Spatial Pattern Change Simulation of Land Use in Yongchuan District of Chongqing City

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Abstract In order to study the county scale land use structure during the rapid urbanization and more accurately grasp the dynamic process of land use and cover change, we combine GIS technology with CLUE-S model to research the spatial pattern change of land use in Yongchuan District of Chongqing City. The results show that the forest and farmland were main land use types going through changes in Yongchuan District during 2000-2010, accounting for more than 90% of the total area in each year; during 2000 - 2010, the urban area was significantly increased, an increase of 16.11%, and the urban area during 2005 - 2010 was changed more dramatically than during 2000 - 2005; forest area was slightly increased and farmland area was reduced by 1660 ha in 10 years. We set three scenarios on land use change in Yongchuan District for simulation and compare the predicted results. It can be concluded that driven by rapid urbanization, the change in land use landscape pattern in Yongchuan District is mainly focused on forest and farmland, the urban area is substantially increased, and the forest area also shows an increasing trend while the farmland area is reduced accordingly. Under ecological protection scenarios, the land use type having a protective effect on the ecological environment achieves better control effect.

Key words Land use change, Spatial pattern simulation, CLUE-S model

1 Introduction

Land is a carrier of various terrestrial ecosystems, and the changes in land use structure will cause changes in a variety of ecosystem types, area and spatial distribution. The changes in land cover have a direct impact on the global and regional environment[1-2]. Compared with study abroad, the current domestic study on China's land use and land cover change remains to be further deepened, for example, the land use change patterns are highly heterogeneous in space[3-4], and there is a need to increase the diversity of the study region and strengthen the microscopic scale study[5]. For the study of land use and land cover change, many models have been constructed in consideration of different purposes, and the widely used model is CLUE-S model[6-8] which can better show land use change process different temporal and spatial scales, but there are limitations in the space expression of macro demand for various types of land, so the predicted results of other models as the land use demand data are input into CLUE-S model to make up for this defect. Currently, due to the impact of global climate change[9-10], the land use studies are mainly focused on the process of land use change[11-12], drive mechanism and model[13-14], and scenario forecasting and optimization[15]. The studies are mainly the quantitative studies on medium and large scale land use structure[16], and there is a shortage of qualitative studies on land use structure. Meanwhile, the county scale, as the basic unit of administration, is also the optimal scale for sustainable land use, management and planning[17]. On the county scale, we use CLUE-S model to simulate the land use and land cover change and perform a quantitative analysis of its structural features, in order to provide scientific support for land use planning and ecosystem management of other cities.

2 Overview of study area and

2.1 Study area Yongchuan District is located in the western part of Chongqing City and north bank of upper reaches of the Yangtze River, 55 km away from the main city zone. It is a hilly area featuring a humid subtropical climate, with four distinct seasons, abundant rainfall, long non-frost period and few annual sunshine hours. The pillar industries in this area include machinery equipment, electronic information, non-ferrous metal smelting and rolling, paper making and paper products and other industries. Yongchuan is a modern logistics base and manufacturing base built in Chongqing, so it is very necessary to study the land use change in this area.

2.2 Data sources The data sources are the Landsat TM remote sensing images with spatial resolution of 30 m in 2000, 2005 and 2010 in Yongchuan District. Under the support of ArcGIS, with raster image as the background, we perform three kinds of correction (radiation correction, geometric correction, and RGB false color composite) on the remote sensing data, and then use human-computer interaction to extract the required data. Meanwhile, based on fieldwork and sample checking, we improve the patch data that can not accurately judge the type in the process of remote sensing image interpretation. In this study, based on *National Land Classification Standard* (GB/T21010-2007), the land use type is divided into six types: forest, shrub and grass, waters, farmland, cities and towns, and bare land.

