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Construction land expansion simulation and landscape effect analysis of the urban agglomeration in central Yunnan

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Abstract. Carrying out the simulation of urban construction land expansion is an effective way to follow the objective law of land use change, taking into account cultivated land and ecological protection, and guiding the rational expansion of construction land. It is also an important attempt to find the coordination of land space layout between planning. Taking the urban agglomeration in central Yunnan as an example, this paper selects 2000, 2005, 2009 and 2015 as research periods to analyse the spatio-temporal expansion characteristics of construction land in whole region. The results show that the overall distribution of construction land is relatively dispersion at four time points, mainly along the northeast-southwest direction, and the distribution in the southwest direction is the most concentrated. Using FLUS model simulate the construction land spatial expansion pattern by 2020 under the scenarios of planning guidance and policy restraint, and analyze the ecological effects of spatial expansion. The simulation results show that the construction land expansion area under the two scenarios is continuously increased, but the degree of expansion is different. The construction land fragmentation degree and fractal dimension have been reduced compared with the previous, and the degree of intensive utilization of construction land is increased.

1. Introduction

With the rapid advancement of urbanization and industrialization, urban expansion and spread has become a significant feature of land use change now and in the future[1]. Due to the rapid expansion of the scale and spatial distribution of urban construction land, urban land use planning and management are facing a severe test. At the same time, urban expansion and the accompanying land use changes have a great impact on urban morphology, resident lifestyle and ecosystem services, and disorderly urban sprawl leads to the loss of regional cultivated land and frequent occurrence of ecological problems[2]. Urban construction is the inevitable requirement of social development and the improvement of people's living quality, and the protection of cultivated land and environment is also imminent. Therefore, to ensure that the cultivated land and ecological environment are effectively protected, managing and guiding the reasonable spread of construction land expansion has become an urgent problem to be solved.

The construction land expansion is the core part of land use/cover change (LUCC), the changes often have a profound impact on regional economic development and ecological environment changes. Understanding the characteristics and laws of urban development, describing and analyzing the dynamic evolution behavior in the process of urban expansion, and then building an effective urban spatial expansion model to simulate and predict it can be used to guide the study of regional urban development and land allocation for urban planning and management, ecology. Environmental protection provides decision[3]. At present, there are many research on the analysis and simulation of urban expansion, among which the analysis of urban expansion mainly focuses on the characteristics of spatial-temporal evolution[4], driving force mechanism[5] and ecological environment effect[6]. The simulation methods of urban expansion are also based on CLUE-S model[7], cellular automata(CA) model[8] and multi-agent(MAS) model[9], and coupled with multiple[8] urban spatial expansion scale prediction models applied to LUCC research. Each model has different advantages in analyzing and predicting the number of land use, expressing the neighborhood relationship between land use changes, reflecting human factors and so on[10]. However, in the process of land use pattern simulation, most of the models often train and calculate the conversion probability of each land type individually, which not only ignores the relationship between different land types, but also fails to reflect the competition and interaction between land types[11]. The FLUS (Future Land Use Simulation) model based on adaptive inertia mechanism of roulette selection proposed by Liu et al.[12] can effectively solve the above problems and has high simulation accuracy.

The urban agglomeration in central Yunnan is one of the 19 national important urban agglomerations that China focuses on at present and even in the future. It is the main body of Yunnan Province participating in regional cooperation and competition at home and abroad, and is also the focus area of various planning concerns. The direction and layout of construction land expansion is one of the issues that needs to be paid attention to in the process of urban agglomeration development. However, due to the high spatial heterogeneity of the land system itself, and the different emphasis of each planning system, objectives and contents, the lack of coordination lead to the conflicts of land use between planning. Carrying out the simulation and prediction study of urban agglomeration construction land expansion is also an important attempt to seek coordination of land space layout between planning.

Based on the above background, this paper analyzes the spatio-temporal variation characteristics of construction land of the urban agglomeration in central Yunnan in 2000, 2005, 2009 and 2015. The FLUS model was used to simulate the growth process and expansion characteristics of construction land under planning guidance and policy restraint scenarios. The ecological effects of urban spatial expansion are revealed by landscape ecology knowledge analysis, which can provide reference for the urban agglomeration in central Yunnan planning, intensive and economical land use, cultivated land and ecological environment protection.

