Spatial and temporal evolution of urban land use change in Nanchang by CA-Markov model

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Research Article

Keywords: Nanchang, Land use change, CA-Markov model, Predicted, Sustainable development

Posted Date: September 14th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3287445/v1

Abstract

With the Rapid urban expansion and development, the contradiction between human and land has gradually emerged, and how to scientifically and rationally use land is an inescapable problem. Nanchang was selected to study in the study, land use change images of Landsat from 2005 to 2020 was analyzed, and predicted land use situation of Nanchang in 2035 by CA-Markov model, to analyze and evaluate the scientific and effective use of land resources in Nanchang. The results show that from 2005 to 2020, woodland continued to decrease, with a total decrease of 300.27 km^2 in 15 years; unused land was developed into construction land and agricultural land, the proportion of unused land became less and less; the proportion of grassland and construction land increased, and the expansion rate of construction land increased. Agricultural land, woodland, grassland and water area are greatly affected by elevation slope; The construction land is greatly affected by the convenience of transportation, and the old construction land as the initial boundary of expansion has driven the transformation of surrounding land use. In 2035, agricultural land will remain largely stable; wood land will slightly decrease; both grassland and water area show a decreasing trend; the construction land increase by 306.31km^2. Understanding the characteristics and laws of land use change in Nanchang is conducive to urban sustainable development planning. Simultaneous development and protection are conducive to the sustainable use of land resources and sustainable regional development.

1. Introduction

With the rapid development of urbanization, the scale of land use has undergone great changes(Cai et al., 2020; Wang et al., 2021). The expansion of construction land and shrinking of woodland grassland and water area had made the contradiction between people and land increasingly prominent(Zhou et al., 2020b). When the contradiction between people and land gradually emerges, it inevitably leads to certain ecological threats, such as frequent geological disasters, global warming, serious industrial pollution, soil desertification and other problems(Jin et al., 2021). Formulating eco-friendly land use policies according to the law of urban development(Brady and Irwin, 2011). It is necessary to research temporal and spatial changes of urban land use and its influencing factors, so as to seek reasonable land development and utilization methods, and exploring scientific spatial layout are conducive to the proposal of regional sustainable land use development strategies.

Remote sensing data and models enrich the method to study urban land use change(Liu et al., 2022; Wang et al., 2022). Yi (1993) successfully determined the transfer probability of land use type by remote sense image, and predicted the change trend of land use type by using the Markov chain model, which put forward reasonable suggestions for the future development strategy of the city. Ming(2001) used satellite image data for spatial overlay analysis to obtain spatial and attribute data of land use change. Based on this, he carried out dynamic analysis of land use change, clarified regional characteristics of land use change in the Bohai Rim region, and provided policy support for sustainable land use. According to the spatial meaning of land use change, Shujin(2002) subdivided the unchanged part, the transferred part and the newly added part into three spatial types. Based on this, he evaluated and analyzed the existing quantitative analysis and dynamic attitude models for estimating the rate of land use change, and proposed a revised spatial analysis and calculation model to accurately measure the degree and rate of dynamic change of various types of land use, and predicted the impact of Beijing's urban development on the marginal areas. Huangjing et al.(2008) took Hangzhou as study area, analyzed its urban expansion by SLEUTH model, predicted the existing development trend, traffic guidance, moderate protection of farmland and compact city, concluded through comparative analysis that the strict protection of basic farmland has a certain inhibitory effect on the development of urban expansion. Helen (1985) creatively used the CA model to simulate land use change in combination with geography theory. On this basis, the CA model is also widely used in urban planning and development manage (Chen et al., 2018; Zhao et al., 2019). White and Engelen (1993) simulated the spatial and temporal structure and trends of urban land use in the United States by building a CA model, results showed that they had very similar fractal dimensions. Nouri et al (2014) have successfully run the CA-Markov model to predict land change in the Anza area, the future trend of land use change was simulated successfully and the countermeasures were put forward, and it leads to the research direction for land use change. On the basis of Helen, scholars synthesize the advantages and disadvantages of different models and optimize the models based on different conditions, which improved the prediction accuracy of regional land use change. Based on complex system theory and agent model, Youqi (2011) summarized the current research progress of land use change science from the perspectives of theory and method. The shortcomings of the existing ABM model are analyzed, and it is proposed to combine the ABM model with the agent model to reasonably predict the dynamic process of land use change (structure and function), and explain evaluate land change. Shuang(2018) used the Markov model to predict the number of land use changes, and then input the prediction results as parameters into the CA model to realize the simulation and prediction of spatial distribution, its simulation results are reliable, and the driving factors and weights adopted by the algorithm are reasonable, which can better explain the land use change in 2013 and reasonably predict the land development in the future. Chunzhu(2020) explores the technical method system of urban development boundary delineation based on MCR and CA models, and constructs the urban development boundary delimited by the integration of MCR model and CA model from the perspective of actual supply and ideal demand according to the principle of supply and demand balance, which can scientifically optimize the urban development pattern, effectively solve the contradiction between urban development and agricultural land protection, and provide method reference and decision-making basis for planning practice. Zhiguo(2021) took Ninxia as the research area, based on land use and related remote sensing data, combined with CA-Markov to compare and analyze the future urban growth boundary development under the condition of ecological environment quality assessment, achieved the desired effect. Xiaoqi(2021) innovatively introduced the dynamic spatial Markov chain model on the basis of the static (spatial) Markov chain model to systematically analyze the spatial and temporal situation and influencing factors of urban tourism development in China. Degang(2021) used the CA-Markov model to predict the spatial pattern of land use/cover under ecological conservation scenario (EVC) and natural change scenario (NVC), respectively, and used the modified carbon density InVEST model to evaluate the carbon storage in the Yellow River Basin from 2005 to 2030 for six periods, it provides scientific significance for the implementation of ecological protection. Therefore, the combination of RS and GIS technology, combined with the prediction of CA-Markov model, can better predict the temporal and spatial changes of land use change, which is conducive to realizing the sustainable use of regional land resources and regional sustainable development, and promoting the development of urban planning and the promotion of beautiful China(Gashaw et al., 2018; Mitsova et al., 2011; Zhou et al., 2020a). Since October 2010, Nanchang was included in the first batch of low-carbon pilot cities in China, and since then, many scholars have studied the spatial structure, land use drivers and urban development strategies of Nanchang, but most of them just consider time or space factor, and there are shortcomings in comprehensiveness. In this study, we propose to identify the spatiotemporal change mechanism of land use in Nanchang through the prediction of remote sensing imaging and CA-Markov model, clarify the characteristic factors of land use change, predict the trend of land use change, and propose a rational and efficient use strategy of land resources.

