05	22 950.73	15 857.69	0	0
Culverts	2 642.95	14 095.72	3 523.93	68 264.86	135.54	0
Soil formation and conservation	926.16	11 678.67	10 571.79	10 165.19	90.36	0
Clean up the environment	700.27	8 493.58	7 567.42	15 857.69	451.79	0
Biodiversity	835.80	10 616.97	9 600.45	34 674.58	90.36	0
Maintaining nutrient cycling	790.63	880.98	790.63	790.63	0	0
Food producing	5 556.97	1287.59	1671.61	2 236.34	0	0
Raw material production	655.09	2 914.02	2 462.23	2 213.75	0	0
Aesthetic landscape	361.43	4 675.99	4 224.20	20 827.33	45.18	0
Total	19 291.27	92 796.84	72 037.28	179268.69	903.59	0

By 2020, the value of all types of ecosystem services in Dongting Lake has undergone some changes. The area of farmland was 4834947.87 hectares, and the ecosystem service value per unit area was still 19291.27 yuan, with a total value of 93272284796.0949 yuan. The area of forest land was 2082232.17 hectares and 205.83 hectares respectively, with an ecosystem service value per unit area of 92,796.84 yuan and a total value of 193243665895.92 yuan. The area of grassland was reduced to 527.22 hectares, with an ecosystem service value of 72,037.28 yuan per unit area and a total value of 37,979,49494.7616 yuan. The area of wetlands was 541858.23 hectares, with an ecosystem service value of 179268.69 yuan per unit area and a total value of 97138215057.8187 yuan. The area of bare land was reduced to 41.04 hectares, the ecosystem service value per unit area was 903.59 yuan, and the total value was 37,083.3336 yuan. In summary, the total value of ecosystem services (ESV) of Dongting Lake in 2020 is 791444850952.1615 yuan.

3. Results and analysis

3.1 Changes in land use area in the Dongting Lake area

From the land use change data of Dongting Lake in 20 years, it can be concluded that the change of agricultural land area was the largest (380965.14 ha) during 2000-2020; followed by forest land (2082438.00 ha); wetland was the third largest change with 171765.72 ha, and the rest of the land use types changed more slowly. From the Dongting Lake land use conversion matrix, it can be seen that the land type changes from 2000 to 2020 are, in descending order, farmland, forest land, wetland, construction land, grassland, shrubs and bare land.

3.2 Analysis of land use transfer matrix in Dongting Lake area

Based on the calculation results of the land use transformation matrix (Table 2), the magnitude of changes in the selected seven land use types within the Dongting Lake area from 2000 to 2020 was analyzed as follows.

Table 2: Land Use Conversion Matrix of Dongting Lake from 2000 to 2020

Land use area (ha)	Type of land use in 2020						
Land use types, 2000	Building site	Grassland	Bare ground	Cropland	Woodland	Wetlands	Total
Building site	139772.88	0.45	0	758.61	3.78	3953.07	144488.79
Grasslands	79.83	72.81	1.8	374.67	78.66	124.02	731.79
Bare ground	17.28	0.99	2.79	38.88	0	17.46	77.4
Cropland	137358.18	201.15	20.07	4418741.43	151685.82	91699.92	4799706.57
Woodland	15040.35	236.34	5.76	257766.21	1929737.25	712.44	2203498.35
Wetlands	13539.06	15.48	10.62	157268.07	932.49	445351.32	617117.04
Total	305807.58	527.22	41.04	4834947.87	2082438.00	541858.23	7765619.94

(1) Farmland: The area of farmland in the Dongting Lake region increased by 35,241.3 hectares from 2000 to 2020, which mainly came from 257,711.76 hectares of forest land, 157,268.07 hectares of wetland, and 758.61 hectares of construction land. There is also a part of farmland converted to other

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land use types, of which 151685.73 hectares of farmland was converted to forest land, 137358.18 hectares of farmland was converted to construction land, 91,699.92 hectares of farmland was converted to wetland, and 201.15 hectares of farmland was converted to forest land.

(2) Forest land. from 2000 to 2020, the forest land area of Dongting Lake will be reduced by a net area of 153025.38 hectares. The reduced area is mainly transformed into 257,711.76 hectares of farmland and 150,039.9 hectares of construction land. The increased area mainly came from farmland and wetland, both of which were 151685.73 ha and 932.49 ha respectively.

(3) Wetlands.The area of wetlands in Dongting Lake from 2000 to 2020 will have a net decrease of 75,258.81 hectares. Among them, 157268.07 hectares of wetlands are converted into farmland, 13639.06 hectares into construction land, 932.49 hectares into forest land, 15.48 hectares of wetlands into grassland, and 10.62 hectares into bare land. Another 91,699.92 hectares of farmland, 3,953.07 of construction land, 712.35 hectares of forest land, 124.02 hectares of grassland, 17.46 hectares of bare land, and 0.09 hectares of shrubs were converted to wetland.

(4) Construction land.The net increase of construction land in the Dongting Lake region from 2000 to 2020 is 161,318.79 hectares. Its main sources of increase are 137,358.18 hectares of farmland, 15,039.9 hectares of forest land and 13,539.06 hectares of wetland. There is also part of the construction land converted into other land types, of which 3953.07 hectares are converted into wetlands, 758.61 hectares into farmland, 3.78 hectares into woodland and 0.45 hectares into grassland.