2. Study area and data sources

2.1 Study area
The urban agglomeration in central Yunnan is located in the southwestern border of China and the western Yunnan-Guizhou Plateau. It is between 100°43′ - 104°49′ east longitude and 24°58′ - 25°09′ north latitude. It belongs to the lake basin Karst Plateau landform, mainly mountainous and Intermountain basin landforms, with gentle relief. It is the economic core area with Kunming as the core and the radius of about 200 km in central Yunnan Province. It is composed of 4 prefecture-level cities of Kunming, Qujing, Yuxi, Chuxiong Yi Autonomous Prefecture and seven counties (cities) in the northern part of Honghe Hani Yi Autonomous Prefecture. There are 49 counties and districts in the whole region, with a territory area of 111421.6995 km^2, accounting for 29% of the total land area of Yunnan Province. In 2015, the total population reached 20.8825 million, and the gross national product was 863.1355 billion yuan, an increase of 6.5907% over the previous year. The ratio of three

industrial restructuring in 2015 was 10.81:42.91:46.28, and the secondary and tertiary industries were the main components of GDP.
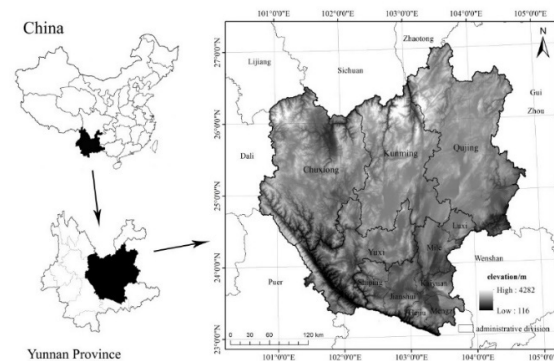

Figure 1. Map of geographical location of study area

2.2 Data source and processing
The basic data involved in this paper mainly include land use data (vector, raster) in 2000, 2005, 2009 and 2015 from the National Earth System Science Data Sharing Platform; spatial driving force data: (1) topographic factors: elevation, slope and aspect data are obtained by SRTM 30 m resolution DEM data that are converted by ArcGIS 10.2, and the DEM data are provided by the geospatial data cloud platform. (2) Traffic accessibility factors: the distance to the urban industrial and mining land, to the village land, to the road, to the railway, to the airport land, to other construction land, to river system and other neighborhood factors were calculated by ArcGIS 10.2 Euclidean distance tool. (3) socio-economic factors: population, socio-economic development data from the "Statistical Yearbook of Yunnan Province" (2009, 2015), Using ArcGIS 10.2 software to realize the spatial grid map of various socio-economic factors. (4) Restriction factors: because the study area contains multiple basins such as Dianchi Lake and Fuxian Lake, the lake area is 625.1380 km^2. This paper uses it as a restriction conversion factor. (5) land policy factors: prime cropland and ecological environment protection have important constraints on the expansion of construction land. In this paper, take it as a policy factor, and data comes from Yunnan Planning and Design Institute. According to the research needs, land use types are divided into seven categories: cultivated land, garden plot, forestland, grassland, construction land, water area, unused land. The raster dimensions of all the above layers are 1km, and raster image row and column numbers are the same.

3. Method and model

3.1 Spatial expansion characteristics of construction land

3.1.1 The transfer of gravity center
The transfer of gravity center of construction land means that the change of the coordinates of gravity center reflects the centralized distribution of construction land in space. The model is:

$$X_t = \frac{\sum_{i=1}^{n}(C_{ti} \times X_i)}{\sum_{i=1}^{n} C_{ti}} \qquad Y_t = \frac{\sum_{i=1}^{n}(C_{ti} \times Y_i)}{\sum_{i=1}^{n} C_{ti}} \qquad (1)$$

where X_t and Y_t are the coordinates of gravity center of construction land distribution in the t year; C_{ti} is the area of construction land of the i-th sub-district in the t-th year (this paper selects the city and state under the jurisdiction of the urban agglomeration in central Yunnan as the sub-district). X_i and Y_i are the coordinates of the geometric center of the i-th sub-district.

3.1.2 Standard deviation ellipse

Standard deviation ellipse can directly and accurately measure the multi-faceted characteristics of spatial pattern, and distinguish various states of spatial pattern by the difference between ellipses[13]. It is usually used to measure the spatial distribution characteristics of data of a set of points. Therefore, this paper assigns the plaque area of each construction land to the geometric center of the corresponding plaque to achieve the purpose of standard deviation ellipse analysis. The formula is:

$$\delta_x = \sqrt{\frac{\sum_{i=1}^{n}\left(w_i x_i' \cos\theta - w_i y_i' \sin\theta\right)^2}{\sum_{i=1}^{n} w_i^2}} \qquad\qquad \delta_y = \sqrt{\frac{\sum_{i=1}^{n}\left(w_i y_i' \sin\theta - w_i y_i' \cos\theta\right)^2}{\sum_{i=1}^{n} w_i^2}} \tag{2}$$

where δ_x δ_y are the standard deviation along the x and y axes. x_i' and y_i' are the relative coordinate of each construction land plaque to the average center of the construction land after turning into a point. w_i is the area of construction land in each city and state. θ is the angle of rotation from the true north direction clockwise to the long axis of the ellipse.

