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THE DYNAMIC CHANGES OF LANDSCAPE CONNECTIVITY IN MOMOGE WETLAND BASED ON LONG TIME SERIES REMOTE SENSING DATA

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ABSTRACT

In this study, based on the land cover/utilization data of Momog Nature Reserve for 4 periods from 2009 to 2023, we quantitatively analyzed the landscape connectivity changes of Momoge Wetland in the last 15 years by using morphological spatial pattern analysis. The results found that the total area of the Momoge wetland increased, in which the area of marshes and saline land decreased, and the area of lakes increased significantly; the wetland equivalent connectivity area (*ECA*) increased by 162.45 km^2, and the network connectivity (*DOC*) increased by 14.86%.

Index Terms— Landscape connectivity, Morphological spatial pattern analysis, Remote sensing images, Momoge

1. INTRODUCTION

The study of wetland landscape connectivity has been one of the hotspots in ecology and environmental science. Wetland landscape connectivity refers to the connectivity and interactions within wetland ecosystems and between wetlands and other surrounding ecosystems. This connectivity measures the extent to which wetland landscapes facilitate or impede biological migration and other ecological fluxes between habitat patches, contributing to a better understanding of the degree of fragmentation of wetland patches as biological habitat for biodiversity conservation and regional ecosystem functioning [1]. With the increasing human activities, the ecological pattern of wetlands has been changed, the connection between different wetland patches has been severed, and the connectivity of wetlands has been drastically reduced, resulting in different degrees of degradation of wetland functions [2], which in turn adversely affects biodiversity and ecosystem functions. Therefore, it is important to study the dynamic changes of wetland landscape connectivity under the influence of human activities.

Current research methods for measuring wetland landscape connectivity include the following: 1) Graph network-based methods. With flexible visual representations and well-developed algorithms, this method has been increasingly and successfully applied to characterize wetland habitat networks for conservation and restoration, as well as to assess the connectivity between individual species wetland landscape elements [3]. 2) Methods based on FRAGSTATS and Conefor software [4]. Although some researchers have argued that the metrics of connectivity in FRAGSTATS software have limitations because measures of structural connectivity may not be representative of ecological function, FRAGSTATS software is still widely used in wetland landscape connectivity studies. Conefor software not only provides descriptive values of wetland landscapes, but also provides decision support for wetland landscape planning and habitat conservation by identifying connected key wetland landscape elements [5]. 3) Morphological Spatial Pattern Analysis (MSPA). This method involves applying a series of image processing techniques to raster layers so as to categorize the target features into different landscape categories such as core, bridging, etc., and to study the morphological mechanisms of different features by means of non-cross-cutting morphological types [1][6]. 4) Landscape connectivity assessment model, i.e., the minimum depletion distance model and the circuit theory model. This method is based on the general paradigm of ecological network construction and adopts two different resistance surface assignment schemes to assess the wetland landscape connectivity [7]. 5) Landscape connectivity index method. Commonly used indices that do not transmit misleading information and are sufficiently responsive to changes in connectivity are the integral index of connectivity (IIC) and the probability of connectivity (PC) [8]. Each of these methods has its own merits and all reflect wetland landscape connectivity from different perspectives.

Momoge National Nature Reserve is a typical wetland-type reserve and a major migratory pathway for waterbirds in the northern part of China's eastern migratory zone, and was listed on the list of Wetlands of International Importance in 2013. Between 1992 and 2015, the amount of incoming water to the Momoge wetland decreased due to the warm and dry climate and the construction of upstream water conservancy projects, coupled with the increase of dikes for field construction and the increase of artificial facilities, which reduced the wetland area and increased the degree of fragmentation in the protected area [9].

The related research of Momoge wetland has received attention from scholars at home and abroad. At present, scholars have analyzed the land use change and its driving force in Momoge wetland based on remote sensing technology [10] [11], Relevant studies were carried out on landscape pattern and hydrological connectivity changes [9], remote sensing analysis of wetland cold island effect [12], dynamic monitoring of wetland ecological security [13] and aboveground biomass of wetland reeds [14], impacts of wetland restoration projects on whooping crane population and midway habitat [15], and identification of seasonal wetlands based on remotely sensed data [16], and some research results were achieved. However, the "Network of Interconnected River and Lake Systems" program was implemented in the Momoge Wetland in 2017, resulting in a lack of in-depth analysis of the dynamics of anthropogenic stressors and landscape connectivity, which is insufficient to support the urgent need for biodiversity conservation and management in the Momoge Wetland.

