Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

Study on the Dynamic Simulation of Forest Landscape Pattern in Shangri-La Based on CLUE-S Model

Zhiwei Zhang[1], Zhiwei Yang[1*], Keqin Xu[2], Li Sheng[1]
[1]School of Architecture and Design, Chongqing College of Humanities, Science & Technology, Chongqing, 401520, China.
[2]School of River and Ocean Engineering, Chongqing Jiaotong University, Chongqing, 400074, China
*Corresponding Author.

Abstract:

The land utilization change date of three different stages (1999, 2009 and 2019) in Shangri-La was obtained by using the spatial-overlay approach for the space date. Furthermore, the CLUE-S model was applied to predict the trends in land use changes in the research area. On the base of land utilization space date in 2019, the factors of elevation height, gradient, exposure, roads and resident were considered in the CLUS-S model to imitate the land utilization spacial pattern change from 2019 to 2028. ROC method was used to verify the simulation results. The simulation of land using spatial pattern is based on the CLUE-S model, which can promote the management and sustainable development of protected areas and provide a scientific basis for forest landscape management and forest management.

Keywords*: Landscape ecology, Shangri-La, CLUE-S; Land using simulation.*

I. INTRODUCTION

Landscape spatial dynamic simulation model is to study the overall changes and evolution process of landscape pattern in time and space [1]. The landscape is a dynamic process, and this dynamic feature of landscape is reflected in the study of changes in spatial structure at different spatial scales. With the continuous development of landscape ecology, people pay more and more attention to the research of landscape spatial pattern dynamics. And many landscape dynamic simulation and prediction models have been well developed and applied [2].

Since the simulation of spatial data in the CLUE-S model is mainly carried out in the form of grids, the geographic information system is used to convert the five driving factor maps of the land using into grid format, and the grid size is 30m x 30m. The CLUE-S model driving selection can be divided into two categories: one is the static driving factors; the other is the dynamic driving factors [3]. As Pontius R. G. mentioned, in order to validate the landscape type change model, the ROC (Relative Operating Characteristics) method can be used to test the logistic regression results [4].

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

II. SELECTION OF MODEL DATA AND FACTORS

Based on the platform of GIS technology, the spatial data of landscape type is processed, and the prepared factor data layer and landscape type data layer are expressed in ArcGRID format. Moreover, the File Converter module, provided by the CLUE-S model, is used to convert forest land, agricultural land, building land, water area, unused land, grassland. And the ASCII files of five driving forces were converted into a single record text file [5].

According to the factor selection rules, 5 driving factors of landscape change using were selected in this study. The names of the drivers and their brief descriptions are shown in TABLE I.

TABLE I. Driving factors of land use change

FACTOR	DRIVER	CODE	FACTOR DESCRIPTION
DISTANCE	Spatial distance to road	sclgr0.fil	Calculate the distance from the center of each pixel to the
	Spatial distance to village	sclgr1.fil	Calculate the distance from the center of each pixel to the
TERRAIN FACTOR	Elevation	sclgr2.fil	Contour generation DEM
	Slope	sclgr3.fil	DEM generation
	Aspect	slgr4.fil	DEM generation

III. SIMULATION OF THE SPATIAL PATTERN OF FUTURE LAND USING CHANGE IN THE STUDY AREA

The entire city of Shangri-La was set as the regional constraint. The spatial topographic map data of land using in the study area in 2009 (the pixel size of the deleted grid data is 30*30 m), the driving factors affecting land using change mentioned above and other parameters required for model simulation are used. The CLUE-S model simulates the spatial change of land using in the study area from 2009 to 2019. After checking the simulation accuracy, it simulates the spatial change of land using in the study area in the next 10 years (2019-2028). There are two different simulation cases.

3.1 Main Parameter Settings (main 1)

In the CLUE-S model, the main parameter settings of the main 1 file are shown in TABLE II.

TABLE II. Settings of main parameters

LINE NUMBER	PARAMETER VALUE
1	6
2	1

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

LINE NUMBER	PARAMETER VALUE
3	5
4	5
5	3576
6	3589
7	0.76
8	578518.861
9	3093653.104
10	0 1 2 3 4 5
11	0.7 0.6 1 1 0.4 0.9
12	1 126 266
13	2019 2028
14	0
15	1
16	0
17	2
18	0
19	0

3.2 Regression Equation (alloc 1)

In the CLUE-S model, the alloc 1.reg file is the result of the regression equation. The specific input is as follows:

Row 1: Number code of land use type; Row 2: Regression equation constant of land use type; Row 3: Number of explanatory factors and explanatory factor code of regression equation of land use type; Below: Repeat another land use type according to the same order.

