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Exploration on the Development Boundary Delimitation Method of Small and Medium-sized Cities under Multi-scenario Simulation

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Abstract: *Research purposes: In order to solve the problem that the development boundary of small and medium-sized cities is "inaccurate" and it is difficult to coordinate with the current land and space planning, the purpose is to form a set of universal development boundary demarcation process of small and medium-sized cities. Methods: Optimize the existing practice of demarcation research methods, fully connect with the pattern of land development and protection, combine the artificial neural network model (GEOSOS model) and use Model Builder to design a land use simulation model with "double evaluation" results and "reverse" protection red line module, and consider the policy-oriented influence, and comprehensively consider the above aspects to explore a method of boundary demarcation of urban development that is coordinated and unified with development and protection. Research: The simulated land use results of the model based on "positive development guidelines" and "reverse scale control" are in line with the law of urban spatial expansion of small and medium-sized cities represented by dangyang city. The research results can not only provide reference for the future urban development of dangyang city and the spatial planning of dangyang city, but also provide technical support for the demarcation of urban development boundaries in China.*

Keywords: *Urban Development Boundary; Artificial Neural Network Model; CA Model; Delineation Method; Land Spatial Planning*

1. Introduction

Under the background of ecological civilization construction, urban sprawl leads to serious problems such as inefficient utilization of urban land, ecological destruction, environmental pollution, and traffic congestion. As an effective measure and means to curb urban spatial sprawl, urban development boundary plays an important role in effectively controlling urban sprawl and scientifically improving urban land intensive use.[1] At present, in the reform of land and space planning, aiming at the problems such as erosion of basic farmland and ecological security as well as inefficient utilization of urban land, various circles in China have carried out extensive research on it[2]-[6].

There are three main technical methods to demarcate the boundary of urban development: First, the demarcation method of positive thinking of "spontaneous growth". The models commonly used to simulate urban expansion include cellular automata, SLEUTH model and artificial neural network. Cellular automata have the ability to simulate the spatio-temporal evolution process of complex systems and is suitable for simulating the dynamic growth of cities. Artificial neural network is a model suitable for simulating nonlinear complex systems. Cellular automata and artificial neural network can be used together, that is, ANN-CA model.[7][11] Second, the reverse thinking method of "first bottom and then figure" delineates the unsuitable areas with limited construction conditions or sensitive ecological environment by means of land suitability evaluation, cultivated land quality evaluation and ecological infrastructure law, and then delineates the development boundary based on bottom line control [12]-[18]. The third method is "comprehensive coordination", which not only follows the principle of "first bottom and then figure" to define the restricted development areas of urban expansion, but also pays attention to the demand of urban development for urban land expansion [19]. At present, the positive demarcation method of "spontaneous growth" is only suitable for big cities or biased to meet the development needs of cities, but the role of resource constraint is lacking. Among them, cellular automata have a weak influence on factors such as topography and geological disasters, and it will also make it difficult to distinguish between urban construction land and village construction land and to solve the problem of excessive growth of construction land around villages. The artificial neural network model itself has the

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advantage of simulating complex systems, but its calculation principle is complex, the parameters are learned in the black box, and the prediction results are difficult to adjust[20]. In the reverse thinking demarcation method of "first bottom and then figure", the single-field analysis has great limitations on the results of suitability zoning of urban development, and the boundary obtained can not meet the actual space requirements of urban development. The demarcation method of "comprehensive coordination" considers the development of urban space from the perspective of resource constraints and construction needs, but it is not closely integrated with the current land space planning, and its technical methods have not yet formed a universal process.

At present, most of the practical research focuses on the development boundary demarcation method of big cities, but there is little research on the development boundary demarcation method of small and medium-sized cities. In order to meet the requirements of high-quality development of land space, we should combine the Guidelines for Demarcation of Urban Development Boundary, optimize the existing practice of demarcation research methods to fully connect with the pattern of land development and protection. The artificial neural network model (GEOSOS model) uses Model Builder to design a land use simulation model with "double evaluation" results and "reverse" protection red line module, considering that the development of small and medium-sized cities is more active. The development boundary is usually influenced by policy orientation. Considering the above aspects comprehensively, we want to find a method to demarcate the boundary of urban development that is coordinated and unified with development and protection, so as to solve the problem of "inaccurate demarcation" of urban development boundary and form a set of development boundary demarcation process for small- and medium-sized cities that can be popularized.

2. Method Construction

Based on the practice of land space planning, on the basis of analyzing and studying the inappropriateness of common development boundary demarcation methods to small and medium-sized cities, this paper explores the boundary demarcation methods of urban development that meet the requirements of land space planning and the development characteristics of small and medium-sized cities.

2.1 Optimize the Overall Land Space Development and Protection Pattern

The evaluation path of “Evaluation of environmental carrying capacity of resources and suitability evaluation of land development" is studied. Guided by the evaluation results, the land space is systematically and coordinately analyzed in combination with the current land classification. The spatial attributes and grades of single suitability space and compound suitability space are classified and evaluated, and the land development and protection pattern are preliminarily defined according to the principle of " ecology > agriculture > town".

2.2 Optimize the Simulation Model of Urban Land Use

In this study, ANN artificial neural network model and urban land use simulation model are used to construct the practical path that combines two scenario simulation models of "positive development guidance" and "reverse scale control", and the boundary of urban development is preliminarily delineated.

2.2.1 Constructing ANN Artificial Neural Network Model

The main geographic simulation software (Geo SOS for ArcGIS) is used to simulate and correct the experimental data to obtain appropriate parameter values. This software can effectively train the neural network. After reading the parameter values, the model can simulate the real city according to the law of land spontaneous evolution.