In this paper, taking Momoge Nature Reserve as the study area, we select Landsat series satellite remote sensing images and Gaofen-1 satellite images, apply remote sensing feature classification method of artificial visual interpretation, interpret land cover information of multi-temporal phases from 2009 to 2023, and use landscape index, anthropogenic direct disturbance rate, combined with morphological spatial pattern analysis and graph theory model, to analyze remote sensing analysis of the landscape of Momoge Wetland in the past 15 years. Remote sensing analysis of anthropogenic stress and changes in landscape connectivity, comparative analysis of the evolutionary characteristics of the pattern of the Momoge wetland and the changing law of human activities in each period, with a view to providing a scientific theoretical basis and data foundation for the conservation and management of biodiversity in the Momoge wetland.

2. METHODS

2.1. Study Area

Momoge National Nature Reserve (45°42′25″N ~ 46°18′N, 123°27′E ~ 124°4′33″E) is located in Zhenlai County in the western part of the Songnen Plain in the western part of Jilin Province, China (Fig. 1), with a total area of about 1440 km^2 [9]. Among them, the natural wetland area accounts for more than 80% of the total area of the study area, which is the largest wetland reserve in Jilin Province and one of the most well-preserved wetlands in Songnen Plain [12].

The wildlife resources of the reserve are rich and diverse, among which there are 298 species of birds belonging to 17 orders and 50 families, including 120 species of wetland waterbirds [17]. The terrain in the area is characterized by high northwest and low southeast, overall flat, relative height difference is only 2-10 m. The climate of the area is temperate continental monsoon climate, with an average annual temperature of 4.9 ℃, annual precipitation is close to 400 mm, and more than 80% of the precipitation is concentrated in the months of June to September [9].

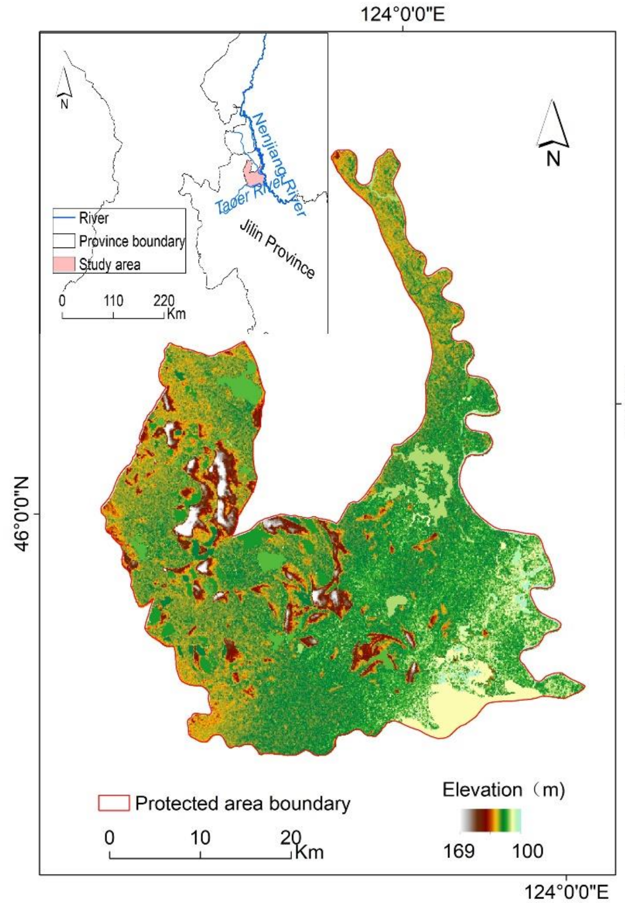

Fig 1. Location of study area (Top left: location of study area in Jilin Province).

2.2. Data Sources

In this study, the MSS/TM/ETM+ series remote sensing images in the Landsat series provided by Geospatial Data Cloud [18], Land Observation Satellite Data Service [19]and Google Earth Engine (GEE) were used (TABLE I). Based on the site survey, Momoge wetland landscape were classified into five categories: marshes, lakes, floodplain wetlands, rivers and reservoirs (artificial wetlands), and the rest of the landscape were classified as arable land, woodland, grassland, saline land, and residence-industrial land.

