Analysis of Urban Spatial Historical Evolution and Exploration of Land Use/Cover Change Based on 3S and Cellular Automata in Tianjin (China)

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Abstract. This paper analyzes the evolution of urban space in Tianjin in the past few decades, and discusses the relationship between future land use/cover change (LUCC) and urban development in Tianjin, China. Tianjin is an important city of the Beijing-Tianjin-Hebei region whichis one of the three major urban agglomerations in China. The production and living of human beings have a huge impact on land use change in the region. This paper uses the remote sensing images of six phases in Tianjin from 1987 to 2023 to measure the LUCC in Tianjin over the past 40 years, and analyzes the natural and social drivers that influence its changes. The cellular automata model (CA) and GIS technology were used to predict the future development of urban development in Tianjin, and the results of simulation analysis of land use types in Tianjin in 2028 were obtained.

Keywords: urban spatial historical evolution, Land Use/Cover Change, urban spatial, cellular automata, Tianjin

1 INTRODUCTION

Land use change is the result of natural interactions between humans and our survival. LUCC is an extremely complex process that is influenced by the interaction of natural and social systems in different spatial and temporal scales [1]. At present, research on land use change and its impact is increasingly becoming the core of global environmental change and sustainable development research [2]. The current research of LUCC in China is mainly concentrated in some active or fragile areas [3].

With the development and application of 3S technology, the research on the use of spatial simulation forLUCC has gradually emerged and become popular. According to the data, most studies still use the CA Model and CLUE-S Model [4].The cellular automaton (CA) provides a more scientific method for the simulation of geographic systems with spatio-temporal features. The CA model can easily acquire some of the necessary features of spatial dynamics and simulate the expansion of the city through a "top to down" approach to create a more appropriate LUCC model.

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Tianjin,as being one major city of the Beijing-Tianjin-Hebei region and economic belt, has been fully influenced by human activities and economic development. The strong support of government policies, the investment of the economy and the key planning and construction of the city have made Tianjin flourish. In the next few years, the development trend of Tianjin in China cannot be underestimated. LUCC can objectively reflect the land use situation in Tianjin, and its analysis and prediction are of great reference value for Tianjin's future planning and development.

The aim of this paper is to analyze the LUCC data in the past few decades and explore potential future LUCC dynamics in Tianjin using 3S technology and CA model.

2 DATA AND PROCESSING

2.1 Study area

As one of the four municipalities of China, Tianjin has abundant land resources. Among them, more than 40% of the total land area of the city is cultivated land; the residential area and industrial and mining land accounts for 18.33%; water area accounts for 26.43%; unused land accounts for 5.69%. At the same time, more than 1,200 square kilometers of wasteland and tidal flats to be developed are located in the Binhai New Area along the lower reaches of the Haihe River.

2.2 Data processing

According to the purpose and specific conditions of the study, this paper uses the TM image of the Landsat series satellite as the basis for the detection of LUCC.

In this study, multi-temporal remote sensing data was selected. The original data used between July and September was used in this study. Tianjin spans the top and bottom of the two strips of TMwhich makes four scenes need to be spliced before use.In this study, the geometric correction of the TM image in 1987 is firstly carried out, and the quadratic polynomial transformation model in the geometric correction model is adopted. Based on the corrected 1987 TM image, the TM images of 1993, 2000, 2008, 2015 and 2023 were geometrically corrected one by one, so that the calibration results can be well satisfied with the LUCC detection studies.

3 METHODOLOGY

3.1 Principle of the classification method

CA is a local grid dynamics model with discrete time, space and state, spatial interaction and time causality. It has the ability to simulate the spatio-temporal evolution process of complex systems and powerful computing power.

Use the language of the collection to describe the CA model.

$$S_{t+1} = f(S_t, N) \tag{1}$$

S is a limited set which represents the cell state. N represents the cell neighborhood. t is the time of the conversion. f is the local conversion rule. In this study, the CA modeling framework includes four components: the historical LUCC maps in the past few decades, the probability maps, the neighborhood characteristics and the transition rules which will influence the LUCC[5].

3.2 Principle of predictive model

Thetwo-dimensional cellular automaton's neighbor definitions are commonly used by the model of Von·Neumann and the model of Moore.