The ANN artificial neural network model is mainly divided into two stages: training and simulation. In the training stage, the artificial neural network is trained by sampling data to obtain the network weight value, and various factors affecting land use change, statistical values of various land use types in the domain window and current land use types are input to obtain the probability value of each land use type. Through the probability values of each land use type obtained in the simulation, the maximum value corresponds to the land use type to be converted, and then the threshold value is compared to determine whether it can be converted. The formula is as follows:

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$$P(k,t,l) = (1 + (-\ln\gamma)^{\alpha}) \times P_{ann}(k,t,l) \times \Omega_k^t \times con(S_k^t) \quad (1)$$

At cell time t, the conversion probability of the first land use type P= random factor × artificial neural network calculation probability × neighborhood development density × conversion suitability.

In the process of simulation, ANN artificial neural network not only considers the spatial distance, terrain, slope, land suitability, but also takes into account the spatial variable of quality disaster risk. According to the characteristics of small and medium-sized cities, the selection of influencing factors is appropriately adjusted, so that the land use conversion value obtained by the model in the training of land use conversion rules is more accurate, and the results obtained by the model training will be more consistent with the actual development of small and medium-sized cities.

2.2.2 Constructing the Simulation Model of Urban Land Use

The core of constructing urban land use simulation model is the model building and realization of conversion rules. The model is built by ArcGIS Model Builder and the urban land use simulation can realize the simulation and prediction of urban land use. The restrictive constraint and rigid constraint parts in the comprehensive cycle model of urban land use simulation (Figure 1) fully meet the requirements of land space planning, and evaluate the degree of development suitability more scientifically by putting in the evaluation results of land development suitability and applying the evaluation results to the demarcation of development boundary. By establishing the rigid constraint model, the permanent basic farmland red line and ecological red line can be avoided more accurately, which accords with the principle of "bottom line constraint".

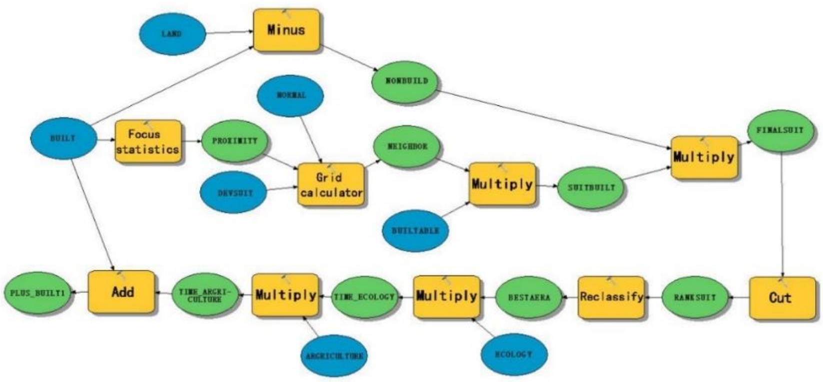

Fig. 1: Comprehensive cycle model of urban land use simulation

2.2.2.1 Domain Influence and Conversion Rules of Random Variables

The state of the cell and the surrounding land use conditions determines whether the cell will develop into urban land. The neighborhood is set as RxR to identify the PROXIMITY of the neighboring land. Random factors are inevitable and uncertain in the process of urban expansion, so random disturbance factors are introduced to reflect its uncertainty, and NORMAL grid is used to represent random influencing factors.

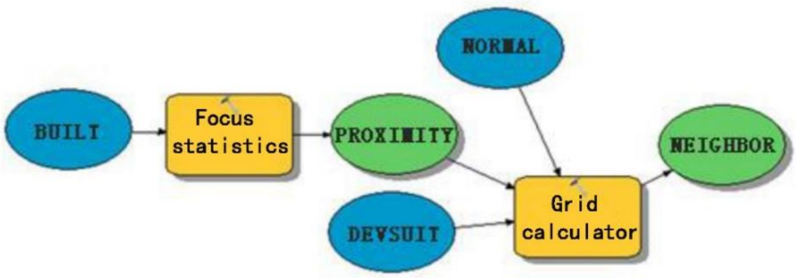

Fig.2: Cell neighborhood function, random factor function and absolute restrictive constraint model

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2.2.2.2 Conversion Rules of Influencing Factors of Land Space

Urban expansion can be seen as determined by a series of spatial factors, such as traffic, hydrology, topography, economy, etc. Taking the land development suitability evaluation grid as the comprehensive evaluation value reflecting these spatial factors, the evaluation value is converted into positive value DEVSUIT by grid calculator. The suitability of neighboring construction land expressed by neighbor is as follows:

$$NEIGHBOR=DEVSUIT+PROXIMITY\times 10+NORMAL\times 2 \quad (2)$$

Where DEVSUIT represents the transformed land development suitability evaluation value, PROXIMITY represents the adjacent current land use, and NORMAL represents random influencing factors.