3.2 Research model

3.2.1 FLUS model
FLUS model[12] can simulate the interaction and spatial dynamic changes of various land use change types. It is a multi-class cellular automata model, mainly composed of "Neural Network Based Appropriateness Probability Calculation (ANN)" and "Adaptive Inertia Competition Mechanism".

ANN module is a multi-layer feedforward neural network, which consists of one input layer neuron, one or more hidden layer neurons and one output layer neuron. The expression is:

$$ap(p,k,t) = \sum_j w_j k \times sigmoid\left(net_j(p,t)\right) = \sum_j w_{j,k} \times \frac{1}{1 + e^{-net_j(p,t)}} \tag{3}$$

where $ap(p,k,t)$ is the suitability probability of the k land type on the grid p on the time t. $w_j k$ is the weight of the hidden layer and the output layer; sigmoid is the excitation function from the hidden layer to the output layer; $net_j(p,t)$ is the signal received on the time t of the j hidden layer grid p. For the suitability probability $ap(p,k,t)$ of ANN output, the sum of suitability probabilities of various types of land use is equal to 1 at iteration time t and grid p, i.e.: $\sum_k ap(p,k,t) = 1$.

For the adaptive inertial competition mechanism, the core factor is the adaptive inertia coefficient. The inertia coefficient of each land type is determined by the difference between the actual land quantity and the demand, and is adaptively adjusted in the iterative calculation, resulting in the quantity of each land type approaching the target quantity, whose expression is:

$$Intertia_k^t \begin{cases} Intertia_k^{t-1} & \left(|D_k^{t-1}| \le |D_k^{t-2}|\right) \\ Intertia_k^{t-1} \times \dfrac{D_k^{t-2}}{D_k^{t-1}} & \left(D_k^{t-1} < D_k^{t-2} < 0\right) \\ Intertia_k^{t-1} \times \dfrac{D_k^{t-1}}{D_k^{t-2}} & \left(0 < D_k^{t-2} < D_k^{t-1}\right) \end{cases} \tag{4}$$

where $Intertia_k^t$ is the inertia coefficient of land type k at time t; D_k^{t-1} and D_k^{t-2} are the difference between the number of grids of land type k and the number of demands at time t-1 and t-2.

Neighbourhood uses Moore neighborhood or extended Moore neighborhood as neighborhood scope. Its neighborhood effect $\Omega_{p,k}^t$ can be expressed as:

$$\Omega_{p,k}^t = \frac{\sum_{N \times N} con\left(c_p^{t-1} = k\right)}{N \times N - 1} \times w_k \tag{5}$$

where $\sum_{N \times N} con\left(c_p^{t-1} = k\right)$ is the number of grids of land type k at the end of the iteration time t-1 in the window of N×N; w_k is the neighborhood weight of each type of land use.

Based on the above steps, the total probability of transforming the grid p into the k land type in time t can be calculated, and the land type with high suitability probability can be allocated to the grid in CA iteration time. The total probability T of the grid P converted to land type k at time t can be expressed as:

$$TP_{p,k}^t = ap(p,k,t) \times \Omega_{p,k}^t \times Intertia_k^t \times \left(1 - \left(sc_{c \to k}\right)\right) \tag{6}$$

where $sc_{c \to k}$ is the cost of converting land use type c to type k; $\left(1 - \left(sc_{c \to k}\right)\right)$ is the degree of difficulty of conversion.

The specific flow of this paper is shown in Figure 2.
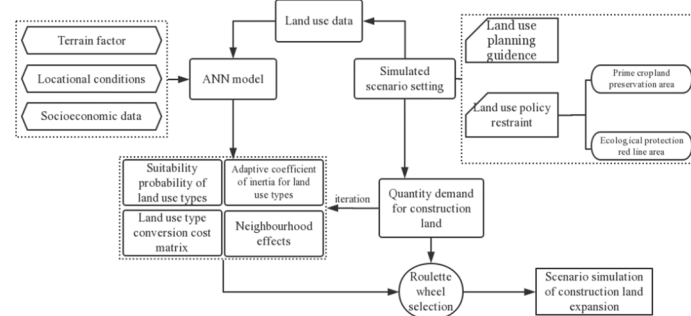

Figure 2. Technique flow chart

3.2.2 Simulation accuracy verification

The simulation accuracy of the FLUS model is verified by the Overall Accuracy (OA) and Kappa coefficients. Based on the land use status of the base year, the land use of the target year is simulated. Among them, the OA and Kappa coefficients are between 0 ~ 1, and the closer the value is to 1, the higher the simulation accuracy.

3.3 Scenario for construction land simulation

3.3.1 Land use planning guidance

The quantity demand of future construction land under the guidance of the "Land Use Planning" is based on each city land use planning (2006-2020) and the county land use planning (2006-2020), the planning targets of cultivated land and construction land specified by various departments in terms of social economy, population, and food forecasts. As a government policy indicator, the land use planning will have a major impact on the future construction land use pattern of the study area.

