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Original Research

Multi Scenario Simulation of Land Use in Chaohu Lake Basin Based on PLUS Model

Jiang Jia, WeiLing Guo*, Liuyang Xu, Chang Gao

School of Geomatics, Anhui University of Science & Technology, NO. 168 Taifeng Road, Huainan 232001, China

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Abstract

Land is the fundamental resource upon which human survival depends. Research on land use change coverage (LUCC) is crucial for predicting the future development of human society. This study focuses on the Chaohu Lake Basin as the research area and selects three-time nodes to analyze the spatiotemporal characteristics and driving forces of LUCC in the Chaohu Lake Basin from 2000 to 2020. Three scenarios were established: natural development (ND), ecological protection (EP), and cultivated land protection (CP). The LUCC of Chaohu Lake Basin in 2030 was simulated by the PLUS model CARS module. Conclusion: (1) More than 95% of the land types are woodland, urban land, cultivated land, and water bodies. From 2000 to 2020, 562.1634 km² of cultivated land decayed and 544.9752 km² of urban land expanded, with land transfers primarily occurring between farmland and urban land. (2) The accuracy validation results of the PLUS model show an overall accuracy as high as 95.27% and a kappa coefficient of 0.9182, meeting the requirements for land use simulation and prediction. (3) Annual precipitation and population are the main drivers of changes in urban land and arable land. (4) A comprehensive comparison of LUCC simulation results under three scenarios shows that the expansion of urban land is restricted under the CP scenario while also ensuring the total amount of farmland. This research provides a scientific basis and a decision-making reference for local government land resource development and optimization.

Keywords: land use, PLUS model, driving force, multi scenario prediction, Chaohu Lake Basin

Introduction

Human life depends on land, and research on LUCC has always been a hot topic [1-4]. The Land Use Change Scientific Research Programme, which was developed in 1993 by the International Geosphere and the Biosphere and the Global Change Human Factors Programme, establishes a relationship between LUCC and global environmental shifts [5, 6]. LUCC has emerged as a focal point for scholars. After more than 30 years of development, scientific theories and methods for researching land use change have found widespread applications in the fields of resource management, regional development, and ecological assessment [7-10]. Moreover, they integrate various models to provide scientific and theoretical support for global development.

At present, scholars' research on land use change includes national, provincial, municipal, and other administrative regions and watersheds [11-13].

*e-mail: wlguo28@aust.edu.cn
Tel: +86-18555685008

The research contents mainly include the spatiotemporal characteristics of LUCC [14], driving factors [15, 16], ecosystem services assessment [17, 18], landscape pattern change [19], and simulation prediction [20-22]. The commonly used models are CA, CLUS, FLUS, and Markov [23-27]. Asif et al. used CA-Markov to study LUCC in the Cholistan and Thal deserts in Punjab, Pakistan, and predicted land use patterns in 2038, concluding that topography will accelerate urbanization [28]. Sun et al. used CLUE-S and CA-Markov models to predict LUCC in the Gurvanbulag area of Bulgan Province, Mongolia, and concluded that the study area showed a trend of water body decrease and grassland growth. and verified that the CLUE-S model is more accurate than the CA-Markov model [29]. Nouri et al. explored the spatiotemporal changes in Anzali in Gilan Province in northwestern Iran using Markov and concluded that the forest and wetland area decreased and the urban area expanded significantly [30]. Liu et al. applied the FLUS model and ecological service system to improve LUCC in Jinan, and the data showed that the urban ecological security pattern and landscape index were optimized [31]. The above model is inadequately deficient in simulating land use change at the patch scale. Liang X [32, 33] and others developed the PLUS model for land use simulation, which solved the above problems, and scholars also applied the PLUS model to conduct related research [34-37]. Lin et al. applied the PLUS model for simulation analysis of cultivated land in Haikou City, and the results showed that economic development led to urban expansion and reduced farmland area in Haikou, and the urban expansion rate could be constrained under the CP scenario [38]; Zhang et al. used the PLUS model for research for the prediction of landscape ecological risk in the Fujian Delta region and predicted the landscape pattern in 2050. The simulation data showed that most of the changed arable land is transferred to urban land [39]; Lin et al. took the Fuxian Lake basin as a case, applied different models to simulate LUCC, compared the simulation data of the three models, and found that the PLUS model is most suitable for application at the watershed scale [40]; Wang et al. used the PLUS model to study the simulation of future land use change in typical watersheds in arid areas under multiple scenarios and verified the practicability of the PLUS model in arid areas. The PLUS model can make great predictions [41]; According to the PLUS and INVEST models, Li Xiang et al. studied the multi-scenario simulation of the impact of LUCC on habitat quality in Tianjin, and the analysis showed that habitat quality is closely related to LUCC., and the acceleration of urbanization will become the resistance to sustainable development [42]. Therefore, in this paper, the PLUS model with better applicability and higher accuracy at the watershed scale is selected for research.

In recent years, with the rise of the central region, the urbanization expansion of the Wanjiang urban belt, and the rapid development of the regional social economy, the Chaohu Lake Basin, as the core area of Anhui Province, has also caused corresponding changes in its land use structure and ecological environment. Chaohu Lake is one of the "three rivers and three lakes" of national key pollution control, and in recent years, the eutrophication of Chaohu Lake has gradually intensified and has become an important constraint on the economic and social development of the Chaohu Lake Basin and even the whole province. This article takes the Chaohu Lake Basin as an example and analyzes the spatiotemporal characteristics of LUCC from 2000 to 2020 using a transfer matrix and dynamic degree analysis. Based on the experience of existing research, 14 driving factors were selected to analyze the main influencing factors of LUCC. Three scenarios of ND, EP, and CP are set up, predicting LUCC in the Chaohu Lake Basin by 2030 through the PLUS Model. They will then compare and analyze the prediction results under the three scenarios to provide a reference for future land resource allocation in the Chaohu Lake Basin.