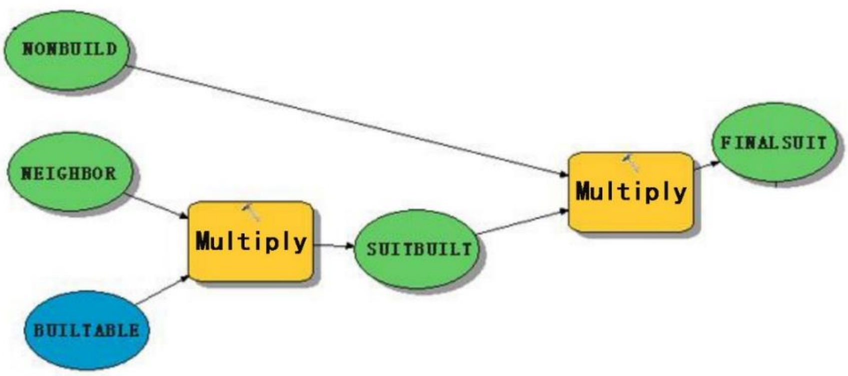

Fig. 3: Transformation model of influencing factors of land space

2.2.2.3 Conversion Rules of Hierarchy Constraints

RANKSUIT is obtained by grading the obtained value of the neighboring buildable non-current land FINALSUIT, and then the best value of BESTAREA in the most suitable area for construction is taken.

$$BESTAREA=\{1, 0\} \quad (3)$$

The number 1 represents the highest value of the region suitable for construction, and the number 0 represents the region other than the most suitable region for construction.

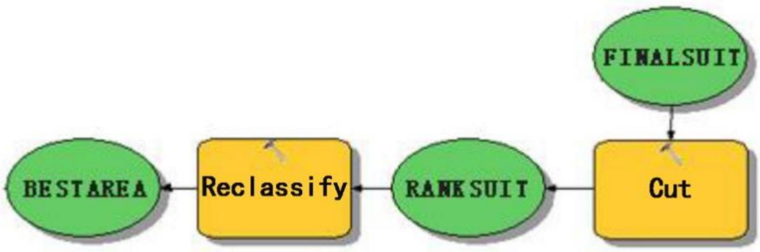

Fig. 4: Building appropriate level constraint model

2.2.2.4 Conversion Rules of Rigid Constraints

Ecological red line and permanent basic farmland are two rigid red lines that cannot be touched, and development and construction need to be strictly restricted. The ecological red line grid and permanent basic farmland grid in Dangyang city are determined, and the conversion rules are as follows:

$$ECOLOGY=\{1, 0\} \quad (4)$$

$$ARGRICULTURE=\{1, 0\} \quad (5)$$

The number 1 represents the conversion value of plots not within the ecological red line and those not within the permanent basic farmland, and the number 0 represents the conversion value of plots

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within the ecological red line and those within the permanent basic farmland.

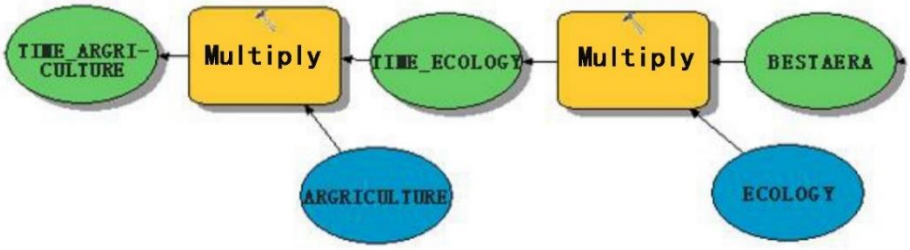

Fig. 5: Rigid constraint rule model

2.3 Guarantee the Scale Delimitation and Quantification

By combining the comprehensive growth rate method, regional density distribution method, population transfer prediction and urbanization level prediction, the scale of urban centralized construction areas are defined, and the indexes are subdivided according to the scale structure of urban and rural areas to restrict the expansion ceiling of urban and rural land by scale.

2.4 Ensure That the Development Is Rigid and Flexible

On the basis of the prediction results of the model, considering the demand and flexibility of land use, the elastic development area and the special purpose area should be preliminarily demarcated, so as to reflect the characteristic attributes of rigid control and elastic guidance of the development boundary. The delineation of urban flexible development areas is mainly at the township level in the central urban area, and this range is mostly the village in the city or the village on the edge of the city in the urban-rural integration area. Special-use areas refer to the regional space which is not suitable to be divided from the development boundary and closely related to the city, such as ecological and agricultural values. In practice, it is necessary to make a good connection with the blue-green space of centralized construction areas, so as to form a complete urban ecological network system.

2.5 Strengthen the Adaptability of Policy Tools

We should pay attention to long-term planning, accurately predict land use such as infrastructure facilities and major development projects, and use the put-in land index. At present, some scholars have proposed to adjust and revise the development boundary by using the time limit of space boundary, so as to ensure the legal effect and effective implementation of urban development boundary, and achieve the purpose of combining planning with management.