2. Material and method

2.1 Study site

Nanchang City is located in the north-central part of Jiangxi Province, in the lower reaches of the Gan River, the lower reaches of the Fu River, and the shore of Poyang Lake, located at 115°27'~116°35' east longitude and 28°11'~29°11' north latitude (Fig. 1)(Li et al., 2021). It borders Shangrao City in the east, Fuzhou City in the south, Yichun City in the west, and Jiujiang City in the north, with a land area of 7432.21 square kilometers. Nanchang is dominated by plains, the southeast area is flat, the northwest area is more hilly, the terrain difference is large, the forest coverage accounts for about 30% of the total area of the city. The soil of Nanchang is mainly composed of red soil, purple soil, stony soil, aquic soil and paddy soil.

2.2 Data collection

The basic data of this study were obtained from the Landsat TM/ETM + image through the US Geological Survey (https://www.usgs.gov/), and the data of Landsat 5 TM in 2000, the data of two periods in 2005, the data of Landsat 7 in 2015, and the data of Landsat 8 in 2020 were selected, each phase contains two scenes, the orbital numbers are 122/40 and 121/40, and the cloud cover is below 5%. The specific impact information is shown in Table 1.

Table 1
Data information of the remote sensing image

Series	Data identification	Stripe	Row	Cloud cover %	Data time
Landsat5 TM	LT51210402005304BJC00	121	40	0.03	2005-10-31
	LT51220402005311BJC00	122	40	0.54	2005-11-07
	LT51210402010014BJC00	121	40	0.01	2010-01-14
	LT51220402010309BKT00	122	40	0.75	2010-11-05
Landsat7	LE71210402015292EDC00	121	40	0.37	2015-10-19
	LE71220402015043EDC00	122	40	0.01	2015-02-12
Landsat8	LC81210402020106LGN00	121	40	0.11	2020-04-15
	LC81220402020225LGN00	122	40	4.96	2020-08-12

In order to complete the simulation of land use change, combined with the existing classification basis, and improve on this basis, so that the classification can provide the basis and guarantee for the research of land use change, it is divided into 6 categories with reference to the land use/land cover monitoring data classification system of the Chinese Academy of Sciences, including agricultural land, woodland, grassland, water area, construction land and unused land. See Table 2 for specific explanations. Other economic, land and forestry data are from Jiangxi Provincial Statistical Yearbook, Jiangxi Provincial Water Resources Bulletin and Jiangxi Provincial Ecological and Environmental Status Bulletin.

