

Simulation of Land-Use Policies on Spatial Layout with the CLUE-S Model

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ABSTRACT

Currently, the simulation of land use and land cover change is one of the research focuses in land resource management. Models for simulating this topic have been used by lots of scholars. In the process of experiments, especially using the models, to grasp the characteristics of data has a significant impact on the simulation results. With the changes in policies of land use, the spatial layout has shown a new form. How to simulate the change is one of the focuses in the current Land Resource Management. Therefore, this paper analyzes the current land use of the study area in two aspects: the structure and spatial layout, studying on changes in demand according to the current major changes of policies for land use in the area.; based on the in-depth analysis, by making reasonable choices of land use classification and using the logical regression analysis and ROC curve to select driving factor which is suitable for the characteristics of the study area; a reasonable simulation is then conducted for the impact on the spatial layout for land use change policies through CLUE-S model. The result shows that the exact parameters in line with the characteristics of the study area in CLUE-S mode could simulate the land use spatial layout for many land-use policies such as ‘construction land uphill’, ‘construction land making room for arable land’, ‘construction land along the river and road development’, ‘key industries land expansion’. The results have certain significance on land use changes and land use planning. In order to assist the decision making and improve the efficiency of land use, using this method can help the department of land and resource use to simulate the situation of the land use from the structure and the spatial layout in future according to the demands and the local policies of the land.

1. Introduction

The simulation of land use cover change is using models and math methods to simulate the changing situations of spatial distribution of land use, which can demonstrate and analyze the spatial variation through the layers and GIS rather than confined to the structured figures for the area, location or related attributes of different land use types.

The Conversion of Land Use and its Effects modeling framework (CLUE) is used to simulate the land use change. Based on it, the CLUE-S is an improved model for small scale regional application, which is more systemic, is mainly used to study the rationalization of the land use spatial layout and coordination distribution of the variety demands among the different land use types. Therefore, the CLUE-S model is more applicable to the experimental requirements of this paper.

2. Introduction of CLUE-S Model

The CLUE-S model is divided into two parts: the demand analysis and the demand distribution. statistically, the demand analysis calculates the area changes for all

land use types; while in the demand distribution, area demand for different land types is converted into special land use change in the study area. When all the conditions provided, the CLUE-S will compute the most likely changes in land use. In the model, for each raster pixel i , it will calculate the total probability ($TPROP_{i,u}$) specific to each land use type u according to the formula:

$$TPROP_{i,u} = P_{i,u} + ELAS_u + ITER_u \quad (1)$$

where $P_{i,u}$ is the suitability of land use type u for the location i ; the $ELAS_u$ refers to the conversion elasticity for land use u ; $ITER_u$ is the iteration variable for land use type u , which marked the relative competitiveness of this type. For all types of land use, when the distribution area is less than the demand area the iteration variable will rise, and when excessive it will down.

3. Analysis of the Regional Situation

3.1. Overview of the study area

The selected study area is a part of a county land, including the county seat. This region is located in plateau of Southwest China, and has an obviously undulate ter-

rain. As shown in Figure 2, the terrain of the study area can be divided into three parts: the western, the central and eastern: the western is of high altitude, slope, and vegetation type of forest, with a few garden plot, arid land, irrigated land, villages and natural reserves; the central area is of flat terrain and the most of construction and irrigated land, with towns nearby the highway and the main channel, and irrigated land scattered with villages and other agricultural land; the east area is flat, covered arid land, with the most land of easy grade compared with the western topography.

3.2. Data and Adjustment of Land Classification

The data is from the second national land survey database, base period 2009. There are twenty-three the third level land use types in the study area. The CLUE-S model can only simulates 12 kinds of space layout of land changes at one time, and the classification and setting of different land use types will greatly affect the function of the selected driving factors. Therefore, it is necessary to make pertinent division among the 23 types according to the situation and characteristics in the study area so as to rank the land use types of close spatial relationships, same characteristics or same land use demand into one class for effective simulation. The 23 land use types could be adjusted and re-classified as follows.

- Paddy field linking together with the irrigated field, their location and land use requirements are roughly the same. So they are classified into ‘paddy field and irrigated land’.
- The pond of agricultural land and facilities scattering in paddy field, irrigated land and arid land could be unified into ‘other land’.
- The land of small areas for mining, railway, highway, reservoir, hydraulic construction, scenic and special use, rivers and beaches, , with higher requirements on the conditions of land use and thinner probability for transforming into the other land use types. There are no increasing needs of land use for this type, so they are unified into ‘the other unchanged land’.

