Dynamic changes and trend prediction of land use in Suizhou city based on PLUS model

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Abstract. To explore the law of land use change in Suizhou City, strengthen land resource management and improve the efficiency of land resource utilization, this paper study the dynamic changes and trend prediction of land use in Suizhou City. In this study, three periods of Landsat-TM/ETM and Landsat 8 satellite image data in 1995, 2005 and 2015 were selected, and the evolution of land use pattern in Suizhou City from 1995 to 2015 was analyzed by calculating its land use area and percentage, land use dynamics and establishing a land use transfer matrix. The PLUS model Kappa coefficient was found to be 0.81 and the accuracy meets the requirement. We considered six natural factors, two social factors, and one limiting factor and predicted the land use pattern of Suizhou City in 2035. The results show that from 1995 to 2015, the proportion of cultivated land and forest land area was 33.43%~34.23% and 61.29%~62.49%, respectively. The proportion of unused land had always been the lowest, accounting for 0.01%. The proportion of grassland, water area, and construction land was 0.25%~0.27%, 2.48%~2.83%, and 0.60%~2.20%, respectively. The land area of construction land in Suizhou City changed the most dramatically among all land types from 1995 to 2015, with a land use dynamics of 13.28%. From 1995 to 2015, cultivated land in Suizhou City was mainly transformed into construction land and forest land, accounting for 42.28% and 44.28% of the outflow area, respectively. The conversion of forest land to arable land accounted for 66.50% of the transferred area. The increase in construction land mainly derived from arable land and forest land, accounting for 66.60% and 32.21% of their transferred area, respectively. The Kappa coefficient of the PLUS model was 0.81, indicating that the model can be used for the study of land use change in Suizhou City. The prediction results indicate that the construction land area in Suizhou City will significantly increase by 2035 and expand to the southwest, northeast, northwest, and central regions, with an increase in forest land area, a decrease in cultivated land area, and a slight reduction in grassland, water area and unused land area. The study results can provide a decision-making basis for land use policies and planning measures in Suizhou City, and also facilitate relevant departments to guide urban construction and land development activities more reasonably.

Keywords: Land use change; Suizhou City; PLUS model; Land use transfer matrix.

1. Introduction

Land resources are an important foundation for human survival and development, an irreplaceable material wealth of human society, carring the continuation of human civilization[1]. Land resources provide fundamental material conditions for humanity and play an essential role in economic development, food security, biodiversity[2], and water cycling [3]. To meet the requirements of social development, people change the land use pattern by transforming and utilizing the different properties of land. The most direct result of changes in the pattern and utilization of regional land resources is land use change [4], which has a profound impact on socioeconomic and ecological environment. It is one of the most important changes in land surface systems and a hot topic in natural and social science research [5]. With the growth of population and the acceleration of urbanization, great changes have taken place in the utilization and scale of land resources, of which increasing attention has been paid to utilization and management. Land resources also face various complex issues in terms of utilization and allocation, such as urbanization and land development, unreasonable and unsustainable land use, land pollution, and environmental issues. Therefore, the study of land use change is particularly important to gain a better understanding of the problems that exist in the land use process, ensure the sustainable use of land resources, optimize the regional land use structure, and formulate more scientific and reasonable land use policies.

The main means of studying land use change is to clarify the driving factors of regional land use pattern changes by setting various land use models and explanatory models. Niu Tongli et al. [6] analyzed the driving factors and spatiotemporal changes of land use patterns in the Yangtze River Basin based on the PLUS model, and obtained information on the changes of various land use types in the Yangtze River Basin. Wang You et al. [7] predicted the future land use pattern of Jingtai County and analyzed the land use development trend of Jingtai County based on the FLUS model. Guo et al. [8] dynamically simulated land use changes in the southern Loess Plateau region based on CA cellular automata and Markov models. Wang Yan [9] and others simulated and predicted the land use quantity and land use pattern in various scenarios in Urumqi based on the Markov-PLUS model.

The PLUS model, evolved from the FLUS model, proposes a patch generation land use change simulation model based on raster data, which can be used to simulate future land use situations. This model can explore the causes of various land use changes better, simulate multi class land use patch level changes, and support planning policies to achieve sustainable development through new analysis strategies and new multi class seed growth mechanisms, coupling with multi-objective optimization algorithms. This contribution preprocesses the remote sensing image data of Suizhou City from 1995 to 2015 using ArcGIS 10.8.1, and then analyzes and predicts the land use changes in Suizhou City using the PLUS model. The aim is to understand the characteristics and driving factors of land resource changes in Suizhou City, predict the land use situation in Suizhou City by 2035, and provide ideas for optimizing the allocation of land resources and land management in Suizhou City.