Table 2
Land use definition

No.	Land use type	Definition
1	Agricultural land	Agricultural land, including paddy fields, dry land, etc
2	Woodland	Including woodland, woodland, thinned forest, and other woodland
3	Grassland	It is mainly herbaceous plants and covers more than 5% of all kinds of grasslands
4	Construction land	Refers to residential areas and other construction land such as industrial and mining, transportation, etc
5	Waters	Refers to natural land waters and land used for water conservancy facilities
6	Unused land	Unused land, including hard-to-use land

2.3 Method

Land use dynamics refers to the change of a certain land use quantity in a certain period of time in a certain area:

$$K = \frac{U_2 - U_1}{U_1} \times \frac{1}{T} \times 100\%$$

Where: U_1 is the value of land uses of a type in the U_1 period; U_2 is the value of land uses of a certain type in the U_2 period; T is the study period; K is Land use dynamics(Li et al., 2017).

The category of land use in a certain period can be compared with the possible situation in the Markov process, which is only relevant to the type of land use of the previous period. Therefore, the following formula can predict the evolution of the land:

$$S_{t+1} = P_{ij} \times S_t$$

where, S_{t+1}, S_t. are the land use state at t and t + 1 period; P_{ij} is the land use type transfer probability matrix, which can be expressed by the following formula(Alves et al., 2022):

$$P_{ij} = \begin{bmatrix} P_{11} & \cdots & P_{1n} \\ \vdots & \ddots & \vdots \\ P_{n1} & \cdots & P_{nn} \end{bmatrix}$$

The cellular automata model (CA) is a grid dynamics theory in which the interaction and temporal connections of space are local, and the space-time relationships and morphological conditions are scattered(Zheng et al., 2012). The formula is as follows:

$$S_{t+1} = f\left[S_t\ N\right]$$

Where: S is the finite discrete set state of the cell; t, t + 1 are different moments, N is the domain of the cell, and f is the cell transformation rule of local space. The Markov model has the ability of time series deduction, while the CA model has the advantage of predicting the dynamic evolution of complex systems in time and space. Since land use change also has the nature of Markov process, the synthesis of the two models can scientifically and reasonably deduce the dynamic change of land use.

The Kappa coefficient is used to detect the prediction accuracy of land pattern evolution, and the calculation formula is:

$$k = \frac{p_0 - p_e}{1 - p_e}$$

where: p_0 is the sum of the sample sizes for each class correctly classified divided by the total number of samples, which is the overall classification accuracy(Wagner et al., 2019). Suppose the true number of samples of each class is a1, a2 ... a_c, and the number of samples predicted for each class is b1, b2... b_c,and the total number of samples is n:

$$p_e = \frac{a_1 \times b_1 + a_2 \times b_2 + \cdots + a_c \times b_c}{n \times n}$$

Usually, kappa falls between 0 ~ 1, which can be divided into five groups to represent different levels of consistency: 0.0 ~ 0.20 very low consistency (slight), 0.21 ~ 0.40 general consistency (fair), 0.41 ~ 0.60 medium consistency (moderate), 0.61 ~ 0.80 high consistency (substantial) and 0.81 ~ 1 almost perfect (almost perfect).

Remote sensing image extraction application Envi, version 5.1, image processing and geostatistical analysis application Arcgis version 10.3. All the statistical analyses were performed using SPSS software, version 24.0 (SPSS Inc., USA).

3. Results and analysis

Taking Nanchang as the research area, analyzed and studied the characteristics of land use change in 2005, 2010, 2015 and 2020. The relationship between driving factors such as DEM, slope, and road distribution data was analyzed, and the above elements were selected as the driving factors of land use simulation in Nanchang to construct a CA-Markov model. Using a single land use dynamic, land use structure table, and land use transfer matrix method, coupled with land use classification and processed to predict the future development of land use in Nanchang of 2035.

Through remote sensing image extraction and land use dynamics formula calculation, the various land use areas of Nanchang City in 2005, 2010, 2015 and 2020 were classified and counted, and the land use status map of the four phases was obtained, and the land use situation was shown in Fig. 2. Agricultural land is the most widely distributed land type, dominating land use in various periods, and agricultural land has always accounted for more than 50%; followed by woodland and water areas, both accounting for about 16%; The proportion of unused land is getting smaller and smaller, the proportion of grassland and construction land is increasing, and the expansion rate of construction land is increasing. From 2010 to 2020, agricultural land continued to decrease, and the expansion rate of construction land further increased, while in the process of construction land expansion, the conversion of agricultural land and construction land was frequent, and the quality and quantity of cultivated land were greatly affected. From 2005 to 2020, the woodland continued to decrease, with a total decrease of 300.27 km2 in 15 years, which changed greatly from the quantitative point of view, and also showed that Nanchang's urban economic development should pay more attention to the coordinated development of ecology and agriculture. Unused land continued to decrease between 2005 and 2020, and unused land was developed for construction or converted into agricultural land. Base on remote sensing image extraction and land use dynamic formula calculation, various types of land use areas of Nanchang in 2005, 2010, 2015 and 2020 were classified and counted, and land use status maps of the four phases were obtained, as shown in Fig. 2.

