Frontiers in Environmental Research
Print ISSN: 2960-0251
Online ISSN: 2960-026X
DOI: https://doi.org/10.61784/fer3051

THE SPATIOTEMPORAL EVOLUTION OF LAND USE IN THE NANJING METROPOLITAN AREA AND DELIMITATION OF URBAN DEVELOPMENT BOUNDARIES BASED ON THE PLUS MODEL

ChenXi Xu[1#*], YongYi Chen[2#], JiaTong Yao[1]
[1]*College of Economics and Management, Nanjing Forestry University, Nanjing 210037, Jiangsu, China.*
[2]*College of Art and Design, Nanjing Forestry University, Nanjing 210037, Jiangsu, China.*
[#]*ChenXi Xu and YongYi Chen are both the first authors.*
[*]*Corresponding Author: ChenXi Xu*

Abstract: This study focuses on the spatiotemporal dynamics of land use in the Nanjing Metropolitan Area and the scientific delimitation of its development boundaries. Based on land use observation data from 2000 to 2020, the study found that the Nanjing Metropolitan Area underwent rapid urban expansion over the two-decade period. The built-up area increased significantly from 2,318 square kilometers, reaching nearly double the 2000 level by 2020, while farmland—the land use type that shrank the most—decreased by a total of 4,171 square kilometers. By incorporating the PLUS model, this study identified the drivers of land expansion and conducted multi-scenario projections of land use patterns for 2025 and 2030. The results indicate that under natural evolutionary trends, construction land will continue to encroach upon farmland and ecological spaces. To curb the disorderly sprawl of urban areas, the study established a delineation approach centered on "ecological priority, farmland protection, and coordinated development." Using GIS spatial analysis techniques and incorporating the rigid constraints of ecological and farmland red lines, the study preliminarily delineated the rigid urban development boundary for the Nanjing Metropolitan Area. The delineation results indicate that the total area of the rigid development boundary within the study area is 93,474.54 hectares, accounting for 65.45% of the total land area, primarily encompassing basic farmland protection zones and ecologically sensitive areas. The framework established in this study provides quantitative evidence and spatial constraint schemes for the optimization of territorial space and sustainable development at the metropolitan level.
Keywords: Nanjing metropolitan area; PLUS model; Urban development boundary

1 INTRODUCTION

Against the backdrop of rapid new-type urbanization, the conflict between human social development and environmental protection is intensifying. As a vital component of the Yangtze River Delta urban agglomeration, the Nanjing Metropolitan Area faces severe challenges posed by imbalanced land-use structures and disorderly spatial expansion. Over the past two decades, this region has witnessed massive urban sprawl, primarily at the expense of valuable farmland and vital ecological spaces. To balance urgent urban development needs with overarching ecological and food security, the scientific delineation of urban development boundaries has emerged as a core task of contemporary territorial spatial planning. Establishing rigid boundaries is essential to curb inefficient land development and ensure the sustainable use of regional resources, thereby laying a spatial foundation for high-quality development [1,2].

Previous studies have extensively explored the mechanisms of urban expansion and the methodologies for boundary delineation. Scholars have utilized various spatial analysis techniques to evaluate land use dynamics, often relying on traditional Cellular Automaton (CA) models to simulate future land patterns. However, conventional CA models suffer from notable limitations when it comes to revealing the complex drivers of land use change and simulating patch-level evolution. Their rigid transition rules and constraints often fail to capture the dynamic, non-linear characteristics of realistic urban growth. Consequently, while earlier research established foundational frameworks for spatial control, the simulation accuracy and rule adaptability of these traditional tools remain insufficient for addressing the highly complex land transfer mechanisms observed in rapidly developing metropolitan areas.

To overcome the rigidity of traditional simulation tools and enhance the scientific rigor of boundary delineation, this study constructs a PLUS (Patch-generating Land Use Simulation) model framework tailored for the Nanjing Metropolitan Area [3-5]. The innovation lies in the deep coupling of the PLUS model's random seed mechanism with rigid spatial constraint elements. By integrating urban expansion suitability evaluation with ecological and agricultural constraints, this approach not only quantifies land transfer patterns from 2000 to 2020 but also identifies the specific driving forces of regional expansion. Furthermore, the study establishes a comprehensive research framework spanning "historical evolution analysis," "future trend forecasting," and "rigid boundary control." The overall methodology begins with a theoretical review, employs a combination of qualitative and quantitative methods to categorize regional environmental conditions, and utilizes Geographic Information System (GIS) software to ensure data consistency and precise spatial resolution, ultimately achieving a scientifically grounded delineation of rigid urban development boundaries [6,7].