2. General Situation

The schematic diagram of the study area is shown in Figure 1. Suizhou City (31°19N~32°26′N,112°43′E~113°46′E) is located in the northern part of Hubei Province, at the intersection of the Yangtze River and Huai River basins, with a total area of 9636 km^2. Its jurisdiction includes Guangzhou, Zengdu District, and Suixian. The topography of Suizhou City is dominated by low mountains and hills, with Tongbai Mountain in the north which belongs to the western section of the Huaiyang Mountains and a narrow plain in the central part. Suizhou City has a subtropical monsoon climate, abundant rainfall and natural resources, rich historical heritage and cultural landscapes. In 2021, its national high-tech zone ranked second in Hubei Province in terms of economic performance, only behind Wuhan Donghu New Technology Development Zone. By the end of 2022, the permanent population of Suizhou City was 2.0137 millionand the urban permanent population was 1.174 million, with an urbanization rate of 58.32%.

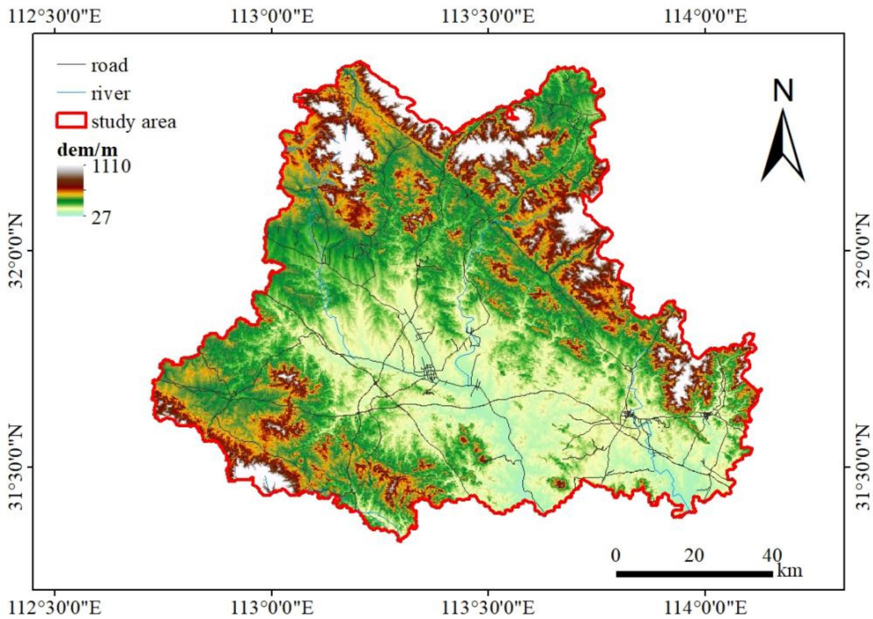

Figure 1 Schematic diagram of the study area

3. Data source and processing

The data used mainly consists of remote sensing data, including Landsat TM/ETM and Landsat 8 satellite image data from 1995, 2005, and 2015, with a resolution of 1km.The terrain elevation data comes from geospatial data cloud, with a resolution of 30m; Soil, demographic data, grid data of GDP, annual average temperature and annual precipitation were obtained from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences with a resolution of 1km. According to the latest classification standard for land use and spatial resource management "Land Use Classification Status" (GB/T 21010-2017) , combined with the regional characteristics of Suizhou City, this paper classifies the land use types of Suizhou City into six types: cultivated land, forest land, grassland, water area, construction land, and unused land.

4. Research Method

4.1 Dynamic degree of single land use

The dynamics of single land use is an index used to describe the amplitude and speed of changes in various types of land over a period of time [10, 11]. The dynamic degree of single land use reflects the intensity and rate of land use change, and its expression is:

$$K=\frac{U_b-U_a}{U_a}\times\frac{1}{T}\times 100\% \tag{1}$$

In the formula(1), U_a and U_b represent the area of a single land use type at the beginning and end of the study; T is the study period ; K represents the dynamic degree of a certain land class within the research period.

4.2 Land use transfer matrix

The land use transfer matrix represents the changes among land use types within a certain period of time, that is, the area of a certain land use type converted to other land use and the area transferred from other land use types during the study[12]. The rows and columns of the matrix represent various types of land use, including cultivated land, forest land, grassland, water area, construction land, and unused land. The calculation formula is as follows:

$$S_{ij}=\begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix} \tag{2}$$

In the formula(2), n represents n different types of land cover; i represents the land type transferred in the previous phase; j represents the land type in the next phase of land transfer; S_{ij} represents the area from the previous phase to the next phase.