3.1 Land use characteristics and transfer changes of Nanchang

Agricultural land is the most widely distributed type of land, and occupies a dominant position in the land utilization in all periods, with the proportion of agricultural land always above 50%. Next, woodland and water area both accounted for about 16%. The proportion of unused land decreased, the proportion of grassland and construction land increased, and the expansion speed of construction land increased rapidly. Agricultural land kept decrease from 2010 to 2020 (Table 3), and the expansion speed of construction land kept in increasing. In the process of construction land expansion, the transformation of agricultural land and construction land is frequently, which greatly affects the quality and quantity of cultivated land. From 2005 to 2020, woodland continued to decrease, with a total decrease of 300.27 km^2 in 15 years. From the perspective of quantity, the change of woodland was large, which also reflected that the urban economic development of Nanchang should pay more attention to the coordinated development of ecology and agriculture to a certain extent. As for unused land, it decreased from 2005 to 2020, most of the unused land was developed into construction land or converted into agricultural land.

Table 3
Dynamic table of land use classification in Nanchang City, 2005–2020

	Area/km^2	Change/%	Area /km^2	Change /%	Area /km^2	Change /%	Area /km^2
Time	2005	2005–2010	2010	2010–2015	2015	2015–2020	2020
Agricultural land	3901.22	0.79%	3932	-1.20%	3884.81	-1.35%	3832.46
Woodland	1202.07	-1.18%	1187.84	-1.08%	1175.07	-23.18%	902.64
Grassland	92.74	-17.93%	76.11	-0.05%	76.07	311.46%	313.69
Waters	1159.53	-3.44%	1119.61	0.20%	1121.9	14.81%	1288.04
Construction land	516.87	4.03%	537.69	11.82%	601.26	38.13%	830.52
Unused land	312.18	6.14%	331.34	-1.83%	325.28	-17.60%	268.03

In the land transfer situation from 2005 to 2010, the changes of agricultural land and construction land were more obvious. The area of agricultural land transferred out from 2005 to 2010 was 72.05km^2, the largest the part of which was converted into construction land, about 37.91km^2, which shows that the expansion of construction land occupies serious agricultural land. In terms of transfers, agricultural land was the most transferred part, with 40.675km^2, which was due to the conversion of woodland into agricultural land. For construction land, construction land increased by 20.825 km^2 from 2005 to 2010, with agricultural land occupying the most. From the perspective of the total area of land types, the transferred area of agricultural land was greater than that of transferred out, and the total amount of agricultural land was increased. The transfer out of construction land is less than that of transfer in, and the transfer out part is mainly converted into agricultural land by the value of 21.894 km^2, the total amount increases. The transfer of agricultural land in and out frequently, and the expansion speed of construction land is relatively fast. Both woodland and grassland have decreased, and unused land has increased, possibly because some water areas have increased due to water level change, resulting in an increase in unused land.

From 2010 to 2015, the more obvious land use transfer was still construction land and agricultural land. 6.158 km^2 of construction land was transferred out, the value of which converted into agricultural land was 5.045 km^2, and 69.711 km^2 was transferred in construction land, of which mainly agricultural land and woodland were transferred. For woodland grasslands, woodlands and grasslands continued their decreasing trend. Unused land remained unchanged, and from the perspective of land use transfer matrix, the transformation of unused land and water area was still relatively frequently.

In the land use transfer from 2015 to 2020, the largest type of land transferred from agricultural land was construction with the value of 273.334 km^2, and the largest transfer was woodland by 287.720 km^2, for the woodland was used as farmland after land reclamation. For construction land, the largest transfer is agricultural land by 125.222 km^2, because part of the construction land isreturned to farmland, and the most transferred is also agricultural land, and construction land occupies part of the agricultural land. From 2015 to 2020, agricultural land continued to decrease, woodland continued to decrease, and grassland and water areas increased, which may be caused by the abandonment of agricultural land.

According to the calculation results, the annual average change is mainly to construction land, and the dynamic change of single land use is more obvious, which is 4.03% in 2005–2010, 11.08% in 2010–2015, and 38.13% in 2015–2020, respectively. For agricultural land, due to the large base, the change is not obvious; The dynamics of single land use of woodland showed a decreasing trend year by year, which was − 1.18% in 2005–2010, -1.08% in 2010–2015, and − 23.18% in 2015–2020. The change of single land use dynamics of grassland is more obvious, of which 311.46% from 2015 to 2020, which may be due to the reduction of unused land, this paper classifies tidal flats into unused land, due to the change of water level may lead to the transformation of coastal tidal flats into grassland in some waters, grassland itself accounts for relatively small, so the land use dynamics are obvious when the change occurs, and the base of grassland area is small, and with the strengthening of urban expansion parks and community greening, the grassland area increases rapidly. As a whole, the use of land and woodland gradually decreased, while the area of water and grassland increased. The construction land expanded rapidly, and the agricultural use gradually decreased. It can be seen that urban development increased the use of land and woodland, and in the process of urban development, with the construction of parks and other landscapes, the area of water and grassland increased.