0
-3.78
5
0.0018 0
0.0059 1
0.0001 2
0.0874 3
0.0006 4
1
21.9027
3
-0.64314 1

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

0.87867 2
0.743152 3

2 −3.4 3 7
5
-0.0065 0
0.00143 1
-0.000145 2
-0.009246 3
0.008345 4

3
−2.3142
5
-0.001264 0
0.001344 1
-0.00012 2
-0.009236 3
0 . 0 0 9 2 4

4
−5.4349
3
-0.000124 0
0.048145 3
-0.002356 4

5
−2.3087
2
0.97575 2
0.678538 3

3.3 Land Use Transfer Matrix (allow.txt)

According to the landscape type in the study area and it's changing law, the conversion rules between various landscape types are established. In TABLE III, the row represents the original landscape type; the column represents the transferred landscape type; "1" represents that the two landscape types can be

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

converted; and "0" represents that the conversion cannot be transferred. It is assumed, during the two periods, the construction land cannot be converted to other land using types, but other land using types can be converted. (TABLE III)

TABLE III. Transfer matrix of land types

	WOODLAND	FARMLAND	CONSTRUCTION LAND	WATER	UNUSED LAND	GRASSLAND
WOODLAND	1	1	1	0	0	0
FARMLAND	1	1	1	0	1	1
CONSTRUCTION LAND	0	0	1	0	0	0
WATER	0	0	0	1	0	0
UNUSED LAND	1	1	1	0	1	0
GRASSLAND	1	1	1	0	0	1

3.4 Demand Plan

3.4.1 Demand scenario 1 (demand.in 1)

Due to the limitation of the obtained data and to ensure its consistency, this study conducted the linear interpolation between the area of land using types, which is obtained by visual interpretation of TM remote sensing images in 2009, and the areas of land using types obtained by visual interpretation of IRS remote sensing images in 2019. Moreover, using CLUE-S to simulate the spatial distribution map of land using types in 2019. After that, simulating the spatial distribution map of land using types in 2028.

From 2009 to 2019, the area of forest land has increased, while the area of agricultural land has decreased. Assuming that the future land using development in the study area tends to return farmland to forest and close mountains for forest cultivation, the area of forest land increases, while the areas of other land using types change, and the demand area 1 could be gotten. (TABLE IV)

TABLE IV. Demand on land use type in project 1 (AREA: hm^2)

YEARS	WOODLAND	FARMLAND	CONSTRUCTION LAND	WATER	UNUSED LAND	GRASSLAND
2019	950942.97	38180.52	1671.93	3758.85	108444.6	38781.99
2020	953391.20	37425.35	1701.53	3758.85	106338.8	38781.99
2021	956039.43	36670.18	1731.13	3758.85	104233	38781.99
2022	958487.66	35915.01	1760.73	3758.85	102127.2	38781.99
2023	961035.89	35159.84	1790.33	3758.85	100021.4	38781.99
2024	963584.12	34404.67	1819.93	3758.85	97915.6	38781.99

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

2025	966132.35	33649.5	1849.53	3758.85	95809.8	38781.99
2026	968680.58	32894.33	1879.13	3758.85	93704	38781.99
2027	971228.81	32139.16	1908.73	3758.85	91598.2	38781.99
2028	976325.30	31383.99	1938.33	3758.85	89492.4	38781.99

3.4.2 Demand scenario 2 (demand.in 2)

The study area is one of the "Three Parallel Rivers World Natural Heritage Sites", which is a key protected area in the world. With the development of eco-tourism in recent years, tourism is as a function to promote the economic development [6]. Therefore, the needs of the landscape planning requires to protect and develop farmland and properly develop some forest land around the residents. Thus from 2019 to 2028, the area of forest land would decrease, the area of farmland would increase, and the area of other land using types would change. The demand area 2 could be gotten. (TABLE V)

TABLE V. Demand on land use type in project 2 (AREA: hm^2)

YEARS	**WOODLAND**	**FARMLAND**	**CONSTRUCTION LAND**	**WATER**	**UNUSED LAND**	**GRASSLAND**
2019	950942.97	38180.52	1671.93	3758.85	108444.6	38781.99
2020	950676.84	39349.74	1762.43	3758.85	106549.4	38781.99
2021	950510.71	40518.96	1852.93	3758.85	104654.2	38781.99
2022	950344.58	41688.18	1943.43	3758.85	102758.9	38781.99
2023	950178.45	42857.4	2033.93	3758.85	100863.7	38781.99
2024	950012.32	44026.62	2124.43	3758.85	98968.5	38781.99
2025	949846.19	45195.84	2214.93	3758.85	97073.28	38781.99
2026	949680.06	46365.06	2305.43	3758.85	95178.06	38781.99
2027	949513.93	47534.28	2395.93	3758.85	93282.84	38781.99
2028	949347.80	48703.5	2486.43	3758.85	91387.62	38781.99