3.3.2 Land policy restraint

From the perspective of national strategy that takes into account ecological security and food security priorities, this paper uses the ecological protection red line and the prime cropland protection red line defined by the study area as the land policy restraint for the expansion of construction land (Figure 3). Land types such as water, woodland and prime cropland within the red line are required to be unsuitable areas for construction. This scenario is based on the basis of planning guidance scenarios and is proposed to balance and coordinate the conflict among the planning objectives of various departments.
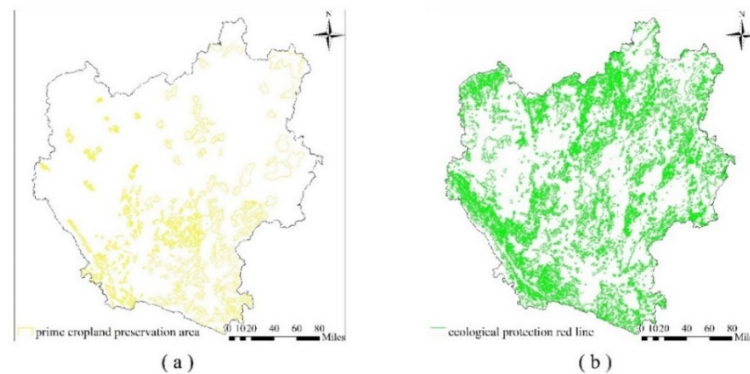
Figure 3. Prime cropland preservation area and ecological protection red line

3.4 Landscape effect analysis
Drawing on the relevant research[6,10,14], this paper uses landscape analysis software to select the following seven landscape pattern indices: patch density (PD), patch fragmentation (FN), fractal dimension (FD), landscape shape index (LSI), contagion index (CONTAG), Shannon's diversity index (SHDI) and Shannon's mean index (SHEI), which evaluated and analyze the landscape ecological effects of construction land expansion simulation from patch scale and landscape scale.

4.Result

4.1 Analysis of expansion characteristics of construction land

4.1.1 Quantity expansion characteristics
Based on the statistical analysis of multi-period construction land data of the urban agglomeration in central Yunnan, the change of construction land from 2000 to 2015 was obtained (Figure 4). The construction land area of whole region has grown rapidly, from 3311.7349 km^2 in 2000 to 4796.5740 km^2 in 2015, with an average annual growth rate was 2.5%, and the land development intensity from 2.97% to 4.31%. In 15 years, it has expanded by 1.4512 times, and the growth of construction land has changed significantly. In the past 15 years, the construction land of the urban agglomeration in central Yunnan has been increasing continuously. The main reason is that with the continuous adjustment and improvement of the scale structure and spatial layout of the cities and towns in China, the function orientation of some urban districts under the jurisdiction of the urban agglomeration has changed, such as the Chenggong district function orientation has changed from the former vegetable and flower base to politics, culture and education center. Guandu district as Kunming International Airport and Luoshiwan International Trade City site selection and the addition of urban housing in the surrounding areas.
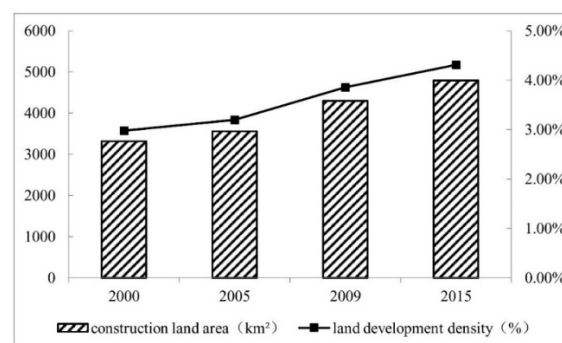

Figure 4. Construction land area and development intensity in study area

4.1.2 Spatial expansion characteristics

At four time points, the standard deviation ellipse long axis of construction land of the urban agglomeration in central Yunnan is northeast-southwest, and the short axis is northwest-southeast. It reflects that the distribution trend of construction land of the urban agglomeration in central Yunnan in 2000, 2005, 2009 and 2015 is northeast-southwest, and the southwest is the most concentrated (Figure 5). During the study period, the standard elliptical difference angle θ of construction land in the urban agglomeration changed from 26.3683° to 43.1447°, the rotation was slow and the directional distribution of construction land was stable. The urban agglomeration is located in the west of Yunnan-Guizhou Plateau, with a small of flat dams and a large area of mountainous area in the whole region, and the construction land is a land use type seriously affected by the terrain, resulting makes the urban land use development pattern of the urban agglomeration of with the dam area as the center and spreading to the periphery according to the circle-type expansion. In recent years, with the continuous promotion of the new land policy of "building land on hills", requires strict protection of cultivated land in the dam area, and guides the construction land to the mountain area development (slope is between 8° and 25°), resulting the expansion of construction land area in whole region gradually spreads to the mountainous. The overall situation of construction land of filling in the dam area, scattered distribution in mountainous area, and the distribution of construction land tends to be discretized, which made the standard deviation ellipse gradually increased from 62.3550 km in 2000 to 77.9861 km in 2015, and the length axis is reduced from 94.8002 km to 81.0118 km. The combination of the two results in an increase in the ellipse shape index from 0.6577 in 2000 to 0.9626 in 2015. The polarization characteristics are not obvious (Table 1).