The mathematical definition of the model of Von·Neumannis :

$$N_{Neumann} = \{v_i = (v_{ix}, v_{iy}) | |v_{ix} - v_{ox}| + |v_{ix} - v_{ox}| \le 1, (v_{ix}, v_{iy}) \in Z^2\} (2)$$

The mathematical definition of the model of Moore is:

$$N_{Moore} = \{v_i = (v_{ix}, v_{iy}) | |v_{ix} - v_{ox}| \le 1, |v_{ix} - v_{ox}| \le 1, (v_{ix}, v_{iy}) \in Z^2\} (3)$$

Where$v_{ix}$and$v_{iy}$are the row and column coordinate values of the neighbor cells, $v_{ox}$and V_{oy} are the row and column values of the center cell.

4 RESULT AND DISCUSSION

4.1 Analysis of the LUCC in the past few decades in Tianjin

The preprocessed remote sensing images are then supervised and classified. After the classification is completed, the classification results should be evaluated accurately, and the inspection report is obtained. The results show that the overall classification accuracy and Kappa coefficient meet the classification requirements. The classification result appears as the six images from 1987 to 2023. (Fig.1).

After obtaining the results of LUCC by analysis the classified satellite images for the detection years, the ArcGIS platform and its spatial analysis function were used to extract the land cover of the study areas from 1987 to 1993, 1993 to 2000, 2000 to 2008, 2008 to 2015, and 2015 to 2023. The matrix is transferred and the change type, change area and rate of change of the corresponding LUCC in the study area are measured. The ENVI band operation is performed on the classified land cover classification maps of adjacent years, and different conversion types are assigned different values. Re-measure the number, rate and type of conversion of each type of land use type (Table 1, Table 2).

Table 1. Proportion of land cover types obtained from classified satellite images. (1987-2023). (Unit:%)

Land Type /Year	1987	1993	2000	2008	2015	2023
Building Land	7.31	12.78	12.67	19.89	28.29	33.14
Arable Land	44.02	62.56	74.38	64.19	58.38	57.13
Woodland	38.92	13.47	5.03	4.46	3.93	2.29
Waters	9.75	11.19	7.72	11.46	9.40	7.44
Total	100	100	100	100	100	100

Table 2. Growth rates of land cover types (1987-2023). (Unit: Square kilometers / Year)

Land Type/Year	*1987-1993*	*1993-2000*	*2000-2008*	*2008-2015*	*2015-2023*
Building Land	130.85	-2.87	20.81	335.63	119.95
Arable Land	443.65	281.69	-71.50	-275.10	-36.08
Woodland	-605.94	-201.30	-9.80	-11.99	-39.27
Waters	34.634	-78.27	60.44	-49.28	-44.63
Total	3.2	-0.75	-0.06	-0.74	-0.04

From 1987 to 2023, the type of LUCC in Tianjin has undergone tremendous changes in the past decades. Among them, the growth rate is the largest in construction land, and it has maintained a strong multi-growth trend. Among them, woodland is significantly reduced, and its decline is the largest. The urban expansion has the characteristics of large scope and fast speed. In the early stage, the six center districts were used as the core to expand rapidly. Later, the land reclamation was expanded by land reclamation. The expansion of the new core of Binhai New Area and the outer suburbs began (Fig. 2).

