# Study of urbanization trend prediction in Nanchang based on CA-Markov model

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**Abstract.** In order to promote the healthy development of Nanchang city in the future and maintain the virtuous cycle of urban ecosystem, this paper uses CA-Markov model to simulate and forecast the land use of Nanchang city in 2030 and explore the urbanization process of Nanchang city. Firstly, the land use changes in Nanchang from 2000 to 2020 are described, followed by land use simulations for Nanchang in 2020 as a verification of accuracy, and land use projections for Nanchang in 2030 based on accuracy requirements. The results show that:(1) the rate of urban expansion will continue to be maintained or even gradually increase from 2020 to 2030 under the expansion model based on the period 2000-2020. (2) The main factor in the change of land use types in the built-up area of Nanchang over the past two decades is socio-economic factors, with natural factors taking second place. (3) The area of land development intensity in Nanchang will reach its peak in 2030, and the expansion of the municipal districts will gradually slowdown in favour of Nanchang and Xinjian counties, which have a more extensive land area and are close to the central urban area.

**Keywords:** Nanchang; CA-Markov model; urbanization; land use change; forecasting study

## 1. Introduction

As a complex ecosystem combining nature-economy-society, the city is the main place for human survival and development, where society, economy and nature interact with each other and influence each other.[1-3] With the rapid development of the world economy, China is experiencing a rapid rate of large-scale urbanisation unprecedented in human history. At the same time, from the perspective of urban development around the world, large-scale urbanisation is an inevitable trend resulting from a robust process of socio-economic development and a natural process of geospatial aggregation of non-agricultural industries and populations in the context of high industrialisation [4-6]. At the same time, the process of urbanisation is accelerating, human demand for natural resources is increasing, the ecological environment in which it is located is gradually being destroyed, and urban ecological problems are becoming increasingly prominent. The current situation of urban land use is gradually changing rapidly and the changes are characterised by different spatial and temporal distributions, so the study of the urbanisation process is of great importance for sustainable urban development.[7]

With the development of remote sensing technology, RS and GIS technology has the significant advantage of low cost and high efficiency in the study of urban land use change, so the macro control of urbanization process through remote sensing method has become a new research hot spot[8-9] . At the same time, the promotion of the concepts of green cities and sustainable development has led to a growing interest in land-use change modelling by scholars and people from all walks of life.[9-10] CA-Markov models are gradually being applied to the prediction of land use change, compared to the traditional GIS-based prediction of land use types. CA-Markov models can support multi-factor and multi-objective forecasting, and the generated results can be visualized into maps, which can facilitate targeted analysis of land use change.[11] Zhu Lei et al. (2020) made a sensitivity analysis of different parameters based on CA-Markov model for arable land in the oasis area of the Manas River basin[12] ; Wang Lixia et al. (2020) used the Weihe River region as the study area, calculated interannual NDVI values based on MODIS data, and used the CA-Markov model to simulate the spatial and temporal variation of NDVI in the region using the rank of NDVI as the metacell type. [13]; Ruci Wang and Hao Hou et al. (2019) monitored and simulated changes in farmland dynamics in Hangzhou from 1995 to 2035[14] . Nanchang, the capital city of Jiangxi Province, is the core city of the Poyang Lake City Cluster, the economic, political and cultural centre of Jiangxi Province, and one of the important central cities in the middle reaches of the Yangtze River. Since the new century, its development has been a great achievement, actively driving the local regional economy while the rate of urbanisation is accelerating and environmental problems are becoming increasingly serious[1]. Monitoring the urbanisation process in Nanchang and predicting and evaluating its

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future land use changes are of great significance, and the results can be used as a basis for decision making on the sustainable development of Nanchang city, which is needed to promote the healthy development of the city in the future, and can also serve as a theoretical guarantee for maintaining a virtuous cycle in the urban ecosystem.

This study will take Nanchang City as an example, based on the Landsat Global 30m Fine Classification of Land Cover Types 2000-2020, carry out monitoring of the urbanisation process in Nanchang City over the past two decades and analyse its intrinsic driving forces, simulate and forecast the land use of Nanchang City in 2030 through the Land Suitability Atlas and CA-Markov model, and explore the The results of this study will provide theoretical support for the future development of Nanchang City and provide a scientific basis for the formulation of sustainable urban development policies for the harmonious co-existence of people and the environment.