2 DATA AND METHODOLOGY

2.2 Research Framework

This study starts with theoretical research. By reviewing literature reviews on the delineation of urban development boundaries and spatial control mechanisms, it sorts out and discusses regional profiles and control mechanisms. Qualitative analysis is carried out from two aspects: urban expansion suitability evaluation and ecological agriculture constraint, and the environmental conditions and basic land use status of the study area are classified and summarized. Finally, based on the analysis of spatial control in the region from 2000 to 2020, the PLUS model is used to further simulate land use changes in 2025 and 2030.
Research structure of this paper is shown in Figure 1.

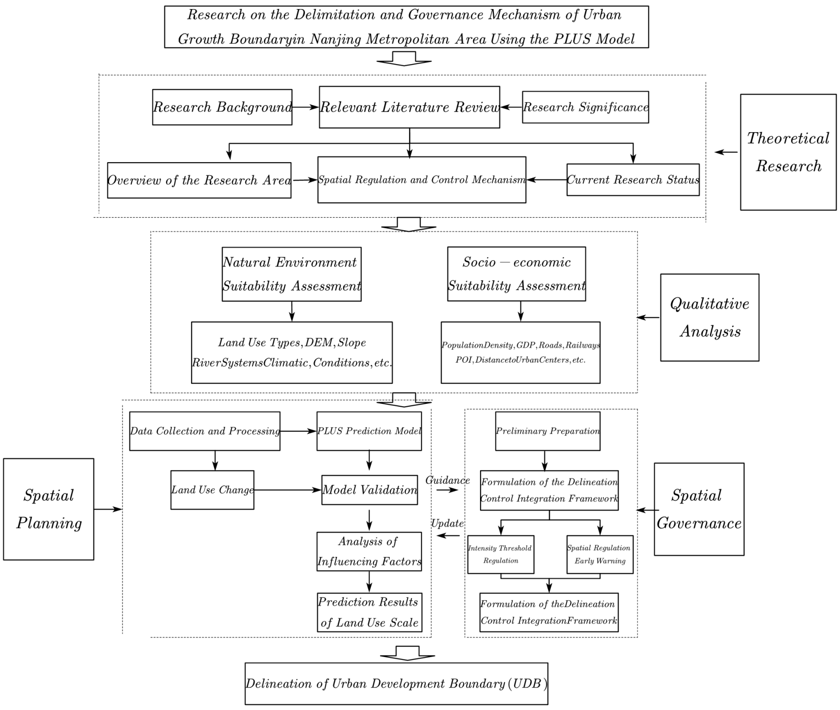

Figure 1 Research Structure of This Paper

2.3 Data Sources and Preprocessing

This study obtains data by consulting official statistical authoritative documents such as statistical yearbooks and databases issued by government statistical bureaus and industry associations, reading credible journal articles and research reports, and using technical means such as experimental computer simulation or statistical model derivation. To improve the accuracy of simulation, this study uses Geographic Information System (GIS) software to analyze and process data, transforms all data into the WGS1984 coordinate system, and resamples them to a spatial resolution of 30 meters × 30 meters to ensure consistent rows and columns. The study mainly involves the following types of data [8-10]. Data type analysis and source table is shown in Table 1.

Table 1 Data Type Analysis and Source Table

Type	Data Name	Data Type	Data Accuracy	Data Source
Natural Environment Data	Land Use	Raster	30m×30m	https://geocloud.cgs.gov.cn/
	Soil	Raster	1km×1km	https://www.resdc.cn/; Resource and Environment Data Sharing Center, Chinese Academy of Sciences
	Elevation Data	Raster	30m×30m	—
	Slope Data	Raster	30m×30m	—
	Annual Precipitation	Raster	1km×1km	—
Economic and Social Data	Population Density	Raster	1km×1km	https://www.resdc.cn/
	Gross Domestic	Raster	1km×1km	https://www.resdc.cn/

Type	Data Name	Data Type	Data Accuracy	Data Source
	Product			
	Distance to Main Roads	Vector	—	https://openmaptiles.org/
	Distance to Secondary Roads	Vector	—	https://openmaptiles.org/
	Distance to Railways	Vector	—	https://openmaptiles.org/

Visualization of driving factors in the Nanjing Metropolitan Area is shown in Figure 2.

