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Land Use and Cover Change Simulation and Prediction in Hangzhou City Based on CA-Markov Model

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Abstract. With the rapid development of economy, land use and cover change (LUCC) of Hangzhou City in Zhejiang Province since 1990 changed dramatically, characterized with the shrink of farmland area, primarily due to the urbanization construction. In this article, LUCC data derived from China's current land use datasets in 1990 and 2000 were studied using ArcGIS and IDRISI to make clear land use structures; CA-Markov model was used to simulate and predict its temporal and spatial change rules and driving factors of DEM, slope, population, GDP, road and distance to each land use types were also considered. The results showed that construction land maintained the growth momentum while farmland area decreased. Other land use types kept a stable level. Spatial raster contrast and Kappa index proved that CA-Markov model was in high consistency for the LUCC prediction. From the future's prediction results, decreased farmland and forest area contributed to the urban expansion before 2060 and forest area became the only source after 2060.

Keywords: CA-Markov; land use and cover change; Hangzhou city

1. Introduction

Land use and cover change (LUCC) is one of the core themes of the global change research. As the global population, resources and environmental issues become increasingly prominent [1]-[3], contradiction between human and land has severely restricted the social and economic development and acceleration of urbanization process greatly changes original land features [4].

In the1970s, especially since the 1980s, with the rapid development of remote sensing, remote sensing image data are widely used in LUCC information acquisition, spatial and temporal process expression and model analysis and simulation [5], [6]. There are many models for land use dynamic change and simulation, such as cellular automata (CA) [7], Clue-s model [8], Markov model [9], CA-Markov model [10], [11], etc. CA-Markov model combines both the concept of a CA filter and Markov change procedure, perfecting the spatial configuration results of Markov analysis prediction, which can effectively simulate research area's land cover change.

In this paper, future LUCC in Hangzhou City was simulated and predicted using the CA-Markov model for the purpose to reveal the characteristics of land cover types in Hangzhou City and provide a reference for the further research. The analysis of land use structures and changes from 1990 to 2000 was carried out using LUCC data and GIS software.

2. Study Area

Hangzhou City, provincial capital of Zhejiang Province, locates in China's southeastern coastal areas, the lower reaches of Qiantang River and is an important center city of the Yangtze River Delta and southeast transportation hub. Counties include Yuhang, Xiaoshan, Linan, Chun'an, Jiande, etc. (Fig. 1). The terrain is

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complex and diverse, for the western part is a hilly region and the main mountains include Tianmu Mountain etc., and the eastern part is a plain dotted with lakes and dense river network. The city is in a subtropical monsoon climate region with a mild and humid weather and adequate rainfall. The annual average temperature is about 16.2℃ and average annual precipitation is 1100-1600 mm.