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3 Research methods

3.1 CLUE-S model CLUE-S (the Conversion of Land Use and its Effects at Small regional extent) is specifically developed for the spatially explicit simulation of land use change based on an empirical analysis of location suitability combined with the dynamic simulation of competition and interactions between the spatial and temporal dynamics of land use systems. More information on the development of the CLUE-S model can be found in Verburg et al. (2002)[18] and Verburg and Veldkamp (2003) The more recent versions of the CLUE model: Dyna-CLUE (Verburg and Overmars, 2009) and CLUE-Scanner include new methodological advances. The model is sub-divided into two distinct modules, namely a non-spatial demand module and a spatially explicit allocation procedure. The non-spatial module calculates the area change for all land use types at the aggregate level. Within the second part of the model these demands are translated into land use changes at different locations within the study region using a raster-based system. The user-interface of the CLUE-S model only supports the spatial allocation of land use change. For the land use demand module different model specifications are possible ranging from simple trend extrapolations to complex economic models. The choice for a specific model is very much dependent on the nature of the most important land use conversions taking place within the study area and the scenarios that need to be considered. The results from the demand module need to specify, on a yearly basis, the area covered by the different land use types, which is a direct input for the allocation module. Non-spatial part and spatial part constitute the main part of CLUE-S model[19]. The analysis and simulation of CLUE-S model is mainly composed of four basic steps[20]: (i) Using the Logistic regression method to calculate the influence of the selected driving factors on land use change, thereby getting the probability distribution of different land use types; (ii) Setting the relative elasticity of land use change according to the difficulty in the conversion between various land use types and empirical studies; (iii) Using the scenario analysis combined with forecasting model and regional socio-economic data to determine the land use needs in the study area; (iv) Completing the spatial distribution of land use type by simulating the time deduction of land use.

3.2 Model setting

3.2.1 Setting of land demand module. In CLUE-S model, the first thing is to predict different land demand programs; the second thing is to input the results of different land demand programs into land demand module model; the last thing is to perform the spatial distribution and simulation of different land demand. In this study, using FNN combination forecasting model [namely GM (1, 1) combined with NARMA (p, q) recursive network], we forecast the demand for a variety of land types in the study area.

3.2.2 Setting of ELAS parameter. ELAS parameter indicates the possibility and difficulty in conversion between different land use types in the study area within a certain period of time, with value ranging from 0 to 1. The greater the value of this parameter, the greater the difficulty in the conversion of a land use type to other types, the higher the stability of this land use type. The parameter value is determined mainly based on empirical study of land use change in the study area, survey and subjective understanding. After the initial identification, it is further adjusted by model test. The adjusted ELAS parameter values are shown in Table 1 and Table 2.

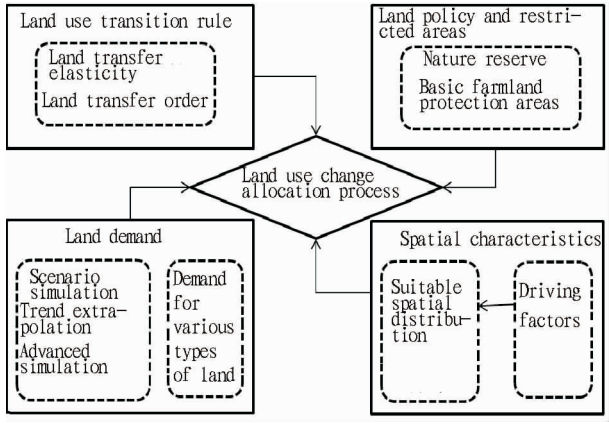

Fig.1 The distribution process of land use change in the model

Table 1 ELAS parameter values of various land use types

Type	Forest	Shrub and grass	Waters	Farmland	Cities and towns	Bare land
ELAS	0.6	0.5	0.6	0.3	0.8	0.7

Table 2 ELAS parameter values of different land use types under three kinds of simulation scenarios

Land use types	Natural growth scenario	Economic development scenario	Ecological protection scenario
Forest	0.6	0.5	0.7
Shrub and grass	0.4	0.7	0.6
Waters	0.6	0.6	0.7
Farmland	0.5	0.4	0.5
Cities and towns	0.7	0.9	0.7
Bare land	0.8	0.8	0.8