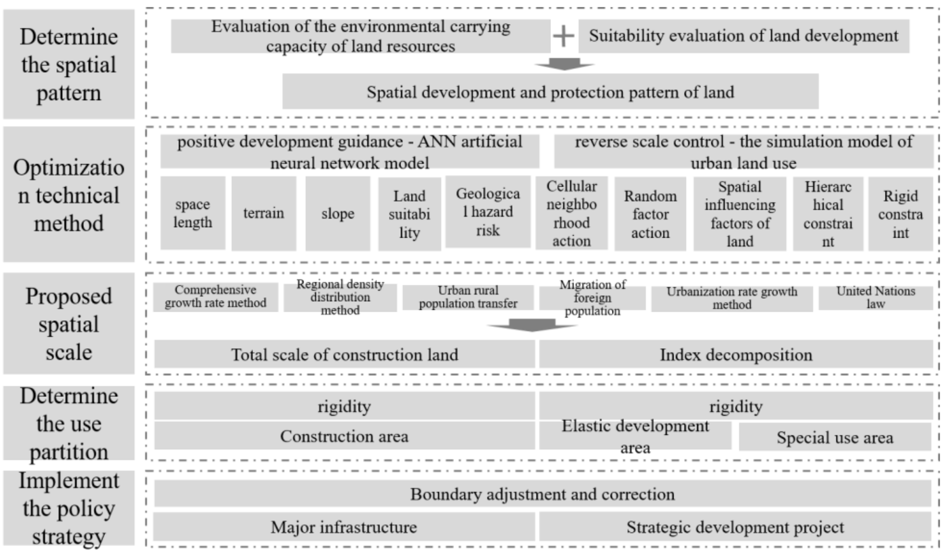

Fig. 6: Flow chart of development boundary demarcation

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3. Research Design

3.1 Overview of the Study Area

Dangyang, located in the central and western parts of Hubei Province, is in the stage of rapid industrialization and urbanization. It is a typical small and medium-sized city, and its economic and social development and infrastructure construction have created a huge rigid demand for limited land space. Compared with big cities, it is necessary to consider the great changes in spatial form caused by the introduction and layout of major strategic projects. The external forces have a greater influence on spatial expansion and the flexibility of development is also greater. In terms of resource protection, there are unique resource conditions, which require both reasonable utilization and proper protection. On the demand of management and control, the management level is relatively low, and the implementation of policies is relatively difficult, so it is necessary to scientifically delimit and reasonably guide the development boundary.

3.2 Data Sources

The experimental data include the data of land change survey in 2014-2018, the data of the third land space survey in 2020, the latest data of land use planning, vector data of Dangyang ecological red line and permanent basic farmland in Dangyang, statistical yearbook of Dangyang (2013-2018), master plan of Yichang and master plan of Dangyang. Dangyang city's land development suitability evaluation, urban land evaluation, geological disaster evaluation, traffic trunk lines, traffic hubs, distance evaluation of central towns, etc.

Table 1: Data types and source statistics

serial number	data type	Data details	data source
one	Vector data	Administrative divisions of Dangyang city	Natural resources department
two		The Third Land Survey of Dangyang city	
three		Distribution of nature reserve	
four		land use planning	
five		Permanent farmland protection red line	
six		ecological wealth	
seven	raster data	Digital elevation model (DEM)	Spatial data cloud website
eight		Landsat8 satellite digital products	
nine		Net primary productivity NPP	Chinese Academy of Sciences Resources and Environment Science Data Center
10		Chinese soil data set	Website of Soil Science Data Center
11	Other data	Daily value of Hubei meteorological station set (2008-2017)	China Meteorological Data Network
12		Remote sensing image	Natural resources department
13		Dangyang city Statistical Yearbook	
14		Dangyang city City Master Plan	
15		Overall environmental planning of Yichang city	
16		Geological disaster prevention and control planning in Dangyang city	
17		Water environment function zoning in Hubei Province	Water conservancy department website
18		Total amount of water resources development and utilization in Dangyang city	Dangyang city Municipal People's Government
19		Spatial Analysis and Pollution Assessment of Cr, Cu, Zn and Pb Contents in Soil of Hubei Province	China National Knowledge Infrastructure
20		Peak acceleration of ground motion	China Seismic Parameter Zoning Network
21		Types and occurrence rate of meteorological disasters	Dangyang city Meteorological Bureau
22		General survey data of basic water conservancy projects	Water Conservancy Bureau

3.3 Data Processing

3.3.1 Reclassification of Land

In order to balance the differences and uniformity of all kinds of land use and highlight the heterogeneity of all kinds of land use in the study area, the original land use types are reclassified into 9 categories: urban construction land, cultivated land, grassland, woodland, water area, garden, wetland, village construction land and unused land, which are interpreted as the basic data for simulating urban land use.

Table 2: Conversion table of land use classification

Land use category (major category)	land use Grid value	Including ground class
Urban construction land use	one	Land for roads, towns and villages, commercial land, park squares, mining land, airport land, scenic spots and special land.
plough	2	Dry land, irrigated land and paddy field
lawn	three	Natural pasture, artificial pasture and other grasslands
waters	four	Pond surface, aquaculture pond, land for hydraulic construction, land for irrigation and water conservancy facilities, water surface of lakes, reservoirs, ditches and rivers
woodland	five	Bamboo forest land, arbor forest land, shrub land and other forest land
Unused land	six	Bare land, Kugaji, natural reserve
field	seven	Orchards, tea gardens and other gardens
wetland	eight	Inland beaches and marshes
Village construction land	nine	Villages, village settlements, facility agricultural land and rural roads

3.3.2 Analysis of Influencing Factors Of Urban Spatial Expansion

The driving factors of the spatial expansion of the central Dangyang city are considered from Dangyang's superior location. Major national roads, county roads and urban trunk roads are selected for transportation accessibility, while airports, railway stations, long-distance passenger stations and expressway exits are considered for transportation hub accessibility. The accessibility is comprehensively evaluated and scored by grading threshold. Then, yaahp software is used to test and predict the weight of accessibility of main roads and transportation hubs, and comprehensively determine the location dominance of Dangyang city. Among the limiting factors, considering that the terrain has a great influence on the land use expansion of small and medium-sized cities, and in the hilly area of Dangyang, the influencing factors such as geological disasters are selected.