4.3 PLUS model

The PLUS model mainly includes two parts: a new land expansion analysis strategy (LEAS) and a CA cellular automaton based on multi class random patch seeds (CARS). This is a new type of complex model that is improved on the basis of the FLUS model. This model can not only explore the driving factors of various land use changes more deeply, but also simulate the changes of various land use types at the patch level more accurately [13].

4.3.1 LEAS

The Land Expansion Analysis Strategy (LEAS) is mainly used to extract useful information and rules from complex data, and the model simplifies the analysis procedure of conversion probability, with temporal variation characteristics. This model uses the Random Forest Classification (RFC) algorithm [14], a decision tree based ensemble classifier, to analyze the relationship between land use types and driving factors. The final output is the growth probability of the k-th land use type on the i-th cell. The calculation formula is shown in (3) [15].

$$P_{i,k}^{d} = \frac{\sum_{n=1}^{M} I[h_n(x)=d]}{M} \tag{3}$$

In the formula(3), the value of d is 0 or 1. If there are other land use types that have transformed into k-type, the value of d is 1. If they have not been transformed into k-type, the value of d is 0; X represents a vector composed of multiple driving factors; I(~) represents the indicator function of the decision tree set; h_n(x) is the prediction type of the nth decision tree of vector x; M is the total number of decision trees.

4.3.2 CARS

CA Cellular Automata (CARS) is a multi-type random patch seed mechanism that simulates the evolution of multiple land types through threshold descent. The expansion intensity of different land use types is expressed by the neighborhood weight parameters, which reflect the expansion ability of each category under the influence of spatial driving factors [16]. The calculation formula is as follows:

$$X_i = \frac{\Delta TA_i - \Delta TA_{min}}{\Delta TA_{max} - \Delta TA_{min}} \tag{4}$$

In the formula(4), the neighborhood weight parameter of land class is represented by X_i, where i represents a certain land class. The maximum and minimum changes of ΔTA are represented by ΔTA_{max} and ΔTA_{min}, respectively, and the changes of land class TA are represented by ΔTA_i.

4.3.3 Model accuracy verification

Testing the accuracy of the model can calculate its Kappa coefficient, which ranges from 0 to 1. The accuracy and feasibility of the model can be evaluatedaccording to this coefficient. The closer the kappa coefficient is to 1, the higher the accuracy of the model is. Usually, a Kappa coefficient exceeding 0.75 indicates that the model meets the required accuracy standards and can be used for simulation and prediction [7]. The calculation formula for Kappa coefficient is as follows:

$$\mathrm{Kappa} = \frac{\mathrm{P_0} - \mathrm{P_c}}{\mathrm{P_p} - \mathrm{P_c}} \tag{5}$$

In the formula(5), the overall accuracy of the simulation results is represented by P0; The accuracy of simulating each grid in a random state is represented by P_c.

5. Result and Analysis

5.1 Land use area and proportion in different time periods

As shown in Table 1, in 1995, cultivated land and forest land were the main types of land use in Suizhou City, with an area of 3282.49 km^2 and 6002.58 km^2, respectively, accounting for 34.17% and 62.49% of the total area. The area of grassland, water, construction land is 24.29 km^2, 237.98 km^2 and 57.75 km^2 respectively, accounting for 0.25%, 2.48% and 0.60%. The unused land area is 0.75km^2, accounting for 0.01%, with the smallest proportion among the six land types. In 2005, the land pattern of Suizhou City was adjusted, but cultivated land and forest land remained the primary land types, with an area of 3289.65 km^2 and 5953.87 km^2, respectively, accounting for 34.23% and 61.95% of the total area. The land type with the smallest area proportion was still unused land, with an area of 0.77 km^2 and an area proportion of 0.01%. In 2015, the main land types in Suizhou City remained unchanged, with cultivated land and forest areas of 3212.57 km^2 and 5890.10 km^2, accounting for 33.43% and 61.29% respectively. The proportion of unused land area was still the least, with an area of 0.81km^2 and an area proportion of 0.01%. The proportion of construction land area reached 2.20% in 2015, with an area of 211.18 km^2. To some extent, these data reflect the demand and impact of Suizhou on the adjustment of land use pattern in the process of economic development and urbanization.

