Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 20 | No. 2 | pp. 447-458 | 2021
Original Research Paper
https://doi.org/10.46488/NEPT.2021.v20i02.001
Open Access Journal

Simulation and Prediction of Zhuzhou Urban Wetland Landscape Pattern Based on LCM Model

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 18-03-2020
Revised: 08-06-2020
Accepted: 15-06-2020

Key Words:
Urban Wetland
LCM
Landscape pattern
Land use change

ABSTRACT

The urban wetland is a precious wealth of the city, which has a very important role and value for the development of human and society. Zhuzhou is a traditional industrial city in China, which is located in the lower reaches of the Xiangjiang River and rich in urban wetland resources. In order to protect, utilize and manage urban wetland resources scientifically, based on LCM model platform, using Landsat series remote sensing images and other data, this paper systematically analyses the land use change process of Zhuzhou urban wetland from 2006 to 2016 and simulates and forecasts the urban wetland landscape pattern in 2021. The prediction results show that the urban wetland in Zhuzhou city will change continuously in 2021, but the overall change is relatively small, which is basically consistent with the change trend and regain of urban wetland in 2006~2016. Among them, the change of paddy fields area is the largest, with a total decrease of 1364.8ha; the increase of reservoirs area is 82.4ha; the decrease of pond area is 34.6ha, while riverine wetland is basically unchanged. In addition, Zhuzhou urban wetland landscape pattern change is affected by both natural and human factors, while human activities have a more significant impact on the wetland, with both positive and negative effects.

INTRODUCTION

Throughout the ages, human beings live by the water, and cities are built by the water. Wetland provides water for urban production and life and creates a harmonious and comfortable living environment for people. Zhuzhou city is located in the lower reaches of Xiangjiang River system in Hunan Province, China. As one of the first eight key industrial cities, Zhuzhou urban wetland has been seriously affected, especially the area and quantity of wetland has been shrinking, because of the huge consumption of natural resources due to the traditional industrial characteristics dominated by the heavy chemical industry for a long time. In the 21st century, Zhuzhou has stepped into a new process of rapid urbanization, becoming an important part of China's "two type construction demonstration area" - Changsha Zhuzhou Xiangtan City Group. Urban development and construction are also actively undergoing transformation and upgrading. The land use presents a new development trend and spatial layout, and the urban wetland landscape pattern changes accordingly. Therefore, it is of great significance for the scientific protection, utilization and management of Zhuzhou urban wetland resources and the revelation of the law of urban land use change to analyze the temporal and spatial change characteristics of urban wetland landscape pattern and carry out future scenario simulation.

At present, there is no scientific definition of the concept of urban wetland in a strict sense. The academic community generally believes that urban wetland refers to the ecological system with transitional nature of land and water in the urban area, such as coast and estuary, river bank, shallow water marsh, water source protection area, natural and artificial pond, and wastewater treatment plant (Wang & Lv 2007), which is the complex of artificial wetland, semi-artificial wetland and natural wetland. Relevant researches on urban wetland at home and abroad are mainly focused on wetland dynamic pattern research (He et al. 2020, Qin et al. 2020, Liu 2011, Gong et al. 2011, Kong et al. 2012, Gong 2013), wetland ecosystem service function and value evaluation research (Bernard et al. 2020, Chen & Yang 2012, Vileisis 1997, Xie et al. 2006, Wang et al. 2010, Pang 2014, Gao et al. 2017, Yang et al. 2017), wetland ecological restoration and technology research (Eric et al. 2020, James & Greg 2007, Cui & Yang 2001, Xu & Huang 2010, Tuo 2002, Shen 2003), wetland protection and management research (HAO et al. 2019, Wang et al. 2019, Zhan et al. 2012), etc.

Generally speaking, the evolution of urban landscape pattern is mainly reflected in land use/land cover change (LUCC) (Turner et al. 1995). The urban wetland is not only a type of urban landscape but also a way of urban land use. Wetland use characteristics directly reflect the nature and process of human activities' interference on urban wetland ecosystem and can be used as the main sign of wetland ecosystem landscape pattern characteristics (Fu 2001). Therefore, it is of great practical value to analyze the characteristics of urban wetland use change and make scenario analysis and simulation prediction of its future development trend (Wu et al. 2013). At present, many kinds of LUCC simulation and prediction models have been applied in landscape pattern research and practice. According to different research objects, theoretical basis and technical methods, there are mainly the following types: Optimization model (Rounservell 2000), System Dynamics model (Muller & Zeller 2002), Cellular Automata model (Jantz et al. 2010, Guan et al. 2011, He et al. 2011, Zheng et al. 2010, Li & Yeh 2002, Torrens & O'Sullivan 2001), Multi-Agent model (Mase 1995), Integrated model, etc. Among them, the Integrated model combines different model technologies, integrates different model methods, and seeks the most appropriate simulation solutions for different problems. This kind of model is relatively more scientific, easy to operate, easy to dynamic control, more in line with reality. The main models widely used include Clue (Veldkamp & Fresco 1996), Clue – s (Luo et al. 2010, Zheng et al. 2012, Li et al. 2011, Zhou et al. 2012), LCM (Amir & Mohammad.2019, Chen et al. 2019, Liu et al. 2017, Mishra et al. 2014, Su et al. 2018, Wei 2015, Yang 2012), etc.

Based on the above background, this study relies on LCM model platform, using Landsat series remote sensing image data, socio-economic multi-source data, analyses the spatial and temporal changes and influencing factors of Zhuzhou urban wetland from 2006 to 2016, and simulates and forecasts the urban wetland landscape pattern in 2021. It is hoped to provide scientific reference for Zhuzhou city planning, macro policy making and sustainable development of urban wetland.