The adjusted spatial distribution map and grid quantity statistics of the 9 land use types are as follows. (1 hectare for 1 grid area) After adjustment, the area of the forest is the largest in the study region, the second is the paddy field and dry land, and the area of other land use type is much less.

4. Simulation for the change of the land use

4.1. Analysis on the land use policies

According to the local land use planning of the study area, the development of social economy, the policies

about the land use change and the development prospect of the three major industries, the major policies which affect the land use change from now to 2015 can be summarized as follows.

1) By 2015, the construction land area will increase 34 hectares, the flower planting area will increase 609 hectares and the cultivated land area will increase 232 hectares in the study region.

2) The land use policy is ‘developing along river and road’ for the foreign industry.

3) In the policy of ‘construction land up the hill (low mound and gentle slope)’, construction land provides the land for the cultivated land.

4) All of the land use planning must be in accordance with the principles of ‘centralized layout’ and ‘the intensive use of land’.

4.2. Data preparation

Before using the CLUE-S model to simulate the change of land use, lots of files should be prepared in the installation path of the model. Of all of the files, the text file can be edited directly, while others need preliminary analysis on the layer by the Arc GIS software, then converted to raster data and output as ASC II format.

Table1. Summary of the files of the CLUE-S model needed by the experiment

File name	Representative meaning	File number
cov_all.0	Distribution grid map contains all the land use type	1
cov1_*.0	Distribution grid map contains each land use type	9
region*.fil	Raster map of land use change restricted region	1 or more
demand.in1	The land use demand of each year	1
sc1gr*.fil	Driving factor	At least 1 for each land use type
allow.txt	Change matrix	1
alloc1.reg	Logistic regression results	1
main.1	Main parameter file	1

1) Determining the grid size.

According to the requirement of the grid size of the

CLUE-S model, the unit shall be in hectares. According to the CLUE-S model application case, using three grid area, 6.25 hectares (i.e. grid size of 250m), 1 hectare (grid size of 100m) and 0.4096 hectares (grid size of 64m) to simulate the change of the land use. And finally, 1 hectare is selected as the experimental grid size, for its computation convenience and moderate grid map display and so will not reduce the speed and the accuracy of the calculation.

2) Preparation for the file of the restricted region.

In the file region1.fil (limit change area), with no nature reserve in the study area, the land use polygon is zoned for land use change restricted area since it will not change under normal circumstances or occurs only a small change in a particular year, and it will be made mask in order to ensure that the land use polygon under the mask does not participate in the land use change.

3) Preparation for the file of the area demands.

In the file demand.in1, according to the land demand of the land use change of the study area in the simulated year, the area of the garden and the plough land should be increased. In the plough land, the area of the paddy field and irrigated land will increase because of the move of the construction land, and area of the arid land remains unchanged. The area of the Village land, the construction land and other agricultural land will increase a little. The new construction land will be distributed according to a certain proportion based on the present area ratio of village land and construction land, the transfer and change characteristics of the village land with the area expansion and position change of the cultivated land and the land use demand of the village land and the construction land in the simulated year. The other unchanged land will maintain the original area. The area of forest and natural reserve will reduce.

Table2. Summary of the demands of all the land use types from 2009 to 2015

Unit: the number of the grid

Year	Paddy field and irrigated land	Dry land	Other agricultural land	Garden	Forest	Construction land	Village land	Natural reservation	Other unchanged land	The total number of the grid
2009	3263	4159	246	1303	5958	579	716	715	532	17471
2010	3302	4159	247	1405	5827	581	720	699	532	17471
2011	3340	4159	249	1506	5695	583	723	683	532	17471
2012	3379	4159	250	1608	5564	585	727	668	532	17471
2013	3418	4159	251	1709	5432	587	731	652	532	17471
2014	3456	4159	252	1811	5301	589	735	636	532	17471
2015	3495	4159	254	1912	5170	591	738	620	532	17471

4) Selection for the driving factors.