TABLE I
REMOTE SENSING IMAGE DATA INFORMATION

Time	Number	Sensor	Resolution
2009-10-03	120028	Landsat-5 TM	30m
2014-09-15	120028	Landsat-8 OLI	30m
2018-09-26	120028	Landsat-8 OLI	30m
2023-10-01[a]	13357027[b]	Gaofen-2	1m, 4m

Note: [a] represents other time (2023-10-11, 2022-10-21); [b] represents other number (13357028, 13357029, 13356917, 13356918, 13380645, 13380649, 13380564, 13380648, 13380647, 13380563, 13380646, 10692174).

2.3. Morphological Spatial Pattern Analysis

Morphological Spatial Pattern Analysis (MSPA) is a mathematical morphology-based method for metrics and identification of patches in raster images. The method performs a binary digital image by segmentation through erosion, dilation, open operation, and closed operation to detect detects and localizes mutually exclusive landscape morphological feature types, thus at the image element level This method detects and locates mutually exclusive landscape morphological feature types on a binary digital image, thus recognizing patch elements with unique features at the pixel level [20].

2.4. Wetland Landscape Connectivity Analysis

Of the seven patch types obtained from the MSPA analysis, the core class elements correspond to the network nodes and the bridging class elements correspond to the links between these nodes [1]. Component refers to the whole consisting of structurally interconnected nodes and links connecting the nodes. In this study, the relationship between wetland structure and landscape connectivity was explored through the *ECA* index and *DOC* index using the component as a unit of landscape structure. The formula is as follows:

$$ECA = \sqrt{\sum_{i=1}^{NC} C_i^2} \tag{1}$$

$$DOC = \frac{ECA}{\sum_{i=1}^{NC} C_i} \times 100\% \tag{2}$$

where, C_i is the size of the area of the i -th landscape component of the wetland; NC is the number of components. The more connected the wetland landscape network elements are, the fewer components they tend to exhibit. DOC is 100% when all elements are interconnected into a single component.

3. RESULTS

3.1. Changes in Area of Various Wetland Types

Between 2009 and 2023, the total area of Momoge wetland increased from 928.15 km^2 in 2009 to 1022.90 km^2 in 2023, an increase of 10.21%. The main manifestations are an increase in the area of lakes, from 73.78 km^2 in 2009 to 332.94 km^2 in 2023; a decrease in the area of marshes, from 419.76 km^2 in 2009 to 248.54 km^2 in 2023; and an increase in the area of saline soils, from 21.69 km^2 in 2009 to 35.69 km^2 in 2023 (Fig. 2). This may be the result of conversion of marshes to cropland, increased soil salinization, increased water volume, and increased lakes (alkali blisters).

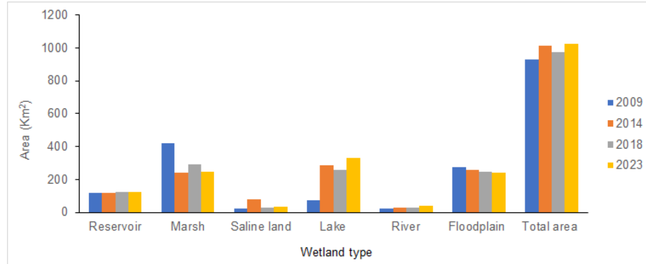

Fig 2. Changes in the area of Momoge wetland from 2009 to 2023.

3.2. MSPA-Based Analysis of Wetland Landscape Patterns

Among the 7 patch types analyzed by MSPA, only core and bridge can construct wetland landscape network [1]. Between 2009 and 2023, there is little change in the eastern core of Momoge; fragmented patches increase in the central core; and patches increase in size and fragmentation decreases in the southwestern core (Fig. 3). The number of bridging patches increased significantly in the west; bridging patches began to appear in the central and southeastern portions of Momoge, and the connectivity of the western wetland landscape increased significantly (Fig. 3).