3.2.3 Design of scenarios. (i) Natural growth scenario. Based on Markov model, according to the area of various land use types in Yongchuan District in 2010 and land use transfer matrix probability table during 2000 – 2010, the naturally growing area of land use type in 2015 is forecasted. (ii) Economic development scenario. Based on the overall land use planning during 2006 – 2020 in Yongchuan District, the expansion of construction land is restricted to make city construction concentrated in the specific areas to form a more reasonable and intensive land use development pattern. According to previous research experience, this scenario simulation corrects the probability of transfer from farmland and waters to urban land at 40% and 60%, respectively, during the Markov process. (iii) Ecological protection scenario. Ecological protection scenario is to promote the formation of stable multi-level

ecosystems in the study area. The relevant environmental policies are developed, and the development of the land type with great ecological service function is restricted, to better protect and improve the ecological environment in the study area. Based on previous research experience, this scenario simulation determines the probability of transfer from farmland, waters and shrub land to urban land at 50%, 70% and 70%, respectively, during the Markov process.

4 Results and analysis

4.1 CLUE-S model simulation accuracy test Using ROC test, we test the simulation precision of CLUE-S model, and the results are shown in Table 3. Except bare land, the ROC values of other land types are more than 0.75, indicating that the main driving factors selected in this study can strongly explain the spatial distribution pattern of land use types. The higher the ROC values, the better the driving factors to explain changes in the land type. The ROC values of waters (0.893) and cities and towns (0.881) are high, so the driving factors selected have good ability to explain the waters and land for cities and towns. The ROC values of farmland (0.754) and bare land (0.742) are low, mainly due to the dispersion and small area of bare land. The farmland is widely distributed in the study area and the total area is large, so there are obvious differences in the spatial distribution. The driving factors can not well explain the differences in spatial distribution, thereby reducing the accuracy of farmland.

Table 3 ROC test on various land use types

Types	Forest	Shrub and grass	Waters	Farmland	Cities and towns	Bare land
ROC	0.831	0.841	0.893	0.754	0.881	0.742

4.2 Dynamic change in land use in Yongchuan District According to the remote sensing images in Yongchuan District in 2000, 2005 and 2010, we classify the land use types, and use GIS spatial overlaying analysis to get the land use conditions at three stages (Table 4) and land cover conditions (Fig. 2). As can be seen from Table 4, during 2000 – 2010, the land use type was mainly forest and farmland in Yongchuan District, accounting for more than 90% of total area at each stage. During 2000 – 2010, the urban area was significantly increased, an increase of 16.11%, and the change in the urban area during 2005 – 2010 was more intense than during 2000 – 2005. The forest area was slightly increased in 10 years; the farmland area decreased by 1660 ha in 10 years; the area of shrub and grass and waters decreased by 98 ha and 36 ha, respectively.

Table 4 The change in the area of different land use types in Yongchuan District at three stages

Land use type	Area//ha			Percentage of change//%		
	2000	2005	2010	2000 – 2005	2005 – 2010	2000 – 2010
Forest	61185.00	61805.00	62359.00	1.01	0.90	1.92
Shrub and grass	4527.00	4613.00	4429.00	1.90	–3.99	–2.16
Waters	1259.00	1228.00	1223.00	–2.46	–0.41	–2.86
Farmland	76613.00	75841.00	74953.00	–1.01	–1.17	–2.17
Cities and towns	3625.00	3716.00	4209.00	2.51	13.27	16.11
Bare land	4.00	10.00	4.00	150.00	–60.00	0.00

3.3 Future scenario simulation of land use in Yongchuan District According to three kinds of scenarios, combined with the actual situation of relatively slow land use change, we build the land use transition matrix under three kinds of scenarios, calculate the regional demand for land under different scenarios (Table 5), and simulate the spatial pattern of land use in 2015 under different scenarios (Fig. 3). (i) Natural growth scenario. Based on the constant change of land use transition matrix in Yongchuan District during 2000 – 2010, this scenario gets the demand for land in 2015. From Fig. 3 and Table 5, it can be found that under the natural growth scenario, the land use pattern in 2015 continues the existing trends, and the increased urban land and woodland are mainly supplemented by shrub and grass land, followed by farmland. (ii) Economic development scenario. Based on the regional economic development policy (namely to accelerate the conversion of farmland and grassland to garden plot and urban land, reasonably control the growth rate of woodland, and maintain the area of waters and unused land), this scenario gets the demand for land based on ecosystem services in 2015. From Fig. 3 and Table 5, it is found that in 2015, the forest and urban land increases, while shrub and grass land and farmland decreases. Shrub and grass land and farmland are still the main sources of forest and urban land expansion. (iii) Ecological protection scenario. This scenario assumes that the use of woodland, waters and farmland having an important role in the ecological environment can not be changed, and assumes that the areas with critical slope of higher than 25° are restricted areas and the change in the land use types within these areas is prohibited. From Fig. 3 and Table 5, it is found that in 2015, the forest area is increased most, the shrub and grass land area is increased, and the urban land area is increased slowly. In the ecological protection scenario, the farmland area is reduced, so the forest land, shrub and grass land coupled with a small amount of urban land is converted to supplement.