In the setting of the file sclgr*.fil (driving factor), according to the present situation of land use and the land use policies of the study area, different kinds of the land area, location and other factors, 11 driving factors have been selected preliminarily. The 11 driving factors are altitude (S0), distance to the river (S1), distance to the reservoir water and the hydraulic construction land (S2), distance to the arid land (S3), elevation level (S4), distance to the road (S5), distance to the irrigate land (S6), distance to the garden (S7), distance to the reservoir water (S8), farmland slope grade (S9) and slope grade (S10). These driving factors should be converted to raster data by Arc GIS software, and then output as ASC II file. By applying the CLUE-S model with convert.exe software,

different land use type files and different driving factors can be transformed to one file with a certain format which could be read by SPSS software convenient and fast.

In the process of the experiment, each land use type should be made logistic regression analysis with every driving factors at first, and then should be made logistic regression analysis with all the driving factors by using the "Forward: Conditional" method. The SPSS software can select the main effect driving factors automatically. Through the two logistic regression analysis, the classification ability of the equation in different driving factors for all the land use types and area value in the ROC curve can be judged.

The area value in the curve of ROC should be between 1 and 0.5. The value greater than 0.5 and closer to 1 means the diagnostic effect is better; between 0.5~0.7 means a lower accuracy; between 0.7~0.9 means a certain accuracy; above 0.9 means a high accuracy. In the process of trial and error, the classification ability of equation of the driving factor lower than 70% or the area value under the ROC curve lower than 0.7 are to be eliminated out of the equation. The classification ability of equation is mainly used to determine the relationship

from land use type to driving factor, and the area value under the ROC curve is used to determine the relationship from driving factor to land use type, the regression equation which the area value under the ROC curve is the most should be selected, and the regression parameters of the equation should be recorded and entered into the file named alloc1.reg (regression results). Table 3 is the summary of the selection scheme to different land use type and its classification ability of equation and area value under the ROC curve.

Table 3.The summary of the driving factor selection

Land use type code and name	The scheme of the driving factor selection	The classification ability of equation (%)	The area value under the ROC curve
0 Paddy field and irrigated land	S1 \ S3 \ S4	85	0.814
1 Arid land	S1 \ S2 \ S4 \ S5	78	0.738
2 Other agricultural land	S5 \ S6 \ S8 \ S9	99	0.875
3 Garden	S2 \ S3 \ S4 \ S6 \ S9	93	0.838
4 Forest	S1 \ S2 \ S3 \ S6 \ S9	83	0.920
5 Construction land	S1 \ S2 \ S3 \ S5 \ S6 \ S9	97	0.973
6 Village land	S2 \ S6 \ S9	96	0.932
7 Nature reserve land	S2 \ S3 \ S5 \ S9	96	0.838
8 Other change land	S1 \ S3 \ S5 \ S6 \ S9	97	0.924

It can be obtained from table 3 that both the classification ability of equation and the area under the ROC curve related to different land use types is higher than 70% and 0.7. Among all the 9 land use types, 4 land use types' ROC value is higher than 0.9, and 4 land use types' ROC value is higher than 0.8. Therefore, the model has a strong explanatory ability.

5) Change matrix and elastic coefficient

Coefficient matrix and elastic are set up in order to determine the rule and order of the mutual transformation among the different land use types. It also needs to analyze the present situation of the land use in the study area concretely. Before simulating the change of the land use, the change matrix should be entered into the file named allow.txt, and the elastic coefficient should be entered into the main parameter file named main.1.

According to the characteristics and change policies of the study area, 'the other unchanged land use type' is set in the change matrix, which cannot be transformed to any other land use type or transformed from any other land use type, 'reservations land' is set, which cannot be transformed to any other land use type, and 'paddy field and irrigated land' is set which cannot be transformed to 'construction land'. Other values in a matrix are set to 1, as

convertible relationship.

6) Main parameter file

The file named main.1 contains a set of 20 parameters, such as the number of land use types or the max number of independent.

4.3. Simulating the land use

When the prepared data are stored in the CLUE-S model's installation path, open the user interface of the CLUE-S model, select a region restricted file and a demand file for land use, then click "run" to start the simulation. If there are some errors in the simulation process, the error can be corrected with reference to the problem in the log file.

5. Results analysis

The simulation results will be saved in the installation path automatically through the output file format which has been selected on the main parameter file. Among them, the file named cov_all.6 is the simulation result of the land use change of the sixth year (2015) from the base period (2009). The result could be display by Arc GIS to determine whether the simulation result is consistent with the experimental requirements. If not, it could be adjusted properly by correcting the parameter settings.