Research Area and Data Sources

Overview of the Research Area

The geographical location of the Chaohu Lake Basin is between 116°25′21″E and 118°21′01″E, 30°56′57″N and 32°16′17″N (Fig. 1), situated between the Yangtze River and the Huaihe River, encompassing 11 counties and districts. The basin area is 14882.28 km². The climate is characterized by a subtropical monsoon with substantial annual precipitation. Chaohu Lake is the fifth-largest freshwater lake in China and is located in a region with relatively abundant water resources. The Chaohu Lake Basin plays an important role in Chinese economic development. On the other hand, it is also a developed economic region in Anhui Province, a key development area in the central rise strategy, and the core area of the Wanjiang urban belt [43].

Data Sources

The research data for this study encompasses three main types: land use data, socioeconomic data, and natural data. Detailed information about these data sources is presented in Table 1. In this study, the resolution was resampled to 30 m, and the projection method was WGS-1984-UTM-zone-50N.

Research Methods

This research is primarily divided into four parts. In the first step, land use data from the Chaohu Lack Basin for the years 2000, 2010, and 2020 are reclassified, with natural geography and socioeconomic data resampled to a 30 m resolution. In the second step, the dynamism

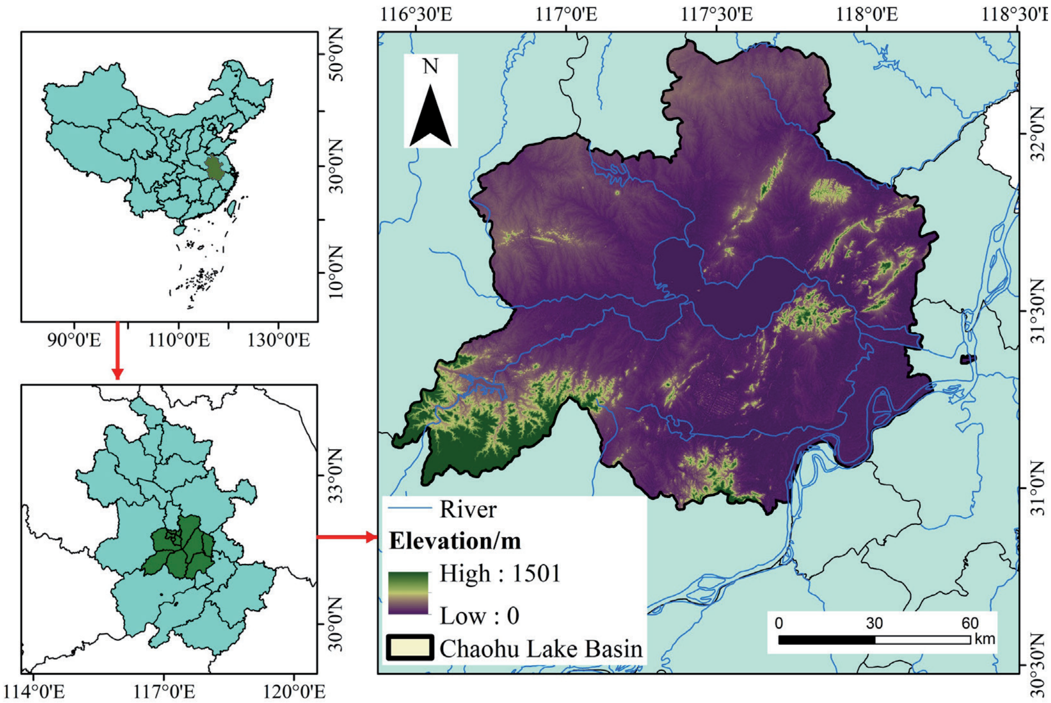

Fig. 1. Schematic diagram of the study area.

Table 1. Data information.

Data type	Data name	Unit	Time	Data sources
Land use data	Land use data	/	2000,2010,2020	Resource Environment Science and Data Center of the Chinese Academy of Sciences (https://www.resdc.cn/)
Socioeconomic data	population	Person/km²	2019	
	GDP	Ten thousand yuan/km²	2019	
	Distance from primary road	m	2020	OpenStreetMap (https://www.openstreetmap.org/)
	Distance from secondary road			
	Distance to tertiary road			
	Distance from highway			
	Distance from railway			
	Distance from government			
	Distance from water body			
Natural data	DEM	m	/	Geospatial Data Cloud (http://www.gscloud.cn)
	Slope	/	/	
	Soil types	/	1995	(https://www.resdc.cn/)
	Annual average temperature	mm	2020	
	Annual precipitation	°C	2020	

of land use and the transition matrix are utilized to analyze the spatiotemporal pattern changes and land use transition trends in the Chaohu Lack Basin. In the third step, a PLUS model is constructed, and its simulation accuracy is verified. Finally, the LEAS module is used to conduct expansion analysis and driver factor contribution analysis, followed by a driving force analysis. The CARS module is then applied to predict multiple scenarios of land use patterns in the Chaohu Lack Basin for the year 2030. The research flow chart is shown in Fig. 2.