MATERIALS AND METHODS

Research Area Overview

Zhuzhou city is located in the lower reaches of the Xiangjiang River, in the east of Hunan Province, China. As of 2016, Zhuzhou has a total area of 11247.55 km^2. The urban area is about 853.4 km^2, and the built-up area is 142 km^2. The urban area has a permanent population of about 780,000, which governs four administrative areas (Fig. 1): Tianyuan District, Lushong District, Hetang District and Shifeng District. This paper takes Zhuzhou urban wetland as the research object, selects Zhuzhou urban area in 2016 as the specific research scope, covering the existing central urban area and built-up area.

Data Source and Preprocessing

Research data source

The research data in this paper mainly includes image data, basic data and statistical data. Among them, the Landsat series remote sensing image data (30M) and DEM data in 2006, 2011 and 2016 are from the geospatial data cloud platform of the computer network information centre of the Chinese Academy of Sciences (http://www.gscloud.cn); Zhuzhou city administrative boundary (2016) and Zhuzhou

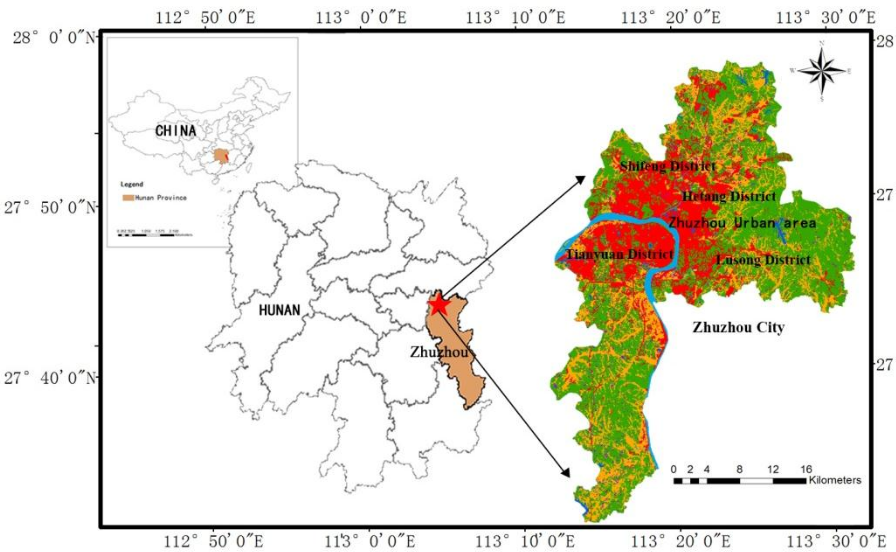

Fig. 1: Location of the study area.

wetland census patch data (2010) are provided by Zhuzhou Forestry Bureau; the statistical data (2006~2016) are from Zhuzhou Statistical Years; the data of water resources (2006~2016) are from Zhuzhou Water Resources Bulletin. In addition, Zhuzhou City Master Plan (2006~2020) and Zhuzhou City land use status map are provided by Zhuzhou City Planning and Design Institute; Google HD satellite map of Zhuzhou City (2006~2016) is downloaded from the internet with 91 satellite map assistant software.

Classification of Urban Wetland Landscape

Based on the Ramsar Convention and the current urban land classification standard of the wetland classification system in China, Zhuzhou urban wetland landscape is divided into two categories and five sub categories, and the construction land and woodland are included in the classification system as non-wetland landscape (Zhan et al. 2020). The specific classification and description is shown in Table 1.

Data Interpretation

In this paper, Envi5.3, ArcGis10.4 and other spatial analysis and processing platforms are used to preprocess all remote sensing images. Ecognition software is used to segment the processed remote sensing images in multi-scale and spectral difference, to realize the preliminary classification of Zhuzhou wetland landscape, and human-computer interactive interpretation combined with artificial visual interpretation. Finally, the accuracy of all remote sensing images is above 80%, which meets the accuracy of medium resolution remote sensing images and the requirements of this study (Fig. 2).

Research Methods

Land Change Modeler for Ecological Sustainability (LCM) is a software platform integrating remote sensing image processing and geographic information system software Terr Set. It is a software model developed by Clark lab and Conservation International for many years. It integrates MLP-ANN, Logistic Regression, Markov Chain/External Matrix model, Soft and Hard prediction and a series of models, which are suitable for the context analysis of various land changes.

Main process of LCM model prediction: Firstly, based on the multi-source wetland information data of Zhuzhou city and the remote sensing image interpretation map of urban wetland in 2006, 2011 and 2016, the LCM model platform is used to analyze the structure and spatial change of wetland land, and the influencing factors of wetland land change are preliminarily selected. Then with the help of 2006 and 2011 wetland remote sensing image interpretation map, taking Zhuzhou City Master Plan (2006~2020) as the potential impact of intervention changes, the LCM platform is used to build the transformation potential model, determine the land change impact factors, and simulate the urban wetland land use change in 2016. Next, the simulation results are compared with the actual distribution map of Zhuzhou urban wetland in 2016 to verify and improve the accuracy of LCM model construction. Finally, based on the remote sensing images of 2011 and 2016, the tested and improved LCM model is applied to simulate and predict the land use change of Zhuzhou urban wetland in 2021, and the final research results are obtained after analysis and calculation (Fig. 3).

Table 1: Classification of urban wetland in Zhuzhou city.