Table 1 Land use area and proportion in Suizhou City

land type	1995		2005		2015	
	area(km^2)	percentage(%)	area(km^2)	percentage(%)	area(km^2)	percentage(%)

cultivated land	3282.49	34.17	3289.65	34.23	3212.57	33.43
woodland	6002.58	62.49	5953.87	61.95	5890.10	61.29
meadow	24.29	0.25	25.53	0.27	24.79	0.26
waters	237.98	2.48	271.61	2.83	270.65	2.82
construction land	57.75	0.60	68.87	0.72	211.18	2.20
unused land	0.75	0.01	0.77	0.01	0.81	0.01

5.2 Analysis of Land Use Dynamics

The six types of land use changes in Suizhou City from 1995 to 2015 are shown in Table 2. From 1995 to 2005, the dynamic degree of land use in forest land was less than 0, but the absolute value was low and the area reduction was not significant. Among the six types of land, the land use dynamic degree of construction land was the highest, reaching 1.93%, with relatively obvious expansion. The change in water area was also relatively obvious, and the dynamic degree of land use reached 1.41%. Grassland and unused land both show an increasing trend, with land use dynamics of 0.51% and 0.33%, respectively. The change in cultivated land area was stable, and its land use dynamic degree was only 0.02%. From 2005 to 2015, the cultivated land area began to decrease, and the dynamic degree of land use was -0.23%. The water area was beginning to stabilize, with no distinct changes, and the dynamic degree of land use was -0.04%. Both forest land and grassland show a downward trend, with land use dynamics of -0.11% and -0.29%, respectively. Only the area of construction land and unused land increased and the construction land expanded the most significantly, with a land use dynamics of 20.66%. The growth rate of unused land area was relatively slight, with a land use dynamics of 0.03%. During 1995-2015, the cropland, forest land, grassland and water area decreased by 69.92 km^2, 112.48 km^2, 0.50 km^2 and 32.67 km^2 respectively, construction land increased by 153.43 km^2, and unutilized land increased by 0.06 km^2. It implies that among all land use types in Suizhou City, the expansion of construction land was the most obvious, with a land use dynamic degree of 13.28%. The area of water and unused land increased to a certain extent, with land use dynamics of 0.69% and 0.38%, respectively. The change in grassland area was not evident, and the dynamic degree of land use was 0.10%. Both cultivated land and forest land showed a downward trend, with land use dynamics of -0.11% and -0.09%, respectively.

Table 2 Changes in Land Use Area in Suizhou City

land type	1995-2005		2005-2015		1995-2015	
	lose one's temper(%)	area change(km 2)	lose one's temper(%)	area change(km 2)	lose one's temper(%)	area change(km 2)
cultivated land	0.02	7.15	-0.23	-77.08	-0.11	-69.92
woodland	-0.08	-48.71	-0.11	-63.77	-0.09	-112.48
meadow	0.51	1.24	-0.29	-0.74	0.10	0.50
waters	1.41	33.63	-0.04	-0.96	0.69	32.67
constructi on land	1.93	11.12	20.66	142.31	13.28	153.43
unused land	0.33	0.02	0.42	0.03	0.38	0.06

5.3 Analysis of Land Use Transfer Matrix

The transfer matrix of land use area in Suizhou City from 1995 to 2015 is shown in Table 3. The transfer-in and transfer-out situations of various categories can be obtained from the land use transfer matrix [17]. According to Table 3, in the land use area transfer matrix of Suizhou City from 1995 to 2015, the transfer-out area of cultivated land was 250.63 km^2, and the transfer-in area was 178.09 km^2. The transfer-out area was dominated by construction land and forest land, accounting for 42.28% and 44.28% of the outflow area, respectively. The transfer-in area was mainly composed of forest land, accounting for 89.58% of the transfer-in area. The outflow area of forest land was 239.89 km^2, and the inflow area was 126.14 km^2. The outflow area was mainly farmland, accounting for 66.50% of the outflow area, and the inflow area was mainly farmland, accounting for 87.98% of the inflow area. The outflow area of grassland was 2.04 km^2, and the inflow area was 2.54 km^2. The outflow area was mainly forest land, accounting for 79.03% of the outflow area, and the inflow area was mainly forest land, accounting for 90.83% of the inflow area. The outflow area of the water area was 27.60 km^2, and the inflow area was 60.08 km^2. The outflow area was dominated by cultivated land and forest land, accounting for 48.47% and 46.65% of the outflow area, respectively. The inflow area was mainly cultivated land and forest land, accounting for 55.57% and 44.01% of the inflow area, respectively. The transfer-out area of construction land was 5.87 km^2, with a transfer-in area of 159.12 km^2. The transfer-out area was mainly farmland, accounting for 85.55% of the transfer-out area. The transfer-in area was mainly farmland, with a small portion being forest land, accounting for 66.60% and 32.21% of the transfer-in area, respectively. It can be concluded that the transfer-in area of construction land was much larger than the transfer-out area. The transfer-out area of unused land was 0.39 km^2, with a transfer-in area of 0.44 km^2. The outflow area was mainly construction land, accounting for 87.18% of the transferred-out area, and the transfer-in area was mainly forest land, accounting for 81.82% of the transfer-in area.