Table 1. Standard deviation ellipsoid statistics of construction land of the urban agglomeration in central Yunnan in 2000, 2005, 2009 and 2015

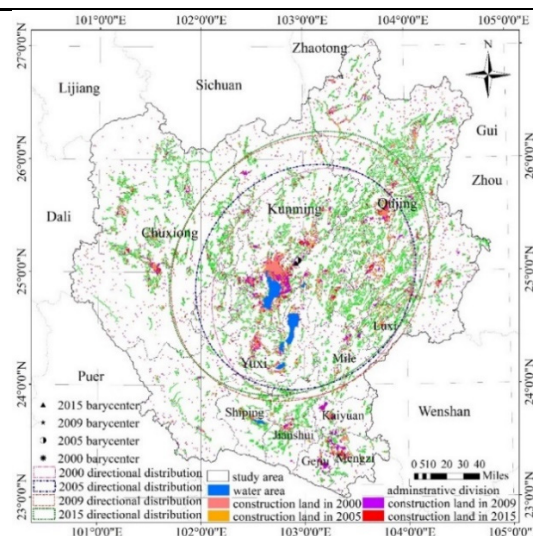| Year	Center of gravity coordinates of construction land	Center of gravity offset/km	Corner θ°	Standard deviation along the long axis/km	Standard deviation along the short axis/km	Shape index	Elliptical area/km²
2000	102°57′7.51″E 25°06′18.10″N	-	26.3683	94.8002	62.3550	0.6577	34850.7536
2005	102°56′46.12″E 25°06′7.92″N	0.0678	39.8467	83.4706	75.0511	0.8991	37396.7934
2009	102°55′51.98″E 25°04′40.36″N	0.3079	40.9431	82.6773	76.0550	0.9199	51551.8895
2015	102°55′40.24″E 25°04′45.80″N	0.0382	43.1447	81.0118	77.9861	0.9626	51077.7961

Figure 5. Construction land growth and spatial distribution characteristics of the urban agglomeration in central Yunnan

In this paper, the standard deviation ellipse analysis reference to Zhou Hao[13] and other related research, will set the standard deviation series to level 1, will be about 68% of the construction land

included in the ellipse, statistics of four time points of construction land standard deviation ellipse area (Table.1). The construction land of the urban agglomeration in central Yunnan affected by terrain factors, the area change range is larger, but from the current expansion situation, the overall construction land in each city is more concentrated. The center of gravity corresponds to the spatial distribution position of construction land. The construction land in the whole region moves to the southwest with a total of 0.4624 km, but the center of gravity is always located in Guandu District. The main reason is that with the acceleration of urbanization, the central urban area is given priority to development, and the degree of intensive utilization of construction land is improved.

4.2 Optimal scale determination

According to Pan et al.[15], it is considered that the inappropriate spatial pixel scale in land use simulation may lead to inappropriate expression of land use information. The inappropriate algorithm expression in land use conversion can be solved by expanding neighborhood shape or increasing or reducing neighborhood size to improve the accuracy of simulation results. Therefore, this paper uses FLUS model to simulate and analyze different neighborhood sizes (3×3, 5×5, 7×7, 9×9, 11×11) with spatial pixel scale of 1 km, and determines the optimal neighborhood size by Kappa coefficient and overall accuracy (OA) test. The results show that with the increase of the neighborhood size, the accuracy of land use simulation of the urban agglomeration in central Yunnan presents an obvious curve inflection point effect (Figure 6). The Kappa coefficient increases from 0.9833 in the molar neighborhood 11×11 to 0.9838 in 3×3, the OA coefficient increases from 0.9898 in the molar neighborhood 11×11 to 0.9900 in 3×3, and the main inflection point is located at the neighborhood 5×5 and 9×9, the accuracy of the double coefficients at the neighborhood 5×5 is the highest. Therefore, the optimal scale of the urban agglomeration in central Yunnan is determined to be spatial pixel resolution of 1 km and neighborhood size of 5×5.
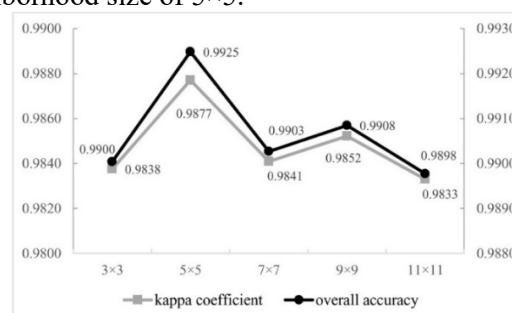