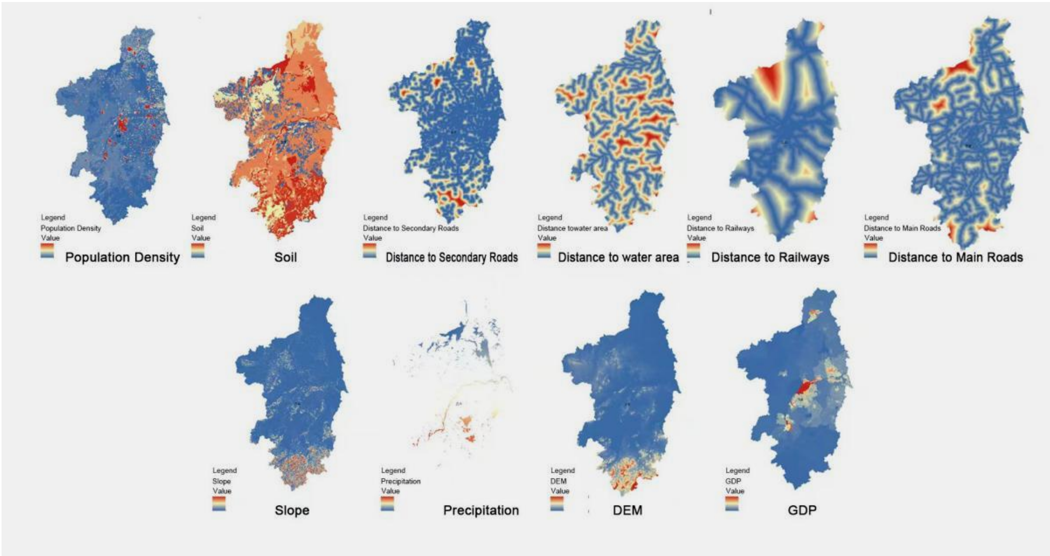

Figure 2 Visualization of Driving Factors in the Nanjing Metropolitan Area
Source: http://bzdt.ch.mnr.gov.cn

2.4 Land Use Simulation (PLUS) Model

The PLUS (Patch-generating Land Use Simulation) model is a new land use simulation method that combines the random forest algorithm and the multi-type random patch seed expansion (CARS) mechanism. It aims to solve the limitations of traditional CA (Cellular Automata) models in simulation accuracy, rule adaptability, and dynamic evolution capability. By constructing the LEAS (Land Expansion Analysis Strategy) rule framework, the PLUS model can more accurately capture the driving factors of land use change and their influence laws, thereby realizing the scientific simulation and prediction of land use spatial pattern. Its functional principle is as follows:

$$TP_k = \begin{cases} (r + TP_k) \times w & \text{if } r + TP_k \le 1 \\ 1 \times w & \text{if } r + TP_k > 1 \end{cases} \tag{1}$$

Firstly, the PLUS model uses the random forest algorithm to mine the main driving factors of land use change from multi-dimensional natural environment and socio-economic data, such as population density, GDP, transportation network, etc., and quantifies the contribution of these factors to various land use changes. Secondly, the LEAS method is used to calculate the growth probability of each land use type, and combined with the transfer matrix, dynamic rules for multi-type land change are generated. This rule generation process not only considers historical data, but also integrates current policies and planning requirements, with high adaptability. Finally, based on the CARS mechanism, the PLUS model allows land use patches to expand gradually according to a certain probability, thus simulating the land use evolution model that conforms to the spatio-temporal dynamic characteristics.

Compared with traditional CA models, the PLUS model shows significant advantages in accuracy and applicability. The introduction of the random forest algorithm enables the PLUS model to extract the driving logic of land use change from multi-dimensional data, improving the scientificity and accuracy of simulation results. At the same time, the LEAS framework allows customized rules for different types of land, supports more complex transfer mechanisms, and overcomes the rigid problem of traditional CA models in rule design. In addition, the CARS mechanism enhances the dynamic characteristics of simulation, making land use patches more realistically reflect the spatio-temporal expansion process. Thanks to these improvements, the PLUS model has wider applicability in the field of land use simulation, especially in complex situations such as urban-rural planning and ecological protection.