Table 3 Land Use Transfer Matrix in Suizhou City from 1995 to 2015 (Unit: km^2)

1995	2015						
	cultivated land	woodland	grass	waters	construction land	unused land	total
cultivated land	3031.74	110.98	0.20	33.39	105.98	0.08	3282.37
woodland	159.52	5762.35	2.31	26.44	51.25	0.36	6002.23
grass	0.14	1.61	22.24	0.05	0.23	/	24.28
waters	13.38	12.88	0.03	210.35	1.32	/	237.95
construction land	5.02	0.64	0.00	0.20	51.88	/	57.75
unused land	0.02	0.03	/	0.00	0.34	0.36	0.75
total	3209.82	5888.49	24.78	270.42	211.00	0.80	9605.32

5.4 Prediction results and analysis of land use scenarios

5.4.1 Analysis of driving factor selection

The transformation of land use types during different time periods is influenced by the interaction between natural environment, social structure, and economic activities [18]. Due to the spatial differences, accessibility, quantifiability, and consistency principles of each driving factor, this work combines the reality of Suizhou City with previous research (Wu 2019) to set up a development scenario based on the triple drive of natural, social, and limiting factors. Among them, natural factors such as DEM, slope, aspect, precipitation, temperature, and soil were selected as driving factors. GDP and population were selected as social factors. The limiting factor is water. The three kinds of factors are shown in Table 4.

Table 4 Driving factors of land use change in Suizhou City

Factor type	Driving factors	meaning
Natural factors	elevation	The elevation value of the center point of each grid unit
	slope	The slope value of the center point of each grid unit
	slope orientation	The slope direction value of the center point of each grid unit
	precipitation	Precipitation at the center points of each grid unit
	air temperature	The temperature at the center point of each grid unit
	soil	Soil types of each grid unit
social factors	GDP	GDP of each grid unit center point
	population	Population density at the center point of each grid unit
limiting factor	waters	Grid units with a land use type of water body

5.4.2 Accuracy verification

This article uses the CA cellular automaton module in the PLUS model, based on the land use data of Suizhou City in 2005 (Figure 2), to simulate the land use of Suizhou City in 2015, and obtain the 2015 land use simulation map (Figure 3). To verify the accuracy of the model, formula (5) was used to calculate the Kappa coefficient of the model, resulting in a Kappa coefficient of 0.81. In Figure 2 and Figure 3, it can be observed that the distribution of various types of land in the simulation map is basically consistent with the current map, with certain deviations in part of cultivated land in the southeast andpart of construction land in the central and northwest. The Kappa coefficient obtained in this paper is greater than 0.75, indicating that the model has relative high accuracy and can be used to predict the land use pattern of Suizhou City in 2035.