Category	Primary type	Secondary type	Description
Urban wetland	Natural wetland	Riverine wetland	Permanent river, including rivers and their tributaries, stream, waterfall seasonal (with seasonal attributes) or intermittent (no obvious seasonal dependence)rivers, streams, floodplains(refers to the flood of floodwaters on both sides of the river）
	Artificial wetland	Reservoirs	Reservoir, lake, barrage, water storage area formed by dam, park wetland
		Pond	Agricultural pond, water storage pond，Aquatic ponds such as fish and shrimp culture and small landscape water bodies
		Paddy fields	Rice fields, lotus, water bamboo fields, etc.
		Wastewater treatment plant	Sewage plant, treatment pool, oxidation pool, etc.
Non Urban wetland	Construction land		The land for the construction of buildings and structures is for urban and rural housing, public facilities, industrial and mining land, energy, transportation, water conservancy, communications and other infrastructure.
	Woodland		All the land for trees, bamboos, shrubs and ground covers.

Note:
(1) In this study, a riverine wetland refers to a natural river with an average width of more than 30m and a length of more than 5km.
(2) In this study, reservoirs wetland is more than 8ha artificial water body, while the pond wetland is less than 8ha artificial water body.
(3) Hunan Province is one of the main rice producing areas in China. In this paper, there are large areas of paddy fields, which play an important role in the Zhuzhou urban ecosystem. Therefore, paddy fields are one of the main types of urban wetland research in this paper.

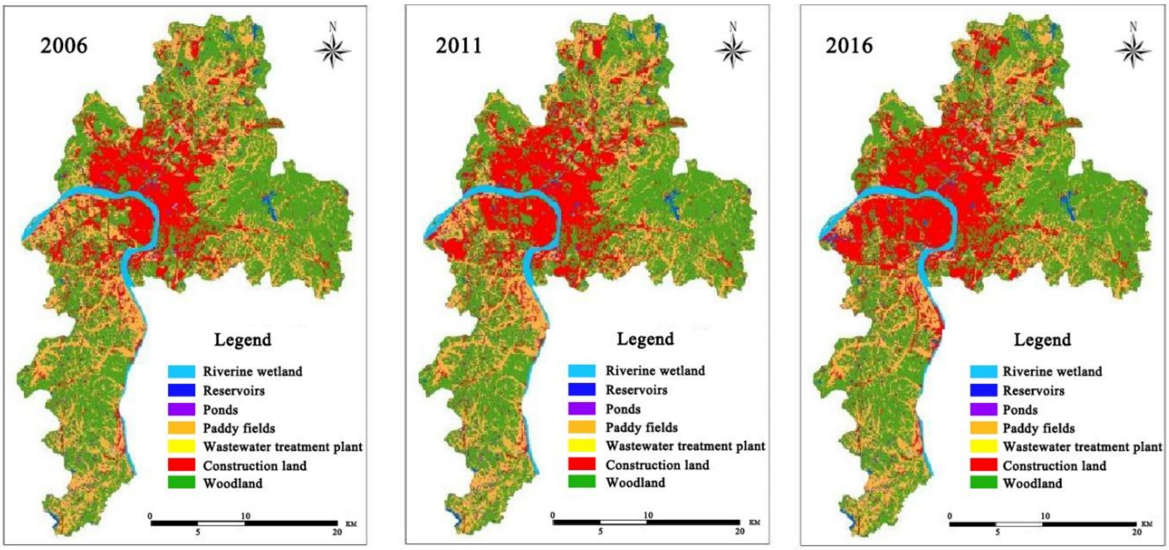

Fig. 2: Classification map of an urban wetland landscape in Zhuzhou city in 2006, 2011 and 2016.