In practical applications, the PLUS model is often used to predict the spatio-temporal dynamic changes of urban and rural land use, providing a scientific basis for regional planning. In the urban expansion scenario of this study, the model can simulate the impact of different planning strategies on the land use pattern and help optimize resource allocation and layout. It provides a scientific and accurate means to solve the complex problems of land use change.

2.5 Calibration Method

Due to the gradually emerging limitations of the traditional Kappa coefficient in verifying the accuracy of prediction results, this paper selects the FoM (Figure of Merit) coefficient as an alternative indicator to more accurately evaluate the prediction effect of the model. The calculation formula of the FoM coefficient is as follows:

$$\mathrm{FoM} = \frac{B}{A + B + C} \tag{2}$$

Where A represents the area of the region predicted by the model to change continuously but actually unchanged; B is the area of the region predicted to change and accurately predicted; C is the area of the region that actually changed but not predicted by the model; D represents the area of the region predicted by the model to be unchanged and accurately predicted. These variables constitute a comprehensive evaluation of the model prediction results. Studies have shown that the FoM coefficient ranges from 0 to 0.59, and the larger the value, the higher the prediction accuracy. Usually, a FoM value lower than 0.3 is considered poor, 0.3 is moderate, and above 0.3 indicates high prediction quality.

In previous studies (Varga et al., 2019), 12 different driving factors were selected and divided into two parts: natural environment data and socio-economic data. Natural environment data mainly came from remote sensing images with a resolution of 1×1 km, including land use type, annual average temperature, annual average precipitation, evapotranspiration, night light and other related indicators. Socio-economic data included GDP, distance to main roads and railways, distance to government locations, population density, industrial density, etc. These data existed in the form of points, lines and polygons, comprehensively reflecting the actual situation of the eco-economic system. In the analysis process, the calculation of relevant distances was completed through geometric models to ensure the comprehensiveness and accuracy of research data.

In this paper, the growth probability of each land use type is calculated according to the change of land use data from 2010 to 2020. The results show that the FoM coefficient of land use change predicted by the model from 2010 to 2020 is 0.35 (as shown in Figure 3), indicating that the prediction effect is ideal and can meet the basic requirements of prediction accuracy in this study (Deng and Quan, 2022). This result not only reflects the scientificity and rationality of the model prediction, but also provides a reference for verification methods in future land use change research. In addition, the introduction of FoM makes up for the deficiency that the traditional Kappa coefficient is difficult to capture prediction details, improving the comprehensiveness and reliability of model evaluation.

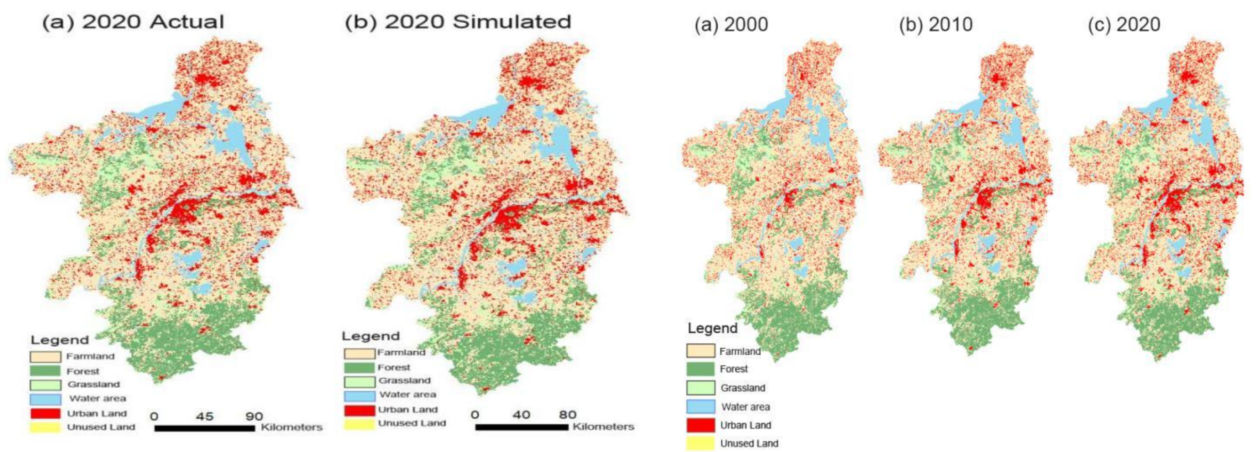

Figure 3 Land Use Status of the Nanjing Metropolitan Area
Source: http://bzdt.ch.mnr.gov.cn