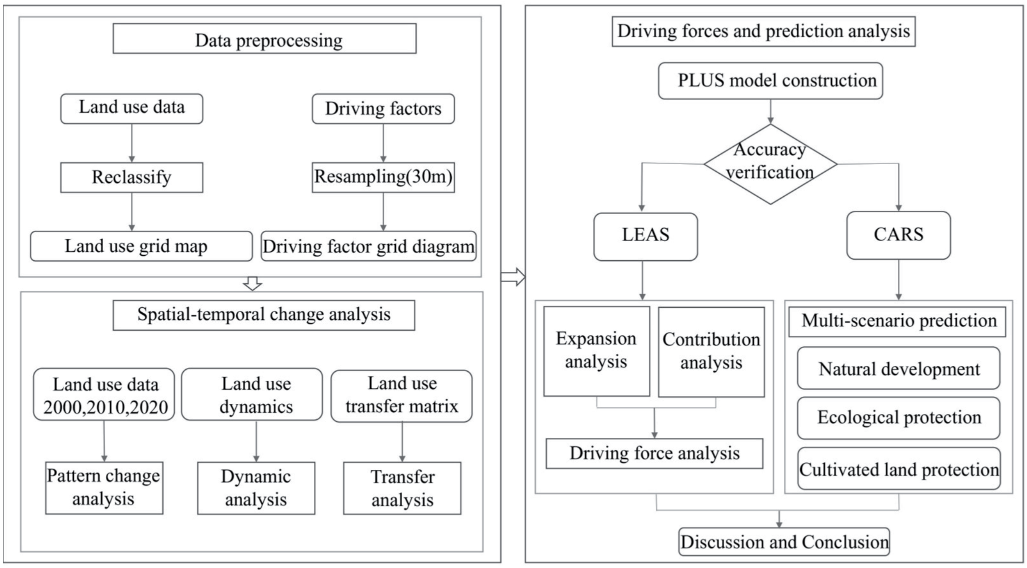

Fig. 2. Technical flow chart.

Land use Transfer Matrix

The land use transfer matrix is usually used to study the transformation relationship between various land types within a time period.

$$P_{ij} = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1N} \\ P_{21} & P_{22} & \cdots & P_{2N} \\ \cdots & \cdots & \cdots & \cdots \\ P_{N1} & P_{N2} & \cdots & P_{NN} \end{bmatrix} \quad (1)$$

In the formula, i and j represent the type of land before and after transfer; N is the number of land types; and P_{ij} represents the transfer area between land types.

Land use Dynamics

The dynamics of land use quantitatively reflect the range and speed of changes in various regions. Depending on the object of study, it can be divided into single land use dynamics (SLUD) and comprehensive land use dynamics (CLUD).

SLUD

This indicator is used to measure the speed and magnitude of changes in various land use types in the research area.

$$\mathrm{H} = \frac{\mathrm{M_b} - \mathrm{M_a}}{\mathrm{M_a}} \times \frac{1}{\mathrm{T}} \times 100\% \quad (2)$$

In the formula, M_b and M_a are the areas of land types at the end and beginning, respectively, and T is the time interval.

CLUD

This indicator measures the rate of change in the overall land type in the study area. The calculation formula is:

$$\mathrm{L} = \frac{\sum_{i=1}^{n} |\mathrm{S_{bi}} - \mathrm{S_{ai}}|}{2\sum_{i=1}^{n} \mathrm{S_{ai}}} \times \frac{1}{\mathrm{T}} \times 100\% \quad (3)$$

In the formula, L represents the CLUD; S_{bi} and S_{ai} are the areas at the end and beginning of the study period, respectively, and T represents the duration of the study. The larger the L value is, the faster the land changes in the area.

PLUS Model

The PLUS model integrates the land expansion analysis strategy (LEAS) and the CA model based on multitype random patch seeds (CARS), compensating for the deficiencies of the CA model based on PAS in terms of the conversion rule mining strategy and land use dynamic change simulation strategy. At the same time, it incorporates the impact and driving role of future planning policies on land use changes [44].

LEAS

In the LEAS module, the expansion intensity of land types at any time interval can be studied. We need to provide initial and final land use data as well as driving factor data, which can be run after setting random forest parameters to obtain the development probability of various types of land and the role of driving factors in the expansion process of each land type. LEAS reduces the process of data operation, avoids additional data output, and more efficiently analyzes the change process.

CARS

The CARS module is a CA model that includes a patch generation mechanism based on multitype random land use seeds [25]. Through this module, the current situation can be simulated to verify its accuracy, and future land development scenario predictions can also be realized. Different parameters can be set to achieve the land use demand of different scenarios, and the optimal allocation of land resources can be obtained through policy intervention. The neighborhood weight is the magnitude of the expansion capacity, and the calculation formula is:

$$C_i = \frac{\Delta TA_i - \Delta TA_{min}}{\Delta TA_{max} - \Delta TA_{min}} \quad (4)$$

In the formula, C_i represents the neighborhood weight parameter of a certain land type i, ΔTA_i is the change area of land type i, and ΔTA_{max} and ΔTA_{min} are the land types with the largest and smallest changes in area.

The overall probability of each type of land use was calculated using a stochastic patch generation mechanism to simulate the change of each land use under the setting of each land use growth probability constraint with the following equation:

$$NP_{i,k}^{d=1,t} = P_{i,k}^{d=1} \times \Omega_{i,k}^{t} \times D_k^t \quad (5)$$

where: $NP_{i,k}^{d=1,t}$ denotes the integrated probability; $P_{i,k}^{d=1}$ is the probability of suitability of land class k for spatial unit i; D_k^t. This is an adaptive driving coefficient that reflects the degree of future land use demand for land use type k. This coefficient depends on the difference between the amount of land use at the current iteration t and the target demand for land use type k; $\Omega^t_{i,k}$; is the domain effect of spatial cell i, i.e., the proportion of land use components covered by k in the next neighborhood.