3.2 Predictive analysis of land use pattern in Nanchang

Taking 2010 land use as the base period and 2015 as the end period, the land use transfer probability matrix and land use suitability atlas were created. On this basis, 2015 is set as the base period, the land use status in 2020 is simulated, and the Kappa coefficient is used to quantitatively test according to the comparison between the simulation results and the actual 2020 land use results.

According to the simulation results, the Kappa value is 0.94, which proves that the simulation effect of the study area is good, and the land use of Nanchang in 2035 is simulated and predicted, and the error classification of the simulation results in 2020 is shown in Table 4. Through the area of land use change directly extracted and predicted in 2020, it can be seen that unused land, building land and agricultural land have quite high prediction effect, and the change is kept below 5%. Woodland, grassland, and water areas were slightly less effective, with a variation of 5-7.5%.

Table 4
Nanchang Land Simulation Error Table

Land types	Actual land use area of 2020/km^2	Projected land use area of 2020/km^2	E Error
Agricultural land	3832.46	3768.9	-1.66%
Woodland	902.64	970.03	7.47%
Grassland	313.69	330.11	5.23%
Waters	1288.04	1192.5	-7.42%
Construction land	830.52	801.36	-3.51%
Unused land	68.03	68.62	0.86%
Total	7235.38	7131.52	

Use CA-Markov model to simulate land use, the accuracy of the simulation results is tested to ensure the rationality and effectiveness of the model. On the basis of passing the accuracy test, taking 2020 as the base period, the land use transfer probability matrix is entered, the land use suitability atlas is set to the prediction range of 15 years, and the land use in Nanchang City in 2035 is simulated and predicted, and the statistical analysis is obtained as shown in Table 5 and Table 6. From the perspective of land use structure changes (Figs. 2 and 3), agricultural land will not change much in 2035 and 2020, and will remain basically stable. Woodland has decreased slightly, from 12.48–11.12%, which also requires attention to environmental protection in social and economic development; The grassland and water area showed a decreasing trend, and the overall change was not obvious. For construction land, Nanchang accounted for 11.48% in 2020 and 15.83% in 2035, an increase of 306.31km^2, which is also an inevitable trend of Nanchang's social and economic development; the overall change of unused land is not obvious, accounting for 0.79% in 2035 and 0.94% in 2020, respectively.

Table 5
Land use simulation structure table of Nanchang City

Land types	Actual land use area of 2020/km^2	Percentage	Projected land use area of 2035/km^2	Percentage	Land use change
Agricultural land	3832.46	52.97%	3778.49	52.63%	-0.09%
Woodland	902.64	12.48%	798.73	11.12%	-0.77%
Grassland	313.69	4.34%	355.11	4.95%	0.88%
Waters	1288.04	17.80%	1054.21	14.68%	-1.21%
Construction land	830.52	11.48%	1136.83	15.83%	2.46%
Unused land	68.03	0.94%	56.39	0.79%	-1.14%
Total	7235.38	100%	7179.76	100%	

Table 6
Land use transfer matrix from 2020 to 2035 (unit: km^2)

2035/2020	Agricultural land	Woodland	Grassland	Waters	Construction land	Unused land	Total
Agricultural land	3515.66	72.10	25.40	164.64	0.28	0.41	3778.49
Woodland	11.67	729.90	38.91	18.26	0.00	0.01	798.73
Grassland	50.77	51.09	242.67	10.48	0.01	0.10	355.11
Waters	0.25	0.02	0.05	1037.53	0.00	16.38	1054.21
Construction land	251.53	48.58	6.25	51.11	779.25	0.11	1136.83
Unused land	1.21	0.00	0.02	4.37	0.00	50.79	56.39
Total	3831.09	901.68	313.29	1286.39	779.54	67.79	3778.49
Transfer in	262.83	68.84	112.45	16.69	357.58	5.61	
Transfer out	315.42	171.79	70.62	248.86	0.29	17.00	
Change	-52.596	-102.951	41.823	-232.173	357.291	-11.394	

From the perspective of land use simulation dynamics in Nanchang, agricultural land changed the least, and the annual land use dynamics were − 0.09%; and showed a decreasing trend, and the dynamic degree of single land use was − 0.77%. The increase in grassland may be caused by changes in topography, water and soil, and the single land use dynamic is 0.88%; In the land use simulation of Nanchang, the water area showed a trend of decrease in 2035, and the single land use dynamic degree was − 1.21%. The change of construction land is the most obvious, and the expansion of urban and rural construction land is relatively fast, mainly reflected in the junction of existing construction land and other land use types, and the dynamic degree of single land use is 2.46%; With regard to unused land, there was little change overall, with a single land-use dynamic of -1.14%, which is due to a normal decrease due to the use of land partially for use.