Figure 6. Response of Kappa Coefficient and overall accuracy in neighborhood size change

4.3 Simulation process and accuracy verification

In this paper, the FLUS model is calibrated with the 2009 land use status data as data support and the simulation target year is 2015. The results show that the land use simulation results of the urban agglomeration in central Yunnan under the FLUS model have higher similarity with the land use status map in 2015, but the simulation results of each land type are more compact than the current situation, especially for the construction land (Figure 7). From the perspective of simulation accuracy, the overall accuracy (OA) value is 0.9925, and the Kappa coefficient is 0.9877. Compared with the related literature[11], the simulation accuracy is higher and the simulation effect is ideal, indicating the applicability of the FLUS model in the urban agglomeration.
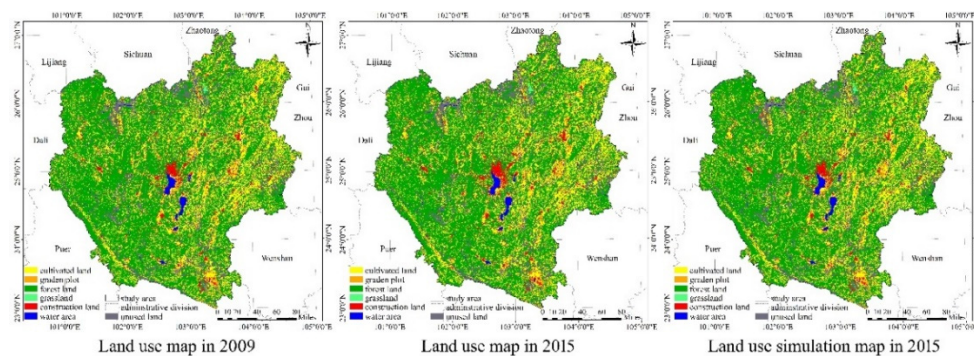
Figure 7. The urban agglomeration in central Yunnan land use map in 2009 and 2015 and the simulation result based on FLUS model in 2015

4.4 Scenario simulation of construction land expansion
Based on the land use situation in 2015, this paper predicts the spatial pattern of construction land expansion of the urban agglomeration in central Yunnan in 2020 by calculating the suitability probabilities of various types of land, setting up the demand of construction land and land use transfer rules under different scenarios in 2020.

According to the quantity demand of construction land in the land use planning of each city of the urban agglomeration in central Yunnan, by 2020, the total demand area of construction land increased continuously. The construction land area under planning guidance was 5290.5778 km^2 and the construction land area under policy restriction was 4996.4635 km^2. The results showed that compared with 2015, the area of construction land under the guidance of the planning increased by 494.0038 km^2 and the expansion of construction land was mostly carried out by filling, mainly distributed around the built-up area, along the lakes, rivers and road traffic network; due to the double index of ecological red line and prime cropland protection area. The area of construction land under the policy restriction has only increased by 199.8895 km^2 and the expansion of construction land still shows different degrees of centralization in space. Compared with the spatial expansion of construction land under the guidance of planning, the layout is relatively compact, mainly distributed in the vicinity of the built-up area of Kunming 4 main urban areas, Chuxiong, Yiliang, Luquan and Yuanmou counties, etc. Although the expansion area is small, the speed of expansion has been controlled to a certain extent (Figure 8).
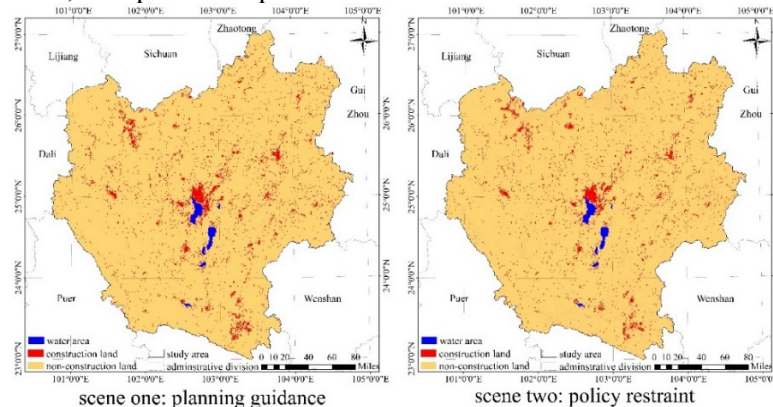