## 2. Data and methods

### 2.1 Study area

Nanchang (Fig. 1), located in the lower reaches of the Ganjiang and Fuxiang rivers, is situated slightly north of the central part of Jiangxi province. It is bordered by Dongxiang County in Fuzhou City and Yugan County in Shangrao City to the east, Fengxin County and Gao'an City in Yichun City to the west, Linchuan County in Fuzhou City and Fengcheng County in Yichun City to the south, Yongxiu County and Duchang County in Jiujiang City to the north, and Poyang Lake, the largest freshwater lake in China, to the northeast.[16] . The topography of the city is mainly plain terrain, its geographical location of bearing east and west, connecting north and south, and the superposition of multiple policy locations have injected a constant impetus to the development of Nanchang over the past 20 years, with the development of Honggu Tan New Area, the construction of Poyang Lake Ecological Economic Zone, the construction of Changjiu Integration and a series of other policy measures implemented one after another, resulting in a significant increase in the economic level of Nanchang, a continuous expansion of the population, a faster pace of urbanisation and a continuous increase in the area of urban land. The pace of urbanization has been accelerated, and the area of urban construction land has been increasing.

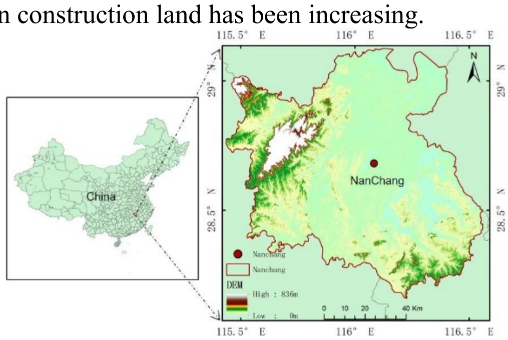


**Fig 1** Topographical map of the study area

### 2.2 Research Data

The land use data used in this study was obtained from the Earth Big Data Science Project Data Sharing Service Platform (https://data.casearth.cn/), in which the global 30m land cover fine classification products for 2000, 2010 and 2020 were obtained, and Nanchang City was selected for the classification products to be downloaded; and according to the help document therein, the The land use names corresponding to the corresponding codes were then extracted and reclassified using ArcGIS 10.2 software, and the final land use results data were presented as five primary classifications of forest land, cropland, wetland, building land and water bodies for the final land use change analysis and the prediction and simulation of land use results in Nanchang in 2030.

### 2.3 Model and accuracy validation

The models currently used for the simulation of land use types in built-up areas are mainly the CLUE-S model, SD model and CA model, among which the CA model has good results in simulating the spatial and temporal processes of urban built-up area systems due to its top-down dynamic simulation. The CA-Markov model, on the other hand, combines the ability of the CA model to simulate spatial changes in complex systems with the Markov model's ability to make long-term predictions, enhancing the accuracy of the landscape type transfer matrix and achieving good results in analysing and modelling land use, and has therefore also been widely used in recent years in land use cover[17-18] .

In order to verify the validity of the CA-Markov model simulation in Nanchang City, model validation is needed first. Kappa coefficients are often used to assess the accuracy of the classification of remotely sensed data and to calculate the consistency of two maps[14] . Kappa coefficients quantify the changes in quantity, location and integrated information during landscape change in terms of spatial location and quantity, and are calculated as follows[19-20]

$$\text{Kappa}=\frac{P_0-P_c}{1-P_c}$$

where $P_0$ is the correct simulated proportion. $P_c$ is the expected value of the correct simulated proportion in the random case. kappa coefficient is usually between 0 and 1. When the kappa coefficient is greater than 0.75, the agreement between the simulated results and the true distribution is high, and when the kappa coefficient is between 0.4 and 0.75, the agreement is more general. When the kappa coefficient is less than 0.4, the agreement is poor. Previous research has shown that Map comparison Kit 3 software can provide both quantitative and positional errors to validate the model.