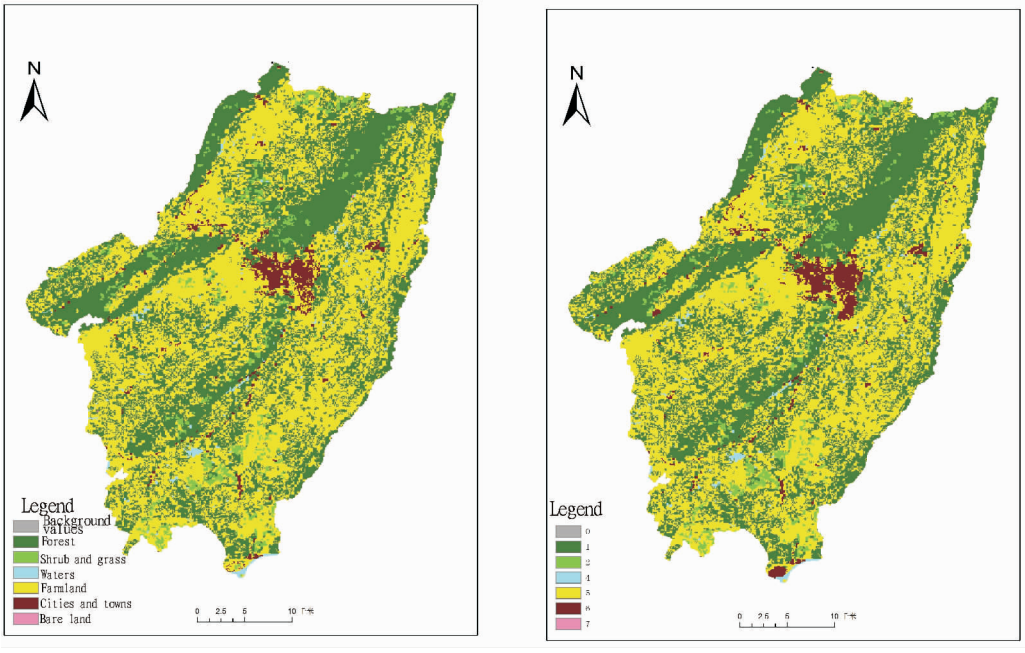

Fig. 2 The land use cover in Yongchuan District in 2005 and 2010

Table 5 The area of various land types under different scenarios Unit: ha

Scenarios	Forest	Shrub and grass	Waters	Farmland	Cities and towns	Bare land
Land use in 2010	62359.00	4429.00	1223.00	74953.00	4209.00	4.00
Natural growth in 2015	68836.46	2882.65	1223.00	73583.61	5942.88	4.00
Economic development in 2015	68723.14	2801.87	1213.00	73010.39	6330.63	4.00
Ecological protection in 2015	70816.68	4528.80	1233.00	71559.82	5068.85	4.00