Figure 8. Simulation results of construction land expansion based on FLUS model

4.5 Landscape ecological effects of construction land expansion
In this paper, patch and landscape scales were used to analyze the change of the expansion pattern of construction land of the urban agglomeration in central Yunnan from 2000 to 2020 and reveal the landscape effect (Table 2). From the patch scale, the patch density of construction land increased from 0.0052/ha to 0.0215/ha in 2000-2015, and the patch fragmentation increased from 0.0049 to 0.0051. indicating that the degree of landscape fragmentation of construction land in the study area increased

gradually during this period. The landscape dimension increases from 1.6133 to 1.6504, and the landscape shape index increases from 66.2904 to 80.7111, indicating that the complexity of landscape patch shape for construction increased. Comparing the landscape pattern of construction land under two scenarios simulations in 2020, it is found that although the expansion area increases, the fragmentation and fractal dimension of construction land are lower than before. Influenced by policy restraint, the construction land patches density and fragmentation are relatively low, and the fractal dimension decreases. The impact on urban prime cropland, ecological environment and landscape pattern is small, and the layout of construction land is more compact and reasonable, which is the direction of future urban development.

From the perspective of landscape scale, the CONTAG index of construction land decreased from 42.2119% to 40.4574% in 2000-2015, indicating that the landscape patches dominance was decreased, the connectivity between patches was not good, the landscape separation was increasing; SHDI index increased from 0.6245 to 1.2014, indicating that the whole region landscape type is rich, the degree of fragmentation is high, and the heterogeneity is also increased. SHEI index decreased from 1.1189 to 0.6174, indicating that there was no obvious dominant type in the landscape and the patch are evenly distributed. Compared with CONTAG index under the two scenarios simulation, the index showed an upward trend, and reached the maximum under policy restraint, indicating that the dominance of landscape patches increased and the connectivity between patches was better; SHDI and SHEI index both showed a downward trend, and reached the minimum under policy restraint, indicating that patch types increased and showed a balanced trend of distribution, the degree of patch combination was more aggregated, landscape types showed the pattern with the most diversity and uniform distribution.

Table 2. Landscape pattern index of construction land of the urban agglomeration in central Yunnan

Landscape pattern index	2000	2005	2009	2015	2020 Planning guidance	2020 Policy restraint
Patch density (PD/a·ha)	0.0052	0.0078	0.0210	0.0215	0.0222	0.0198
Patch fragmentation (FN)	0.0049	0.0050	0.0055	0.0051	0.0050	0.0047
Fractal dimension (FD)	1.6133	1.6315	1.6504	1.6504	1.6503	1.6495
Landscape shape index (LSI)	66.2904	71.2754	80.5359	80.7111	80.7500	78.5337
CONTAG/%	42.2119	40.1090	40.7417	40.4574	41.3474	42.3101
Shannon's diversity index (SHDI)	0.6245	1.1454	1.1948	1.2014	1.1978	1.1639
Shannon's mean index (SHEI)	1.1189	0.6396	0.6140	0.6174	0.6144	0.5981

5. Conclusion and discussion

This paper taking the urban agglomeration in central Yunnan as an example, analyzes the quantity and spatial expansion characteristics of construction land in 2000, 2005, 2009 and 2015, and using the FLUS model to simulate the spatial expansion of construction land under the two scenarios, and compares the simulation results with the layout of construction land over the years by selecting a variety of indexes at the landscape level to reveal the landscape ecological effects, and draw the following conclusions:

(1) At four time points, the construction land of the urban agglomeration in central Yunnan distributes along the northeast-southwest direction, and the southwest direction is the most concentrated, the long axis rotates slowly along the clockwise direction, and the directional distribution characteristics are stable. However, due to topographic factors, the expansion of construction land of the urban agglomeration in central Yunnan gradually spreads to the mountainous areas, showing the overall situation of "filling in the dam area, gentle slope-mountainous scattered distribution", the distribution of construction land tends to disperse, and the polarization characteristics tend to weaken. As a whole, the center of gravity of construction land shifts to the southwest, and the shift is small. The center of gravity has been located in Guandu district. The main reason is that with the acceleration of urbanization, the central city has given priority to development, and the degree of intensive utilization of construction land has been improved.

(2) Through model correction, compared with the land use status in 2015, the OA value reaches 0.9925, Kappa coefficient is 0.9877, and higher simulation results are ideal. Based on two scenarios, the construction land expansion in the urban agglomeration in 2020 was simulated and forecasted. The results show that the total demand for construction land under the two scenarios is continuously increasing, but the degree of expansion is different. The expansion of construction land under the planning guidance is mostly in the form of filling, mainly distributed around the built-up area, lakes and rivers and along the road traffic network; the expansion of construction land under the policy restraint still shows different degrees of concentration in space, but due to the ecological red line and the prime cropland protection area, compared with the expansion layout under the planning guidance, it is more compact and the expansion area is small, but the expansion speed is controlled to some extent.