From the perspective of land use transfer matrix, agricultural land transfer in and out frequently, agricultural land mainly transferred out of the land category is grassland and construction land, of which construction land accounts for a relatively large amount, 251.53 km^2, which to a certain extent shows that the expansion of construction land may occupy cultivated land, so in the future land use in Nanchang City, more attention should be paid to the divination balance of cultivated land and the protection of cultivated land, the transferred land types are woodland and water area, respectively, 72.10 km^2 and 164.64 km^2, This may be due to climatic conditions as well as hydrological changes; Some of the woodland is converted into construction land and agricultural land, and the conversion area is small; The transfer of grassland is mainly agricultural land and woodland, and some grassland suitable for agriculture and forestry is converted into agricultural land and woodland; Regarding construction land, there are almost no transfers, mainly agricultural land, land and water areas, which are 251.53 km^2, 48.58 km^2 and 51.11 km^2 respectively, and the construction scale has expanded significantly compared with 2020. For unused land, from the simulation results, from 2020 to 2035, the area will change from 67.79 km^2 to 56.39 km^2, showing an overall decreasing trend, but the change is not much, from urban development to occupy part of the unused land, but most of the unused land is retained, which is related to the ease of use of this part of the unused land.

From the perspective of natural factors, agricultural land, woodland, grassland and water area are greatly affected by the elevation slope. However, construction land is greatly affected by convenient transportation, and the old construction land as the starting boundary of expansion has driven the transformation of surrounding land use, resulting in frequent land use type changes within this range. From the perspective of land use structure changes, agricultural land will not change much in 2035 and 2020, and it will remain basically stable. Woodland has decreased slightly, from 12.48–11.12%, which also requires attention to environmental protection in social and economic development; The grassland and water area showed a decreasing trend, and the overall change was not obvious. For construction land, Nanchang accounted for 11.48% in 2020 and 15.83% in 2035, an increase of 306.31km^2, which is also an inevitable trend of Nanchang's social and economic development; the overall change of unused land is not obvious, accounting for 0.79% in 2035. From the perspective of land use simulation dynamics in Nanchang, agricultural land changed the least, and the annual land use dynamics were − 0.09%; Woodland showed a decreasing trend, and the dynamic degree of single land use was − 0.77%. The increase in grassland may be caused by changes in topography, water and soil, and the single land use dynamic is 0.88%; In the land use simulation of Nanchang, the water area showed a trend of decrease in 2035, and the single land use dynamic degree was − 1.21%. The change of construction land is the most obvious, and the expansion of urban and rural construction land is relatively fast, mainly reflected in the junction of existing construction land and other land use types, and the dynamic degree of single land use is 2.46%; With regard to unused land, there was little change overall, with a single land-use dynamic of -1.14 per cent, which is due to a normal decrease due to the use of land partially for use. From the perspective of land use transfer matrix, agricultural land transfer in and out frequently, agricultural land mainly transferred out of the land category is grassland and construction land, of which construction land accounts for a relatively large amount, 251.53km^2, which to a certain extent shows that the expansion of construction land may occupy cultivated land, so in the future land use in Nanchang City, more attention should be paid to the divination balance of cultivated land and the protection of cultivated land, the transferred land types are woodland and water area, respectively, 72.10 km^2 and 164.64 km^2, This may be due to climatic conditions as well as hydrological changes; Some of the woodland is converted into construction land and agricultural land, and the conversion area is small; The transfer of grassland is mainly agricultural land and woodland, and some grassland suitable for agriculture and forestry is converted into agricultural land and woodland; Regarding construction land, there are almost no transfers, mainly agricultural land, wood land and water areas, which are 251.53 km^2, 48.58 km^2 and 51.11 km^2 respectively, and the construction scale has expanded significantly compared with 2020. For unused land, from the simulation results, from 2020 to 2035, the area will change from 67.79 km^2 to 56.39 km^2, showing an overall decreasing trend, but the change is not much, from urban development to occupy part of the unused land, but most of the unused land is retained, which is related to the ease of use of this part of the unused land. From the perspective of natural factors, agricultural land, woodland, grassland and water area are greatly affected by the elevation slope. However, construction land is greatly affected by convenient transportation, and the old construction land as the starting boundary of expansion has driven the transformation of surrounding land use, resulting in frequent land use type changes within this range.