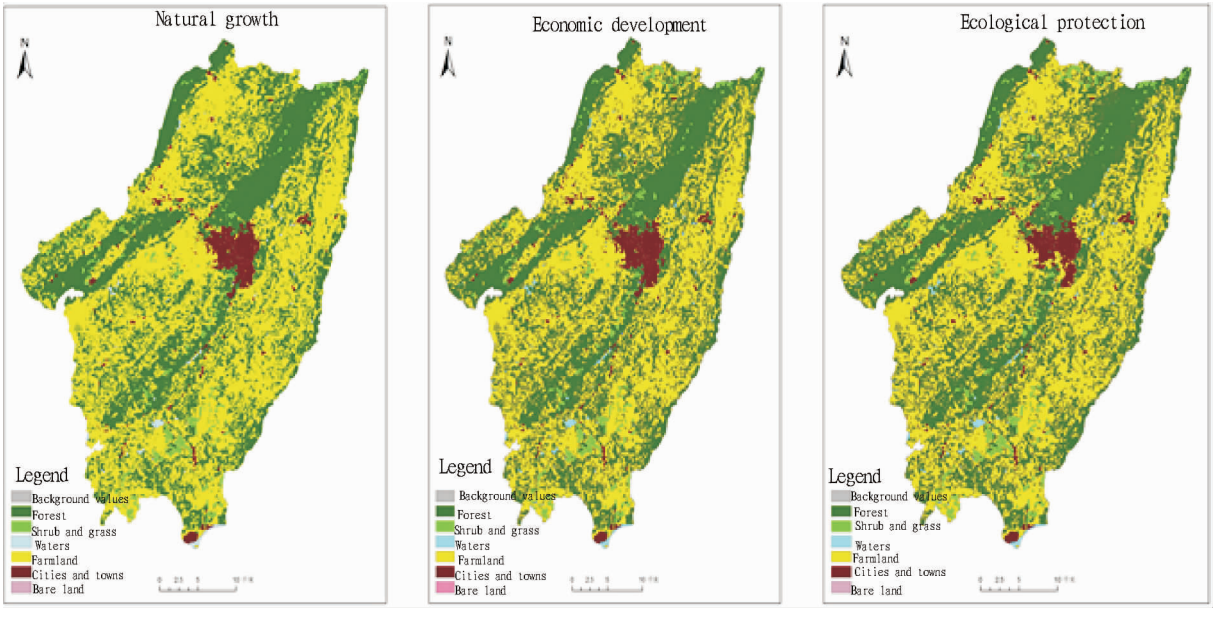

Fig. 3 Land use simulation and forecast in Yongchuan District in 2015 under different scenarios

4 Conclusions and discussions

4.1 Conclusions In this paper, we combine GIS technology with CLUE – S model to research the spatial pattern change of land use in Yongchuan District of Chongqing City. The results show that the forest and farmland were main land use types going through changes in Yongchuan District during 2000 – 2010, accounting for more than 90% of the total area in each year; during 2000 – 2010, the urban area was significantly increased, an in-

crease of 16.11%, and the urban area during 2005 – 2010 was changed more dramatically than during 2000 – 2005; forest area was slightly increased and farmland area was reduced by 1660 hm^2 in 10 years. We set three scenarios on land use change in Yongchuan District for simulation and compare the predicted results. It can be concluded that driven by rapid urbanization, the change in land use landscape pattern in Yongchuan District is mainly focused on forest and farmland, the urban area is substantially increased, and the forest area also shows an increasing trend while the farmland area is reduced accordingly. Under ecological protection scenarios, the land use type having a protective effect on the ecological environment achieves better control effect.

4.2 Discussions This paper studies the land use in Yongchuan District of Chongqing City, further simulates the land use change in the coming years, and considers the competitive relationship between different land use types as the influencing factors, in order to accurately simulate the land use trends in the next few years under different scenarios. In the short term, the land use type change is significantly associated with human economic activity, but there are difficulties in the quantitative and qualitative study on the factors influencing human economic activity, so this paper only studies and forecasts the land use pattern change in Yongchuan District, and the distribution difference under the combined effect of time and space is not accurately reflected. To be able to make scientific decisions on land use spatial pattern, there is a need to simulate the impact of various scenarios on land use pattern, and the ideal scenarios include ecological protection mode and farmland protection mode. Under the impetus of urban-rural integration, the agricultural structure is changed and the construction of industrial zones is promoted in Yongchuan District, so a lot of arable land in the region is converted to construction land. It is necessary to pay attention to policy factors, which have a greater impact on land use type change than the daily human activities and natural factors under normal circumstances. Therefore, there is a need to include policy factors in the impact factor modules of CLUE-S model and consider the impact of policy factors land use trends, to improve simulation accuracy.

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