Scenario Settings

According to the research standards that are widely accepted by scholars [38, 39, 41], this study sets up three scenarios, ND, CP, and EP, to predict the spatial pattern of LUCC in the Chaohu Lake Basin in 2030. Taking the water body as the restricted development area, ND indicates that the land types other than the water body can be transferred to each other, under the CP scenario, the transfer of cultivated land to other land is not allowed, and under the EP scenario, the transfer of woodland and grassland to other land is restricted. Before simulating the three scenarios, a land use cost transition matrix needs to be set up. The matrix only includes 0 and 1, where 0 indicates that conversion is not possible and 1 indicates that conversion is possible. With reference to the existing research results [25, 40], the cost transition matrices for each scenario are set as shown in Table 2:

Results Analysis

Analysis of Spatiotemporal Patterns of Land Use from 2000 to 2020

Temporal and Spatial Distribution Characteristics

The spatiotemporal changes in land type area in the Chaohu Lake Basin are shown in Table 3 and Fig. 3. After reclassification, the area is divided into six primary land types in the table, and the cultivated land area accounts for more than 60% of the total area, occupying the main position in the Chaohu Lake Basin. From the data in the table, it can be concluded that the area of arable land and forestland continues to decrease, with only 6.4989 km² of forestland decreasing. However, the arable land area has sharply decreased at an astonishing speed, with 562.1634 km², a decrease of 3.78%; urban land has rapidly expanded by 544.9752 km² in 20 years, an increase of 3.66%, with water bodies, unused land,

Table 2. Conversion Cost Matrix for Various Scenarios.

	Natural development						Cultivated land protection						Ecological protection					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
a	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1
b	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0
c	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0
d	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0
e	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1
f	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

*Note: a, b, c, d, e, and f respectively refer to cultivated land, woodland, grassland, water body, urban land, and unused land.

Table 3. Land use area and proportion from 2000 to 2020 (km²).

	2000		2010		2020	
	Area	Proportion	Area	Proportion	Area	Proportion
Cultivated land	9744.9552	65.48%	9504.7038	63.87%	9182.7918	61.70%
Woodland	1823.4558	12.25%	1821.9384	12.24%	1816.9659	12.21%
Grassland	665.3178	4.47%	665.5401	4.47%	667.8999	4.49%
Water body	1258.8345	8.46%	1275.6969	8.57%	1276.5735	8.58%
Urban land	1388.8197	9.33%	1613.1249	10.84%	1933.7949	12.99%
Unused land	0.8991	0.01%	1.278	0.01%	4.2561	0.03%

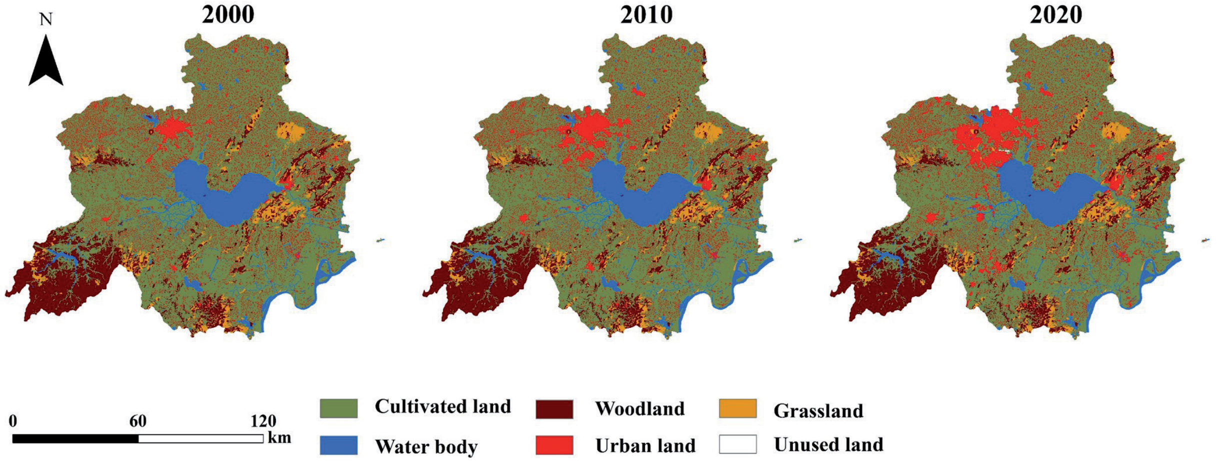

Fig. 3. Land use distribution from 2000 to 2020.

and grasslands increasing by 14.739 km², 3.357 km², and 2.5821 km², respectively, showing a continuous growth trend.

Dynamic Analysis of Land Use

As shown in Fig. 4, from 2000 to 2020, the CLUD of the Chaohu Lake Basin was 0.19%, which is relatively low overall, indicating a relatively stable situation. The land use dynamics were lower between 2000 and 2010, at only 0.16%; from 2010 to 2020, the dynamics increased to 0.22%.

From 2000 to 2020, the areas of farmland and woodland decreased, and the dynamics of single were -0.29% and -0.02%, respectively. The areas of grassland, water bodies, and urban land became larger, and the dynamics of singles were 0.02%, 0.07%, and 1.96%, respectively. Due to the small area occupied by unused land, it will not be discussed here, among which the SLUD of urban land is the largest, indicating that the change in urban land is more drastic.