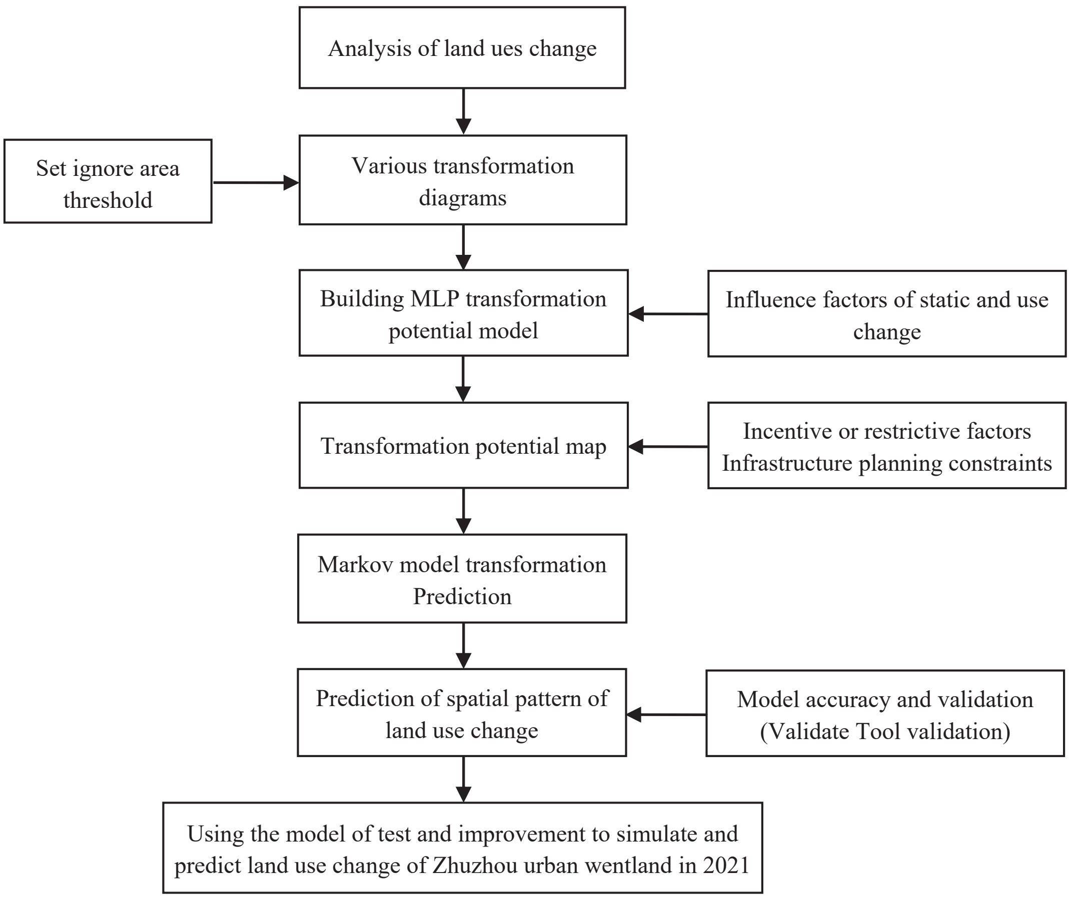

Fig. 3: Schematic diagram of LCM model construction process.

Key to LCM Model Construction

Determine the influencing factors of urban wetland land use change. Index analysis method is used to verify the relevance, and Cramer'v index value is selected for index quantitative evaluation. The calculation formula is as follows:

$$\text{Cramer's V} = \sqrt{\frac{x^2}{nxmin[(r-1),(s-1)]}} \quad \ldots(1)$$

In the formula, X^2 represents chi-square test results, R and S represent the number of rows and columns respectively, and N represents the number of samples. Cramer's V is 0.15 or a little higher, indicating that the influencing factor has a good correlation with the land use change; Cramer's V is 0.4 or a little higher, indicating that the influencing factor has a good correlation with the land use change.

Build MLP model of urban wetland transformation potential. MLP-ANN and Logistic Regression were used to construct and transform the model, and the potential index of model variables was calculated.

Markov Chain model was used to predict the variation of land use transformation in urban wetland potential transformation map, and the transformation probability matrix of urban wetland land was obtained.

Validate tool is used to test the modified Soft and Hard prediction model and obtain the prediction map of the spatial pattern change of urban wetland. Among them, the Hard prediction model results in the prediction map of urban wetland land use change. The results of the Soft prediction model are the distribution map of the vulnerability of urban wetland land use change. However, the distribution map does not show the specific result of land change, but indicates the degree of change of extremely changing areas, which is a change trend set of all selected transitions.

RESULTS AND ANALYSIS

Analysis of Wetland Land use in Zhuzhou City from 2006 to 2011 and 2011 to 2016

The land use of urban wetland reflects not only the basic relationship between wetland and urban land use change, but also the succession relationship of urban wetland landscape pattern and its interaction with urban development. In this study, the basic data and spatial changes of Zhuzhou urban wetland in 2006, 2011 and 2016 are obtained by using multi-source data and LCM platform, as shown in Table 2, Fig. 4 and Fig. 5.

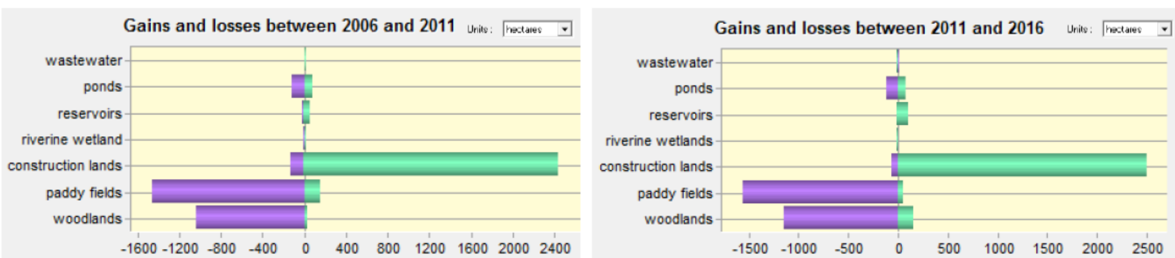

Fig. 4: Gain and loss of Wetland Land in Zhuzhou city during 2006~2011 and 2011~2016.

Table 2: Changes of Wetland Land in Zhuzhou city from 2006 to 2016.

Category	Land type	Area（ha）			Variation and range	
		2006	2011	2016	Variation in 2006-2016 (ha)	The rate of five-year dynamic change in 2006-2016 (%)
Wetland type	Riverine wetland	2216.7	2215.0	2208.9	-7.8	-0.18
	Reservoirs	474.8	527.0	619.6	144.8	15.25
	Pond	2346.5	2302.2	2262.5	-84.0	-1.80
	Paddy fields	22648.0	21332.9	19819.9	-2828.1	-6.25
	Wastewater treatment plant	4.1	4.4	12.2	8.1	98.78
	subtotal	27690.1	26381.4	24923.1	-2767	-5.00
Non Wetland type	Construction land	14952.7	17277.1	19724.2	4771.5	15.96
	Woodlands	43456.0	42440.3	41445.5	-2010.5	-2.31
	subtotal	58408.7	59717.4	61169.7	2761	2.36
Wetland rate		32.16%	30.64%	28.95%	3.21%	-

The results show that:

1. From the perspective of land use area changes, from 2006 to 2016, Zhuzhou urban wetland mainly changed from artificial wetland land to construction lands, while there was a small amount of mutual transformation between various types of artificial wetlands, and a small amount of non wetland land to artificial wetland. Among them, the change of paddy fields area is the largest, with a total decrease of about 2828.1 ha, with a five-year dynamic rate of 6.25%; the cumulative increase of reservoirs wetland area is about 144.8 ha with a five-year dynamic rate of 15.25%; the mutual increase and decrease of pond wetland area, with a total decrease of about 84 ha, with a five-year dynamic rate of 1.80%; the increase and decrease of riverine wetland and wastewater treatment area are relatively small. However, the dynamic degree of five-year change of wastewater treatment plant area is the highest among all wetland types, reaching 98.78%. In addition, the change of construction land area is the largest among all land types, with a cumulative increase of about 4771.5 ha, and its five-year dynamic rate of change is 15.96%; the same change of woodland area is more, with a cumulative decrease of about 2010.5 ha, and its five-year dynamic rate of change is 2.31%.
2. From the perspective of various land use spatial changes (Fig. 5), during 2006~2016, Zhuzhou urban wetland land use changes were mainly concentrated in the outskirts of the urban built-up area, and extended to the north and south with the main urban area as the centre, with Tianyuan District as the key change area, and there were some changes in Shifeng District, Lusong District and Hetang district. Among them, the change of land use in reservoirs wetland area is concentrated in Tianyuan District and Hetang District, which is mainly transferred from paddy fields and pond wetland, in the form of urban wetland park; the change of paddy fields is mainly concentrated in Tianyuan District, Shifeng District and Lusong District, which is mainly converted into construction land; the change of pond wetland is mainly concentrated in Tianyuan District and Shifeng District, which is mainly converted into construction land. In addition, the spatial change of riverine wetland and wastewater treatment plant is very small, which can be ignored.

Influencing Factors of Urban Wetland Change in Zhuzhou City

Using ArcGIS 10.4 software and Cramer's V index value calculation, combined with multi-source data, this study has determined five types of urban wetland impact factors: elevation, slope, distance from the public and commercial centre, distance from the centre of human disturbance and distance from the main road. The correlation verification results are as follows (Fig. 6): the Cramer's V of elevation is 0.1663; the Cramer's V of the slope is 0.1703; the Cramer's V of distance from the public and commercial centre is 0.0951; the Cramer's V of distance from the centre of human disturbance is 0.0851; the Cramer's V of distance from the main road is 0.0965.

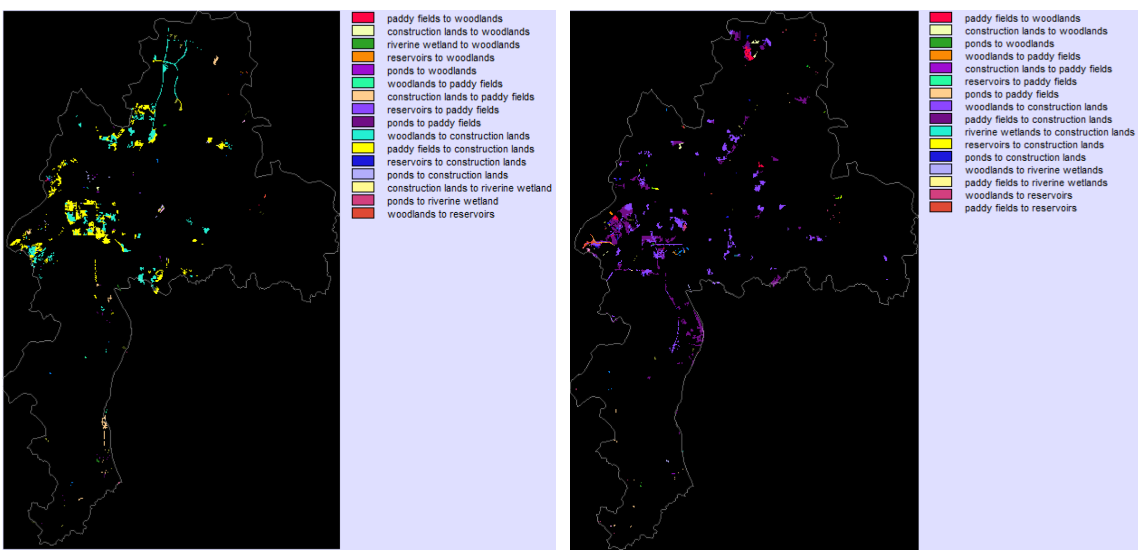

Fig. 5: Land use spatial change map of Zhuzhou city in 2006-2011 and 2011-2016.

Cover Class :	Cramer's V :	P Value :
Overall V	0.1663	0.0000
paddy fields	0.3500	0.0000
riverine wetlands	0.2664	0.0000
reservoirs	0.2021	0.0000
construction lands	0.1932	0.0000
wastewater	0.0601	0.0000
ponds	0.0538	0.0000

Cover Class :	Cramer's V :	P Value :
Overall V	0.1703	0.0000
paddy fields	0.3753	0.0000
riverine wetlands	0.2818	0.0000
reservoirs	0.2012	0.0000
construction lands	0.1775	0.0000
wastewater	0.0616	0.0000
ponds	0.0551	0.0000

Cover Class :	Cramer's V :	P Value :
Overall V	0.0951	0.0000
paddy fields	0.2226	0.0000
riverine wetlands	0.1250	0.0000
reservoirs	0.1206	0.0000
construction lands	0.1151	0.0000
wastewater	0.0333	0.0000
ponds	0.0204	0.0000

Cover Class :	Cramer's V :	P Value :
Overall V	0.0851	0.0000
paddy fields	0.1754	0.0000
riverine wetlands	0.1577	0.0000
reservoirs	0.1516	0.0000
construction lands	0.0969	0.0000
wastewater	0.0214	0.0000
ponds	0.0061	0.0000

Cover Class :	Cramer's V :	P Value :
Overall V	0.0965	0.0000
paddy fields	0.2267	0.0000
riverine wetlands	0.1340	0.0000
reservoirs	0.1207	0.0000
construction lands	0.1077	0.0000
wastewater	0.0328	0.0000
ponds	0.0222	0.0000

Fig. 6: Test explanatory power of elevation, slope, distance from public and commercial service centres, distance from main disturbance centres and distance from main roads.