3 RESULTS

3.1 Land Use Change in the Nanjing Metropolitan Area (2000–2020)

Over the two decades from 2000 to 2020, the land use pattern of the Nanjing Metropolitan Area has undergone significant changes (see Figure 4 and Table 2 for details). With the continuous advancement of social and economic activities, the core area covered by the study, especially the zone along the Yangtze River, has gradually evolved into an urban area with a high concentration of population. During this period, the outward expansion of cities continued, promoting a steady increase in built-up area, which grew by 2,318 square kilometers from 2000 to 2020. By 2020, the built-up area of the region nearly doubled, reaching twice the level of 2000. Due to the long agricultural history and plain-dominated landform of the region, farmland accounts for approximately 60% of the total study area.

Table 2 Land Use Status of the Nanjing Metropolitan Area

Year	2000	2000	2010	2010	2020	2020
Type	Area (km²)	Proportion (%)	Area (km²)	Proportion (%)	Area (km²)	Proportion (%)

Year Type	2000 Area (km²)	2000 Proportion (%)	2010 Area (km²)	2010 Proportion (%)	2020 Area (km²)	2020 Proportion (%)
Farmland	43644177	60.24	41303111	57	40389840	55.94
Forest	12097218	16.69	11970823	16.52	11657106	16.15
Grassland	2912089	4.02	2564068	3.54	2973173	4.12
Water Area	6866834	9.48	7475249	10.32	7207899	9.98
Urban Land	6915762	9.55	9062581	12.5	9903218	13.72

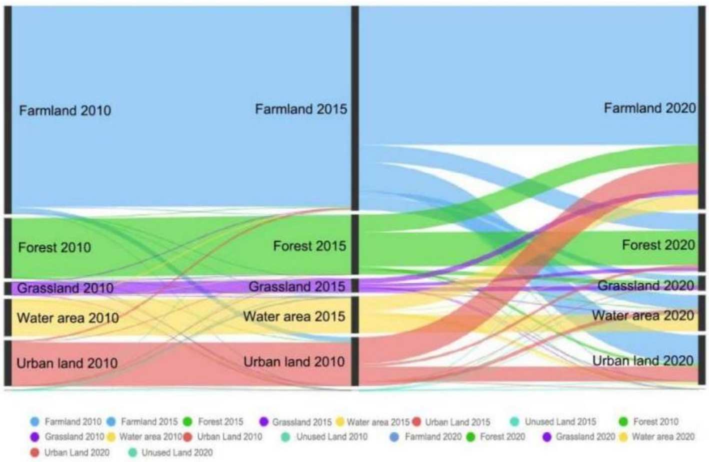

Figure 4 Sankey Diagram of Land Use Transition in the Nanjing Metropolitan Area

Land use status of the Nanjing Metropolitan Area is shown in Figure 3.
Land use status of the Nanjing Metropolitan Area is shown in Table 2.

3.2 Land Use Transition in the Nanjing Metropolitan Area (2000–2020)

To study the land use transition in the region, the changes from 2000 to 2010 were mainly the mutual transfer among farmland, forest and water areas. The conversion between farmland and forest was the most common change, with 148 square kilometers of farmland converted to forest and 200 square kilometers of forest converted to farmland. 2,207 square kilometers of farmland were converted to urban land.
Sankey diagram of land use transition in the Nanjing Metropolitan Area is shown in Figure 4.
Land use changes from 2010 to 2020 were mainly manifested as the mutual transition among farmland, forest and construction land. 3,202 square kilometers of forest were converted to farmland. The newly increased urban land was mainly converted from farmland, with 5,268 square kilometers of farmland converted to urban land.
Land use transition in the Nanjing Metropolitan Area (2000–2010) is shown in Table 3.