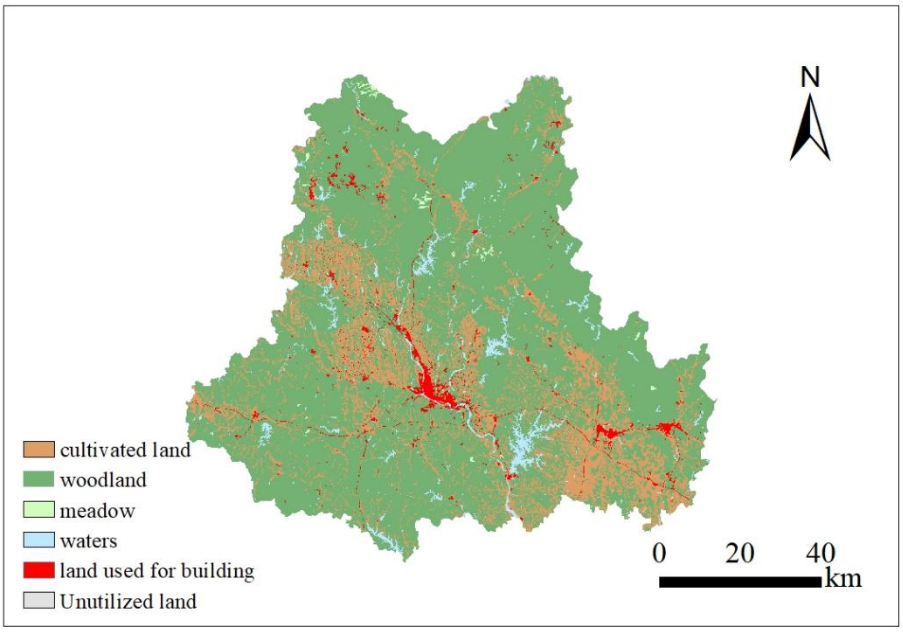

Figure 2 Land Use Status in Suizhou City in 2015

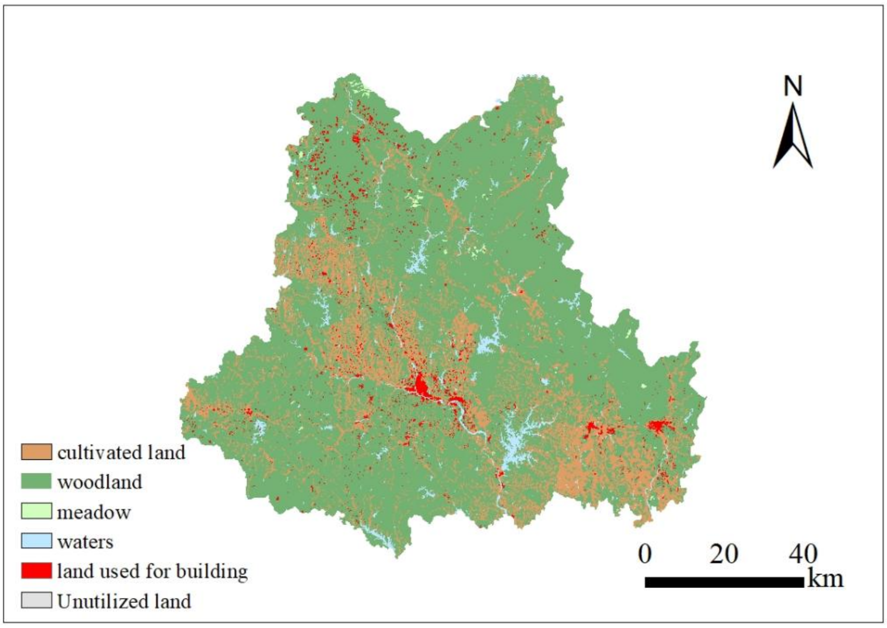

Figure 3 Land use simulation in 2015

5.4.3 Simulation and prediction

The predicted results of land use scenarios in Suizhou City in 2035 (Figure 4) and the current land use situation in Suizhou City in 2015 (Figure 2) show that compared to 2015, the cultivated land in the southeast of Suizhou City has decreased in 2035, with most of the reduced cultivated land transformed into forest land and construction land, belonging to the main type of land that has been transferred out. A part of the forest land is converted into construction land, but the overall trend is still expanding due to the conversion of some cultivated land into forest land. The overall pattern of grassland, water area, and unused land in the Figures 2 and Figure 4 is consistent. The construction land has expanded obviously, mainly concentrated in the southwest, northwest, northeast, and central regions of Suizhou City, with obvious clustering characteristics. It is expected that the land category will continue to grow in the future.

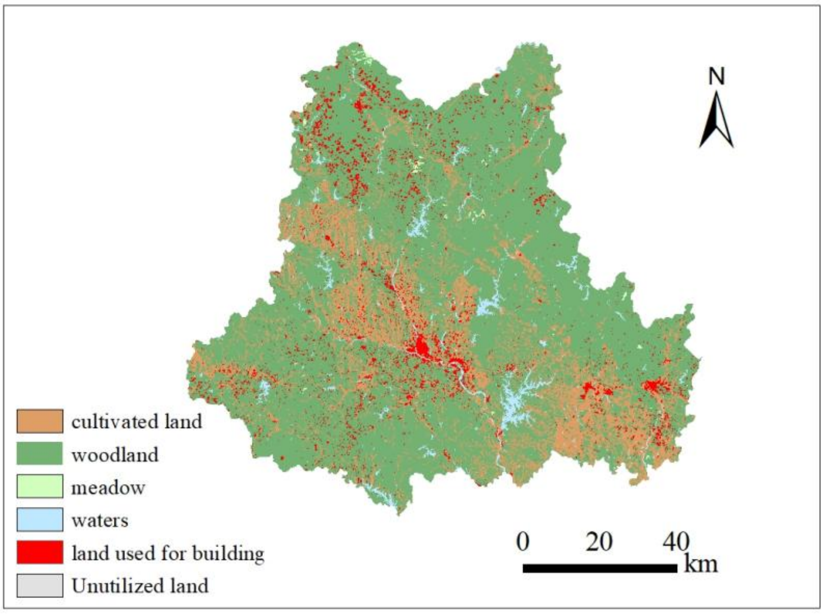

Figure 4 Land Use Scenario Prediction Results for Suizhou City in 2035

The predicted results of land use pattern in Suizhou City in 2035 (Table 5) show that the primary types of land use in Suizhou City will still be farmland and forest land, accounting for 18.13% and 74.16% respectively. However, compared to 2015, the proportion of farmland will decreased by 15.3% and the proportion of forest land will increased by 12.87%. Grassland, water area, and unused land will have a relatively small proportion and stable area changes, with area proportions of 0.24%, 2.80%, and 0.01% respectively, reducing by 1.29 km^2, 1.86 km^2, and 0.30 km^2. With the development of the economy and the advancement of modernization, other land will be occupied by construction land to varying degrees. It can be seen that the area of construction land is going to change mostly in 2035, expanding by 236.72 km^2. In 2035, its proportion of area will increase from 2.20% to 4.66%.