The results of the above five kinds of factors showed that elevation, slope, distance from the public and commercial centre, distance from the centre of human disturbance, distance from the main road were all related to the land uses change of Zhuzhou urban wetland. Among them, the natural factors (elevation, slope) have a strong correlation, while the human factors (distance from the administrative and commercial centre, distance from the human disturbance centre, distance from the main road) have a relatively weak correlation.

Construction of Transition Potentials Model

Using LCM model platform, the sub-models of riverine wetland use change, reservoirs land use change, ponds land use change, paddy fields land use change, woodland land use change and construction land use change are combined to model transformation potential. After analysis and calculation, 21 maps of transformation potential of various classes are obtained, some of which are shown in Fig. 7 and Fig. 8. In these maps, the value of colour increases with the change from cold colour to warm colour, which indicates that the potential of one type of land to another is greater. After a comprehensive analysis of all the transformation potential maps, the results show that: the closer to the central urban area, the higher the transformation potential of all kinds of urban wetlands in Zhuzhou city, especially in the flat area, the greater the transformation potential of pond and paddy fields to construction land; the lower the transformation

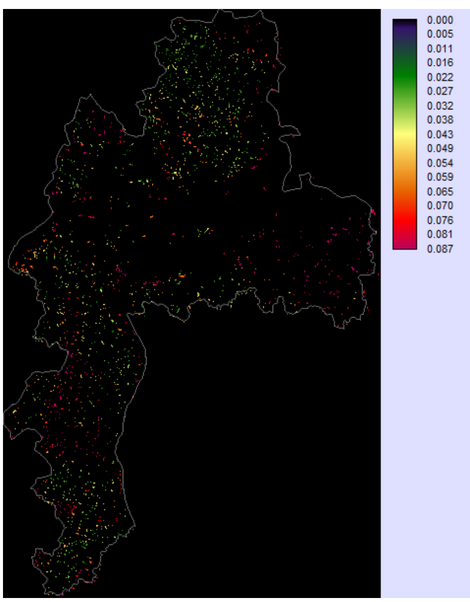

Fig. 7: Transition of pond into construction land potential.

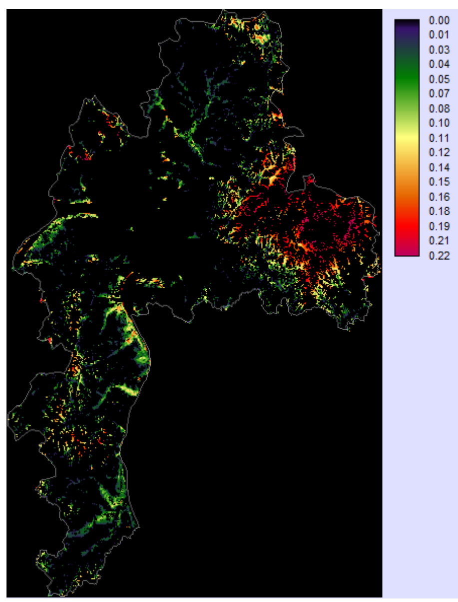

Fig. 8: Transition of paddy fields into construction land potential.

potential of wetlands in the peripheral area of the city, especially in the mountainous area with a large slope, the lower the transformation potential of all kinds of wetlands; the potential of intertype transformation is generally low, but the potential of transformation from a small number of regional ponds and paddy fields to reservoirs areas is large.

Simulation Prediction and Result Test of Urban Wetland Land Use Change in 2016

In the LCM platform, Markov Chain method is applied to calculate the transformation probability matrix of the urban wetland land transfer changes in 2016, and the probability matrix results (Table 3) are obtained, which reflect the transformation probability matrix between various types of land. Using the result and the Hard prediction model, we can finally generate the prediction map of urban wetland land use in Zhuzhou city in 2016.

In order to verify and provide the accuracy of LCM construction, this study uses validate tool to compare the prediction map of wetland land use in Zhuzhou city in 2016 with the current map of wetland land use in Zhuzhou city. The validate tool classifies the capacity of maintaining land use type area (maintaining quantity consistency) in LCM modelling into three categories: none (no [n]), complete (perfect [P], medium [M]). Based on the traditional kappa coefficient formula, four kinds of kappa expansion indexes are generated by adding spatial information parameters: random Kappa index (kno), location Kappa index (klocation), hierarchical location Kappa index (klocation strata), and standard Kappa index (kstandard). The test results (Fig. 9) show that: the comprehensive index of kapps coefficient of all the tested is higher than 0.8, the consistency of the two comparison drawings is high, the difference is small, and the simulation and prediction effect is good. It is predicted

Table 3: Probability matrix of land class transformation.