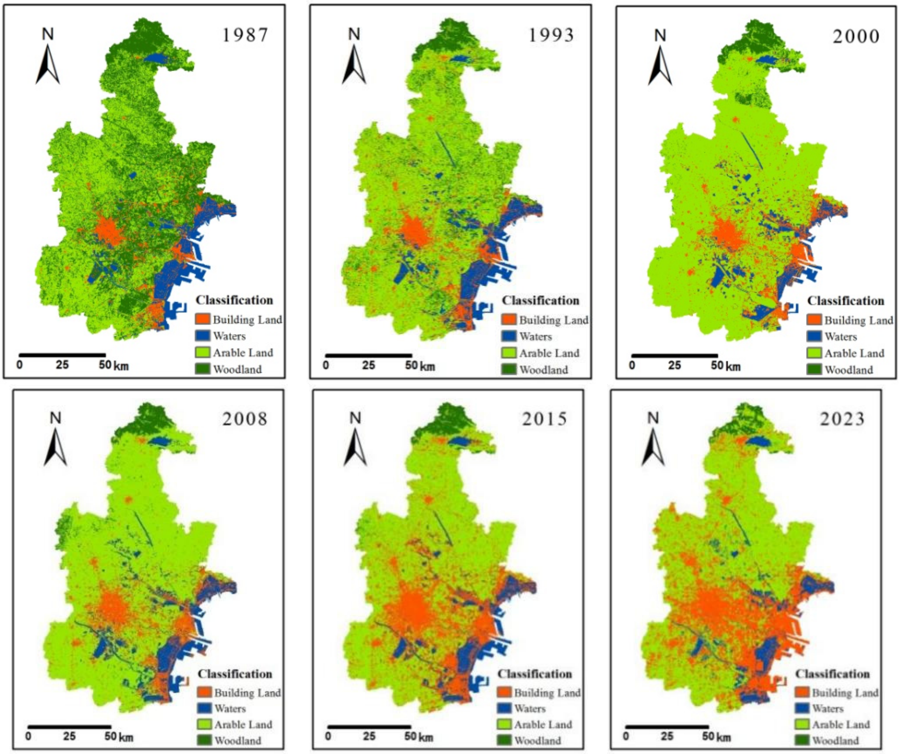

Fig. 1. Classified satellite images for the detection years (1987, 1993, 2000, 2008, 2015,2023).

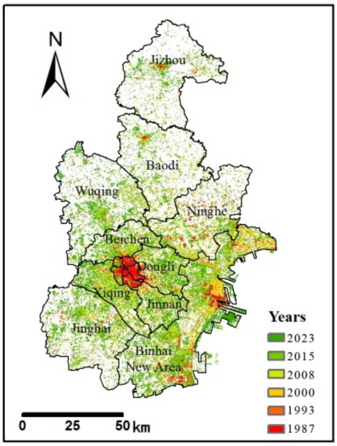

Fig. 2. Urban expansion from 1987 to 2023

4.2 Analysis of the driving mechanism of urban expansion in Tianjin

The development and change of cities are influenced and influenced by natural, social, economic, cultural, political, legal and other factors at different time and space scales. For natural reasons, there are mountains in the north of Tianjin, and the rest of the terrain is low-lying. The flat terrain provides a broad space for urban expansion. In 2005, Binhai New Area was written into the “Eleventh Five-Year Plan” and incorporated into the national development strategy, becoming a national-level new district with national key support for development and opening up. In April 2017, the CPC Central Committee and the State Council decided to establish the Xiong'an New District in Hebei which provide new policy support for Beijing-Tianjin-Hebei. In short, under the influence of social economy, natural environment, policy control and other factors, the pattern of land use in Tianjin has evolved over time.

5 CONCLUSIONS

The urbanization level of Tianjin will be greatly improved in 2028(Fig.3), as can be seen from the area of construction land in the map. The city center of Jizhou District will separate for two parts, so the urban functions of these two centers can also be planned and allocated in advance. There will also be a smaller urban center in the northern part of Wuqing. Because it is bordered by Beijing, it can make full use of its location advantages for urbanization in the future. The six districts in the city have reached saturation as far as the simulation is concerned. The expansion of the city will be carried out in the four districts around the city. Infrastructure and transportation construction will also follow the pace of urbanization.

The area of cultivated land will also decrease, which is an inevitable trend in the urbanized environment. However, as a municipality with a dense population, it is extremely urgent to keep the cultivated land and green area. The waters were originally concentrated around the Binhai New Area, but the construction of the building will reduce the water area. At the same time, the surrounding areas of the Qilihai and other wetlands are affected by urbanization, and the problem of ecosystem disorder cannot be ignored. Therefore, policies should be introduced to protect the reservoirs and wetlands. The distribution of woodland is still concentrated in the northern part of Jizhou, and the area is also decreasing. In the future, the ecological environment of Tianjin can be expected to protect through the protection of national policies and the protection of forest land in northern Tianjin.

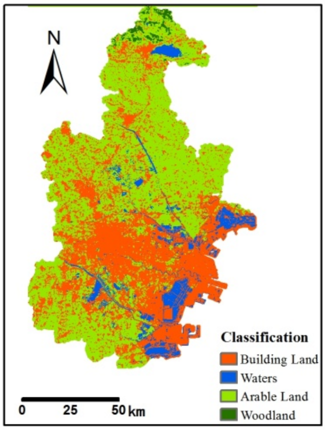

Fig. 3. Land use type simulation map of Tianjin in 2028 based on IDRISI Selva.

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