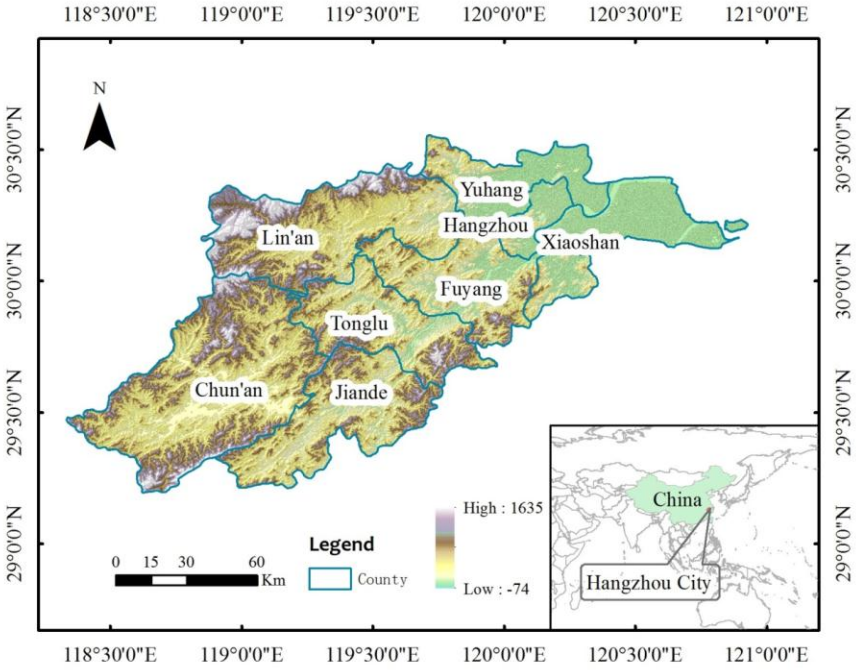

Fig. 1: Study area

3. Data and Method

3.1. LUCC data

Land use datasets of Hangzhou City were derived from China's current land use datasets using remote sensing monitoring data. They were provided by Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (http://www.resdc.cn). Landsat TM/ETM remote sensing images were selected as the main data source and artificial visual interpretation was applied to finish data production [12]. Farmland interpretation accuracy reached 99%, grass land, forest and construction land accuracy was 98%, and the comprehensive qualitative accuracy was 95%. Land use types were divided into six primary types including farmland, forest, grass land, water area and unused land and 25 secondary types. In this paper we mainly focus on the changing rules of the six primary land use types.

3.2. CA-Markov model

The two techniques used to model land use change are Markov Chain Analysis and CA Analysis. The Markov Chain Analysis is mainly in terms of quantity of prediction of land use change and unable to obtain the change degree of the land use types from a spatial view; while CA model has strong dynamic simulation ability to present spatial and temporal changes. CA-Markov model absorbs advantages of Markov and CA model about space and time series prediction and can be applied in land use change simulation.

Using known land use datasets for two different time periods for Hangzhou City, 1990 and 2000, CA-Markov model was used to simulate and predict land use types in 2010 using ArcGIS 10.2 and IDRISI 17.0 and followings were two major aspects:

a) The Markov module was used to predict land use change based purely on the state of land use in 2000 and on land use change in the preceding 10 years between 1990 and 2000. It would then output a transition probability matrix, a transition areas matrix, and a set of conditional probability images.

b) CA-Markov module would use the transition areas table and the conditional probability images to predict land cover change over the period specified in Markov chain analysis. Then a 5 by 5 contiguity filter

would be used to develop a spatially explicit contiguity-weighting factor to change the state of cells based on its neighbors. The contiguity filter was applied to a series of suitability maps identified for each land cover class.

For enhancing accuracy of prediction result, driving factors of DEM, slope, population, GDP, road and distance to each land use types were considered to construct the suitability maps. Relevant data were also acquired from RESDC. Driving factors were transferred to the same projection in ArcGIS with 1 km×1km horizontal resolution. LOGISTICREG module in IDRISI was used to undertake binomial logistic regression and prediction from image or attribute values files and employs Maximum Likelihood Estimation (MLE) procedure to find the best fitting set of parameters (coefficients) [13].

3.3. Kappa index

Kappa index method can be applied in precision analysis of CA-Markov model. Kappa index is commonly used to evaluate the correct classification precision of remote sensing image [14]. Kappa index calculation formula is described as follows:

$$Kappa = \frac{(P_0 - P_C)}{P_P - P_C} \quad (1)$$

Where P_0 is the proportion of correct simulation, P_C is expected proportion of correct simulation in random circumstances, and P_P is the proportion of correct simulation in ideal circumstances.

The standards for Kappa index are that when two land use image exactly the same, the Kappa index equals 1; when index is greater than or equal to 0.75, it indicates high consistency; when index is less than or equal to 0.4, it indicates poor consistency.

4. Results and Analysis

4.1. Land use structure and changes

The prominent land use type in Hangzhou City was forest, accounting for about 67% of the total land area of the region and keeping a slight growth, which was related to the large-scale afforestation activities. Farmland area decreased by 139 km^2 from 1990 to 2000, on the contrary, construction land maintained the growth momentum with the social and economic development. Grassland, water area and unused land maintained a relatively stable level. Detailed statistical data were listed in Table 1.