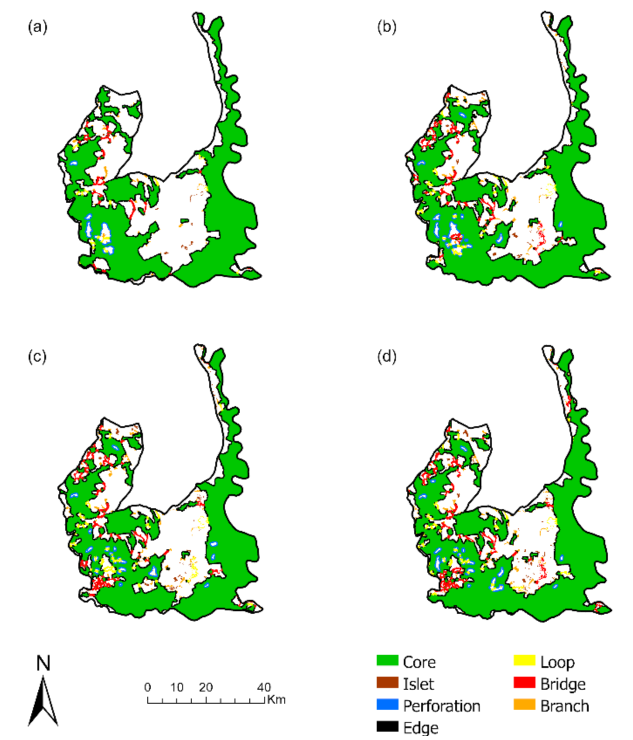

Fig 3. MSPA-based reclassification of Momoge wetlands with edge width of 10 during 2009-2023: (a) 2009; (b) 2014; (c) 2018; (d) 2023.

Between 2009 and 2023, the *ECA* index of the Momoge wetland increased from 495.52 km^2 in 2009 to 688.99 km^2 in 2014 and then slowly decreased to 657.97 km^2 in 2023 (Fig. 4). Accordingly, the *DOC* index for the Momoge wetland increased from 65.58% in 2009 to 84.38% in 2014 and then slowly decreased to 80.44% in 2023. Overall, Momoge wetland landscape connectivity increased between 2009 and 2023, with the best wetland landscape connectivity in 2014.

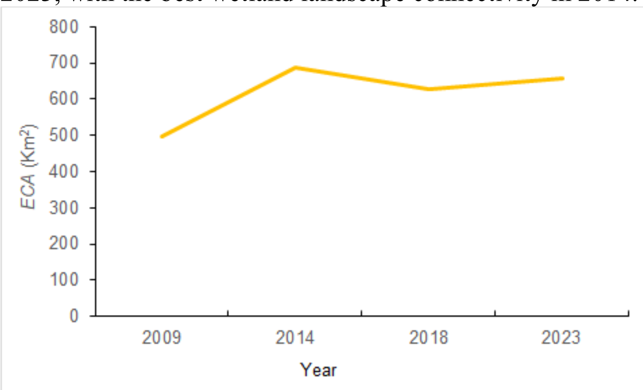

Fig 4. Changes in the *ECA* index of Momoge wetland from 2009 to 2023.

4. CONCLUSION

In this paper, landscape connectivity in Momoge wetland based on the land cover/utilization data of Momoge for the four periods from 2009 to 2023 were quantitatively analyzed, combined with morphological spatial pattern analysis. Between 2009 and 2023, there is an increase in the number of lakes and a decrease in the area of marshes in Momoge, with a general upward trend in wetland landscape connectivity.