## 3. Analysis of results

### 3.1 Land use distribution

The resultant data after reclassification of the land use result data for the three periods 2000, 2010 and 2020 are shown in Figure 2 below, and the study area was classified into five feature types, namely wetlands, cropland, forest land, water bodies and building land. The reclassification results were subjected to a transformation matrix analysis to obtain the conversion of the land use areas of the various feature types in the study area for the two adjacent periods.

From 2000 to 2010 (Table 1), the expansion of building land increased from 503.18km$^2$ in 2000 to 797.47km$^2$, a growth rate of 58%, reaching the peak of the town's growth rate in 20 years. The increase in the area of building land was mainly due to the conversion of feature types such as arable land, woodland and water bodies, with 275.56km$^2$ of arable land, or 34.55%, and 14.59km$^2$ of woodland, or 1.83%. It shows that in the early 20th century, Nanchang city expanded from the centre outwards, encroaching on large areas of arable land, while forest land was also damaged to a large extent. In addition, there were varying degrees of conversion between the areas of the three land use types: wetlands, arable land and water bodies. During this period, 3.75km$^2$ of arable land was converted to wetland type, accounting for 10.36% of the total wetland area in 2010, and 2.28km$^2$ of water bodies were converted to wetland, accounting for 6.29% of the total wetland area in 2010. Moreover, the total area of woodland and wetland were both on a downward trend during this period, while that of cropland, wetland and building land was on an upward trend, indicating that the general trend of land use type change was from natural state land use types such as woodland and wetland to artificially constructed land use types such as cropland and building land, indicating a sharp increase in urbanisation.

From 2010 to 2020 (Table 2), the area of built-up land increases by 200km$^2$, from 797.47km$^2$ in 2010 to 997.87km$^2$, a growth rate of 25%, which is also a reflection of the increased urbanisation process. The increase in the area of building land was mainly converted from feature types such as arable land and water bodies, with the area of arable land being 184.64km$^2$, accounting for 18.50% of the area of building land in 2010, and the area of water bodies being 6.33km$^2$, accounting for 0.63% of the area of building land in 2010. Overall, the areas of arable land and forest land all show a clear downward trend, while the areas of building land, water bodies and wetlands show an upward trend during the period 2010-2020. The total area of cultivated land decreases by 189.16km$^2$ and the total area of forested land decreases by 75.86km$^2$. The slowdown in the rate of growth of urban areas and the increase in the area of water bodies and wetlands indicate that government departments have become aware of environmental issues during this period and have begun to slow down the damage caused by human activities and gradually increase the area of land use types in their natural state.

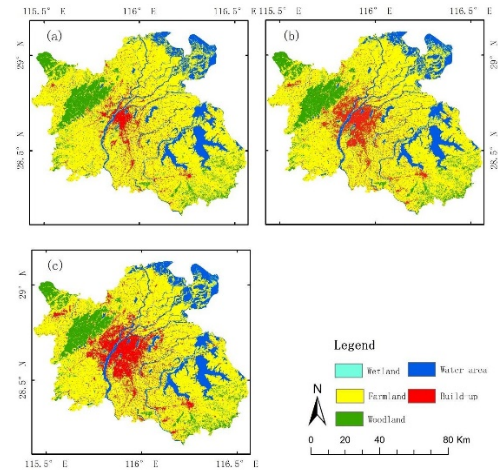


**Fig 2** Land use distribution in Nanchang from 2000 to 2020: (a) Land use distribution in Nanchang in 2000; (b) Land use distribution in Nanchang in 2010; (c) Land use distribution in Nanchang in 2020