Table 3: Space influence factors

evaluating indicator	Evaluation factor	Grading threshold	Evaluation value
Accessibility of main roads	National highway	Distance from national highway and provincial highway ≤ 3KM	five
		3 km < 6 km or less from national and provincial roads	four
		Distance from national highway and provincial highway > 6 km	one
	Daoxiang avenue	Distance from county road and township road ≤3KM	four
		3KM< < Distance from county road and township road ≤ 6KM	three
		Distance from county road and township road > 6 km	one
	Town road	Distance from urban roads ≤3KM	three
		3KM< < Distance from urban roads ≤6KM	2
		Distance from town road > 6 km	one
Accessibility of transportation hub	airport	30 minutes or less by car.	four
		30 minutes < drive ≤60 minutes	three
		Drive > 60 minutes	2
	train station	30 minutes or less by car.	five
		30 minutes < drive ≤60 minutes	four
		Drive > 60 minutes	2
	Long distance passenger station	30 minutes or less by car.	three
		30 minutes < drive ≤60 minutes	2
		Drive > 60 minutes	one
	Expressway entrance and exit	Drive≤30 minutes	4
		30 minutes<Drive≤60 minutes	3
		Driv>60 minutes	2
Urban disaster assessment	Distance from seismic fault zone	Unilateral≥400M	5
		Unilateral 200-400M	4
		Unilateral 100-200M	3
		Unilateral 30-100M	2
		Unilateral<30M	1

3.4 Land Use Simulation

3.4.1 Land Use Scenario Simulation Based On "Positive Development Guidance"

In this study, the geographical simulation software (Geo SOS for ArcGIS) is used to simulate the experimental data, so as to obtain appropriate parameter values. The software can effectively train the

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neural network. After reading the parameter values, the model can simulate the real city.

Simulation process: First of all, the reclassified land use change data in 2014 and 2018 is used to train the model. The comprehensive evaluation value of the spatial variable factor is automatically identified and calculated by using Geosoforarcgis. In each iteration, the land that can be converted in the adjacent range is dynamically calculated by using Geosoforarcgis tool. Secondly, random sampling is used to obtain training data about urban development and spatial variables from 2014 to 2018. The software automatically and continuously adjusts the model parameters to make the calculated values approach the actual values, so as to find the optimal parameters of the model. The calculated values of output layer neurons reflect the probability values of various land use. After obtaining the parameter values, this model is used to simulate the urban expansion process in this area. Finally, the transformation matrix between land types is used to judge, and combined with the training output parameter values, the urban land expansion is simulated.

Table 4: ANN Model Judgment Matrix Table

Land use category	Urban and rural construction land	plough	lawn	waters	woodland	Unused land	field	wetland	Village construction land
Urban land	1	0	0	0	0	0	0	0	0
plough	1	1	0	0	0	0	1	0	0
lawn	0	0	1	0	0	0	0	0	0
waters	0	0	0	1	0	0	0	0	0
woodland	0	0	0	0	1	0	0	0	0
Unused land	1	0	0	0	0	1	0	0	0
field	0	1	0	0	0	0	1	0	0
wetland	0	0	0	0	0	0	0	1	0
Village construction land	0	1	0	0	0	0	0	0	1

Simulation results: From the simulation of ANN artificial neural network model, Dangyang is expanding. Among them, the central city mainly expands to southeast, which is consistent with the development direction of the central city in the overall urban and rural planning and develops towards Jinqiao area. The scale of land expansion in Qianzhen, Wangdian Town and Ganxi Town is larger than that in the other four towns. There are many scattered plots of land around Geba Cement and Shuanglian Industrial Park, which are consistent with the land demand for key projects in the overall urban and rural planning. Urban land is mainly concentrated in the central city and seven towns, and there is a great demand for land.

Table 5: Simulation results of ANN artificial neural network model

Planning period	Scale of urban construction land (hectare)	Increase or decrease in planning period (hectares)	Number of iterations (times)	Number of conversion cells (number)
2019-2025	6532.4050	+439.1213	60	7475
2026-2030	6897.2175	+362.8125	50	6229
2031-2035	7260.0300	+362.8125	50	6229

Table 6: Adjustment table of simulated land use

Land use category	Current land area (hectare)	Simulated land area (ha)	Simulated land area in 2025 (hectare)	Simulated land area in 2030 (hectare)	Simulated land area in 2035 (hectare)	Increase or decrease in planning period (%)
Urban constructio n land	6099.03	7260.03	6534.405	6897.2175	7260.03	0.0054
plough	84257.01	84890.07	84494.408	84692.2388	84890.07	0.0029
lawn	638.28	638.28	638.28	638.28	638.28	0.0000
waters	24988.59	24988.59	24988.59	24988.59	24988.59	0.0000
woodland	76801.77	76801.77	76801.77	76801.77	76801.77	0.0000
Unused land	23.31	23.22	23.2762.5	23.248125	23.22	0.0000
field	9636.75	9013.77	9403.1325	9208.45125	9013.77	-0.0029
wetland	612.27	612.27	612.27	612.27	612.27	0.0000
Village constructio n land	11948.31	10777.32	11509.189	11143.2544	10777.32	-0.0054
total	215005.32	215005.32	214982.04	215005.32	215005.32	0.0000