Table 1: Area and proportion of Land use types in study area from 1990-2000

Land use types	Year 1990		Year 2000	
	Area/km^2	Ratios	Area/km^2	Ratios
Farmland	3690	21.64%	3551	20.82%
Forest	11474	67.28%	11540	67.66%
Grass land	380	2.23%	387	2.27%
Water area	1032	6.05%	1035	6.07%
Construction land	473	2.77%	539	3.16%
Unused land	6	0.04%	3	0.02%

Convertible probability matrix of land use types (Table 2) provided a perspective of quantitative analysis to understand evolution process and mechanism of land use types. It could be inferred from Table.2 that from 1990 to 2000, the probability of farmland and water area transferring to construction land was higher than other land use types; unused land, grass land and farmland contributed to growth of forest area. Dominated land use types had not changed.

4.2. Simulation analysis of land use in 2010 and accuracy test

Land use maps in 1990 and 2000 were defined as input data to simulate 2010 land-use scenario. Here we used two methods to verify forecast accuracy. One method was spatial raster contrast to verify whether land cover type in spatial location was the same as the actual map. Result was shown in Fig.2 that simulation error

of inconsistent area occupied 3.0% of total number of raster, mostly appeared in the northeast of the city. 97% of regions were consistent with the actual map in 2010.

Table 2: Convertible probability matrix of land use types in Hangzhou City from 1990-2000

Land use types	Farmland	Forest	Grass land	Water area	Construction land	Unused land
Farmland	0.5089	0.3346	0.014	0.0525	0.0897	0.0003
Forest	0.1238	0.8135	0.0299	0.0235	0.0092	0.0001
Grass land	0.1649	0.6435	0.165	0.0213	0.0053	0
Water area	0.1947	0.2249	0.0062	0.5522	0.0208	0.001
Construction land	0.4883	0.1915	0.0043	0.0688	0.247	0
Unused land	0.5	0.5	0	0	0	0

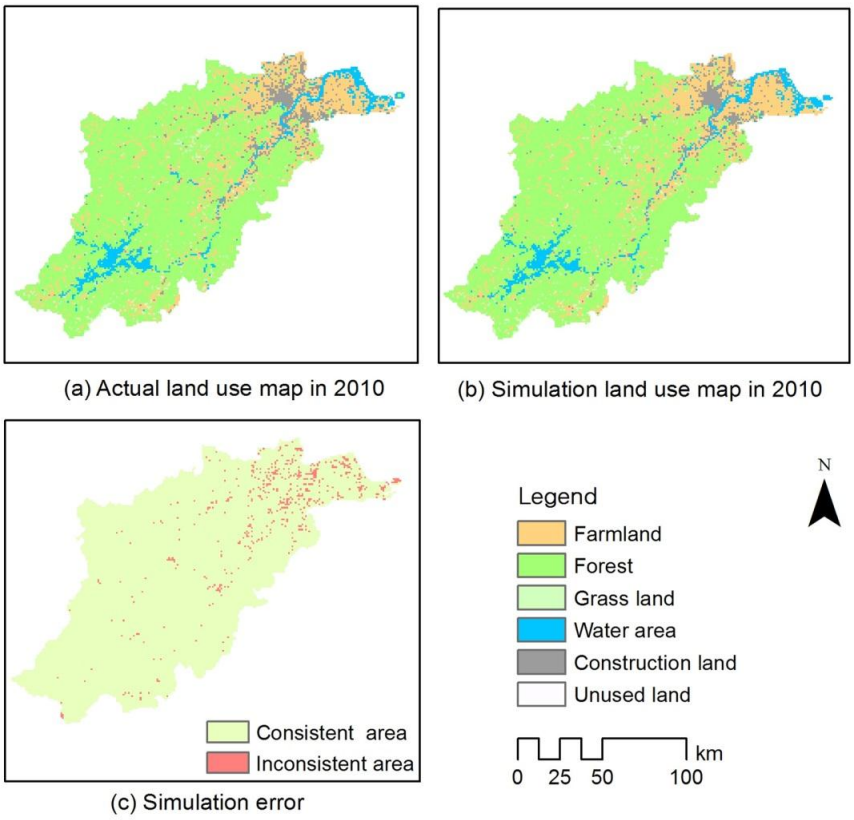

Fig. 2: Verification of forecast accuracy for land use types of Hangzhou City in 2010

Another method was Kappa index. Crosstab module in IDRISI software performed a cross-tabulation analysis that compared images containing categorical variables of actual land use map and simulation one. After comparison of interpretation results of 2010, Kappa index of the simulation result was 0.9718, showing high reliability and application of CA - Markov model in prediction of land use types has good reliability. As to the particular land use type, results in Tab.3were showing that Kappa indexes of farmland, forest, glass land and water area were higher than 0.75, proving they were in high consistency with actual land use map; Kappa indexes of construction land and unused land were around 0.75, predicting results were comparatively good.