3.5 Land using Map for the First Year of the Simulation (cov_all.0)

The land use allocation map for the first year of the simulation in the study area (2019) is shown in Figure 1. A total of 5 driving factors of land using/covering change were used for the simulation in the study area. They are: Sclgr0: Spatial distance to road; Sclgr1: Spatial distance to residential area; Sclgr2: Elevation; Sclgr3: Slope; Sclgr4: Slope aspect. Each driving factor file is converted into ASCII code using ArcGIS and input into the model [7].

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

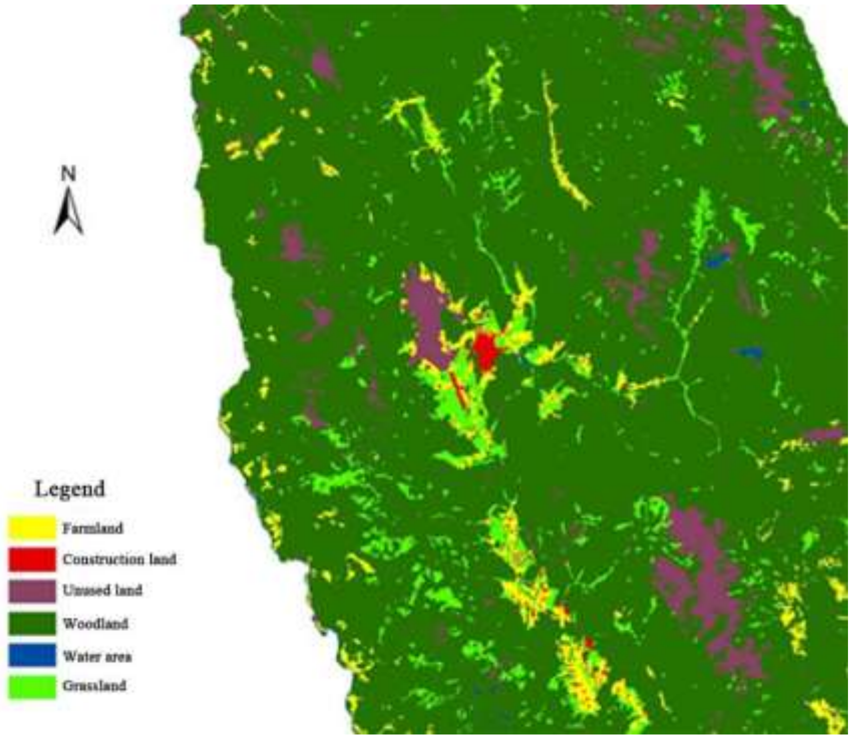

Fig 1: Land use distribution in 2019(part of Shangri-La)

3.6 The Stability of Land Using Type Conversion

The stability of land using type conversion (the value of ELAS parameters) parameters mainly depend on the understanding of land using changes in the study area and previous knowledge and experience. Of course, it can also be debugged in the process of model verification. According to the current features and changing characteristics of land using in the study area, different ELAS parameter values are assigned to each land using type, and a more suitable parameter scheme is selected for the final simulation [8]. The stability of the conversion of various land using types in the study area is shown in TABLE VI.

TABLE VI. Stability of the conversion of different land use type

LAND USE TYPE	STABILITY
WOODLAND	**0.7**
FARMLAND	**0.6**
CONSTRUCTION LAND	**1**
WATER	**1**
UNUSED LAND	**0.4**
GRASSLAND	**0.9**

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

In the study area, construction land belongs to a relatively stable and fast-growing land using type. After a certain land using type being converted into construction land, it is generally difficult to convert it into other land using types, and there will be no major changes in a short period of time. So set its stability to 1.0, which means that small conversions of building land are negligible over the forecast period.

Agricultural land is the largest land type in the study area, which is also the main source of various types of construction land. It is relatively easy to be transformed into other land types. With the increasing of the population, there is a requirement of economic development, which means the need for agriculture land is larger, so the stability is set to 0.6.

Since Shangri-La is mainly dominated by forest land, the forest land in the study area cannot be converted into other land using types. So the forest land stability is set to 0.7.

Compared with the above three land using types, unused land has lower stability and is easier to be converted into other land using types, which means the ELAS parameter is set to 0.4.

The grassland type will be more difficult to convert to other land using types with high stability, so its ELAS parameter is set to 0.9.