(3) The landscape pattern index of construction land spatial expansion is increasing year by year, the patch shape complexity is increasing, the landscape separation is increasing, the landscape pattern is unstable, and the degree of fragmentation is relatively serious, showing a "starry" pattern of dispersion in space. Comparing the landscape pattern of construction land under the two scenarios in 2020, it is found that although the expansion area increases successively, the fragmentation degree and fractal dimension of construction land are lower than before, the degree of intensive utilization of construction land is increased, and the expansion layout of construction land under the policy constraint is more compact.

The expansion of construction land is a complex non-linear dynamic process and involves many natural and social factors. In this paper, FLUS model is used in scenario simulation, but there are still some shortcomings in selecting driving factors, spatial scales and model coupling. Firstly, the pattern of construction land is different in different spatial and temporal scales, so it is necessary to further explore the scale law and scale effect of the pattern and driving factors to indicate the direction of rational land use and development. Secondly, in this scenario simulation, the quantity demand of construction land is based on the land use demand data from the land use planning to the planned target year. However, in the process of construction land expansion simulation, the determination of land use demand data not only considers the economic, social and policy factors that affect the change of regional construction land, but also excavates the interaction between the structure, function and dynamic behavior of urban system. It is necessary to further study the construction land scale prediction and expansion simulation under the multi-model coupling, and set up a reasonable scenario plan to explore a more suitable way for the future development of the city. Therefore, the multi-scale, multi-temporal, multi-model coupling simulation of construction land expansion evolution based on FLUS model is the focus of future research.

Acknowledgments

References

[1]   Zhang Z.X., Liu F., Zhao X.L., et al. (2018) Urban expansion in China based on Remote Sensing Technology: A Review. Chinese Geographical Science, 28(5): 727–743.

[2]   Chen H., Jia B., Lau S.Y. (2007) Sustainable urban form for Chinese compact cities: Challenges of a rapid urbanized economy. Habitat International, 32(1): 28-40.

[3]   Zhang H., Luo Y.Y., Zhang L.T. (2010) A nonlinear polynomial model for urban expansion incorporating genetic algorithm and support vector machines. ACTA GEOGRAPHICA SINICA, 65(6): 656-664.

[4]   Li S.Y., Liu X.P., Li Z.G., et al. (2018) Spatial and temporal dynamics of urban expansion along the Guangzhou-Foshan Inter-City rail transit corridor, China. Sustainability, 10(3): 1-18.

[5]   Wang Z.W., Lu C.H. (2018) Urban land expansion and its driving factors of mountain cities in

China during 1990-2015. Journal of Geographical Sciences, 28(8): 1152-1166

[6] Cui W.P., Li Y.B., Li R.K., et al. (2017) Landscape ecological effect of urban expansion in the central area of Chongqing City. Chinese Journal of Ecology, 36(1):205-215.

[7] Zhang W., Liu M., Qi Y.S. (2014) Land-use scenarios simulation based on the CLUE-S model in Kunming. Chinese Journal of Ecology, 33(6):1655-1662.

[8] Zhao D.L., Du M., Yang J.Y., et al. (2009) Urban land expansion simulation model based on SD and CA. Acta Geographica Sinica, 29(3):439-444.

[9] Yang Q.S., Li X. (2007) Integration of multi-agent systems with cellular automata for simulating urban land expansion. Scientia Geographica Sinica, 27(4):542-548.

[10] Yang Q.K., Duan X.J., Jin Z.F., et al. (2017) Spatial scenario simulation and landscape ecological effect based on construction land expansion of Nantong City. Scientia Geographica Sinica, 37(4):528-536.

[11] Zhu S.H., Shu B.R., Ma X.D., et al. (2017) The delimitation of urban growth boundary based on the idea of "anti-planning" and FLUS model: a case study of Jiawang district, Xuzhou City. Geography and Geo-Information Science, 33(5):80-86.

[12] Liu X.P, Liang X., Li X., et al. (2017) A future land use simulation model(FLUS) for simulating multiple land use scenarios by coupling human and natural effects. Landscape and Urban Planning, 168:94-116.

[13] Zhou H., Lei G.P., Yang X.X., et al. (2017) Simulation of cultivated land under RCPs scenarios in typical basin of Sanjiang Plain. Transactions of the Chinese Society for Agricultural Machinery, 48(10):121-133.

[14] Li X., Li D., Liu X.P., et al. (2017) Geographoical simulation and optimization system(GeoSOS) and its application in the analysis of geographic national conditional. Acta Geodactica Cartographica Sinica, 46(10):1598-1608.

[15] Pan Y., Andreas R., Yu Z.R., et al. (2010) The impact of variation in scale on the behavior of a cellular automata used for land use change modeling. Computers, Environment and Urban Systems, 34:400-408.