(5) Grassland: From 2000 to 2020, the area of grassland in Dongting Lake region will decrease by 204.57 hectares. Among them, 347.67 ha of grassland was transformed into farmland, 124.02 ha area was transformed into wetland, 79.83 ha was transformed into impervious surface, 76.41 ha area was transformed into woodland, 2.25 ha was transformed into shrubs, and 1.8 ha was transformed into bare ground. Another 223.74 hectares were converted to woodland, 201.15 hectares to farmland, 72.81 hectares to grassland, 15.48 hectares to wetland, 12.6 hectares to shrubs, 0.99 hectares to bare land, and 0.45 hectares to building land.

(6) Bare land. There was a net decrease of 36.36 ha of bare land in the Dongting Lake region from 2000 to 2020. Among them, 38.88 hectares of bare land was transformed into farmland, 17.46 hectares into wetland, 17.28 hectares into construction land, and 0.99 hectares into grassland. Another 20.07 hectares of farmland, 10.62 hectares of wetland, 5.76 hectares of woodland, and 1.8 hectares of grassland were converted to bare land.

3.3 Analysis of changes in the value of ecosystem services

According to the calculation, the value of various types of ecosystem services of Dongting Lake in 2000 was as follows: the area of farmland was 4799706.57 hectares, the value of ecosystem services per unit area was 19291.27 yuan, and the total value amounted to 92592435362.6439 yuan. The area of forest land is 392.22 hectares and 2203106.13 hectares respectively, with an ecosystem service value per unit area of 92,796.84 yuan and a total value of 204,477,683,825.214 yuan. The area of grassland is 731.79 hectares, and the ecosystem service value per unit area is 72,037.28 yuan, with a total value of 52716161.1312 yuan. The area of wetlands is 617,117.04 hectares, the ecosystem service value per unit area is 179,268.69 yuan, and the total value is 110,626,976,3337.4776 yuan. The area of bare land was 77.4 hectares, the ecosystem service value per unit area was 903.59 yuan, and the total value was 69,937.866 yuan. In summary, the total value of ecosystem services (ESV) of Dongting Lake in 2000 was 40.775 billion yuan.

By 2020, the value of all types of ecosystem services in Dongting Lake has undergone some changes. The area of farmland is 4834947.87 ha, and the ecosystem service value per unit area is still 19291.27 yuan, with a total value of 93272284796.0949 yuan. The area of forest land was 2082232.17 hectares and 205.83 hectares respectively, with an ecosystem service value per unit area of 92,796.84 yuan and a total value of 193243665895.92 yuan. The area of grassland was reduced to 527.22 hectares, with an ecosystem service value of 72,037.28 yuan per unit area and a total value of 37,979,49494.7616 yuan. The area of wetlands was 541858.23 hectares, with an ecosystem service value of 179268.69 yuan per unit area and a total value of 97138215057.8187 yuan. The area of bare land was reduced to 41.04 hectares, the ecosystem service value per unit area was 903.59 yuan, and the total value was 37,083.3336 yuan. In summary, the total value of ecosystem services (ESV) of Dongting Lake in 2020 was 79.144 billion yuan.

According to the ecosystem service analysis method, the value of ecosystem services of each category

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in the Dongting Lake region in 2000 was, in descending order, woodland and shrub, wetland, farmland, grassland, and bare land, which was the same as the situation in 2020. The total value of ecosystem services of Dongting Lake increased by 38.369 billion yuan in two decades, and the ecological service value of wetlands in Dongting Lake accounted for 2.71% in 2000 and 12.27% in 2020, which proves that the ecological protection measures for Dongting Lake in the past 20 years have been effective [5].

4. Conclusions

Dongting Lake has become an important natural treasure trove for Hunan and the whole country by virtue of its role in water supply, aquaculture, flood storage and maintenance of ecological balance. However, due to the evolution of the natural environment and inappropriate human utilization, the land cover of the Dongting Lake area has undergone significant changes.Between 2000 and 2020, the land use changes in the Dongting Lake area were mainly characterized by an increase in farmland and construction land, and a decrease in forest land, wetland, grassland, shrubs and bare land. The land use conversion matrix shows that the wetland area of Dongting Lake has a net decrease of 75,258.81 ha, which is mainly converted into farmland, construction land, forest land, grassland and bare land.In 2000 and 2020, the value of each type of ecosystem service, in descending order, is forest land and shrubs, wetland, farmland, grassland and bare land. It is worth noting that the ecosystem service value of Dongting Lake wetland has increased by 9.56% during the 20-year period, indicating that the protection and management measures in recent years have achieved certain results.

In summary, the Dongting Lake area has experienced significant land use changes over the past 20 years, especially the significant reduction of wetland area. However, the increase in the value of wetland ecosystem services also shows the positive impacts of conservation and management efforts. In the future, there is a need to further enhance ecological protection and land use optimization in the Dongting Lake area to ensure its sustainable development as an important natural resource and the maintenance of ecological balance. These findings provide an important scientific basis and reference for ecological protection and land management in the Dongting Lake area.

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