3.7 Stepwise Logistic Regression Analysis

The correlation between the driving factors and a certain land using type could be analyzed by Logistic regression [9]. Before analysis, the ASCII files of the forest land, agricultural land, construction land, water area, unused land, grassland and five driving factors were converted into single recording files with File Converter software, and then input into SPSS 20.0. After that, each land using type and 5 driving factors were analyzed to get the ß value for each driving force [10]. The result is as follows:

From the logistic results, the following regression model is obtained:

(1) WOODLAND:

$$\log\left(\frac{p_0}{1-p_0}\right) = -3.7872 + 0.001859x_0 + 0.005945x_1 + 0.000143x_2 + 0.087452x_3 + 0.000695x_4$$

(2) FARMLAND:

$$\log\left(\frac{p_1}{1-p_1}\right) = 21.9027 - 0.64314x_1 + 0.87867x_2 + 0.743152x_3$$

(3) CONSTRUCTIONLAND:

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

$$\log\left(\frac{p_2}{1-p_2}\right) = -3.4375 - 0.0065x_0 + 0.00143x_1 - 0.000145x_2 - 0.009246x_3 + 0.008345x_4$$

(4) WATER:

$$\log\left(\frac{p_3}{1-p_3}\right) = -2.3142 - 0.001264x_0 + 0.001344x_1 - 0.00012x_2 - 0.009236x_3 + 0.009232x_4$$

(5) UNUSED LAND:

$$\log\left(\frac{p_4}{1-p_4}\right) = -5.4349 - 0.000124x_0 + 0.048145x_3 - 0.002356x_4$$

(6) GRASSLAND:

$$\log\left(\frac{p_5}{1-p_5}\right) = -2.3087 + 0.97575x_2 + 0.678538x_3$$

3.8 Model Collaboration

ROC (relative operating characteristic) is a method to validate land using/covering change models [11]. The method is derived from binary likelihood tables, each of which corresponds to a different hypothesis for a future land using type. The content of each possibility table is the actual change and unchanged cell versus the simulated change and unchanged [12]. The ROC value of a complete random model is 0.5, while a satisfying ROC value is 1.0. The verification of ROC is completed in SPSS20.0, while the actual land using is selected as the "State variable" and the predicted suitable area for the corresponding land using type is selected as the "Test variable". The results shows that the ROC curve values were all greater than 0.5, indicating that the model fits well.

Generally, when the ROC value is greater than 0.7, the identified driving factors can be explained better [13]. The ROC test results (Fig 2-Fig 7) show that the ROC values of various land types are: forest land 0.957, agricultural land 0.987, construction land 0.921, water area 0.761, unused land 0.573, grassland 0.821, and river beaches 0.5. From the ROC results, it can be seen that the pre-side accuracy of the unused land is low, which the ROC value is 0.573. The reason for the lower accuracy can be explained by the relatively strong dynamic characteristic of land using types, which means the land using type could be transformed into several other land using types in a relatively short period of time [14]. The land, located near the forest and agriculture land, could be transformed into unused land, and then it can be transformed into agriculture land. Due to the increase in population, it could be transformed into the construction land [15].