**Table 1** Change in land use type transfer in Nanchang from 2000 to 2010

| | Arable land | Woodland | Wetlands | Building sites | Water bodies |
|---|---|---|---|---|---|
| **Arable land** | 5379.86 | 25.33 | 3.75 | 275.56 | 60.30 |
| | 98.42％ | 3.11％ | 10.36％ | 34.55％ | 5.36％ |
| **Woodland** | 39.02 | 787.39 | 0.00 | 14.59 | 0.67 |
| | 0.71％ | 96.70％ | 0.00％ | 1.83％ | 0.06％ |
| **Wetlands** | 0.02 | 0.00 | 30.16 | 0.00 | 0.01 |
| | 0.00％ | 0.00％ | 83.34％ | 0.00％ | 0.00％ |
| **Building sites** | 0.00 | 0.00 | 0.00 | 503.18 | 0.00 |
| | 0.00％ | 0.00％ | 0.00％ | 63.10％ | 0.00％ |
| **Water bodies** | 47.14 | 1.56 | 2.28 | 4.14 | 1047.40 |
| | 0.86％ | 0.19％ | 6.29％ | 0.52％ | 94.58％ |
| **Total area** | 5466.04 | 814.28 | 36.19 | 797.47 | 1107.47 |

**Table 2** Change in land use type transfer in Nanchang from 2010 to 2020

| | Arable land | Woodland | Wetlands | Building sites | Water bodies |
|---|---|---|---|---|---|
| **Arable land** | 5176.25 | 18.70 | 7.57 | 184.64 | 78.87 |
| | 98.09% | 2.53% | 15.82% | 18.50% | 6.80% |
| **Woodland** | 80.31 | 719.62 | 0.00 | 9.42 | 4.94 |
| | 1.52% | 97.45% | 0.00% | 0.94% | 0.43% |
| **Wetlands** | 0.00 | 0.00 | 36.19 | 0.00 | 0.00 |
| | 0.00% | 0.00% | 75.62% | 0.00% | 0.00% |
| **Building sites** | 0.00 | 0.00 | 0.00 | 797.47 | 0.00 |
| | 0.00% | 0.00% | 0.00% | 79.92% | 0.00% |
| **Water bodies** | 20.32 | 0.11 | 4.10 | 6.33 | 1076.61 |
| | 0.39% | 0.02% | 8.56% | 0.63% | 92.78% |
| **Total area** | 5276.88 | 738.43 | 47.85 | 997.87 | 1160.43 |

### 3.2 CA-Markov model prediction results

Figure 3 shows the prediction results of land use types based on the CA-Markov model, and the land use results for 2020 and 2030 were predicted in the study. The year 2020 is used as the evaluation data for accuracy verification, and the Kappa coefficients are calculated with the result data of land use of Nanchang City in 2020 extracted through remote sensing data, and the simulation results of Nanchang City in 2020 are verified through the software Map comparison Kit 3 to obtain the Kappa histograms of 0.81, 0.92, 0.83, the Kappa location and

Kappa cumulative statistics, indicating that the selected impact factor dataset has met the accuracy requirements of the prediction. This image factor dataset was used for the simulation of the land use status in 2030 to obtain Figure 3-b.

The land use results for 2020 were analysed in a transformation matrix with the land use types predicted for 2030 by the CA-Markov model to obtain the conversion of land use areas for various feature types in the study area for the adjacent years 2020-2030 (Table 3). The results of the transformation matrix analysis show that the area of built-up land still shows an increasing trend and the rate of increase is greater compared to the previous decade, with a total increase of 668.13km2. The increased area of built-up land is mainly converted from the former arable land, accounting for 33.51% of the urban area in 2030. This indicates that the increase in town area during that period was mainly through the conversion of arable land resources, with a large amount of arable land being developed into building land.

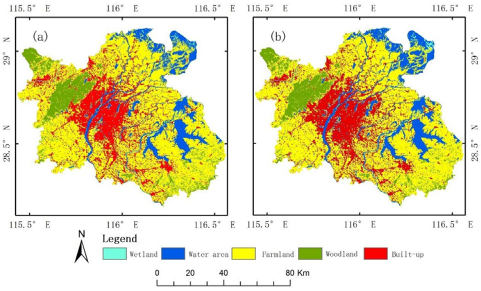


**Fig 3** CA-Markov model land use type projection results: (a) 2020 land use projection results; (b) 2030 land use projection results