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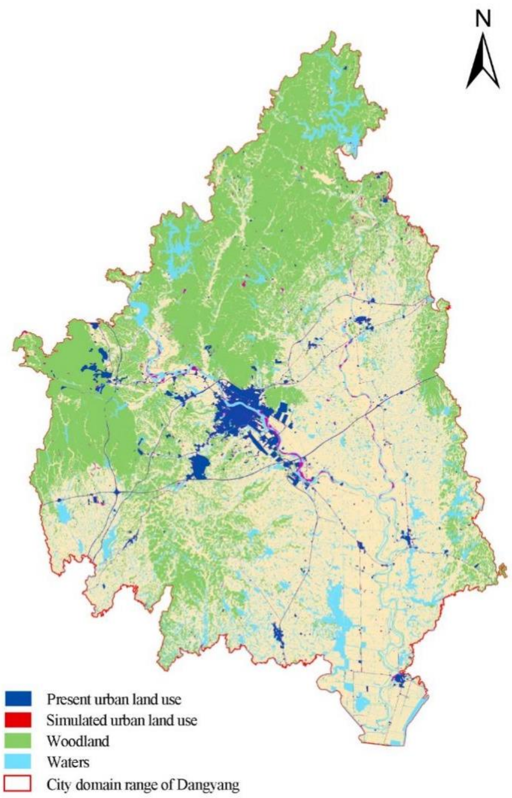

Fig. 7: Comparison between current urban land use and ANN model simulation results of urban land use in 2035

3.4.2 Land Use Scenario Simulation Based On "Reverse Scale Control"

In this experiment, the simulation model of urban land use is built by ArcGIS Model Builder and the conversion rules of the model are optimized to realize the simulation and prediction of urban land use.

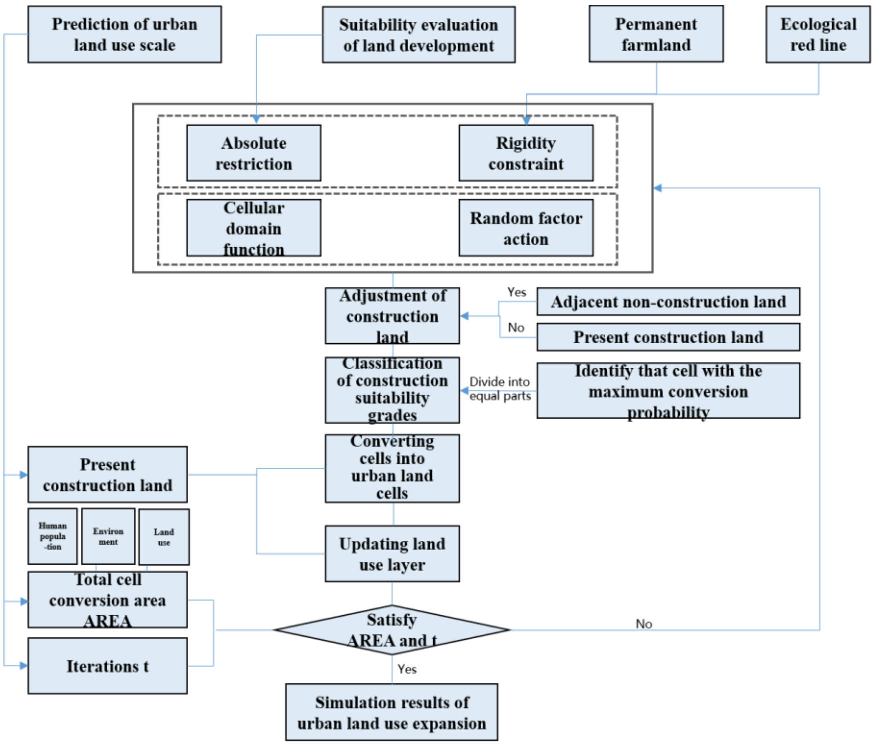

Fig.8: Overall flow chart of urban land use simulation

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Land use simulation: Firstly, the cell unit of this study is set to 30x30 meters; The cell state is expressed as S = {1, 0}, where number 1 represents urban land and number 0 represents non-urban land, and the cell state can only be 1 or 0 at a specific time t1; The neighborhood of cells is set to 7x7, and each cell is affected by the surrounding 48 neighborhoods. The determined conversion value of land development suitability evaluation is used as one of the restrictive conditions of urban land expansion simulation, and the data of permanent basic farmland and ecological red line are used as rigid constraints. Secondly, the specific process of using the BUILT model for simulation is as follows: input the current construction land BUT, start the first cycle simulation, automatically calculate the cell neighborhood, random factors and conversion probability by the built model, and use the predicted urban land use scale in Dangyang city to control the total land use, identify the cells with the maximum conversion probability and convert them into urban land, then deduct the grid data of permanent basic farmland and ecological red line to get the convertible urban construction land, and finally add the current urban construction land, so as to complete a generation-sending process, update the land use layer and get the first simulated urban land expansion result. Using the updated land-use layer, the above operations are repeated, and the effects of neighboring cities and random factors are calculated. Then, the maximum cell-cell conversion probability is repeatedly and dynamically updated, and the second and third simulation results of urban land use expansion are obtained.

Simulation results: The number of cells transformed by successive iterations will decrease in turn, and the base of the transformation results of the last two iterations is too small in the urban area, and the total amount of urban land can be reached by one iteration. Finally, the results of one iteration are selected as the results of this simulation, that is, the scale of urban construction land can reach 7,285.95 hectares by 2035. According to the simulation of urban land use, the urban land in Dangyang is generally concentrated and developed on the basis of each town, while the central urban area is expanded to Jinqiao area on the basis of concentrated development, while the other seven towns have less obvious land expansion. There is more land scattered around Gezhouba Cement Plant, and there is a great demand for land.