Table 5 Land Use Structure Prediction Results for Suizhou City in 2035

land-use type	2015		2035		Area change from 2015 to 2035 (km^2)
	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	
cultivated land	3212.57	33.43	1743.68	18.13	-1468.89
woodland	5890.10	61.29	7130.81	74.16	1240.71
meadow	24.79	0.26	23.51	0.24	-1.29
waters	270.65	2.82	268.79	2.80	-1.86
construction land	211.18	2.20	447.90	4.66	236.72
unused land	0.81	0.01	0.52	0.01	-0.30

6. Conclusion and discussion

6.1 Conclusion

(1) From 1995 to 2015, cultivated land and forest land were always the main land types in Suizhou City, accounting for 33.43% to 34.23%, 61.29% to 62.49%, respectively. The proportion of unused land area was always the lowest, accounting for 0.01%. The proportion of grassland, water area, and construction land was higher than that of unused land, accounting for 0.25% to 0.27%, 2.48% to 2.83%, and 0.60% to 2.20%, respectively.

(2) Between 1995 and 2015, the land use dynamics of construction land in Suizhou City reached 13.28%, with the most drastic change in land area among all land use types. The land use dynamics of water area and unused land were 0.69% and 0.38%, respectively, indicating a certain degree of increase in land area. The dynamic degree of grassland land use was 0.10%, and the change in land area was not evident. The dynamic degree of land use in cultivated land and forest land was -0.11% and -0.09%, respectively, with a slight decrease in land area.

(3) From 1995 to 2015, the cultivated land in Suizhou City was mainly transformed into construction land and forest land, accounting for 42.28% and 44.28% of the transfer-out area, respectively. Forest land was mainly converted into arable land, accounting for 66.50% of the transfer-out area. The increase in construction land mainly derived from cultivated land and forest land, accounting for 66.60% and 32.21% of their transfer-in area, respectively. Among them, the area of cultivated land converted into construction land is relatively large. The area of grassland transfer out and in is mainly forest land, accounting for 79.03% and 90.83% respectively. The increase in water area mainly comes from cultivated land and forest land, accounting for 55.57% and 44.01% of the transfer-in area, respectively. The area of unused land transferred out is 0.39 km^2, and the area transferred in is 0.44 km^2, with relatively small changes in transfer.

(4) The Kappa coefficient calculated by comparing the actual and current maps of Suizhou City in 2015 is 0.81, indicating that the model can effectively simulate land use changes in the study area. By simulating the land use pattern of Suizhou City in 2035 using the PLUS model, it is found that the proportion of forest land is expected to increase by 12.87%, while the proportion of cultivated landwill decrease by 15.3%. The proportion of construction land is going to increase from 2.20% to

4.66%, with a obvious increase and expansion towards the southwest, northeast, northwest, and central regions. The area of grassland, water, and unused land will be slightly reduced by 1.29 km^2, 1.86 km^2, and 0.30 km^2 respectively.

6.2 Discussion

Land use dynamics and the land use transfer matrix have been widely used to analyze the dynamic changes of land use. Zhu et al. [19] analyzed the land use change in the Songhua River Basin through the land use dynamics and the land use transfer matrix. Tong and Lang [20] analyzed the spatiotemporal pattern of land use change in Wuhan City through the dynamic degree of land use. Based on the previous research, this paper selects the dynamic degree of land use and the land use transfer matrix to analyze the changes in land use types in Suizhou City from 1995 to 2015, and explores the spatiotemporal change pattern of land use in Suizhou City in recent years, providing a reference for land development activities.

The PLUS model used in this work effectively elucidates the impact of various factors on land use expansion during a specific period. It has great applicability and robustness in large-scale and multi scenario scenarios, and is more accurate in simulating patch level changes in land use. Zhou et al. [21] used the PLUS model to study the spatial changes of "three life" in Urumqi City in four scenarios by 2030. Yang et al. [22] used the PLUS model to simulate the multi scenario changes in land use in Fuzhou City by 2030. The PLUS simulation results closely match the future regional development pattern under the current socio-economic development trend, and are applied in this study to provide effective suggestions for optimizing the allocation of land resources and national spatial planning in Suizhou City.

However, although this paper considered multiple factors, including natural, social, and limiting factors, the high-precision data acquisition needs to be improved, and the selection of driving factors can be further optimized. In the next study, other potential factors such as policies can be considered to improve the comprehensiveness and accuracy of the model, so as to further improve the accuracy of simulation results.