Table 3 Land Use Transition in the Nanjing Metropolitan Area (2000–2010)

Land Use Type (km²)	2010 Farmland	2010 Forest	2010 Grassland	2010 Water Area	2010 Urban	2010 Unused
2000 Farmland	36221.15	148.31	32.79	650.16	2207.78	19.57
2000 Forest	200.11	10504.88	19.05	11.87	118.93	32.67
2000 Grassland	187.12	98.77	2247.89	57.88	27.37	1.86
2000 Water Area	134.53	4.72	6.04	5982.60	52.01	0.24
2000 Urban	426.14	14.41	1.00	24.99	5749.60	8.04
2000 Unused	0.39	1.01	0.01	0.08	0.40	8.57

Land use transition in the Nanjing Metropolitan Area (2010–2020) is shown in Table 4.

Table 4 Land Use Transition in the Nanjing Metropolitan Area (2010–2020)

Land Use Type (km²)	2020 Farmland	2020 Forest	2020 Grassland	2020 Water Area	2020 Urban	2020 Unused
2010 Farmland	25137.64	3156.26	1045.24	2426.90	5268.34	36.30
2010 Forest	3202.07	6173.37	703.58	166.76	458.03	12.14
2010 Grassland	831.01	572.52	684.28	88.56	113.40	0.26

2010 Water Area	2677.34	158.15	145.60	3157.11	546.70	3.34
2010 Urban	4470.78	407.14	96.63	644.56	2516.81	5.10
2010 Unused	32.02	23.95	0.53	3.23	9.61	1.54

3.3 Land Use Prediction for the Nanjing Metropolitan Area

The PLUS model is used to predict the future land use status of the Nanjing Metropolitan Area. The results show that land use changes in the study area are closely related to human activities, especially from 2000 to 2020, which is mainly reflected in the rapid expansion of construction land and the substantial reduction of farmland area.
In the study area, farmland area has decreased the most and is the most frequently converted land use type. The primary reason is the advancement of urbanization, which has led to the large-scale conversion of vast farmland around the original city to other types of land use, especially built-up areas. In addition, even farmland that has not been directly converted has been affected by urbanization to varying degrees. Another important factor leading to the reduction of farmland area is the implementation of environmental protection policies, such as ecological land policies like returning farmland to forest, which have converted part of farmland to forest and water areas.
The prediction results reveal that the most prominent spatial feature in the metropolitan center is the continuous expansion of existing building complexes and the emergence of a large number of new buildings. However, at the same time, farmland and ecological land (including forest, grassland and water areas) have been significantly reduced. With the continuous progress and development of the study area, the trend of urban expansion will inevitably encroach on farmland and ecological land, resulting in the continuous reduction of farmland, forest and water areas, and the further expansion of construction land.
Prediction results of land use in the Nanjing Metropolitan Area based on the PLUS model (2025–2030) is shown in Figure 5.

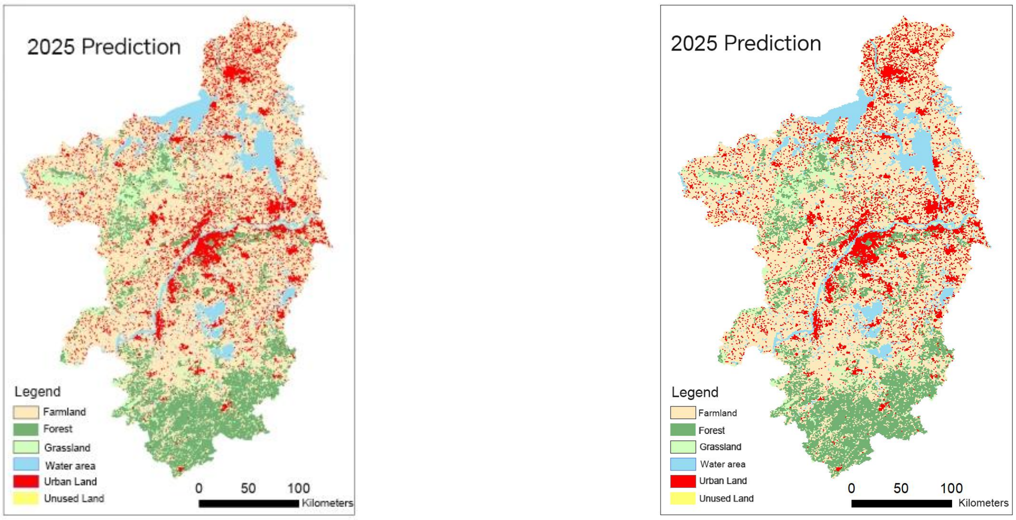

Figure 5 Prediction Results of Land Use in the Nanjing Metropolitan Area based on the PLUS model (2025-2030)
Source: http://bzdt.ch.mnr.gov.cn