**Table 3** Change in land use type transfer from 2020 to 2030 in Nanchang

| | Arable land | Woodland | Wetlands | Building sites | Water bodies |
|---|---|---|---|---|---|
| **Arable land** | 4499.19 | 1.46 | 0.00 | 719.88 | 56.36 |
| | 98.26% | 0.22% | 0.00 % | 43.21% | 4.68 % |
| **Woodland** | 79.25 | 659.14 | 0.00 | 0.00 | 0.03 |
| | 1.73% | 98.30% | 0.00 % | 0.00% | 0.00 % |
| **Wetlands** | 0.48 | 0.00 | 47.37 | 0.00 | 0.00 |
| | 0.01% | 0.00% | 46.44 % | 0.00% | 0.00 % |
| **Building sites** | 0.00 | 9.97 | 38.10 | 946.12 | 3.68 |
| | 0.00% | 1.49% | 37.35 % | 56.79% | 0.31 % |
| **Water bodies** | 0.00 | 0.00 | 16.54 | 0.00 | 1143.89 |
| | 0.00% | 0.00% | 16.21 % | 0.00% | 95.01 % |
| **Total area** | 4578.92 | 670.57 | 102.01 | 1666.00 | 1203.96 |

## 4. Discussion

Combined with the results of the transformation matrix, it can be seen that the urbanisation process in Nanchang City reached its peak around 2010. From Figure 2, it can be seen that the expansion of the built-up area was dominated by the northwest and due north directions, and gradually changed from single-direction expansion to multi-directional joint development, and the expansion directions during the study period were mainly concentrated in the due north and northwest directions, with the northeast and northwest directions in the time period of 2005-2010 The expansion of the town during the period 2010-2020 was mainly in the north-west, north-east and due-south directions, while the expansion in other directions was not significant. Due to the large number of lakes within Nanchang and the significant influence of topography, the expansion of Nanchang's built-up area shows a clear directional pattern, indicating that urban expansion in Nanchang is influenced by both anthropogenic activities and natural conditions.

The CA-Markov model was used to simulate the development of the built-up area of Nanchang in 2030, based on the river and lake systems, slope, topographic relief and the distance of traffic routes, etc. The results of the study show that the built-up area of Nanchang is mostly located around river and lake systems, major traffic routes and areas with gentle slope and topographic relief, with the highest probability of the initial type of arable land being transformed into land for construction The probability of the initial type of arable land being converted into building land is the highest. At the same time, the simulation results show that the intensity of land development in Nanchang will peak in 2030, and the expansion of the municipal districts will gradually slow down to Nanchang County and Xinjian County, where the land area is more extensive and close to the central city.

## 5. Conclusion

This paper uses the Landsat Global 30m Land Cover Fine Classification product for 2000-2020, reclassifies it to obtain land use type data for Nanchang in 2000, 2010 and 2020, and simulates and predicts the land use type of Nanchang in 2030 by CA-Markov model based on the land use data of the three periods. The land use result data for 2030 was obtained. Based on the above land use types in Nanchang for different periods, the spatial and temporal dynamics of the built-up area in the study area for different periods were monitored and the underlying driving forces were analysed through a transfer matrix.

The results of the study show that the main factor in the change of land use types in the built-up area of Nanchang over the past two decades has been socio-economic factors, with natural factors taking second place. Socio-economic development is an important factor contributing to the expansion of the built-up area, and is also the main driving force behind the gradual increase in the expansion rate of the built-up area. When the economy of an area develops at a high rate, it will have a polarising effect, gathering capital and population, which will further drive the expansion of the built-up area. There is a clear spatial and temporal divergence in the development of the built-up area of Nanchang, which is due to the differences in geographical characteristics between its different regions, creating the existence of a geographical divergence in expansion. The simulation results show that the rate of urban expansion will continue to be maintained or even gradually increase from 2020 to 2030 based on the expansion pattern from 2000 to 2020. Therefore, the future development of the built-up area of Nanchang should strengthen the intensive use of land, improve the government's intervention mechanism, protect the ecological environment and promote the coordinated development of urban and rural areas.