Analysis of Land Use Transfer

The land type transition matrix and chord diagram of the Chaohu Lake Basin from 2000 to 2020 reveal the transfer situation of various land types (Table 4 and Fig. 5). In terms of the transfer-out area, farmland is the main part of the transferred-out land type, with an area of 577.7802 km², accounting for 94.39% of the total transfer-out area. The majority of this transfer is to urban land, with a transfer area of up to 543.5847 km², accounting for 94.25% of the transformed area. Woodland, grassland, water bodies, and urban land were transferred out by 6.9597 km², 7.5096 km², 6.1668 km², and 13.7079 km², respectively, accounting for 1.14%, 1.23%, 1.01%, and 2.24% of the total transfer-out area. Urban land is the main part of l transferred-in land type, with an area of 588.6831 km², accounting for 91.27% of the total transfer-in area. Cultivated land, forest, grassland, and water bodies were transferred-in by 15.6168 km², 0.4698 km², 10.0917 km², and 23.9058 km², respectively, with transfer-in area proportions of 2.55%, 0.08%, 1.65%, and 3.91%. Overall, the transfer is from cultivated land to urban land.

PLUS Model Accuracy Verification

To ensure the accuracy of the research, the CARS module was used to simulate the LUCC of the Chaohu Lake Basin in 2020 (Table 5 and Fig. 6). The simulated data were compared with the actual data downloaded

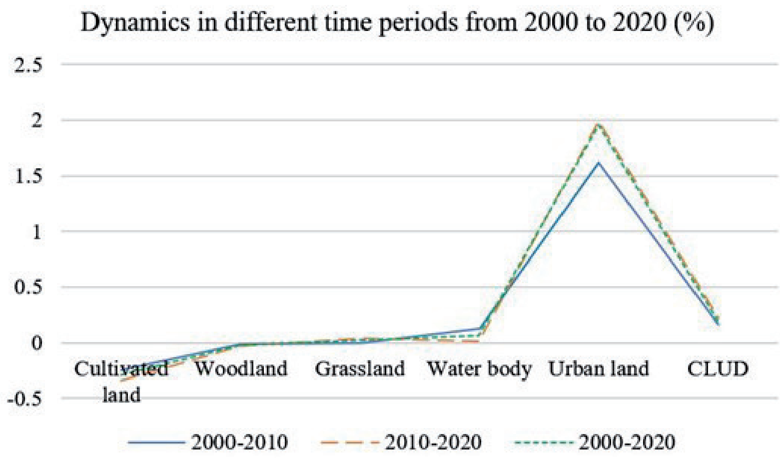

Fig. 4. Dynamics in different time periods from 2000 to 2020 (%).

in 2020, and the accuracy of the PLUS model was obtained (Fig. 7). The model's accuracy was presented through Kappa coefficients and overall accuracy. The verification results showed that the overall accuracy was as high as 95.27%, and the Kappa coefficient was 0.9182. The spatial distribution obtained from the PLUS model simulation has a high similarity with the actual distribution. The simulation accuracy of cultivated land, woodland, grassland, and water bodies is above 95%, and the areas with larger simulation errors are mainly urban land and unused land. Overall, the spatial simulation accuracy is relatively high, and the research accuracy meets the simulation requirements.

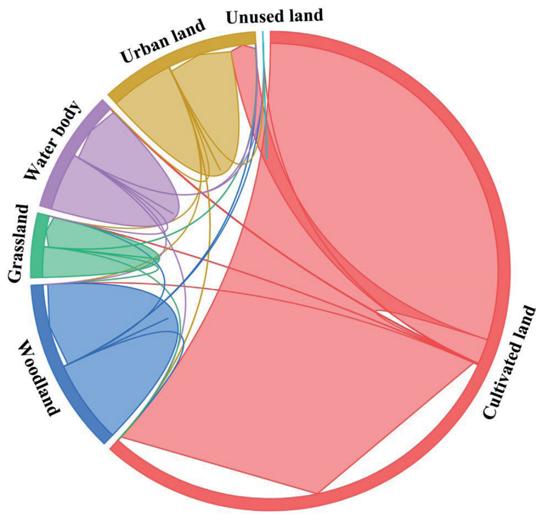

Fig. 5. Land use change trajectory from 2000 to 2020.

Analysis of the Driving Forces of LUCC

LUCC is caused by various factors. In this study, natural and economic factors were comprehensively considered to analyze the main driving forces of LUCC in the Chaohu Lake Basin (Fig. 8). The results show that the population factor has the greatest impact on the expansion of urban land area, followed by DEM and distance from secondary roads. Overlaying the urban land increase area and population grid data reveals that the increased construction area is mostly distributed around the government locations in the Chaohu Lake Basin, where the terrain is relatively flat, the population is dense, and socioeconomic activities are frequent.

Table 4. 2000-2020 land use type transfer matrix (km²).

	Cultivated land	Woodland	Grassland	Water body	Urban land	Unused land	Transfer out
Cultivated land	9167.175	0.2124	8.5617	23.0265	543.5847	2.3949	577.7802
Woodland	1.0737	1816.4961	0.0153	0	5.4936	0.3771	6.9597
Grassland	0.0198	0.1143	657.8082	0	7.3755	0	7.5096
Water body	3.4002	0.0018	0.5265	1252.6677	2.2293	0.009	6.1668
Urban land	11.1231	0.1413	0.9882	0.8793	1375.1118	0.576	13.7079
Unused land	0	0	0	0	0	0.8991	0
Transfer in	15.6168	0.4698	10.0917	23.9058	558.6831	3.357	/

Table 5. Comparison of simulated and actual land use grid in 2020.