Given:	Probability of changing to:						
	Riverine wetlands	Reservoirs	Ponds	Paddy fields	Wastewater treatment plant	Woodlands	Construction land
Riverine wetlands	0.9965	0.0000	0.0000	0.0000	0.0000	0.0135	0.0000
Reservoirs	0.0000	0.9700	0.0117	0.0134	0.0000	0.0030	0.0419
Ponds	0.0015	0.0865	0.9501	0.3123	0.0005	0.0235	0.2260
Paddy fields	0.0000	0.0518	0.0420	0.9354	0.0000	0.0201	0.2606
Wastewater treatment plant	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
Woodlands	0.0000	0.1532	0.2244	0.0131	0.0000	0.9760	0.3233
Construction land	0.0002	0.0325	0.0264	0.0076	0.0000	0.0508	0.9913

Classification agreement/disagreement
According to ability to specify accurately quantity and allocation

Information of Allocation	Information of Quantity: No[n]	Medium[m]	Perfect[p]
Perfect[P(x)]	P(n) = 0.4694	P(m) = 0.8985	P(p) = 1.0000
PerfectStratum[K(x)]	K(n) = 0.4694	K(m) = 0.8985	K(p) = 1.0000
MediumGrid[M(x)]	M(n) = 0.4503	M(m) = 0.8731	M(p) = 0.8719
MediumStratum[H(x)]	H(n) = 0.1250	H(m) = 0.3935	H(p) = 0.3935
No[N(x)]	N(n) = 0.1250	N(m) = 0.3935	N(p) = 0.3935

AgreementChance = 0.3250
AgreementQuantity = 0.2685
AgreementStrata = 0.0000
AgreementGridcell = 0.5796
DisagreeGridcell = 0.0254
DisagreeStrata = 0.0000
DisagreeQuantity = 0.0715

Fig. 9: Validation of urban wetland land use change prediction in 2016.

that the LCM model of Zhuzhou Urban Wetland in 2016 is effective and up to standard.

Simulation and Prediction of Land Use Change of Urban Wetland in 2021

Based on the remote sensing image interpretation map of Zhuzhou city in 2011 and 2016, this paper uses the LCM to simulate and predict the urban wetland land use change in 2021, and finally obtains the land use change prediction map (hard prediction map) and vulnerability distribution map (soft prediction map) of Zhuzhou city in 2021 and relevant data (Table 4, Fig.10, Fig.11), among which the hard prediction map is a wetland land use map with the same classification as the input data; the soft prediction map is a continuous map showing the vulnerability of urban wetland land use in 2021, which does not indicate what will change but indicates the extent of urban wetland land use in areas with rapid changes.

The prediction results in 2021 show that the overall change of Zhuzhou urban wetland is relatively small compared with 2016. Among them, the area of riverine wetland remained unchanged basically; the area of reservoir area increased by 82.4 ha in total, with a five-year dynamic rate of 9.75%, mainly distributed in Shifeng District in the north of urban area; the area of pond wetland increased or decreased with a total of 34.6 ha, with a five-year dynamic rate of 1.53%; the area of paddy fields still decreased the most, with a total of 1364.8 ha and a five-year dynamic rate of change of 6.89%, mostly concentrated in the outskirts of the central city, mainly converted into construction land, but the analysis found that the basic farmland is still well protected and controlled. In addition, urban construction land is further expanded from the central urban area to the surrounding areas, especially in the north and east of the urban area, with a cumulative increase of 2289.3 ha and a five-year dynamic rate of 11.61%.

CONCLUSION AND DISCUSSION

(a) At present, "Urban Wetland" does not have a completely scientific and recognized concept, but the research on urban wetland has been one of the hot spots in the academic circle. In this paper, referring to domestic and foreign practices and current standards, combined with the current situation of Zhuzhou wetland, the urban wetland is divided into riverine wetland, reservoirs, pond, paddy fields, wastewater treatment plant and other

Table 4: Table of predicted changes of Urban wetland land in Zhuzhou city from 2016 to 2021.

Category	Land type	Variation and range			
		2016	2021	Variation in 2016~2021(ha)	The rate of five-year dynamic change in 2016-2021(%)
Wetland type	Riverine wetland	2208.9	2219.1	10.2	0.46
	Reservoirs	619.6	680.0	60.4	9.75
	Pond	2262.5	2227.9	-34.6	-1.530
	Paddy fields	19819.9	18455.1	-1364.8	-6.89
	Wastewater treatment plant	12.2	13.8	1.6	13.11
	subtotal	24923.1	23595.9	-1327.2	-5.33
Non Wetland type	Construction land	19724.2	22013.5	2289.3	11.61
	Woodlands	41445.5	40535.3	-910.2	-2.20
	subtotal	61169.7	62548.8	1379.1	2.26
Wetland rate		28.95%	2671%	2.24%	-

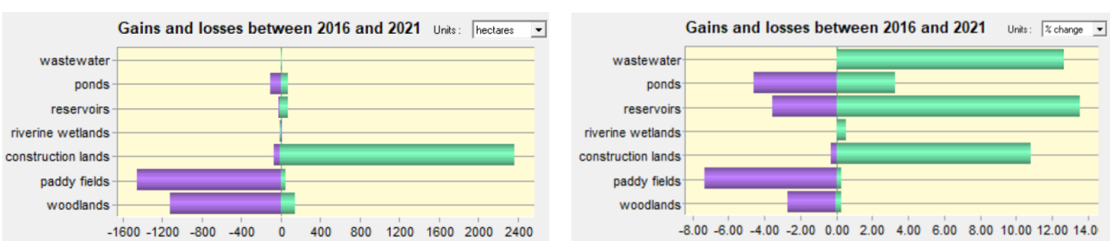

Fig.10: Gain and loss and proportion change of Zhuzhou urban wetland in 2016~2021.