Table 7: Simulation results of constrained CA model

Iterations	Scale of urban construction land (hectare)	Increase or decrease in planning period (hectares)	Number of conversion cells (number)
one	7285.95	+1186.92	13188
2	7321.95	+36	400
three	7322.76	+0.81	9

Table 8: Statistical table of land use for simulation results

Iterations		Urban construction land	Non-urban construction land
Repeat for the first time	Number of cells	80955	2304170
	Area (hectares)	7285.95	207375.3
Second iteration	Number of cells	81355	2303770
	Area (hectares)	7321.95	207339.3
The third iteration	Number of cells	81364	2303761
	Area (hectares)	7322.76	207338.49

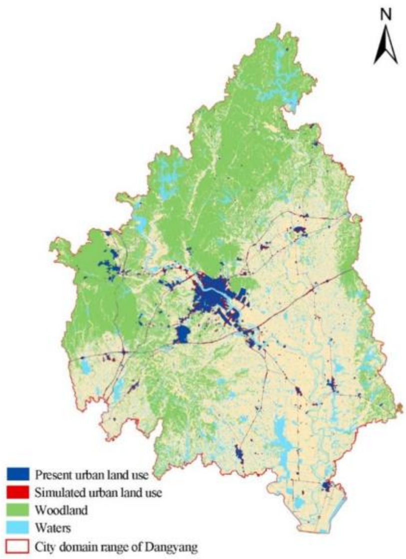

Fig. 9: Comparison between current urban land use and CA model simulation of urban land use in 2035

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3.4.3 Integration and Optimization of Simulation Results

Comparing the urban land use in 2035 simulated by the two models, it can be seen that the urban land use in 2035 simulated by the urban land use model is gradually expanding, which is constrained by the suitability of land space development and rigid boundary, while the ANN neural network model expands according to the rule of spontaneous growth of urban land use, and the simulated urban land use in 2035 has a relatively large expansion range. But overall, the results of urban land use simulated by the two models are consistent in the development direction and the rule of land use aggregation. The simulation results of the two models can be integrated and corrected to obtain the optimized prediction results of urban land use simulation in 2035.

The urban land expansion results simulated by the two models are intersected by GIS tools, and the finely divided map spots are cleaned up, so that the map spots with too small area are removed, and the urban land which not only accords with the urban development but also ensures the ecological security is not destroyed is obtained. According to the simulation results, the development direction and law of urban land can be analyzed, that is, Yuquan Street-Baling Industrial Park-Yanwumiao Group, seven concentrated towns, Shuanglian Industrial Park and Gezhouba Cement can be regarded as important areas for urban land development, and the debris map spots outside the important development areas can be deleted to obtain the optimized urban land layout map.

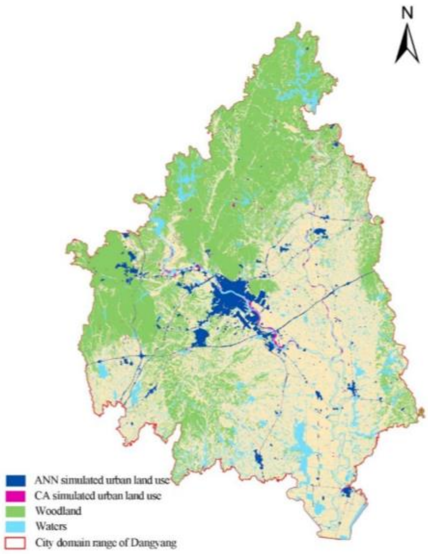

Fig. 10: ANN model simulation of urban land use in 2035; CA model simulation results of urban land use in 2035

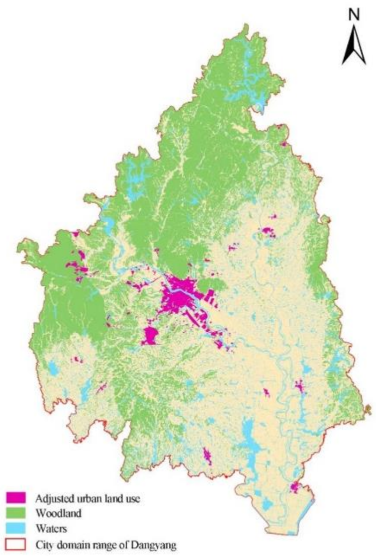

Fig. 11: Optimization diagram of simulation results of urban land use

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3.4.4 Initial Boundary of "Scale Constraint"

The mountain greening vegetation in Dangyang is better. The boundary of urban development should avoid the natural mountain and the destruction of mountains. Permanent farmland, as an important part of the "Three Districts and Three Lines" in land space planning, has a great influence on the spatial expansion of cities and towns, and the avoidance of permanent basic farmland must be considered when delimiting the boundaries of urban development. The red line of ecological protection is the bottom line of ecological environment security, and it is also a rigid constraint factor that restricts the development and construction of cities and towns. The avoidance of the red line of ecological protection must also be considered when delimiting.

Based on the above considerations, the layout of urban land in the main urban area of Dangyang city in 2035, the future development trend of "eastward expansion and southward migration", etc., for the convenience of management, with traffic roads, rivers, basic farmland, ecological red lines and other ground features as boundaries, the urban centralized construction areas are delineated to meet the demand of construction land.