	Cultivated land	Woodland	Grassland	Water body	Urban land	Unused land
Simulation	10211594	2028011	727397	1418415	2148661	1791
Actual	10203102	2018851	742111	1418415	2148661	4729
Accuracy	96.37%	98.01%	97.49%	99.57%	83.90%	66.48%

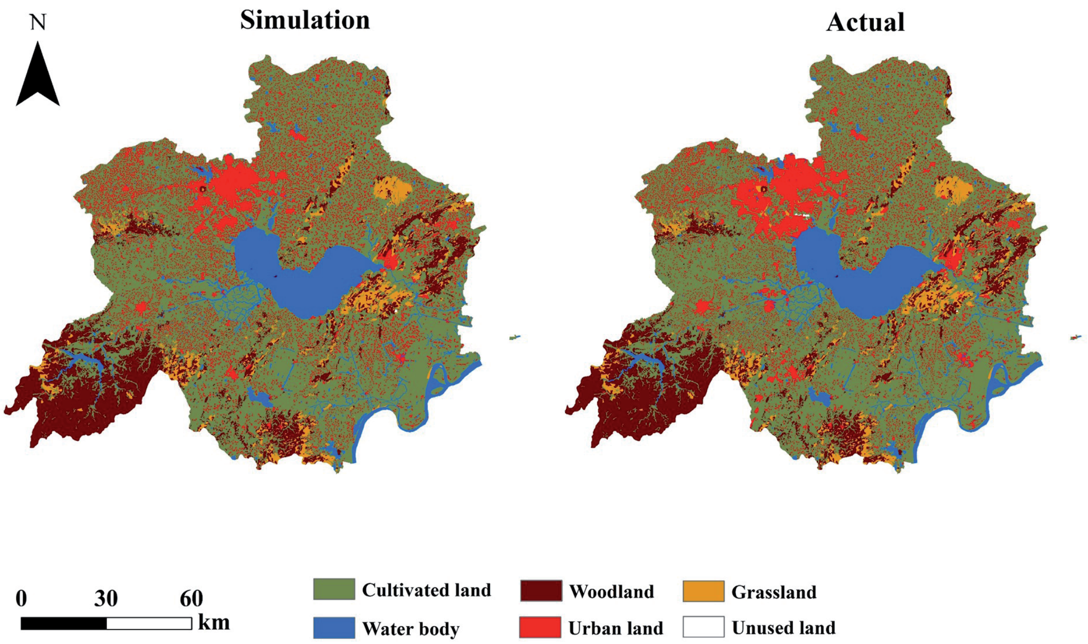

Fig. 6. Land use simulation and actual distribution in 2020.

In particular, the increase in construction land in Hefei city is the most significant, which is related to the rapid economic development and accelerated urbanization process in Hefei city in recent years. The main reason for the increase in arable land area is annual precipitation, followed by soil type, distance from secondary roads, and slope. The amount of water needed for crop growth and the type of soil determine the main factors in cultivated land expansion. Cultivated land expansion mainly occurs along more distinct rainfall boundaries (Fig. 9).

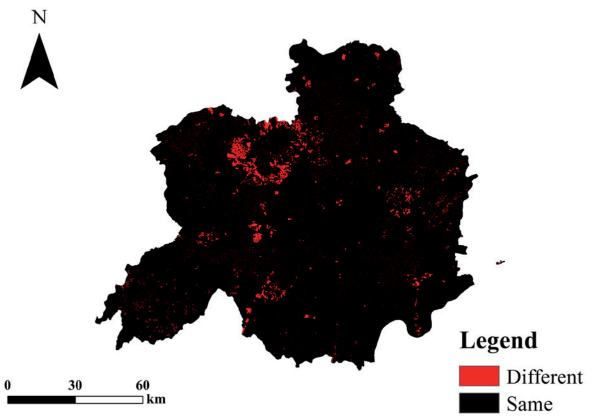

Fig. 7. Differences between simulation and actual land use in 2020.

Land Use Simulation Under Different Scenarios

The expansion intensity of various land types and 2020 LUCC data generated by the LEAS module were used to simulate the LUCC situation in the Chaohu Lake Basin under three scenarios of ND, EP, and CP in 2030 by setting scenario parameters in the CARS module. The simulated LUCC data are compared with the 2020 LUCC data in Table 6 and Fig. 10.

Under the ND scenario, cultivated land still occupies the main position, with an area of 8884.7505 km^2, accounting for 59.7% of the total area. The data show that in this scenario, the area of arable land, grassland, and forestland decreases, with no significant changes in the area of grassland and forestland. The area of arable land decreases by 298.0413 km^2, a decrease of two percentage points. The area of urban land, water bodies, and unused land gradually expanded, with less increase in water bodies and unused land. Urban land expanded

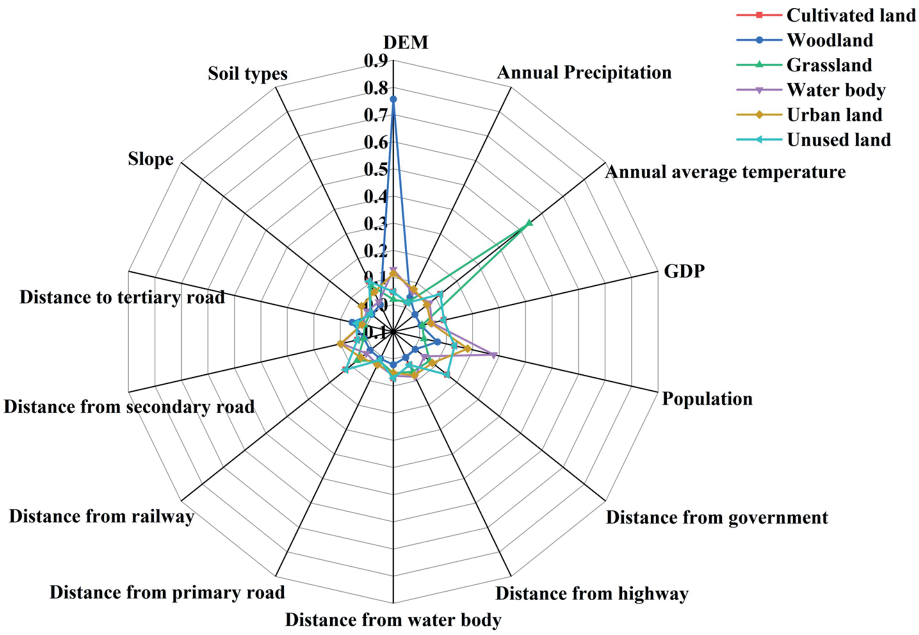

Fig. 8. Contribution of land use expansion drivers.