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

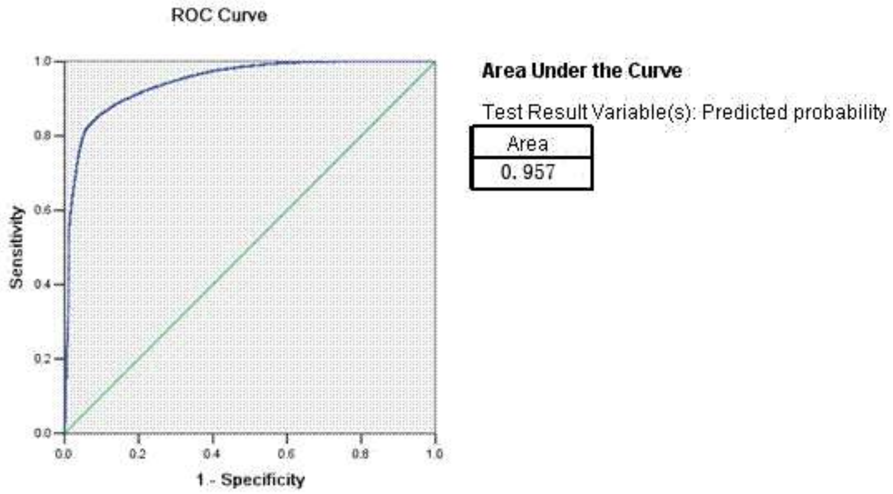

Fig 2: The ROC curve of forest

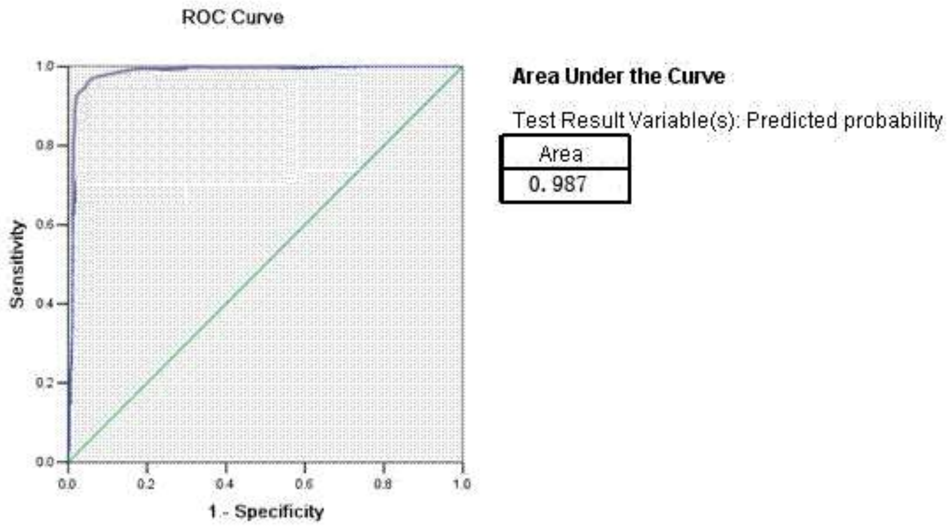

Fig.3: The ROC curve of farmland

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

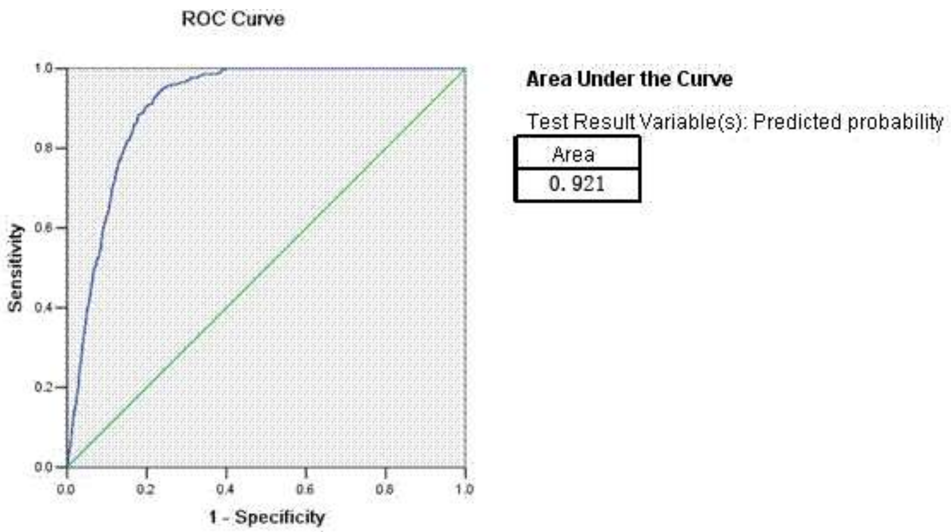

Fig 4: The ROC curve of settlements

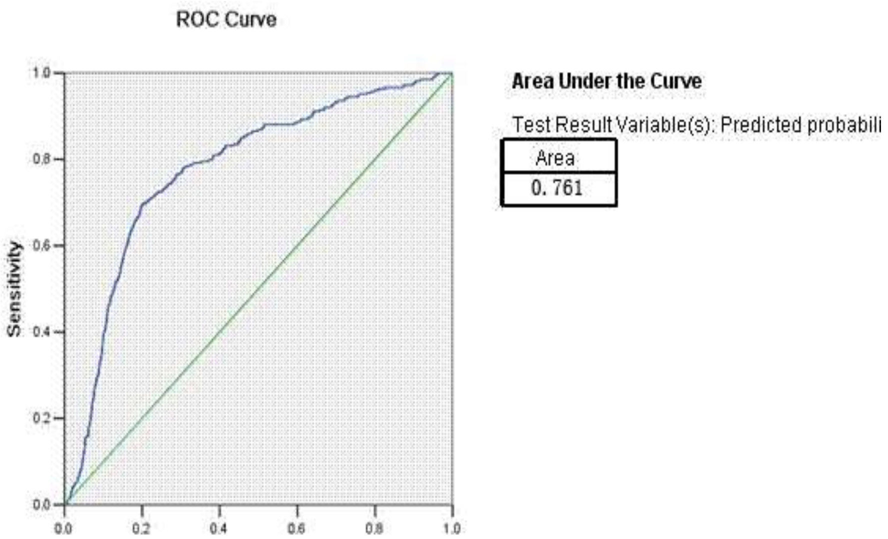

Fig 5: The ROC curve of water

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

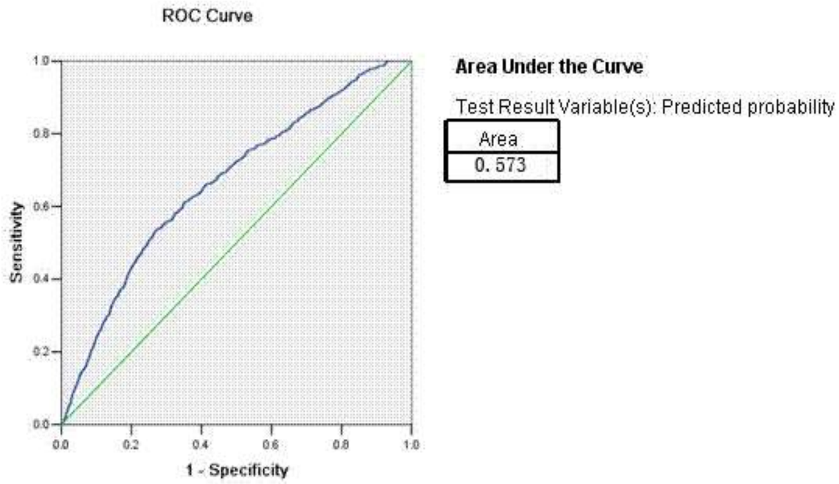

Fig 6: The ROC curve of unused land

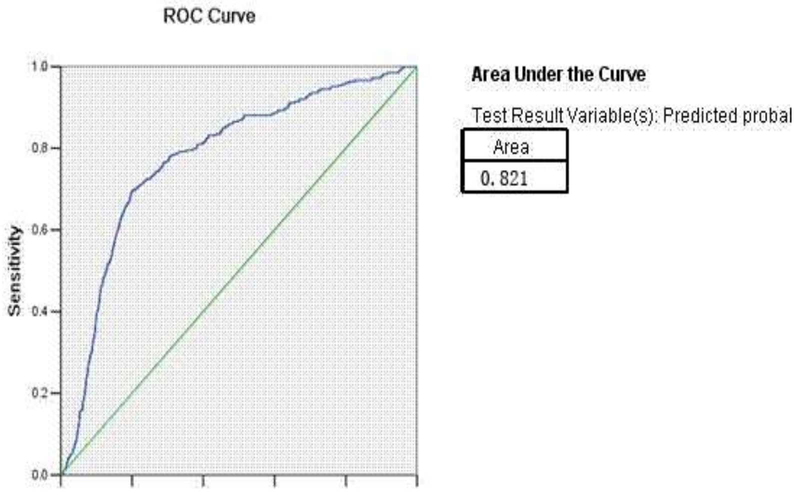

Fig 7: The ROC curve of meadow

As shown in the above figures, after obtaining satisfactory regression results of other land using types, the probabilities of each land using types were calculated to obtaining the spatial distribution probability suitability chat of land using.

3.9 Simulation Results

3.9.1 Model validation

The Kappa coefficient can quantitatively reflect the accuracy of the model simulation [16]. Kappa=(P0-PC)/(PP-PC). Using the land using map of the study area in 2019 as a reference, to test the accuracy of the CLUE-S model which simulate the land using changes from 2009 to 2009. The calculated

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

Kappa coefficient is 0.8217, which has reached a good level. The comparison figures is shown in Fig 8.