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6. REFERENCES

[1] W. K. Tang, L. Yu, W. Q. Zhou, J. Yue, Z. Zhou, "Dynamic changes in the landscape connectivity in Shenzhen City determined based on the long time series of remote sensing data," *Remote Sensing for Natural Resources*, vol. 34, no. 3, pp. 97-105, 2022.
[2] X. Yan, Z. Niu, "Preliminary study on wetland connectivity in Baiyangdian basin," *Acta Ecologica Sinica*, vol. 39, no. 24, pp. 9200-9210, 2019.
[3] Z. Hu, S. Wang, G. Fei, "Evaluation method of structural connectivity for rivers and lakes based on theory of fractal geometry," *Advances in Science and Technology of Water Resources*, vol. 36, no. 6, pp. 24-43, 2016.
[4] L. Zhang, G. Hou, F. Li, "Dynamics of landscape pattern and connectivity of wetlands in western Jilin Province, China," *Environment, Development and Sustainability*, vol. 22, no. 3, pp. 2517-2528, 2020.
[5] Anonymous "Findings from Technical University of Munich Yields New Data on Deforestation (Identifying suitable multifunctional restoration areas for Forest Landscape Restoration in Central Chile)," *Ecology, Environment & Conservation*, pp. 446, 2017.
[6] M. M. Zhang, X. Q. Wu, "Changes in hydrological connectivity and spatial morphology of Baiyangdian wetland over the last 20 years," *Acta Ecologica Sinica*, vol. 38, no. 12, pp. 4205-4213, 2018.
[7] Y. R. Wu, J. J. Wu, X. L. Bi, Y. Z. Li, L. X. Xiao, "Application of the least cost distance model and the circuit theory model in the evaluation of wetland landscape connectivity in the Yellow River Delta," *Acta Ecologica Sinica*, vol. 42, no. 4. pp. 1315-1326, 2022.
[8] G. Baranyi, S. Saura, J. Podani, F. Jordán, "Contribution of habitat patches to network connectivity: Redundancy and uniqueness of topological indices," *Ecological Indicators*, vol. 11, no. 5, pp. 1301-1310, 2011.
[9] Z. Cui, H. Shen, G. X. Zhang, "Changes of landscape patterns and hydrological connectivity of wetlands in Momoge national natural wetland reserve and their driving factors for three periods," *WETLAND SCIENCE*, vol. 14, no. 6, pp. 866-873, 2016.
[10] X. Y. Li, J. Li, Y. Z. Bi, X. Q. Li, Y. C. Dai, S. Ma, Z. X. Zhang, "Land use change in Momoge nature reserve and its driving forces analysis," *Territory & Natural Resources Study*, no. 3, pp. 22-27, 2014.
[11] Y. X. Liu, C. Z. Wang, "The research on the wetland dynamic change characteristics of Momoge nature reserve based on the Landsat data," *NATURAL SCIENCES JOURNAL OF HARBIN NORMAL UNIVERSITY*, vol. 32, no. 3, pp. 112-118, 2016.
[12] X. Y. Xiang, F. X. Li, J. Du, Y. Liu, K. S. Song, B. Y. Zhao, H. H. Zhou, X. Y. Ma, "Remote sensing analysis of cold island effect in Momoge wetland," *J. Anhui Agric. Sci*, vol. 47, no. 23, pp. 82-87, 2019.
[13] X. Y. Chen, Q. H. Chen, Z. Wang, "The research and practice of Momoge wetland ecological security dynamic monitoring based on remote sensing," *GEOMATICS & SPATIAL INFORMATION TECHNOLOGY*, vol. 39, no. 10, pp. 150-153, 2016.
[14] Y. Zhao, D. Mao, D. Zhang, Z. Wang, B. Du, H. Yan, Z. Qiu, K. Feng, J. Wang, M. Jia, "Mapping Phragmites australis Aboveground Biomass in the Momoge Wetland Ramsar Site Based on Sentinel-1/2 Images," *Remote Sensing*, vol. 14, no. 3, pp. 694, 2022.
[15] H. Jiang, Y. Wen, L. Zou, Z. Wang, C. He, C. Zou, "The effects of a wetland restoration project on the Siberian crane (Grus leucogeranus) population and stopover habitat in Momoge National Nature Reserve, China," *Ecological Engineering*, vol. 96, pp. 170-177, 2016.
[16] L. Xing, Z. Niu, C. Jiao, J. Zhang, S. Han, G. Cheng, J. Wu, "A novel workflow for seasonal wetland identification using bi-weekly multiple remote sensing data," *Remote Sensing*, vol. 14, no. 4, pp. 1037, 2022.
[17] R. Z. Xu, J. F. Gao, "Research on the influence of Momoge wetland landscape pattern dynamics on Siberian Crane habitat," *Chinese Journal of Wildlife*, vol. 42, no. 1, pp. 106-113, 2021.
[18] (2022) Geospatial Data Cloud. [Online]. Available: https://www.gscloud.cn/#page1/1.
[19] (2023) Land observation satellite data service platform. [Online]. Available: https://data.cresda.cn.
[20] J. Velázquez, J. Gutiérrez, A. Hernando, A. García-Abril, "Evaluating landscape connectivity in fragmented habitats: Cantabrian capercaillie *(Tetrao urogallus cantabricus*) in northern Spain," *Forest Ecology and Management*, vol. 389, pp. 59-67, 2017.