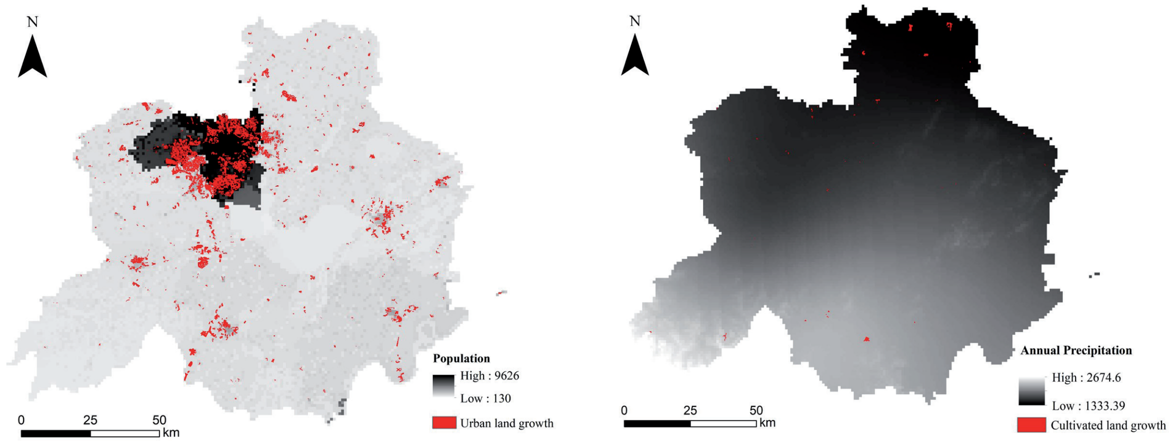

Fig. 9. Overlay of urban land and cultivated land change regions and highest contribution factors.

significantly, with an area of 2240.2881 km^2, an increase of 306.4932 km^2. The expansion area was mainly concentrated around the Hefei metropolitan area. This indicates that without policy intervention, urban land will continue to encroach on the cultivated land near the city, leading to a significant reduction in cultivated land area.

Under the EP scenario, the establishment of forestland and water bodies cannot be transferred out to protect ecological land. The data show that the area of cultivated land and grassland has decreased, with a farmland area of 8874.6156 km^2, a decrease of 308.1762 km^2, a grassland area of 654.093 km^2, and a decrease of 7.3422 km^2. The area of forestland and urban land has expanded, with an urban area of 2240.2881 km^2, an expansion of 306.4932 km^2, a forest area of 1831.3713 km^2, and an increase of 14.4054 km^2. The changes in unused land and water bodies are minimal. This scenario is similar to ND, except that the forest area has increased to protect ecological land from encroachment, but the expansion of urban areas has not improved.

Under the CP scenario, cultivated land and water bodies are designated as restricted areas, and transfer to other types of land is not allowed. The data showed that the area of farmland and building land increased, the area of cultivated land was 9209.3247 km^2, an increase of 26.5329 km^2, the area of urban land was 1937.8809 km^2, an increase of 4.086 km^2, the area of forestland and grassland decreased, the area of forestland was 1812.0321 km^2, a decrease of 4.9338 km^2, the area of grassland was 641.7261 km^2, a decrease of 26.1738 km^2, and the area of water and unused land changed very little. Compared with the ND and EP,

Table 6. Scenario comparison in 2030 (km²).

	2020 Actual	Natural development	Ecological protection	Cultivated land protection
Cultivated land	9182.7918	8884.7505	8874.6156	9209.3247
Woodland	1816.9659	1812.0321	1831.3713	1812.0321
Grassland	667.8999	661.4352	654.093	641.7261
Water body	1276.5735	1277.4618	1277.4618	1277.4618
Urban land	1933.7949	2240.2881	2240.2881	1937.8809
Unused land	4.2561	6.3144	4.4523	3.8565

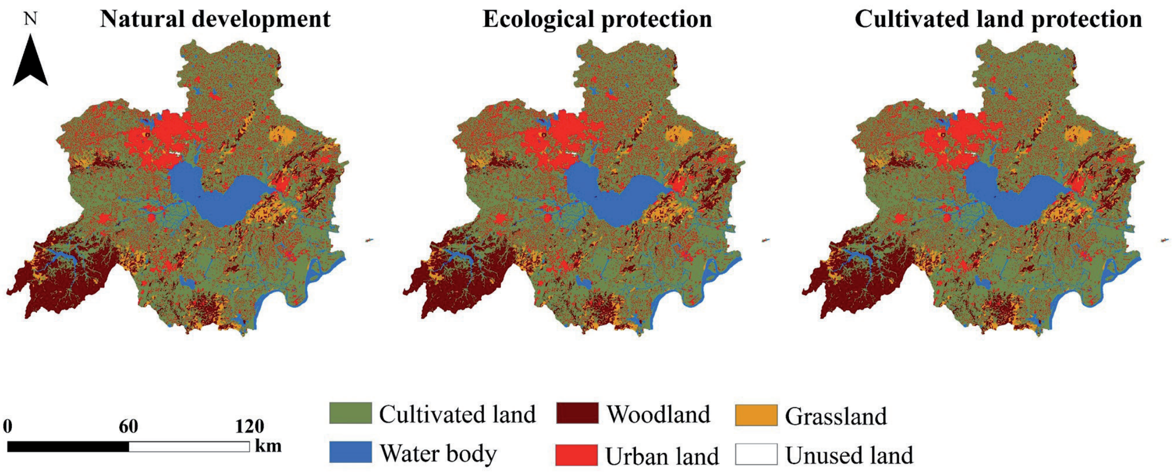

Fig. 10. Simulated distribution of LUCC in 2030 under ND, EP, and CP.

the area of cultivated land not only did not decrease, but also increased. Under this scenario, cultivated land was effectively protected, food security was ensured, and there was no significant loss of forest and grassland. Most importantly, the large-scale expansion of urban land was effectively controlled, which is beneficial for ecological construction and sustainable development.