## References

1. Zhou Jiangwen. Natural ecological evaluation and driving force analysis of Nanchang City [D]. Donghua University of Technology, 2020. DOI:10.27145/d.cnki.ghddc.2020.000084.
2. Jay Gao, Yansui Liu, Yifu Chen, Land cover changes during agrarian restructuring in Northeast China, Applied Geography 26 (2006) 312- 322
3. Jieying Xiao, Yanjun Shen, Jingfeng Ge, Ryutaro Tateishi, Changyuan Tang,Yanqing Liang, Zhiying Huang, Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing, Landscape and Urban Planning 75 (2006) 69-80.
4. Ma Ting. Spatial and temporal characteristics of urbanization in China from the perspective of night-light remote sensing [J]. Journal of Geoinformation Science,2019,21(01):59-67.
5. Wang X.X., Liu J.Y., Zhuang D.D., Wang L.M. Spatial and temporal characteristics of spatial morphological changes in Chinese megacities[J]. Journal of Geography,2005(03):392-400.
6. Zhou Chunshan, Ye Changdong. Spatial growth characteristics of Chinese megacities and its causes[J]. Journal of Geography,2013,68(06):728-738.
7. Li Yuan, Lin Feng, Yan Zexing. Analysis of urbanization evolution based on Landsat remote sensing image--Xiamen city as an example[J]. Urban Architecture,2019,16(25):138-142.DOI:10.19892/j.cnki.csjz.2019.25.030.
8. Jinxia Lv , Weiguo Jiang , Wenjie Wang, Zhifeng Wu, Yinghui Liu, Xiaoya Wang and Zhuo Li Wetland Loss Identification and Evaluation Based on Landscape and Remote Sensing Indices in Xiong'an New Area, Remote Sensing. 2019, 11, 2834; doi:10.3390/rs11232834
9. Lopez, E., Bocco, G., Mendoza, M., & Duhau, E., Predicting land cover and land use change in the urban fringe a case in Morelia City, Mexico. landscape and Urban Planning, (2001) 55(4), 271-285.
10. Mathan M. & Krishnaveni M., Monitoring spatio-temporal dynamics of urban and peri-urban land transitions using ensemble of remote sensing spectral indices-a case study of Chennai Metropolitan Area, India, Environ Monit Assess (2020) 192: 15
11. Qian Ya. Evolutionary trends and prediction of vegetation cover in Jiangsu Province, 2006-2015[D]. Nanjing University of Information Engineering, 2021. DOI:10.27248/d.cnki.gnjqc.2021.000288.
12. Zhu Lei, Xia Xinxin, Yang Aimin, Jin Han. Parametric sensitivity analysis of CA-Markov model for arable land expansion in the oasis zone of Manas River basin [J/OL]. Arid Zone Research:1-12[2020-0822].
13. Wang Lixia, Zhang Jiawei, Meng Nina, Sui Lichun, Zhang Shuangcheng, Liu Zuo. Simulation and prediction of spatial and temporal variability of NDVI in the Weihe River basin based on CA-Markov[J]. Soil and water conservation research,2020,27(04):206-212.
14. Wang, Ruci, Hao Hou and Yuji Murayama 2018. Scenario-Based Simulation of Tianjin City Using a Cellular Automata-Markov Model. Sustainability 10: 2633.
15. Wang Yanjie. Study on the evolutionary characteristics of wetlands and their driving forces in Nanchang City [D]. Jiangxi Normal University, 2020. DOI:10.27178/d.cnki.gjxsu.2020.000709.
16. Ye Bin. Research on the spatial and temporal evolution characteristics of urban heat island effect in Nanchang based on Landsat satellite images[D]. Guilin University of Technology,2019. doi:10.27050/d.cnki.gglgc.2019.000002.
17. Li X. Research on remote sensing monitoring and simulation of urban built-up areas in Nanchang [D]. Donghua University of Technology,2017.
18. Schucknecht, Anne, Matschullat, Jörg, Erasmi, Stefan. Spatial and temporal variability of vegetation status in Paraíba, Northeastern Brazil( 2012).DOI:10.1109/IGARSS.2012.6351643
19. Zhang X. Simulation and prediction of wetland landscape pattern dynamics in the south coast of Hangzhou Bay based on CA-Markov model[D]. Zhejiang University, 2013