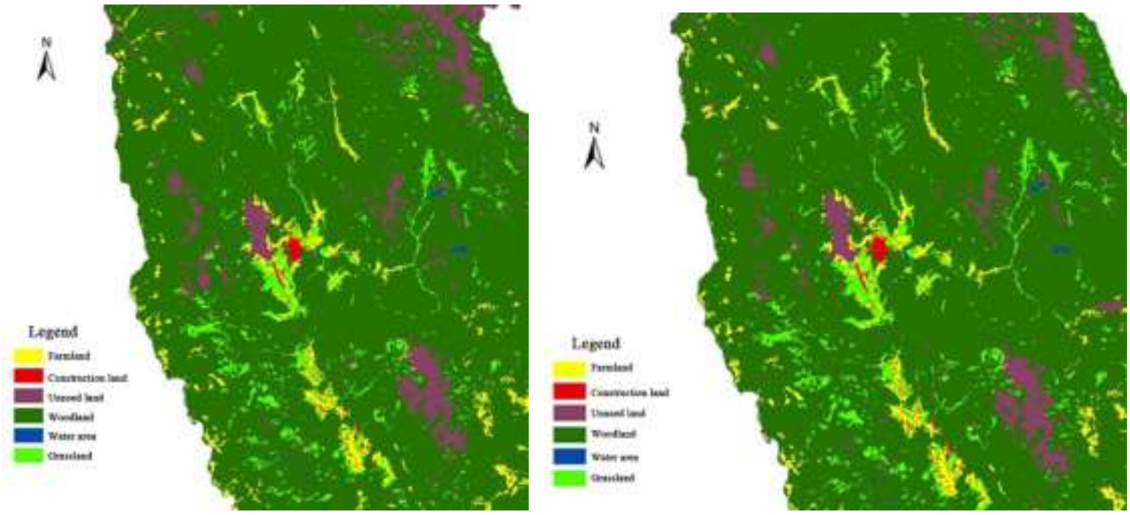

Fig 8: The actually land using distribution and simulation results in 2019(part of Shangri-La)

3.9.2 Scenario 1 simulation

Input the data of demand scenario 1 into the model, and simulate the land using change in the study area from 2019 to 2028 (in the main file, after repeated testing, the conversion elasticity coefficient of each land using type is adjusted to 0.7, 0.6, 1, 1, 0.4, 0.9; the iteration coefficient is adjusted to 1, 126, 266), shown as Fig 9.

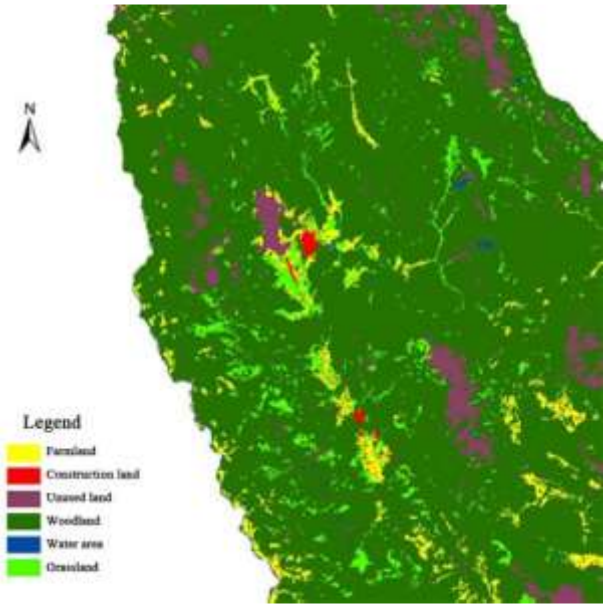

Fig 9: Simulation of land use distribution in 2028 for scenario 1(part of Shangri-La)

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 1931-1945
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

3.9.3 Scenario 2 simulation

In simulation 2, input the data of demand scenario 2 into the demand simulation module (in the main file, after repeated testing, the conversion elasticity coefficient of each land using type is adjusted to 0.6, 0.5, 1, 1, 0.4, 0.9; the iteration coefficient is constant), which is shown in Fig 10.

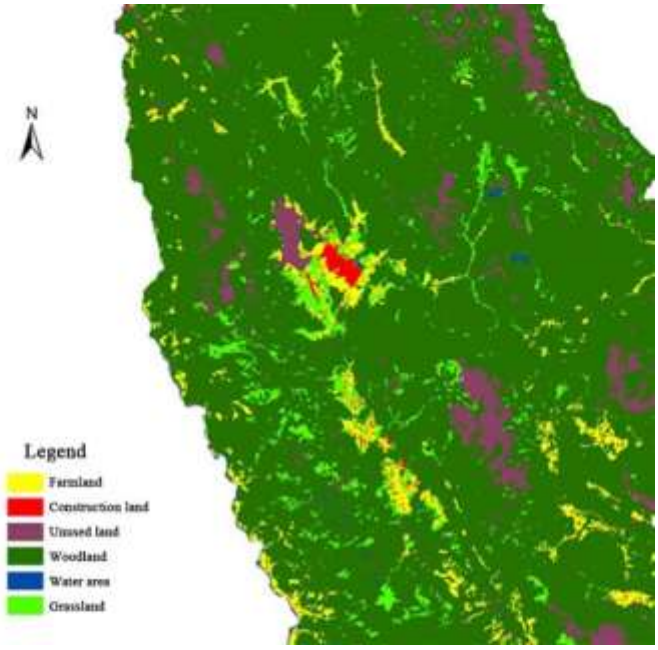

Fig 10: Simulation of land use distribution in 2028 for scenario 2(part of Shangri-La)

3.9.4 Comparison of the simulation results

Under Scenario 1, the main focus is on protecting the ecological environment. Based on the policy of protecting forest land, the area of unused land is reduced, which increases the area of forest land. However, the ecological benefits are not significant. The original forest land in Shangri-La has been already large, so scenario 1 has little significance for improving ecological benefits.