4 PRELIMINARY DELINEATION AND ANALYSIS OF URBAN DEVELOPMENT BOUNDARIES

4.1 Delineation of Rigid Urban Development Boundaries in the Nanjing Metropolitan Area

Against the background of ecological civilization construction and high-quality development, the core idea of delineating rigid development boundaries in the Nanjing Metropolitan Area is to take ecological priority and resource protection as the core, clarify ecological redlines, cultivated land protection redlines and the bottom-line thinking of land use, and ensure that ecologically sensitive areas and basic farmland are free from development encroachment. This delineation emphasizes scientific layout and intensive use of resources, conducts dynamic evaluation through simulation models (such as the PLUS model) and technical means, balances ecological protection and urbanization needs, and optimizes urban spatial structure. At the same time, it focuses on regional coordinated development and promotes the functional zoning and integrated coordination of urban agglomerations within the Nanjing Metropolitan Area.
The purpose of delineating rigid urban development boundaries is to ensure ecological and environmental security, maintain food security and the sustainable use of land resources, and provide spatial constraints and directional guidance for the high-quality development of the regional economy. This boundary delineation can effectively curb the disorderly expansion of cities and inefficient land development, promote cities to develop in an efficient and compact direction, and provide a scientific basis for long-term planning in the future. Against the background of ecological

civilization construction, this delineation is an important measure to achieve balanced development of economy, society and ecology.

This research aims to adhere to the strategy of ecological protection priority by integrating the rigid constraints of ecological protection priority and cultivated land redlines. Combined with quantitative analysis and model simulation, it scientifically evaluates the potential impacts and ecological risks of land use and reasonably delineates development boundaries. It ensures that the urban ecological environment is not damaged, avoids the disorderly expansion of urbanization, and guarantees a win-win development path of ecological and economic benefits.

4.2 Delineation Ideas

The delineation of urban boundaries in the Nanjing Metropolitan Area is based on the construction of ecological civilization, adhering to the principles of "ecological priority, cultivated land protection, and coordinated development". By comprehensively considering various factors such as ecological protection, land resource utilization, and economic and social needs, a scientific and reasonable spatial control system is constructed.

Based on a scientific analysis of the development status of the Nanjing Metropolitan Area, this study introduces and superimposes different types of spatial constraint elements to delineate the boundaries and internal areas of the Nanjing Metropolitan Area on the premise that the delineation of rigid boundaries is not affected. Firstly, priority is given to identifying and protecting ecologically important areas such as water sources, basic farmland, and wetlands to avoid ecological damage caused by disorderly expansion; secondly, the rigid constraints of the cultivated land redline are strictly observed to ensure food security and the sustainable use of land resources; meanwhile, combined with the strategic position of the Nanjing Metropolitan Area in the Yangtze River Delta region, the needs of urban construction and land development are coordinated, and the spatial layout is rationally planned. In addition, the study also uses quantitative analysis tools such as the PLUS model to simulate land use changes under different scenarios, evaluate land resource carrying capacity and ecological and environmental risks, and provide data support for boundary delineation. Finally, the functional positioning of ecological protection areas, construction areas and general control areas is clarified through zoning control strategies. Combined with satellite remote sensing images of the Nanjing Metropolitan Area, clear development boundaries are ensured, resource protection is coordinated with urban development, laying a spatial foundation for the high-quality development of the Nanjing Metropolitan Area.

4.3 Delineation Results

Based on the results of national spatial suitability evaluation, GIS spatial analysis software is used for superimposition to obtain agricultural and ecological spaces. After processing fragmented patches, the rigid urban development boundary of the Nanjing Metropolitan Area is delineated. The delineation results of the development boundary show that the rigid urban development boundary in the study area is 93,474.54 hectares, accounting for 65.45% of the national land area of the Nanjing Metropolitan Area. Among them, the rigid constraint areas are mainly composed of basic farmland protection areas and ecologically sensitive areas to be protected, followed by lake water systems and basic farmland. The constrained areas for urban expansion are mainly concentrated in regions with concentrated ecological resources such as Zijin Mountain, Zhima Ridge, Laoshan Mountain, Qinglong Mountain, Dalian Mountain, Yuntai Mountain and Donglu Mountain.