4. Conclusion

The rapid development of cities has intensified the contradiction between people and land. Agricultural land in Nanchang is the most widely distributed land type, with more than 50% in all periods; followed by woodland and water, both with more than 16%; The proportion of unused land is getting smaller and smaller, the proportion of grassland and construction land is increasing, and the expansion rate of construction land is increasing. Construction land will increase from 830.52km^2 in 2020 to 1136.83km^2 in 2035, an increase of 36.88%. Agricultural land continued to decrease, the expansion rate of construction land further increased, the conversion of agricultural land and construction land was frequent, and the quality and quantity of cultivated land were greatly affected. The continuous reduction of forest land also shows to a certain extent that Nanchang's urban economic development should pay more attention to the coordinated development of ecology and agriculture. Unused land is also decreasing, and it is being developed as construction land or converted into agricultural land. In land use, full attention should be paid to the balance of cultivated land for construction and cultivated land, so as to promote the healthy and sustainable development of cities. Conversion of agricultural land is the most active and the rate of renewal is faster. From the perspective of natural factors, agricultural land, forest land, grassland and water area are greatly affected by the elevation slope. The construction land is greatly affected by the convenience of transportation, and the old construction land as the starting boundary of expansion has driven the transformation of surrounding land use. Simultaneous development and protection, improving land protection system and land resources monitoring system are conducive to the sustainable use of land resources and regional sustainable development in urban development, and promote the construction of ecological civilization.

Declarations

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The research results were supported by National Science Foundation (Grant No. 42361003); Opening fund of Xinjiang Key Laboratory of Water Cycle and Utilization in Arid Zone, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences; Youth Science and Technology Talent Project and the discipline innovation team of "Rural Revitalization and Social Policy Innovation" of Jiangxi University of Finance and Economics; Science Foundation of Jiangxi Education Department (Grant No.GJJ190269; No.JG2022050).