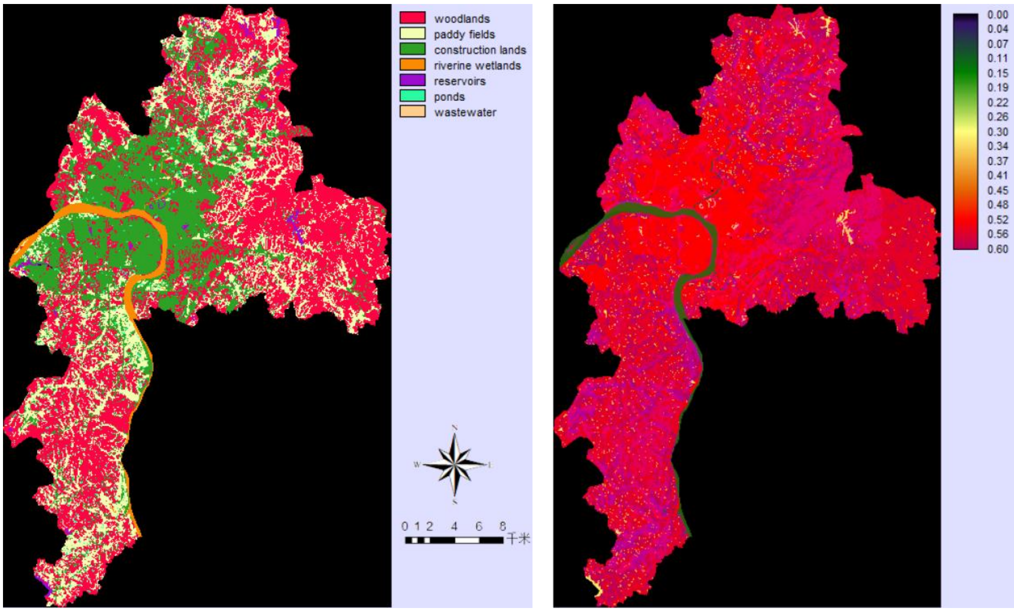

Fig. 11: Change hard and soft prediction of urban wetland land use in Zhuzhou City in 2021.

types to carry out relevant research, which has certain theoretical and practical reference value.

(b) Through the analysis and research on the land use change of urban wetland in Zhuzhou city from 2006 to 2016, the results show that: on the one hand, the overall spatial layout and area of Zhuzhou urban wetland have remained relatively stable in the past decade, most of the change areas are concentrated in the periphery of the central urban area, mainly from the artificial wetland to the construction land; on the other hand, during the period of 2006~2016, Zhuzhou's urbanization process has been intensified, and a large number of ponds and paddy fields in suburban areas have changed into various types of urban construction land. In addition, the research results also reflect that Zhuzhou city is actively transforming and upgrading its urban development, and the construction of ecological civilization has achieved preliminary results: Xiangjiang River water resources have been gradually effectively protected, and the number of reservoirs and ponds represented by wetland parks has increased, and most of them are concentrated around the river, irrigation land and pool concentration areas. These analyses are basically consistent with the current situation of Zhuzhou's urban development.

(c) The simulation and prediction results of Zhuzhou urban wetland in 2021 are consistent with the overall change trend of the wetland from 2006 to 2016, and basically, conform to the Master Planning of Zhuzhou City (2006-2020) and the actual development direction. This shows that the research methods and achievements based on LCM can be used as auxiliary technical tools for urban master planning and urban wetland system planning, and provide scientific support for the overall protection and sustainable utilization of urban wetland resources.

(d) To some extent, the research results of Zhuzhou wetland land use change reflect the basic characteristics of urban wetland landscape pattern: the degree of landscape fragmentation and separation is large, and the diversity and evenness of landscape are poor. In addition, the evolution of wetland landscape pattern is driven by many natural and human factors, among which natural geographical conditions are one of the key factors affecting wetland land use, and human activities also have a huge impact on wetland land use, with both positive and negative effects. Therefore, it is necessary to monitor the wetland resources of Zhuzhou city (including wetland area, wetland spatial change, wetland environmental quality, wetland biodiversity, etc.) in a long-term and dynamic way, and master the driving force of urban wetland landscape evolution in an all-round way. At the same time, we can use the methods and results of this study, combined with the Zhuzhou city master plan, to determine the key areas of urban wetland construction in the future, and speed up the construction of wetland park and waterfront space.

(e) It is suggested to strengthen the protection and utilization of wetland in Zhuzhou from the urban planning stage. On the one hand, expand the control scope of the existing urban blue line, bring important artificial wetlands into the blue line protection scope, and strengthen the social service function of urban wetland. On the other hand, the primary protection status of the Xiangjiang River is further emphasized. A buffer zone is set around the blue line to build protective green space and strictly control other construction. Furthermore, it is suggested to carry out the special planning of the Zhuzhou wetland system and incorporate it into the urban master plan, so as to realize the strategic goal of Zhuzhou's ecological civilization city construction.

(f) Due to the limitation of the original spatial resolution (30 × 30m) of the Landsat series remote sensing image, which is the basic data source used in this study, there are some limitations in the extraction of urban wetland information data, especially for some riverine wetlands whose average width of the water surface is less than 30m, which cannot be effectively identified. Therefore, it has a certain impact on the accuracy and effectiveness of the simulation prediction and result analysis of LCM. In the follow-up research, we can try to choose a higher resolution HD remote sensing image to solve such problems. In addition, as a kind of comprehensive model, the intelligent architecture of LCM needs to be improved, and the involvement of multi-source data information is also an important direction of model improvement.

FUNDING

This research is funded by the Research Foundation of Education Bureau of Hunan Province, China (Grant No. 14B196, 18C1802, XJT2015(291)-186); Key Project of Science and Technology plan of Hunan Province, China (Grant No. 2018NK2052).

ACKNOWLEDGMENTS

This study is supported by Hunan Education Department's "12th five-year plan" Key Discipline Funding Project (2011-76); The state forestry administration's 13th five-year key discipline.

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