Scenario 2 is mainly based on the economic development model. In order to meet the needs of local economic development, the area of forest land is reduced by a certain amount, while the agricultural land and the land for construction is greatly increased, reflecting the rapid development of the economy. To a certain extent, it has promoted the development and utilization of forests.

III. CONCLUSION

The CLUS-S model was used to simulate the spatial pattern of land using in Shangri-La in 2028 with two simulation scenarios. The simulation results passed the ROC test, which was good and the overall fit was great. Through the comparison of the two simulation cases, it is reflected, in land demand scenario 1, the results showed that more unused land and agricultural land were converted into forest land, but the distribution of newly added forest land was not reasonable. The ecological benefits of the newly added forest land are not significant. For the land demand scenario 2, the various types of land demand in this scheme are customized to promote local economic development. Under the condition of reasonable distribution, the forest land area is reduced to a certain extent, and the agricultural land and building land are increased.

REFERENCES

[1] Premalatha M (2008) Efficient cogeneration scheme for sugar industry. Journal of Scientific & Industrial Research 67: 239-242

[2] Lu Jinglong. Research on dynamic simulation and prediction method of forest landscape composition structure. Shanxi Agricultural University, 2002, 22(3): 234-248.

[3] Li Shujuan. Dynamic Process of Forest Landscape and Landscape Ecological Evaluation in Maoer Mountain Area [PhD Thesis]. Northeast Forestry University, 2004

[4] Liu Yansui, Jay Gao. Analysis of land degradation situation along the Great Wall in northern Shaanxi. Acta Geographica Sinica, 2002, 57(4): 443-450.

[5] Zhang Yongmin, Zhao Shidong, P.H.Verburg. CLUE-S model and its application in the simulation of temporal and spatial dynamic changes of land use in Naiman Banner. Journal of Natural Resources, 2003, 18(3): 310-318.

[6] Guo Jinping, Zhang Yunxiang. Spatial correlation degree of landscape elements and landscape pattern analysis in Guandi Mountain Forest Area. Forestry Science, 1999, 35(5): 28-33.

[7] Milne B. T., Johnston K.M. Forman R.T.T. Scale-dependent proximity of wildlife Habitat in a Spatially-Neutral Bayesian model. Landscape Ecology, 1989, 2(2): 101-110.

[8] Forman R.T.T. Land mosaic: the ecology of landscape and region. Cambridge: Cambridge University Press, 1995, 3-7.

[9] Pearson S.M. Estimate the landscape patterns of species with different life forms. The pace and pattern of landscape change. 12th. Annual symposium of USIALE, USA. 1997, 16-19.

[10] Velázquez A., Romero F.J., Rangel-Cordero H., Heil G.W. Effects of landscape changes on mammalian assemblages at Izta-Popo Volcanoes. Mexico. Biodiversity and Conservation, 2001, 10(7): 1059-1075.

[11] Thomas C., Dinger M.C., Boughton D.A. Catastrophic extinction of population sources in a butterfly metapopulation. American Naturalist, 1996, 148(6): 957–975.

[12] Skanes H.M., Bune R.G.H. Direction of landscape change (1741-1993) in Virestad, Sweden--characterised by multivariate analysis. Landscape and Urban Planning, 1997, 38(1): 61-75.

[13] Rhodes O. E. Jr., Chesser R.K. Genetic concepts for habitat conservation: the transfer and maintenance of genetic variation. Landscape and Urban Planning, 1994, 28: 55-62.

[14] Fukamachi K., Iida S., Nakashizuka T. Landscape patterns and plant species diversity of forest reserves in the Kanto region, Japan. Vegetatio, 1997, 130(1): 99-100.

[15] Gibson D.J., Scottl C., Ralph G. Ecosystem fragmentation of oak-pine forest in New Jersey Pinelands. Forest Ecology and Management, 1988, 25: 105-122.

[16] Spies T.A., Ripple W.J., Bradshaw G.A. Dynamics and pattern of a managed coniferous forest landscape in Oregon. Ecological Applications, 1994, 4(3): 555-568.