Table 3: Comparison with actual and simulation areas of land use types of Hangzhou city in 2010

Land use types	Actual area/km^2	Simulation area/km^2	Kappa index
Farmland	3284	3460	0.9208
Forest	11486	11520	0.9929
Grass land	388	389	0.9154
Water area	1039	1030	0.9257
Construction land	853	651	0.7489
Unused land	5	5	0.7500

4.3. Forecast result and analysis

CA-Markov model was used to predict future land use patterns of Hangzhou City every ten years on the basis of previous simulation result. According to the prediction result shown in Figure 3, proportion of farmland area kept reducing momentum before it reached stable value in 2060. In contrast, the construction area increased by 1.8% relative to 2010 from 2010-2060, which was mainly contributed by the decrease of farmland area. The reduced forest area became the only source of increased construction land after 2060. Grassland, water area and unused land still kept a stable state in the future showing no drastic fluctuations.

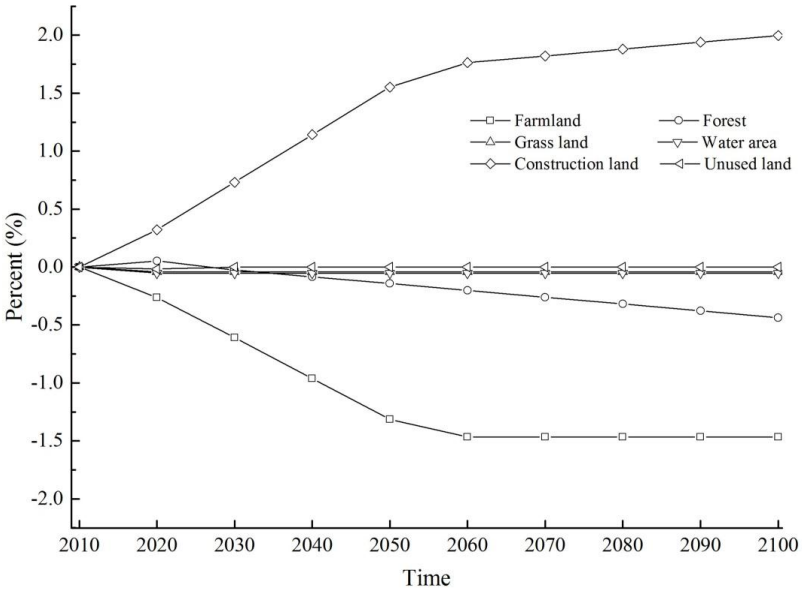

Fig. 3: The proportion changes of each land use type of future relative to 2010

5. Conclusions and Discussions

Based on China's current land use datasets, the paper studied the land use changes in Hangzhou City from 1990 to 2000 using ArcGIS and IDRISI. Actual land use maps in 1990 and 2000 were defined as input data using the CA - Markov model to simulate 2010 land-use scenario and 97% of regions were consistent with the actual map in 2010. Kappa index was 0.9718 showing high consistency and reliability. Future simulation results from 2020 to 2100 provided scientific basis for decision-making of land use planning in Hangzhou City.

Land use change simulation is a very complicated process affected by natural, economic, social and other factors which are often difficult to quantify. Although in this paper driving factors of DEM, slope, population, GDP, road and distance to each land use types were considered, simulation results of land use types like construction area and unused land were still large room for improvement. In addition, in the process of simulation, all the data were processed into spatial resolution of 1k m×1km without considering the scale effect of land use. The maximum extent to reflect mechanisms of the natural and human impacts on geographical spatial system needs further research.

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