Table 9: Control Table of Urban Land Use Scale

grade		name	Controlled land (hectare)
city town collect middle hair exhibition district region	Center City	Center City	4268.59
	heavy point town	wang dianzhen	153.09
		Herong town	309.04
		Banyue Town	161.67
		Ganxi town	251.81
	one kind town	Qianzhen town	100.01
		lianghe town	117.78
		Caobuhu town	220.01

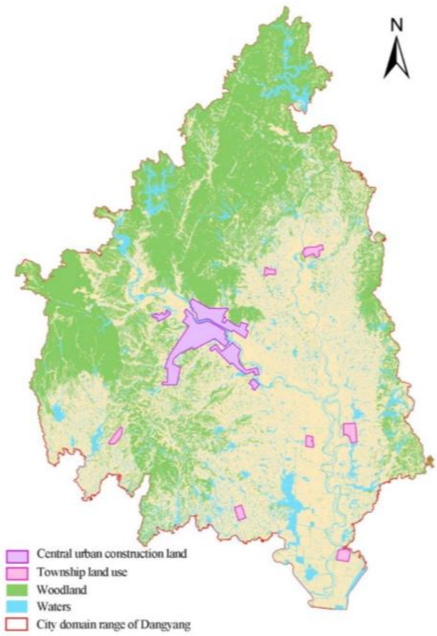

Figure 12: Centralized urban construction area

3.4.5 "Rigid-Elastic Combination" Framed Zoning

Considering the delineation of urban flexible development areas and special-purpose areas comprehensively, combined with the urban development situation of Dangyang city, 15% of the urban centralized construction scope is reserved as the urban flexible development reserved area in this study, and the ecological corridor formed by the Juhe River crossing the central city and the mountains in the southwest is considered to be included in the urban development boundary in this delineation.

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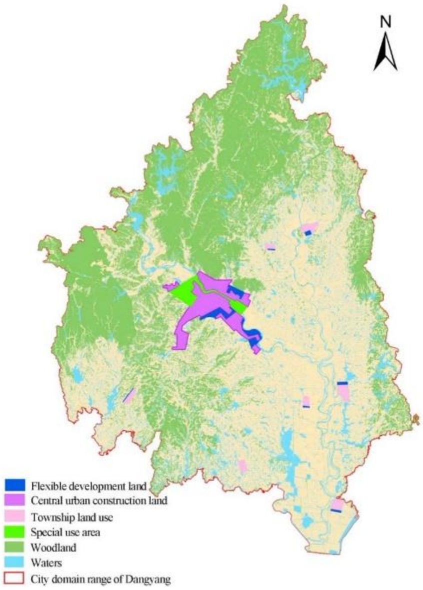

Figure 13: Urban centralized construction area, flexible development area and special purpose area

3.4.6 "Policy Coordination" Boundary Correction

The future development of Dangyang city and the site selection of major construction projects should be considered for the revision of urban development boundary. At the municipal level, it is necessary to reserve development and construction land for Shuanglian Industrial Park and Gezhouba Cement Plant, leaving room for the future industrial development of Dangyang city.

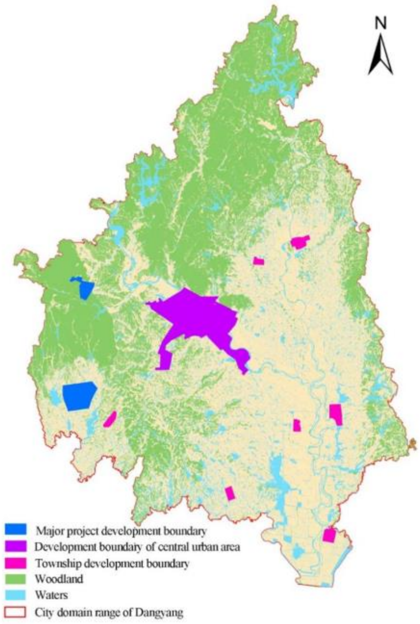

Fig. 14: Boundary of urban development in Dangyang city

4. Conclusion

According to the rule of mutual restraint and cooperation between urban land use expansion and ecological security, taking Dangyang city as the research area and urban space as the core perspective, this paper tries to construct the boundary model of urban development from the perspectives of "positive development guidance" and "reverse scale control", and explores the method and process of boundary demarcation of urban development suitable for small and medium-sized cities. The main conclusions are as follows:

The improvement of the two scenario simulation models of "positive development guidance" and "reverse scale control" is suitable for small and medium-sized cities with clear characteristics and active development. For small and medium-sized cities with special terrain in Dangyang, adding the variable of disaster risk to the ANN artificial neural network model can make the conversion value obtained by training the model in land use conversion rules more in line with the characteristics of the city itself. Urban land use simulation model scientifically determines the suitability of land development according to the evaluation results of land development suitability and the rules of establishing rigid constraints, effectively avoids permanent basic farmland and ecological red line, and predicts urban land use from the perspective of "rigid constraints". ANN artificial neural network model and urban land use simulation model aim at the different development goals between the bottom line constraint and urban growth demand, and realize the synergy between them from the perspective of urban space, which makes up for the shortcomings of previous urban models by considering the characteristics of small and medium-sized cities, bottom line constraint and land use demand, etc. Considering the collaborative analysis with the development strategy, the future development land is predicted in advance, which enhances the practicality of development boundary demarcation.

The technical method of urban development boundary formed in this study can not only provide reference for the future urban development of Dangyang city and the spatial planning of Dangyang city, but also provide some technical support for the demarcation of urban development boundary in China, improve the accuracy and scientificity of the demarcation of urban development boundary, and provide decision-making basis for urban planning and management.

Although the current model can better simulate and predict the spatial pattern of cities and towns. As a complex system, the evolution of cities and towns is influenced by a variety of factors, and the access of relevant data and materials is limited, so we cannot consider all the development factors in the simulation. Urban development boundary has become a mature tool in European and American countries. If we can learn from foreign excellent successful cases and experiences and apply them to our country, we can better realize sustainable urbanization and need more in-depth exploration and attempt.

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