Rigid urban development boundary of the Nanjing Metropolitan Area is shown in Figure 6.

Figure 6 Rigid Urban Development Boundary of the Nanjing Metropolitan Area
Source: http://bzdt.ch.mnr.gov.cn

5 CONCLUSIONS

This study conducted a comprehensive analysis of land use evolution in the Nanjing Metropolitan Area from 2000 to 2020 and, based on the PLUS model, scientifically simulated and delineated the spatiotemporal evolution trends and development boundaries for the next decade. The findings indicate that urban expansion was significant over the two-decade period, with the conversion of farmland to urban land serving as the primary driver of regional land use change; this expansion trend is projected to remain robust in future forecasts. By scientifically identifying key elements such as ecologically sensitive areas, water systems, and basic farmland, the study successfully delineated a rigid urban development boundary covering 65.45% of the total area, effectively designating areas with concentrated ecological resources—such as Purple Mountain and Lao Mountain—as constraint zones for urban expansion. This achievement not only enhances the efficiency of land resource utilization but also provides safeguards against the fragmentation of ecological spaces.

Although this study improved simulation accuracy through the PLUS model, certain limitations remain. The current model primarily relies on historical patterns and raster data for driver identification, and there is room for improvement in its ability to respond in real time to future macro-policy adjustments (such as the details of cross-provincial collaborative governance). Furthermore, although the data resolution has reached 30 meters, further refinement is needed for management at the more micro-level community scale. Future research will focus on integrating more social sensing data and dynamic policy intervention scenarios to further optimize spatial control mechanisms and explore how to achieve a dynamic balance between healthy, sustainable urban development and ecological conservation more precisely within complex administrative boundaries.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Chen Yuyu, Yu Mingxiao. A Study on the Methodology for Local Coordinated Optimization of County-Level Urban Development Boundaries Based on Strategic Orientation: A Case Study of Qiandongnan Prefecture. Urban Architecture, 2025, 22(14): 69-72.

[2] Wu Haiming. A Study on the Dynamic Changes in Land Use and Their Driving Factors in Tai'an City Based on ArcGIS. Technology and Market, 2025, 32(07): 145-149.

[3] Niu Shuai, Wang Xiaoli, Wang Qinghua, et al. Monitoring and Evaluation of Urban Development Boundaries: Conceptual Understanding, Indicator Construction, and Dynamic Management. Planner, 2025, 41(07): 84-90.

[4] Wang Xinzhe. Dynamic Maintenance of Territorial Spatial Master Plans: Practical Exploration, Management Coordination, and Mechanism Optimization. Journal of Urban Studies, 2025, 3(03): 41-47.

[5] Huang Huifang, Ma Shilin, Zhao Bingyan, et al. A Study on the Delimitation of Permanent Basic Farmland in Yunnan Province Based on the Coordination of the "Three Lines". Geology, Mining, and Surveying, 2025, 41(02): 94-100.

[6] Wei Yi, Li Ran. Technical Analysis of Village Planning Compilation in the Vicinity of Urban Development Boundaries: A Case Study of Gaohu Community, Guangde City. Anhui Architecture, 2025, 32(05): 28-29.

[7] Kong Lingwei. Research on Highway Land Classification and Spatial Control Systems under the Context of Territorial Spatial Planning. Integrated Transport, 2025, 47(03): 23-26.

[8] Deng Mulin, Zhu Jiang, Ouyang Xiaofu, et al. A Study on the Compliance Review Mechanism for Construction Project Land Use Based on a Hierarchical Control System of General-to-Detailed Planning. Journal of Human Settlements in Western China, 2025, 40(01): 188-194.

[9] Zhang Lina. Pathways to Achieving Land Resource Optimization and Environmental Protection Goals in Territorial Spatial Planning. Housing and Real Estate, 2025(06): 43-45.

[10] Feng Zhen, Huang Wei, Wang Di, et al. A Study on the Optimization of Urban Development Boundaries Based on the FLUS Model: A Case Study of Wuyi County, Zhejiang Province. Architecture and Culture, 2025(02): 63-65.