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Figures

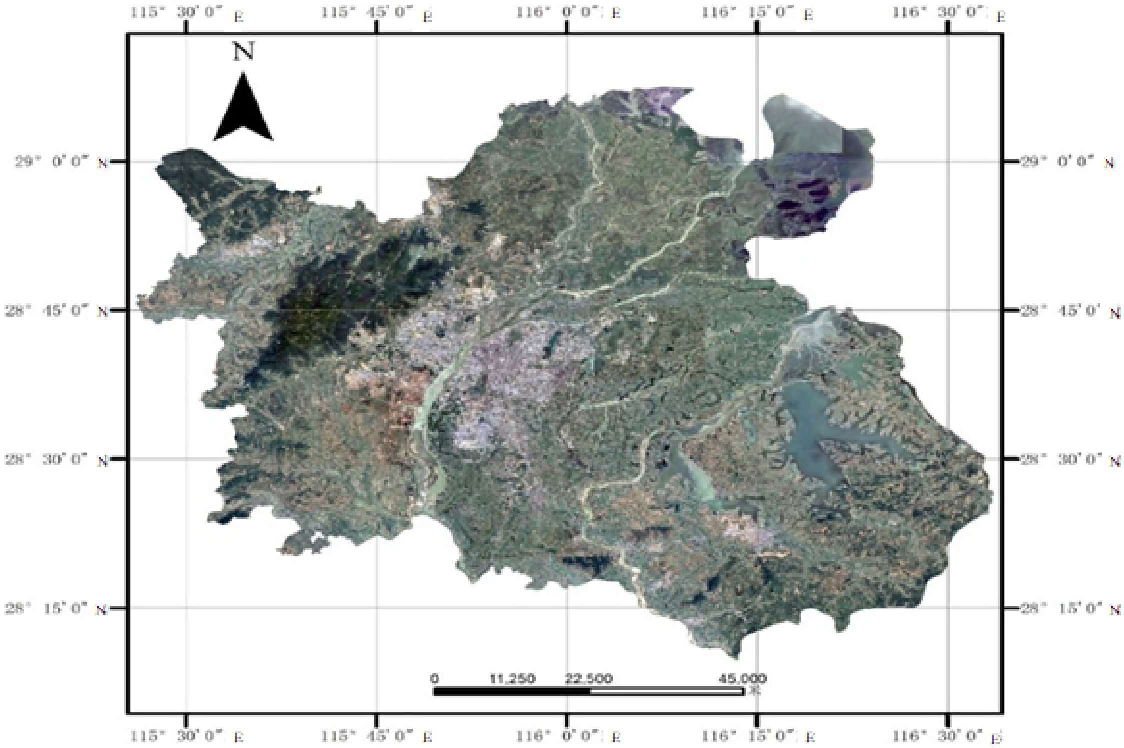

Figure 1

Location map of Nanchang city

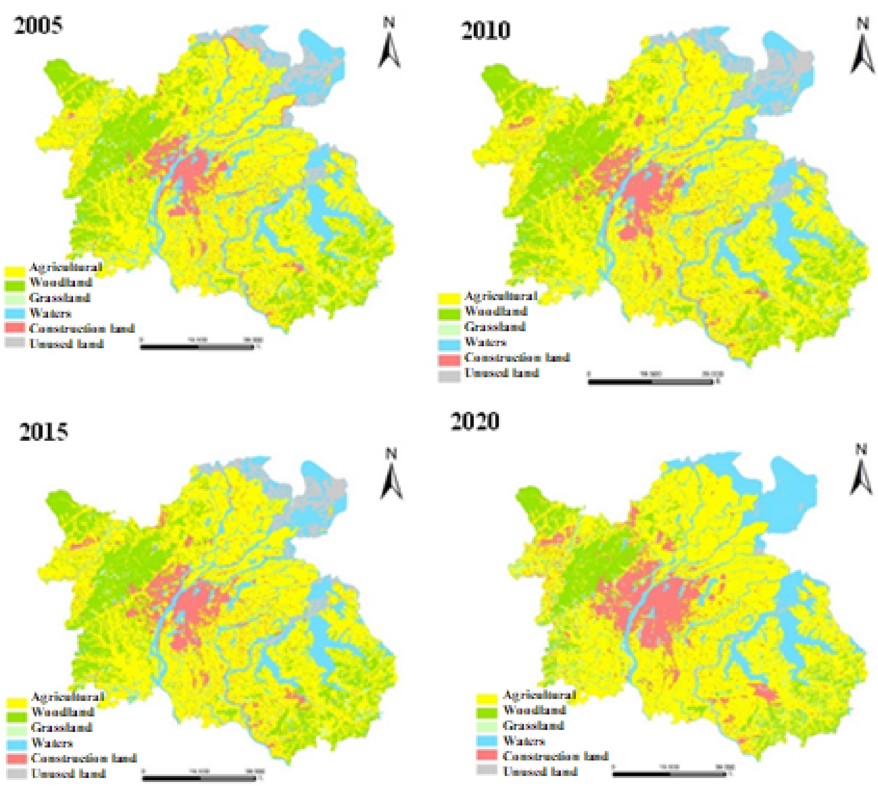

Figure 2

Land use classification map of Nanchang from 2005 to 2020

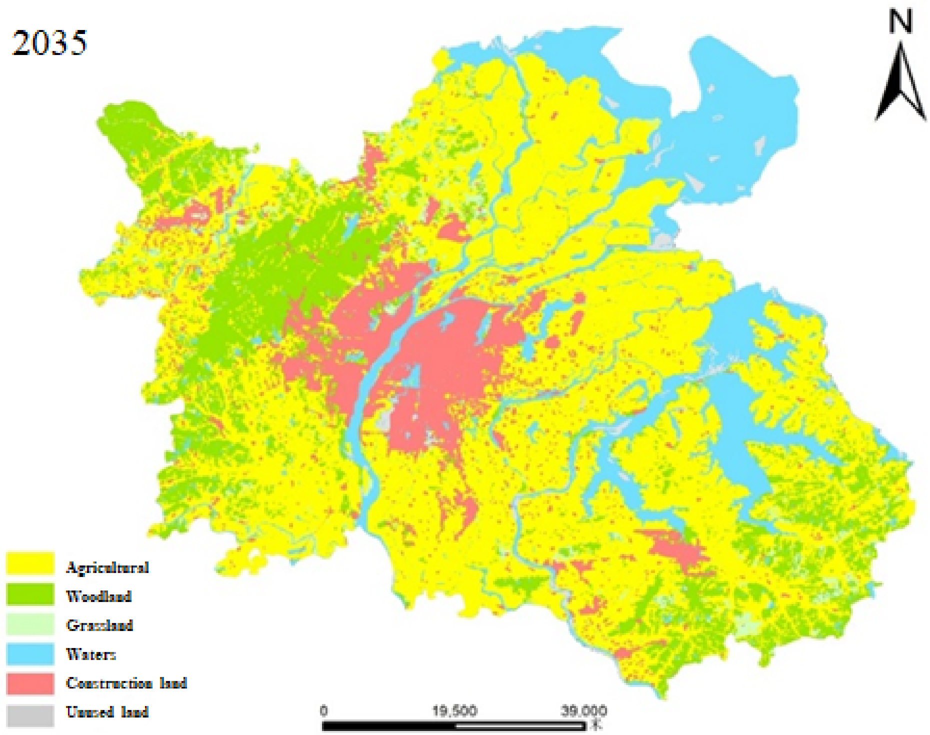

Figure 3

2035 Nanchang land use classification map