Depending on the Figure 1 (a) and (b), analyze the change condition of the spatial layout of the nine land use types between 2009 and 2015 comparatively, combined with the policy analysis of the study area, these results could be obtained.

1) The original spatial layout of the towns is changed, but the land use is still concentrated as before, the area of the towns increases a little, and the overall layout is moved to the east. A portion of the land which belonged to the towns before has transformed into paddy field and irrigated land. At the same time, a part of village land which was once used by the towns is spared, and a part of forest land which was one used by the towns is also spared from the flat terrain area to the gentle slope. As discussed before, the simulation results reflect the land use policies of the experimental area like 'centralized layout', 'the intensive use of land', 'construction land up the hill', 'towns providing land for plough (low mound and gentle slope)' and 'construction land development along the river and road'.

2) The village land area increases a little, and the layout is more concentrated. The village land scattered in paddy field and irrigated land originally is transferred to the side's edge on the west and east of the paddy field and irrigated land. This change is accorded with the demands of the land use policies of this area like 'centralized layout' and 'the intensive use of land'.

3) Garden area increases to a great extent, which is in accordance with land use policy 'newly increase flower area 609 hectares'. Most of the new garden occupies the original forest land, with its spatial layout of dry land and its future developing along the highway trend. This change meets the needs of flower products for export.

4) Cultivated land area is increases 232 hectares, which is in accordance with the requirement of the land use policy.

5) Natural reservation area reduces a little, much of which is transformed to forest. This change meets the demand of the land use.

In summary, the experimental results are consistent with the experimental purpose. The simulation experiment could simulate the main change of the land use on the basis of the land use policies of the study area.

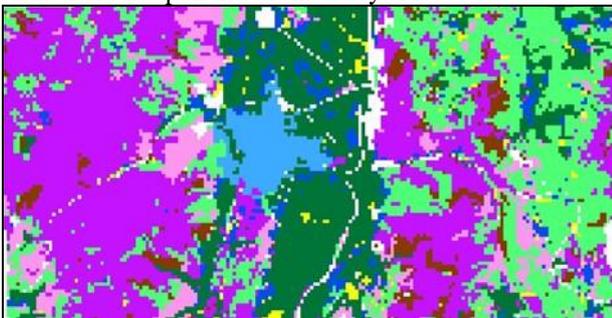


Figure 1(a) spatial layout distribution grid of nine land use

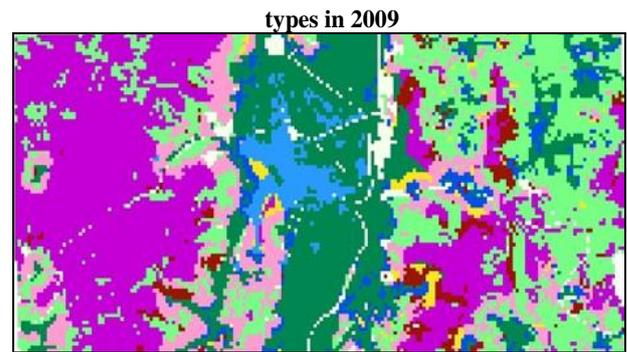


Figure 1(b) spatial layout distribution grid of nine land use types in 2015.

6. Conclusion

The land use change simulation is greatly influenced by land classification and the selection of driving factors corresponding to the different land use types. Therefore, in the simulation of the land use change based on the land use policies of the study area, this paper use Arc GIS software to analyze the structure and the spatial layout of the current land use situation of the study area at first, in order to analyze the dynamic demand of the land use according to the major land use change policies of the study area in the simulated year. Then, on the basis of analyzing the current land use situation and main land use change policies, the land use type is classified reasonably. After that, repeatedly screen the driving factors by using logistic regression model and ROC curve value, in order to choose the most suitable driving factors for the eventual land use characteristics of the study area. Finally, make the reasonable simulation through CLUE-S model for the spatial layout change based on the changes in the land use policies.

The results show that choice of the suitable parameters and driving factors according to the characteristics of the study area could make the simulation process more smoothly and the simulation accuracy higher. This paper realizes using the CLUE-S model to simulate the spatial layout change of the land use based on the land use policies like 'construction land up the hill', 'towns providing land for plough', 'construction land developing along the river and road', 'important industrial land expansion', 'centralized layout' and 'the intensive use of land' at the same time. The research results have certain significance to explore the change of the spatial layout like analyzing the land use change or the planning land use.

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