References

[1] .Chen B: Research on Simulation of Land Use Change and Optimization of Land Use Structure in Wanzhou District Based on FLUS Model (Master, Southwest University, China 2021). p.76.

[2] .Yang D: Analysis of spatiotemporal characteristics and driving forces of land use change (Master, Henan University, China 2020). p.80.

[3] .Li H, Li X, Jia M, et al. Research on Multi scenario Prediction of Land Use Pattern in Changji Demonstration Zone Based on CA Markov Model. Geographic Information World. Vol. 26 (2019) NO. 03, p. 18-24.

[4] .Gong W, Yuan L, and Fan W. Land use change and prediction in Harbin based on CA Markov. Journal of Agricultural Engineering. Vol. 28 (2012) NO. 14, p. 216-222.

[5] .Li R, Guan Q, and Merchant J W. A geospatial modeling framework for assessing biofuels-related land-use and land-cover change. Agriculture, Ecosystems & Environment. Vol. 161 (2012), p. 17-26.

[6] .Niu T, Xiong L, Chen J, et al. Simulation and multi scenario prediction of land use change in the Yangtze River Basin based on PLUS model. Journal of Wuhan University (Engineering Edition). Vol. 57 (2023) NO. 02, p. 129-141+151.

[7] .Wang Y and Cheng W. Dynamic changes and trend prediction of land use in Jingtai County based on the FLUS model. Land and Natural Resources Research (2023) NO. 05, p. 11-15.

[8] .Guo B, Zhang L, Wen W, et al. Dynamic simulation of land use in the southern Loess Plateau based on the CA Markov model. Resources and Environment of Arid Regions. Vol. 28 (2014) NO. 12, p. 14-18.

[9] .Wang Y and Deng W. Research on Land Use Change and Simulation in Urumqi City Based on Markov PLUS Model. Henan Science and Technology. Vol. 42 (2023) NO. 18, p. 95-100.

[10] .Shi C, Zhou Y, Liu Y, et al. Research on Land Use Change and Prediction in Dehong Prefecture, Yunnan

Province Based on CA Markov Model. Western Forestry Science. Vol. 51 (2022) NO. 01, p. 102-109.

[11] .Ran Y. Simulation and prediction of land use change in Banan District based on the CA Markov model. Anhui Agricultural Bulletin. Vol. 27 (2021) NO. 11, p. 125-130.

[12] .Wu T: Simulation of Land Use Change in Nanjing City Based on CLUE-S Model (Master, Wuhan University, China 2019). p.67.

[13] .Liang X, Guan Q, Clarke K C, et al. Understanding the drivers of sustainable land expansion using a patch-generating land use simulation (PLUS) model: A case study in Wuhan, China. Computers, Environment and Urban Systems. Vol. 85 (2021), p. 101569.

[14] .He Q, Guo F, Fang H, et al. Identification of corn diseases based on improved LeNet-5 model. Jiangsu Agricultural Science. Vol. 50 (2022) NO. 20, p. 35-41.

[15] .Krizhevsky A, Sutskever I, and Hinton G. ImageNet Classification with Deep Convolutional Neural Networks. Advances in neural information processing systems. Vol. 25 (2012) NO. 2.

[16] .Chen L, Cai H, Zhang T, et al. Multi scenario simulation analysis of land use in the Raohe River Basin based on the Markov-FLUS model. Journal of Ecology. Vol. 42 (2022) NO. 10, p. 3947-3958.

[17] .Li J and Gao M. Land use change and ecological effects in seasonal arid areas of the Yellow River Delta. Jiangsu Agricultural Science. Vol. 46 (2018) NO. 19, p. 306-310+318.

[18] .Liu X and Sun Q. Simulation study of land use change in Zichang City based on the FLUS model. Henan Science and Technology. Vol. 40 (2021) NO. 27, p. 105-108.

[19] .Zhu Y, Liu J, Zhang B, et al. Dynamic changes in land use in the Songhua River Basin: A case study from 2005 to 2020. Agriculture and Technology. Vol. 44 (2024) NO. 01, p. 73-76.

[20] .Tong W and Lang F. Remote sensing monitoring and analysis of land use/cover change in Wuhan over the past 20 years. Surveying and Mapping Geographic Information. Vol. 46 (2021) NO. 05, p. 83-87.

[21] .Zhou M and Wang C. Multi scenario Simulation of "Three Lives" Space in Urumqi City Based on PLUS Model. Chinese Environmental Science (2024), p. 1-11.

[22] .Yang H, Jiang C, Zheng R, et al. Land use change and scenario simulation in Fuzhou City based on the Markov PLUS model. Anhui Agricultural Science. Vol. 52 (2024) NO. 02, p. 56-62+68.