Discussion

In this article, the model used to study the application of the Chaohu Lake Basin is the PLUS model. In previous studies by scholars, models used in the LUCC process included CA-Markov, FLUS, CLUS, and PLUS [24-27]. Based on previous experience, each of these models has its own unique advantages and highlights. After comparison, it was found that the PLUS model has the best applicability and accuracy, which is consistent with the results of many studies [41]. The research results of this article validate the accuracy of the model, with kappa coefficients and overall accuracies of 0.9182 and 95.27%, respectively. The reduction in arable land area and the expansion of urban areas are prominent characteristics of LUCC in the Chaohu Lake Basin and are also the results of many other regional studies [34, 35]. LUCC will inevitably lead to changes in the landscape pattern in the Chaohu Lake Basin, with a decrease in the degree of landscape fragmentation and an increasing concentration of urban land and residential life. The multiscenario prediction of LUCC in 2030 in this study shows that national policies have played a significant role. Under the implementation of CP, the expansion of urban land can be effectively controlled. while also ensuring the area of cultivated land.

The significant increase in urban land will lead to some negative impacts. Some scholars have found that the acceleration of urbanization leads to an increase in daytime temperatures in cities, which in turn affects climate changes such as rainfall. In addition, urbanization inevitably causes environmental pollution, damaging the water quality of the basin. More importantly, the expansion of urban areas threatens food security, thereby endangering human survival. According to the results of this study, following the current development trend, the development trend of building land encroaching on arable land will become a resistance to sustainable development, a situation that has also appeared in many scholars' research. Therefore, in response to this situation, this study proposes two suggestions for the land resource planning department:

1. Restrict the expansion of urban land. It will have a negative impact on the landscape pattern of the Chaohu

Lake Basin. In future planning, the utilization of existing land in cities should be improved, land resources should be conserved, and environmental pollution from new construction should be prevented.

2. Adhere to the red line of cultivated land to ensure food security. The expansion of urban land leads to a reduction in cultivated land area and a consequent decrease in grain output. The reduction of cultivated land will hinder social development, and the relevant departments responsible for land planning should strictly control the food security line and enhance awareness of farmland protection among land users.

In this article, relying only on historical data and previous experience, although the simulation accuracy meets the requirements for simulation and prediction, there is a certain degree of difference in the simulation results, which has some impact on the accuracy of the results. In subsequent research, additional parameters can be added to improve simulation accuracy. Moreover, there is some subjectivity in the parameterization process, which will have little impact on the results. In the future, better algorithms can be applied to calculate the parameters and improve the reliability of the results.

Conclusions

1. We analyzed the land use pattern in the Chaohu Lake Basin from 2000 to 2020, and it is evident that there have been significant changes in land use from 2000 to 2020, with the most drastic changes occurring from 2010 to 2020. From the perspective of land use dynamics, the dynamics of cultivated land and urban land are relatively high, indicating that these two types of land have undergone more changes, with cultivated land showing a stable decline trend while urban land continues to expand. According to the land use transfer matrix, it is found that the conversion of land is mainly manifested as the conversion of cultivated land to urban land.

2. The simulation accuracy of the model is checked by the CARS module, the overall accuracy of the PLUS model is 95.27%, and the kappa coefficient is 0.9182. It shows high accuracy and applicability, which meet the requirements of simulation experiments.

3. Through the LEAS module, the expansion of land in the Chaohu Lake Basin was analyzed, and the main driving factors behind the land use change were excavated. It was found that the expansion of urban land was mainly related to population, DEM, and distance from roads, and the expansion area was mainly around the Hefei metropolitan area, which indicated that the expansion of cities and towns had a great relationship with people's living needs and transportation infrastructure, while the changes of cultivated land were mainly related to natural factors (annual rainfall, soil type), which is due to the need for water and the fertility of the land for the growth of crops.

4. According to the results of the multi-scenario simulation, it is easy to find that there are certain differences in land use patterns under different scenarios in 2030, which forms a sharp contrast in the allocation of land resources. Under the scenario of natural development and ecological protection, the area of cultivated land is still greatly reduced, and the area of urban area is rapidly expanded, but the difference is that the area of woodland has increased under the ecological protection scenario, which indicates that the ecological protection policy has played a certain role; under the scenario of cultivated land protection, the cultivated land shows an increasing trend, although the urban land is still expanding, but the expansion range is greatly limited, it is worth noting that the ecological land has also been protected under this scenario.

Taking a comprehensive view and considering a range of factors, the cultivated land protection scenario emerges as the optimal model for future development in the research area. This scenario provides decision-makers with valuable insights when formulating strategies for efficient spatial arrangement.

Author Contributions

Conceptualization, Jiang Jia and Weiling Guo. methodology, Weiling Guo and Chang Gao. validation, Liuyang Xu and Chang Gao. date curation and visualization, Jiang Jia and Liuyang Xu. writing – original draft preparation, Jiang Jia. writing – review and editing, Jiang Jia and Weiling Guo. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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